Appendix 5.E

Habitat Restoration

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5.E.0 Executive Summary

Over the past 150 years, most of the tidal wetland habitat in the Sacramento–San Joaquin River Delta (Delta) has been lost as a result of levee construction and reclamation (Whipple et al. 2012). Of the 2,200 square kilometers (km^2) (544,000 acres) of tidal freshwater and brackish marsh in the San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) 150 years ago, only 125 km^2 (31,000 acres) remain, a decrease of more than 90% (Nichols et al. 1986). In a recent assessment of the historical ecology of the Delta, freshwater emergent wetland (both tidal and nontidal) was found to have decreased from an estimated 449,420 acres to 11,590 acres today, a decline of 97% (Whipple et al. 2012). This lost habitat has included seasonally inundated floodplains, subtidal and intertidal freshwater and brackish wetlands, and shallow-water channel margin.

Historically, large tidal wetlands, floodplains, and channel margins provided a mosaic of habitats for resident and seasonally migratory fish such as Sacramento splittail, sturgeon, and juvenile Chinook salmon (Whipple et al. 2012). These aquatic habitats provided organic material in a variety of forms, including decaying emergent vegetation, phytoplankton, zooplankton, macroinvertebrates, and insects that are part of the Delta trophic foodweb, both in shallow-water floodplain and tidal habitats and in adjacent pelagic habitats.

Restoration of tidal, riparian, and floodplain environments has been identified as an important implementation action that can help restore ecosystem functions that would benefit listed fish species, as well as a large variety of other aquatic species and wildlife (Simenstad and Cordell 2000; California Department of Fish and Game et al. 2010; Clipperton and Kratville 2009; Sommer et al. 2001; Moyle 2008; and others). Consequently, restoration is a major component of the BDCP and is intended to provide substantial benefits. This appendix describes the proposed restoration for covered fish species under four conservation measures (CMs)—*CM4 Tidal Natural Communities Restoration, CM5 Seasonally Inundated Floodplain Restoration, CM6 Channel Margin Enhancement*, and *CM7 Riparian Natural Community Restoration*—and expected outcomes, including the likely ecological benefits based on both quantitative (habitat suitability indices [HSIs] and habitat productivity) and qualitative (literature review) analyses.

5.E.0.1 Proposed Restoration and Expected Outcomes

The BDCP provides ambitious significant set of measures to enhance aquatic and terrestrial environments in the Plan Area. CM4, CM5, CM6, and CM7 present restoration actions intended to benefit covered fish species. The beneficial effects of these actions on covered fish species are described and evaluated separately. However, these four measures should be viewed as an integrated effort to restore a continuum of environments in the Delta, ranging from tidal brackish marsh to riverine floodplain. Collectively, these measures represent an ambitious strategy to address the loss of normative habitats throughout the Plan Area described by Whipple et al. (2012). CM4, CM5, CM6, and CM7 call for restoration of up to 65,000 acres of tidal natural communities and transitional updlands to accommodate sea level rise in the Delta, 10,000 acres of seasonally inundated floodplain, 20 miles of channel margin, and 5,000 acres of riparian habitat to benefit covered fish species. *CM2 Yolo Bypass Fisheries Enhancement* is also considered a habitat restoration measure. However, because the primary mechanism for creating additional aquatic habitat in the Yolo Bypass is through increased flows and flooding, the benefits of this measure to covered fish species are fully evaluated in Appendix 5.C, *Flow, Passage, Salinity, and Turbidity*. The following sections briefly summarize the proposed habitat restoration and the expected outcomes that are described in detail in this appendix.

The proposed habitat restoration actions have two principal objectives.

1. To increase the amount and value of available habitat for covered species. This objective relates to the direct habitat needs unique to each species and life stage.

2. To enhance the ecological functions and services of the Delta especially in regard to the Delta foodweb that supports many covered fish species.

Each species and each life stage has unique habitat requirements that will be provided to varying degrees by the conservation measures. At the same time, aquatic vertebrate (including all covered fish species), invertebrate, and plant species operate as a biological community that benefit from the normative functions of the Delta partially supported by environments like those created by the conservation measures. The restoration would create shallow tidal marsh environments that contribute to the primary production of the Delta (Lopez et al. 2006). Phytoplankton production in the Delta fuels the zooplanktonic community that forms the food base of many Delta fish species (Baxter et al. 2010).

The desired ecological conditions and objectives of the aquatic habitat restoration actions for covered fish species are listed below.

- Increased access to substantial areas of seasonally inundated floodplain, tidal wetland, and channel margin aquatic habitat. In the past, aquatic habitat restoration projects in the Delta have been relatively small (typically less than 100 acres) and not of sufficient size to provide substantial benefits to covered fish species and ecosystem processes. Under the BDCP, the objective is to increase access to substantial new areas of high-value aquatic habitat: approximately 15,000 acres during the near-term (NT), 22,000 acres during early long-term (ELT), and 49,000 acres during late long-term (LLT). Restoration at this massive scale is expected to improve connectivity of habitats for fish and help restore the ecological processes of the Delta. *CM3 Natural Communities Protection and Restoration* (Chapter 3, *Conservation Strategy*, Table 3.4.3-5), includes a description of intentional and unintentional restoration in the Delta, primarily of tidal wetlands, and a description of their consequences. BDCP restoration is unique in its large-scale approach, coordinated efforts across a range of aquatic environments and deliberate nature, combined with a robust monitoring and adaptive management plan.

- Enhanced food production in the restored habitats as well as the export of food resources to adjacent channels and downstream areas. The goal is to increase food availability for covered fish species to enhance their growth rate and survival, contributing to increased species abundance and recovery.

- Establishment of new shallow-water intertidal and subtidal habitat areas (predominantly 4 feet in depth and less) that are compatible with natural processes, existing topography and elevations, and future sea levels. Shallow-water habitat provides opportunities for greater habitat diversity.

- Restoration of aquatic habitats that are geographically distributed across all regions of the Delta to increase the diversity and connectivity of habitats available for fish in the Sacramento River and North Delta, the Consumes and Mokelumne Rivers in the East Delta, the San Joaquin River in the South Delta, the West Delta, and Suisun Marsh.
- Increased spatial diversity and complexity of habitat types, including variation in water depths, tidal hydrodynamics, water velocities and residence times, salinity gradients, seasonally inundated environments and permanently inundated subtidal habitats.
- Phased implementation of restored habitat to be compatible with BDCP operations and infrastructure to maximize habitat benefits and reduce the risk that fish and other aquatic organisms are vulnerable to State Water Project (SWP) and Central Valley Project (CVP) south Delta export operations.
- Restored habitats that reduce the risk of stranding, exposure to increased risk of predation, and exposure to adverse water quality conditions such as low dissolved oxygen (DO) concentrations and toxic contaminants.

5.E.0.1.1 CM4 Tidal Natural Communities Restoration

Restoration of 65,000 acres of tidal natural communities within the Plan Area (including transitional uplands to accommodate sea level rise) represents a 63% increase in the extent of these tidal communities over current conditions. For some tidal natural communities such as tidal freshwater emergent wetland, BDCP restoration actions will more than double their extent in the Delta (13,900 acres of restoration compared to 8,947 acres of tidal freshwater emergent wetland existing today). This extensive restoration of tidal natural communities is expected to increase available habitat for delta smelt, longfin smelt, splittail, and salmon. In addition, restoration of tidal environments may create permanent year-round rearing habitat for juvenile green and white sturgeon. While the focus is on benefits to these covered fish species, the restoration should also benefit other native fish, invertebrate, and plant species that make up the normative biological community in the Delta. Tidal habitat restoration also is intended to produce food and export food, which would directly benefit delta and longfin smelt and Sacramento splittail, and may indirectly benefit sturgeon. Restored tidal habitat will be designed to provide an ecological gradient among subtidal, tidal mudflat, tidal marsh plain, riparian, and upland habitats, which are anticipated to provide a net ecological benefit to covered species. Tidal restoration would occur in the restoration opportunity areas (ROAs) within the Suisun Marsh, Cache Slough, West Delta, East Delta, and South Delta geographic subregions; there is no restoration planned under CM4 in the North Delta or Suisun Bay subregions.

Sea level rise associated with climate change will shift the salinity zones, frequency of inundation, and depth. This appendix accounts for those changes as part of the assessment of benefits of the restoration by relying on DSM2 outputs for the ELT and LLT that include assumptions about the effects of sea level rise and restoration in the Delta on hydrodynamics in the ROAs.

In addition to the direct benefit of providing physical habitat for covered fish, tidal wetland restoration is expected to enhance productivity in the Delta and contribute to the Delta foodweb. Studies in locations throughout the United States, including the Bay-Delta and elsewhere along the Pacific Coast, indicate the potential for substantial ecological benefits from restoring tidal wetlands, including foodweb support for fish species (Boesch and Turner 1984; Baltz et al. 1993; Simenstad et al. 1982; West and Zedler 2000; Bottom et al. 2005; Maier and Simenstad 2009; Simenstad et al. 2000; Howe and Simenstad 2011) and the export of nutrients and prey organisms to adjacent channels (Shreffler et al. 1992; Lucas et al. 2002; Schemel et al. 2004; Sommer et al. 2004a, 2004b; Lopez et al. 2006). Of the Delta habitats, the tidal marsh sloughs have the highest particulate organic matter (POM) and phytoplankton concentrations and support the greatest zooplankton growth rates (Müeller-Solger et al. 2002; Sobczak et al. 2002, 2005). The shallow littoral edges of marsh systems often are associated with high standing stocks of fishes in California (e.g., Allen 1982; Moyle et al. 1986; Nobriga et al. 2005) and elsewhere (e.g., Kneib 1997, 2003). When tidal mudflat is inundated, it serves as shallow open-water habitat for pelagic fish species, including splittail, salmonids, and sturgeon, and provides forage on benthic invertebrates.

Juvenile fish could benefit directly from increased phytoplankton and detritus produced in marsh channels and indirectly if that production is exported downstream (Benigno and Sommer 2008). The export of marsh production helps transfer the higher production of shallow-water habitats to the deepwater habitats preferred by pelagic fish species such as delta smelt and longfin smelt (Lucas et al. 2002). Production from the lower Yolo Bypass, including Liberty Slough and Cache Slough marshes, stays relatively intact as it moves down the estuary (Monsen 2003). This production may contribute significantly to the greater foodweb, ultimately benefitting open-water species such as delta smelt and longfin smelt (Brown 2004).

While there is general support from the scientific literature for the value of shallow-water habitats to support phytoplankton production in the Delta, the effectiveness of conversion of that production to zooplankton food for pelagic fish can be reduced by the presence of introduced clam species. In some cases, these introduced clams consume much of the phytoplankton produced in an area. Lucas and Thompson (2012) and Lopez et al. (2006) as well as other studies point out that invasive bivalves such as *Corbicula* can consume large amounts of phytoplankton in freshwater and in some cases can keep up with production levels resulting in little or no net production leaving shallow areas (Lucas and Thompson 2012). In areas with higher salinity such as Suisun Bay, the overbite clam (*Portamocorbula amurensis*) has a similar impact on phytoplankton (Cloern and Jassby 2012). (See Appendix 5.F, *Biological Stressors on Covered Fish,* for more detail regarding the potential for further bivalve invasion in the Delta, including in restored areas.) Consumption by clams and the effect of nutrients and hydrodynamics on phytoplankton transport result in a complicated relationship between habitat restoration, phytoplankton production, and food for pelagic fish species (Lucas et al. 2002). The conclusion is that while the scientific rationale for restoration of normative tidal habitats in the Delta is sound, much needs to be learned regarding how that restoration is optimized to benefit covered fish species. For example, Lucas et al. (2002) found that the ability of clams to reduce phytoplankton is dependent on site-specific features. These features could be incorporated into the design of restoration to minimize the effect of clams and to maximize production of planktonic food in the Delta.

Restoration of shallow tidal habitat called for in CM4 is the most ambitious action available at this time to enhance food production in the Delta while enhancing other ecological functions provided by normative tidal habitat in the Delta. In this appendix we evaluate the potential of restored habitat to enhance productivity of the Delta based on a simple depth relationship (Lopez et al. 2006) while cautioning that the realities highlighted by Lucas and Thompson (2012) may limit the value of restoration in regard to phytoplankton production. Due to the scale of restoration and the complexities of the Delta foodweb, this restoration should be approached in an experimental (i.e., adaptive) manner to ensure that lessons learned on early restoration projects are incorporated into subsequent projects. Using this approach, the effectiveness of restoration actions is expected to increase over time.

5.E.0.1.2 CM5 Seasonally Inundated Floodplain Restoration

Floodplains are recognized as key habitats for many species in the Delta and contribute to the production of food to downstream areas (Opperman 2012). Currently, most Central Valley floodplains are severed from their rivers by levees, channelization, and flow regulation, restricting the high natural productivity of floodplain habitats (Mount 1995). Studies suggest that restoring river–floodplain connectivity in the Plan Area could enhance both primary production (Ahearn et al. 2006) and zooplankton growth (Grosholz and Gallo 2006), ultimately benefitting higher-level consumers like fish species (Opperman 2012).

The proposed restoration of 10,000 acres of seasonally inundated floodplain habitat and the increase in flooding in the Yolo Bypass are expected to increase the amount and value of accessible rearing habitat for juvenile salmon and splittail. For salmon, the intent is to route salmon away from the interior Delta and through habitat that is favorable for growth. These expected benefits are supported by a number of existing studies (e.g., Sommer et al. 2001; Whitener and Kennedy 1999; Moyle et al. 2007).

Extensive research on the Yolo Bypass and lower Cosumnes River, in addition to research in the Sutter Bypass, indicates that native fish such as Sacramento splittail and juvenile Chinook salmon show enhanced growth and fitness when they have access to floodplain habitats (Swenson et al. 2003; Moyle and Grosholz 2003; Sommer et al. 2001, 2004; Crain et al. 2004; Ribeiro et al. 2004; Feyrer et al. 2004). (See Appendix 5.C, *Flow, Passage, Turbidity, and Salinity*, for more detail regarding the growth benefits for salmonids as a result of *CM2 Yolo Bypass Fisheries Enhancement*.) Floodplain restoration also is expected to increase the export of production downstream, providing increased food supplies (phytoplankton, zooplankton, insects, and small fish) for pelagic fish species such as delta smelt and longfin smelt (Kneib et al. 2008). Studies indicate links between carbon produced on floodplains and the downstream foodweb (Sobczak et al. 2005; Opperman et al. 2010). Ahearn et al. (2006) found that floodplains that are inundated in pulses can act as a "productivity pump" for the lower estuary. Lucas and Thompson (2012) concluded that the value of floodplains to produce phytoplankton and detritus is enhanced because their seasonal inundation excludes species such as *Corbicula* clams that may reduce production from downstream tidal marshes.

5.E.0.1.3 CM6 Channel Margin Enhancement

Development in the Plan Area has included extensive actions to stabilize and simplify the margins of the Sacramento and San Joaquin Rivers. Extensive areas have been stabilized through rock rip-rap, berms, and other structures. This has led to the loss of physical elements (e.g., woody debris, rocks) and vegetation (emergent plants, woody riparian, and submerged aquatic vegetation [SAV]) associated with channel margin. Channel margins, shallow water areas, and banks can serve as substrates for invertebrate communities that support foraging fish. The use of channel margin by fish depends on species- and age-specific dietary preferences and foraging behavior. Isotope studies indicate that the majority of fishes in littoral habitats have diets dominated by nearshore invertebrates such as amphipod grazers from SAV and epiphytic macroalgae. In the Delta, juvenile Chinook salmon (both hatchery and untagged fish) feed predominantly on zooplankton and chironomids (dipteran insects), with some amphipods derived from channel margin habitat and other littoral sources (Grimaldo et al. 2009). Studies of littoral habitats in the Pacific Northwest have found that sub-yearling juvenile Chinook salmon feed primarily on amphipods (*Corophium* spp.), dipteran insects, and some zooplankton (*Daphnia* spp.), with a shift in diet from insects to amphipods and larval fish as juveniles increase in length and move toward the estuary mouth

(McCabe et al. 1986 and Bottom and Jones 1990 as cited in Lott 2004). Delta smelt and other pelagic species are not expected to benefit from food resources in channel margin habitats, because they typically are associated with open-water habitat.

The value of channel margin habitat enhancement for salmonids will be increased, if located along the major migration routes and linked to other important habitats through the Delta. Evidence from the northwest United States suggests that connectivity of foraging habitat (e.g., the length, condition, and complexity of pathways) affects the importance of habitats to juvenile Chinook salmon. For instance, juvenile Chinook salmon were less abundant in dendritic tidal channel systems as distance from the main distributary channels increased (Beamer et al. 2005 cited in Fresh 2005). However, recent work in the San Francisco estuary, including the Plan Area, has shown occupation of very small intertidal dendritic channels (Gewant and Bollens 2011).

There is some indication that channel margin could be extremely important rearing habitat in years with low precipitation when floodplains are not functioning. A study by McLain and Castillo (2009) found that densities of Chinook salmon fry in the Sacramento River and Steamboat Slough were higher compared with Miner Slough and Liberty Island Marsh during a low outflow year. Fry apparently bypassed marshy habitats at the downstream end of the Yolo Bypass because outflow during the winter was relatively low and flows into the Yolo Bypass were negligible (McLain and Castillo 2009).

5.E.0.1.4 CM7 Riparian Natural Communities Restoration

Riparian woodland and forest historically occurred in the Delta in large stands that followed major river channels and floodplains, particularly along the mainstem Sacramento River and San Joaquin River at the southern edge of the Plan Area (Whipple et al. 2012). Forest clearing, changes in river hydrology, and channelization has resulted in a reduction from historical levels of riparian woodland and forest by over 75%. The BDCP will restore 5,000 acres of riparian forest and scrub in the Delta, an increase of 29%, primarily in association with restoration of tidal and floodplain habitats and channel margin enhancements. Riparian habitat restoration is anticipated to increase inputs of organic material to adjacent channels, resulting in increased aquatic productivity, increased extent of shaded riverine aquatic habitat, and increased production and export of terrestrial vertebrates into the aquatic ecosystem.

Riparian vegetation influences the food chain of a stream by providing organic detritus and terrestrial insects. Riparian vegetation also controls aquatic productivity dependent on solar radiation (Meehan 1991).

Although the covered fish species do not rely primarily on riparian habitat, they are directly and indirectly supported by the habitat services and food sources provided by the highly productive riparian ecosystem, particularly during flood flows when riparian habitats are inundated. Riparian vegetation is a source for organic material (e.g., falling leaves), insect food, and woody debris in waterways and can influence the course of water flows and structure of instream habitat. This debris is an important habitat and food source for fish, amphibians, and aquatic insects (Opperman 2005).

Salmonids rely on riparian shade and the resulting cooler water temperatures that control basic metabolic processes. Salmonids also benefit from contributions of the riparian community to the aquatic foodweb in the form of terrestrial insects and leaf litter that enter the water. Riparian vegetation also supports the formation of steep, undercut banks that provide cover for salmonids.

5.E.0.2 Evaluation Methods

This appendix uses both quantitative and qualitative methods to estimate the effects of the proposed restoration activities. In addition to literature review, these methods include a habitat suitability index (HSI) approach, which is based on data obtained from trawls and CALSIM, DSM2, and RMA Bay-Delta model outputs, and a Habitat Productivity Analysis. The habitat suitability analysis focuses on the direct benefits to fish in terms of increased habitat availability. The analysis of habitat productivity considers the indirect benefits to fish from improved ecological functions in restored habitats, with a focus on food production. A summary of methods for each conservation measure is provided below.

5.E.0.2.1 Methods for Evaluating Tidal Marsh Restoration (CM4)

The potential value of the CM4 restoration for most covered fish species was evaluated in terms of (a) habitat suitability of the restored habitat for covered fish species, and (b) the potential contribution of the restored environments to phytoplankton production and the Delta foodweb.

5.E.0.2.1.1 Habitat Suitability

Restoration proposed under CM4 for delta smelt, longfin smelt and juvenile salmonids was evaluated using a habitat suitability approach (Schamberger et al. 1982). The habitat suitability method captures knowledge about the habitat requirements of species in the form of ratings that are integrated to derive an HSI. The HSI is a measure of habitat condition with respect to the species/life stage requirements. The species-specific HSI then is applied to the total quantity of available or restored habitat to derive habitat units (HUs). HUs are the interpretation of the habitat types (e.g., deep water, intertidal, shallow water) from the perspective of a species and life stage.

Habitat Suitability Analysis was done for delta smelt, longfin smelt, and salmonids (juvenile foragers and migrants). Habitat requirements and models used in the analysis were developed through extensive consultation with regional species experts, by reference to published scientific literature, and by analysis of existing data from regional monitoring programs. There was insufficient information to construct suitability models for sturgeon and lamprey. The habitat suitability approach was not used for splittail at this time because of the very broad tolerances of splittail for conditions in the Plan Area. Instead, potential benefits for splittail were evaluated qualitatively.

Habitat suitability indices for delta smelt, longfin smelt, and salmon were based on suitability ranges for salinity, temperature, and turbidity for individual life stages. These suitability indices were combined with habitat preferences based on depth, substrate, and vegetation to calculate HUs for the acreage strata. While these parameters do not represent the entire suite of possible characteristics of habitat, these parameters were the ones for which evidence of a relationship to the species exists and for which future projections of conditions under the BDCP could be made through modeling or supposition. Consideration of additional parameters will be needed during actual site-specific restoration.

For delta smelt, all life stages were considered because the entire extent of species habitat occurs within the Plan Area. For longfin smelt, the analysis only considered egg (spawning) and larval stages because other life stages generally occupy habitat outside the Plan Area in San Francisco Bay. For salmonids, all spawning was assumed to occur outside the Plan Area and adult passage through the Delta was not evaluated in the habitat suitability analysis. Instead, the analysis focused on two juvenile behavior forms, foragers and migrants, which spend time in the Delta and are affected by

CM4 restoration. Only juvenile and adult life stages of splittail were assumed to occupy the subregions addressed in CM4, whereas most spawning occurs upstream in Yolo Bypass and other areas not included in CM4.

The habitat suitability analysis used two types of data: estimates of acres by depth strata that would potentially be restored under a hypothetical restoration footprint and estimates of temperature, salinity, and turbidity at points within the BDCP permit term. Acres of habitat strata in each geographic subregion under the hypothetical footprint were estimated using GIS. Temperature and salinity changes that could occur in the future as a result of *CM1 Water Facilities and Operation* were evaluated using DSM2 and other models described in Appendix 5.C, *Flow, Passage, Turbidity, and Salinity*. No method currently exists to estimate turbidity in the Delta in the future. As a result, the assumption was made for the analysis that turbidity in the Delta would remain constant. However, regional variation in turbidity was included in the analysis using turbidity levels recorded in regional monitoring programs.

5.E.0.2.1.2 Habitat Productivity

The analysis of habitat productivity was designed to assess potential foodweb enhancements that may result from proposed tidal habitat restoration activities. The analysis examined two main sources of foodweb support: phytoplankton production and marsh-derived production.

The potential of restored habitat under CM4 to enhance productivity in the Delta was evaluated using an index of potential phytoplankton production based on a simple relationship between phytoplankton growth rate and depth developed by Lopez et al. (2006). While it is recognized that the production of food in the Delta is a complex process, the relationship between phytoplankton production and depth is well established even if it is complicated by clams and other factors. In the absence of an overall quantitative model for food, the depth relationship provides an easily quantifiable index of one aspect of food and was used as a metric to compare potential food production from CM4 restoration across the Plan Area and over the BDCP permit term. Their productivity-depth relationship was applied to average depth within habitat strata of each geographic subregion. Depth and acreage was estimated using GIS. Estimated phytoplankton productivity from this relationship was weighted by the area of each depth strata to produce an index termed “prod-acres” that was used to compare restoration potential at each implementation period. Prod-acres is an index of potential phytoplankton production used to compare potential benefits of restoration between areas and time periods; it is not used as an estimate of phytoplankton production. As discussed above, while the value of shallow water areas to produce phytoplankton is a generally accepted premise, the production of zooplankton food for covered fish species is complicated by the presence of bivalve clams such as *Corbicula* that may directly consume phytoplankton and decrease the production zooplankton that are food for covered fish species. The conversion of phytoplankton to zooplankton food for covered fish species is also complicated by hydrodynamic factors that may not result in transfer of phytoplankton to areas where it can be consumed by fish species. Additionally, as described in Appendix 5.F, *Biological Stressors on Covered Fish,* and in Appendix 5.D, *Contaminants,* other important regional actions may also influence the actual food production in the Delta. Recognizing the complicated relationship between restored habitat, other Delta stressors, and food for pelagic fishes, it was concluded that the prod-acre relationship provided a useful index for comparing CM4 restoration benefits between area and time periods relative to existing biological conditions.

Other contributions to Delta productivity such as detrital pathways were considered qualitatively by synthesis of available literature.

5.E.0.2.2 Methods for Evaluating Floodplain Restoration (CM5)

The potential benefit from CM5 restoration was evaluated based on a) increase in inundation acreage that provides benefits to covered fish species and b) the occurrence of inundation and the length of residence time in relation to the production of food resources for covered fish species. Potential actions to restore seasonally inundated floodplains were configured into a set of conceptual south Delta corridors, with each corridor being a delineation of actions such as levee setbacks, creation of flood bypasses, riparian planting, and channel margin enhancement. A combination of two or three corridors would need to be implemented (or portions of these corridors) to achieve the requirement to restore 10,000 acres of seasonally inundated floodplain[1]. The four geographic corridors are (two with two sub-options each) that were analyzed as alternative scenarios to achieve the 10,000 acre restoration goal of CM5 are as follows:

1. San Joaquin River
   a. Corridor 1A: Levee setbacks on both banks of the San Joaquin River from Vernalis to Interstate 5.
   b. Corridor 1B: An alternative version of Corridor 1A along the San Joaquin that includes only a right-bank levee setback and connection of Walthall Slough with the San Joaquin River via a weir. Corridor 1B is assessed separately from Corridor 1A.
2. Paradise Cut
   a. Corridor 2A: Expansion of the Paradise Cut flood bypass and modifications to Paradise Cut weir.
   b. Corridor 2B: An expanded version of Corridor 2A that also includes levee removal around Fabian Tract. Corridor 2B is essentially Corridor 2A plus Fabian Tract. Fabian Tract is not hydraulically modeled separately from Paradise Cut in terms of flood evaluations; however, the flood and ecological benefits of Corridor 2B are examined discretely.
3. Corridor 3: Selected levee setbacks along Middle River on Union Island.
4. Corridor 4: Levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River.

Implementation of CM4 could use combinations of restoration from these four corridors to achieve the 10,000 acre restoration goal of CM5.

Hydrologic Engineering Center River Analysis System (HEC-RAS) modeling was used to compare existing habitat acreages with those restored under BDCP floodplain restoration scenarios. The flow-related habitat criteria for floodplain spawning of splittail and rearing of salmon, along with riverine and Delta food production (phytoplankton and zooplankton production on inundated floodplains), were selected as key indicator species/processes to assess. An arbitrary minimum threshold was set where it was assumed that 30% of a corridor's new floodplain areas needed to be

[1] As with the hypothetical restoration scenario for tidal natural communities, the south Delta corridors represent potential restoration concepts, some of which may be implemented. Depending on further studies during Plan implementation, floodplain restoration may be accomplished in other locations in the south Delta.

inundated (along with the seasonality and duration requirements) in order for meaningful outputs to accrue.

5.E.0.2.3 Methods for Evaluating Channel Margin Restoration (CM6)

The assessment of channel margin restoration was qualitative, although the Corps of Engineers Sacramento River Bank Protection Project revetment database was consulted to summarize existing habitats and species association. In addition, the qualitative assessment relied on review of pertinent literature and the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) evaluations of CM6.

5.E.0.2.4 Methods for Evaluating Riparian Habitat Restoration (CM7)

The assessment of riparian habitat restoration was also qualitative and relied on the current scientific literature related to the ecological role of riparian vegetation as well as reviews of on-going riparian restoration in the Central Valley.

5.E.0.3 Summary of Conclusions

The proposed tidal marsh, floodplain, channel margin, and riparian restoration measures (CM4, CM5, CM6, and CM7) will increase access to suitable habitat for all covered fish species and restore important ecological functions of the Delta. Considered as a whole, the restoration under these conservation measures represents by far the most ambitious effort to date to restore habitat and ecological functions in the Delta. The proposed restoration provides a mosaic of habitats for the covered fish community that results in a wide diversity of habitat benefits; restoration of some areas provides limited value for some species but greater benefits for others—a consideration that must factored into evaluation of overall restoration benefits. For example, CM4 restoration in the South Delta subregion provides limited benefits for delta smelt because of turbidity and temperature limitations but provides greater benefits for splittail. Considered together, CM4, CM5, CM6, and CM7 greatly increase the natural environments in the Delta across the range of estuarine and riverine environments in the Plan Area. This provides direct habitat benefits for covered fish species and should enhance the normative ecological functions of the Delta. The restoration is also expected to increase production of periphyton, phytoplankton, zooplankton, macroinvertebrates, insects, and small fish that contribute to the local and regional trophic foodweb of each restoration area. However, the extent of this foodweb benefit is uncertain.

Overall, the proposed restoration of aquatic habitats is expected to provide a significant benefit to each of the covered fish species. This conclusion has a high uncertainty because of the unpredictable effects of factors such as competing species (e.g., Corbula), hydrology, and other factors. The significance of the benefits depends on the proportion of the species' life history that is spent in the Plan Area and therefore how long the species could potentially benefit from the restored aquatic habitats. Species with long residence times in the Plan Area such as delta smelt and longfin smelt are expected to substantially benefit from habitat restoration actions. Covered species such as migratory salmonids spend only a few weeks per year in the Plan Area. Because of their relatively short residence time in the Plan Area, natural community restoration actions are expected to provide less benefit to those species.

5.E.0.3.1 CM4 Tidal Natural Communities Restoration

Tidal natural community restoration would greatly expand the area of tidal marsh in the Delta.

Under the hypothetical restoration footprint, BDCP restoration is expected to add about 55,800 acres of subtidal and intertidal habitat for covered fish in the Delta by the end of the permit term, representing a 54% increase in these communities relative to current levels[2]. The greatest increase in tidal acreage would be in the South Delta, followed by Cache Slough, Suisun Marsh, West Delta, and East Delta subregions; there is no restoration under CM4 in the North Delta or Suisun Bay subregions.

Tidal natural community restoration would greatly increase the amount of suitable habitat (measured in habitat units) for covered fish species over existing conditions, even with the expected effects of climate change.

Habitat Suitability Analysis indicates that after tidal natural community restoration is fully implemented by year 40, tidal natural community restoration should substantially increase habitat for the species evaluated as compared to existing conditions. In the analysis, the greatest increase in total HUs was for delta smelt (59% increase), followed by salmonids (50% increase), Sacramento splittail (41%), and longfin smelt (39% increase).

Climate change (absent CM4) added to the aquatic area of the Delta through sea level rise but decreased habitat suitability due to increased water temperature.

In the analysis, sea level rise associated with climate change increased the total aquatic acres in the Delta by about 6% overall, primarily by adding area to deeper subtidal environments. Changes to inflow to the Delta due to climate change generally decreased HSI values for most species by the LLT, because of increased water temperature not related to the BDCP. Overall, climate change alone increased HUs for salmonids and splittail by about 5% each followed by longfin smelt (4%) and delta smelt (1%).

Habitat value (as measured by HSI value) for delta smelt, longfin smelt, and salmon was highest in the "North Delta Arc" encompassing the Cache Slough, West Delta, and the Suisun Marsh subregions. Habitat value was lowest for these species in the East Delta and South Delta subregions where high temperatures and low turbidity reduced suitability.

In the analysis, HSI values for delta smelt were highest in Suisun Marsh, followed by Cache Slough and the West Delta by year 40 when all restoration must be completed. The highest HSIs for longfin smelt were in the West Delta, followed by Cache Slough, Suisun Marsh and the East Delta subregions. HSI values were highest in Cache Slough followed by the West Delta and Suisun Marsh. High temperature and water clarity in the East Delta and South Delta resulted in much lower habitat value for all three species in these subregions.

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[2] The analysis evaluated a hypothetical restoration footprint developed in consultation with fish and wildlife agencies that represents a likely scenario for tidal natural community restoration. The amount of aquatic habitat created by the hypothetical footprint is less than 65,000 acres because approximately 10,000 acres is reserved as "sea level rise accommodation area". These areas are currently uplands adjacent to tidal wetlands but would be expected to convert to tidal areas as sea level rises.

Splittail are expected to benefit from the restoration of tidal marsh and floodplain habitats.

Splittail exhibit a wide tolerance for conditions in the Delta. Their abundance is believed to relate more to the amount and duration of flooding of Yolo Bypass and other floodplain areas used for spawning. Splittail are expected to benefit from the expansion of food production in tidal wetlands due to the expanded flooding of Yolo Bypass (CM2) and, to a much lesser extent, other floodplain areas (CM5).

Tidal natural community restoration has the potential to increase food production (as indexed by prod-acres) by the end of the permit term and this restoration could enhance the Delta foodweb, particularly in Cache Slough.

Potential food benefits from restoration were assessed using a depth-production relationship to derive a comparative index of potential primary production (prod-acres) in current and restored habitat. The increase in shallow marsh environments is expected to increase food for covered fish species both locally and at the scale of the Plan Area. The expectation is that restored shallow areas would promote production of tules and other native macrophytes that will increase the availability of aquatic insects, other invertebrates, and detritus to augment food for covered fish species. The change in the prod-acres index over the implementation period relative to the current level suggests that, by the end of the permit term (LLT), restoration benefits to food production would be greatest in Cache Slough followed by the South Delta. Prod-acre increases in the East Delta and Suisun Bay were appreciably lower than in the Cache Slough and South Delta subregions. Prod-acre increases were negligible in the West Delta and actually declined by the LLT in Suisun Marsh relative to current levels due to the increase in deeper strata projected under CM4 restoration. Transfer of this production to food for listed fish species could be complicated by potential consumption by clams, nutrient levels in the Delta and hydrodynamic factors. However, benefits can be maximized by restoration design and adaptive learning of restoration methods in the Delta.

5.E.0.3.2 CM5 Seasonally Inundated Floodplain Restoration

CM5 expands the area of seasonally inundated floodplain in the south Delta and the Delta as a whole.

BDCP restoration will modify flood conveyance levees and infrastructure to restore 10,000 acres of seasonally inundated floodplain along river channels in the South Delta with 1,000 acres restored by year 15 and another 9,000 acres by year 40 (CM2 floodplain restoration is evaluated in Appendix 5.C, *Flow, Passage, Turbidity, and Salinity*). Most of the remaining floodplain in the Plan Area is in the Yolo Bypass and along the Cosumnes River. These areas presently provide about 61,000 acres of floodplain. CM5 restoration of 10,000 acres in the South Delta represents a 16% increase in floodplain area in the Plan Area.

Restoration of floodplains in the South Delta is expected to provide habitat for salmonids and splittail.

The analysis of CM5 evaluated restoration potential for salmonids and splittail along the four corridors described in Section 5.E.0.2.2, *Methods for Evaluating Floodplain Restoration (CM5)*. Actual floodplain restoration could be implemented using opportunities in one or more of the four corridors to achieve the 10,000 acre restoration goal of CM5. Results of analysis of restoration opportunities in the South Delta are summarized as follows.

- The greatest increase in potentially inundated acres relative to current conditions, was in the Fabian corridor (2B) which increased floodplain habitat for covered fish from 1,673 acres to 8,999 acres, an over 5-fold increase. The analysis assumed a threshold level of inundation that would occur once every 4 years for up to 20 days to define fish habitat. A threshold flow of 15,500 cubic feet per second (cfs) was assumed to inundate habitat for salmonids and a threshold flow of 11,600 cfs for splittail. With these habitat thresholds, hypothetical restoration would inundate 6,895 acres for salmonids and 6,395 acres for splittail.
- Corridor 3, the analysis found that hypothetical restoration increased inundated area from 706 acres to 5,174 acres. Applying the fish habitat thresholds, this would increase inundated floodplain habitat for salmon from 88 acres to 4,250 acres while splittail habitat would increase from 33 acres to 3,800 acres in Corridor 3.
- The overall inundated area for Corridor 1A increased from 2,524 acres to 11,741 acres. Applying the fish habitat thresholds, this increased salmon habitat from 910 acres to 3,500 acres and increased splittail habitat from 412 to 2,000 acres.
- Total potentially inundated acres for Corridor 1B increased from 1,593 acres to 5,380 acres. This resulted in an estimated increase in salmon habitat from 532 acres to 1,750 acres, while splittail habitat increased from 213 acres to 1,200 acres using the fish habitat thresholds.
- Corridor 4 increased potentially inundated acres from 252 acres to 5,881 acres. Applying the fish habitat thresholds, this hypothetical restoration increased salmon habitat from 252 acres to 4,600 acres and splittail habitat from 26 acres to 4,200 acres.

CM5 restoration is expected to enhance ecological services provided by floodplains, including food production.

Floodplains can potentially add significantly to Delta food resources (Lucas and Thompson 2012; Opperman 2012). Restoration of floodplain under CM5 is expected to increase food resources and provide rearing habitat for juvenile salmonids and splittail. Complex habitats that should form between floodplains and adjacent river channels as a result of CM5 should provide refuge from predators. Floodplain inundation supports the establishment of complex woody and scrub habitat along the river channel and floodplain which is essential for riparian dependent birds and mammals; floodplain vegetation can reduce sources of nonpoint pollution and improve water quality.

Splittail abundance in the Delta is believed to be largely limited by the availability of floodplain spawning and rearing habitat (Feyrer et al. 2005). CM5 should increase the amount of floodplain spawning habitat for splittail and create a corridor of habitats for emigrating salmonids and splittail. Floodplain habitat created under CM5 should provide refugia during high-flow events that would reduce stress on juvenile salmonids.

5.E.0.3.3 CM6 Channel Margin Enhancement

Channel margin enhancement under CM6 generally is expected to benefit covered fish species; benefits to fish from the limited spatial extent of the measure will be most effective by targeted selection of sites for enhancement based on existing poor habitat value and biological performance.

CM6 will enhance the condition of channel margins in the Plan Area.

The 20 miles of channel margin enhancement proposed in the Plan Area under CM6 represents approximately 4% of the total length within these channels, a relatively small proportion. However, by targeting areas that have been shown to have poor habitat value and biological performance coupled with extensive occurrence of covered fish species, it is possible that channel margin enhancement, together with associated restoration activities such as *CM7 Riparian Natural Community Restoration*, can provide more than a proportional 4% increase in overall habitat value. Such locations include the greatly altered reach of the Sacramento River between Freeport and Georgiana Slough, for example. Additional research on existing biological performance (e.g., survival studies of particular reaches for Chinook salmon fry) would complement the existing knowledge regarding habitat value. Monitoring would inform the assessment of the change in habitat value resulting from CM6.

CM6 will increase the extent of rearing habitat for covered species in the Plan Area.

The extent to which this enhancement will affect fish on a broad scale depends on the change in overall habitat value relative to existing conditions. CM6 should increase rearing habitat for covered fish species, particularly Chinook salmon fry (foragers). Enhancement and creation of additional shallow-water habitat would provide refuge for foraging salmonids from unfavorable hydraulic conditions and predation, and increase foraging habitat. Benefits for larger actively migrating Chinook salmon juveniles and steelhead may be less than for smaller foraging Chinook salmon fry, although the habitat may serve an important function as holding areas during downstream migration (see below). Rearing habitat for Sacramento splittail is also likely to increase under CM6, particularly given the species' probable use of channel margins for spawning. Delta smelt and longfin smelt may experience minimal increases in rearing habitat because they tend to occur away from shore and are largely found downstream of the main channels proposed for channel margin enhancement. The DRERIP evaluations suggested that there may be some rearing benefit to green and white sturgeon from channel margin enhancement, although little is known about the rearing use of this habitat by these species. Although little is known about Pacific lamprey and river lamprey use of channel margin habitat, the species may benefit from enhancement that increases the area of non-revetted substrate into which ammocoetes can bury; recent monitoring suggests that ammocoetes may be relatively abundant in the substrates in the Plan Area.

CM6 will increase the connectivity of higher value channel margin habitat along important juvenile salmonid migration routes in the Plan Area, with research needed to inform the efficacy of the measure.

The focus of CM6 is to provide habitat along important juvenile salmonid migration routes, and, therefore, the measure will improve longitudinal connectivity between patches of higher value channel margin habitat. This is particularly necessary for reaches that have very low existing habitat value and are heavily used by fish (e.g., the Sacramento River between Freeport and Georgiana Slough). The efficacy of the measure may depend on the lengths of enhanced channel margin and the distance between enhanced areas (i.e., there may be a tradeoff between enhancing multiple shorter reaches that have less distance between them and enhancing relatively few longer channel margin habitats with greater distances between them). Enhanced channel margin habitat in the vicinity of the proposed north Delta intakes (upstream, between the intakes, and downstream) would provide resting spots and refuge for fish moving through this area. Research would inform the extent to which enhanced habitat is used by migrating salmonids and the extent to which the enhancements limit negative effects of reduced flows and alteration.

CM6 will increase connectivity between habitats created in other measures, particularly floodplain (CM5).

Channel margins are the interface between the main channel and floodplains. Restoration proposed under CM6 should add to the benefits of floodplain restoration by creating a normative sequence of riverine, riparian and floodplain habitats.

CM6 has the potential to increase resting habitat within the Plan Area for migrating adult anadromous covered fish species.

The 2009 DRERIP evaluation noted the potential for channel margin enhancement to increase resting habitat for migrating adult Chinook salmon, steelhead, green sturgeon, and white sturgeon as a result of increased channel margin complexity (e.g., woody material) providing refuge from high flows. Large wood, rocky alcoves and riparian vegetation provide resting and feeding habitat to benefit juvenile salmonids.

CM6 has the potential to increase habitat in the Plan Area for nonnative fishes that prey on or compete with covered fish species, which may offset some of the benefits for covered fish species.

A possible downside of restoration of channel margins is that restoration could provide habitat for nonnative fishes, many of which are significant predators on covered fish species. The potential for channel margin restoration to increase habitat for nonnative fishes, in particular littoral predators such as largemouth bass, has been shown from studies of Plan Area channel margins. Habitat features that may benefit covered species such as Chinook salmon fry also may support nonnative species. Enhancement of channel margins with inundated vegetation or woody material may increase predation risk if other features of the habitat support predatory fish (e.g., relatively steep slopes and deeper water). The 2009 DRERIP evaluations of channel margin enhancement found the potential negative outcome to be of similar or slightly lower magnitude than the positive outcomes (e.g., increased rearing habitat; see above).

CM6 has the potential to increase the time spent within channel margin areas by covered fish species, which may increase exposure to contaminants to a small extent.

CM6 also has the potential to increase the time spent in channel margin areas by covered fish species, which may increase exposure to any toxins sequestered in sediments. As discussed in Appendix 5.D, *Contaminants*, the primary toxins that could be present in the sediments are pesticides and metals. Exposure may increase as covered fish species increase the time they spend in areas with toxins. The 2009 DRERIP evaluation of this potential negative outcome suggested it would be of minimal magnitude to covered fish species.

5.E.0.3.4 CM7 Riparian Natural Community Restoration

Riparian areas and associated vegetation provide an array of ecological functions to terrestrial and aquatic communities. Currently, less than 5% of valley floor riparian areas remain and much of that is broken into small, unconnected patches. CM7 will restore up to 5,000 acres of riparian environments.

Restoration of riparian areas under CM7 should provide direct habitat for natural communities (terrestrial and aquatic) and enhance ecological functions associated with riparian environments. In particular, the restoration should reduce nonpoint-source pollution and improve water quality due to the filtering function of riparian vegetation. Shading provided by riparian vegetation will reduce water temperatures locally, enhance food for fish species through delivery of terrestrial insects, and provide wood to enhance structure. Importantly, improved riparian areas will act as a buffer between agricultural and aquatic areas, reducing runoff and agricultural impacts.

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Habitat Restoration

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Acronyms and Abbreviations

µg/L	micrograms per liter
µS/cm	microSiemens per centimeter
Bay-Delta	San Francisco Bay/Sacramento–San Joaquin River Delta
BDCP	Bay Delta Conservation Plan
CDFW	California Department of Fish and Game
cfs	cubic feet per second
CMs	conservation measures
CVP	Central Valley Project
D-1485	State Water Board Water Right Decision 1485
DCC	Delta Cross Channel
Delta	Sacramento–San Joaquin River Delta
DO	dissolved oxygen
DOC	dissolved organic carbon
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
EBC	Existing Biological Conditions
EC	electrical conductivity or salinity
EHW	extreme high water
ELT	early long-term
EPA	U.S. Environmental Protection Agency
FAV	floating aquatic vegetation
FMWT	Fall Midwater Trawl
GIS	geographic information systems
HSI	Habitat Suitability Index
HUs	habitat units
IAV	invasive aquatic vegetation
ICF	ICF International
km^2	square kilometers
LLT	late long-term
LSZ	low salinity zone
LWD	large woody debris
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MHHW	average of the highest tide or mean higher high water
MHW	average high tide or mean high water
MLLW	average (mean) lower low tide elevation
MLW	average of the low tide elevations or mean low water
mS/cm	milliSiemens per centimeter
msl	above mean sea level

MTL	average (mean) tide elevation
NAVD88	North American Vertical Datum of 1988
NMFS	National Marine Fisheries Service
NT	near-term
POC	particulate organic carbon
POD	Pelagic Organism Decline
POM	particulate organic matter
ppt	parts per thousand
RMA	Resource Management Associates
ROAs	Restoration Opportunity Areas
SAV	submerged aquatic vegetation
SKT	Summer Kodiak Trawl
SSC	suspended-sediment concentration
State Water Board	State Water Resources Control Board
SWP	State Water Project
USFWS	U.S. Fish and Wildlife Service
WQCP	Water Quality Control Plan
YOY	young of year

Appendix 5.E
Habitat Restoration

5.E.1 Organization of Appendix

This appendix provides an assessment of the benefits and adverse effects of restoration conservation measures (Conservation Measures [CMs] 4, 5, 6, 7) on covered fish species under the Bay Delta Conservation Plan (BDCP). The appendix is organized as follows.

- **Section 5.E.2**, *Introduction*, provides background on the reasons for implementing restoration in the Sacramento–San Joaquin River Delta (Delta) and the BDCP restoration objectives.
- **Section 5.E.3**, *Objectives*, outlines the goals of the proposed aquatic habitat restoration activities (CM4–CM7).
- **Section 5.E.4**, *Conservation Measure 4 Tidal Natural Communities Restoration*, discusses projected increases in suitable habitat for covered fish species resulting from the restoration of tidal habitats in the Plan Area, along with an analysis of the potential increase in phytoplankton production to support the pelagic foodweb.
- **Section 5.E.5**, *Conservation Measure 5 Seasonally Inundated Floodplain Restoration*, describes the projected benefits of floodplain restoration for covered fish species, with a focus on spawning Sacramento splittail and rearing juvenile Chinook salmon and larval and juvenile splittail.
- **Section 5.E.6**, *Conservation Measure 6 Channel Margin Enhancement*, discusses the expected benefits of habitat enhancements along channels that provide rearing and outmigrating habitat for juvenile salmonids.
- **Section 5.E.7**, *Conservation Measure 7 Riparian Natural Community Restoration*, describes the restoration of riparian forest and scrub in the Plan Area in the context of flood control objectives and managed upstream hydrology and potential benefits to both aquatic and terrestrial species.
- **Section 5.E.8**, *Monitoring and Adaptive Management,* addresses the need for ongoing monitoring and adaptive management of the restored habitats because of the uncertainties inherent in ecological restoration.
- **Section 5.E.9**, *References Cited*.
- **Attachment 5E.A**, *BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description & Assessment Document* (ESA PWA 2012).
- **Attachment 5E.B,** *Review of Restoration in the Delta*.

5.E.2 Introduction

The ecology of the Sacramento–San Joaquin River Delta and Suisun Marsh (collectively, *the Delta*) has been greatly modified as a result of a variety of human activities. Historically, the Delta provided a variety of habitats for resident and seasonally migratory fish species such as Sacramento splittail, green and white sturgeon, and juvenile Chinook salmon. Today, the extent of tidal wetlands, seasonally inundated floodplains, riparian habitats, and channel margins has been greatly reduced. The ecological values of these habitats for fish species include adult holding, foraging, and spawning; egg and larval development; and juvenile rearing (Brown 2003).

The historical Delta was a vast freshwater wetland composed of numerous channels and islands, and saltwater rarely extended much beyond the Carquinez Strait (Contra Costa Water District 2010). Channel margins were vegetated with tules and bulrushes, while higher land supported shrubs and willow forests (Thompson 2006). Seasonal high waters created natural levees along channels and islands that had the saucer-like appearance of natural levees surrounding lower inland areas (Thompson 2006). Inflow closely followed precipitation, with highest flows in winter and early spring. Tidal wetlands, floodplains, and channel margins provided an array of habitats for resident fish such as delta smelt and longfin smelt and seasonally migratory fish such as Sacramento splittail, sturgeon, and juvenile salmon. These aquatic habitats provided primary production material in a variety of forms, including detritus and phytoplankton, that supported zooplankton and a rich native fish community.

European settlement of the Delta began in the mid–nineteenth century. Settlers very quickly began blocking small tributaries and building modest levees to protect personal property. Larger-scale modification of the Delta began in the 1860s when various consortiums raised money to construct larger dike systems ringing islands such as Sherman and Twitchell Islands (Thompson 2006). Early levees were constructed of peat mined from the interior of the islands. Subsidence of the islands was an early problem due to mining of peat and the compaction and draining of peat soils. About the same time, massive amounts of mining sediments from the Sacramento River entered the Delta, filling channels and resulting in greatly increased levels of sediment movement through the Delta and filled distributaries and open water (Nichols et al. 1986).

In the twentieth century channelization, dredging, and diking supported by federal and state funds further transformed the Delta. Channels were consolidated, resulting in a simplified network of relatively deeper channels and large islands (Moyle et al. 2010). Dramatic changes also occurred upstream in the lower portions of the Sacramento and San Joaquin Rivers. Dams and storage reservoirs were constructed to control flooding and provide irrigation and hydroelectricity. Shasta Dam, the largest dam in the Central Valley Project (CVP), was constructed in 1946, and Lake Oroville, the largest State Water Project (SWP) facility was constructed in 1968.

State and federal water projects significantly reduced freshwater inflow through the Delta, which has contributed to the movement of saline conditions eastward of the historical condition (Nichols et al. 1986; Contra Costa Water District 2010). Hydroelectric and flood control dams also altered the season pattern of inflow. Dams now block sediment movement, and the supply of transportable sediment has been diminished (Ruhl and Schoellhamer 2004).

As a result of upstream flow regulation and water diversion, freshwater inflow to the Delta has been greatly reduced, moving the freshwater-saline interface considerably east, while much of the historical tidal marsh has been lost to diking, draining, and infill. The ecological implications of these changes have been well documented (e.g., Kimmerer 2004) and are believed to have significant impacts on covered fish species as well wildlife, plants, invertebrates and noncovered fish species.

Changes to the biological communities of the Delta include dramatic changes in populations of native fishes. The Pelagic Organism Decline (POD) is a term applied to the recent sharp reductions in delta smelt, longfin smelt, striped bass, and threadfin shad (Feyrer et al. 2007; Sommer et al. 2007; Baxter et al. 2010). The causes for the decline are multi-faceted and have not been completely isolated through research. However, the decline of pelagic fish species coincides with changes in the planktonic community in the Delta and the general availability of food for fish species (Lopez et al. 2006; Cloern and Jassby 2010; Kimmerer et al. 2012). Indices of delta smelt abundance improved in 2011, although returns of longfin smelt remain low (<http://www.dfg.ca.gov/delta/data/fmwt/indices.asp>).

5.E.2.1 The Value of Ecosystem Restoration in the Delta

The Delta is a greatly altered, highly variable, and rapidly changing ecosystem (Matern et al. 2002; Lund et al. 2007; Cloern and Jassby 2012). The Delta will continue to change and the future ecosystem will be markedly different from its historical condition, with new species and processes (Moyle and Bennett 2008; Lund et al. 2010; Cloern and Jassby 2012). Conditions in the Delta will evolve regardless of the BDCP, because of climate change and urbanization and the shifting balance between native and nonnative species. The past, while informative, is not necessarily the best template for the future Delta. The BDCP provides biological goals and objectives that describe a future condition that is expected to support native fish and wildlife in the Plan Area; a major way to achieve this vision is the restoration of the Delta called for in the conservation measures.

CM4 would provide expansive restoration of Delta environments including restoration of 65,000 acres of tidal natural communities and transitional uplands, which is a 62% increase in wetted area of the Plan Area. This measure would increase tidal environments across the Delta by 87% with an increase in tidal environments of over 200% in Cache Slough and the South Delta. The type of directed restoration envisioned in the BDCP provides an unprecedented opportunity to shape the evolution of the Delta in ways that can benefit native species. The backdrop of ever-evolving physical and ecological conditions in the Delta will increase the challenges and heighten the uncertainties of restoration. As discussed in this appendix, significant uncertainties exist regarding restoration at the scale of the BDCP including especially the transformative effect of nonnative species on fundamental ecological processes. Nonetheless, the experience to date of accidental changes and deliberate restoration in the Delta demonstrates the potential of large-scale restoration to provide conditions and processes to enhance native species and ecosystems in the Delta.

Restoration of the Delta under the BDCP will be an ongoing process of learning from experience and incorporating research, monitoring, and synthesis of new information. The BDCP provides an unprecendented and unique strategic and coordinated approach that emphasizes the need to improve restoration methods and learn from past experience. An experimental design that identifies questions, prioritizes restoration projects, initiates investigations, and synthesizes results will be needed to translate past experience into useful knowledge and to achieve the goals of the BDCP. The precarious condition of many Delta fish species that is linked to changes in environmental conditions (Baxter et al. 2010) indicates that restoration of Delta environments is essential to their conservation and to management of native fishes in the Delta, notwithstanding the significant uncertainties. The importance of restoration is heightened in the context of regional climate change and resulting increased temperatures and sea level (Callaway et al. 2007). The BDCP provides a clear and essential opportunity for large-scale restoration in the Delta aimed at restoring and enhancing Delta ecosystems that include diverse communities of fish, invertebrates, wildlife, and plants.

5.E.3 BDCP Aquatic Habitat Restoration Objectives

An important component of the BDCP is the restoration of aquatic habitat in the Delta and Suisun Marsh for covered fish species. This restoration is intended to provide habitat for covered fish species and contribute to the restoration of the Delta ecosystem. Habitat refers to environmental conditions relating to performance of a specific species (e.g., delta smelt habitat). In this appendix, the term *habitat* should be interpreted generally as the collection of environmental conditions relating to performance of covered fish species. Following the definition provided in the Ecosystem Restoration Program's (2011) *Conservation Strategy for Restoration*, *ecosystem restoration* is defined as the process of facilitating the recovery of ecosystems that have been degraded, damaged, or destroyed. It includes actions to reestablish interactions among habitat structures and functions that lead to a sustainable and resilient ecosystem, but does not seek to recreate a specific historical configuration of the restored environment, which is often not possible given the multiple interacting stressors that have altered native habitats and biota. Consistent with this definition, the BDCP defines *restoration* as "establishing a species' habitat or a natural community in an area that historically supported it, but no longer does so because of the loss of one or more required ecological factors" (Chapter 12, *Glossary*).

There are three interrelated objectives of proposed BDCP habitat restoration.

1. Increase the amount, diversity, complexity, distribution, and connectivity of tidal wetland (CM4), seasonally inundated floodplain (CM5), riparian woodland (CM7), and channel margin (CM6) natural communities that support the covered species.
2. Restore the natural geomorphic, hydrologic, and biochemical processes that help maintain these communities.
3. Increase productivity and enhance the Delta foodweb, with a focus on increasing the availability of phytoplankton to support the foodweb passing through zooplankton to native fishes.

Specific actions are intended to improve habitat for covered fish in the following ways.

- Improve access to substantial areas of new tidal wetland, floodplain, riparian, and channel margin habitats.
- Increase shallow-water intertidal and subtidal habitats that are compatible with existing topography and elevations as well as future sea levels.
- Increase the geographic distribution of habitats in all regions of the Delta to increase the diversity and connectivity of habitats available for fish in the Sacramento River and northern Delta, the Cosumnes and Mokelumne Rivers in the eastern Delta, the San Joaquin River in the southern Delta, the western Delta, and Suisun Marsh.
- Increase variation in water depths, tidal hydrodynamics, water velocities, residence times, and salinity (EC, or electrical conductivity) gradients to support a range of fresh, saline, and brackish water habitats.
- Facilitate the transport and exchange of sediments, nutrients, and organic materials that contribute to habitat productivity both locally and downstream.

Recognizing the many uncertainties associated with ecosystem restoration, projects will be designed with a phased approach and ongoing monitoring to facilitate adaptive management. If results of monitoring identify adverse effects that would not support meeting the desired biological outcomes, the existing and future restoration actions would be modified and refined as part of adaptive management.

5.E.4 Conservation Measure 4 Tidal Natural Communities Restoration

5.E.4.1 Description

CM4 Tidal Natural Communities Restoration calls for restoration of 65,000 acres of tidal natural communities and transitional uplands to accommodate sea level rise in the Plan Area. (Chapter 3, Section 3.4.4.3.1, *Minimum Restoration Targets*). This would be done by breaching or eliminating levees to increase the amount of tidal environments across the Delta. Specific restoration projects have not been designated. However, restoration sites will be designed to support a variety of habitats and an ecological gradient of shallow subtidal aquatic, tidal mudflat, tidal marsh, transitional upland, and riparian habitats, and uplands (e.g., grasslands, agricultural lands) for sea level rise accommodation, as appropriate to specific restoration sites.

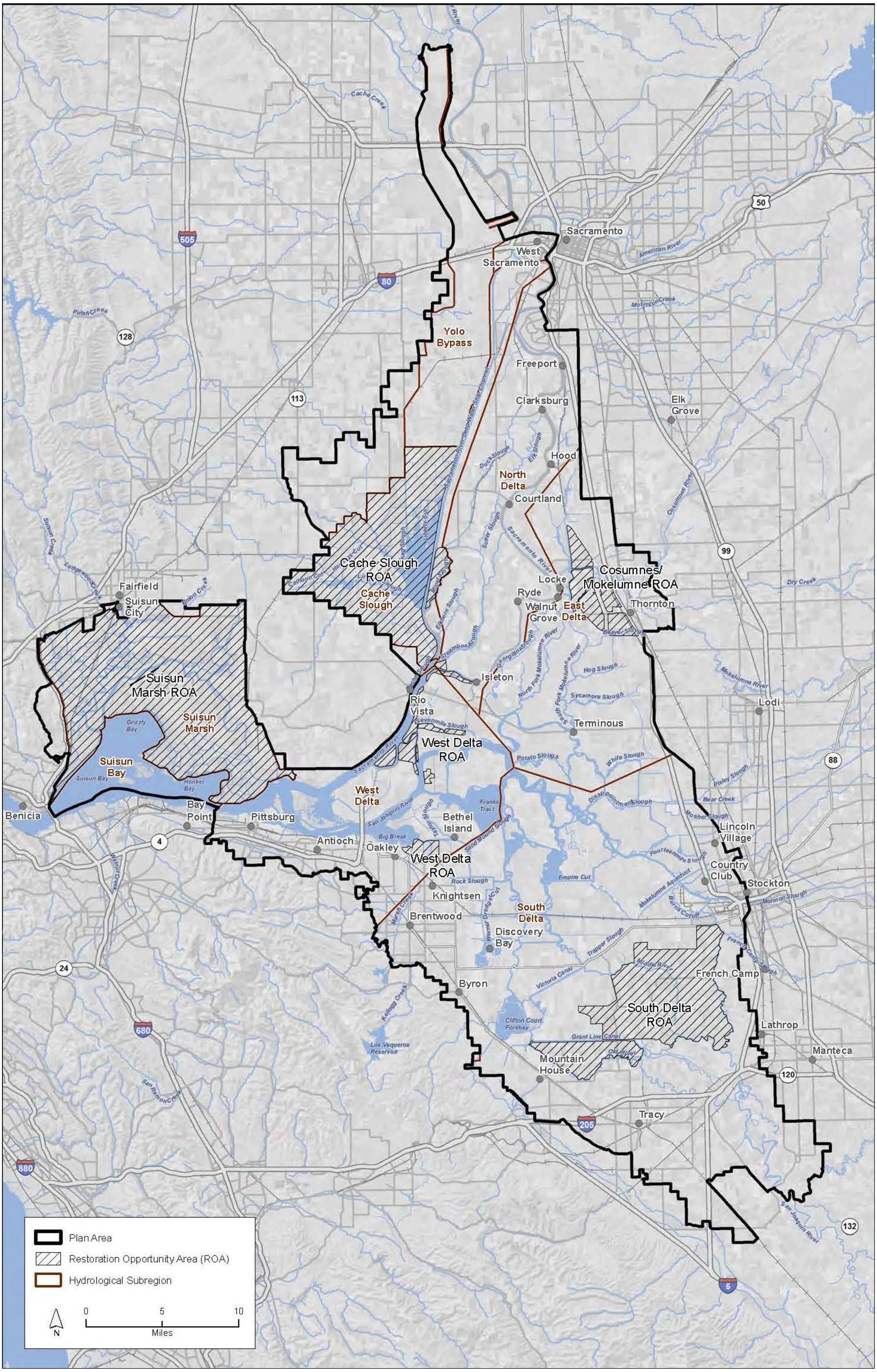
Opportunities for restoration of tidal habitat have been identified in specific portions of the Plan Area subregions. These Restoration Opportunity Areas (ROAs) are areas within the subregions that have been identified as having particularly high potential for restoration (Figure 5.E.4-1). The analysis below evaluates the potential restoration in the ROAs at the scale of the subregion. A brief description of the different subregions is provided below, including location, connectivity to adjacent water bodies, predominant land use and existing vegetation, topographic and bathymetric data, and salinity ranges.

Of the 65,000 acres of tidal natural communities restoration (Objective L1.3), 20,600 acres must occur in particular ROAs within the subregions, consistent with the following minimum restoration targets.

- Suisun Marsh ROA: 7,000 acres of brackish tidal natural communities, of which at least 3,000 acres are tidal brackish emergent wetland and the remainder are tidal perennial aquatic and tidal mudflat.
- Cache Slough ROA: 5,000 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, tidal mudflat).
- Cosumnes/Mokelumne ROA: 1,500 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, and tidal mudflat).
- West Delta ROA: 2,100 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, and tidal mudflat).
- South Delta ROA: 5,000 acres of freshwater tidal natural communities (tidal freshwater emergent wetland, tidal perennial aquatic, and tidal mudflat).

The remaining 34,400 acres will be distributed among the ROAs, or may occur outside the ROAs in order to meet the biological goals and objectives described in Chapter 3, *Conservation Strategy*.

For purposes of evaluating the potential impacts of restoration, a hypothetical restoration footprint was developed for each ROA. This hypothetical restoration footprint was developed based on a feasible scenario of tidal wetland restoration based on restoration suitability (surface elevation, proximity to tidal channels), land status (ownership, parcel size), and other factors (see Chapter 4, *Covered Activities and Associated Federal Actions*, for more discussion of how this hypothetical footprint was developed). The hypothetical footprint is one configuration of restoration that could result from implementation of CM4; actual implementation will depend on land availability, topography, and adaptive learning about large-scale tidal restoration.



GIS Data Source: Conservation Zones, SAIC 2012; Plan Area, ICF 2012; Restoration Opportunity Area, SAIC 2011; Hydrological Subregions, ICF 2012.

Figure 5.E.4-1. Restoration Opportunity Areas

5.E.4.2 Conceptual Model

Each fish species and life stage in the Plan Area has unique habitat requirements that will be addressed by tidal habitat restoration to varying degrees. The BDCP will provide habitat of varying types and suitability for different fish species and life stages. Suitable habitat is defined as an environment with conditions within the physiological tolerances of the species at a time and place necessary to support particular life stages. To be successful, a species must have suitable habitat to support each of its successive life stages that are linked across time and space to complete the life cycle of the species. Habitat conditions within the Plan Area affect covered fish species to varying degrees in large part because of the length of time that each spends in the Delta. For example, salmonids move through the Delta relatively quickly as juveniles and again as adults but spend the majority of their life histories outside the Plan Area. Delta smelt, on the other hand, spend their entire life history in the Plan Area.

Species performance in an environment reflects a complex, multidimensional balancing of many factors. The list of dimensions defining habitat for a species is potentially quite long but includes at least the following.

- Feeding and the ability of the species to find food of the correct type, in sufficient quantity under conditions conducive to feeding.
- Physiological tolerances, which can differ markedly between life stages.
- Types of habitats associated with different life stages.
- Connectivity between habitats over the life history.
- Intra- and interspecies factors associated with competition and predation.

Each of these axes of habitat suitability has associated with it environmental attributes, some of which can be quantified and measured. For example, attributes of physiological tolerance could include temperature, salinity, and oxygen levels for which specific species tolerances can be defined and condition measured in the field. Other attributes, such as habitat selection, may not be as clearly defined and must be inferred from distributional data.

Species do not always select optimal habitat conditions but instead balance different life cycle needs, including the search for food, avoidance of predators, and physiological tolerances for temperature and salinity, ultimately leading to successful reproduction. These needs define the habitat of the species along multiple axes that are the basis for biological performance of the species in the environment.

Habitat suitability for species habitat is defined by associations between species life stages and physical factors that believed to exert a strong control on species performance. The analysis was performed for delta smelt, longfin smelt, and salmonids. There was insufficient information on life history, distribution, and habitat preferences of sturgeon and lamprey to perform a habitat suitability analysis, and therefore possible impacts were evaluated qualitatively. Because of the wide tolerances of splittail for conditions in the Delta, a habitat suitability index (HSI) was not done for splittail at this time.

The habitat suitability analysis is based on a simple model that divides habitat into two elements: environmental attributes and physical habitat (Figure 5.E.4-2). Environmental attributes are related to habitat quality and generally reflect physiological tolerances or behavioral cues that affect productivity or survival. Environmental attributes incorporated into the models described below include temperature, salinity, and turbidity, factors that frequently are discussed in relation to distribution and performance of Delta fish species (e.g., Baxter et al. 2010). Specific suitability relationships are described for environmental attributes and their suitability for species life stages based on observed associations between with presence-absence data from Delta fish monitoring and environmental conditions. These associations were used to create life-stage preference curves that were used to calculate an overall HSI. The second component of habitat is physical habitat type. Habitat types relate to habitat quantity and are measured in acres. As described further below, habitat types were distinguished on the basis of attributes such as depth, topography, vegetation, and tidal influence. Specific types of habitat are selected by species life stages based on the availability of food, predators, or qualities associated with particular lifestage functions such as reproduction. Physical habitat types relate to the capacity of the environment for the species. HSI and habitat selection parameters adjust the acres of habitat types to produce Habitat Units (HUs) as shown in Figure 5.E.4-2.

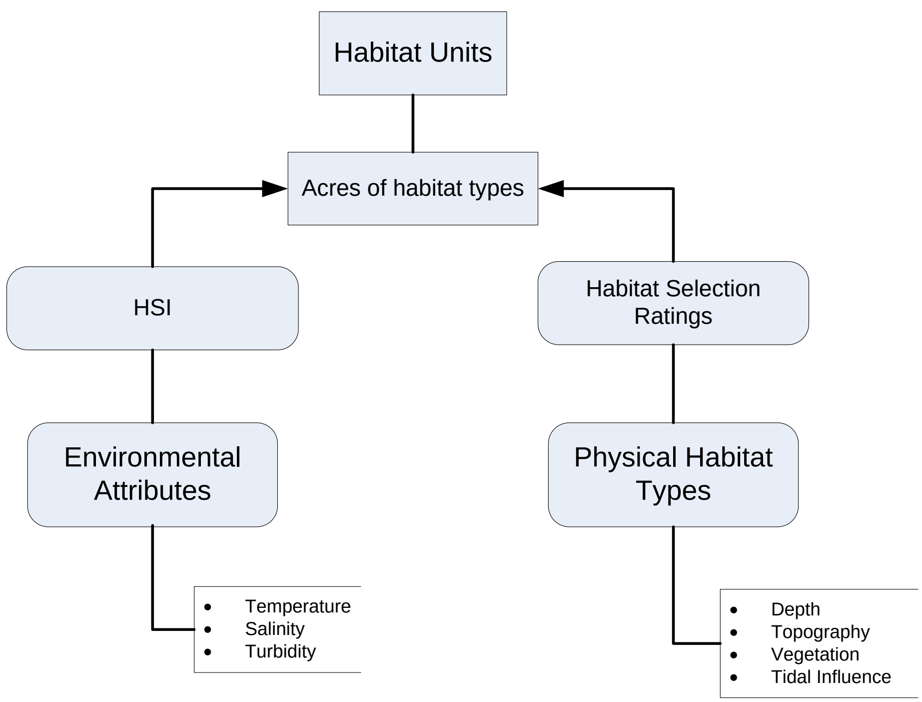


Figure 5.E.4-2. Conceptual Model of Habitat Used in the Habitat Suitability Analysis

5.E.4.3 Consistency with Biological Goals and Objectives

CM4 will advance the biological goals and objectives as identified in Chapter 3, *Conservation Strategy*, Table 3.4.4-3, *Biological Goals and Objectives Addressed by CM4 and Related Monitoring Actions*. The rationale for each of these goals and objectives is provided in Chapter 3, Section 3.3, *Biological Goals and Objectives.* Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met.

5.E.4.4 Evaluation

5.E.4.4.1 Methods

CM4 is intended to benefit covered fish species in two primary ways:

1. By increasing the amount of suitable habitat for each species.
2. By enhancing processes in the plan area that contribute to food that may be consumed by covered species.

Existing and future habitat conditions in the Plan Area were analyzed using habitat suitability analysis and literature review. The habitat suitability method computes an area-weighted index of habitat suitability that is used to compare conditions spatially, over time between implementation periods and between species. Suitability is computed from a set of attributes (e.g., habitat types, temperature, salinity) that are compared to hypotheses about the preference of species life stages with respect to these attributes. The result is a weighting of habitat from the perspective of the covered fish species. Habitat suitability of current and restored habitat was analyzed for delta smelt, longfin smelt, and salmonids. Habitat suitability was not evaluated for splittail because of their lack of specific habitat preferences while suitability was not computed for sturgeon and lamprey because of limited biological information. A literature review was conducted for all covered species and is included in the analysis.

5.E.4.4.1.1 Habitat Suitability Analysis

Habitat suitability analysis compares actions in terms of habitat units, *HU*s, which are the area of specific habitat types weighted by habitat suitability indices, the *HSI*. This method is conceptually similar to the method used in Feyrer et al. (2011). An HSI is a unitless number from 0 to 1, where 0 indicates unsuitable conditions and 1 represents optimum habitat (Terrell et al. 1982). HUs are simply the acres by habitat types weighted by the potential suitability of the habitat and by selection by the life stage (Figure 5.E.4-2). The method used here is similar to the U.S. Fish and Wildlife Service (USFWS) Habitat Evaluation Procedure (Schamberger et al. 1982). HSI ratings are based on species-habitat relationships that document conclusions regarding habitat suitability for a given life stage of a species relative to an environmental attribute such as temperature. HSIs are a commonly used method and are a component of the USFWS Habitat Evaluation Procedure (HEP) (U.S. Fish and Wildlife Service 1980) and a necessary component of the Instream Flow Incremental Methodology (IFIM) (Armour et al. 1984; Crance 1987).

The HSIs are measures of physiochemical habitat conditions within a defined area with respect to species- and life stage–specific requirements. Individual suitability models capture hypotheses regarding how individuals of a given life stage perceive environmental conditions. Bovee (1986) described three types of HSIs based on the data used to develop the relationships. Type 1 curves are based on professional judgment with little empirical data. Type 2 or utilization curves are based on habitat use and measures of conditions at specific sites where species or life stages are observed, Type 3 curves are generalizations of Type 2 curves to define species preference based on frequency distribution of habitats and species occurrence. The HSI curves developed for this analysis are of Type 2 curves and were developed from data collected in state and federal monitoring trawls such as the Fall Midwater Trawl (FMWT), supplemented by consultation with species experts. These data record presence-absence of species along with environmental information to track the association of species with particular conditions in the Delta.

Habitat suitability ratings used in this analysis are indices of association between presence or absence of fish life stages in various monitoring trawls and habitat conditions. As such, the HSIs range from 0 to 1.0 (0 = avoided habitat, 1.0 = preferred habitat) that define the habitat condition or value of attributes such as temperature, salinity, and turbidity. The value of the habitat suitability factor is derived from species–life stage relationships that describe, for example, the temperature association of a life stage. It is important to stress that fish can and often do inhabit areas where the computed HSI value is less than 1.0. Further, an HSI based on recently observed associations between species and conditions may reflect the best habitat available to the species but not necessarily the optimal condition for survival. Habitat suitability analysis does not define habitat needs relative to performance goals such as species recovery or abundance goals. In other words, the analysis provides no assessment of whether habitat quantity or value is sufficient to meet recovery or other management goals for the species. Instead, habitat suitability analysis provides a basis for assessing the potential value of restored habitat and to compare benefits across the plan area and between time period and species.

Habitat Suitability Indices

Habitat suitability of the environmental attributes was determined for individual species and life stages based on multiple environmental attributes (e.g., temperature and salinity). Life stages were selected for the analysis based on their occurrence in the Plan Area. For example, the HSI models for salmonids did not include egg or adult stages because these life stages do not occur in the Plan Area.

Environmental attributes were selected for the analysis based on three criteria.

1. Biological relevance to the species in the Plan Area.
2. Availability of data at the scale of the analysis.
3. Potential to project conditions into the future based on covered activities.

Biological relevance relates to the dimensions of habitat discussed above regarding feeding, physiology, and habitat availability. The scientific literature discusses numerous factors that potentially define habitat for the covered fish species in the Delta. However, the list of modeled habitat factors is reduced by the other two criteria. To be used in the analysis, sufficient data had to be available to describe the condition at the scale of the geographic subregion, and it was necessary to be able to forecast conditions in the future with and without the BDCP either through modeling or other conclusions. For example, planktonic food is an important factor in defining habitat for delta smelt (Bennett 2005) that likely relates to the presence of certain species of zooplankton (Criterion 1). However, there is not sufficient data to characterize zooplankton abundance or community structure at the scale of the subregion (Criterion 2), nor is there the ability at this time to project zooplankton response to future conditions. To incorporate a measure relating to feeding, turbidity was used in the analysis based on its association with delta smelt. The association between delta smelt distribution and turbidity has been suggested to reflect feeding success and avoidance of predators (Bennett 2005) although the association could be due to other factors. Food is not included in the HSI because of the lack of means to model food production at this time; however, an index of food production potential is developed below to compare food production potential between areas and implementation periods. There is sufficient information collected as part of the regional fish monitoring programs to characterize turbidity in the subregions (Criterion 2). At the present time there is no model available to project turbidity in the future, although there is reason to expect that turbidity in the Delta may decline in the future (Ruhl and Schoellhamer 2004). Recognizing the strong association with delta smelt presence, turbidity was used as a factor in the delta smelt model, but turbidity was assumed not to change over the implementation period (Criterion 3).

Hamilton and Murphy (unpublished data 2012, in review) evaluated many of the same environmental attributes used in this analysis for their utility in defining habitat affinity for delta smelt life stages. Their intent was to identify currently available areas in the Delta with high potential for restoration to benefit delta smelt. They concluded that turbidity, temperature, and salinity were usable predictors of delta smelt occurrence. In addition, they found calanoid copepod density to be associated with delta smelt abundance for juveniles and subadults during some months. Hamilton and Murphy also evaluated attributes related to depth, proximity to wetlands, and amount of shallow-water area. These structural habitat elements are partially captured in the physical habitat types delineated as described below. Habitat types were used in this analysis because they could be clearly and relatively easily projected into the future to predict the changes resulting from BDCP restoration. The results of Hamilton and Murphy regarding patterns of suitable habitat across the Delta analysis were generally consistent with those of this analysis.

The HSI relationships in the individual species models were used to compute 0–1 rating values based on both modeled and observed environmental data. For each species evaluated (delta smelt, longfin smelt, salmonids, and splittail), specific characteristics were assigned ratings for each life stage (Table 5.E.4-1).

Table 5.E.4-1. Environmental Attributes Used in the Species Habitat Suitability Models

Species Life Stage	Attributes Used in the Model
Delta smelt egg-larvae	Temperature, salinity, habitat type
Delta smelt larvae	Temperature, salinity, turbidity, habitat type
Delta smelt juveniles	Temperature, salinity, turbidity, habitat type
Longfin smelt egg-larvae	Temperature, salinity, habitat type
Longfin smelt larvae	Temperature, salinity, turbidity, habitat type
Salmonid juveniles	Temperature, turbidity, habitat type

HSIs were calculated for four scenarios for five water-year types. HSIs were calculated for an attribute (e.g., temperature) for a species life stage (e.g., delta smelt larvae) reflecting conditions in an area (e.g., geographic subregion) for a scenario (e.g., evaluated starting operations [ESO]) for a time period (e.g., LLT). For each life stage, HSI values were integrated across multiple attributes to create a single HSI value for a life stage using the geometric mean of the individual attribute HSI values:

$$HSI_{ij} = \sqrt[n]{F_1 \times F_2 \times \dots F_n}$$

(Equation 1)

where

F = An HSI for a life stage reflecting conditions for an environmental attribute (e.g., temperature, turbidity, salinity) ranging from 0 (no suitability/unsuitable) to 1 (ideal conditions).

The geometric mean is similar to an arithmetic mean, but it minimizes the effect of extreme values (Sokal and Rohlf 1981). Because it is computed as the product of a set of suitability factors, the HSI will go to zero (indicating that the habitat has no value for the species) if any single factor goes to zero. HSIs are never negative (i.e., habitat can have no value to a species but a negative value is non-sensical) although there can be negative change in HSI values between alternatives or time periods.

Habitat Units

As shown in Figure 5.E.4-2, HUs are computed by applying the HSI and habitat selection values to the total quantity of available or restored habitat. HUs are indices of habitat potential that incorporate habitat quantity (acres of habitat types), habitat selection, and habitat value (HSI). HUs are a dimensionless index of habitat value for the species (Schamberger et al. 1982). While the calculation of HUs is based on the estimated acreage that potentially would be flooded as a result of habitat restoration, HUs are not the same as area and do not have the units of acreage. The actual acreage potentially available to a species does not change. HUs evaluate these acres relative to the needs of the given species and life stage. While it is instructive to compare habitat acreage and the resulting HUs, the fact that HUs for a species life stage are less than the total area does not mean that the acreage has decreased—it is simply "smaller" in terms of use or preference from the perspective of the given species life stage.

The HUs help interpret the habitat types (Table 5.E.4-1) from the perspective of a species and life stage. The determination of HUs incorporates the concept of key habitat types for different life stages, which involved consideration of the potential of life stages to select particular types of environments over others; for example, delta smelt are assumed to preferentially select shallow intertidal areas for spawning.

HUs are formalized as follows.

$$HU_{ijk} = \sum^{h} (HSI_{ij} \times P_{ijh} \times A_h)$$

(Equation 2)

where,

HSI = Habitat Suitability Index for a species life stage

P = life stage preference for habitat types

A = area of habitat types

i = species

j = life stage

k = geographic subregion

h= fish habitat types (e.g., deep, intertidal, shallow)

Habitat preference (P in Equation 2) is the potential selection of habitat types by a species life stage. Physical habitat types were delineated based on static physical attributes such as geomorphology, vegetation, and location. Selection of habitat types is often a life stage–specific relationship. For example, salmon typically select riffles or pool tail-outs for spawning and do not select pools for spawning, although pools may be preferred habitat for other life stages. HSI brings in dynamic aspects of habitat such as temperature, salinity, and turbidity that overlie habitat affinity or selection. For example, a type of environment might be selected by a species life stage (e.g., shallow intertidal areas for spawning delta smelt), but the habitat suitability may be low because of temperature, water quality, or other habitat suitability attributes.

Limitations and Uncertainties

The habitat suitability analysis provides a structured, transparent approach to evaluating the benefits of tidal habitat restoration for covered fish species. While limited because of scope and current knowledge, it nonetheless provides an explicit structure within which to which to integrate current understanding of habitat for each species and to project patterns of habitat suitability across the Delta. However, some important limitations should be highlighted.

1. The actual definition of habitat from the perspective of the target species is undoubtedly far more complex than considered in this analysis. The observed association of species abundance with environmental conditions reflects a complex, multidimensional balancing of species lifestage requirements. An association between fish and certain conditions may be coincidental rather than causal. An underlying assumption of an HSI is that fish congregate in areas with suitable conditions and avoid areas with unsuitable conditions. However, species do not necessarily select optimal habitat as defined by laboratory experiments. Delta smelt, for example, might be found in areas where temperature or salinity is not optimal (though tolerable), perhaps because of a lack of food or the presence of predators in optimal habitat.
2. Environmental attributes are often not independent and may have appreciable covariation that is not accounted for in an HSI. Cross-correlations may result in coincidental or spurious relationships.
3. The analysis depends on projections of environmental conditions (e.g., temperature, salinity) that are derived from models operating at even larger scales than the geographic subregions. To the extent possible, data were chosen from stations close to or within the ROAs in each subregion. However, the success of a life stage in an environment is an entirely local, usually small-scale phenomenon. Analysis at the scale of the ROA subregion effectively averages across considerable spatial and temporal complexity in habitat conditions.
4. The analysis does not account for the connection of life stages across areas and time. To be successful, fish need habitat of suitable quantity and value for each life stage at appropriate transition periods. Life-history trajectories plot the habitat pathways that determine species performance. However, an HSI considers each life stage and associated habitat in isolation.
5. Habitat suitability analysis does not consider explicitly whether habitat conditions are sufficient or necessary to recover fish species. HUs can increase through restoration even though habitat value declines. Habitat suitability analysis does not address whether increased HUs compensate for reduced habitat value or if habitat conditions are sufficient to meet management needs.
6. Fish movements and the ability of species to find and occupy restored habitat are not accounted for by an HSI, which assumes that the habitat will be occupied if it is encountered by the species life stage. The degree to which the species is habitat-limited also is not considered by an HSI.
7. The habitat associations in the HSI models are based on observed distributions of species and the conditions that exist in the Bay-Delta today. Because of the extent of alteration of the Delta from historical conditions, the associations may not indicate ideal habitat but rather the best that is available under present circumstances.
8. The analysis did not model turbidity over the implementation period because of a lack of tools to project turbidity changes. As a result, it was assumed that turbidity would remain constant

between scenarios. However, there is reason to believe that turbidity may decrease in the future because of changes in sediment input and retention in the Delta (unrelated to the BDCP) (Schoellhamer 2011), which would decrease the HSI values derived in this analysis.

The habitat suitability relationships used in this analysis are based on the best available scientific information garnered from published scientific literature, monitoring and research data sets, and consultation with regional species experts. The resulting relationships are valid conclusions from the best available science but also reflect important limitations in scientific information. Ultimately, they are best viewed as working hypotheses that can be tested and refined during Plan implementation.

Data Sources for Habitat Suitability Models

Suitability models were derived from review of available literature, consultation with regional species experts, and modeling of California Department of Fish and Wildlife (CDFW) trawl data. The results of the analysis are captured as HUs that are the product of the area of various habitat types and the HSI ratings for the same areas. The determination of HUs also incorporates the concept of key habitat types for life stages that were rated in meetings with species experts from USFWS, National Marine Fisheries Service (NMFS), CDFW, California Department of Water Resources (DWR), and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), and the ratings were applied after the habitat suitability analysis was performed. This allowed consideration of life stages selecting particular types of environments over others.

5.E.4.4.1.2 Species Habitat Models

Habitat models were developed for each covered fish species listed below. However, it was concluded that there was insufficient information upon which to build an HSI analysis for lamprey and sturgeon. HSI models have been developed for the following species/species groups:

- Delta smelt
- Longfin smelt
- Salmonids

Delta Smelt Habitat Model

Potentially restored habitat was assessed for three delta smelt life stages:

- Egg-larvae (immediate post-hatch)
- Larvae (yolk sac to development of swim bladder and fins)
- Juveniles (actively feeding and swimming)

Consultation with species experts indicated that the egg stage of delta smelt was relatively impervious to environmental conditions. However, juvenile delta smelt become sensitive to environmental conditions as soon as they are exposed to the environment outside the security of the egg. Because the egg-larvae stage addresses delta smelt at that critical transition from the protected egg to the environment prior to commencing active feeding, it was used in this assessment.

An adult delta smelt life stage was not included after consultation with regional species experts. The adult life stage was considered to be a transitory life stage between actively feeding juveniles and spawning, and an HSI analysis was considered redundant. It was felt that the spawning aspect of the adult stage was adequately addressed by the yolk-sac larvae stage, and the rearing aspect of habitat was captured by the juvenile stage.

For each life stage, simple conceptual models were developed as well as rating curves for attributes associated with habitat value for each life stage.

Rating curves for larval and juvenile delta smelt were developed from analysis of standard monitoring trawl data using General Additive Modeling (GAM) (Hastie and Tibshirani 1986) curves depicting probability of occurrence. The GAM analysis was done developed by Matthew Nobriga (pers. comm., unpublished data) based on CDFW sampling data using methods similar to those described by Nobriga et al. (2008). Specifically, curves for salinity (EC), temperature (degrees Celsius [°C]), and turbidity (Secchi disk reading) were developed for larval (20 millimeter [mm] trawl data) and juvenile (FMWT data) delta smelt. For eggs, temperature relationships were developed from temperature equations from Bennett (2005). Salinity for eggs used larval fish data on the assumption that delta smelt adults would lay their eggs in salinity that is suitable for larvae to survive. All the probability curves were standardized on a 0–1 scale to be suitable for HSI analysis.

Laboratory-based accounts of salinity preferences for species often differ from tolerance observed in the field. To survive, species such as delta smelt balance several factors such as food availability, temperature, osmoregulation, and predation. Fish may be able to survive in the laboratory at high salinities, but to do so requires additional energy (food) such that the observed distribution with salinity may be considerably different from that seen in the laboratory. Both temperature and salinity affect the basic physiology of the organism, and extreme values can result in death. For these reasons, temperature and salinity occur in all delta smelt life stage models.

Egg-Larvae

This life stage captures the transition from egg to larvae and occurs immediately pre- and post-hatching. Delta smelt do not feed during this stage and are sustained by their yolk-sac. Yolk-sac larvae lack development of fins and a swim bladder and are generally unable to swim but move in response to flow (Bennett 2005). These fish are rarely captured in pelagic trawls because of their small size and generally demersal behavior; however, they are captured in small numbers in the CDFW 20-mm surveys. The life stage is assumed to occur coincident with the presumed delta smelt spawning period from February to June (Bennett 2005).

The conceptual habitat model for the egg-larvae life stage includes two environmental factors: temperature and salinity during the February to June period (Figure 5.E.4-3). Because they do not feed, turbidity, which is assumed to affect feeding in later stages, is not used for this life stage.

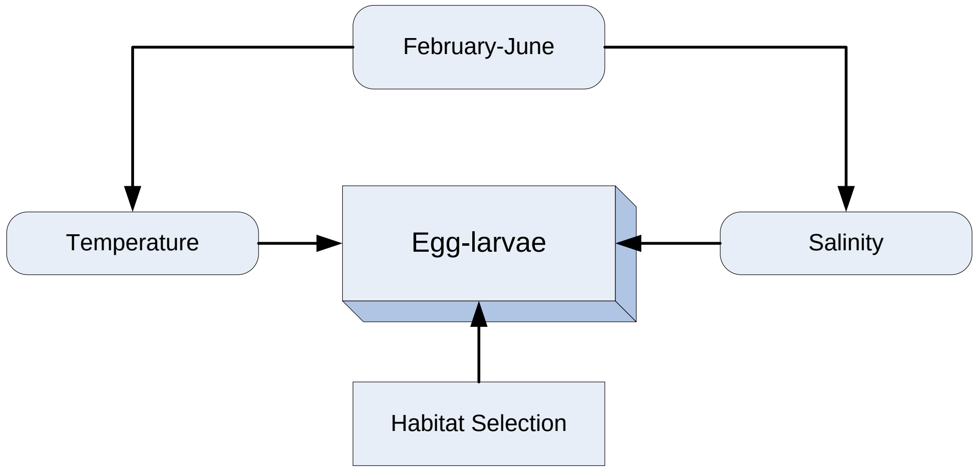


Figure 5.E.4-3. Conceptual Model for Yolk-Sac Larvae Life Stage of Delta Smelt for Habitat Suitability Evaluation of Conservation Measure 4

Salinity

Delta smelt eggs appear to be quite tolerant of a wide range of salinity once they have "hardened" (Bennett pers. comm.; Lindberg pers. comm.). It is hypothesized that the point of vulnerability to salinity is the early yolk-sac stage immediately after hatching. Salinity suitability ratings for the egg-larvae delta smelt were based on the 20-mm survey data for fish less than 20 mm and associated salinity measured as EC. This includes both yolk-sac larvae as well as later, more developed larvae. Lacking more specific data on salinity associations for larval delta smelt, the analysis assumed the same salinity tolerances for both life stages. The data indicate a relatively broad range of salinity tolerances up to EC values of about 4000, after which associations and suitability decline. Figure 5.E.4-4 compares the results from the GAM analysis of the 20-mm trawl data and the assumed HSI relationship. The GAM line is a statistically fitted line associating observed presence-absence data and environmental conditions; the HSI line is the relationship assumed for this analysis and is an interpretation of the GAM line.

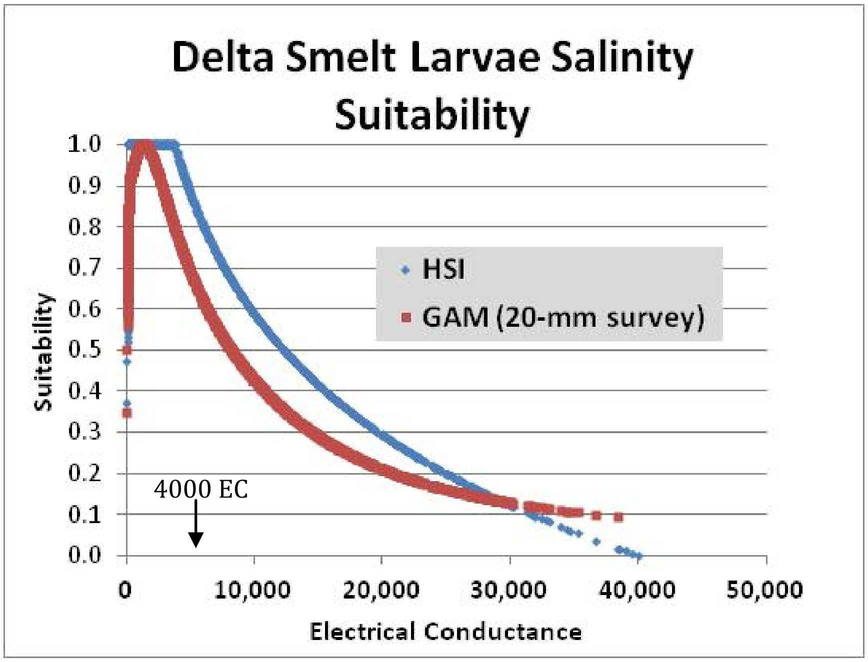


Figure 5.E.4-4. Salinity Suitability Relationship for Delta Smelt Egg-Larvae Life Stage

Temperature tolerance (°C) of the egg-larvae stage was based on temperature requirements for delta smelt eggs based on limited laboratory results. Baskerville-Bridges (reported in Bennett 2005) provides measures of the success of hatching of delta smelt eggs at 10, 15, and 20°C. The highest proportion of hatching occurred at 15°C with appreciably lower success at the two extremes. Based on these results, an egg temperature suitability relationship was derived with the optimal condition (suitability = 1.0) from 12 to 16°C (Figure 5.E.4-5).

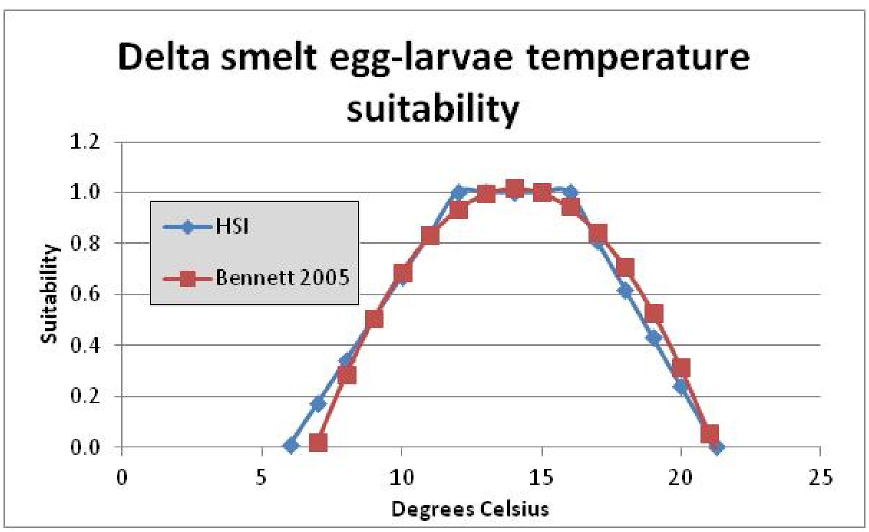


Figure 5.E.4-5. Assumed Temperature Suitability Relationship for Delta Smelt Eggs

Habitat Preference

Spawning of delta smelt has not been observed in the wild (Bennett 2005) but is inferred by the spawning behavior of related species and by the occurrence of yolk-sac larvae in the 20-mm trawl (Bennett 2005). Based on that evidence, it was concluded that delta smelt select shallow intertidal areas for spawning and avoid deeper water (Table 5.E.4-2).

Table 5.E.4-2. Assumed Habitat Preferences for Delta Smelt Life Stages

	Delta Smelt		
Habitat Type	**Egg-Larvae**	**Larvae**	**Juveniles**
Tidal Brackish	0.75	1	0.75
Tidal Fresh	0.75	1	0.75
Intertidal Mudflat	0.25	1	1
Shallow Subtidal	1	1	1
Deep Subtidal	0	1	1

Time Period

The spawning period was assumed to be from February to June (Nobriga and Herbold 2009). Environmental conditions for salinity and temperature from this period for each scenario were derived as described below and used in the suitability functions to evaluate suitability of conditions for delta smelt eggs.

Larvae

A three-factor conceptual model was assumed for larvae along with habitat preference (Figure 5.E.4-6).

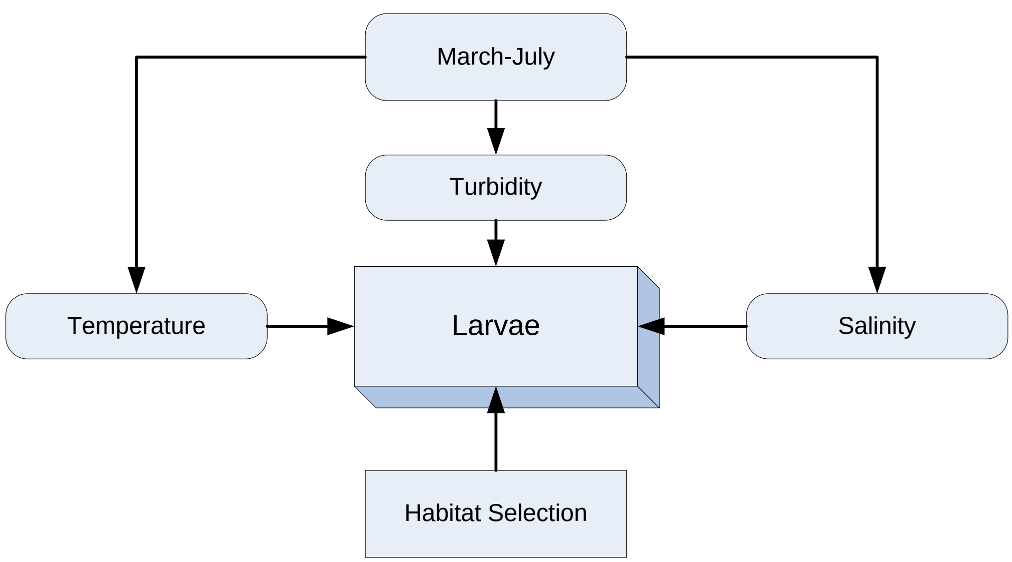


Figure 5.E.4-6. Conceptual Habitat Model for Delta Smelt Larval Life Stage

Turbidity

Delta smelt generally are found post–egg stage in higher turbidity conditions (Bennett 2005; Baxter et al. 2010). Turbidity is believed to provide both protection from predators and a visual background for discovery of prey (Bennett 2005). The assumed relationship for the HSI computation was based on the association of turbidity with the probability of occurrence of larval smelt in the 20-mm trawl survey (Nobriga pers. comm.). The assumed relationship follows the observed relationship closely up to a Secchi disk value of about 60 centimeters (cm) (Figure 5.E.4-7). Regional species experts concluded that there was no reason to suppose the flattening of the relationship at this point indicated a tolerance for increasing levels of water transparency (increasing Secchi disk depth) and that suitability was likely to continue to decrease with increasing transparency. The flattening in the 20-mm trawl data at 60 cm Secchi depth was believed to represent a sampling artifact of standardizing the data between 0 and 1. On the basis of this argument, the HSI relationship shown by the red line in Figure 5.E.4-7 was developed with agency experts.

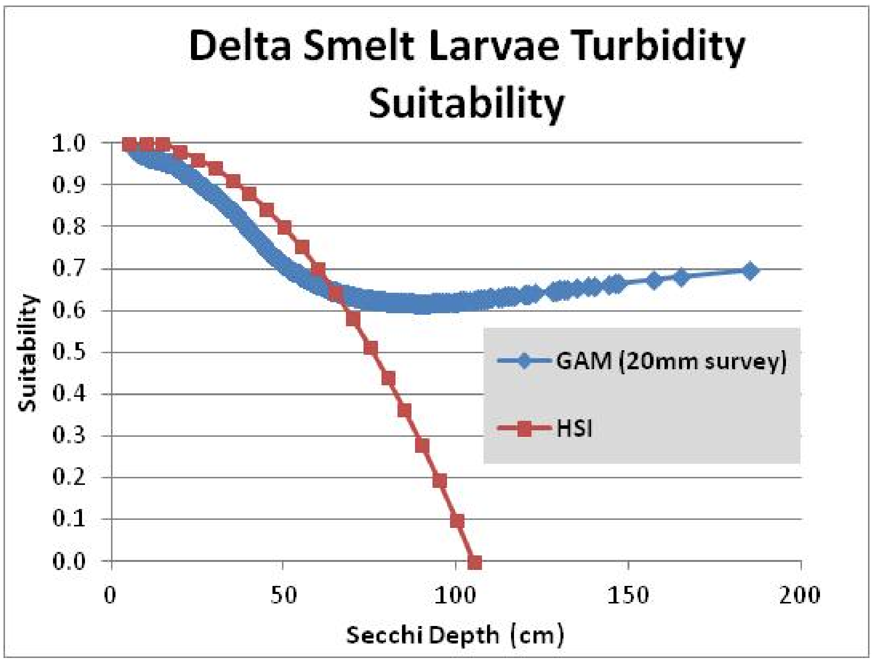


Figure 5.E.4-7. Assumed Turbidity Suitability of Delta Smelt Larvae

Temperature

Temperature suitability for delta smelt larvae was based on the GAM curves of temperature with larval probability of occurrence in the CDFW 20-mm trawl data (Nobriga pers. comm.) as well as species summaries of Bennett (2005) and Nobriga and Herbold (2009) and consultation with regional species experts. Based on these sources, the relationship in Figure 5.E.4-8 was developed with an optimal temperature range (suitability = 1.0) of 15–20°C. On the advice of regional species experts, this same relationship was used for delta smelt juveniles.

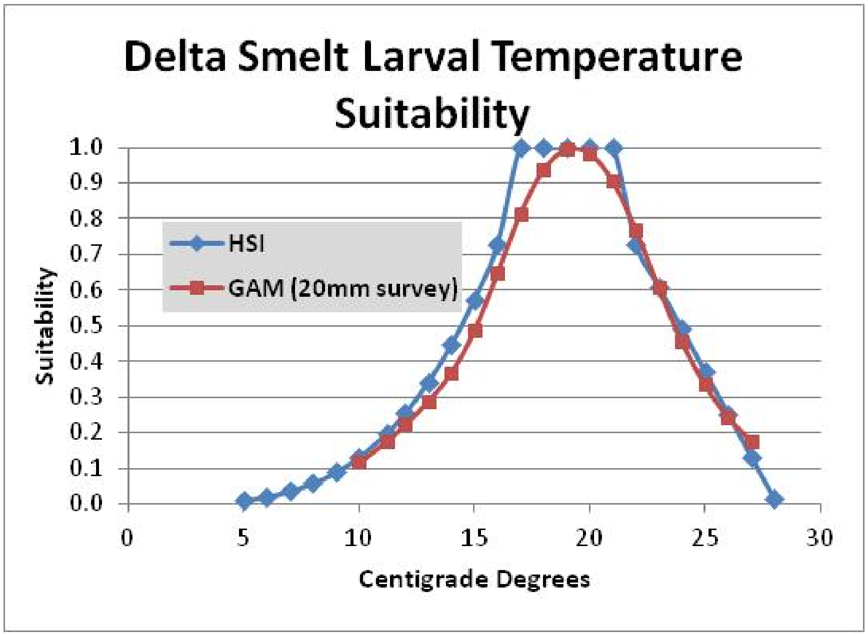


Figure 5.E.4-8. Temperature Suitability for Delta Smelt Larvae and Juveniles

Salinity

The suitability of habitat for larval delta smelt with respect to salinity (EC) was based on GAM analysis of salinity with the probability of occurrence of larvae in the 20-mm trawl developed by Matt Nobriga (pers. comm.). The assumed relationship follows the observed relationship closely (Figure 5.E.4-9). However, the relationship was not assumed to be as sharply peaked as was the case in the observed data. Note that the larval HSI curve is the same as that used for the egg-larvae stage (Figure 5.E.4-4).

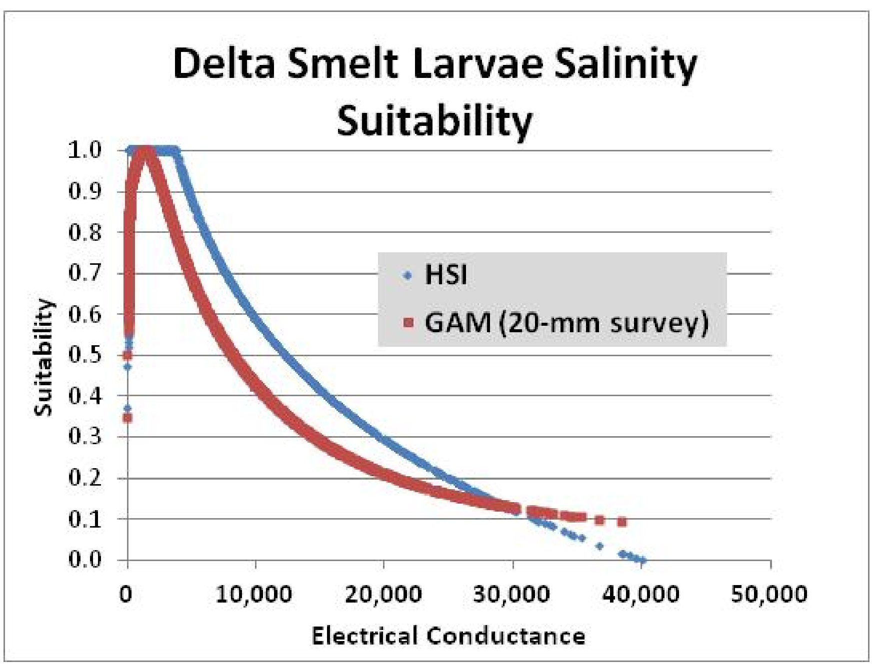


Figure 5.E.4-9. Assumed Salinity Suitability of Delta Smelt Larvae

Habitat Preference

Based on consultation with regional species experts, it was assumed that delta smelt larvae have an equal likelihood to be found in any of the habitat strata; in other words, habitat preference for larvae was set to 1.0 for all habitat types (Table 5.E.4-2). Delta smelt are known to move between depth strata and use tides to facilitate movement or to seek out suitable conditions (Aasen 1999; Baxter et al. 2010).

Time Period

The larval period for delta smelt was assumed to be from March to July (Nobriga and Herbold 2009). Environmental conditions for turbidity, temperature, and salinity from this period for each scenario were derived as described below and used in the suitability functions to evaluate suitability of conditions for delta smelt larvae.

Juveniles

A three habitat value-factor conceptual model plus habitat preference was assumed for juveniles similar to that used for larvae, and the rationale for the model is similar to that discussed above for larval delta smelt (Figure 5.E.4-10).

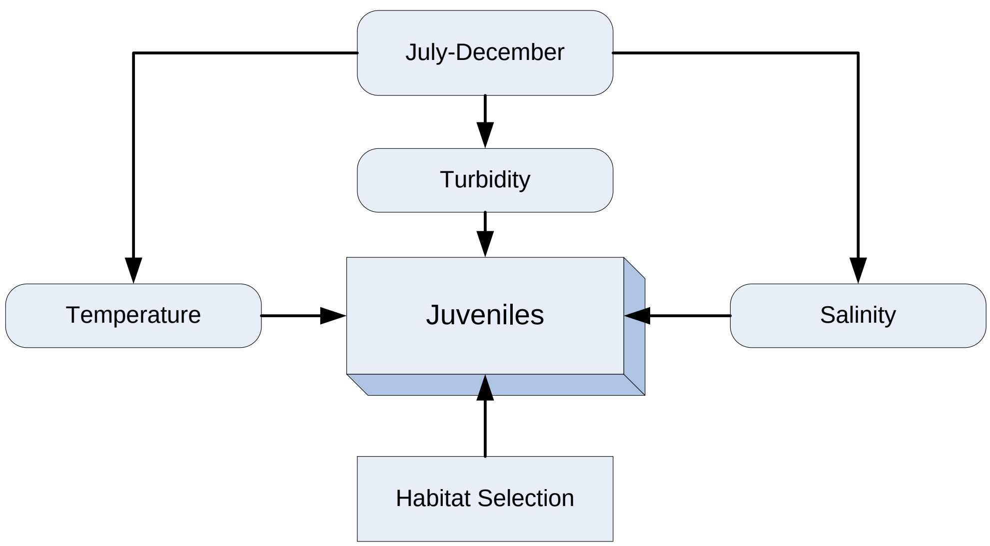


Figure 5.E.4-10. Conceptual Model for Delta Smelt Juvenile Life Stage

Temperature

Temperature suitability for delta smelt juveniles was based on the same curve for temperature as for larval delta smelt. It was the general opinion of agency experts that the 20-mm survey data curve better depicted temperature suitability than the FMWT data. Based on these sources, the relationship in Figure 5.E.4-8 was used with an optimal temperature range (suitability = 1.0) of 15–20°C. On the advice of regional species experts, this same relationship was used for delta smelt juveniles.

Salinity

The suitability of habitat for juvenile delta smelt with respect to salinity (EC) was based on GAM analysis of salinity with the probability of occurrence of juveniles in the FMWT data developed by

Matt Nobriga (pers. comm.). The assumed relationship follows the observed relationship closely (Figure 5.E.4-11). However, the relationship was not assumed to be as sharply peaked as was the case in the observed data.

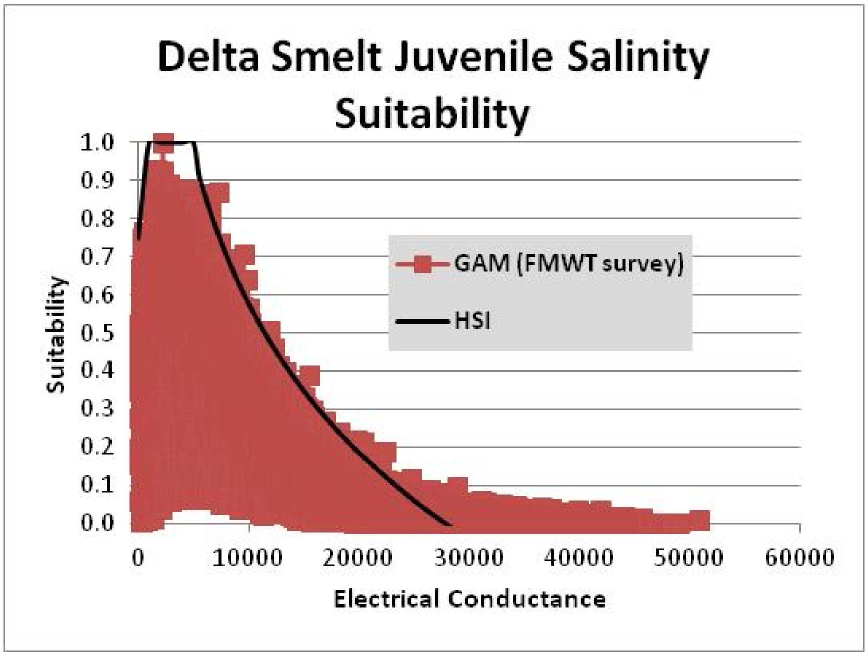


Figure 5.E.4-11. Assumed Salinity Suitability of Delta Smelt Larvae

Turbidity

The rationale for inclusion of turbidity in the juvenile delta smelt model was the same as outlined above for larvae; juvenile delta smelt are associated with areas of higher turbidity, which appears to enhance feeding and perhaps predator avoidance (Bennett 2005). The turbidity suitability rating was based on Nobriga and Herbold (2009) and Nobriga et al. (2008). The assumed relationship closely follows that of Nobriga et al. (2008) and is compared to the FMWT data in Figure 5.E.4-12.

Habitat Preference

Based on consultation with regional species experts, it was assumed that delta smelt juveniles, like larvae, have an equal likelihood to be found in any of the habitat strata; in other words, habitat preference for larvae was set to 1.0 for all habitat types (Table 5.E.4-2). Delta smelt are known to move between depth strata and use tides to facilitate movement or to seek out suitable conditions (Aasen 1999; Baxter et al. 2010).

Time Period

The juvenile period for delta smelt was assumed to be from March to July (Nobriga and Herbold 2009). Environmental conditions for turbidity, temperature, and salinity from this period for each scenario were derived as described below and used in the suitability functions to evaluate suitability of conditions for delta smelt larvae.

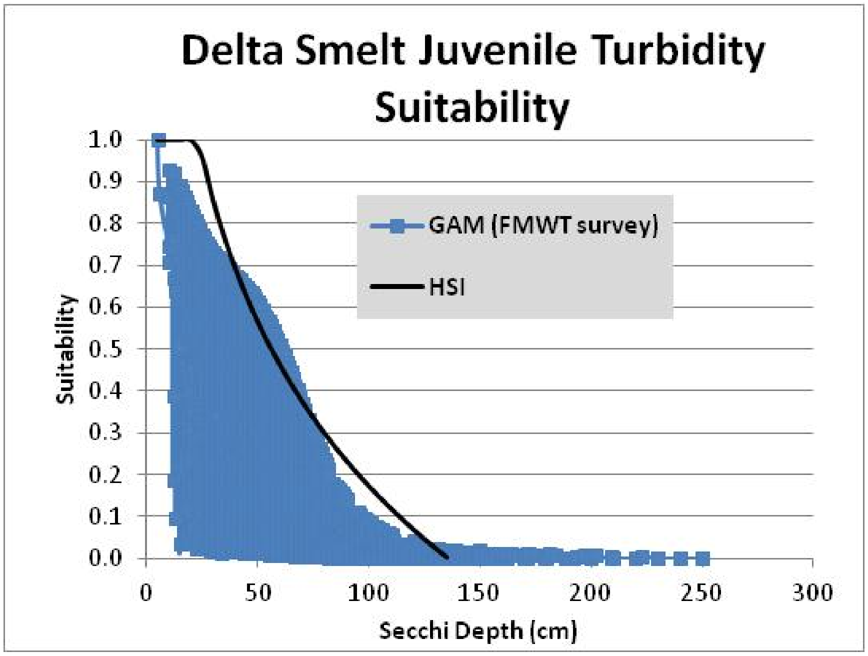


Figure 5.E.4-12. Assumed Juvenile Delta Smelt Turbidity Suitability

Salmonid Habitat Model

Only the juvenile life stage of salmon was considered in this analysis. Adults were assumed to move through the Delta quickly without feeding and would not be affected by the restoration of shallow tidal marshes. Salmonids spawn in tributaries above the Delta. The analysis is non–species specific and applies broadly to juvenile salmonids.

Foraging and Migrating Juvenile Salmonids

Two behavioral forms of juvenile salmonids were considered in the analysis. Juvenile salmonids, especially Chinook salmon, exhibit an array of behaviors related to the use of the Delta (Miller et al. 2010). For purposes of this analysis, two juvenile behavior forms have been distinguished: foragers and migrants. *Foragers* enter the Delta in spring and summer at a relatively young age. They typically spend days to weeks in the Delta, where they feed and grow prior to moving into the ocean. *Migrants* are a larger size and fully smolted when they enter the Delta and move through rapidly on their way to the ocean. Migrants feed as they move through the Delta but less than foraging salmonids. Salmonid populations may exhibit both behaviors, although typically one type predominates. For example, fall-run Chinook salmon in the Sacramento River system are predominantly foragers and most enter the Delta at a small size in their first spring or early summer. Steelhead, in contrast, spend up to a year in upriver areas, have a marked smoltification, and migrate rapidly through the Delta as larger 1-year-old smolts. Populations within the run groupings also have characteristic proportions of foraging and migrating fish.

Similar Delta habitat suitability models were used for both salmonid behavioral forms. The conclusion was that both forms have similar physiological tolerances for temperature and other factors. The two forms differed in regard to their period of exposure to conditions in the Delta, with foragers entering earlier and staying longer than migrants. They also differed in regard to their habitat preferences, with foragers preferring shallow, nearshore areas and migrants preferring deeper, offshore areas.

Habitat suitability conclusions for foraging and migrating juvenile salmonids were similar but differed in regard to their time period and duration within the Delta. A two-factor suitability model was used for both behavior forms but differed in regard to habitat selection and time period (Figure 5.E.4-13 and Figure 5.E.4-14). Physiological tolerances of juvenile salmonids were assumed to be the same for both foraging and migrating behaviors.

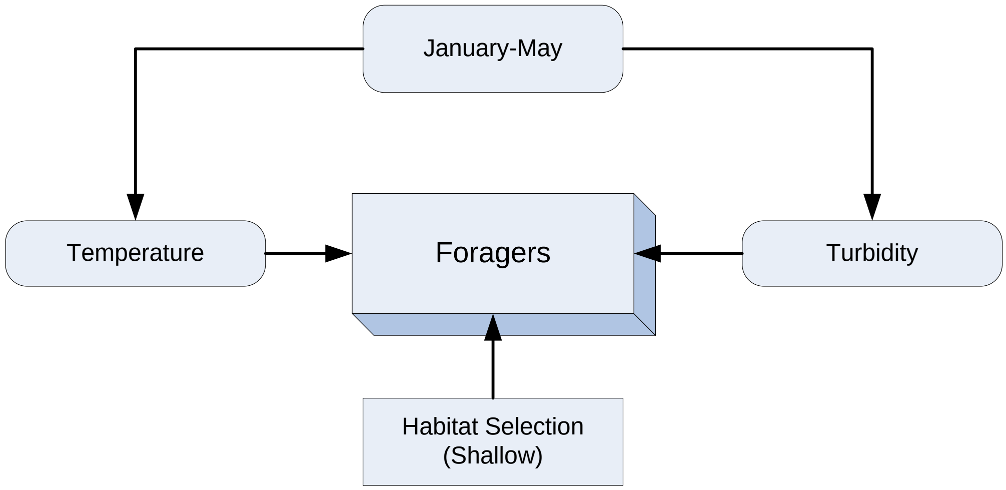


Figure 5.E.4-13. Conceptual Model for Foraging Juvenile Salmonids Developed for the Habitat Suitability Analysis

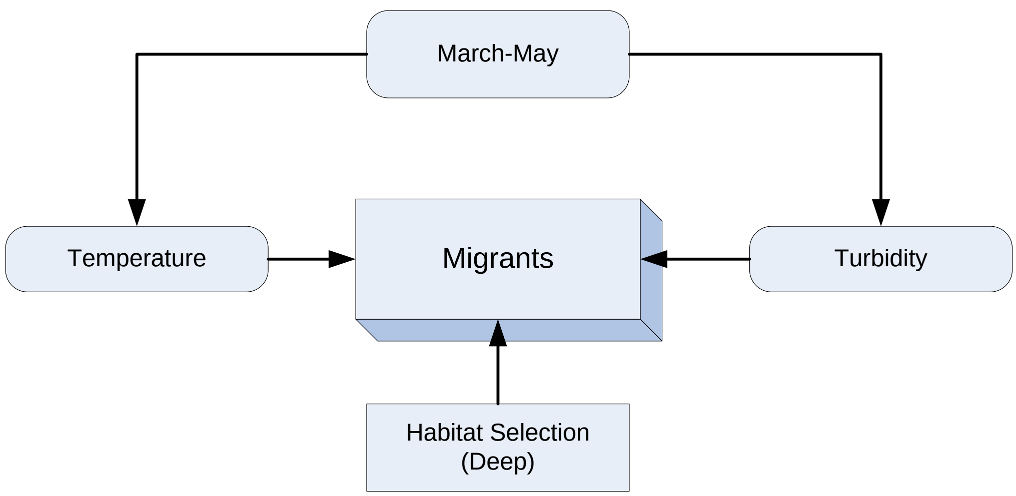


Figure 5.E.4-14. Conceptual Model for Migrating Juvenile Salmonids Developed for the Habitat Suitability Analysis

Temperature affects the basic physiology of salmonids, and extreme values result in lowered growth, delay of smoltification, and death (Marine and Cech 2004). Turbidity affects the prey encounter and predator encounter rates (Gregory and Northcote 1993; Gregory and Levings 1998). Salinity was not considered after consultation with agency experts who felt salinity was not a limiting factor for salmonids because they are physiologically adapting to a changed salinity regime as they move through the Delta. For these reasons, temperature and turbidity occur in the foraging juvenile salmonid life stage model.

Temperature

Temperature suitability for juvenile foraging salmon was based on the literature of previous salmonid HSI studies, by analysis of migration survival in relation to temperature in the Delta, laboratory studies, and consultation with regional species experts (Raleigh et al. 1986; Baker et al. 1995; Marine and Cech 2004). Based on these sources, the relationship in Figure 5.E.4-15 was developed with an optimal temperature range (suitability = 1.0) of 8–16°C for both foraging and migrating juvenile salmonids.

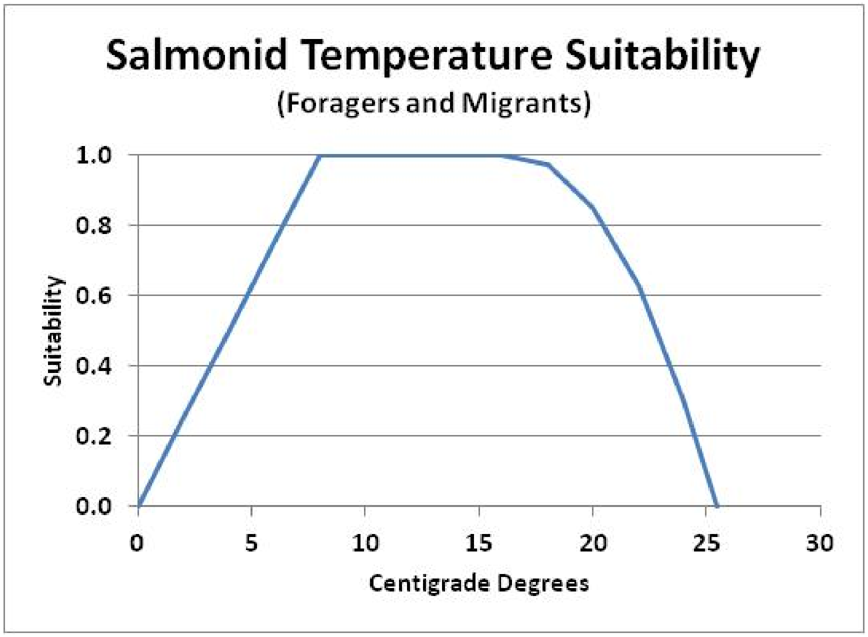


Figure 5.E.4-15. Assumed Temperature Suitability Relationship for Juvenile Salmonids

Turbidity

The rationale for including turbidity in the juvenile salmon model is that turbidity affects both salmon feeding and their avoidance of predators (Gregory and Northcote 1993). Turbidity preferences of juvenile salmonids have not been clearly delineated in the Delta. The hypothesis used here is that habitat suitability for foraging juvenile salmonids is a balance between high turbidity that protects juvenile salmonids from predators and successful foraging for drift, pelagic, and benthic prey. The result is that there is an optimal mid-level of turbidity with lesser suitability at higher and lower levels. Turbidity suitability rating for salmonids is relatively unknown in an HSI setting, especially in the Bay-Delta. This suitability rating was based on Chipps Island trawl data from the USFWS. The assumed relationship in Figure 5.E.4-17 closely follows that of salmon fry and migrants frequency in relation to Secchi depth (Figure 5.E.4-16).

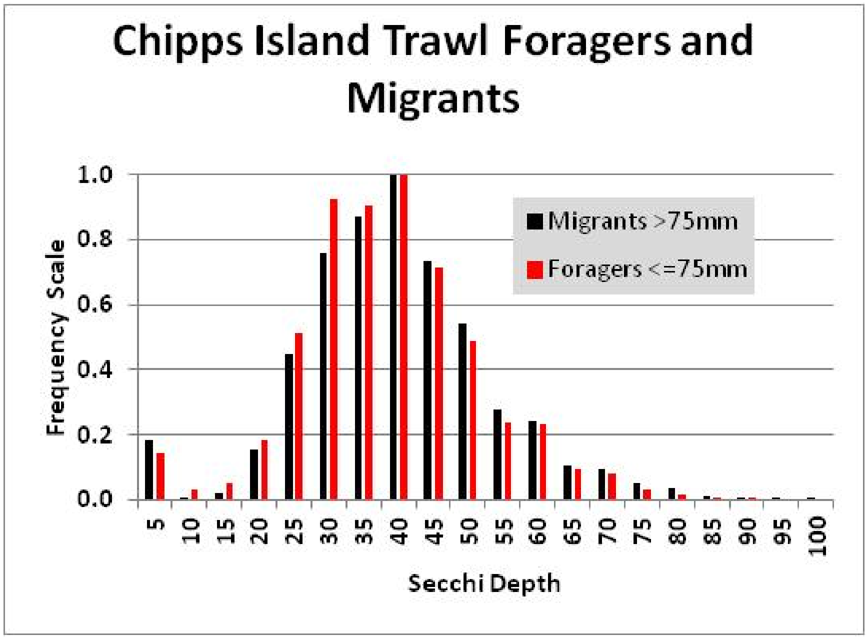


Figure 5.E.4-16. Chipps Island Trawl Frequency of Occurrence Data on a 0–1 Scale

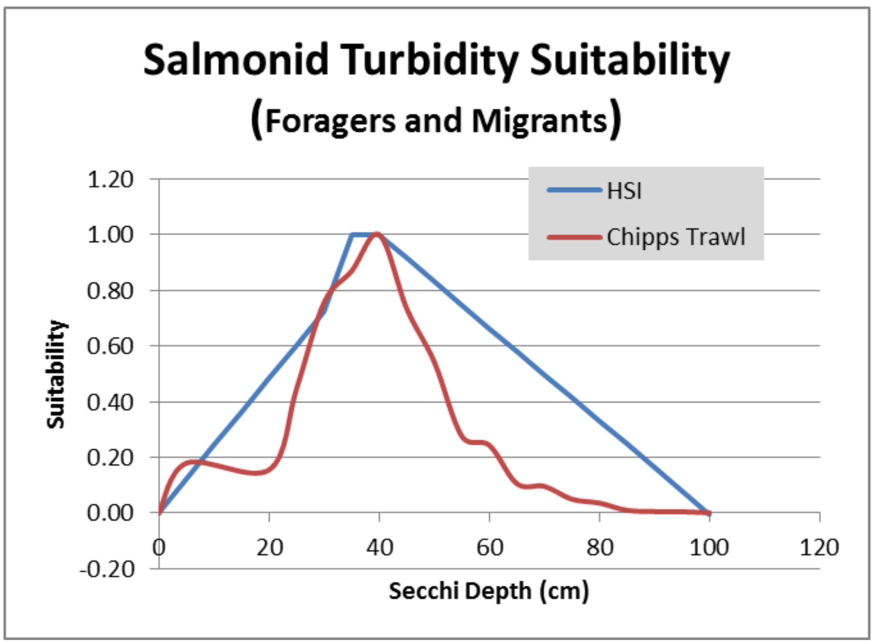


Figure 5.E.4-17. Assumed Juvenile Foraging Salmon Turbidity Suitability

Habitat Preference

Based on consultation with regional species experts, it was assumed foraging juvenile salmon would preferentially use shallow-water habitat for foraging; in other words, habitat preference was set to 1.0 for shallow-water habitat. It was thought that intertidal habitat would provide foraging benefits, but to some lesser extent, so intertidal habitat was assigned a 0.8 out of 1.0. Deepwater habitat (channels) was thought to provide the least foraging benefit and also increased predation risk and was assigned a 0.2 out of 1.0. (Table 5.E.4-3). Migrating juvenile salmonids were assumed to prefer deeper habitat and would be expected to spend less time feeding in shallow marsh areas. These habitat preferences are not assumed to be absolute but simply refer to general tendencies. Foraging juvenile salmonids are migrating and use deeper water while migrants may feed as they move through the Delta.

Table 5.E.4-3. Assumed Habitat Preferences of Juvenile Salmonid Stage

	Salmonids	
	Foragers	Migrants
Tidal Brackish	1	0.2
Tidal Fresh	1	0.2
Intertidal Mudflat	1	0.2
Shallow Subtidal	0.75	0.75
Deep Subtidal	0.2	1

Time Period

The months that juvenile foraging salmonids were thought to be in the Plan Area were from January–May (Williams 2006) while migrating juvenile salmonids were assumed to be present from March–May. Environmental conditions for temperature and turbidity from this period for each scenario were derived as described above and used in the suitability functions to evaluate suitability of conditions for juvenile foraging salmonids.

Longfin Smelt Habitat Model

Habitat suitability relationships were developed based on available literature (Rosenfield and Baxter 2007; Rosenfield 2010) and consultation with species experts, particularly Randy Baxter, CDFW (pers. comm.). Longfin smelt spend a limited portion of their life history in the Plan Area. Longfin smelt move westward into San Francisco Bay and nearshore marine areas after the larvae stage (Rosenfield 2010). Only spawning (egg-larvae) and larvae were assumed to occur in the Plan Area and were evaluated using habitat suitability analysis.

Egg-Larvae and Larval Longfin Smelt

Conceptual models for the egg-larvae and larvae stages of longfin smelt were similar to those for delta smelt. The egg-larvae stage was the pre-feeding stage and incorporated two factors: temperature and salinity (Figure 5.E.4-18).

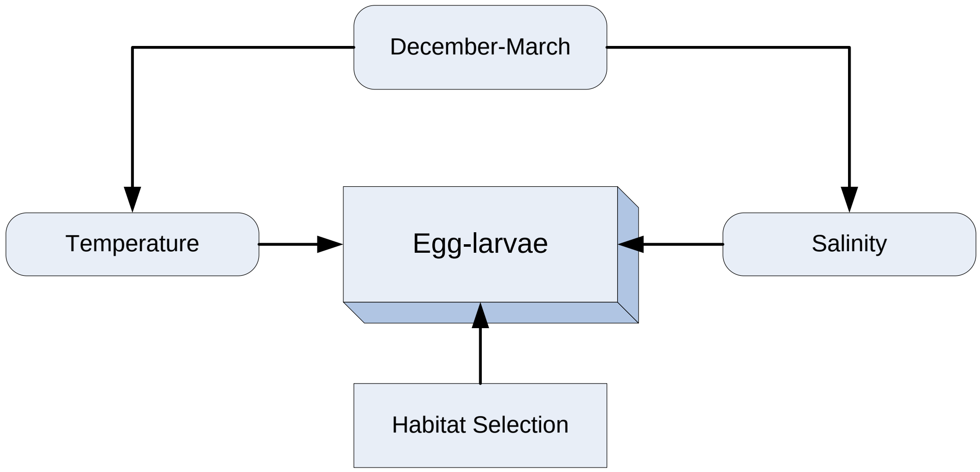


Figure 5.E.4-18. Conceptual Model for Longfin Smelt Egg-Larvae Stage Used in the Habitat Suitability Analysis

The larvae stage was assumed to actively feed, and therefore the additional factor of turbidity was included (Figure 5.E.4-19).

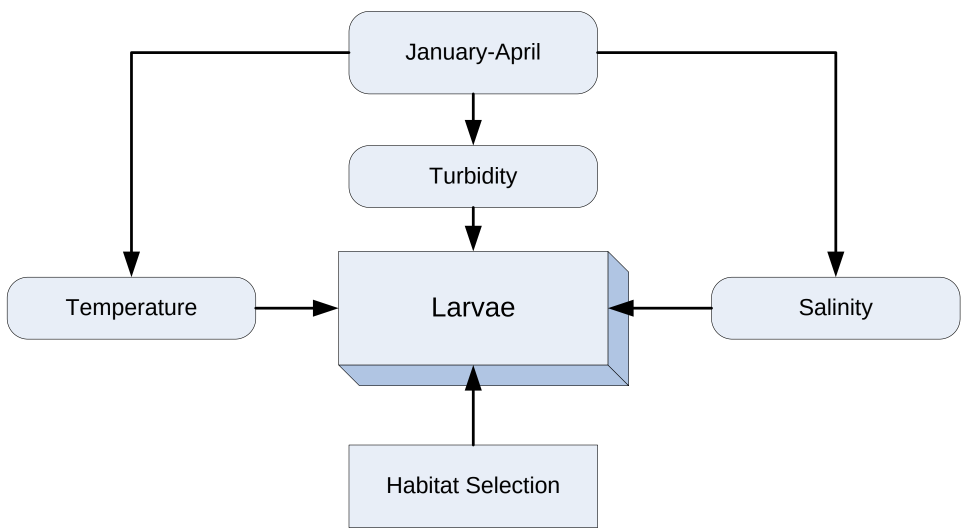


Figure 5.E.4-19. Conceptual Model for Longfin Smelt Larvae Stage Used in the Habitat Suitability Analysis

Temperature

Temperature suitability for longfin smelt eggs and larvae were based on published literature and discussions with Randy Baxter of the CDFW (pers. comm.). Survival in relation to temperature in the Delta was based on Baxter's observation of the CDFW larval delta smelt and longfin smelt trawl data and the CDFW 20-mm trawl data. Based on these sources, the relationship in Figure 5.E.4-20 was developed with an optimal temperature range (suitability = 1.0) of 7–13°C for eggs and 7–20°C for larval longfin smelt.

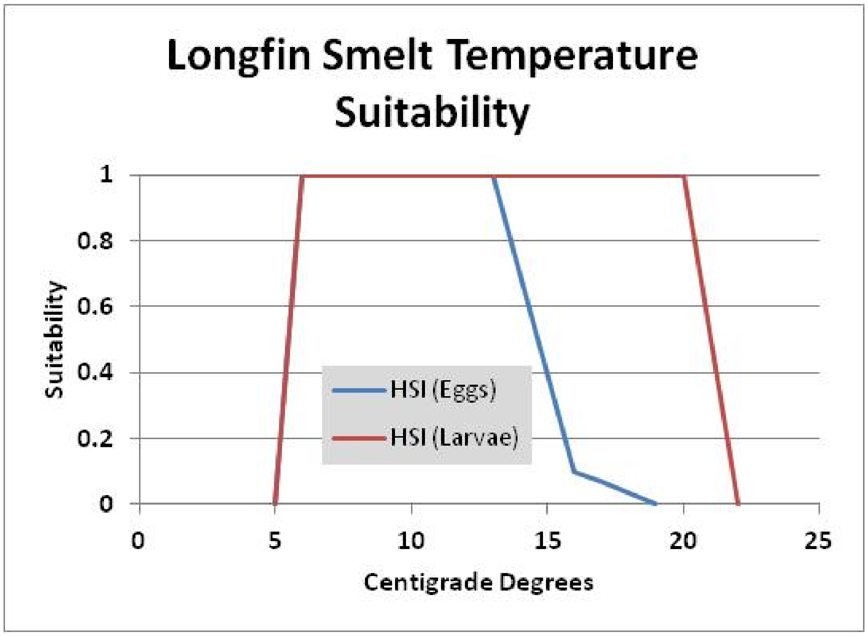


Figure 5.E.4-20. Assumed Temperature Tolerance of Longfin Smelt Eggs and Larvae

Salinity

The suitability of habitat for larval longfin smelt with respect to salinity (EC) was based on a GAM of salinity with the abundance probability of occurrence of larvae in the 20-mm trawl developed by Kimmerer (2009). The assumed relationship follows the observed relationship closely (Figure 5.E.4-21). However, it was assumed that there was little decline in suitability at low salinity as was the case in the observed data. This assumption was made based on the observation of longfin smelt spawn within the limits of freshwater, such as Liberty Island and the Yolo Bypass toe drain, both of which are characterized by very low salinity values (Conrad unpublished data).

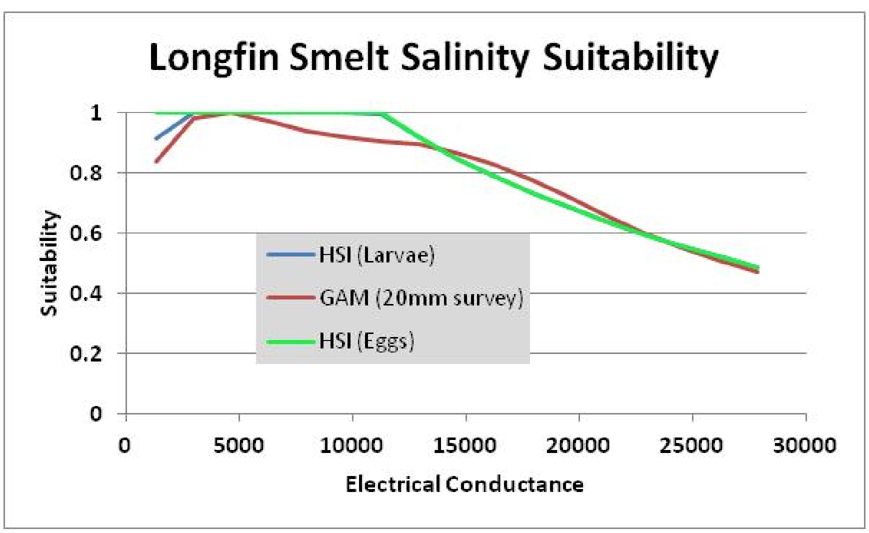


Figure 5.E.4-21. Assumed Longfin Smelt Salinity Suitability

Turbidity

Longfin larval turbidity curves were developed in consultation with Randy Baxter (CDFW), who is a regional agency expert in longfin smelt ecology (Baxter pers. comm.). Baxter advised that like delta smelt, larval longfin smelt benefit from higher turbidity. Turbidity is believed to provide both a protection from predators and a visual background for discovery of prey. It was also his opinion that as longfin smelt become older this is less of an issue and that juveniles are often found in fairly clear water. This was the basis for taking the rating curve only down to 0.5 suitability in waters with over 1 meter of clarity (Figure 5.E.4-22).

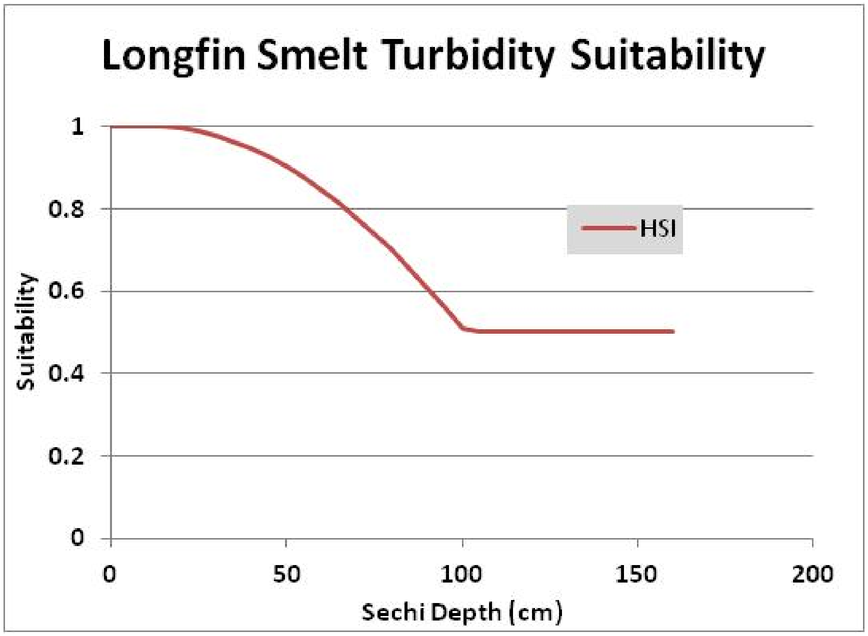


Figure 5.E.4-22. Assumed Longfin Smelt Turbidity Suitability Curve

Time Period

Longfin smelt were assumed to occupy the Plan Area at times different from those of delta smelt (Rosenfield 2010). The following time periods were assumed:

- Egg-Larvae: December–March
- Larvae: January–April

Habitat Preference

Although longfin smelt larvae generally are found near the water column surface (Rosenfield 2008) where they might access shallow-water habitats, juveniles can adjust their position in the water column (Rosenfield 2008) and tend to concentrate in deepwater environments (≥7 meters) (Rosenfield and Baxter 2007). Only a very small proportion of late-stage longfin smelt larvae would be expected to occur in shallow tidal environments.

In consultation with agency experts, it was clearly thought that longfin smelt unlike delta smelt prefer deepwater and channel habitat. The only exception to this was thought to be when the larvae have underdeveloped fins and act more like particles than swimming fish. In accordance with this idea, deep water (below mean lower low water [MLLW]) was considered valuable for all life stages of longfin smelt and was scored with a 1 symbolizing 100% suitability. Only the larvae stage was thought to use intertidal (MLLW–mean higher high water [MHHW]) and shallow water (MHHW–extreme high water [EHW]) and was scored a 1 for these habitats. All other life stages were given 0 scores for intertidal and shallow-water habitat (Table 5.E.4-4).

Table 5.E.4-4. Longfin Smelt Habitat Preferences Used in the Habitat Suitability Analysis

	Longfin Smelt	
	Egg-Larvae	Larvae
Tidal Brackish	0	1
Tidal Fresh	0	1
Intertidal Mudflat	0	1
Shallow Subtidal	0.25	1
Deep Subtidal	1	1

5.E.4.4.1.3 Analytical Design

Time Periods

Tidal natural communities restoration was evaluated for four scenarios representing time periods and progressive implementation of actions over the BDCP permit term.

- Current. Conditions in the Delta prior to licensing and implementation of the covered activities.

Future time periods are measured from the issuance of the final BDCP permits and authorizations.

- Near-term (NT)—0 to 10 years following implementation.
- Early long-term (ELT)—11 to 15 years following implementation.
- Late long-term (LLT)—15 to 50 years following implementation.

Modeled Alternatives

The habitat suitability analysis evaluated habitat in the Plan Area in the NT, ELT, and LLT relative to the current condition with and without the BDCP. The without-BDCP scenarios accounted for climate change, including sea level rise, while the with-BDCP scenarios included both climate change and covered activities for four scenarios, five water-year types and 1–3 life stages, depending on species. Water-year types are defined below.

Future scenarios were evaluated relative to a baseline condition representing current conditions in the Delta. The baseline assumed current habitat configuration and operational provisions specified in the EBC2 (Existing Biological Condition) scenario. EBC2 includes the Fall X2 (the location of the 2 parts-per-thousand contour for bottom salinity) provisions of the Biological Opinion (BiOp) for the Delta issued by the USFWS for CVP/SWP operations (U.S. Fish and Wildlife Service 2008) for Delta water operations. The alternative baseline, EBC1, used in some HCP analyses, was not used in the analysis of CM4. EBC1 does not include the Fall X2 provisions of the BiOp. EBC1 represents operations that were used in the Delta for the last several years because of flow conditions. However, the habitat suitability analysis evaluated conditions across a range of flow conditions, some of which would invoke the Fall X2 provisions.

The habitat potential of the Plan Area under the EBC2 baseline was compared to future scenarios without CM4 (climate change only) as scenarios that include the CM4 habitat restoration as well as the BDCP operations are described in Chapter 3, *Conservation Strategy*. The proposed BDCP operations plus the tidal natural communities restoration under CM4 are referred to as the ESO. The baseline habitat currently available was compared to that expected under the ESO scenarios in the NT, ELT, and LLT periods. Conditions were compared with and without expected climate change impacts that include sea level rise and an increase in water temperature. The resulting analytical scenarios are listed in Table 5.E.4-5.

Table 5.E.4-5. Generalized Analytical Design for the HSI-HU Analysis of CM4

Time Period	Without BDCP (Climate Change Only)	With Climate Change and BDCP
Current	EBC2_Current	EBC2_Current
Near-term (NT)	EBC2_NT	ESO_NT
Early long-term (ELT)	EBC2_ELT	ESO_ELT
Late long-term (LLT)	EBC2_LLT	ESO_LLT

5.E.4.4.1.4 Modeled Data

Derivation of Physical Habitat Extent

Physical habitat types (Figure 5.E.4-2) refer to the extent (acreage) of various types of aquatic habitat that are present currently in the geographic subregions and what will be present in the future given climate change and CM4 restoration. The acreage of tidal habitat currently and under *CM4 Tidal Natural Communities Restoration* was evaluated with respect to three components.

1. Estimation of changes in wetted aquatic acres under a hypothetical restoration footprint.
2. Evaluation of the potential impacts of covered activities, including the hypothetical restoration footprint, on habitat conditions for covered fish species.
3. Analysis of the potential impacts of the hypothetical restoration footprint on phytoplankton production in the Delta in each ROA as described in the hypothetical restoration footprint.

The hypothetical restoration footprint was created in consultation with the management agencies to provide a restoration scenario that could be analyzed with respect to benefits for covered fish species. As described below, a GIS analysis evaluated acreages of various habitat types that could be created under a hypothetical restoration scenario based on topography, possible dike or levee breachings, and climate change. These acreage estimates then were evaluated in regard to their suitability for covered fish species. The habitat suitability analysis considered the effects of change in habitat acres as a result of restoration as well as the changes in Delta conditions resulting from operational changes related to *CM1 Water Facilities and Operation* and the potential conditions that could occur in the future because of climate change. Finally, the hypothetical footprint was evaluated with respect to its potential impact on phytoplankton in the Delta. Phytoplankton is the base of the Delta foodweb that supports covered fish species. The phytoplankton analysis relied on a simple quantitative assessment and qualitative discussion.

The analysis of the three components will be discussed below; for each component, evaluation methods will be described followed by results of the evaluation.

Methods

Hypothetical Restoration Footprint

CM4 calls for the restoration of 65,000 acres of tidal natural communities and transitional uplands to accommodate sea level rise in the Plan Area. Actual restoration over the course of the BDCP permit term will depend on numerous factors, including the availability of restoration sites, topography, and sea level rise associated with climate change. In addition, because restoration of this scale has not been attempted in the Delta, there is much to learn about how to restore habitats and what types of habitats are most needed to meet species needs. In short, it is impossible at this time to describe the specific restoration sites and methods that will be used to implement CM4. However, considerable discussion and planning of restoration needs in the subregions that will guide restoration have occurred between managers and implementing agencies. Based on these discussions, a hypothetical footprint of restoration in the Delta has been created and is described below. The hypothetical restoration footprint lies within the ROA that is, in turn, within a geographic subregion. The acres and types of habitats under this hypothetical footprint were carried forward and evaluated in the habitat suitability analysis for covered fish species.

The hypothetical restoration footprint resulted in the addition of 59,349 acres of aquatic tidal habitat in the Plan Area. The difference between the acres in the hypothetical footprint and CM4 represents practicalities of available restoration sites and Delta topography. The hypothetical restoration footprint described below is only one of many possible restoration scenarios that could result in restoration of more or fewer acres based on implementation realities.

Tidal Wetland Restoration Modeling

A GIS and hydrologic model (referred to as the RMA model) was used to estimate habitat areas for current and potentially restored areas, with and without the effects of climate change. The analysis considered habitat type, topography, bathymetry, tidal datums, and accretion to estimate the amount of different habitat types under current and future conditions, as outlined in the following sections.

Habitat Categories

The modeling of tidal habitats involved the characterization of the BDCP subregions in terms of acreages represented by tidal elevation datums. Nine tidal wetland categories were defined and mapped in GIS (Table 5.E.4-6). These tidal wetland categories were simplified for the analysis of impacts on covered fish species into six fish habitat types (Table 5.E.4-6). Tidal wetland categories and fish habitats are listed from the shallowest to deepest aquatic areas.

Table 5.E.4-6. Characteristics of Aquatic Tidal Wetland Categories and Fish Habitat Types Used in the Spatial Analysis

GIS Tidal Wetland Categories	Fish Habitats	Tidal Datums[a]
Ecotone	Wetted fringe	>EHW
High tidal brackish marsh	Tidal brackish	MHHW–EHW
Mid tidal brackish marsh		
Low tidal brackish marsh		
Total tidal freshwater marsh	Tidal fresh	MHHW–EHW
Intertidal mudflat	Intertidal mudflat	MLLW–MLLW +1 feet
Subtidal 1	Shallow subtidal	MLLW–MLLW +6 feet
Subtidal 2		
Subtidal 3	Deep subtidal	<6 feet

[a] EHW = Extreme High Water; MHHW = Mean Higher High Water; MHW = Mean High Water; MLLW = Mean Lower Low Water.

Topography and Bathymetry

The model analysis of restoration acreage used a base topography/bathymetry surface of Suisun Marsh and the Delta based on Light Detection and Ranging (LiDAR)[3] data from 2003–2008. The data were prepared in GIS raster format and further analyzed for restoration impacts. In some locations, the LiDAR data show the ground at intertidal elevations in areas known to be subtidal, presumably because the LiDAR is showing the water surface and not the actual bathymetry. To correct for this, the topography was adjusted from intertidal elevations to subtidal elevations in the following locations: Little Hastings Tract, the southern tip of Liberty Farms, a small area west of the southern tip of Prospect Island, Discovery Bay, Little Mandeville Island, Mildred Island, and Little Holland Tract. The open-water parts of Little Holland Tract were adjusted to a constant slope from subtidal up to higher elevations. Topography in the west Delta hypothetical footprints was edited to include likely restoration grading.

To create a surface of the tidally connected areas, areas that are currently protected from tidal inundation, or are expected to be in the future, were removed from the topography raster. Excluded areas consist of agricultural areas, developed areas, and managed wetlands, as delineated by the BDCP land-cover map, as well as areas managed by reclamation districts. The hypothetical footprints were divided further into areas designated for restoration in the NT, ELT, and LLT time periods.

Tidal Datums

The assessment used spatially varying tidal datums (EHW, MHHW, mean high water [MHW], MLLW) as hydraulically modeled for each scenario. The tide data used a 10-meter grid that was converted to surfaces for each scenario and tidal datum.

[3] LiDAR (Light Detection and Ranging) is a remote sensing technique that is used in this case to measure surface elevation to precise levels. An airborne laser is used to develop a high-resolution digital elevation map of the surface.

Accretion

The spatial modeling included the effects of sediment accretion. In Suisun Marsh, accretion is due to both inorganic sedimentation and, where marsh vegetation exists, organic sedimentation. In the Delta, accretion is due almost entirely to organic sedimentation in vegetated areas.

Accretion in Suisun Marsh was predicted using the Marsh98 model, a procedure that has been used widely to examine marsh sustainability to sea level rise across San Francisco Bay (Orr et al. 2003). The Marsh98 model is based on the mass balance calculations described by Krone (1987). This procedure assumes that the elevation of a marsh plain rises to elevations that allow colonization of vegetation at accretion rates that depend on the availability of suspended sediment and depth and periods of tidal inundation. When the level of an evolving marsh surface is low with respect to the tidal range, sedimentation rates may be high if the suspended sediment supply is sufficient. However, as the marsh surface rises through the tidal range, the frequency and duration of flooding by high tides are diminished so that the rate of sediment accumulation declines. Marsh98 estimates these physical processes by calculating the amount of suspended sediment that deposits during each period of tidal inundation and sums that amount of deposition over the period of record. Accretion due to organic material also is added directly to the bed elevation at each tidal cycle.

A suspended sediment concentration of 50 milligrams per liter (mg/L) and an organic accretion rate of 2 millimeters per year (mm/yr) were used for the Suisun Marsh ROA. These assumptions are consistent with other regional sedimentation modeling for San Francisco Bay and Suisun Marsh (e.g., Stralberg et al. 2011). For each cell in the topography raster, accretion was interpolated based on the elevation of the cell and then added to raise the cell elevation to a maximum of EHW. For the Delta, it was assumed that the existing vegetated marsh would be able to keep pace and transgress over upland in response to sea level rise. No accretion is assumed to occur in unvegetated areas.

Hypothetical Restoration Footprint

Because the specific BDCP restoration areas have not been established and will not be known until later in project implementation, the restoration areas are estimated using the hypothetical footprint described above and used for the BDCP effects analysis (Chapter 5). For each topographic area (within the hypothetical footprint, outside the footprint, and in marsh areas), tidal datum surfaces were created to match the topography shapes. In Suisun Marsh, each 10-meter cell of topography was accreted and then categorized based on the tidal datums at that cell (Table 5.E.4-6) using MatLab. The existing marsh topography area was categorized separately to account for presumed errors in the LiDAR data. LiDAR-derived elevations in densely vegetated marsh areas are often well above high tide elevations because the LiDAR data measure elevation of the top of the vegetation. To account for this, the existing marsh area in Suisun Marsh was categorized with the highest 18% of marsh as high marsh, the middle 50% as mid-marsh, and the lowest 32% of marsh as low marsh. These ratios are based on analysis of vegetation communities in the BDCP land-cover map.

In the Delta, the restoration sites defined by the hypothetical footprint and cells outside the footprint (i.e., areas not restored to tidal wetland) were categorized in MatLab as marsh if they fell between existing conditions MLLW and the current time step MHHW. This assumes that the bottom edge of the marsh never drowns out, and the upper edge of the marsh migrates upslope with sea level rise. The existing marsh in the Delta was assumed to remain marsh in all future time steps.

Three scenarios were modeled without the BDCP (EBC2, EBC2_ELT, and EBC_LLT). It was assumed that the effects of sea level rise in the NT would be negligible; the habitat suitability analysis assumed that without BDCP restoration the EBC2_NT acreages were the same as the EBC2 acreages to allow comparisons across scenarios with and without BDCP restoration. For the BDCP scenarios (ESO_ELT and ESO_LLT), the footprints that are breached by that time step, the areas outside the footprints, and the existing marsh were merged with the marsh taking the highest priority and the areas outside the footprints the lowest. The area of each habitat in each hypothetical footprint for each time step also was calculated.

Habitat Change over Time

Habitat changes over each implementation period were estimated as follows.

1. Defining initial site elevations.
2. Evaluating how the tidal frame could change over time as a result of sea level rise and the breaching of hypothetical restoration sites.
3. Defining environmental types relative to the tidal frame.
4. Evaluating how site elevations may change over time in response to sedimentation.

Limitations and Uncertainties

The RMA model is a planning-level tool that uses simplifying assumptions to represent conditions and processes such as topography, bathymetry, tide levels, and accretion. The model has the following limitations.

- The topography and habitat mapping data used in the analysis contain known inaccuracies. Known inaccuracies were corrected if they were judged to affect the use of results for planning purposes. Additional inaccuracies may exist.
- Marsh transgression and sea level rise accommodation space are shown in some areas upslope of leveed areas (e.g., east of Montezuma Slough, edge of eastern Delta), which would not actually be subject to transgression. This limitation affects a relatively small acreage.
- The existing marsh area south of Prospect Island (fewer than 100 acres) is incorrectly mapped as leveed under the Existing Conditions and No Project scenarios.
- It was assumed that the accretion of existing vegetated marsh in the Delta would keep pace with sea level rise. This is generally expected to be true for average rates of sea level rise between periods but may not be true toward Year 50, given accelerated rates of sea level rise over time.

Derivation of Environmental Attribute Data

Environmental attributes refer to measures of habitat value and enter into the habitat suitability analysis through the HSI models (Figure 5.E.4-2). Temperature, salinity, and turbidity enter into most of the HSI models (Table 5.E.4-1). Modeling derivation of data for temperature, salinity, and turbidity for the HSI models is described below. Details are provided in Appendix 5.C, *Flow, Passage, Salinity, and Turbidity*.

DSM2 Modeling of Temperature and Salinity

Temperature and salinity inputs to the analysis were derived from the DSM2 model. Use of the DSM2 data allowed projection of conditions in the future due to climate change and BDCP operations that could be related to other areas of the BDCP analysis. Average daily temperature and average monthly salinity data from DSM2 were used as input to HSI analysis for several locations near each ROA. DSM2 stations were selected near the ROAs within the subregions. It was assumed that the modeled values for each subregion would be representative of salinity and temperature in newly inundated restored habitat in the hypothetical footprint, recognizing that this is a simplification. In actuality, environmental conditions show appreciable variation within a subregion, and specific restoration sites might have conditions that differ from the averages used for this analysis.

DSM2 analysis for water years 1975–1990 was used to generate temperature and salinity data for each of the model scenarios. EBC2, which includes the Fall X2 flow provisions called for in the USFWS BiOp, was used to represent the current condition (U.S. Fish and Wildlife Service 2008). Data were averaged for five water-year types as shown in Table 5.E.4-7.

Table 5.E.4-7. Water Years and Water-Year Types Used in DSM2 to Generate Temperature and Salinity Data for HSI Analysis

Water Year	Type
1975	Wet
1976	Critical
1977	Critical
1978	Above normal
1979	Below normal
1980	Above normal
1981	Dry
1982	Wet
1983	Wet
1984	Wet
1985	Dry
1986	Wet
1987	Dry
1988	Critical
1989	Dry
1990	Critical

UnTRIM Models of Sea Level Rise Effects on Salinity

Sea level rise associated with climate change would shift the location of salinity zones, frequency of inundation, and depth. Those changes were accounted for using CALSIM outputs for the ELT and LLT that include assumptions about the effects of sea level rise and restoration in the Delta on hydrodynamics in the ROAs.

The salinity effects of sea level rise in the Bay and Delta channels were simulated with the 3-D UnTRIM model for several assumed sea level rise increments from 15 cm to 150 cm. The calendar year 2002 was used for the UnTRIM model study period. The model was previously calibrated and matched this period without additional calibration adjustments. The analysis assumed a sea level rise of 15 cm for the ELT and 45 cm for the LLT. The NT scenarios assume no sea level rise. The adjustments for coupling ranged from 0.1 to 0.5 foot, with the adjustments varying spatially by scenario. Hydraulic model geometry for the LLT With Project scenario includes deepening and widening of the major tidal channels in Suisun Marsh, as these channels are expected to be deepened as part of either restoration implementation or scour in response to restoration.

The UnTRIM model results generally indicated that the effects of sea level rise on salinity at Martinez and upstream at Chipps Island and Collinsville were linear with sea level rise. The results for the ELT with 15 cm (0.5 foot) assumed sea level rise were about 33% of the effects simulated for the LLT with 45 cm (1.5 feet) assumed sea level rise. The salinity effects at Martinez are the cumulative effects of tidal dispersion (gradient mixing) and gravitational circulation (density effects) between the Golden Gate and the Carquinez Strait. Tidal dispersion causes mixing along the salinity gradient, and gravitational circulation allows salinity to move upstream near the bottom of the channel. High flows increase velocity shear and cause vertical mixing that reduces the gravitational effects. The depth profile and cross-section geometry influence these hydrodynamic mixing processes.

This model includes the effects of salinity gradients and density effects on the tidal flows and allows the "gravitational circulation" during moderate flow events to be evaluated. During moderately high outflows, the fresh water (lower density) will flow near the surface of the estuary while seawater (higher density) will tend to move upstream along the bottom of the channel. This increases the net upstream mixing of seawater and increases the seawater intrusion effects in Suisun Bay and the Delta.

The UnTRIM model simulates practical salinity units (psu), which is very similar to salinity as total dissolved solids in grams per liter (g/l) so that ocean water has a salinity of about 32 g/l (parts per thousand [ppt]) and about 32 psu. The measured salinity data are electrical conductance values (normalized to 25°C). The modeled existing maximum Martinez salinity in the fall months when the outflow was about 4,000 cubic feet per second (cfs) was about 20 psu (32,000 microSiemens per centimeter [μS/cm]). The modeled existing maximum salinity at Chipps Island was about 7.5 psu. The modeled existing maximum salinity at Collinsville was about 5 psu.

These results were incorporated into the DSM2 modeling and in the CALSIM modeling of required Delta outflows for salinity control. The tidal models also were used to demonstrate the patterns of tidal movement and mixing within the Delta (particle tracking). The increase in the average tidal elevation at Martinez was about 44 cm for the 45-cm sea level rise assumed at the ocean boundary. The UnTRIM model simulated a 5% increase in the average tidal prism (water volume between low tide and high tide) for the 45-cm sea level rise case at Martinez. The average tidal prism is proportional to the flood-tide flows (upstream) and ebb-tide flows (downstream) each day. These increased tidal flows throughout the estuary may cause increased tidal dispersion (mixing) along the salinity gradient, and cause the salinity at Martinez and upstream in the Delta to increase with sea level rise.

Turbidity

There is no satisfactory method presently available to predict model turbidity across the Delta. In order to incorporate turbidity into the analysis of restored habitat, empirical data were averaged and used in each scenario. B. J. Miller (pers. comm.) developed a physicochemical database for sampling sites covered by various Interagency Ecological Program surveys that was used to generate a single set of turbidity data that was used for HSI analysis for all scenarios. The Miller data set used turbidity data from Delta fish monitoring efforts, breaking them into subregions very similar to the BDCP but generally at a finer scale (see Figure 2 of Miller 2011). Data were matched to each ROA by selecting the subregions that were contained in the BDCP delineations and then averaging those into one value for each month in the region. There is reason to believe that turbidity in the Delta may be decreasing (clarity increasing) as a result of changes to the input of inorganic suspended material as well as changes in plankton (Ruhl and Schoellhamer 2004; Wright and Schoellhamer 2004). For this reason a more recent data set was used spanning water years 2000–2011 (Table 5.E.4-8). Data were averaged by month and water-year type (Table 5.E.4-8). This procedure makes the assumption that turbidity will not change appreciably over the BDCP permit term, but will vary spatially between ROAs and between water years. As with the analyses of temperature and salinity, it was assumed that turbidity estimates within a subregion (based on survey data in existing water bodies) were representative of turbidity that might occur in areas restored from terrestrial use (e.g., agriculture) to aquatic habitat.

Table 5.E.4-8. Water Years and Water-Year Types Used to Characterize Turbidity for All Scenarios for HSI Analysis

Water Year	Type
2000	Above normal
2001	Dry
2002	Dry
2003	Above normal
2004	Below normal
2005	Above normal
2006	Wet
2007	Dry
2008	Critical
2009	Dry
2010	Below normal
2011	Wet

5.E.4.4.2 Results

5.E.4.4.2.1 Physical Habitat Extent

Table 5.E.4-9 presents the calculated tidal acreages for the Plan Area subregions with and without the BDCP. The without-BDCP estimates reflect expected changes in tidal wetland acreages over the implementation period with sea level rise only. The estimates with the BDCP add the impacts of the BDCP, including restoration under the hypothetical restoration footprint and operational changes. Table 5.E.4-9 characterizes the entire geographic subregion, including both aquatic tidal habitat and nontidal terrestrial habitats (nontidal natural communities). In order to characterize the entire Plan Area, the table also includes acreage estimates for the Yolo Bypass subregion, which is not included in CM4. In the hypothetical footprint, CM4 is projected to increase aquatic habitat by 55,800 acres[4] across all geographic subregions, excluding the Yolo Bypass subregion. No restoration is assumed to occur under CM4 in Suisun Bay or the North Delta subregions. Acreage changes for these two

[4] As discussed above, the hypothetical restoration footprint represents one possible restoration scenario devised by GIS analysts working with regional managers to identify restoration opportunities. The difference between the estimated acres in the hypothetical footprint (55,800) and CM4 (65,000) reflects the realities of topography and land use constraints encountered by the analysts.

subregions represent sea level–rise effects only. The habitat suitability analysis used the acreages in Table 5.E.4-9 for all subregions (excluding the Yolo Bypass) using the fish habitat types in Table 5.E.4-6. The sections that follow describe the conditions in each subregion before and after restoration.

Table 5.E.4-9. Estimated Acres of Habitats in the BDCP Subregions by Time Period without BDCP (Sea Level Rise Only) and with the BDCP[a] (Sea Level Rise + BDCP Restoration)

Tidal Wetland Category by Subregion		Max Elevation	Without BDCP (and with Sea Level Rise)			With BDCP (and with Sea Level Rise)		
			Current	ELT	LLT	NT	ELT	LLT
Cache Slough	Nontidal Natural Communities[b]		52,550	52,080	51,470	48,140	42,370	33,870
	Ecotone	EHW	720	800	450	1,430	1,890	1,610
	Tidal Freshwater Marsh	MHHW	3,460	4,060	5,120	7,030	10,840	14,420
	Intertidal Mudflat	MLLW + 1 feet	840	440	0	800	240	0
	Subtidal 1	MLLW	1,730	1,860	1,750	1,840	3,270	4,100
	Subtidal 2	MLLW –3 feet	1,600	1,810	2,030	1,700	2,260	3,870
	Subtidal 3	MLLW –6 feet	2,990	3,060	3,380	3,050	3,240	6,480
	Unmapped Tidal Natural Communities[c]		990	760	670	880	750	520
	Subtotal		64,880	64,870	64,870	64,870	64,860	64,870
	Subtotal Aquatic Habitat[d]		11,340	12,030	12,730	15,850	21,740	30,480
North Delta	Nontidal Natural Communities		88,450	88,400	87,740	88,470	88,430	88,140
	Ecotone	EHW	80	70	340	70	70	80
	Tidal Freshwater Marsh	MHHW	280	350	1,000	250	330	680
	Subtidal 1	MLLW	210	170	120	200	170	100
	Subtidal 2	MLLW –3 feet	290	290	310	290	290	240
	Subtidal 3	MLLW –6 feet	2,890	2,930	2,960	2,910	2,930	3,080
	Unmapped Tidal Natural Communities		530	510	250	550	520	410
	Subtotal		92,730	92,720	92,720	92,740	92,740	92,730
	Subtotal Aquatic Habitat		3,750	3,810	4,730	3,720	3,790	4,180
Western Delta	Nontidal Natural Communities		67,220	67,090	66,770	65,610	64,480	64,030
	Ecotone	EHW	180	200	220	190	220	200
	Tidal Freshwater Marsh	MHHW	5,100	5,250	5,590	6,330	7,470	8,020
	Subtidal 1	MLLW	1,200	980	710	1,230	1,030	350
	Subtidal 2	MLLW –3 feet	3,300	3,040	2,710	3,380	3,080	1,890
	Subtidal 3	MLLW –6 feet	19,040	19,530	20,120	19,300	19,800	21,660
	Unmapped Tidal Natural Communities		380	350	300	390	350	270
	Subtotal		96,420	96,440	96,420	96,430	96,430	96,420
	Subtotal Aquatic Habitat		28,820	29,000	29,350	30,430	31,600	32,120
Suisun Marsh	Nontidal Natural Communities		69,580	69,530	69,440	65,540	63,800	57,680
	High Tidal Brackish Marsh	~EHW	1,410	820	360	1,450	950	470
	Mid Tidal Brackish Marsh	~MHHW	3,700	3,670	3,140	3,730	3,860	3,210
	Low Tidal Brackish	~MHW	2,830	3,470	4,520	4,650	5,430	7,170

Tidal Wetland Category by Subregion		Max Elevation	Without BDCP (and with Sea Level Rise)			With BDCP (and with Sea Level Rise)		
			Current	ELT	LLT	NT	ELT	LLT
	Marsh							
	Intertidal Mudflat	MLLW + 1 feet	280	260	240	1,390	1,890	2,030
	Subtidal 1	MLLW	1,030	1,040	1,010	2,220	2,820	7,480
	Subtidal 2	MLLW –3 feet	800	820	860	840	950	1,570
	Subtidal 3	MLLW –6 feet	2,360	2,430	2,590	2,330	2,510	2,710
	Unmapped Tidal Natural Communities		770	720	610	620	530	450
	Subtotal		82,760	82,760	82,770	82,770	82,740	82,770
	Subtotal Aquatic Habitat		12,410	12,510	12,720	16,610	18,410	24,640
Suisun Bay	Nontidal Natural Communities		40	40	40	40	40	40
	High Tidal Brackish Marsh	~EHW	150	80	20	140	80	20
	Mid Tidal Brackish Marsh	~MHHW	560	540	200	560	540	450
	Low Tidal Brackish Marsh	~MHW	600	670	1,050	610	650	760
	Intertidal Mudflat	MLLW + 1 feet	140	110	75	150	100	60
	Subtidal 1	MLLW	1,760	1,480	1,000	1,850	1,350	750
	Subtidal 2	MLLW –3 feet	7,230	6,640	5,360	7,425	6,230	4,150
	Subtidal 3	MLLW –6 feet	11,040	11,970	13,820	10,740	12,540	15,320
	Unmapped Tidal Natural Communities		40	30	20	40	40	30
	Subtotal		20,530	20,530	20,520	20,530	20,550	20,530
	Subtotal Aquatic Habitat		20,450	20,460	20,460	20,450	20,470	20,460
East Delta	Nontidal Natural Communities		95,830	95,680	94,690	93,090	92,830	92,370
	Ecotone	EHW	350	290	350	300	310	220
	Tidal Freshwater Marsh	MHHW	1,570	1,800	3,090	2,730	3,050	3,730
	Subtidal 1	MLLW	280	230	180	1,530	1,380	930
	Subtidal 2	MLLW –3 feet	510	480	450	780	880	1,080
	Subtidal 3	MLLW –6 feet	3,210	3,300	3,370	3,280	3,320	3,580
	Unmapped Tidal Natural Communities		890	860	510	940	870	740
	Subtotal		102,640	102,640	102,640	102,650	102,640	102,650
	Subtotal Aquatic Habitat		5,920	6,100	7,440	8,620	8,940	9,540
South Delta	Nontidal Natural Communities		293,400	293,130	292,560	293,540	293,150	270,820
	Ecotone	EHW	840	670	470	820	700	1,330
	Tidal Freshwater Marsh	MHHW	3,560	4,070	4,960	3,390	3,990	15,090
	Subtidal 1	MLLW	1,090	880	700	1,030	810	4,380
	Subtidal 2	MLLW –3 feet	2,310	2,170	1,980	2,260	2,070	7,570
	Subtidal 3	MLLW –6 feet	12,090	12,440	12,810	12,200	12,600	14,360
	Unmapped Tidal Natural Communities		2,100	2,040	1,920	2,140	2,080	1,840
	Subtotal		315,390	315,400	315,400	315,380	315,400	315,390
	Subtotal Aquatic Habitat		19,890	20,230	20,920	19,700	20,170	42,730

Tidal Wetland Category by Subregion		Max Elevation	Without BDCP (and with Sea Level Rise)			With BDCP (and with Sea Level Rise)		
			Current	ELT	LLT	NT	ELT	LLT
Yolo Bypass	Nontidal Natural Communities		46,340	46,320	46,080	46,360	46,310	46,090
	Ecotone	EHW	40	50	200	20	50	160
	Tidal Freshwater Marsh	MHHW	270	280	370	270	290	400
	Subtidal 1	MLLW	0	0	0	0	0	0
	Subtidal 2	MLLW –3 feet	0	0	0	0	0	0
	Subtidal 3	MLLW –6 feet	40	40	40	40	40	50
	Unmapped Tidal Natural Communities		100	100	90	100	100	90
	Subtotal		46,790	46,790	46,780	46,790	46,790	46,790
	Subtotal Aquatic Habitat		350	370	610	330	380	610
Totals	Nontidal Natural Communities		713,410	712,270	708,790	700,790	691,410	653,040
	Ecotone	EHW	2,210	2,080	2,030	2,830	3,240	3,600
	Tidal Freshwater Marsh	MHHW	14,240	15,810	20,130	20,000	25,970	42,340
	Intertidal Mudflat	MLLW + 1 feet	1,200	770	280	2,270	2,200	2,060
	Subtidal 1	MLLW	7,010	6,350	5,190	9,610	10,550	17,830
	Subtidal 2	MLLW –3 feet	15,680	14,890	13,360	16,310	15,410	20,070
	Subtidal 3	MLLW –6 feet	53,460	55,470	58,790	53,670	56,720	66,870
	Unmapped Tidal Natural Communities		5,800	5,370	4,370	5,660	5,240	4,350
	Subregion Total		**822,140**	**822,150**	**822,120**	**822,160**	**822,150**	**822,150**
	Total Aquatic Habitat Excluding the Yolo Bypass		**102,580**	**104,140**	**108,350**	**115,380**	**125,120**	**164,150**
	Unassigned Aquatic Subregion Total[e]		**40,600**	**40,600**	**40,600**	**40,600**	**40,600**	**40,600**
	Plan Area Total[f]		**862,740**	**862,750**	**862,720**	**862,760**	**862,750**	**862,750**

[a] While the Yolo Bypass is not considered part of CM4 it is included in this table to provide complete coverage of the Plan Area.

[b] The nontidal natural communities category is a total of all upland and nontidal natural communities for each aquatic sub-region within the Plan Area.

[c] Tidal natural communities within the BDCP were mapped under two separate mapping efforts: The BDCP Natural Community Modeling effort and the ESA PWA Tidal Habitat Categorization effort. Both efforts mapped the existing condition, however the ESA PWA effort was more spatially explicit, distinguishing between types of tidal and subtidal communities (e.g., ecotone, tidal freshwater marsh, subtidal 1, etc.). The BDCP tidal natural communities' models and the ESA PWA tidal models did not completely overlap, the BDCP modeling effort captured greater amounts of tidal habitat than that of ESA PWA. Those non-overlapping acres are presented in this row for each aquatic sub-region so that the sub-region and Plan Area acreage totals are accurate.

[d] Aquatic habitat subtotal excludes Nontidal natural communities and Unmapped Tidal Natural Community acreages. It is the sum of the habitat analyzed for impacts on covered fish species.

[e] 40,600 acres of the Plan Area are unassigned to a specific aquatic subregion. Unassigned acres comprise lands located in the area of "Plan Area expansion" described in Chapter 2, *Existing Ecological Conditions*.

[f] The Plan Area total varies slightly between time periods because of rounding variability and very slight spatial variations within the GIS dataset. Slight variations within a GIS dataset this large are considered to be well within an acceptable range of error.

EBC = existing biological conditions; EHW = extreme high water; ELT = early long-term implementation period; LLT = late long-term implementation period; MHHW = mean higher high water; MLLW = mean lower low water; NAVD = North American Vertical Datum; NT = near-term implementation period.

Cache Slough Subregion

Existing Conditions

The Cache Slough complex has been recognized as possibly the best functioning freshwater tidal habitat area existing in the Delta. Restoring habitats in the Cache Slough area, in conjunction with floodplain enhancements in the Yolo Bypass, is expected to reestablish an ecological gradient from river to floodplain to tidal estuary and provide tidal freshwater wetland structure and functions adjacent to deeper slough and channel habitats.

Cache Slough borders the North Delta subregion and includes the southern end of the Yolo Bypass and lands to the west, supporting a complex of sloughs and channels (Figure 5.E.4-35). Cache Slough itself is the main waterway in the subregion and together with the Sacramento River Deep Water Ship Channel (DWSC) forms much of the existing tidal habitat in the Cache Slough subregion. The following sloughs and channels also are located in the Cache Slough subregion: Haas Slough, Hastings Cut, Lindsey Slough, Barker Slough, Calhoun Cut, Little Holland Slough, and Shag Slough. Yolo Ranch, Little Egbert Tract, Liberty Island, and Prospect Island are located in the subregion. The subregion has generally low salinity and is heavily influenced by Sacramento flow, Yolo Bypass drainage, and tides.

The Cache Slough area lies immediately downstream of the Yolo Bypass and the two subregions are hydraulically congruous. It contains a diverse array of habitats, including floodplain, freshwater tidal marsh, subtidal shallow-water habitat, channel margin and riparian habitat, and deep open-water habitat. Because it is downstream of the Yolo Bypass, it acts as a transition area for migrating fish. The habitat restoration in the Cache Slough ROA combined with the proposed floodplain habitat actions in the Yolo Bypass are expected to increase the amount and value of accessible rearing habitat for juvenile salmon and splittail. For salmon, the intent is to route them away from the interior Delta and through habitat that is favorable for growth. Cache Slough receives the bulk of juvenile Sacramento splittail emigrating from the Yolo Bypass, which is the most important spawning and nursery habitat area for splittail.

The Cache Slough subregion is about 64,880 acres in extent, which currently includes about 11,340 wetted acres, much of which is subtidal (Table 5.E.4-10). Table 5.E.4-10 identifies the different tidal intervals and the acreages associated with the habitat depths.

The predominant land use in the Cache Slough subregion is agricultural row crops and restored tidal habitat such as Liberty Island. Water quality in this area is influenced primarily by the waters of the Sacramento River, which are of relatively low salinity. Salinity does not vary greatly and ranges between a monthly average of 0.2 ppt and a monthly average of 0.3 ppt. Generally, these concentrations indicate that the complex consists primarily of fresh water and is considered the very low salinity zone of the Delta.

Table 5.E.4-10. Wetted Acres in the Cache Slough Subregion under Existing Conditions and Future Conditions with and without the BDCP

Fish Habitat Type	Current Wetted Acres	Wetted Acres under EBC2_LLT	Wetted Acres under ESO_LLT	Acreage Change from BDCP Restoration Only
Wetted fringe	720	450	1,610	1,160
Tidal brackish	–			0
Tidal freshwater	3,460	5,120	14,420	9,300
Intertidal mudflat	840		0	0
Shallow subtidal	3,330	3,780	7,970	4,190
Deep subtidal	2,990	3,380	6,480	3,100
Total for Cache Slough	11,340	12,730	30,480	17,750

Future Conditions

Sea level rise is expected to have relatively small impacts on the total aquatic area in Cache Slough. In the LLT, wetted acres in Cache Slough increase by about 1,390 acres or about a 12% increase in acreage relative to the current area. Over the course of the implementation period, the analysis indicated sea level rise largely would increase the area of tidal wetland habitat (Figure 5.E.4-23).

By the LLT period, the net increase in aquatic habitat due to the BDCP (removing sea level rise) is about 17,750 acres. Acres added by habitat are shown in Table 5.E.4-10. Restoration results in increases in all habitat types, except tidal mudflat, relative to the current situation but with the greatest increase in tidal freshwater habitat (Figure 5.E.4-24).

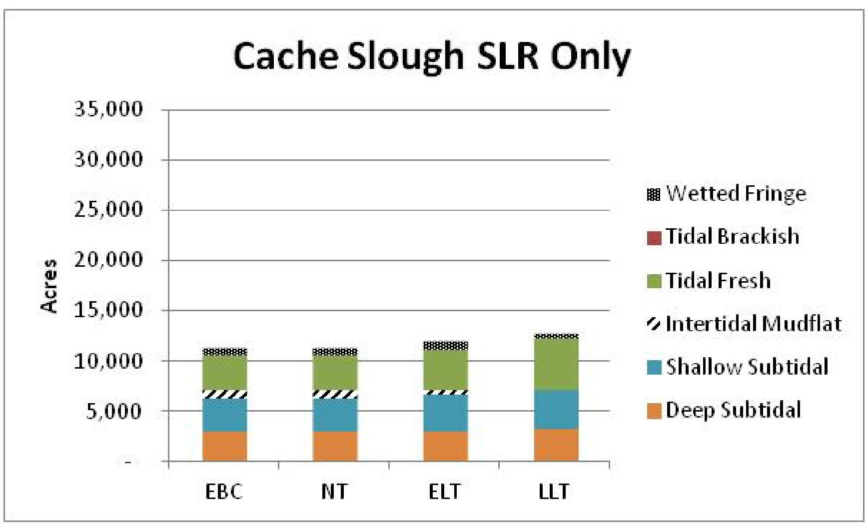


Figure 5.E.4-23. Expected Habitat Changes in Caches Slough due to Sea Level Rise (SLR) Only

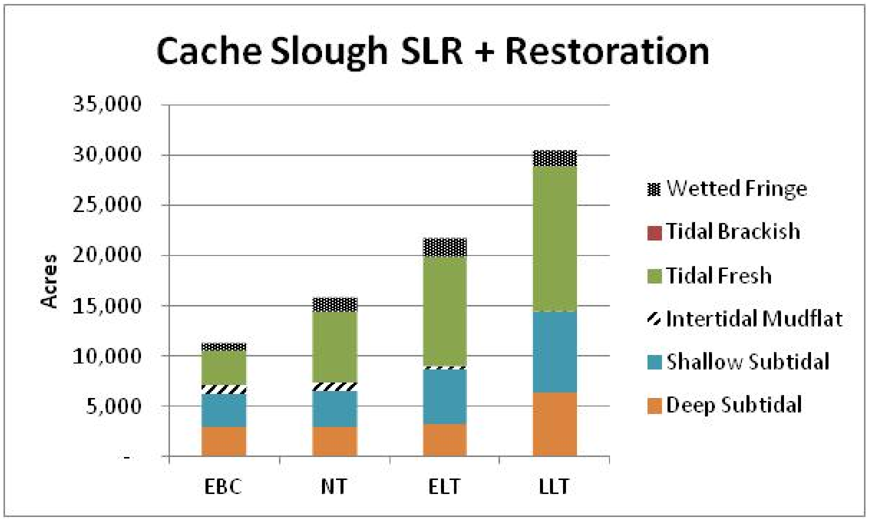


Figure 5.E.4-24. Expected Habitat Changes in Cache Slough due to Sea Level Rise (SLR) and BDCP Restoration

Restoration Considerations

Restored tidal marsh plains will be revegetated through planting and/or natural recruitment (depending on site-specific conditions and phasing considerations) with tules and other native freshwater emergent vegetation. The target restored plant community will reflect the historical composition and densities of Delta tidal marshes. Tidal habitat restoration will be designed, within restoration site constraints, to produce sinuous, high-density, dendritic networks of tidal channels that promote effective tidal exchange throughout the marsh plain and provide habitat for covered fish species.

Tidal habitat restoration actions will provide an ecological gradient among subtidal, tidal mudflat, tidal marsh plain, riparian, and upland habitats to accommodate the movement of fish and wildlife species and provide flood refuge habitat for marsh-associated wildlife species during high-water events. Marsh channels and levee breaches will be designed to maintain flow velocities that minimize conditions favorable to the establishment of nonnative submerged aquatic vegetation (SAV) and floating aquatic vegetation (FAV) and habitat for nonnative predatory fish. Additional analysis about nonnative vegetation and other unfavorable conditions is provided in Appendix 5.F, *Biological Stressors on Covered Fish*.

The following potential negative outcomes could occur as a result of floodplain and tidal wetland restoration in the Cache Slough ROA.

- Increased methylmercury production and local bioaccumulation. (The potential for mercury methylation and associated environmental toxicity is expected to be of low magnitude for covered fish species, but the certainty of that outcome is low because data on mercury toxicity to fish in the Delta are very limited.)
- Contaminant resuspension (e.g., mercury).
- Local toxicity from residual pesticides and herbicides (e.g., pyrethroids).
- Establishment of inland silversides that will prey on or compete with Delta and longfin smelt or alter habitat conditions.

- Establishment of centrarchids that will prey on or compete with covered species or alter habitat.
- Establishment of undesirable clam species that will compete with covered species or alter habitat.
- Establishment of undesirable SAV (e.g., Brazilian waterweed [*Egeria densa*]) will alter habitat conditions.

Additional information regarding predation and SAV and effects on covered aquatic species is discussed in Appendix 5.F, *Biological Stressors on Covered Fish*, and additional information regarding toxics such as methylmercury, selenium, and pesticides and herbicides and effects of these on covered aquatic species is discussed in Appendix 5.D, *Contaminants*.

North Delta Subregion

Existing Conditions

The North Delta is one of the largest subregions in the Plan Area, encompassing 92,370 acres; however, only 3,750 acres are aquatic habitat (Table 5.E.4-11). No restoration is planned for the North Delta under CM4. The subregion includes the mainstem Sacramento River from the confluence with the DWSC to about the city of Sacramento, Steamboat Slough, Sutter Slough, and Miner Slough (Figure 5.E.4-35). Channels that break off of the North Delta subregion into the Central Delta include the Delta Cross Channel into Snodgrass Slough and Georgiana Slough.

Future Conditions

There is no restoration planned for the North Delta subregion under CM4. Sea level rise is expected to increase the area of wetted habitat in the North Delta subregion by 430 acres (Table 5.E.4-11). The greatest increase in area in this subregion due to sea level rise is expected to occur in tidal freshwater habitat (Figure 5.E.4-25).

Table 5.E.4-11. Wetted Acres in the North Delta Subregion under Existing Conditions and Future Conditions without the BDCP

Fish Habitat Type	Current	EBC2_LLT (with Sea Level Rise)
Wetted fringe	80	80
Tidal brackish	–	–
Tidal freshwater	280	680
Intertidal mudflat	–	–
Shallow subtidal	500	340
Deep subtidal	2,890	3080
Subtotal	3,750	4,180

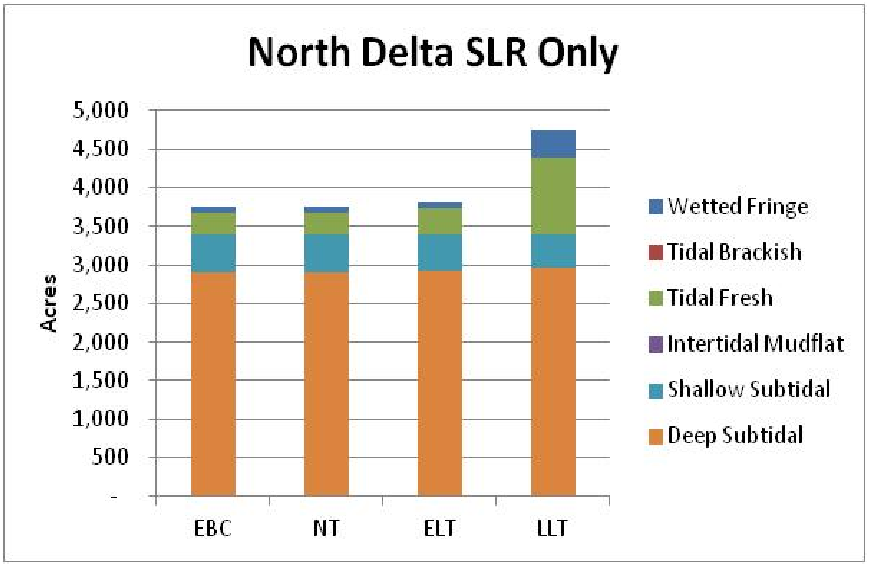


Figure 5.E.4-25. Expected Change in Habitat in the North Delta Subregion due to Sea Level Rise (SLR) Only

West Delta Subregion

Existing Conditions

The West Delta subregion is 96,420 acres in extent including 28,820 aquatic acres (Table 5.E.4-12). The subregion is located at the confluence of the Sacramento and San Joaquin Rivers (Figure 5.E.4-36). The bathymetry and elevation range between more than 10 feet above sea level and more than 15 feet below sea level. The majority of the developed lands in the West Delta, including Pittsburg, Antioch, and Brentwood, are at elevations more than 10 feet above sea level, whereas the majority of the undeveloped lands (i.e., those subject to restoration) are between zero and less than 10 feet below sea level. Figure 5.E.4-36 shows the existing bathymetry and elevation for the west Delta.

Much of the West Delta subregion consists of subtidal habitat with a small portion of freshwater tidal habitat. Table 5.E.4-12 identifies the different tidal intervals and the acreages associated with the habitat depths. The islands in the west Delta primarily support agricultural lands and grasslands. These areas historically were tidal wetlands but have been diked and hydrologically altered. Salinity in the west Delta ranges between 0.2 ppt and 4.6 ppt on average per month. Generally, these concentrations indicate that the west Delta consists primarily of fresh water, but during fall may become brackish.

Table 5.E.4-12. Wetted Acres in the West Delta Subregion under Existing Conditions and Future Conditions with and without the BDCP

Fish Habitat Type	Current Wetted Acres	Wetted Acres under EBC2_LLT	Wetted Acres under ESO_LLT	Acreage Change from BDCP Restoration Only
Wetted Fringe	180	220	200	-20
Tidal Brackish	–			0
Tidal Freshwater	5,100	5,590	8,020	2430
Intertidal Mudflat	–			0
Shallow Subtidal	4,500	3,420	2,240	-1180
Deep Subtidal	19,040	20,120	21,660	1540
Subtotal	28,820	29,350	32,120	2,770

Future Conditions

In the hypothetical restoration footprints, wetted acres in the West Delta would increase by 2,770 acres under the BDCP; sea level rise is expected to increase aquatic area in the subregion by only 530 acres, less than 2% increase over the current acreage (Table 5.E.4-12). The sea level rise increase represents a small increase in deep subtidal and tidal freshwater habitat (Figure 5.E.4-26).

Restoration in the hypothetical footprint in the west Delta is relatively modest, adding only 11% over the current area of the subregion. Restoration is expected to add mainly to the tidal freshwater area (Figure 5.E.4-27).

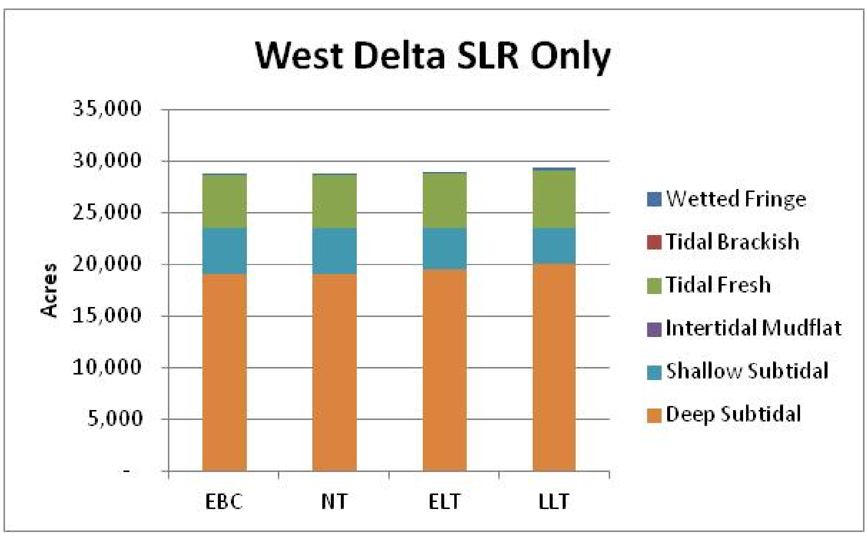


Figure 5.E.4-26. Expected Habitat Changes in the West Delta Subregion due to Sea Level Rise (SLR) Only

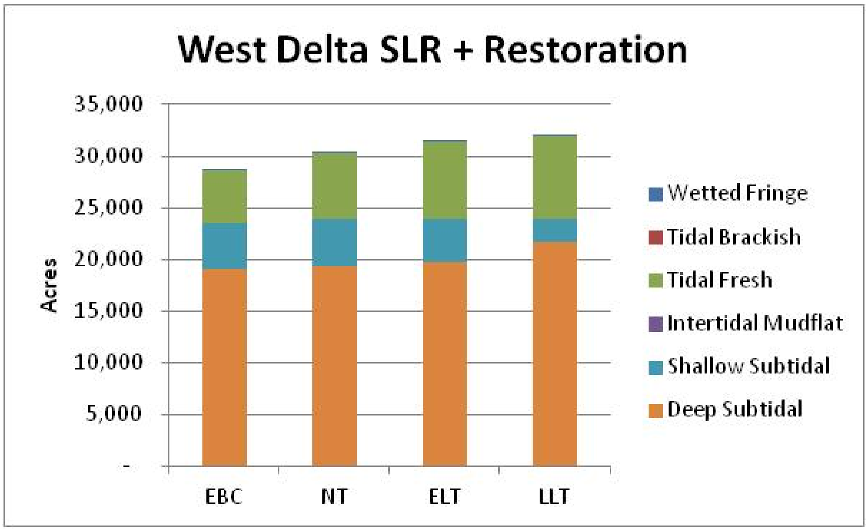


Figure 5.E.4-27. Expected Habitat Changes in the West Delta Subregion due to Sea Level Rise (SLR) and BDCP Restoration

The West Delta ROAs form a continuous chain of restoration area from the split between the Sacramento River and the Deepwater Shipping Channel down to Decker Island, increasing the geographic diversity and continuous corridor of habitat. The restored habitats would provide a potentially important linkage between upstream spawning and rearing habitat areas and the major splittail habitat downstream in Suisun Marsh and Bay.

Restoration is expected to provide local areas of cool water refugia for delta smelt and salmonids. The spatial extent of cool water refugia could be relatively limited for delta smelt. However, in some cases, a substantial effect could result across relatively large areas.

Restoration is expected to provide suitable subtidal habitat for juvenile and adult splittail, although the amounts are substantially less than those expected in the other ROAs. The restored habitat is expected to increase foodweb resources in the area, some of which would likely be exported for use by splittail downstream. The restoration actions are expected to improve growth and survival of juvenile and adult splittail.

Intended positive outcomes are listed below.

- Increase rearing habitat area for Sacramento splittail and Cosumnes and Mokelumne River fall-run Chinook salmon and possibly steelhead.
- Increase production of food for rearing salmonids, splittail, and other covered species migrating to and from the Cosumnes and Mokelumne Rivers.
- Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.

Possible negative outcomes that could result from tidal wetlands restoration in the west Delta are listed below.

- Establishment of centrarchids.
- Establishment of *Corbicula*.

- Establishment of *Egeria*.
- Resuspension and export of mercury and methylmercury to downstream areas.
- Movement of fish and food resources to areas in the central Delta with high predation.
- Local toxicity from residual pesticides and herbicides (e.g., pyrethroids).
- Establishment of inland silversides that will prey on or compete with Delta and longfin smelt or alter habitat conditions.

Suisun Marsh Subregion

Existing Conditions

The Suisun Marsh complex (Suisun Marsh and Suisun Bay) is the largest brackish marsh complex in the western United States. Suisun Marsh itself lies at the western end of the Plan Area and is congruous with Suisun Bay (Figure 5.E.4-37). The Suisun Marsh subregion is about 82,760 acres in extent with about 12,410 acres of aquatic habitat currently. Much of the marsh currently consists of tidal brackish habitat (Table 5.E.4-13).

The elevation and bathymetry range between more than 10 feet above sea level to more than 15 feet below sea level; however, the majority of the marsh is between more than 10 feet above sea level and at sea level. Portions of Suisun Marsh have undergone marked subsidence, although not nearly as much as the neighboring Delta area. This is believed to be the result of diking and removal from tidal inundation. Agricultural and managed wetland activities such as disking, which accelerates the drying and oxidation processes, likely have contributed to accelerated subsidence.

The Suisun Marsh, a brackish marsh, generally has the highest salinity gradient of any of the subregions. The marsh is influenced by different seasonal salinity regimes, controlled by the interplay of tides and the seasonal pattern of outflow from the Sacramento and San Joaquin rivers. Salinity in the marsh is partly controlled by the inflow from the Sacramento River via Montezuma Slough (Moyle 2008). Montezuma Slough has large tidal gates on its upper end that control salinity in the marsh by allowing fresh water to flow in but preventing the tides from pushing it back out again (Moyle 2008). State Water Resources Control Board (State Water Board) Water Right Decision 1641 (D-1641) salinity objectives currently apply to Suisun Marsh and regulate salinity. The salinity in Suisun Marsh varies greatly due to outflow, tides and flow from the salinity control gates. Research on patterns and processes of biological invasion in the San Francisco Bay Estuary by Rudnick et al. (2003) indicated that during 2 years of the CDFW monitoring study, salinity at low tide varied in the Suisun Marsh (1997 mean = 5.4 parts per thousand [ppt], 1998 mean = 0.9 ppt). Additional research by showed that salinity can range between a monthly average of 1 ppt and a monthly average of 8 ppt.

Suisun Marsh subregion also contains extensive areas of diked wetlands that are managed for waterfowl and experience little natural tidal action. These managed areas are separated from tidal sloughs by levees, gated culverts, and other gated structures that control water exchange and salinity. Waterfowl club managers control the timing and duration of flooding to promote growth of food plants for waterfowl. Some of these are managed as perennial wetlands; others are dry-managed during the summer and early fall months, and then are prepared for waterfowl habitat and hunting with a series of flood-drain-flood cycles. Depending on the specific location and operations of the individual managed wetland areas, periodic flooding and discharge can lead to periods of low dissolved oxygen (DO) events in adjoining water bodies, which causes acute mortality in at-risk fish species and impairs valuable fish nursery habitat at very low DO (i.e., <7 mg/L). Managed wetlands can also release elevated levels of methylmercury (MeHg) into adjoining sloughs, a neurotoxin found throughout the Delta that bioaccumulates in the foodweb and adversely affects fish and wildlife (Siegel et al. 2011).

Table 5.E.4-13. Wetted Acres in the Suisun Marsh Subregion under Existing Conditions and Future Conditions with and without the BDCP

Fish Habitat Type	Current Wetted Acres	Wetted Acres under EBC2_LLT	Wetted Acres under ESO_LLT	Acreage Change from BDCP Restoration Only
Wetted Fringe	–		–	
Tidal Brackish	7,940	8,020	10,850	2,830
Tidal Freshwater	–		–	
Intertidal Mudflat	280	240	2,030	1,790
Shallow Subtidal	1,830	1,870	9,050	7,180
Deep Subtidal	2,360	2,590	2,710	120
Subtotal	12,410	12,720	24,640	11,920

Future Conditions

Sea level rise is expected increase total wetted acres in Suisun Marsh by 310 acres a 2% increase in aquatic habitat. This change is largely due to a small increase in tidal brackish habitat (Figure 5.E.4-28).

Restoration under the BDCP is expected to provide an additional 11,920 acres of aquatic area to Suisun Marsh and will increase mainly shallow subtidal and tidal brackish habitat (Figure 5.E.4-29). Restored brackish tidal habitat will generally provide hydrodynamic conditions and ecosystem function similar to those that exist within Suisun Marsh today. To the extent practical, tidal habitat restoration actions will be designed to provide an ecological gradient among subtidal, tidal mudflat, tidal marsh plain, riparian, and upland habitats that are anticipated to provide a net ecological benefit to endemic and covered species (Table 5.E.4-13). As sea level rises new brackish tidal habitat will help remediate lost habitat as it becomes increasingly subtidal over the period of the project. It is recognized that with climate change, sea level rise, increasing temperature that changes in amount of inflow and duration, coupled with changes in tidal levels, salinity and temperature will drive ecosystem gradients within restoration areas.

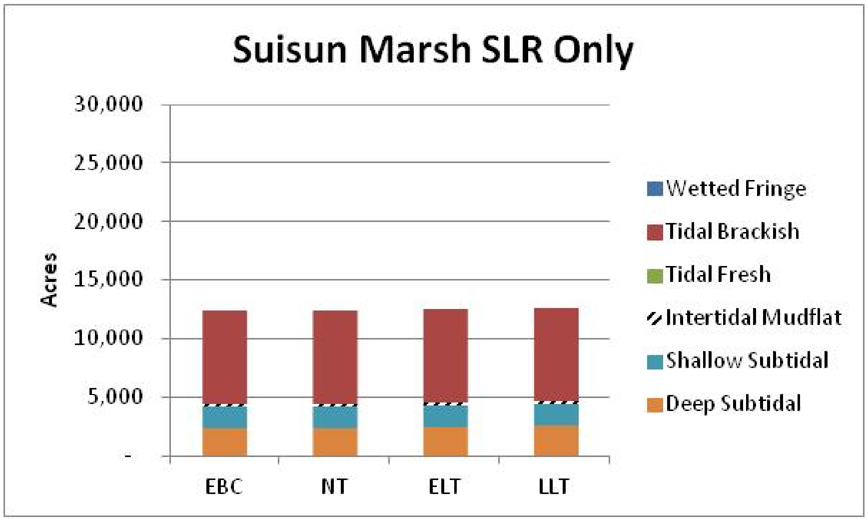


Figure 5.E.4-28. Expected Habitat Changes in Suisun Marsh due to Sea Level Rise (SLR) Only

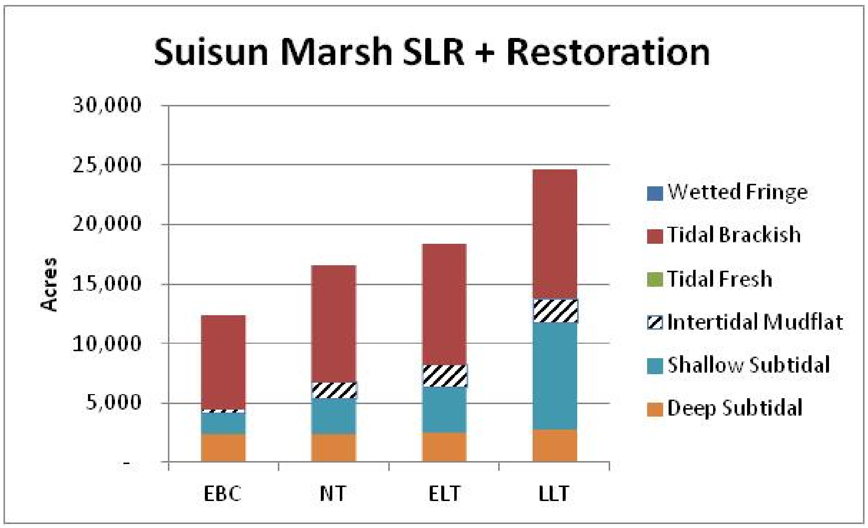


Figure 5.E.4-29. Expected Habitat Changes in Suisun Marsh due to Sea Level Rise (SLR) and BDCP Restoration

Restoration actions in Suisun Marsh would increase the amount of saline intertidal and subtidal habitat in the Plan Area for all covered fish species. Brackish marsh habitats, such as Suisun Marsh, provide an essential rearing habitat for life stages of many covered fish species, including delta smelt and foraging juvenile salmonids, juvenile Chinook salmon (Quinn 2005), splittail and sturgeon.

Restoration of tidal action has the potential to eliminate episodic low DO events that presently overwhelm the ability of the aquatic environment to process organic matter without consuming the *in situ* oxygen. Reducing periodic low DO events in Suisun Marsh will reduce the fish and invertebrate kills associated with this problem. Addressing this problem is expected to have somewhat beneficial effects on regional foodweb productivity and to reduce methylmercury contamination.

The following potential negative outcomes could affect all covered species as a result of floodplain and tidal wetland restoration in the Suisun Marsh ROA.

- Potential for mercury methylation and local bioaccumulation.
- Establishment of centrarchids.
- Establishment of *Corbicula*.
- Establishment of inland silversides.

The potential for undesirable species such as *Egeria* to alter habitat conditions for covered fish is described in Appendix 5.F, *Biological Stressors on Covered Fish*. Because salinity conditions in Suisun Marsh are currently too high to allow for establishment of most species of SAV that occur in the Delta, the magnitude of this impact is expected to be low. Climate change is expected to increase salinity levels in this area of the Delta in the future, further reducing the likelihood of SAV establishment.

Suisan Bay Subregion

Existing Conditions

The Suisun Bay subregion borders the Suisun Marsh and is about 20,530 acres in extent of which 20,450 acres are of aquatic habitat (Figure 5.E.4-37). CM4 does not propose restoration of aquatic habitat to the Suisun Bay subregion. Suisun Bay is a shallow embayment located between Chipps Island at the western boundary of the Delta and the Benicia-Martinez Bridge at the eastern end of the Carquinez Strait. Adjacent to Suisun Bay is the Suisun Marsh. The narrow, 12-mile-long Carquinez Strait joins Suisun Bay with San Pablo Bay. Suisun Bay is a large area of open water that is transitional between the fresh waters of the Delta and the saltwater of San Francisco Bay; it is a shallow region of wind-stirred, brackish water, lined with tidal marshes (Moyle 2008). The main embayments of Suisun Bay include Grizzly Bay, Honker Bay, and Suisun Bay. Table 5.E.4-14 identifies different tidal intervals and the acreages associated with the habitat depths.

Table 5.E.4-14. Wetted Acres in the Suisun Bay Subregion under Existing Conditions and Future Conditions without the BDCP

Fish Habitat Type	Current Wetted Acres	Wetted Acres under EBC2_LLT
Wetted Fringe	–	–
Tidal Brackish	1,190	1,160
Tidal Freshwater	–	–
Intertidal Mudflat	80	40
Shallow Subtidal	8,340	5,740
Deep Subtidal	10,840	13,520
Subtotal	20,450	20,460

Future Conditions

Sea level rise is expected to make almost no change in total wetted acres in Suisun Bay (Table 5.E.4-14). However, sea level rise is expected to appreciably increase the deep subtidal area while decreasing other habitat categories (Figure 5.E.4-30).

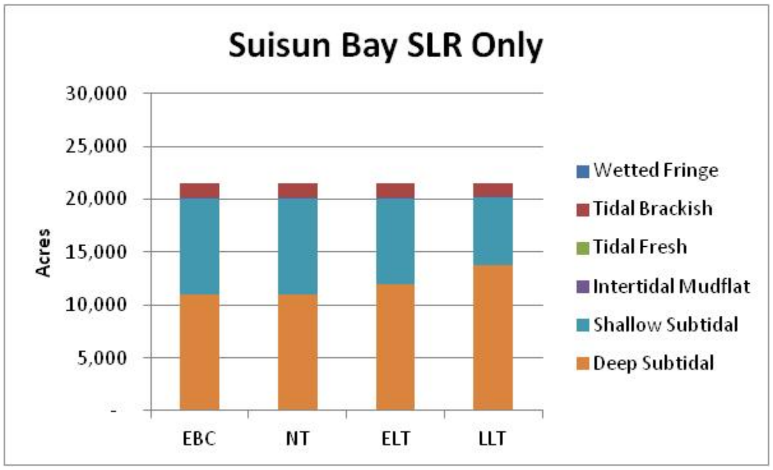


Figure 5.E.4-30. Expected Habitat Change in Suisun Bay due to Sea Level Rise (SLR) Only

East Delta Subregion

Existing Conditions

The East Delta subregion (Figure 5.E.4-38) is 102,640 acres in extent and contains about 5,920 acres of low-salinity wetted habitat, most of which is freshwater tidal and deep subtidal environments (Table 5.E.4-15). The Cosumnes/Mokelumne ROA is located within the East Delta subregion. This ROA currently includes little inundated acreage and consists mainly of diked farm land. The area restored under the hypothetical footprint currently consists primarily of agricultural lands and a complex of sloughs and channels at the confluence of the Cosumnes and Mokelumne Rivers.

Future Conditions

Areas suitable for restoration in the East Delta subregion include McCormack-Williamson Tract, New Hope Tract, Canal Ranch Tract, Bract Tract, Terminous Tract north of State Route 12, and lands adjoining Snodgrass Slough, South Stone Lake, and Lost Slough.

By the LLT period, sea level rise is expected to increase aquatic habitat in the East Delta subregion by about 1,520 acres, a 26% increase over the current area of the subregion (Table 5.E.4-15). Most of the increase would occur in freshwater tidal areas (Figure 5.E.4-31). BDCP restoration would add about 2,060 acres under the hypothetical footprint (Table 5.E.4-15). Most of the restoration would accrue to the shallow subtidal habitats (Figure 5.E.4-32).

Table 5.E.4-15. Wetted Acres in the East Delta Subregion under Existing Conditions and Future Conditions with and without the BDCP

Fish Habitat Type	Current Wetted Acres	Wetted Acres under EBC2_LLT	Wetted Acres under ESO_LLT	Acreage Change from BDCP Restoration Only
Wetted Fringe	350	350	220	-130
Tidal Brackish				
Tidal Freshwater	1,570	3090	3,730	640
Intertidal Mudflat				
Shallow Subtidal	790	630	1,970	1340
Deep Subtidal	3,210	3,370	3,580	210
Subtotal	5,920	7,440	9,500	2,060

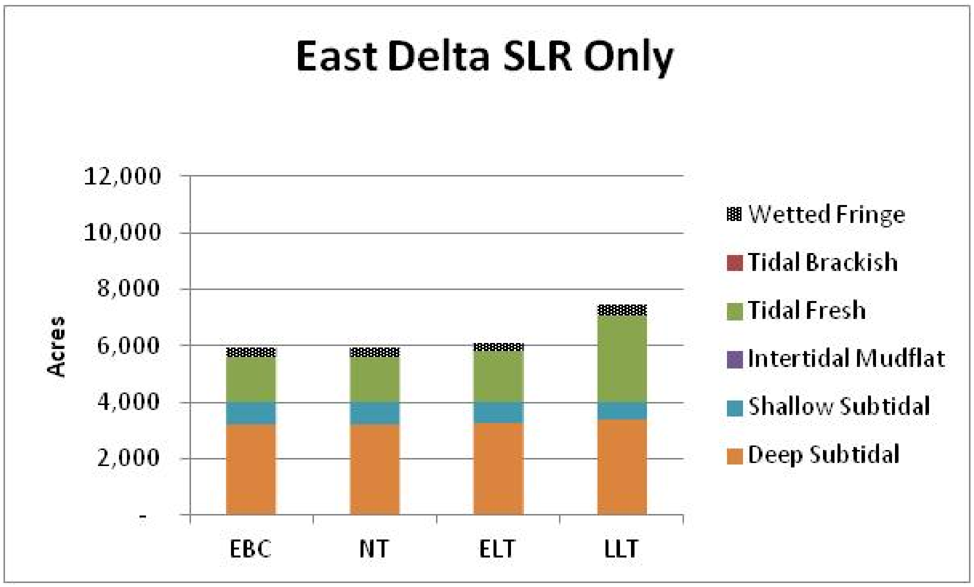


Figure 5.E.4-31. Expected Change in Habitat in the East Delta Subregion due to Sea Level Rise (SLR) Only

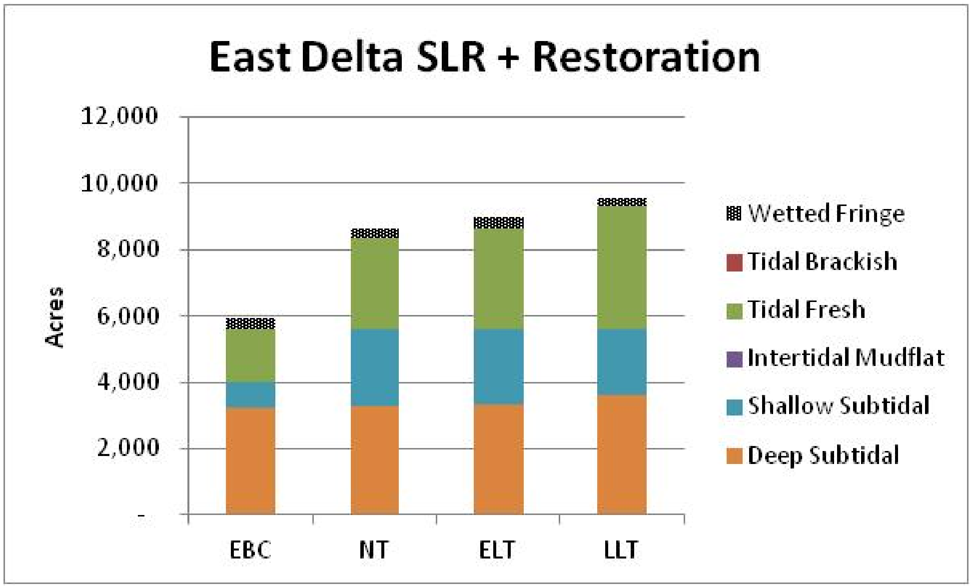


Figure 5.E.4-32. Expected Change in Habitat in the East Delta Subregion due to Sea Level Rise (SLR) and BDCP Restoration

Intended positive outcomes of restoration in the Cosumnes/Mokelumne ROA include the following.

- Increase rearing habitat area for Sacramento splittail and Cosumnes and Mokelumne River fall-run Chinook salmon and possibly steelhead.
- Increase production of food for rearing salmonids, splittail, and other covered species migrating to and from the Cosumnes and Mokelumne Rivers.
- Increase the availability and production of food in the east and central Delta by exporting organic material from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Delta.

Potential negative outcomes of restoration in the Cosumnes/Mokelumne ROA are listed below.

- Establishment of undesirable species that may prey upon, compete with, or alter habitat conditions for covered fish.
- Local effects of contaminants, including local toxicity from residual pesticides and herbicides (e.g., pyrethroids).
- Resuspension and export of contaminants to downstream areas (mercury, methylmercury, and pesticides and herbicides [e.g., pyrethroids]).

South Delta Subregion

Existing Conditions

The south Delta is the largest subregion within the Plan Area encompassing about 315,390 acres only about 19,890 acres or 6% of which are low salinity aquatic environments (Table 5.E.4-16). Much of the aquatic habitat currently consists of deep subtidal areas (Table 5.E.4-16). The subregion consists primarily of agricultural lands and a riverine system including the San Joaquin River and its tributaries, and includes Fabian Tract, Union Island, Middle Roberts Island, and Lower Roberts

Island (Figure 5.E.4-39). The South Delta subregion also includes the SWP and CVP pumping stations along with Old and Middle Rivers.

Table 5.E.4-16. Wetted Acres in the South Delta Subregion under Existing Conditions and Future Conditions with and without the BDCP

Fish Habitat Type	Current Wetted Acres	Wetted Acres under EBC2_LLT	Wetted Acres under ESO_LLT	Acreage Change from BDCP Restoration Only
Wetted Fringe	840	470	1,330	860
Tidal Brackish	–			0
Tidal Freshwater	3,560	4560	15,090	10,530
Intertidal Mudflat	–			0
Shallow Subtidal	3,400	2,680	11,950	9,270
Deep Subtidal	12,090	12,810	14,360	1,550
Subtotal	19,890	20,520	42,730	22,210

Future Conditions

Sea level rise is expected to add about 630 acres of aquatic habitat to the South Delta subregion. This is due to a small increase in deep subtidal habitat by the LLT (Figure 5.E.4-33). All of the south Delta habitat restoration would occur in the LLT to reduce the risk of loss of fish and food supplies produced in a south Delta habitat as a result of entrainment into south Delta exports (Figure 5.E.4-34). Under the hypothetical restoration footprint, about 22,210 acres of aquatic habitat would be added to the South Delta as a result of BDCP restoration (Table 5.E.4-16). Restoration would especially increase the tidal freshwater and shallow subtidal areas (Figure 5.E.4-34). Assumed restoration includes vegetated marsh plain, tidal channel networks with depths that are shallow to medium subtidal, and shallow subtidal open water in the deeper portions of the restoration sites. Restoration is expected to occur on Fabian Tract, Union Island, Middle Roberts Island, and Upper Roberts Island.

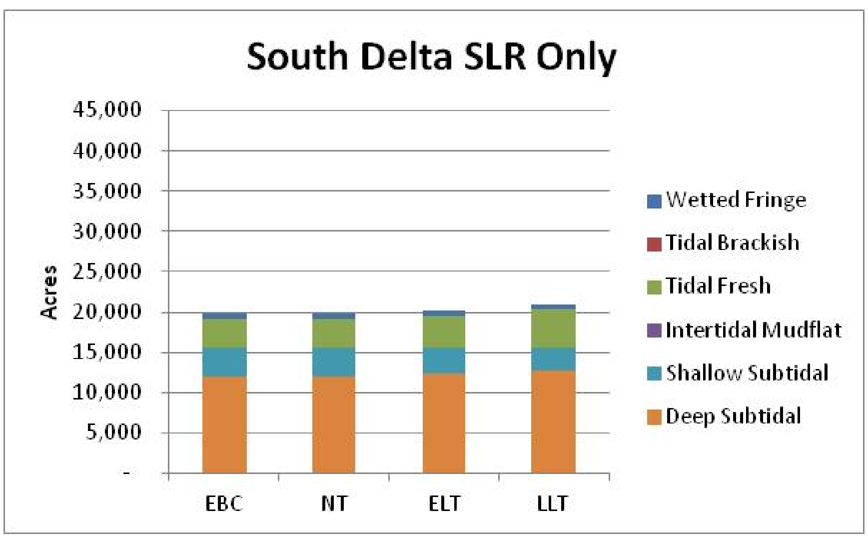


Figure 5.E.4-33. Expected Change in Aquatic Habitat in the South Delta due to Sea Level Rise (SLR) Only

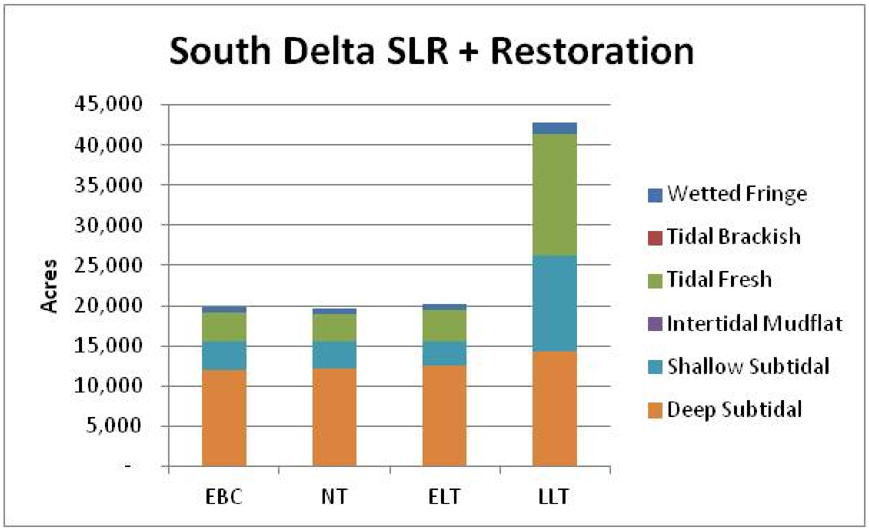


Figure 5.E.4-34. Expected Change in Aquatic Habitat in the South Delta due to Sea Level Rise (SLR) and BDCP Restoration

Under this conservation measure, restoration would include vegetated marsh plain, tidal channel networks with depths that are shallow to medium subtidal, and shallow subtidal open water in the deeper portions of the restoration sites. There would be no restoration in the NT or ELT implementation periods in the South Delta.

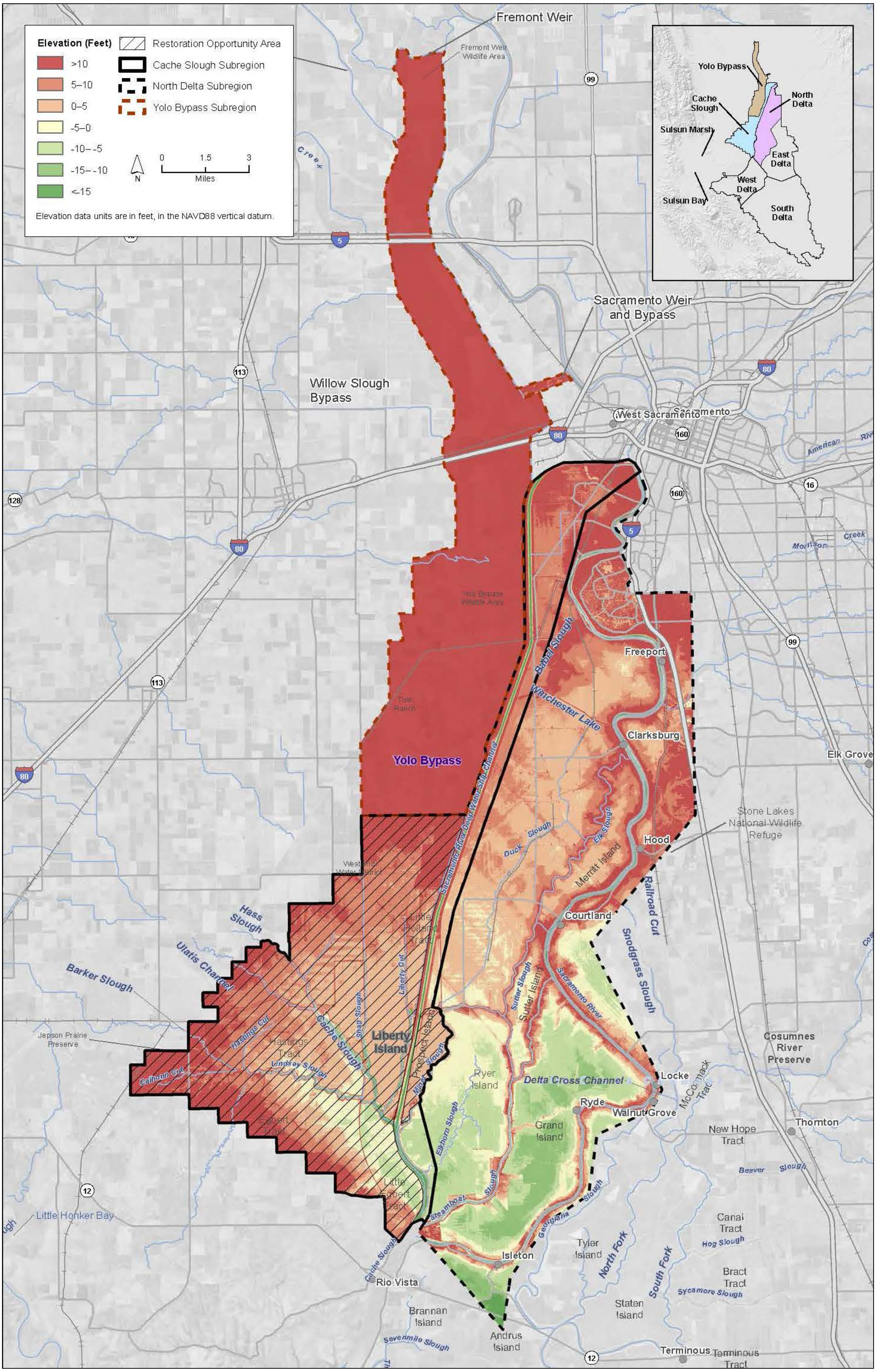
Restoration in the South Delta may provide shallow-water habitat for some delta fish species as evaluated below. However, an important potential benefit of restoration in the South Delta is the contribution to phytoplankton production and the potential benefit to the pelagic foodweb throughout the Plan Area (Section 5.E.4.2.6).

Potential negative outcomes that could occur as a result of tidal wetlands restoration in the South Delta ROA are listed below.

- Resuspension and export of mercury and methylmercury to downstream areas.
- Local toxicity from residual pesticides and herbicides (e.g., pyrethroids).
- Potential for local mercury methylation and bioaccumulation. Establishment of centrarchids.
- Establishment of *Egeria*.
- Production of organic matter that would contribute to low DO.

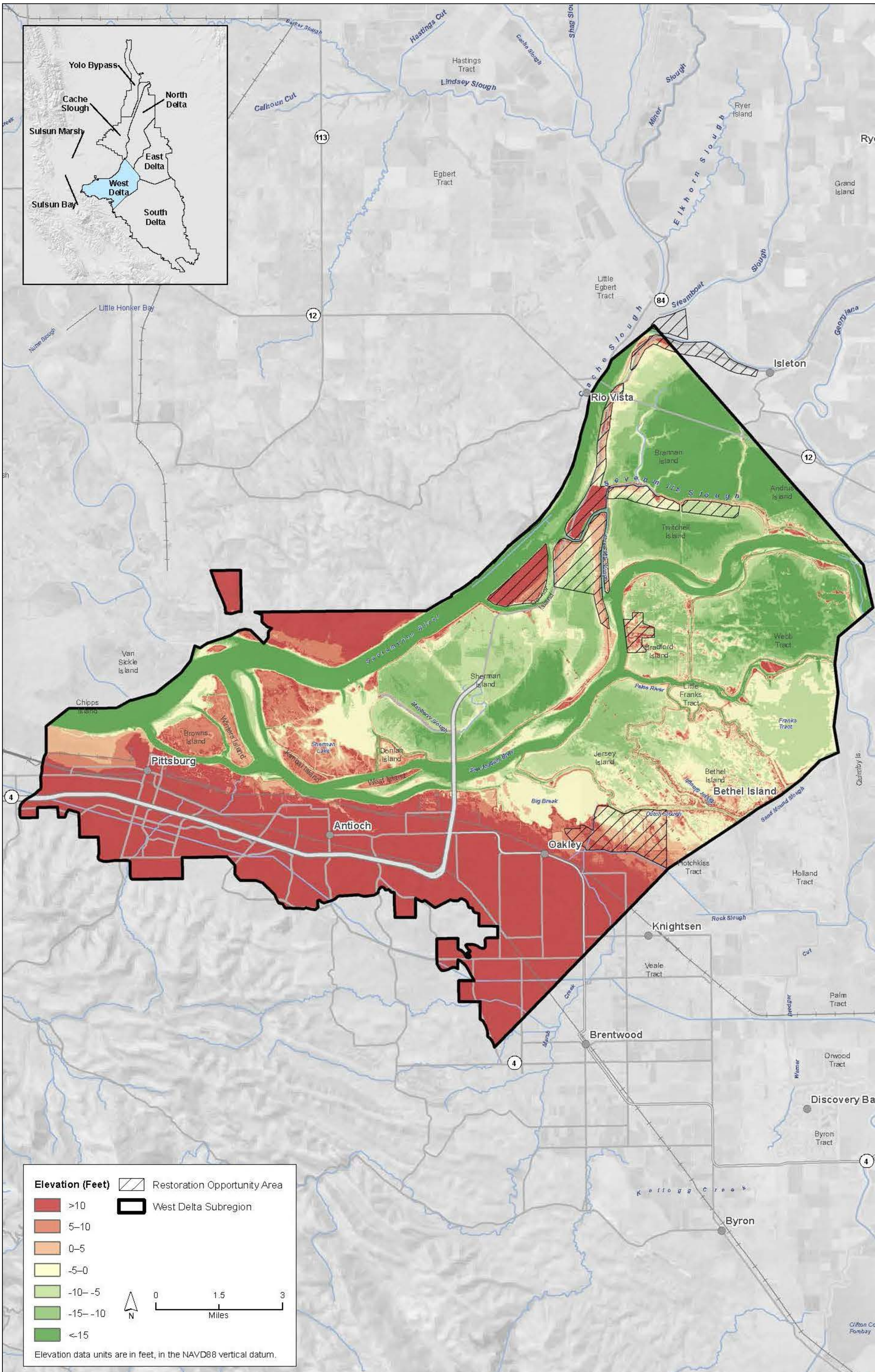
5.E.4.4.2.2 Depth

Depth of each physical habitat type was determined in the analysis described in Section 5.E.4.2.2.4, *Suitability of Restored Habitat for Covered Fish Species*. Depth was a primary determinant of physical habitat types in Table 5.E.4-9. Average depth of each physical habitat type in the LLT is shown in Table 5.E.4-17. These data were used in the splittail HSI analysis and in the estimated phytoplankton contribution in Section 5.E.4.2.6. The one set of depths estimated for the LLT in Table 5.E.4-17 was used for all time periods. This is because the depths were the basis for the definition of physical habitat types. As water level changes in response to sea level rise or restoration, these physical habitat types may move up or down slope but the average depth remains approximately the same. There are some minor changes in depth with restoration as a result of hydraulic changes but these are small and were not considered relevant to this analysis.



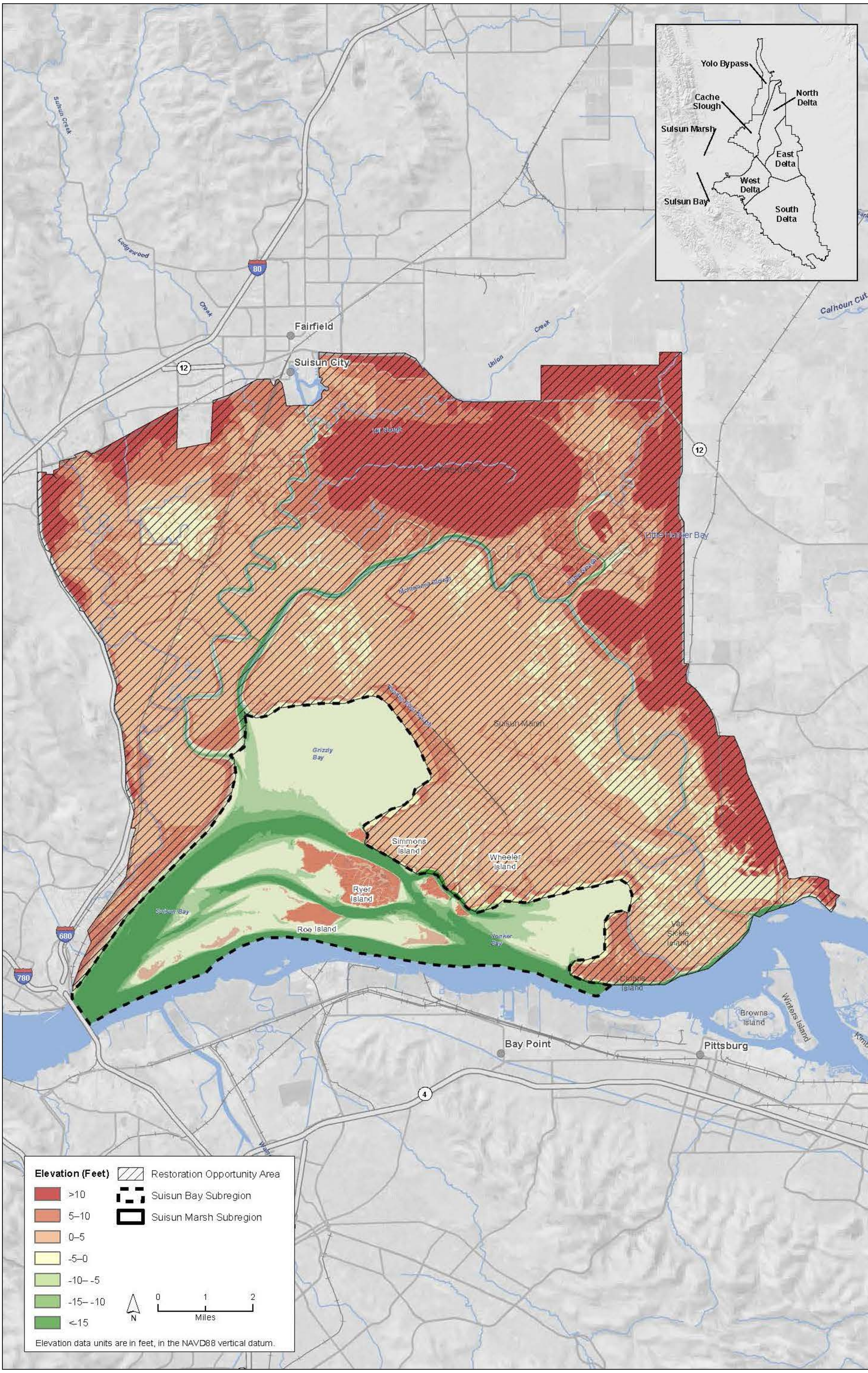
GIS Data Source: Plan Area, ICF 2012; Restoration Opportunity Area, SAIC 2012; Bathymetry, URS 2012; Hydrology Subregions, ICF 2012.

Figure 5.E.4-35. Bathymetry and Elevation Data for the Cache Slough, North Delta, and Yolo Bypass Subregions



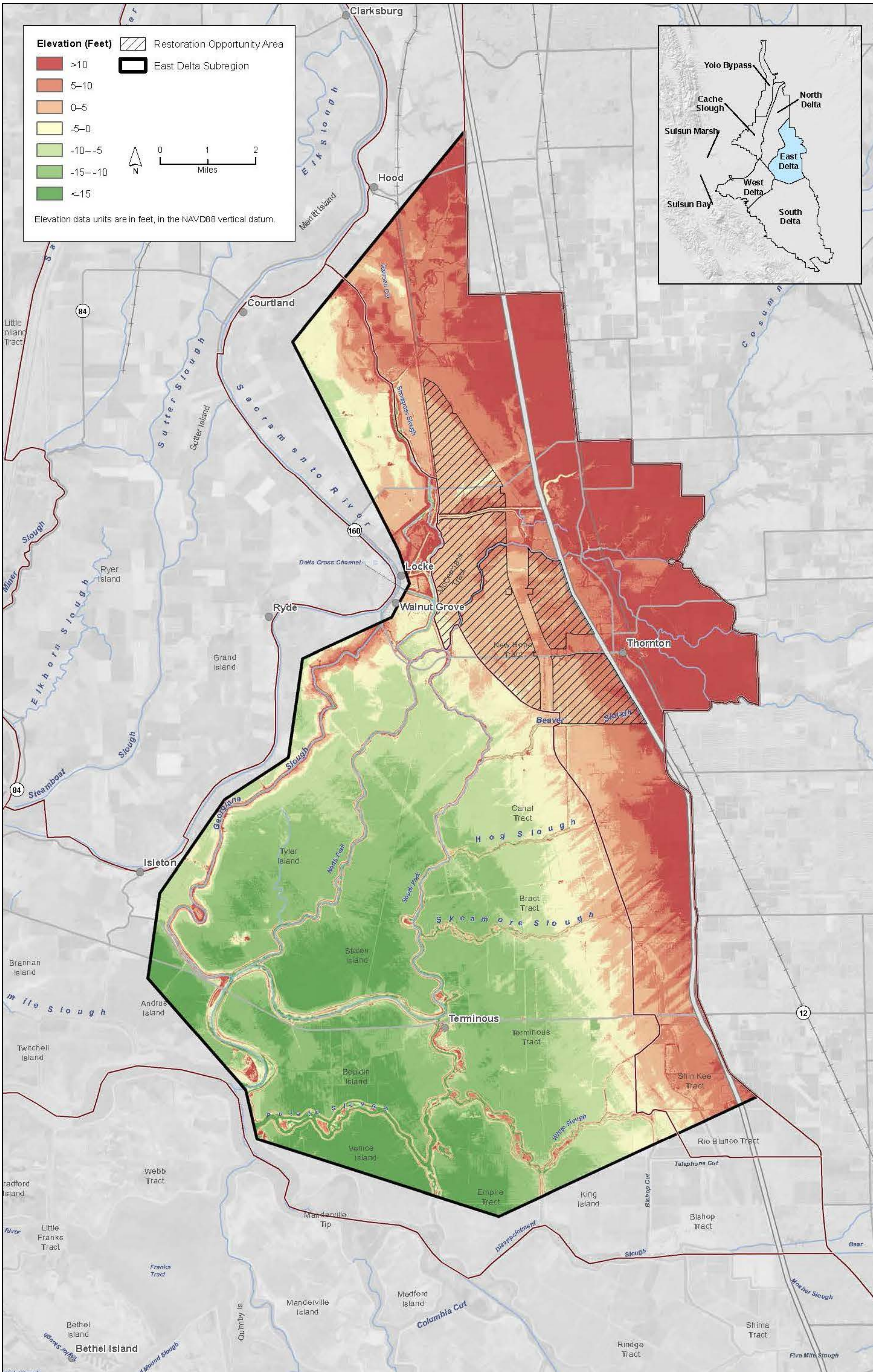
GIS Data Source: Plan Area, ICF 2012; Restoration Opportunity Area, SAIC 2012; Bathymetry, URS 2012; Hydrology Subregions, ICF 2012.

Figure 5.E.4-36. Bathymetry and Elevation Data for the West Delta Subregion



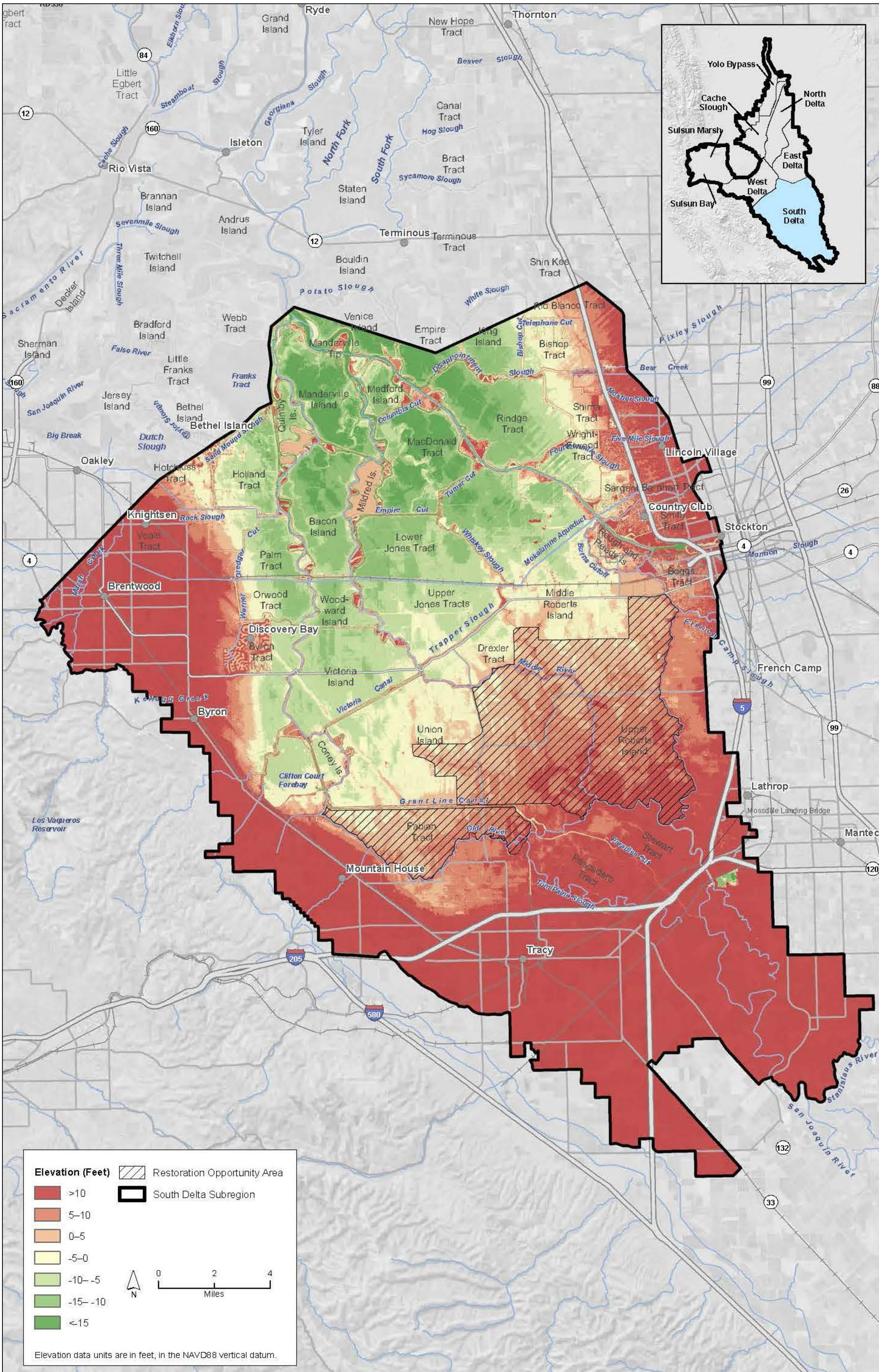
GIS Data Source: Plan Area, ICF 2012; Restoration Opportunity Area, SAIC 2012; Bathymetry, URS 2012; Hydrology Subregions, ICF 2012.

Figure 5.E.4-37. Bathymetry and Elevation Data for the Suisun Marsh and Suisun Bay Subregions



GIS Data Source: Plan Area, ICF 2012; Restoration Opportunity Area, SAIC 2012; Bathymetry, URS 2012; Hydrology Subregions, ICF 2012.

Figure 5.E.4-38. Bathymetry and Elevation Data for the East Delta Subregion



GIS Data Source: Plan Area, ICF 2012; Restoration Opportunity Area, SAIC 2012; Bathymetry, URS 2012; Hydrology Subregions, ICF 2012.

Figure 5.E.4-39. Bathymetry and Elevation Data for the South Delta Subregion

1 **Table 5.E.4-17. Estimated Depth of Physical Habitat in the Late Long-Term Period**

	Habitat Type	Ground Elevation: Maximum (with Respect to Tidal Datum)	Ground Elevation: Maximum (feet NAVD)	Ground Elevation: Average (feet NAVD)	Inundation Depth: Average Depth (feet)	Inundation Depth: Depth at MHHW (feet)
Cache Slough	Tidal Freshwater Marsh	MHHW	7.13	6.24	0.60	0.89
	Intertidal Mudflat	MLLW + 1 feet	5.36	4.86	1.17	2.27
	Subtidal 1	MLLW	4.36	2.86	2.87	4.27
	Subtidal 2	MLLW -3 feet	1.36	-0.14	5.87	7.27
	Subtidal 3[a]	MLLW -6 feet	-1.64	< -1.64	> 7.37	> 8.77
North Delta	Tidal Freshwater Marsh	MHHW	7.29	6.21	0.62	1.08
	Subtidal 1	MLLW	5.13	3.63	2.51	3.66
	Subtidal 2	MLLW -3 feet	2.13	0.63	5.51	6.66
	Subtidal 3[a]	MLLW -6 feet	-0.87	< -0.87	> 7.01	> 8.16
Western Delta	Tidal Freshwater Marsh	MHHW	7.06	5.54	0.88	1.52
	Subtidal 1	MLLW	4.02	2.52	2.99	4.54
	Subtidal 2	MLLW -3 feet	1.02	-0.48	5.99	7.54
	Subtidal 3[a]	MLLW -6 feet	-1.98	< -1.98	> 7.49	> 9.04
Suisun Marsh	High Tidal Brackish Marsh	EHW	8.42	8.06	0.15	
	Mid Tidal Brackish Marsh	MHHW	7.71	7.41	0.43	0.09
	Low Tidal Brackish Marsh	MHW	7.11	5.72	1.16	1.79
	Intertidal Mudflat	MLLW +1 feet	4.33	3.83	1.97	3.68
	Subtidal 1	MLLW	3.33	1.83	3.68	5.68
	Subtidal 2	MLLW -3 feet	0.33	-1.17	6.68	8.68
	Subtidal 3[a]	MLLW -6 feet	-2.67	< -2.67	> 8.18	> 10.18
Suisun Bay	High Tidal Brackish Marsh	EHW	8.22	7.86	0.15	
	Mid Tidal Brackish Marsh	MHHW	7.51	7.21	0.43	0.29
	Low Tidal Brackish Marsh	MHW	6.92	5.66	1.09	1.84
	Intertidal Mudflat	MLLW +1 feet	4.41	3.91	1.84	3.60
	Subtidal 1	MLLW	3.41	1.91	3.55	5.60
	Subtidal 2	MLLW -3 feet	0.41	-1.09	6.55	8.60
	Subtidal 3[a]	MLLW -6 feet	-2.59	< -2.59	> 8.05	> 10.1
East Delta	Tidal Freshwater Marsh	MHHW	6.91	5.86	0.59	1.05
	Subtidal 1	MLLW	4.82	3.32	2.46	3.59
	Subtidal 2	MLLW -3 feet	1.82	0.32	5.46	6.59
	Subtidal 3[a]	MLLW -6 feet	-1.18	< -1.18	> 6.96	> 8.09
South Delta	Tidal Freshwater Marsh	MHHW	6.56	5.38	0.69	1.18
	Subtidal 1	MLLW	4.21	2.71	2.65	3.85
	Subtidal 2	MLLW -3 feet	1.21	-0.29	5.65	6.85
	Subtidal 3[a]	MLLW -6 feet	-1.79	< -1.79	> 7.15	> 8.35

[a] For Subtidal 3 category, value shown for average ground elevation is maximum elevation and values shown for depths are the minimum depths.

5.E.4.4.2.3 Environmental Attribute Data

Environmental data relating to temperature, salinity, and turbidity was derived as described above and then parsed into time periods for each life stage as described in the individual species models. Figure 5.E.4-40 to Figure 5.E.4-60 display the data for each species model by life stage and water-year type. For brevity, only the results for the LLT period are shown and discussed.

Across all subregions and species lifestage periods, the most dramatic change in environmental conditions due to CM4 and BDCP operations was in regard to salinity. Very small changes in temperature were observed (undetectable in most of the figures below). As discussed above, turbidity data was held constant across the time periods and scenarios because of the lack of ability at present to model or forecast turbidity in the Delta.

Cache Slough Subregion

Cache Slough had low salinity for all species life stage periods for delta smelt and longfin smelt (Figure 5.E.4-40, Figure 5.E.4-41, and Figure 5.E.4-42). For most water year conditions, the BDCP (ESO) increased salinity levels in Cache Slough especially during winter and early spring relative to the without BDCP (EBC2) scenario. The difference between the EBC2 and ESO conditions was greatest during the wetter water years while the two conditions tended to converge as conditions became drier.

Temperature was slightly higher under the ESO scenario compared to EBC2 primarily during the winter months. Temperatures were similar across water years.

North Delta Subregion

The North Delta is freshwater, and salinity was very low for all time periods (Figure 5.E.4-43, Figure 5.E.4-44, and Figure 5.E.4-45). Salinity was very similar between the EBC2 and ESO scenarios although salinity was slightly higher under EBC2 in late summer to winter. Temperature was slightly higher in summer under ESO operations. Turbidity in the North Delta was appreciably lower (higher Secchi Disk visibility) than in Cache Slough.

West Delta Subregion

Salinity was appreciably higher in the West Delta compared to Cache Slough and North Delta subregions (Figure 5.E.4-46, Figure 5.E.4-47, and Figure 5.E.4-48). Salinity also increased markedly in drier water years. There was very little difference in salinity between EBC2 and ESO scenarios. Temperature was virtually identical in the two scenarios in the West Delta. Turbidity in the West Delta was similar to that in Cache Slough but appreciably greater (lower Secchi Disk visibility) than the North Delta.

Suisun Marsh Subregion

Salinity in Suisun Marsh was much higher than in the other subregions (except Suisun Bay) and increased sharply as water year conditions became drier (Figure 5.E.4-49, Figure 5.E.4-50, and Figure 5.E.4-51). Salinity was also appreciably higher under ESO scenario than under the EBC2 scenario. Temperature did not vary between the two scenarios. Turbidity was relatively high in Suisun Marsh (Secchi Disk visibility low) compared to other subregions.

Suisun Bay Subregion

Suisun Bay had the highest salinity of any of the BDCP subregions (Figure 5.E.4-52 and Figure 5.E.4-53). Salinity increased from wetter to drier water years indicating the influence of outflow. ESO and EBC2 scenarios had similar levels of salinity although EBC2 has slightly higher salinities for some periods. Temperature was stable between water years and was not influenced by the scenario (Figure 5.E.4-52, Figure 5.E.4-53 and Figure 5.E.4-54). Turbidity in Suisun Bay was relatively high (low Secchi Disk visibility).

East Delta Subregion

The East Delta had low salinity for all species life stage periods for delta smelt and longfin smelt (Figure 5.E.4-55, Figure 5.E.4-56, and Figure 5.E.4-57). Salinity in this subregion is greatly influenced by freshwater inflow from the Cosumnes and Mokelumne rivers. For most water year conditions, the BDCP (ESO) increased salinity levels relative to the without BDCP (EBC2) scenario especially during winter and early spring.

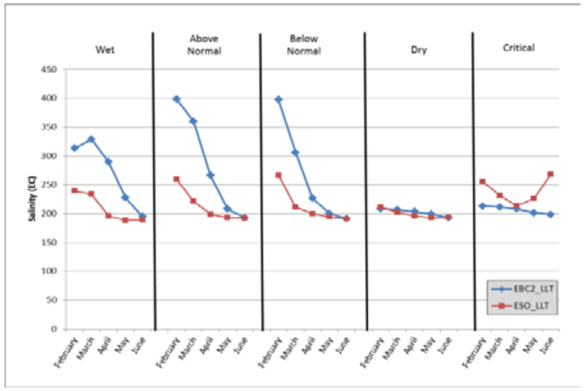
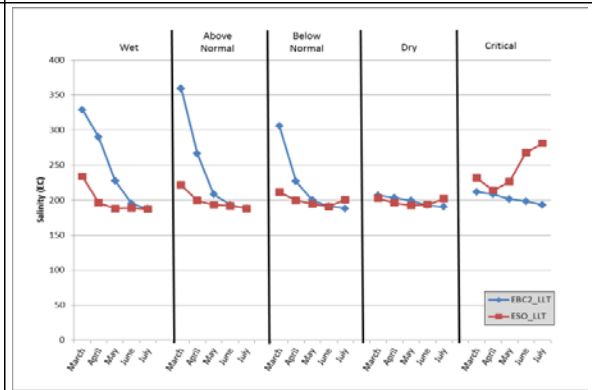
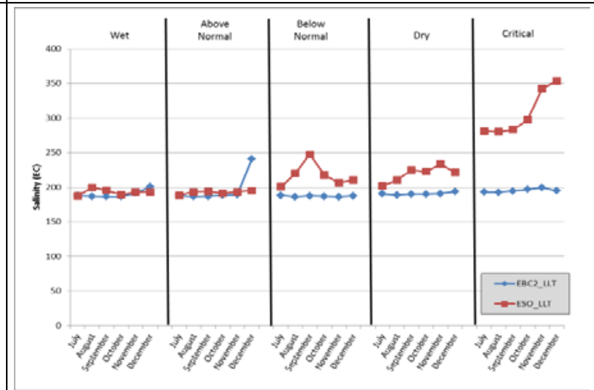
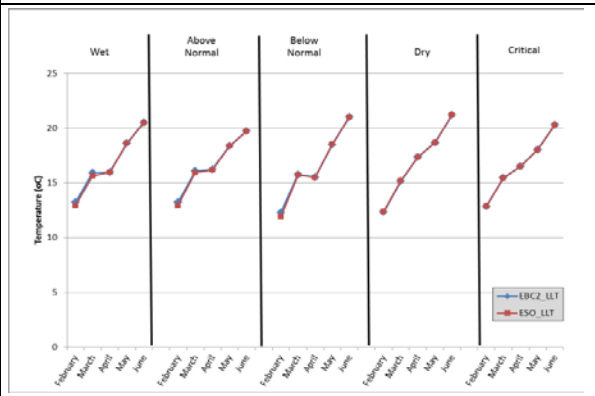
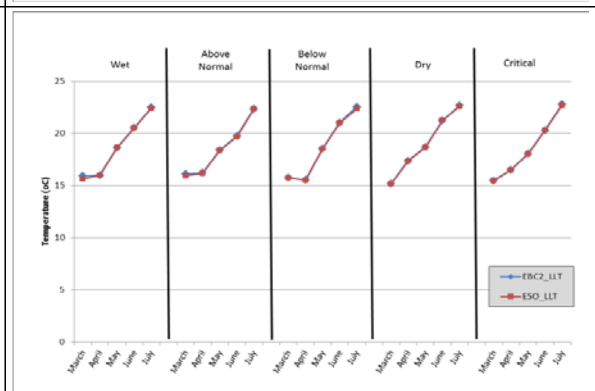
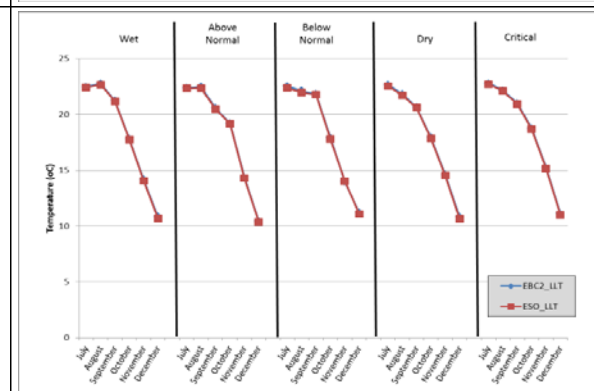
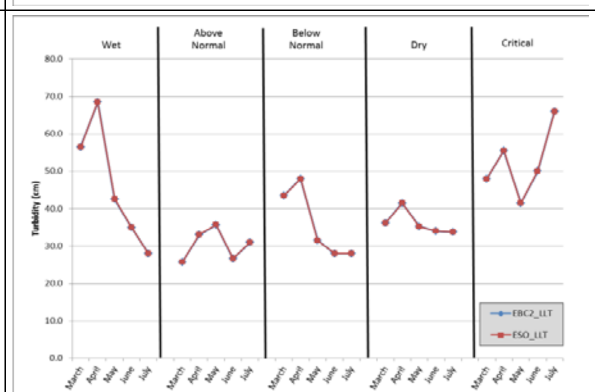
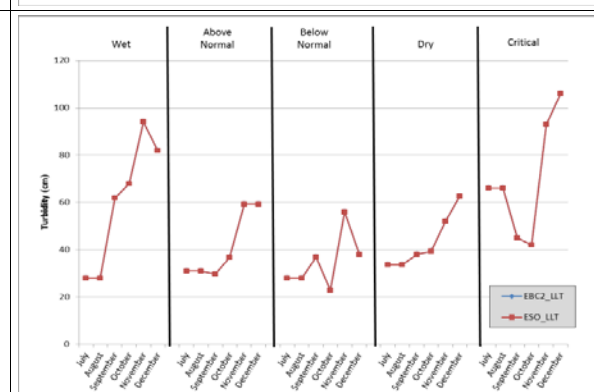
South Delta Subregion

The South Delta had higher salinity than the East Delta with a salinity comparable to Cache Slough (Figure 5.E.4-58, Figure 5.E.4-59, and Figure 5.E.4-60). Salinity increased as water year conditions became drier. For most periods and water years, salinity was slightly higher in the South Delta under the ESO scenario.

5.E.4.4.2.4 Suitability of Restored Habitat for Covered Fish Species

The environmental attribute and physical habitat data presented above was interpreted from the perspective of delta smelt, longfin smelt and salmonids using Habitat Suitability Analysis to derive HUs (Figure 5.E.4-2). Habitat for splittail was analyzed in a similar manner using the single attribute of depth. Results of the Habitat Suitability Analysis are presented below by geographic subregions and species. Tidal marsh restoration under CM4 is presumed to occur within the ROAs as proscribed in the hypothetical restoration footprint discussed above. There are no ROAs in the North Delta and Suisun Bay subregions. For these subregions, estimation of HUs for covered fish species addressed only the current (EBC2) condition and how conditions change under the modeled climate change and sea level rise.

To summarize the results for each species, HUs for each life stage were summed to present the total HUs for the species within the Plan Area. Total HUs for a species generally are greater than the total acres available (because HUs are summed across life stages) although the HUs for each life stage are less than the total acres. The total HUs for the species are a function of the number of life stages considered to occur within the Plan Area. HU benefits for delta smelt, for example, sum across the entire species life history that is assumed to occur within the Plan Area whereas only egg and larval stages of longfin smelt are assumed to occur within the Plan Area. Hence, the total HUs for delta smelt are generally greater for delta smelt than for other species reflecting the fact that delta smelt spend their entire life history within the Delta and are affected by conditions in the Delta; whereas only a portion of the life history of other species is affected.

	Egg-Larvae Period (February–June)	Larval Period (March–July)	Juvenile Period (July–December)
Salinity (EC)			
Temperature (°C)			
Turbidity (Secchi cm.)	Attribute not used.		

1 **Figure 5.E.4-40. Modeled Environmental Data for Cache Slough during Delta Smelt Time Periods During LLT**

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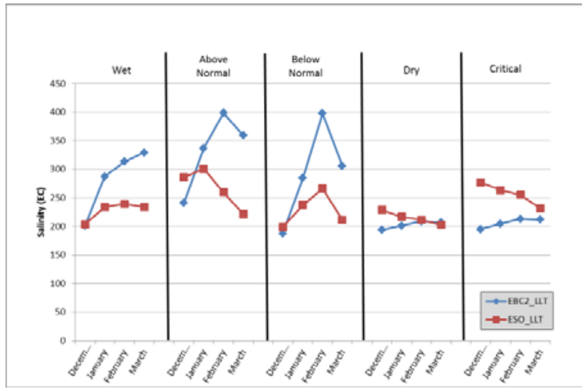
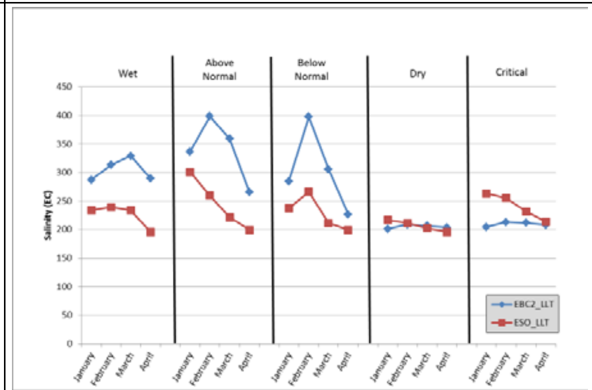
<tr><td>Salinity (EC)</td><td>
</td><td>
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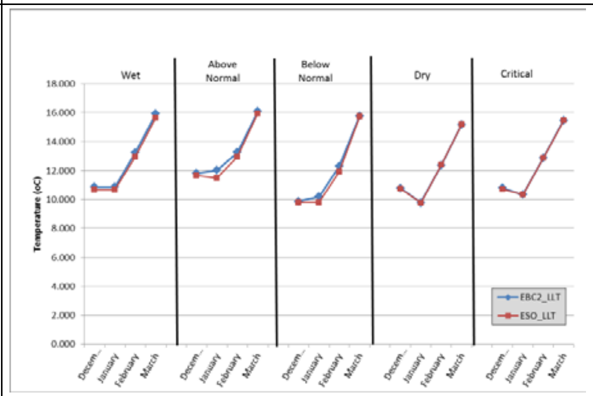
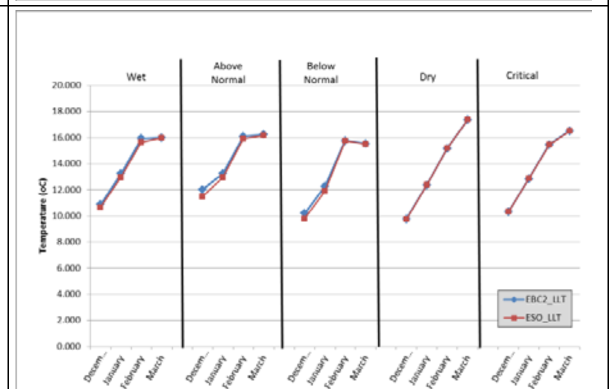
<tr><td>Temperature (oC)</td><td>
</td><td>
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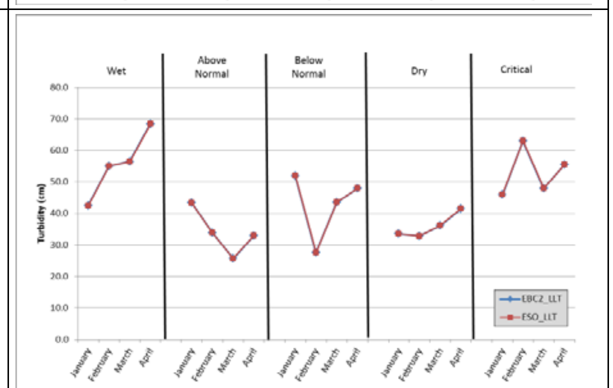
<tr><td>Turbidity (Secchi cm.)</td><td>Attribute not used.</td><td>
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1 **Figure 5.E.4-41. Modeled Environmental Data for Cache Slough during Longfin Smelt Time Periods During LLT**

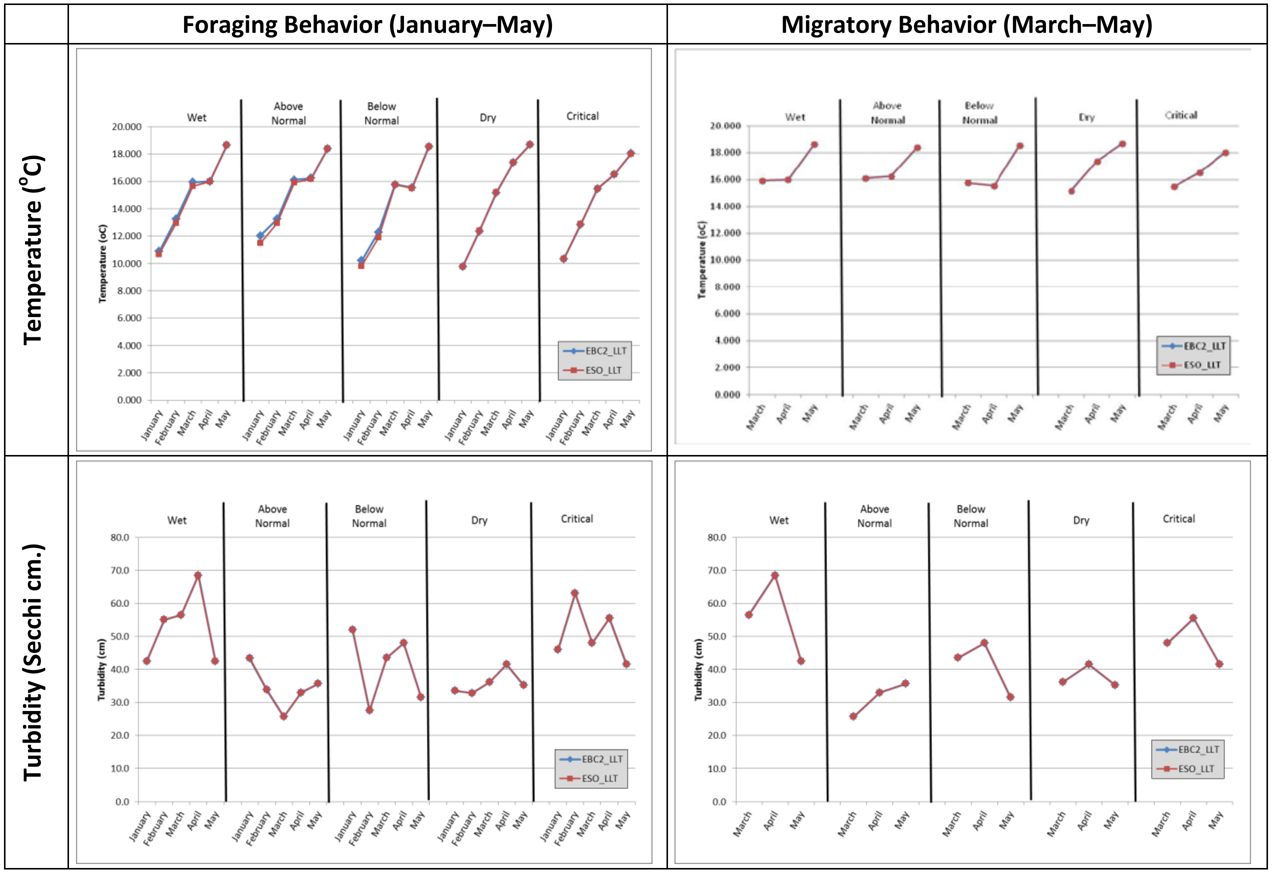


Figure 5.E.4-42. Modeled Environmental Data for Cache Slough during Juvenile Salmonid Time Periods During LLT

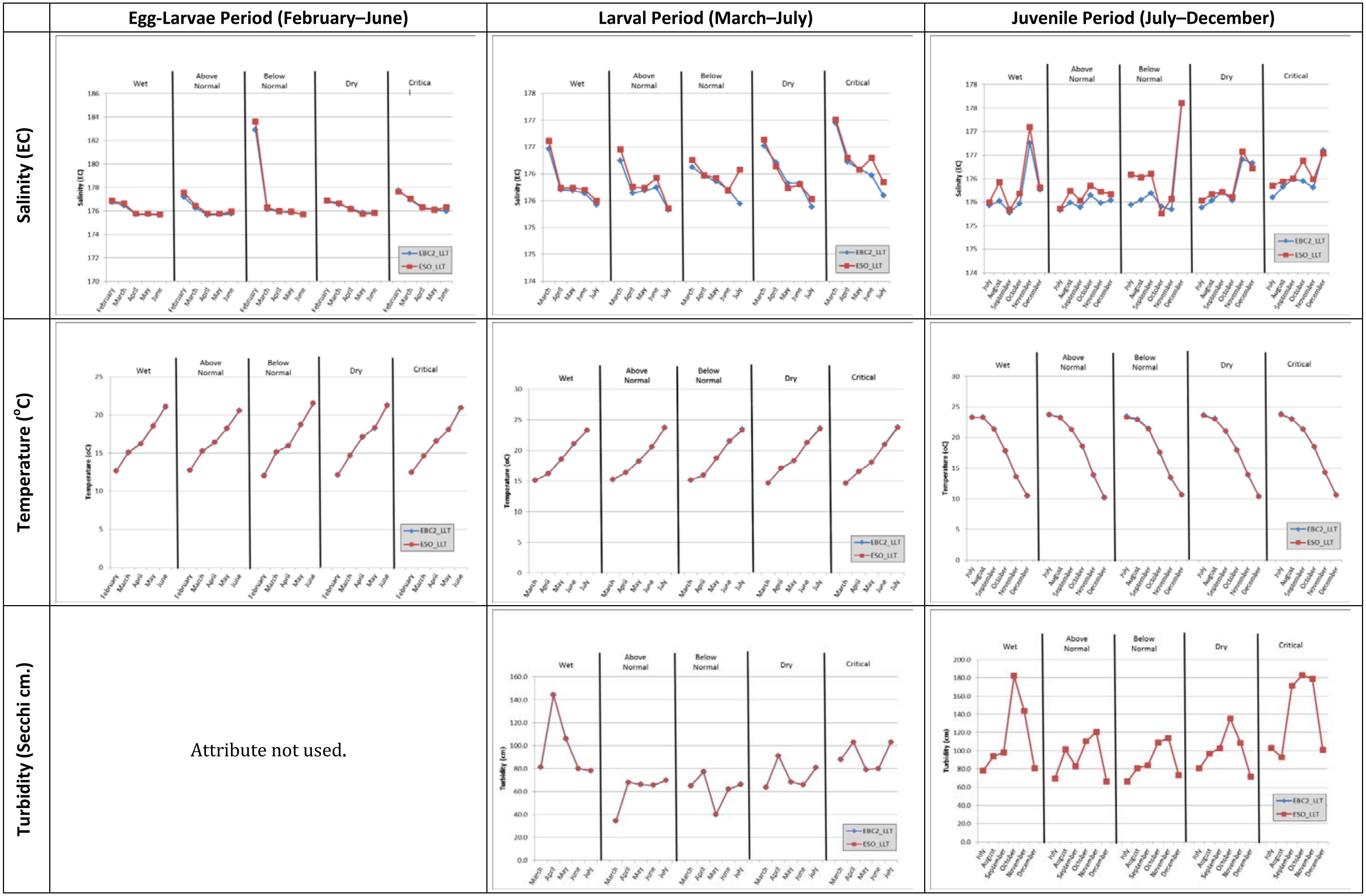


Figure 5.E.4-43. Modeled Environmental Data for the North Delta during Delta Smelt Time Periods

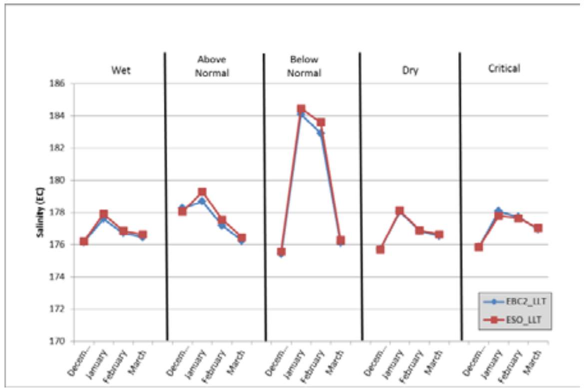
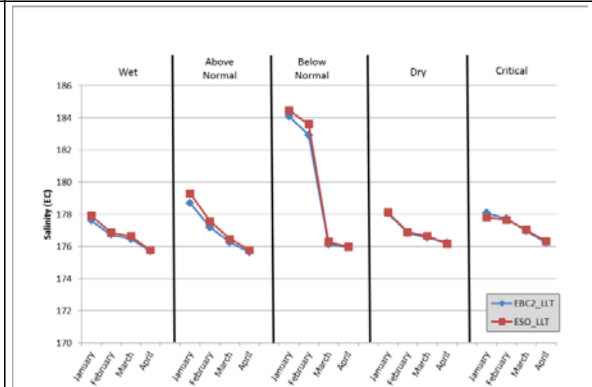
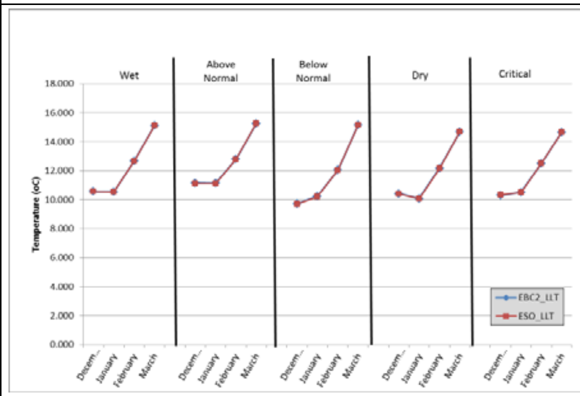
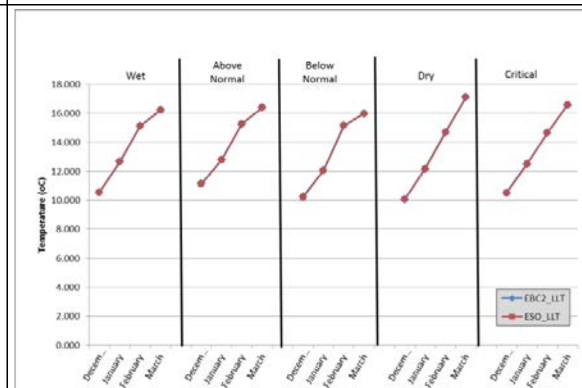
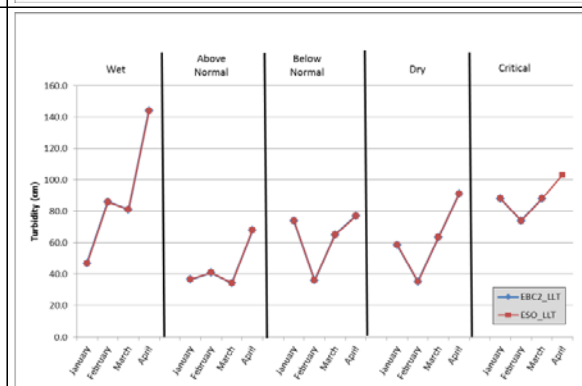
	Egg-Larvae Period (December–March)	Larval Period (January–April)
Salinity (EC)		
Temperature (oC)		
Turbidity (Secchi cm.)	Attribute not used.	

Figure 5.E.4-44. Modeled Environmental Data for the North Delta during Longfin Smelt Time Periods

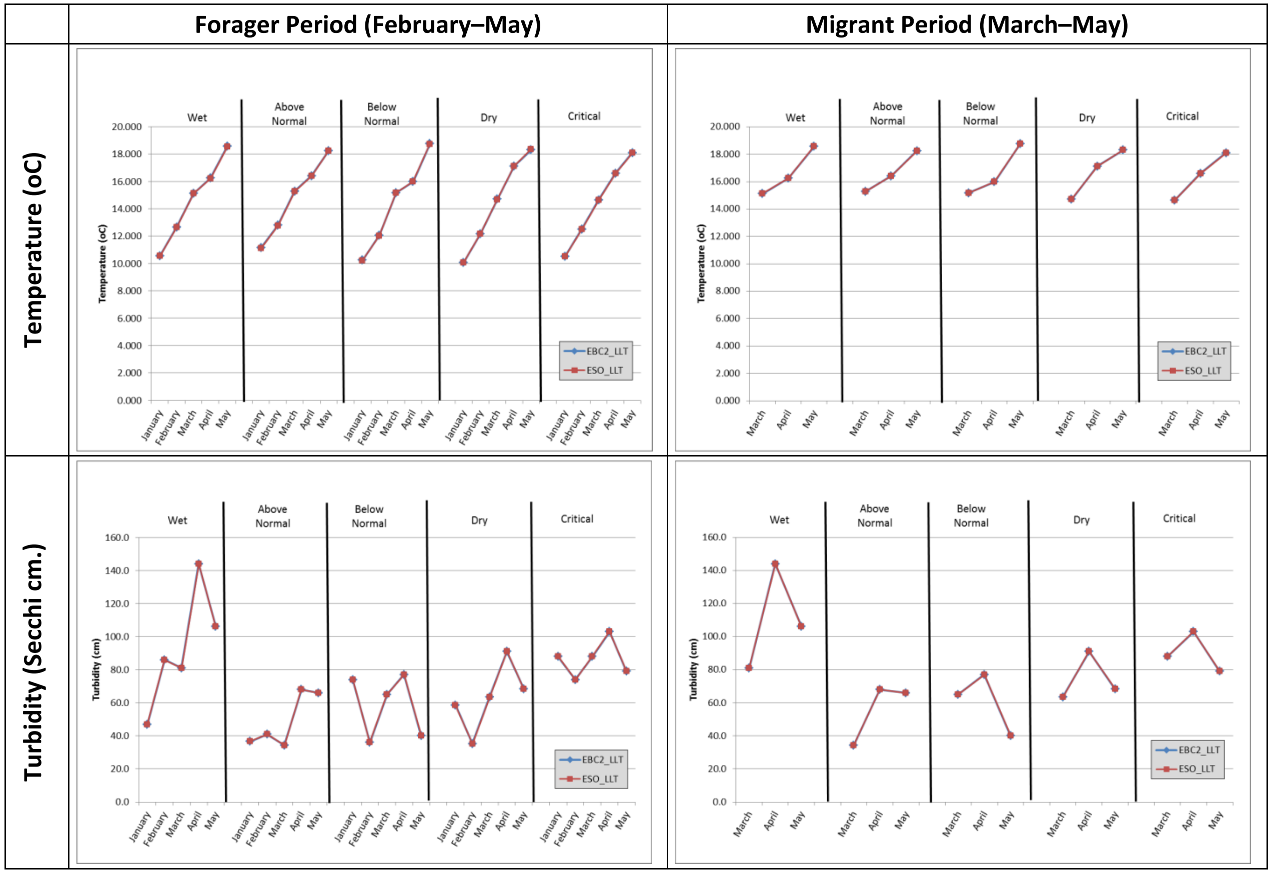


Figure 5.E.4-45. Modeled Environmental Data for the North Delta during Juvenile Salmonid Time Periods

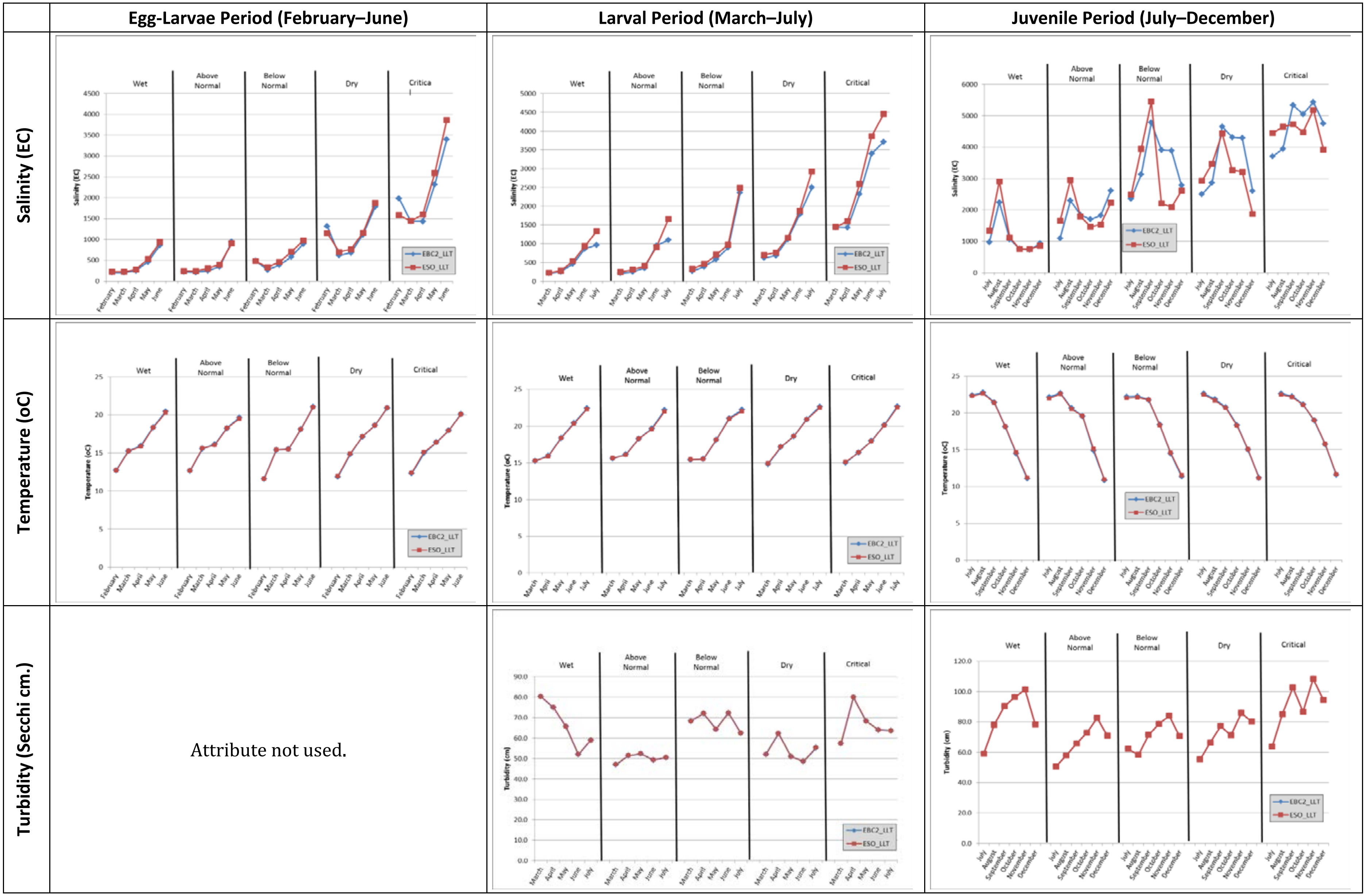
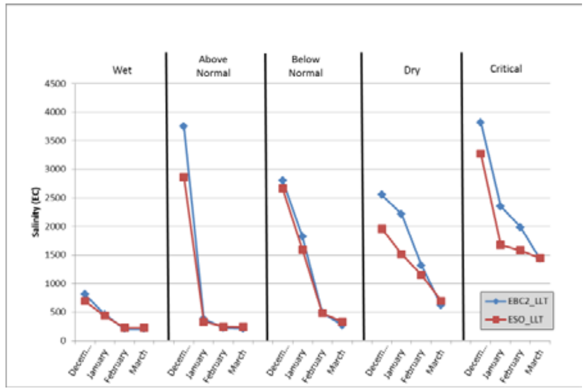
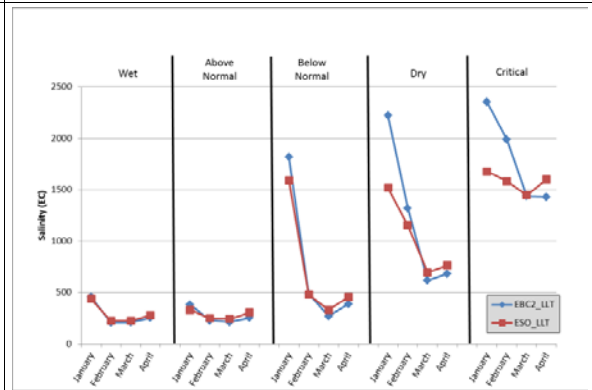
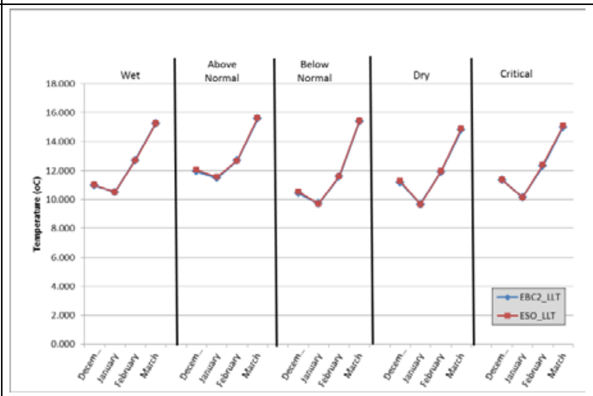
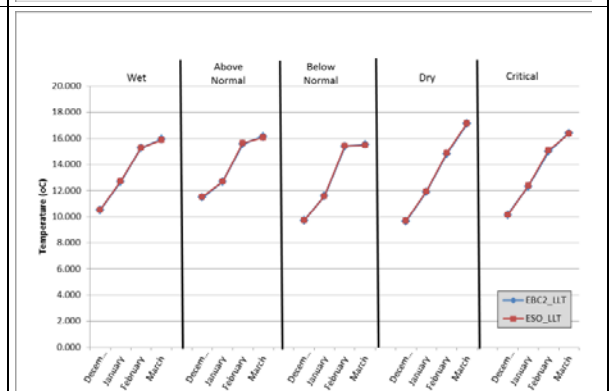
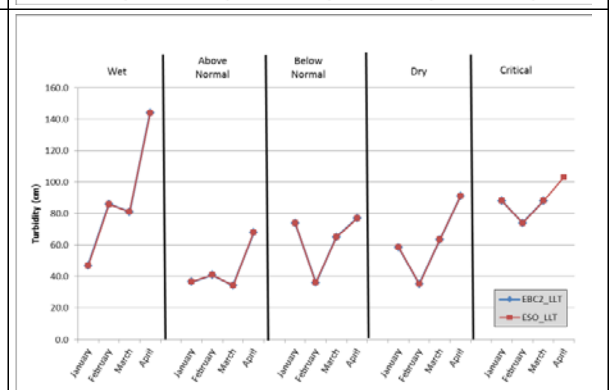


Figure 5.E.4-46. Modeled Environmental Data for the West Delta during Delta Smelt Time Periods

	Egg-Larvae Period (December–March)	Larval Period (January–April)
Salinity (EC)		
Temperature (oC)		
Turbidity (Secchi cm.)	Attribute not used.	

1 **Figure 5.E.4-47. Modeled Environmental Data for the West Delta during Longfin Smelt Time Periods**

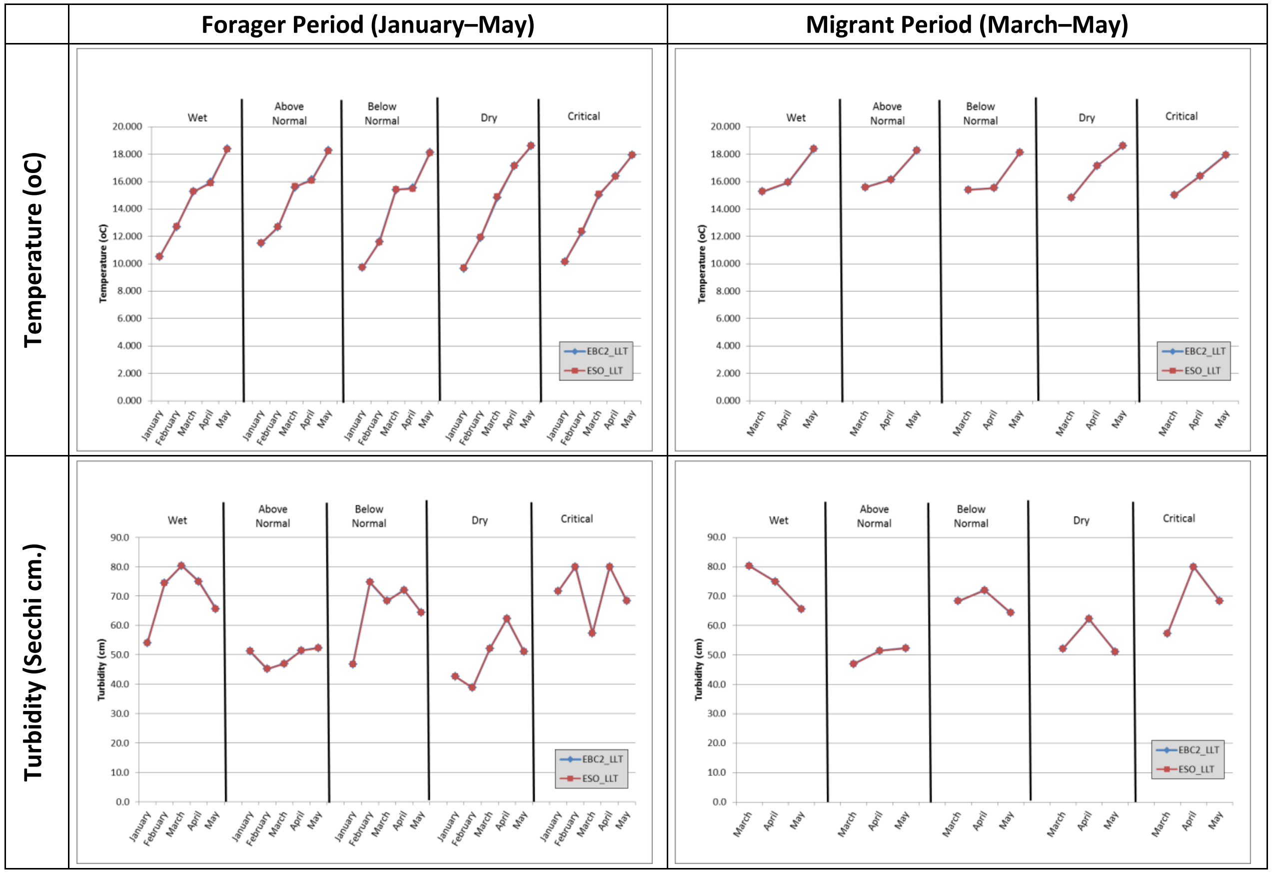


Figure 5.E.4-48. Modeled Environmental Data for the West Delta during Juvenile Salmonid Time Periods

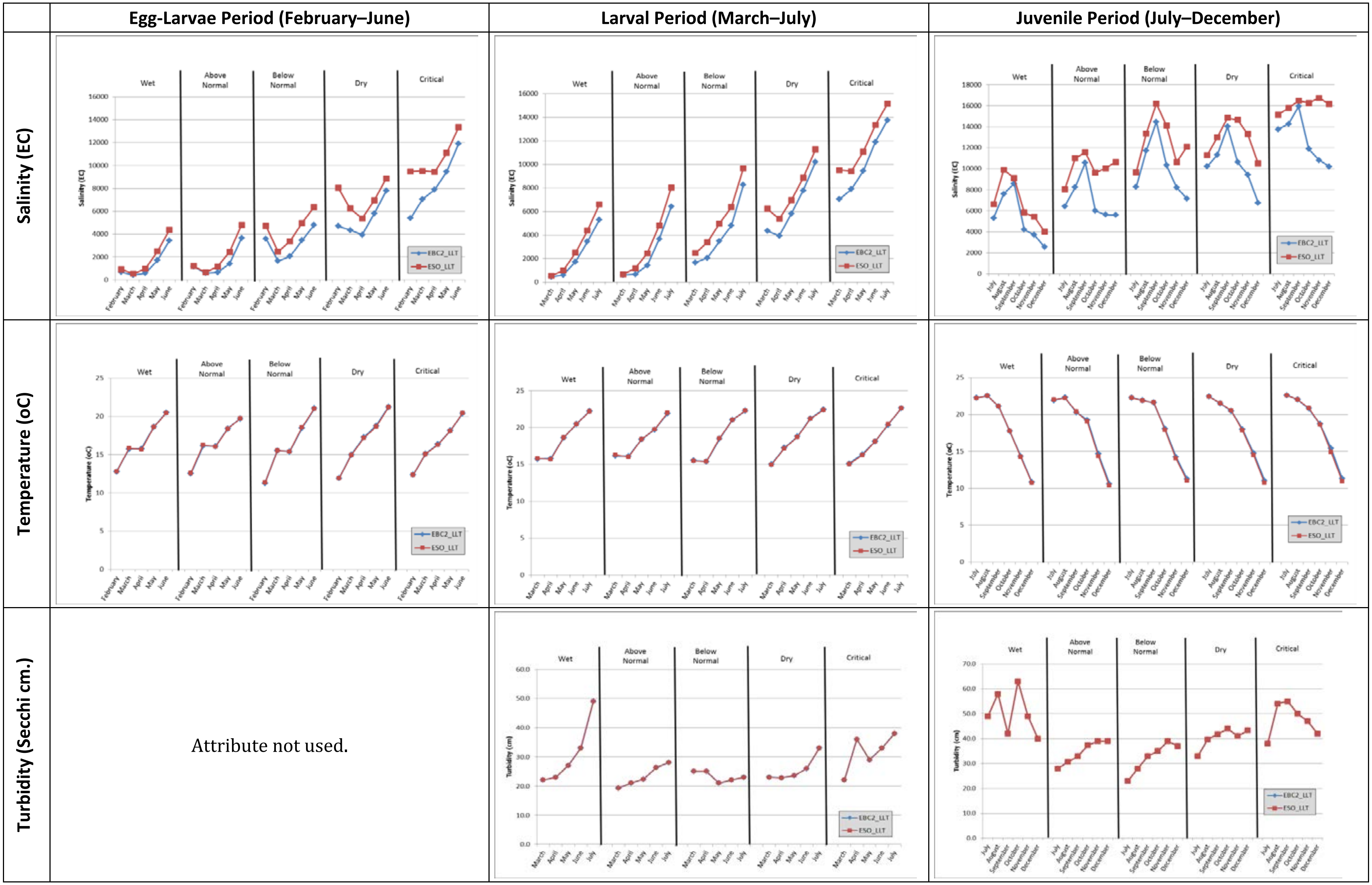


Figure 5.E.4-49. Modeled Environmental Data for Suisun Marsh during Delta Smelt Time Periods

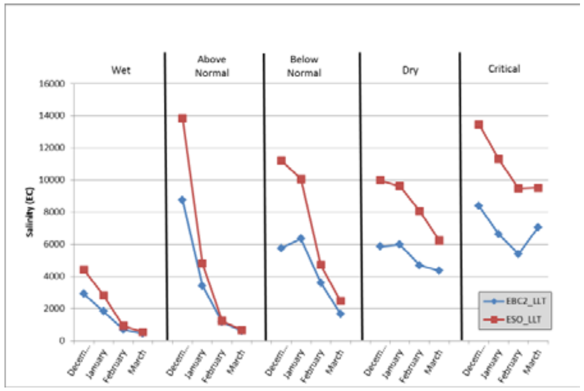
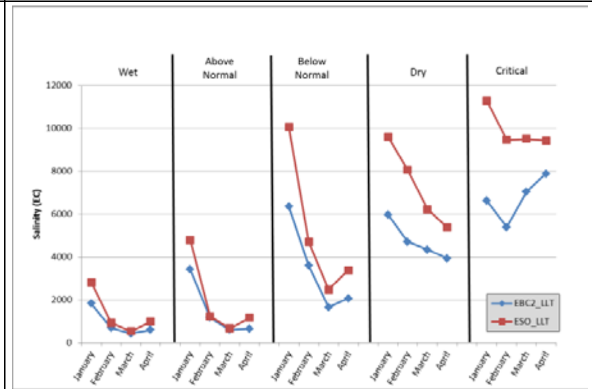
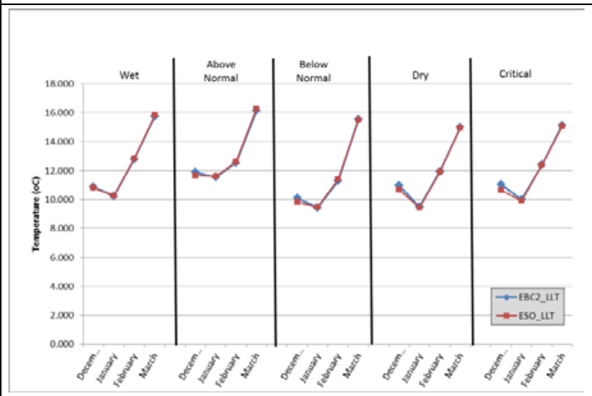
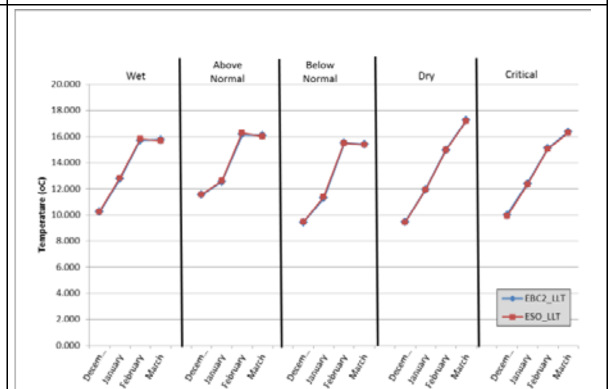
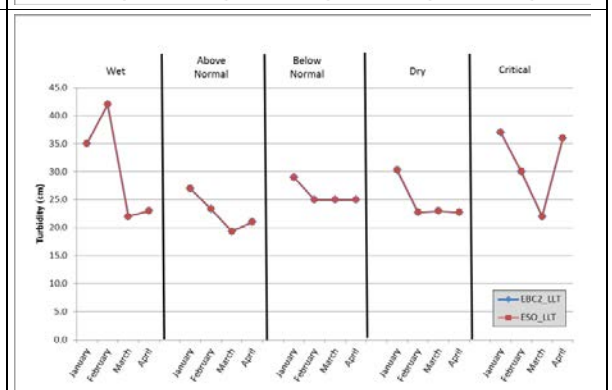
	Egg-Larvae Period (December–March)	Larval Period (January–April)
Salinity (EC)		
Temperature (oC)		
Turbidity (Secchi cm.)	Attribute not used.	

Figure 5.E.4-50. Modeled Environmental Data for Suisun Marsh during Longfin Smelt Time Periods

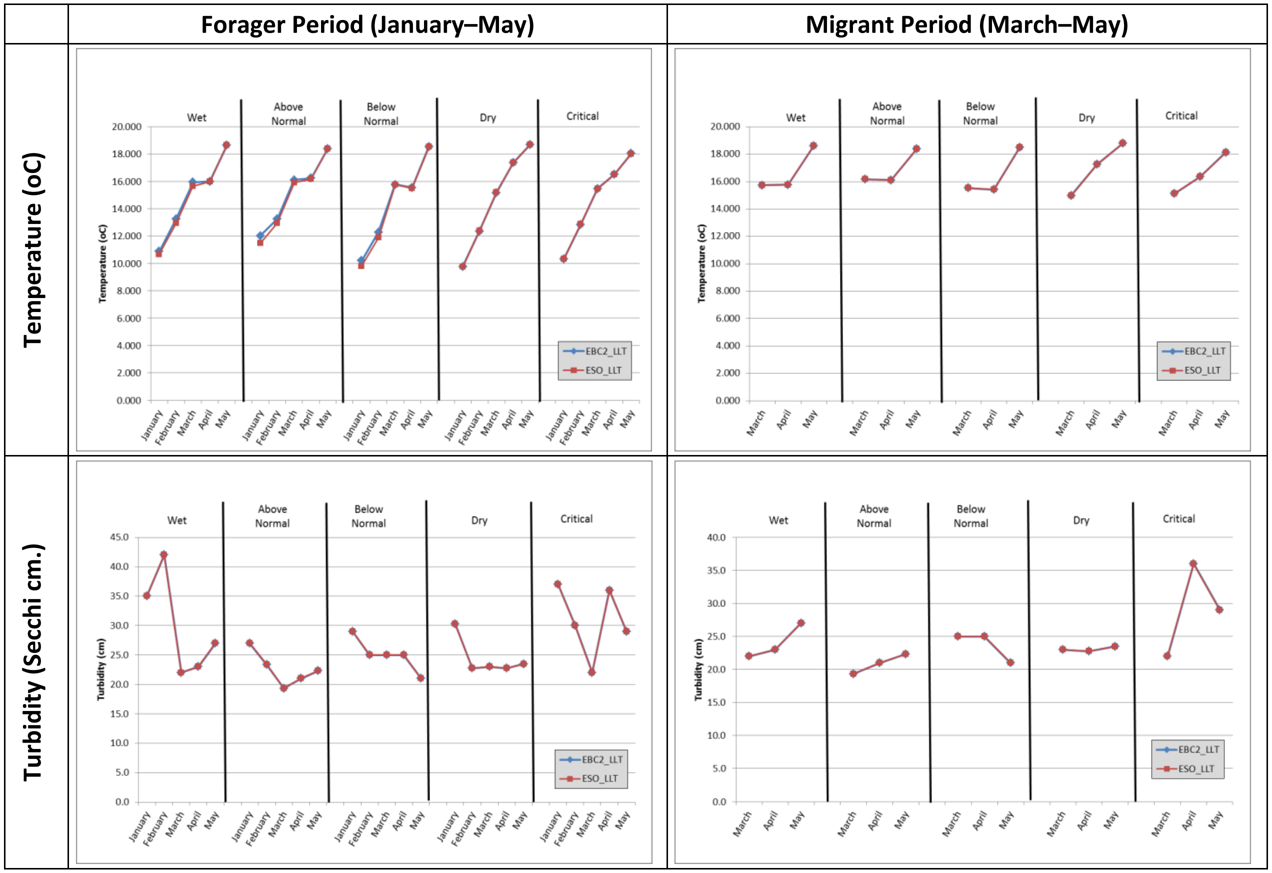
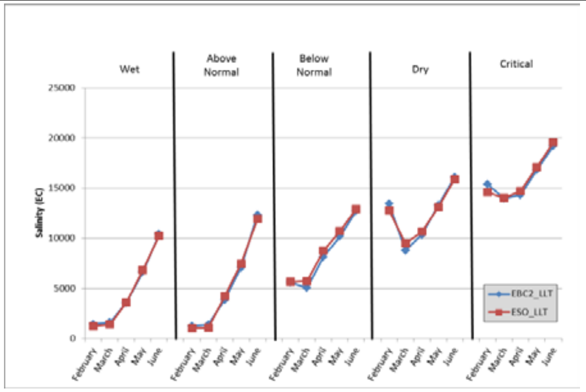
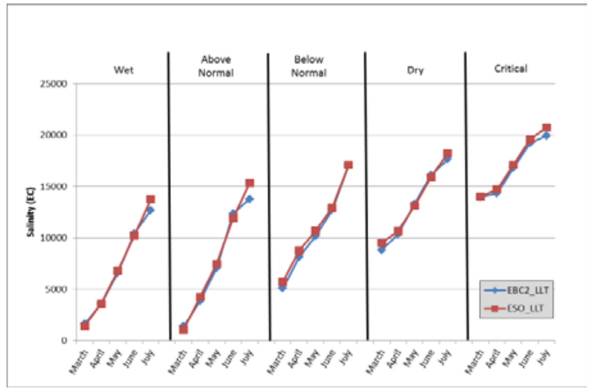
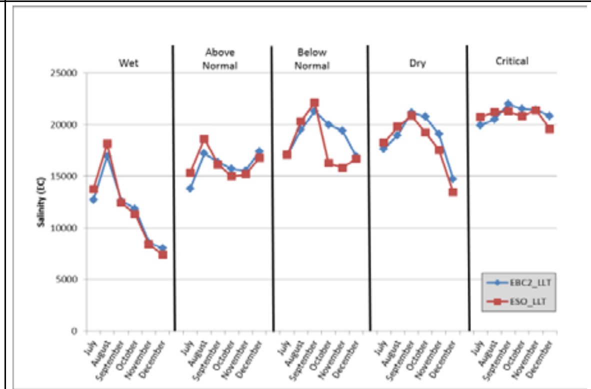
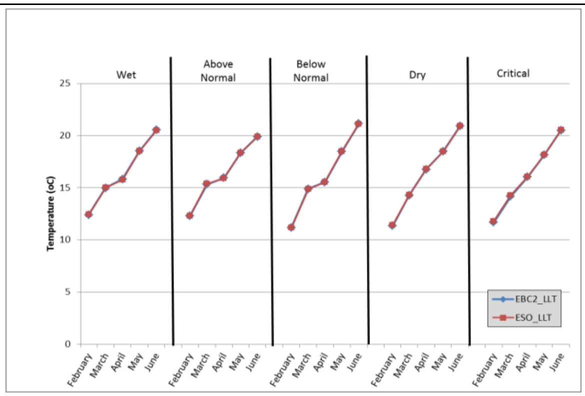
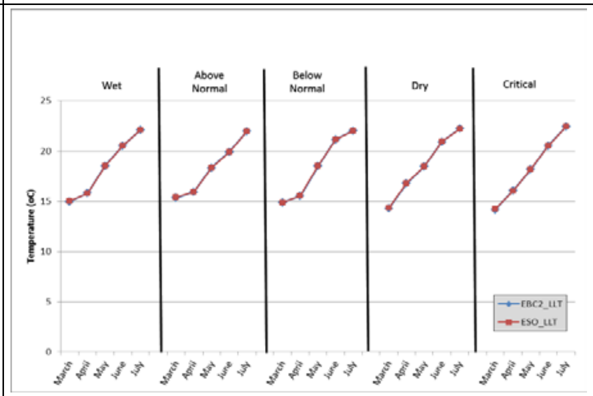
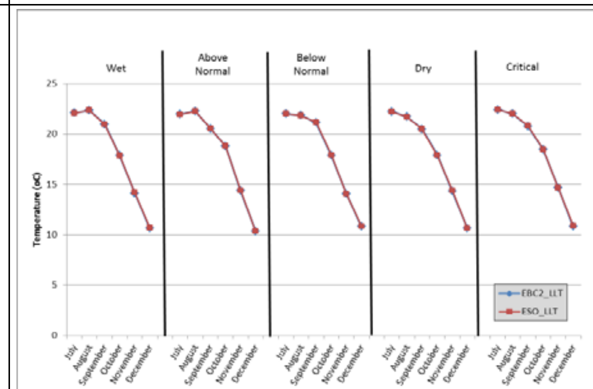
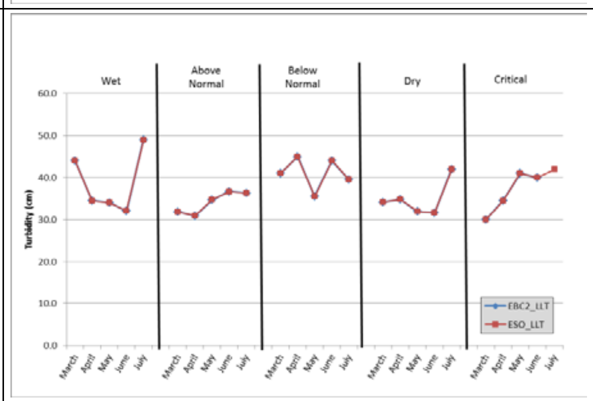
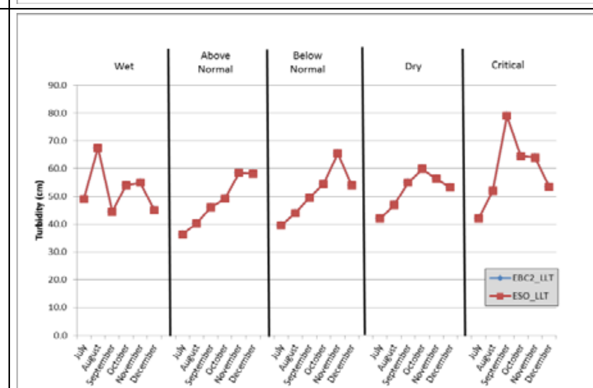
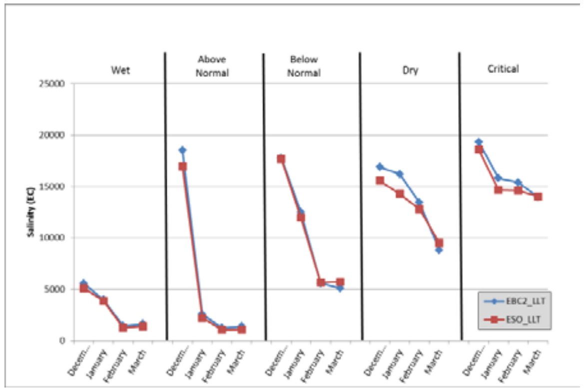
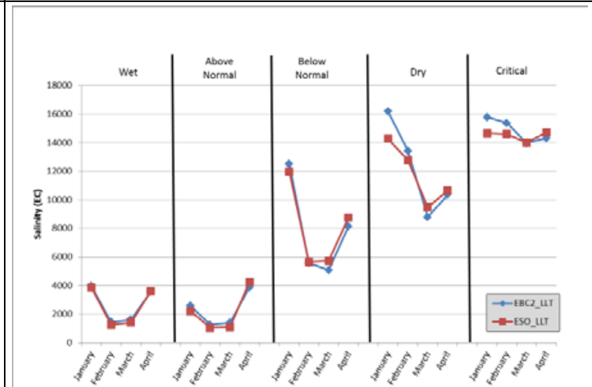
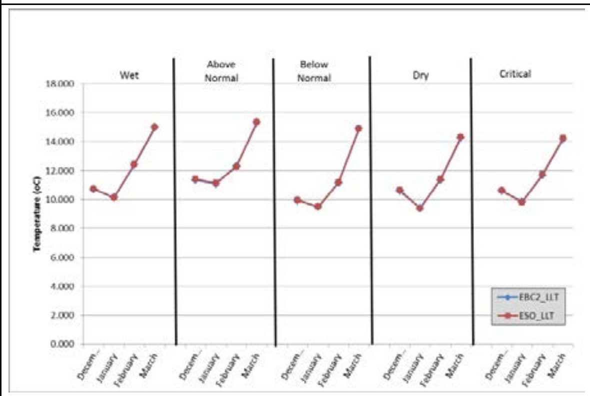
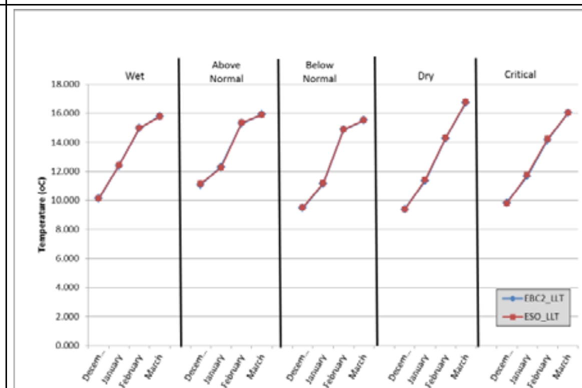
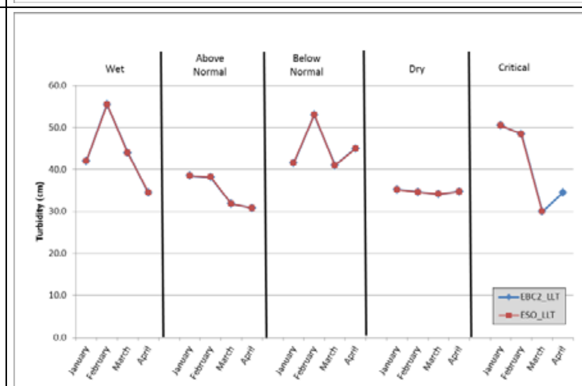


Figure 5.E.4-51. Modeled Environmental Data for Suisun Marsh during Juvenile Salmonid Time Periods

	Egg-Larvae Period (February–June)	Larval Period (March–July)	Juvenile Period (July–December)
Salinity (EC)			
Temperature (oC)			
Turbidity (Secchi cm.)	Attribute not used.		

1 **Figure 5.E.4-52. Modeled Environmental Data for Suisun Bay during Delta Smelt Time Periods**

	Egg-Larvae Period (December–March)	Larval Period (January–April)
Salinity (EC)		
Temperature (oC)		
Turbidity (Secchi cm.)	Attribute not used.	

1 **Figure 5.E.4-53. Modeled Environmental Data for Suisun Bay during Longfin Smelt Time Periods**

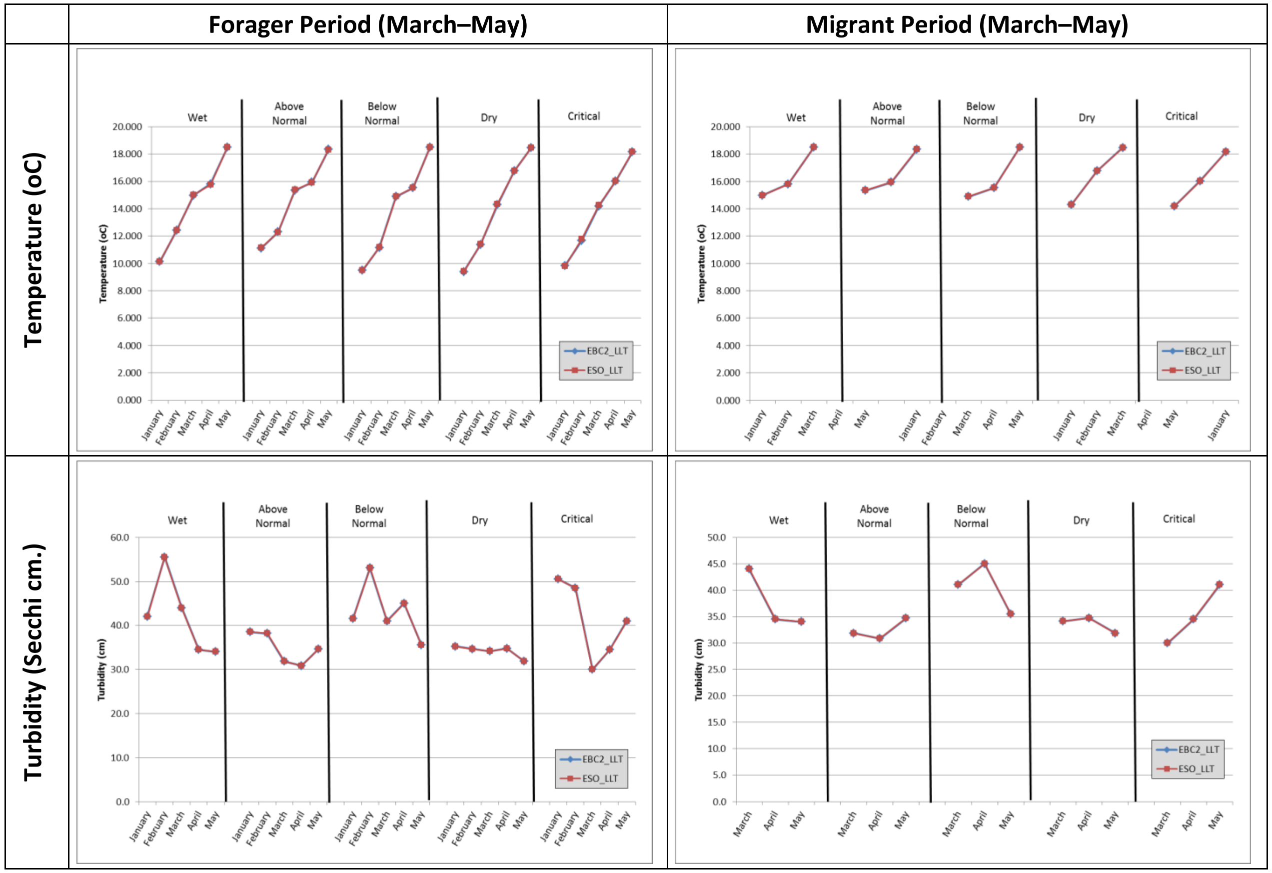
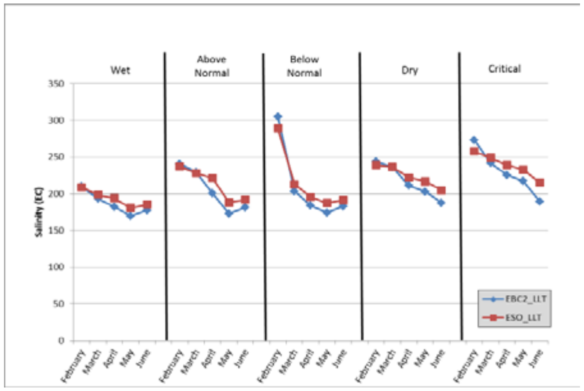
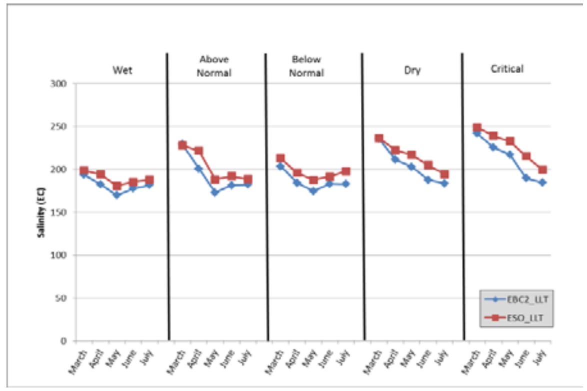
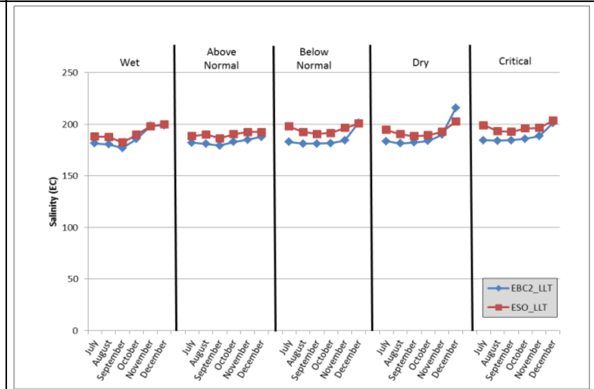
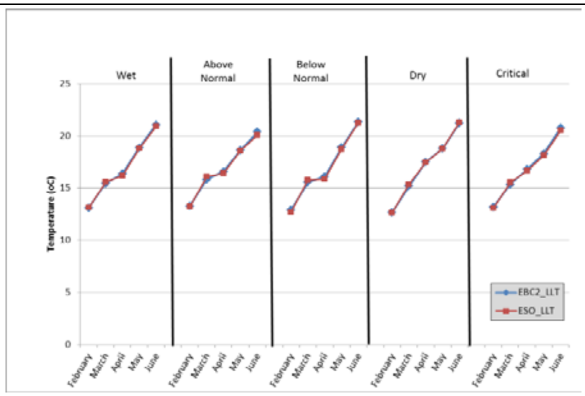
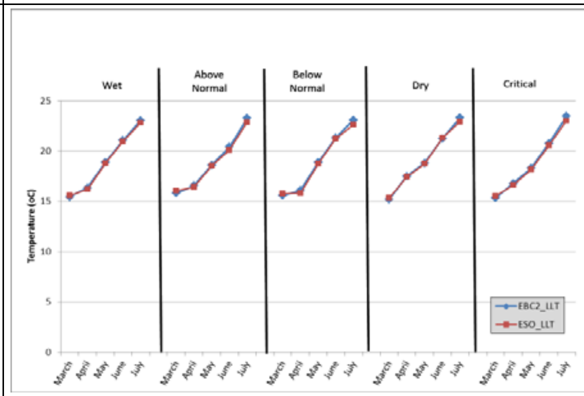
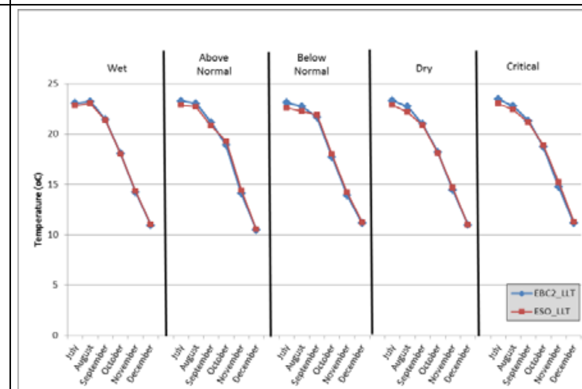
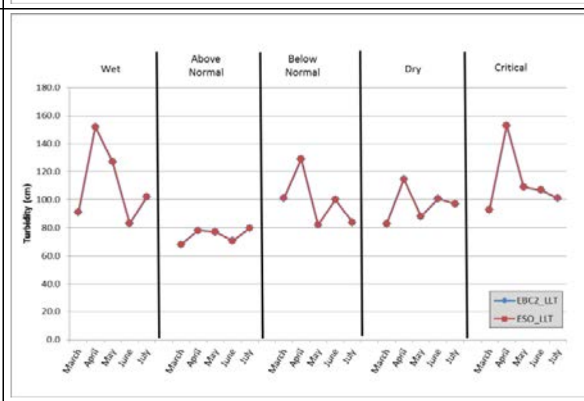
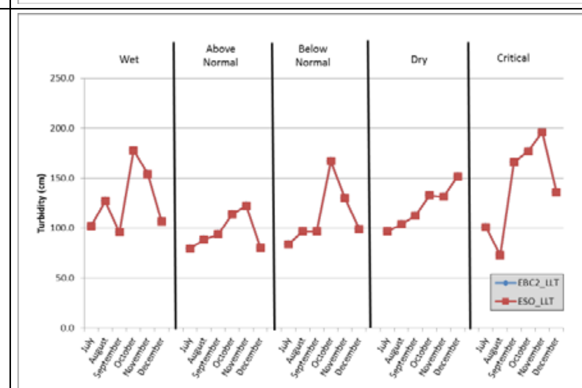
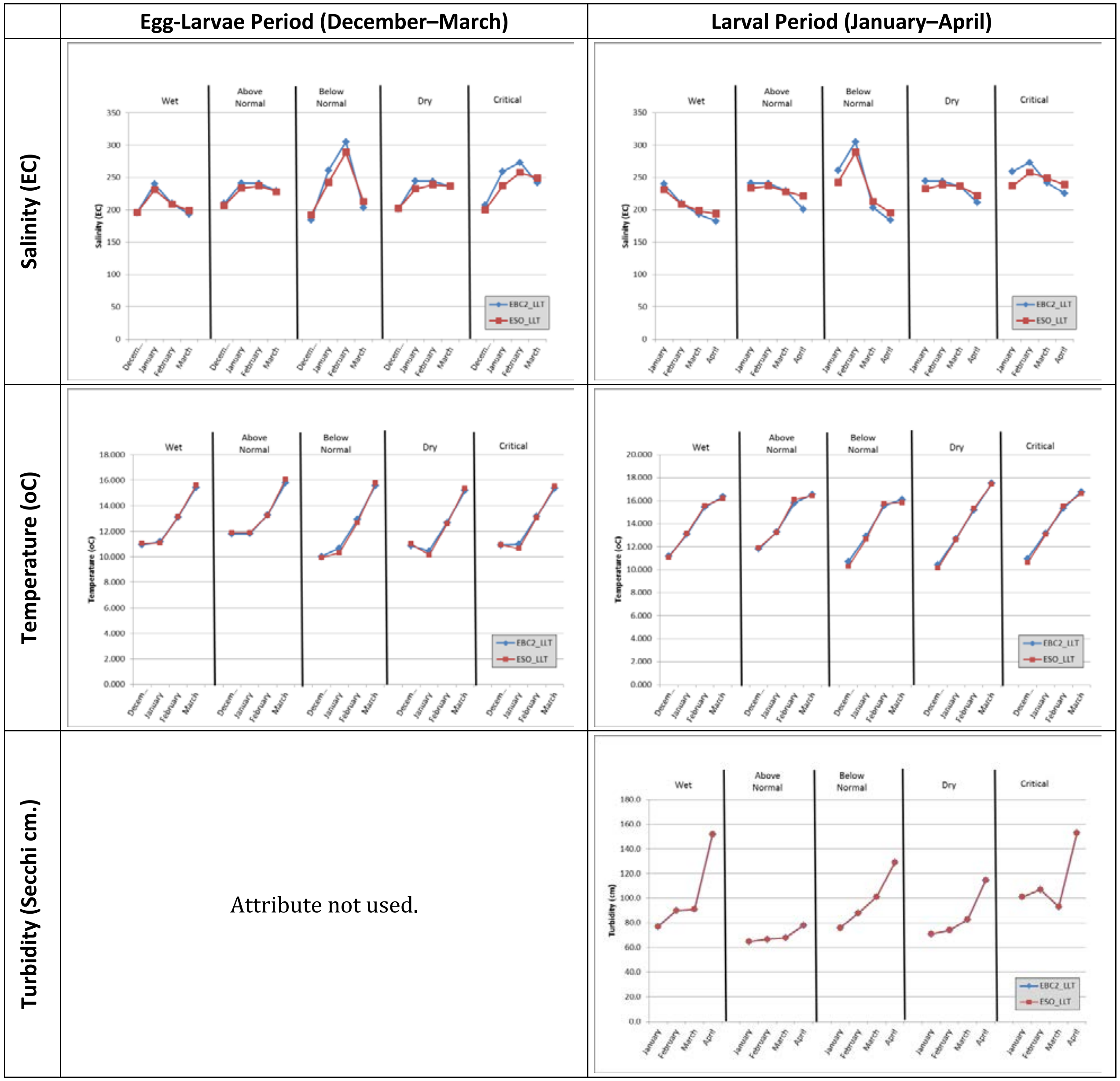


Figure 5.E.4-54. Modeled Environmental Data for Suisun Bay during Juvenile Salmonid Time Periods

	Egg-Larvae Period (February–June)	Larval Period (March–July)	Juvenile Period (July–December)
Salinity (EC)			
Temperature (oC)			
Turbidity (Secchi cm.)	Attribute not used.		

1 **Figure 5.E.4-55. Modeled Environmental Data for East Delta during Delta Smelt Time Periods**



1 **Figure 5.E.4-56. Modeled Environmental Data for East Delta during Longfin Smelt Time Periods**

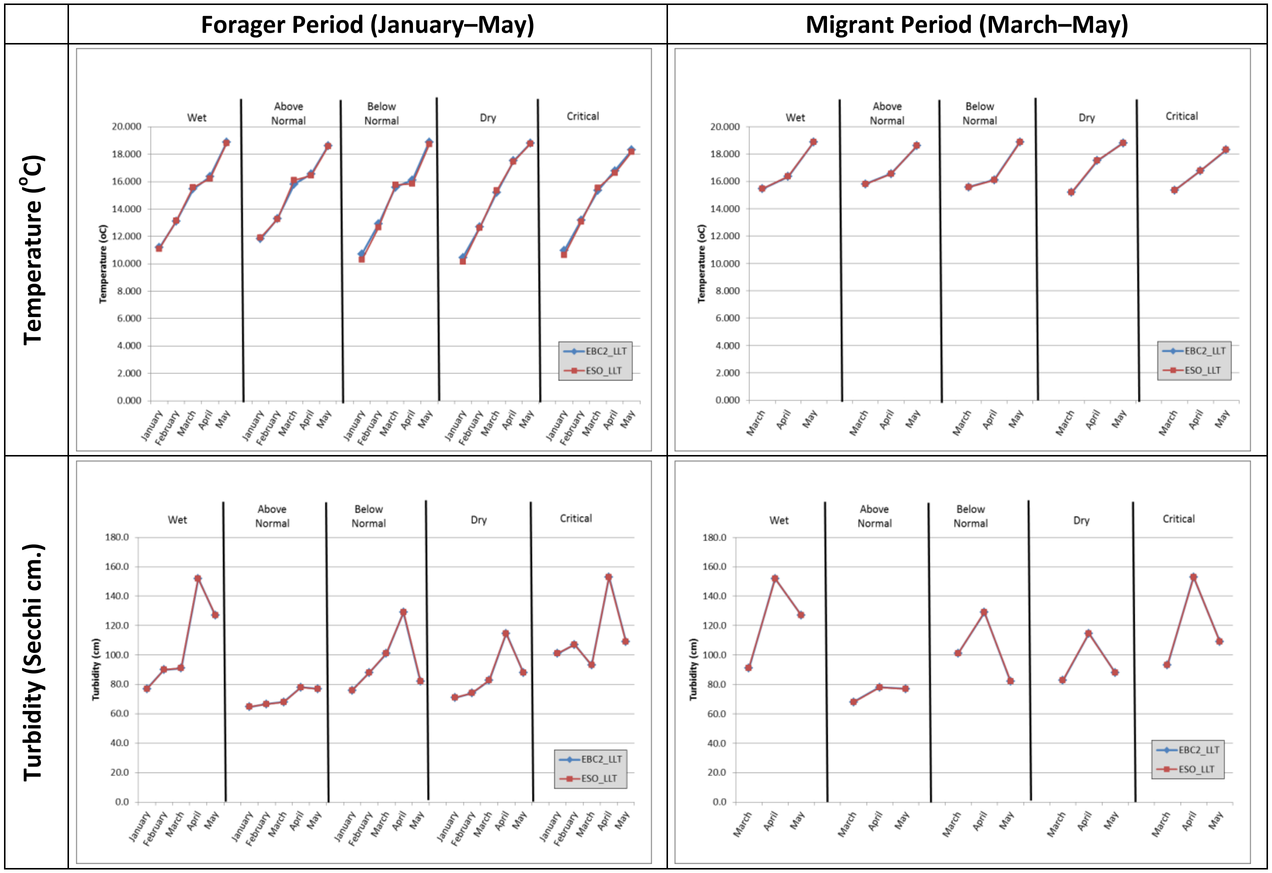
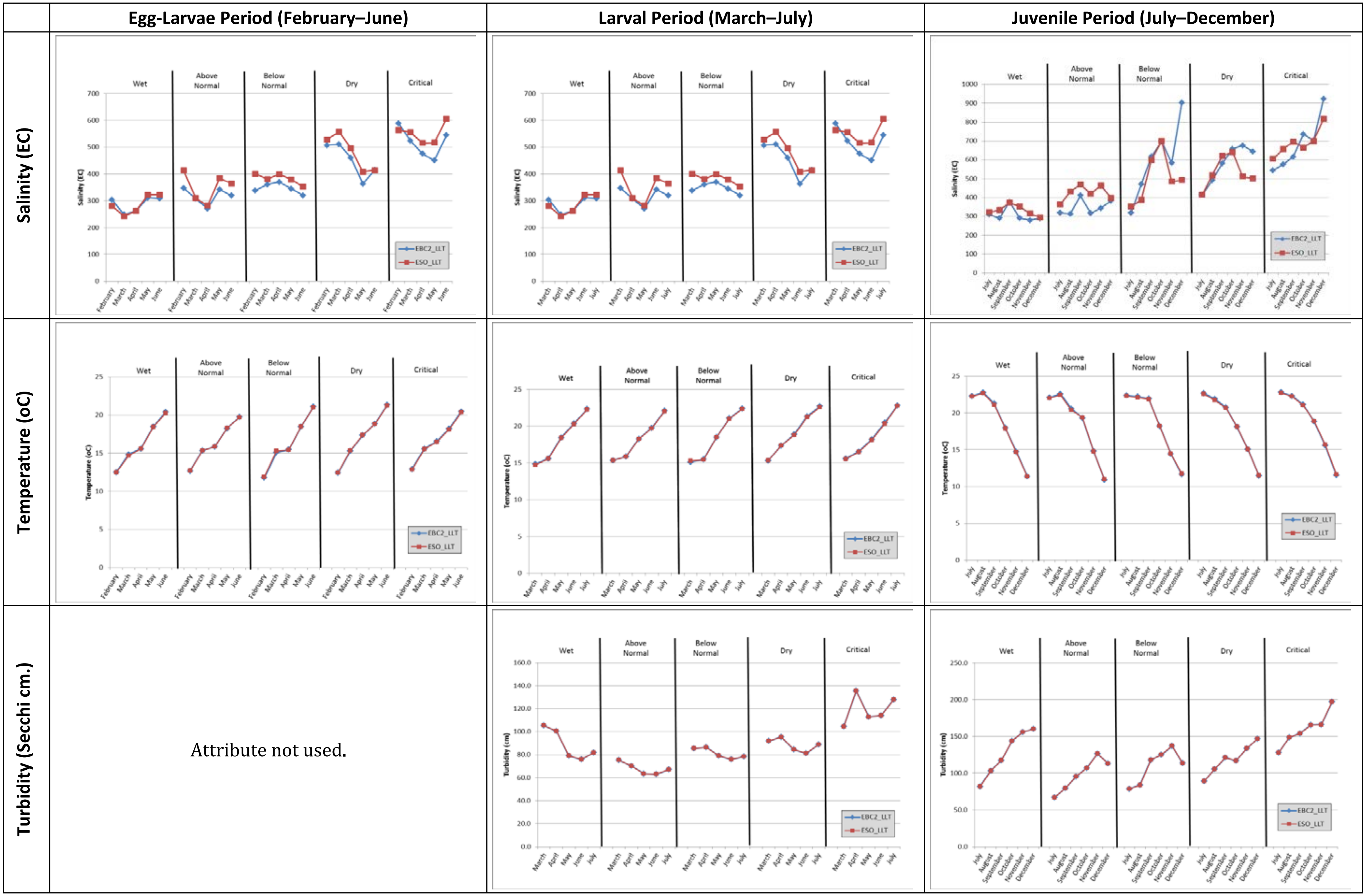
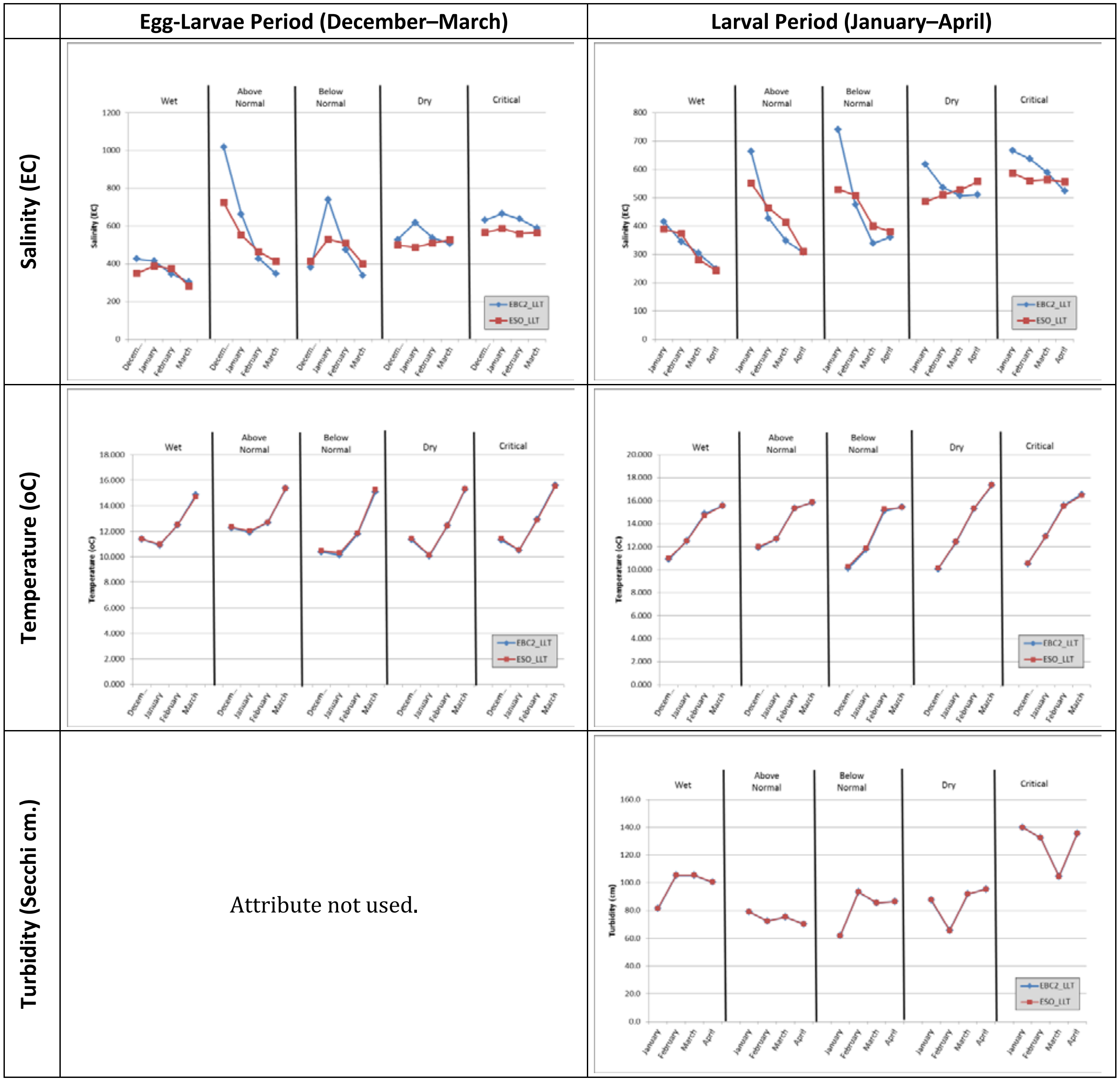


Figure 5.E.4-57. Modeled Environmental Data for East Delta during Juvenile Salmonid Time Periods



1 **Figure 5.E.4-58. Modeled Environmental Data for the South Delta during Delta Smelt Time Periods**



1 **Figure 5.E.4-59. Modeled Environmental Data for the South Delta during Longfin Smelt Time Periods**

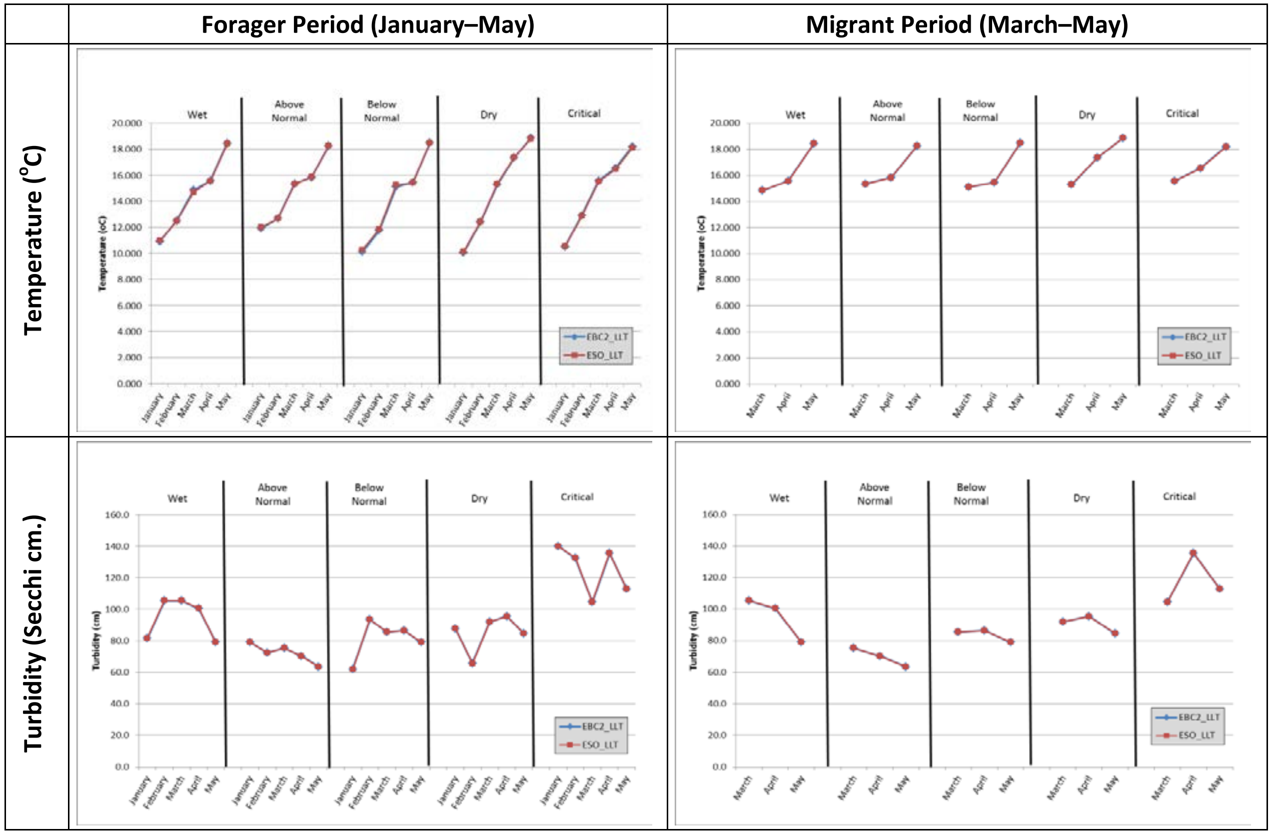


Figure 5.E.4-60. Modeled Environmental Data for the South Delta during Juvenile Salmonid Time Periods

Cache Slough

Delta Smelt

The Cache Slough region provides substantial spawning and rearing habitat for delta smelt (Moyle and Bennett 2008). There is evidence of a year-round population of delta smelt in the area (Sommer et al. 2009), and Cache Slough has become an important focus for restoration activities in the north Delta to increase and improve overall habitat for delta smelt (California Department of Fish and Game 2008). Delta smelt use tidal freshwater habitat as juvenile and adult primary rearing habitat; restoration of areas important for spawning, larval rearing, and food production could benefit delta smelt.

Habitat Suitability Analysis

The future Delta acreages shown in Figure 5.E.4-23 and Figure 5.E.4-24 were evaluated from the perspective of delta smelt in terms of HUs (static quantity) and HSI (dynamic quality) measures. Figure 5.E.4-61 summarizes the change in HUs and HSI across scenarios for delta smelt in Cache Slough. HSI values change between life stages and across scenarios, reflecting changes in temperature, salinity, and turbidity and life stage requirements.

Over the BDCP permit term, sea level rise was estimated to result in relatively modest changes in delta smelt habitat in Cache Slough (Table 5.E.4-18). HUs for the egg-larvae stage for the LLT increased by 7%, larval HUs by 18% and juvenile HUs by 13% relative to the EBC condition due to sea level rise alone. CM4, however, greatly increased available HUs for delta smelt. With CM4 HUs for delta smelt in Cache Slough in the LLT increased by 168%, for egg-larvae, 158% for larvae and 153% for juvenile delta smelt relative to the EBC condition after removing the effect of sea level rise. The increase in HUs for spawning (egg-larvae) reflects the increase in tidal freshwater habitat while all life stages benefited from overall increased habitat acres.

Although HUs (and acres) for delta smelt increased substantially in Cache Slough because of CM4, habitat suitability declined for the egg-larvae life stage (Figure 5.E.4-61). HSI values for larvae increased slightly while the juvenile HSI value was relatively unchanged over the BDCP permit term. The decrease in HSI for the egg-larvae stage is the result of increased water temperatures in the subregion by the LLT primarily due to climate change impacts. There was almost no change in the HSI value for temperature over the period due to covered activities alone reflecting the lack of impact of the BDCP on temperature in Cache Slough (Figure 5.E.4-40). It is unclear from this analysis if the overall increase in HUs as a result of CM4 compensates for the decline in habitat suitability related to increasing temperatures for spawning delta smelt in Cache Slough.

Table 5.E.4-18. Habitat Units Estimated for Delta Smelt Life Stages in Cache Slough Subregion by Time Period, with and without the BDCP

Cache Slough	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	5,348	5,348	5,756	6,006	659
Larvae	9,264	9,270	9,910	10,907	1,643
Juveniles	6,628	6,628	6,988	6,872	243
Total	21,240	21,247	22,654	23,785	2,545
ESO (BDCP Restoration + Sea Level Rise)					
Egg-Larvae	5,348	7,862	11,610	14,970	9,622
Larvae	9,264	12,592	17,549	25,612	16,348
Juveniles	6,628	8,607	11,717	15,780	9,152
Total	21,240	29,062	40,876	56,362	35,122
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	2,514	5,853	8,964	8,964
Larvae	–	3,322	7,639	14,705	14,705
Juveniles	–	1,979	4,729	8,909	8,909
Total	–	7,815	18,222	32,578	32,578

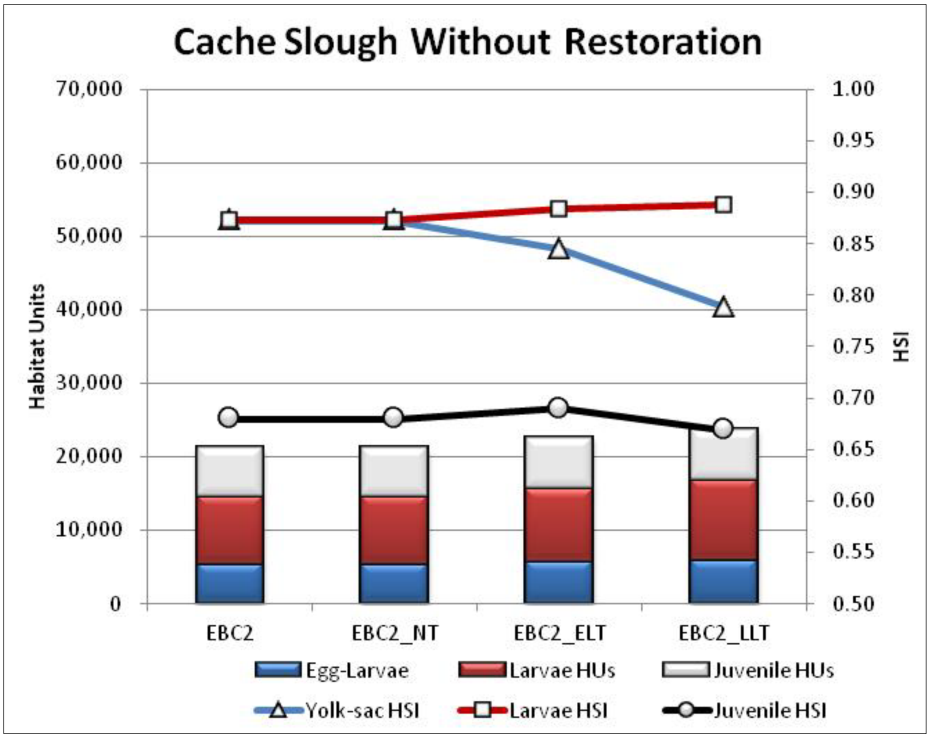


Figure 5.E.4-61A. Sea Level Rise Only: 1,395 Aquatic Acres Added to Subregion

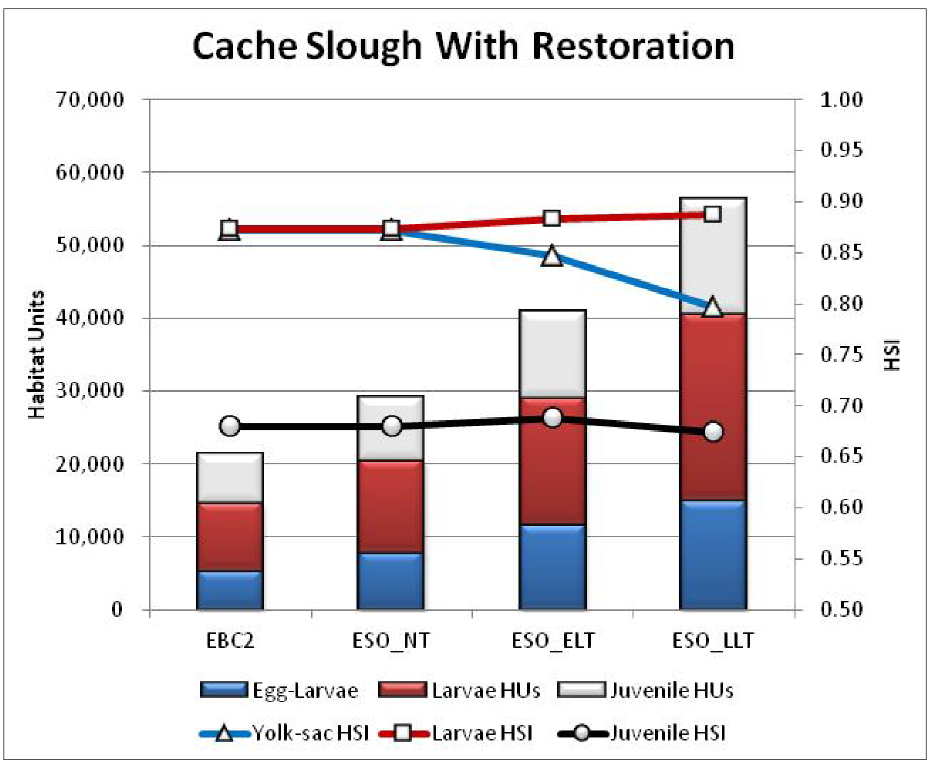


Figure 5.E.4-61B. Restoration Only: 17,746 Aquatic Acres Added to Subregion

Figure 5.E.4-61. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Delta Smelt Life Stages in the Cache Slough Subregion

Longfin Smelt

Longfin smelt use the northern portion of the Delta (Cache Slough, North Delta, Suisun Marsh complex) for spawning and rearing; a CDFW survey in 2008 found larval longfin smelt in small numbers at every station in Cache Slough, Lindsey Slough, and Miner Slough (California Department of Fish and Game 2009). This species is likely to use tidal freshwater habitat as juvenile and adult spawning habitat; restoration of areas important for spawning, larval rearing, and food production could provide a benefit.

A key difference between longfin and delta smelt is the assumed choice of spawning habitat. Longfin smelt are assumed to select deeper subtidal areas for spawning whereas delta smelt are assumed to spawn in shallow tidal areas. In addition, post-larval longfin smelt move westward out of the Plan Area into deeper, higher-salinity areas such as San Francisco Bay (Rosenfield and Baxter 2007). Only spawning (egg-larvae) and larval longfin smelt are assumed to use the Plan Area while all life stages of delta smelt use the Plan Area.

Habitat Suitability Analysis

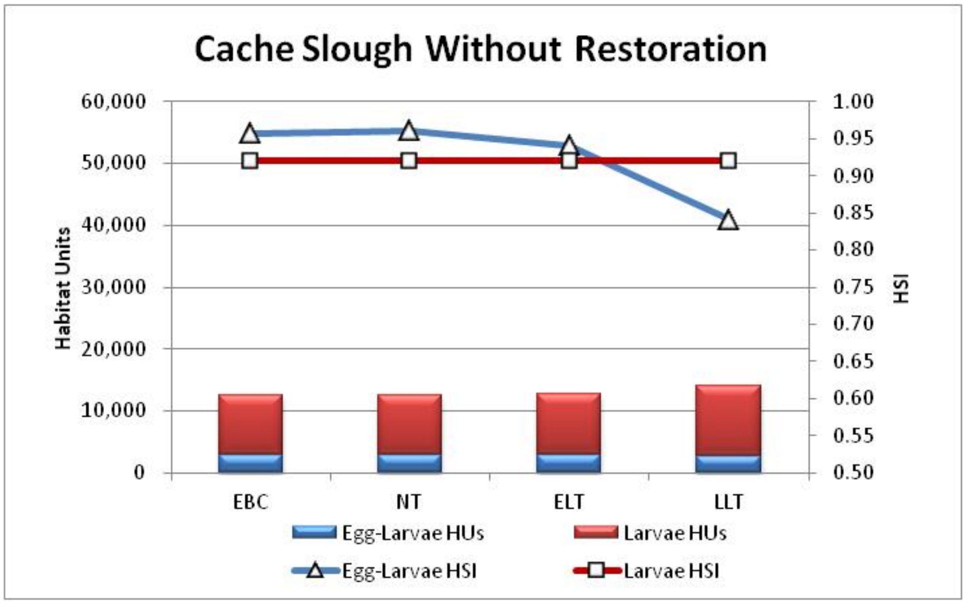
Over the BDCP permit term, sea level rise resulted in small changes in longfin smelt habitat in Cache Slough (Table 5.E.4-19). HUs for the egg-larvae stage decreased by 3% but increased for larval longfin smelt by 16% because of sea level rise alone. CM4 increased HUs for longfin egg-larvae by about 100% and increased HUs in Cache Slough an additional 156% for larvae.

CM4 greatly increased HUs for longfin smelt in Cache Slough primarily for the larval life stage (Table 5.E.4-19). The larvae stage would benefit from the increase in shallow tidal freshwater habitat that may enhance feeding opportunities. Overall, restoration in Cache Slough provided appreciably fewer HUs for longfin smelt compared to delta smelt (Table 5.E.4-18 and Table 5.E.4-19).

Habitat suitability (HSI) for the egg-larvae stage declined in the LLT but remained constant over the BDCP permit term for larval longfin smelt (Figure 5.E.4-62). As for delta smelt, the decline in HSI resulted from increased water temperature primarily due to climate change. The overall impact was toward appreciably greater habitat for longfin smelt in Cache Slough although it is not clear from this analysis whether the increase in habitat quantity compensates for the decrease in habitat value (HSI) related primarily to increasing temperatures.

Table 5.E.4-19. Habitat Units Estimated for Longfin Smelt Life Stages in Cache Slough Subregion, with and without the BDCP

Cache Slough	EBC	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	2,849	2,849	2,915	2,750	(98)
Larvae HUs	9,709	9,709	9,709	11,231	1,522
Total	12,558	12,558	12,624	13,981	1,423
ESO (BDCP Restoration + Sea Level Rise)					
Egg- larvae	2,849	2,907	3,137	5,573	2,724
Larvae	9,709	13,188	13,188	26,347	16,638
Total	12,558	16,095	16,325	31,920	19,362
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-larvae	–	58	221	2,823	2,823
Larvae	–	3,479	3,479	15,116	15,116
Total	–	3,537	3,700	17,939	17,939



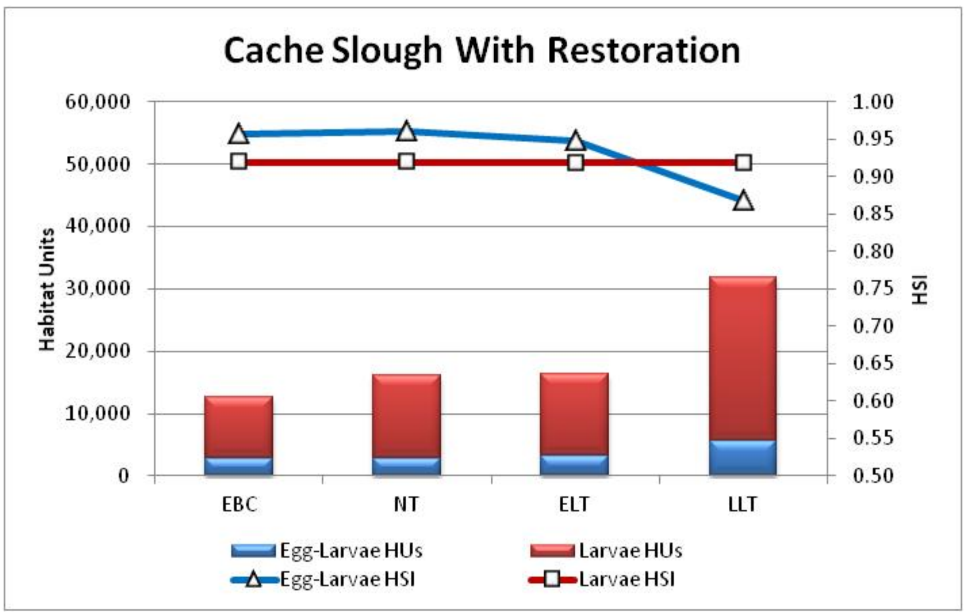


Figure 5.E.4-62. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Longfin Smelt Life Stages in the Cache Slough Subregion

Salmonids

Salmonids, especially those that enter the Yolo Bypass, make extensive use of the Cache Slough area. Fish can move down through the bypass and into Cache Slough where their survival is affected by local conditions. Tidal marsh restoration in Cache Slough is likely to benefit primarily juvenile foraging salmon by providing access to high- value areas for rearing. Increases in size at ocean entry have been shown to correlate with increased ocean survival (Claiborne et al. 2011). The aggregate effects of these improvements in habitat availability and environmental condition are likely to result in better outmigration success for juvenile Chinook salmon.

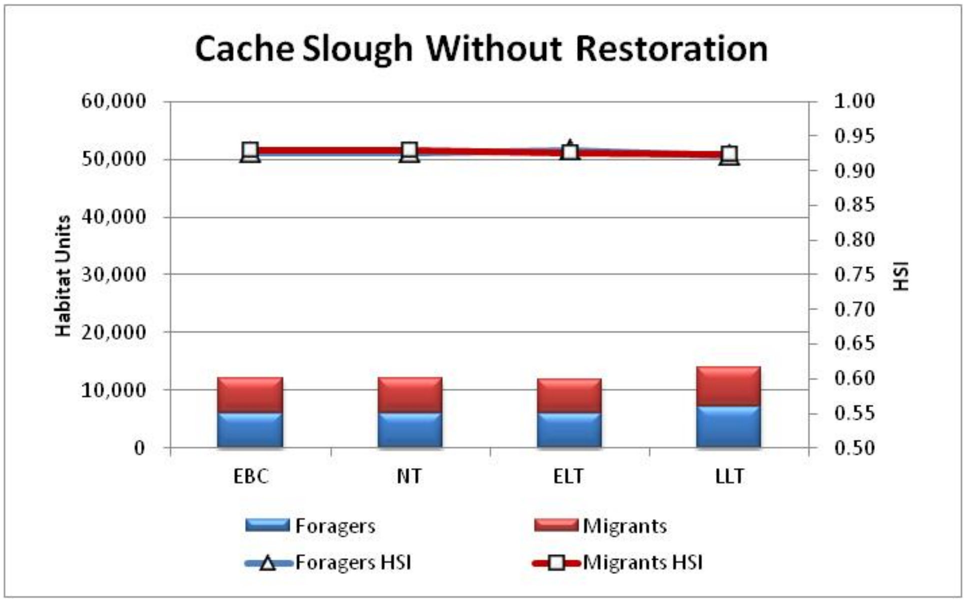
Habitat Suitability Analysis

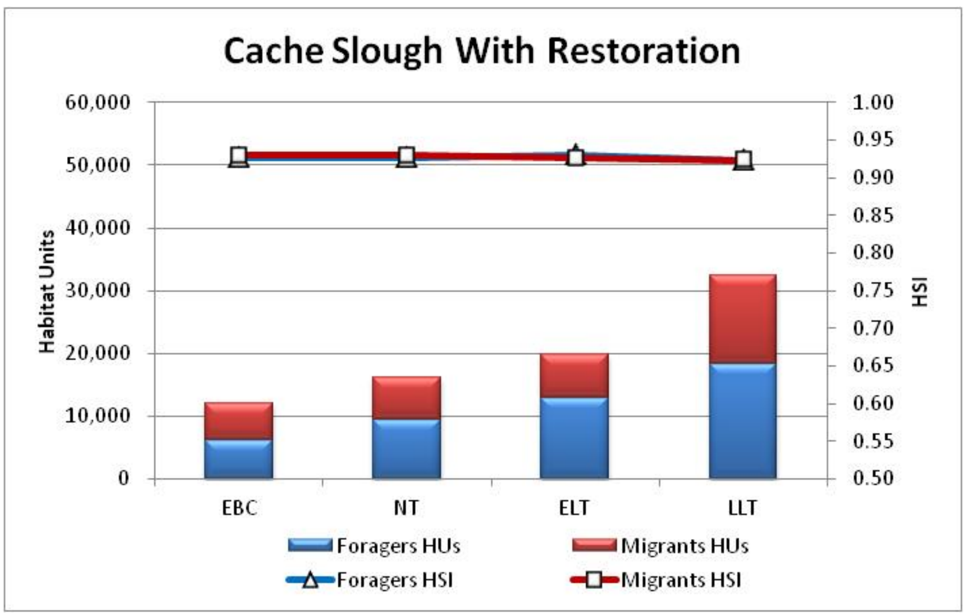
The assessment of HUs and HSI for foraging and migrating juvenile salmon are dominated by two assumptions. First, it was assumed that foraging juvenile salmon preferentially used shallow-water habitat and avoided deeper habitat, whereas the reverse was true for migrating juvenile salmonids. This is not to say that smaller foraging fish do not move into deeper water during some periods and migrate toward the ocean or that larger migrating fish do not periodically move into shallow areas and feed, simply that observations of juvenile salmonids in beach seine and off-shore trawls generally are consistent with the assumed habitat preference. Second, the HSI values for juvenile salmonids were affected by the assumed turbidity rating curve for foraging juvenile salmon. The effect of turbidity on juvenile salmonid survival and preference in the Delta has not been established definitively. The hypothesis used in this analysis was based on Chipps Island trawl data, which indicated a preferred turbidity for foraging juvenile salmonids at 34–43 cm Secchi disk depth, with sharp declines in suitability at higher and lower levels. This general model is consistent with the observations of Gregory and Northcote (1993) who found the highest feeding levels of Chinook salmon fry in moderate turbidity levels (35–150 Nephelometric turbidity units [NTUs]).

Cache Slough produced fewer total HUs for salmonids than it did for delta smelt primarily because only two life stage groups were evaluated whereas habitat for the entire life cycle of delta smelt was evaluated. Current conditions in Cache Slough resulted in approximately equal amounts of habitat for foraging and migrating juvenile salmonids (Table 5.E.4-20). HUs for both foraging and juvenile salmonids were estimated to increase about 17% because of sea level rise alone. However, CM4 increased HUs in Cache Slough for both juvenile salmonid behavior forms by about 175%. Because CM4 restoration increased the amount of shallow-water habitat in Cache Slough, the greatest increase in HUs was for foraging juvenile salmonids relative to migrating salmonids. HSI for both juvenile behavior forms was high throughout the BDCP permit term (Figure 5.E.4-63).

Table 5.E.4-20. Habitat Units Estimated for Salmonid Juvenile Behavior Patterns in Cache Slough Subregion by Time Period, with and without the BDCP

Cache Slough	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Foragers	6,081	6,081	6,034	7,122	1,041
Migrants	5,897	5,897	5,897	6,732	834
Total	11,979	11,979	11,932	13,854	1,875
ESO (BDCP Restoration + Sea Level Rise)					
Foragers	6,081	9,460	13,015	18,250	12,169
Migrants	5,897	6,761	6,761	14,267	8,370
Total	11,979	16,221	19,776	32,517	20,538
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Foragers	–	3,379	6,981	11,128	11,128
Migrants	–	863	863	7,535	7,535
Total	–	4,242	7,844	18,663	18,663

1 

2 

3 **Figure 5.E.4-63. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Salmonid Juvenile**
4 **Behavior Patterns in the Cache Slough Subregion**

North Delta

Delta Smelt

Habitat Suitability Assessment

Although no restoration is proposed in the North Delta subregion, HUs for delta smelt increased slightly by the LLT period because of sea level rise (Table 5.E.4-21). The increase was greatest for the egg-larvae stage reflecting the increase in tidal freshwater habitat.

HSI values for delta smelt in the North Delta were relatively low especially for the juvenile life stage (Figure 5.E.4-64). Habitat suitability was decreased in the North Delta primarily because of high water clarity, especially during fall and winter. Habitat suitability for spawning (egg-larvae) decreased slightly over the BDCP permit term because of increasing water temperature as a result of climate change (Figure 5.E.4-64).

Table 5.E.4-21. Habitat Units Estimated for Juvenile Delta Smelt in the North Delta Subregion

North Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only—No Restoration)					
Egg-Larvae	602	602	600	892	291
Larvae	2,251	2,181	2,238	2,657	406
Juveniles	1,172	1,172	1,280	1,221	49
Total	4,025	3,955	4,118	4,771	746

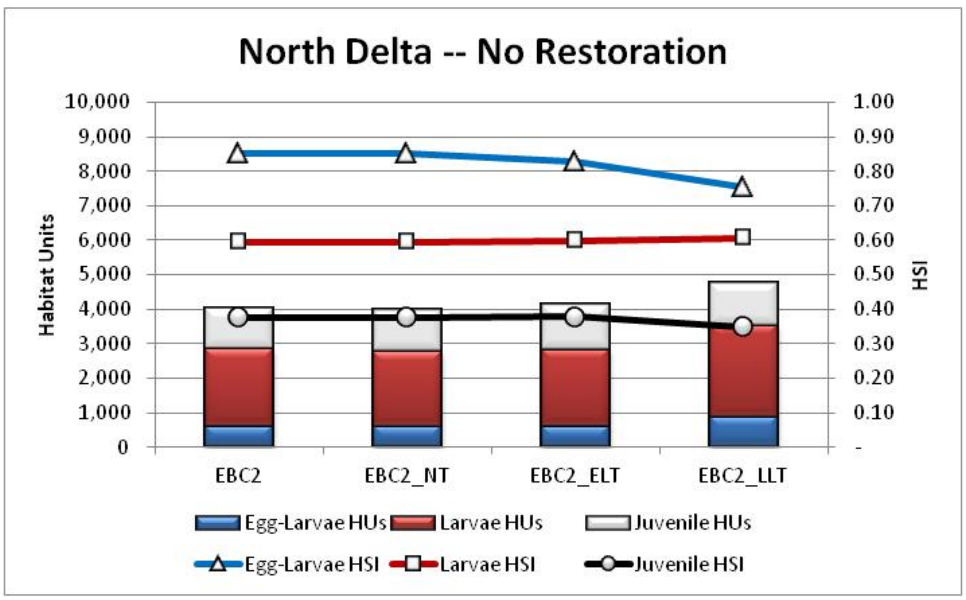


Figure 5.E.4-64. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Delta Smelt in the North Delta Subregion Due to Sea Level Rise Only—No Restoration: 991 Aquatic Acres Added

Longfin Smelt

Habitat Suitability Assessment

The North Delta provided habitat of greater suitability (HSI) for longfin smelt than for delta smelt (Figure 5.E.4-65). Habitat suitability was quite high for longfin smelt spawning (egg-larvae) but declined in the LLT because of climate-related temperature increase. HSI values for larval longfin smelt were somewhat lower because of increasing water temperature in late spring.

Sea level rise increased shallow-water habitat in the North Delta and decreased HUs for longfin smelt spawning (egg-larvae) because of the affinity of longfin smelt for deeper habitat for spawning. Sea level rise increased deeper subtidal habitat as well and produced a small increase in HUs for longfin smelt (Table 5.E.4-22).

Table 5.E.4-22. Habitat Units Estimated for Juvenile Longfin Smelt in the North Delta Subregion

North Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only—No Restoration)					
Egg-Larvae	2,893	2,893	2,925	2,664	(229)
Larvae	3,161	3,161	3,161	3,785	624
Total	6,054	6,054	6,086	6,449	395

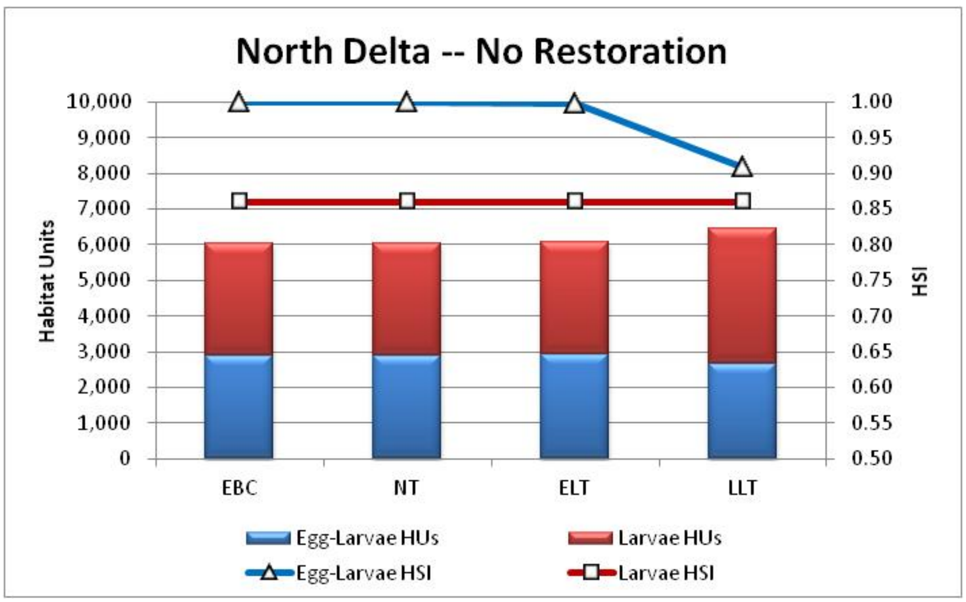


Figure 5.E.4-65. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Longfin Smelt in the North Delta Subregion with Sea Level Rise Only

Salmonids

Habitat Suitability Analysis

Current (EBC) conditions in the North Delta subregion favored migrating salmonids because of the abundance of deeper habitat strata (Table 5.E.4-23). Habitat suitability (HSI) for salmon in the North Delta was quite low compared to other species because of high water clarity that was outside the assumed habitat preference for juvenile salmonids (Figure 5.E.4-66).

Table 5.E.4-23. Habitat Units Estimated for Juvenile Salmonid Behavior Patterns in the North Delta Subregion

North Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only—No Restoration)					
Foragers	808	808	524	1,323	514
Migrants	2,145	2,145	2,145	2,250	105
Total	2,954	2,954	2,669	3,573	619

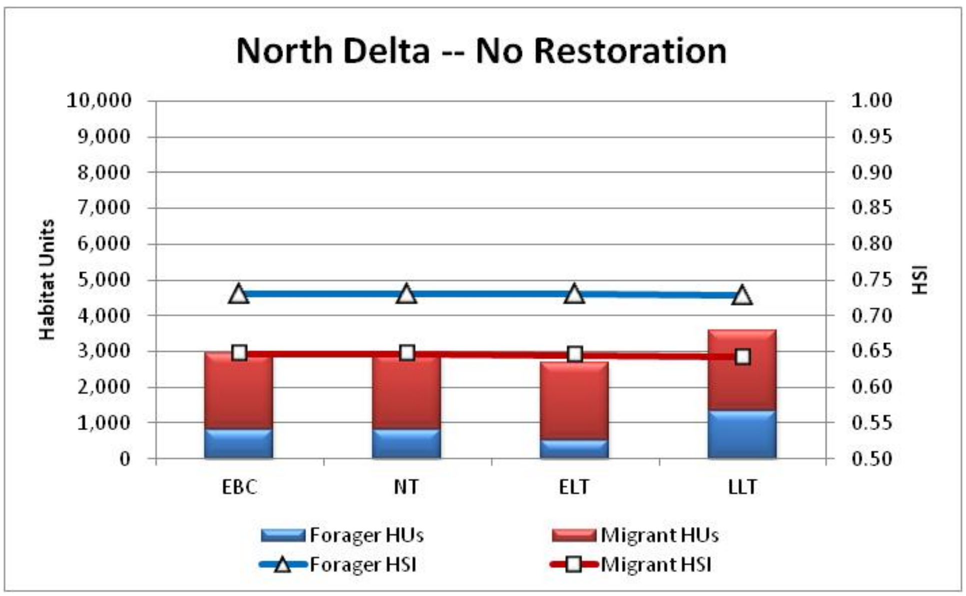


Figure 5.E.4-66. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Salmonid Behavior Patterns in the North Delta Subregion—Sea Level Rise Only, No Restoration: 991 Aquatic Acres Added

West Delta

Delta Smelt

Habitat Suitability Analysis

The West Delta subregion currently provides HUs largely for larval and juvenile delta smelt with relatively small amount of habitat for delta smelt spawning (Table 5.E.4-24). This is because most of the subregion is subtidal with a small amount of tidal freshwater (Figure 5.E.4-67).

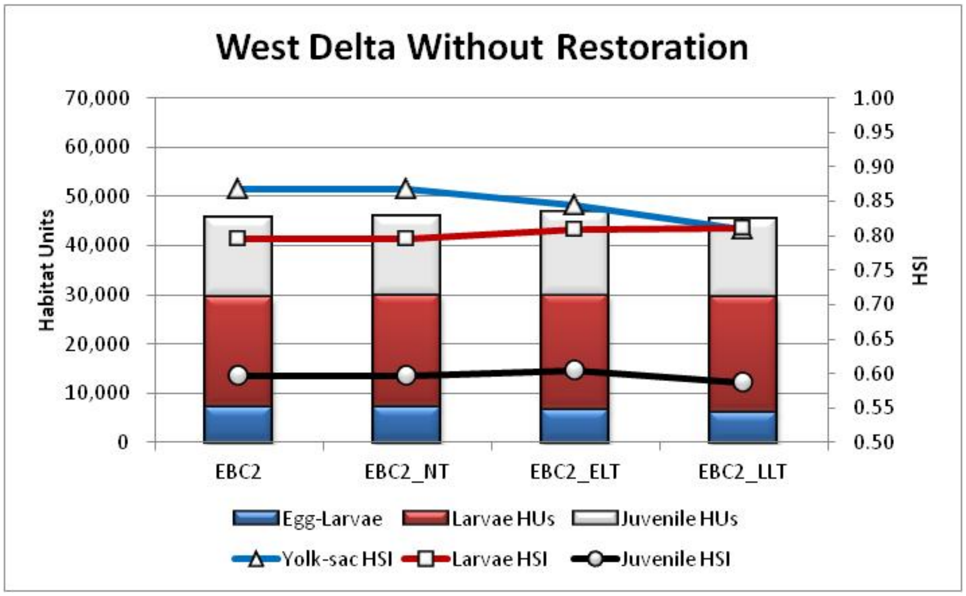
HSI values for delta smelt in the West Delta subregion were moderate (Figure 5.E.4-67). Habitat suitability for spawning (egg-larvae) declined over the BDCP permit term because of increasing temperature due to climate change. Suitability was lowest in all time periods for juvenile delta smelt because of low turbidity in summer and fall months.

HUs for egg-larvae stage in the West Delta subregion decreased under sea level rise by the LLT because shallow-water habitat increased only slightly with sea level rise while HSI values declined for the egg-larvae stage (Table 5.E.4-24). At the same time, HUs for larval delta smelt increased with sea level rise because of the increase in subtidal area and the relatively stable HSI values for this life stage over the study period.

With restoration under CM4 HUs increased for all life stages (Table 5.E.4-24). The biggest gain in HUs was for the larvae stage because of the relative high and stable HSI and the restoration of subtidal habitat. Spawning (egg-larvae) HUs increased under CM4 because of the expansion of shallow tidal freshwater habitat even while the HSI value decreased because of an increase in temperature associated with climate change.

Table 5.E.4-24. Habitat Units Estimated for Juvenile Delta Smelt in the West Delta Subregion by Time Period, with and without the BDCP

West Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	7,231	7,231	6,712	6,161	-1,070
Larvae	22,378	22,799	23,286	23,645	1,267
Juveniles	15,914	15,914	16,858	15,636	-277
Total	45,522	45,943	46,857	45,442	-80
ESO (Sea Level Rise + BDCP Restoration)					
Egg-Larvae	7,231	8,126	8,221	6,766	-465
Larvae	22,378	24,068	25,468	26,029	3,651
Juveniles	15,914	16,662	18,045	17,213	1,300
Total	45,522	48,856	51,734	50,008	4,486
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	895	1,509	605	605
Larvae	–	1,269	2,182	2,383	2,383
Juveniles	–	748	1,186	1,577	1,577
Total	–	2,912	4,877	4,565	4,565



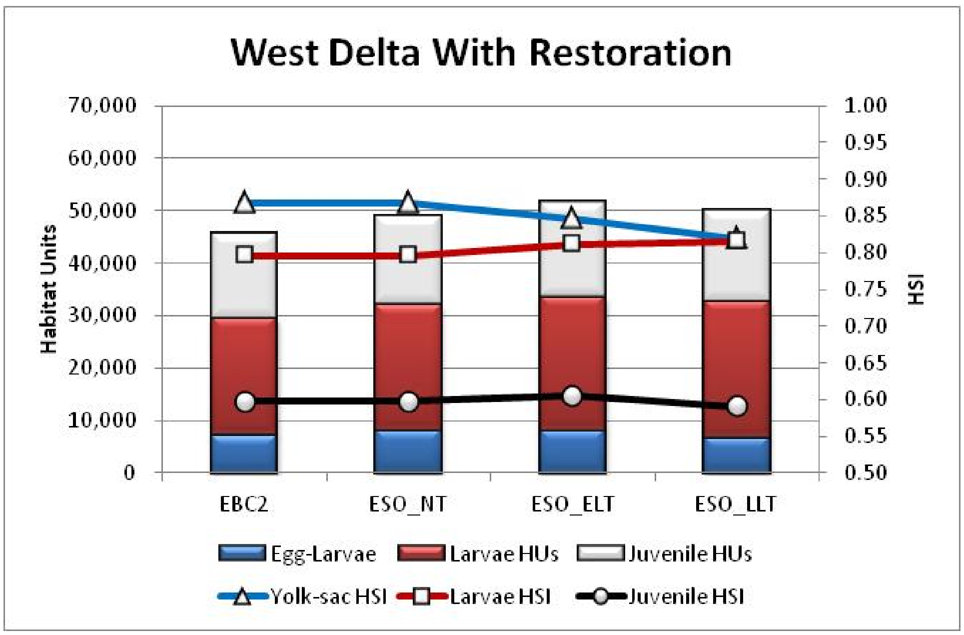


Figure 5.E.4-67. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Delta Smelt in the West Delta Subregion

Longfin Smelt

Although restoration in the West Delta is limited under CM4, the position of the ROA in the central Delta makes it potentially important to longfin smelt. Occurring at the confluence of the San Joaquin and Sacramento Rivers and tidal flow from the west, the area is typically turbid and brackish, conditions that favor longfin smelt (Rosenfield 2010). For this reason, the BDCP restoration actions in the West Delta ROA are likely to benefit longfin smelt.

Habitat Suitability Analysis

The deeper habitat of the West Delta subregion provided higher HSIs for longfin smelt than it did for delta smelt. Currently the subregion provides substantial habitat for both spawning (egg-larvae) and larval longfin smelt (Figure 5.E.4-68). This is because of the preponderance of deeper habitat in the West Delta and preference of longfin smelt for this type of habitat. HSI values for both life stages were appreciably higher than those for delta smelt. Suitability of the area for spawning longfin smelt decreased by LLT because of increased temperature with climate change. This resulted in a slight decrease in HUs for egg-larvae life stage by the LLT (Figure 5.E.4-68).

CM4 provided a small increase in HUs for both longfin smelt life stages (Table 5.E.4-25). Although the HSI for spawning (egg-larvae) longfin smelt declined by the LLT, the increase in acreage due to restoration in the subregion resulted in an overall increase in HUs. However, it is not possible to say from this analysis whether the increased quantity of habitat compensated for the decreased value of habitat because of the climate-related increase in water temperature.

Table 5.E.4-25. Habitat Units Estimated for Juvenile Longfin Smelt in the West Delta Subregion by Time Period, with and without the BDCP

West Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	18,621	18,621	18,963	17,882	(739)
Larvae	25,369	25,369	25,369	25,806	437
Total	43,991	43,991	44,332	43,689	(302)
ESO (Sea Level Rise + BDCP Restoration)					
Egg-Larvae	18,621	18,871	19,018	19,247	626
Larvae	25,369	26,781	26,781	28,309	2,940
Total	43,991	45,652	45,800	47,556	3,566
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	250	55	1,365	1,365
Larvae	–	1,412	1,412	2,503	2,503
Total	–	1,662	1,467	3,868	3,868

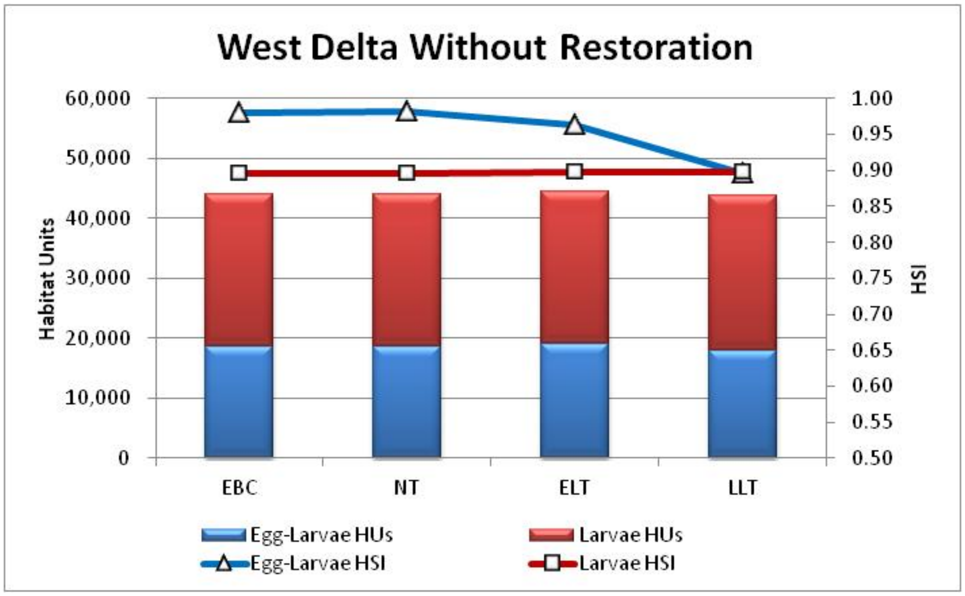


Figure 5.E.4-68A. Sea Level Rise Only: 536 Aquatic Acres Added to Subregion

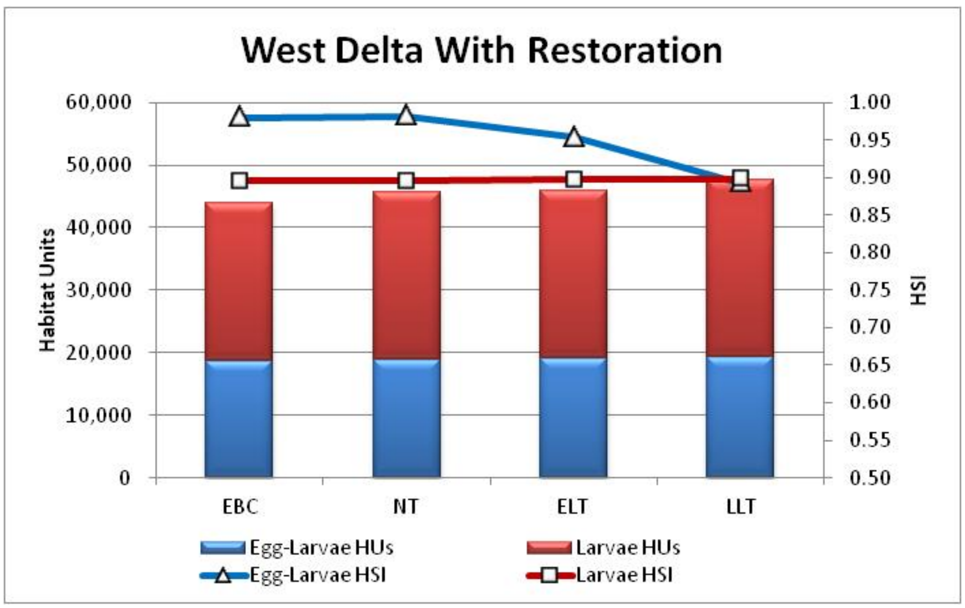


Figure 5.E.4-68B. Sea Level Rise + Restoration: 3,304 Aquatic Acres Added to Subregion

Figure 5.E.4-68. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Longfin Smelt in the West Delta Subregion

Salmonids

Habitat Suitability Analysis

The West Delta subregion provided relatively less habitat for juvenile salmonids under current and restored conditions than it did for delta smelt or longfin smelt (Figure 5.E.4-69). This was largely because the large amount of deepwater habitat is of lower value for foraging juvenile salmonids. The area does, however, provide substantial habitat for migrating juvenile salmonids. HSI values were somewhat reduced by turbidity levels but overall were relatively high and stable throughout the BDCP permit term for both behavioral forms of juvenile salmonids.

Restoration of habitat in the West Delta under CM4 provided a small increase in habitat for both juvenile salmonid behavior forms (Table 5.E.4-26). Most of the increase in salmonid HUs under CM4 accrued to foraging juveniles because the restoration provided a greater increase in tidal freshwater habitat than in subtidal habitat.

Table 5.E.4-26. Habitat Units Estimated for Juvenile Salmonid Behavior Patterns in the West Delta Subregion by Time Period, with and without the BDCP

West Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Foragers	9,459	9,459	7,105	9,602	142
Migrants	19,418	19,418	19,418	19,723	304
Total	28,878	28,878	26,523	29,324	447
ESO (Sea Level Rise + BDCP Restoration)					
Foragers	9,459	10,591	9,041	11,422	1,963
Migrants	19,418	19,902	19,902	20,670	1,252
Total	28,878	30,493	28,943	32,093	3,215
Change from BDCP Restoration Only (Sea Level Rise Removed					
Foragers	–	1,131	1,936	1,821	1,821
Migrants	–	484	484	948	948
Total	–	1,615	2,420	2,768	2,768

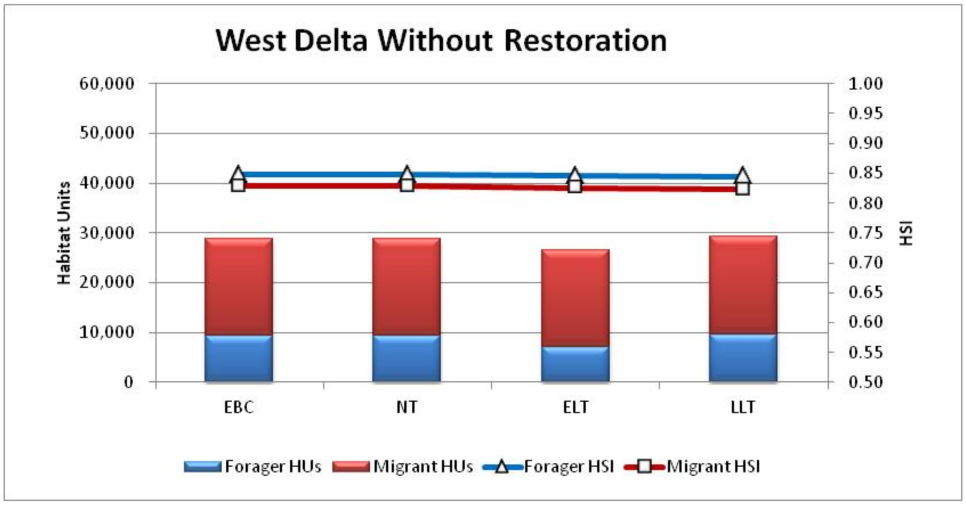


Figure 5.E.4-69A. Sea Level Rise Only: 536 Aquatic Acres Added to Subregion

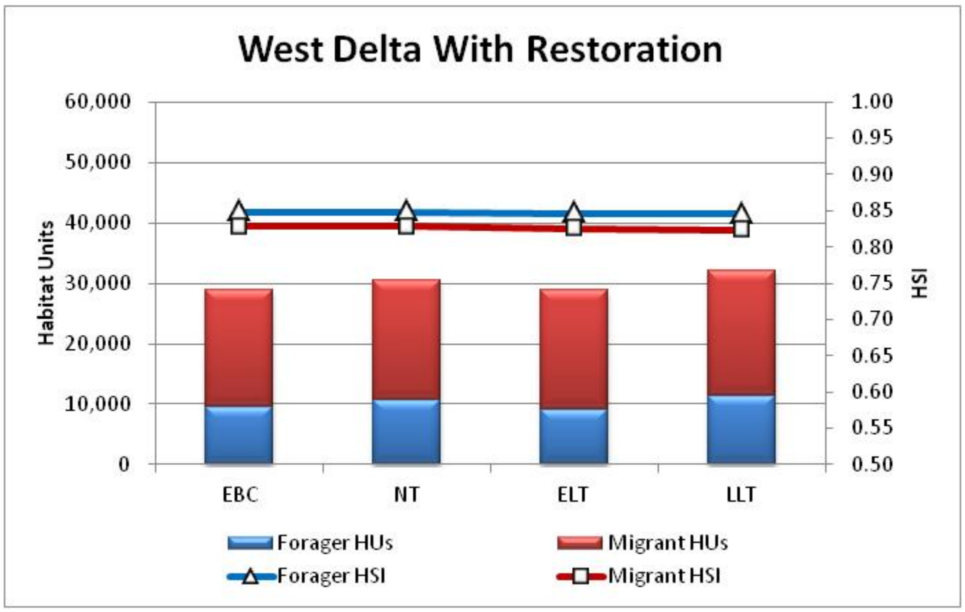


Figure 5.E.4-69B. Sea Level Rise + Restoration: 3,304 Aquatic Acres Added to Subregion

Figure 5.E.4-69. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Salmonid Behavior Patterns in the West Delta Subregion

Suisun Marsh

Delta Smelt

Suisun Marsh is important habitat for larval and juvenile delta smelt, especially in the spring and early summer. Restoration in Suisun Marsh may increase the availability and production of food in the marsh and is expected potentially to increase food resources in Suisun Bay by exporting organic material by tidal flow from the marsh plain and phytoplankton, zooplankton, and other organisms produced in intertidal channels into the Bay.

Habitat Suitability Analysis

Conditions in Suisun Marsh resulted in moderate to low HSI values for delta smelt (Figure 5.E.4-70). The HSI for juvenile delta smelt was relatively low throughout the period because of high salinity values in the marsh in summer and fall. Conditions were better for juvenile delta smelt because of lower salinity in the spring. Absent the BDCP, the suitability of the area for delta smelt spawning (egg-larvae) declined over the BDCP permit term because of an increase in temperature associated with climate change.

Under the BDCP, HSI values for delta smelt in Suisun Marsh declined (Figure 5.E.4-70). Suisun Marsh is the only subregion where HSI values declined appreciably under the BDCP. The cause of the decline in HSI values under the BDCP is an increase in salinity in the marsh in the ELT and LLT periods, caused by a combination of sea level rise and restoration. While salinity was higher in other subregions under the BDCP, it was still within the preferred range assumed for delta smelt and no change in HSI occurred. In Suisun Marsh salinity is appreciably higher than it is for other subregions (except Suisun Bay) and the increase in salinity under the BDCP was enough to move salinity beyond the assumed preferred range.

The increase in salinity in the marsh under the BDCP is largely the result of a shift in the tidal prism as a result of CM4 restoration. Inundation of large areas that are currently terrestrial under CM4 results in a shift in the tidal prism to the east. While there are small changes in salinity in other areas as well, the generally high salinity in Suisun Marsh produced an appreciable decrease in HSI values.

Despite the decrease in HSI, HUs for delta smelt increased in Suisun Marsh under CM4 (Table 5.E.4-27). The greatest gains in HUs were for the spawning (egg-larvae) and larvae stages that benefited from the increase in brackish tidal habitat. However, the value of gains in HUs is moderated by the low HSI values that declined as a result of climate change and covered activities. It is not possible to say from this analysis whether the increased in HUs compensated for the decreased value of habitat because of the increase in salinity under the BDCP.

Table 5.E.4-27. Habitat Units Estimated for Juvenile Delta Smelt in the Suisun Marsh Subregion by Time Period, with and without the BDCP

Suisun Marsh	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	6,547	6,547	6348	5,994	-552
Larvae	10,660	10,642	10,864	11,024	364
Juveniles	7,323	7,323	7,340	7,463	140
Total	24,529	24,511	24,552	24,481	-48
ESO (Sea Level Rise + BDCP Restoration)					
Egg-Larvae	6,547	8,994	9,316	12,947	6,400
Larvae	10,660	14,256	15,716	20,912	10,252
Juveniles	7,323	9,950	10,681	14,694	7,371
Total	24,529	33,201	35,713	48,553	24,024
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	2,447	2,968	6,953	6,953
Larvae	–	3,614	4,852	9,888	9,888
Juveniles	–	2,628	3,341	7,231	7,231
Total	–	8,689	11,161	24,072	24,072

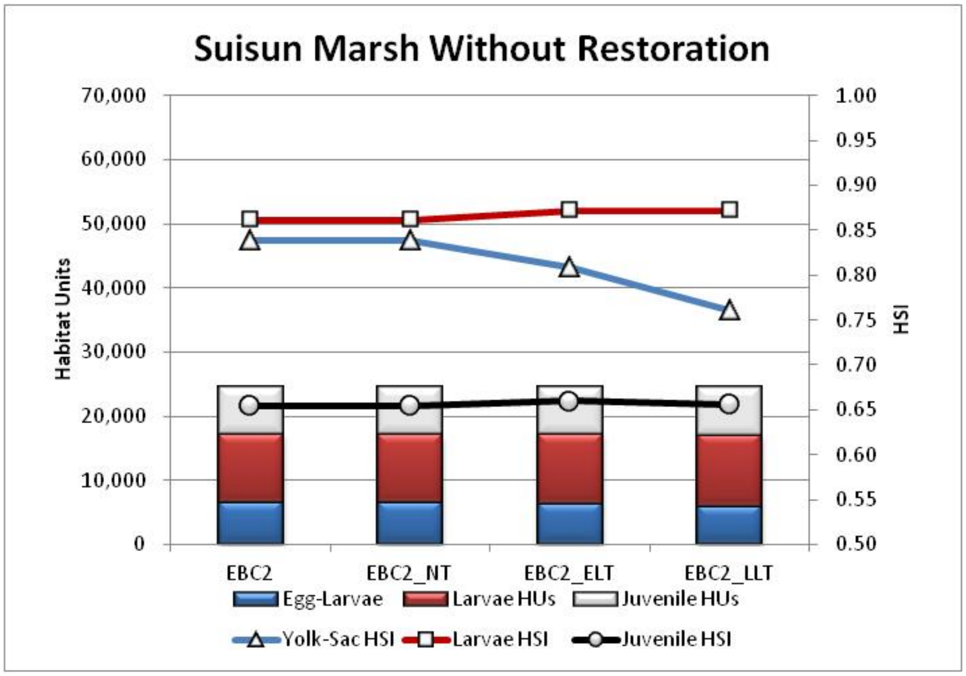


Figure 5.E.4-70A. Sea Level Rise Only: 292 Aquatic Acres Added to Subregion

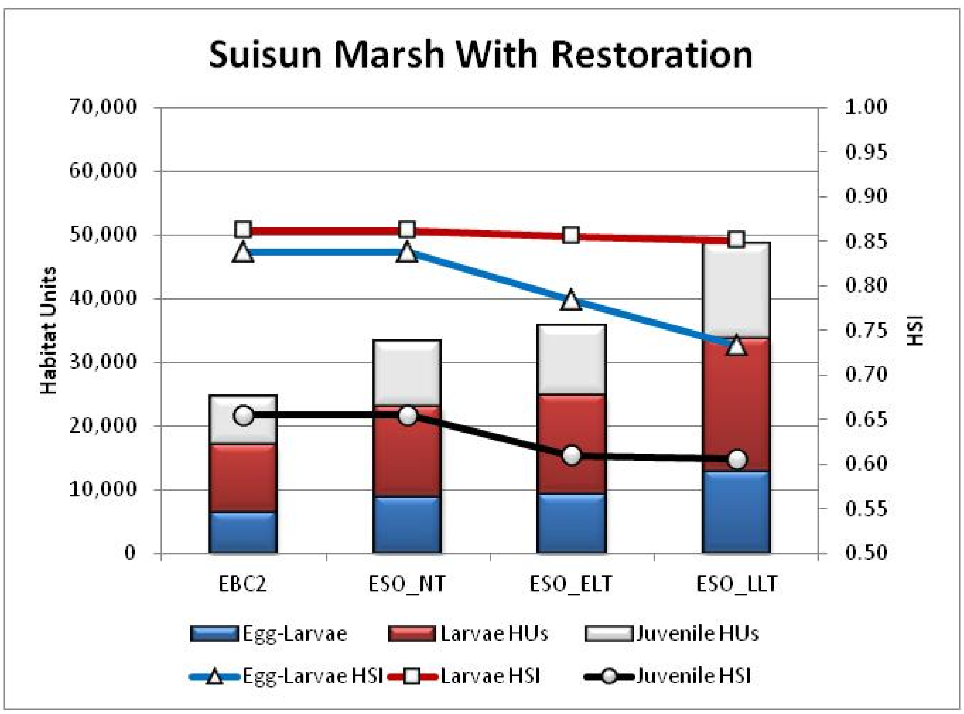


Figure 5.E.4-70B. Restoration Only: 11,926 Aquatic Acres Added to Subregion

Figure 5.E.4-70. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Delta Smelt Life Stages in the Suisun Marsh Subregion

Longfin Smelt

Longfin smelt are widespread in the San Francisco Bay estuary and are detected each year in the western Delta, Suisun Bay, and Suisun Marsh (Baxter 1999; Rosenfield 2008). Soon after they become free-swimming fish, longfin smelt concentrate in deepwater environments and most of the Delta is not considered rearing habitat for juvenile and adult longfin smelt.

Habitat Suitability Analysis

HSI values were quite high in Suisun Marsh for both spawning (egg-larvae) and larval longfin smelt compared to other species with and without the BDCP (Figure 5.E.4-71). However, habitat suitability decreased in the ELT and LLT for spawning (egg-larvae) because of higher temperatures in the spring (March) due to climate change. With the BDCP, the HSI for the egg-larvae stage was somewhat lower in the ELT than it was without the BDCP as a result of slightly higher temperature in spring (March). Values in the LLT for egg-larvae were similar with and without the BDCP.

Because of the preference of longfin smelt for higher-salinity water, the increase in salinity in Suisun Marsh under the BDCP that decreased HSI for delta smelt did not affect the HSI values for longfin smelt and resulted in HSI values for larval longfin smelt near 1.0. The shallow tidal brackish habitat in Suisun Marsh provided few HUs for spawning (egg-larvae) longfin smelt that spawn in deeper habitat. In fact, spawning HUs declined slightly over time as a result of the reduced HSI for egg-larvae stage. Suisun Marsh provides potential feeding areas for larvae stage reflected in the greater number of HUs for larvae (Table 5.E.4-28).

Table 5.E.4-28. Habitat Units Estimated for Juvenile Longfin Smelt in the Suisun Marsh Subregion by Time Period, with and without the BDCP

Suisun Marsh	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Yolk-sac larvae	2,243	2,243	2,302	2,171	(71)
Larvae	11,833	11,833	11,833	12,137	304
Total	14,075	14,075	14,135	14,308	233
ESO (Sea Level Rise + BDCP Restoration)					
Yolk-sac larvae	2,243	2,214	2,299	2,210	(33)
Larvae	11,833	15,852	15,852	23,738	11,905
Total	14,075	18,065	18,150	25,948	11,872
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae HUs	–	(29)	(3)	39	39
Larvae HUs	–	4,019	4,019	11,601	11,601
Total	–	3,990	4,015	11,639	11,639

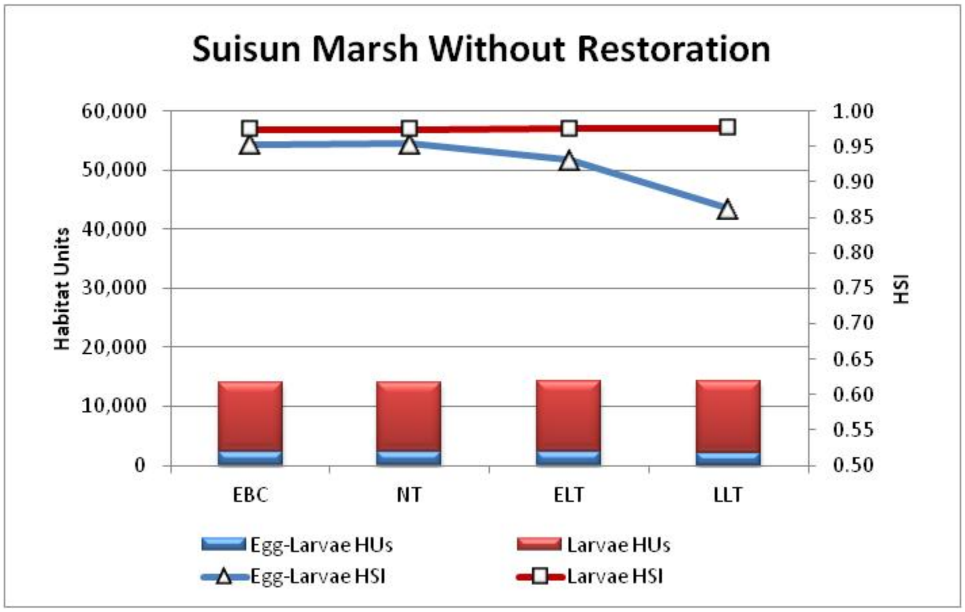


Figure 5.E.4-71A. Without Restoration: 292 Aquatic Acres Added to Subregion

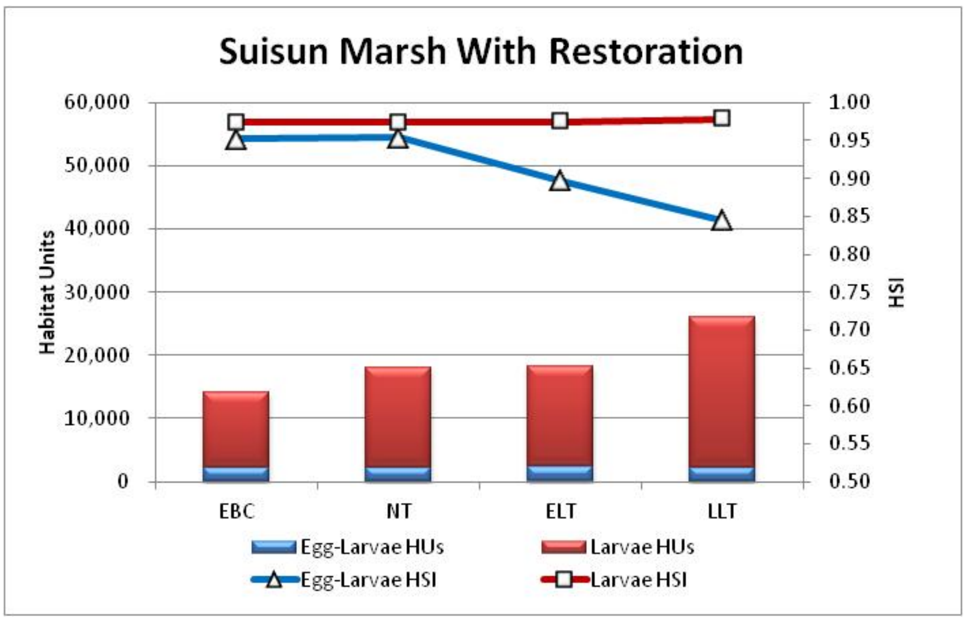


Figure 5.E.4-71B. With Restoration: 12,219 Aquatic Acres Added to Subregion

Figure 5.E.4-71. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Longfin Smelt Life Stages in the Suisun Marsh Subregion

Salmonids

Tidal wetland habitat rehabilitation has the potential to contribute to productive rearing habitat for juvenile Chinook salmon and steelhead. Permanent tidal marshes such as Suisun Marsh may provide critical habitat functions and contribute to improved abundances. For salmonids traveling through the lower estuary, opportunities for growth and development may be currently limited by available habitat; therefore, increases in rearing habitat access might contribute to positive effects.

Tidal habitats may be important to salmonids exhibiting alternative migration and behavioral pathways; a range of life-history patterns provides resilience to variable environmental conditions (Miller and Sadro 2003; Healey 2009; Volk et al. 2010). Juvenile salmonids in the Delta exhibit variation in foraging and migrating behaviors between and within populations. The interconnectedness of wetland habitats along the estuarine gradient probably provides an important rearing function.

Steelhead are generally thought to move quickly through estuarine habitats because of their larger size at outmigration; however, there are few empirical sources of information from the Delta (McEwan 2001). Studies from coastal systems have found a benefit to size at ocean entry and survival for steelhead that rear in estuarine marshes (Bond 2006; Hayes et al. 2008)

Habitat Suitability Analysis

HSI values for foraging and migrating juvenile salmonids were moderate in Suisun Marsh (Figure 5.E.4-72). Habitat suitability for salmonids in Suisun Marsh was reduced by high turbidity values that were outside the assumed optimal value for juvenile salmonids. The shallow tidal brackish habitat that predominates in Suisun Marsh currently provides greater habitat for foraging juvenile salmon relative to migrants; sea level rise, however, increased deeper habitats that favored the migrating behavior (Table 5.E.4-29). CM4 restoration increased the amount of shallow tidal habitat in Suisun Marsh and so provided a greater benefit for foraging juvenile salmonids than for the migrant form (Figure 5.E.4-72).

Table 5.E.4-29. Habitat Units Estimated for Juvenile Salmonid Behavior Patterns in the Suisun Marsh Subregion by Time Period, with and without the BDCP

Suisun Marsh	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Foragers	7,678	7,678	7,443	7,755	77
Migrants	4,037	4,037	4,037	4,230	193
Total	11,715	11,715	11,480	11,986	271
ESO (Sea Level Rise + BDCP Restoration)					
Foragers	7,678	10,575	11,365	14,375	6,697
Migrants	4,037	5,159	5,159	9,085	5,048
Total	11,715	15,734	16,524	23,459	11,744
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Foragers	–	2,897	3,922	6,619	6,619
Migrants	–	1,122	1,122	4,854	4,854
Total	–	4,019	5,044	11,474	11,474

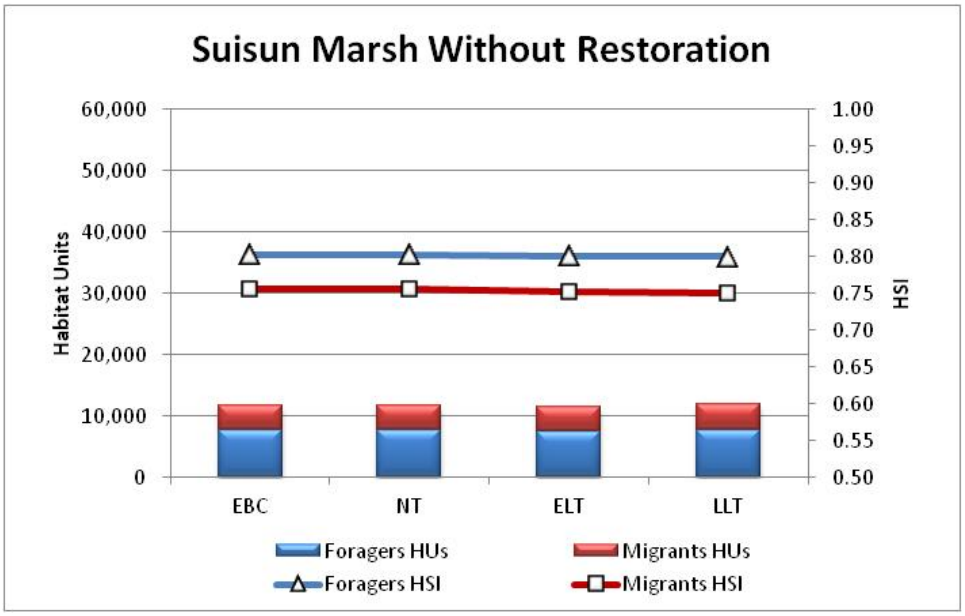


Figure 5.E.4-72A. Without Restoration: 292 Aquatic Acres Added to Subregion

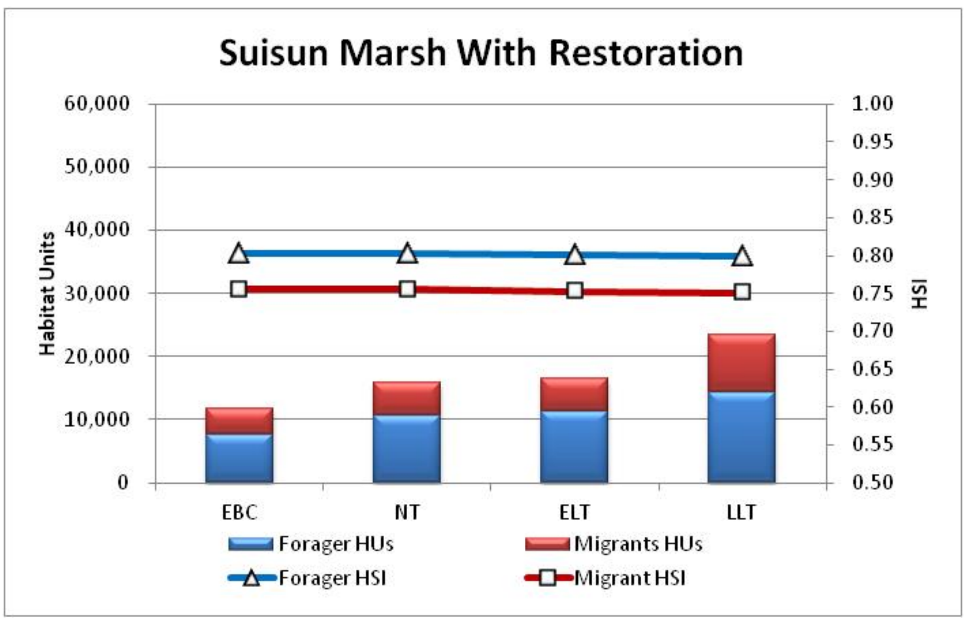


Figure 5.E.4-72B. With Restoration: 12,219 Aquatic Acres Added to Subregion

Figure 5.E.4-72. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Salmonid Behavior Patterns in the Suisun Marsh Subregion

Suisun Bay

Delta Smelt

Although, there is no restoration planned within Suisun Bay it is considered important larval and juvenile delta smelt habitat in certain water years because the rearing area (low salinity zone) moves westward in response to total Delta outflow. Shallow subtidal habitat is expected to decrease and deep subtidal habitat increase with sea level rise. Delta smelt could benefit from restoration activities in adjacent Suisun Marsh that may increase the availability and production of food in

Suisun Bay by exporting organic material via tidal flow from adjacent intertidal habitat into the low salinity zone.

Habitat Suitability Analysis

Because there is no restoration planned in Suisun Bay under the BDCP, the habitat suitability analysis describes current habitat potential and the change in habitat only as a result of the relatively minor change in the subregion expected as a result of sea level rise.

HSI values for delta smelt in Suisun Bay were reduced relative to other geographic subregions because of high salinity and to a lesser extent, high temperature. High salinity particularly reduced habitat suitability in Suisun Bay for the juvenile life stage during the summer especially in drier water years. HSI values for spawning delta smelt in Suisun Bay declined slightly over time because of increasing water temperature (Figure 5.E.4-73). Because the HSI values declined over time, and there was no restoration, overall HUs for all life stages of delta smelt in Suisun Bay declined slightly by the LLT (Table 5.E.4-30).

Table 5.E.4-30. Habitat Units Estimated for Juvenile Delta Smelt in the Suisun Bay Subregion

Suisun Bay	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	7,475	7,475	6,538	4,922	-2,553
Larvae	16,031	16,171	16,145	15,967	-64
Juveniles	12,430	12,430	11,695	11,808	-622
Total	35,936	36,076	34,379	32,697	-3,239

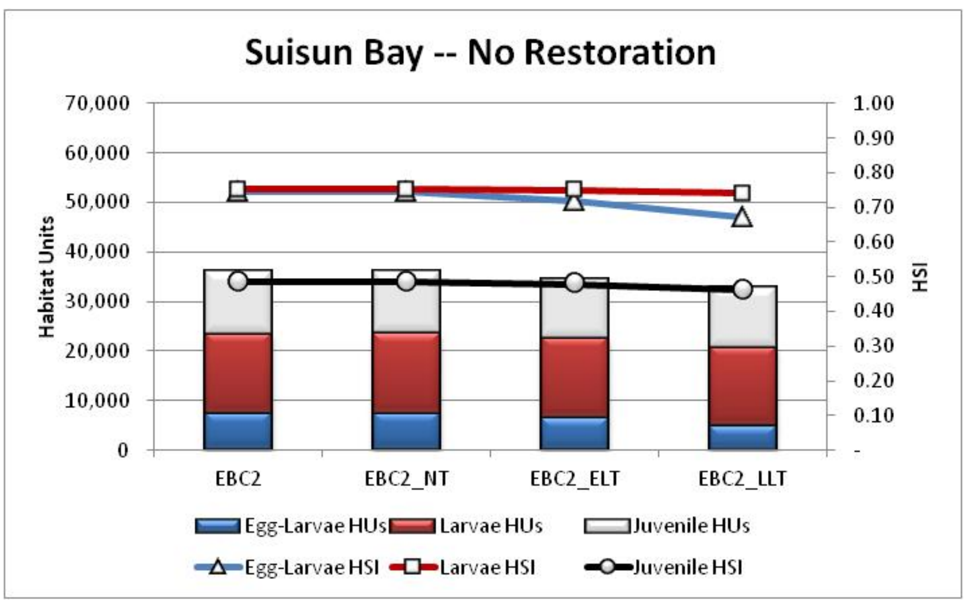


Figure 5.E.4-73. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Delta Smelt in the Suisun Bay Subregion—No Restoration: 17 Aquatic Acres Added to Subregion

Longfin Smelt

Longfin smelt are widespread in the San Francisco Bay Suisun Bay, and Suisun Marsh (Baxter 1999; Rosenfield 2008). Soon after they become free-swimming fish, longfin smelt concentrate in deepwater environments and then move into more saline waters in San Francisco Bay as juveniles.

Habitat Suitability Analysis

The deeper, more saline conditions of Suisun Bay provided better habitat for longfin smelt relative to other species and overall HUs increased even without BDCP restoration because of sea level rise (Table 5.E.4-31). HSI values for larval longfin smelt were near 1.0 because of nearly ideal salinity and temperature conditions. HUs for longfin smelt spawning increased because of sea level rise and the increase in deeper habitat strata favored for longfin smelt spawning (Figure 5.E.4-74). Suitability for spawning (egg-larvae) declined over the period as a result of temperature increases due to climate change.

Table 5.E.4-31. Habitat Units Estimated for Juvenile Delta Smelt in the Suisun Bay Subregion

Suisun Bay	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only—No Restoration)					
Egg-Larvae	10,502	10,502	11,307	12,158	1,656
Larvae	20,570	20,570	20,570	20,810	240
Total	31,072	31,072	31,877	32,968	1,896

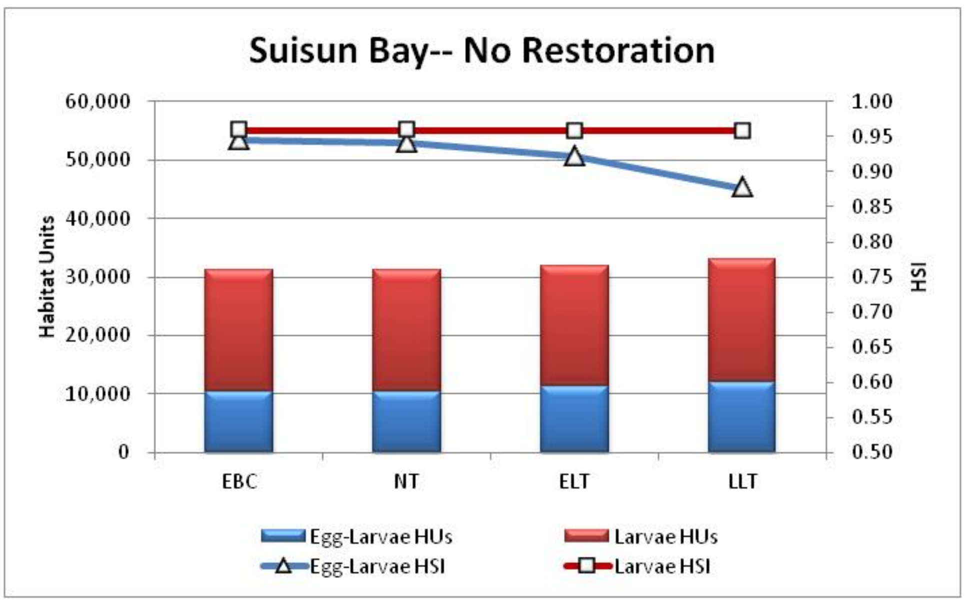


Figure 5.E.4-74. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Longfin Smelt in the Suisun Bay Subregion—No Restoration: 17 Aquatic Acres Added to Subregion

Salmonids

Chinook salmon most likely would forage in intertidal habitat surrounding Suisun Bay on flood tides and move back into channels and sloughs during ebb tides. Migrating smolts most likely would use Suisun Bay as a migratory corridor while they move to the Pacific ocean (Kjelson et al. 1982). Fry could use Suisun Bay and surrounding habitats depending on size and timing of emigration. Salmonids may benefit from restoration actions in adjacent Suisun Marsh that are expected to export organic material, thereby potentially enhancing foodwebs in Suisun Bay.

Habitat Suitability Analysis

Conditions in Suisun Bay over the course of the BDCP permit term resulted in high HSI values for juvenile salmonids (Figure 5.E.4-75). Suitability of habitat for juvenile salmonids was greater in Suisun Bay than it was in Suisun Marsh because turbidity in Suisun Bay was less than it was in Suisun Marsh and the Suisun Bay values fell within the preferred range assumed for salmonids. Because of the preponderance of subtidal habitat and small amount of shallow-water habitat, Suisun Bay provided the most HUs for migrating juvenile salmonids; habitat for foraging juvenile salmonids declined over time because of the reduction in tidal brackish areas due to sea level rise (Table 5.E.4-32).

Table 5.E.4-32. Habitat Units Estimated for Juvenile Salmonid Behavior Patterns in the Suisun Bay Subregion

Suisun Bay	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only—No Restoration)					
Foragers	7,889	7,889	6,008	7,029	(859)
Migrants	17,402	17,402	17,402	18,153	751
Total	25,291	25,291	23,410	25,182	(109)

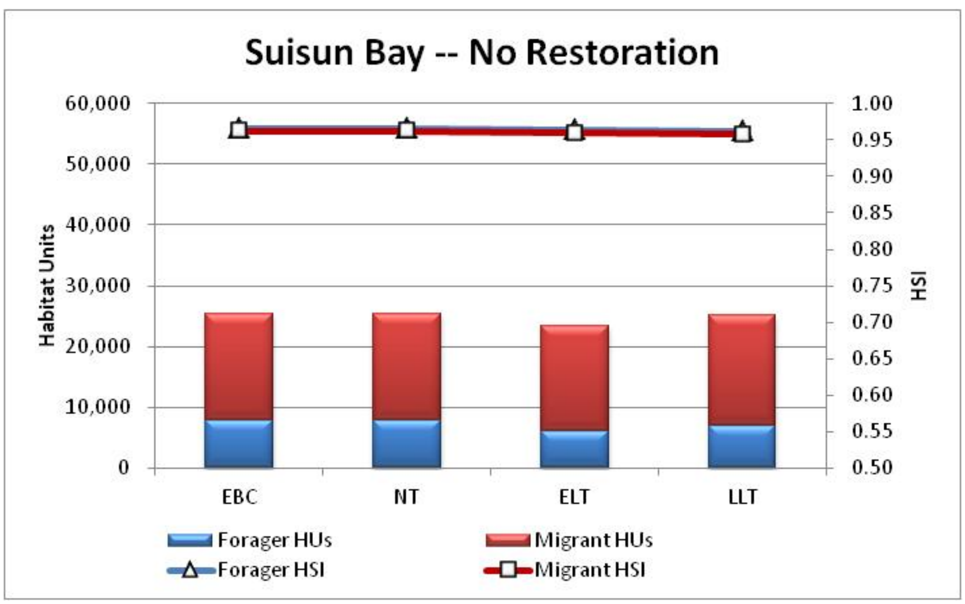


Figure 5.E.4-75. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Salmonid Behavior Patterns in the Suisun Bay Subregion—No Restoration: 17 Aquatic Acres Added to Subregion

East Delta

Delta Smelt

Delta smelt are rare in the East Delta and usually are found as larvae that probably have been transported through the Delta Cross Channel from the Sacramento River.

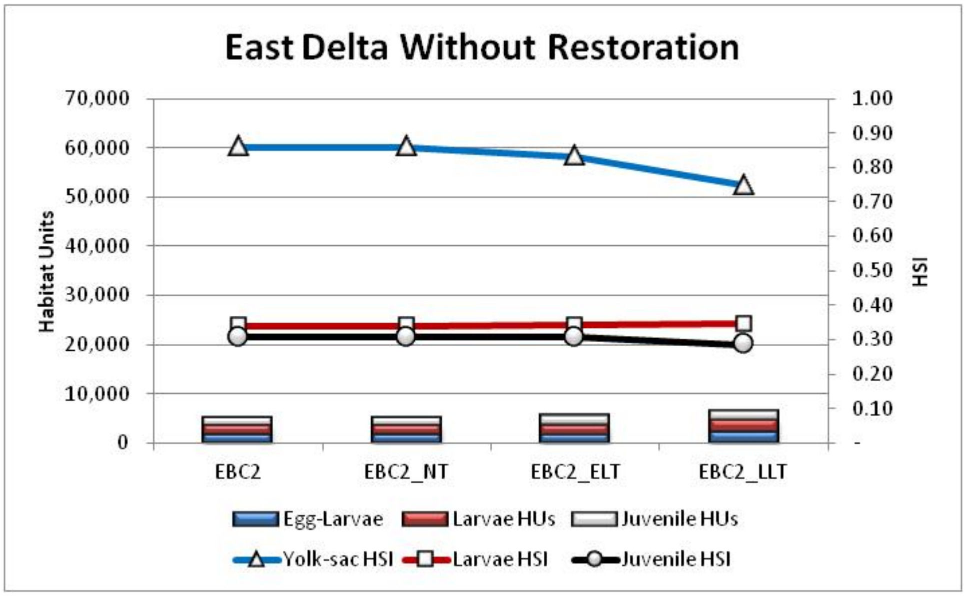
Habitat Suitability Analysis

HSI values for delta smelt in the East Delta subregion were low for larval and juvenile delta smelt (Figure 5.E.4-76). The low HSI for delta smelt in this subregion is primarily because of very low turbidity. HSI values for spawning (egg-larvae) were much higher because turbidity was not included in the egg-larvae habitat suitability model. The East Delta subregion had the lowest HSI values for delta smelt of any of the BDCP subregions. The low suitability of habitat in this subregion was the result of high temperature but especially low turbidity. HSI value for egg-larvae stage decreased by LLT as a result of increasing temperature due to climate change.

As a result of the low habitat suitability of the East Delta subregion, the area produced few HUs for Delta relative to its total acreage especially for larval and juvenile life stages (Table 5.E.4-33). Sea level rise resulted in a small increase in HUs for all life stages. CM4 further increased HUs in the subregion for all life stages but primarily for the egg-larvae stage, which was not affected by the low turbidity. Given the very low HSI values for larval and juvenile life stages of delta smelt, it seems unlikely that expansion of habitat areas would compensate for low habitat value.

Table 5.E.4-33. Habitat Units Estimated for Juvenile Delta Smelt in the East Delta Subregion by Time Period, with and without the BDCP

East Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	1,687	1,687	1,710	2,198	511
Larvae	1,961	1,891	1,987	2,452	491
Juveniles	1,488	1,488	1,789	1,667	180
Total	5,135	5,065	5,486	6,317	1,182
ESO (Sea Level Rise + BDCP Restoration),					
Egg-Larvae	1,687	3,739	3,795	3,701	2,015
Larvae	1,961	2,822	2,985	3,249	1,288
Juveniles	1,488	2,193	2,632	2,243	756
Total	5,135	8,754	9,411	9,194	4,059
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	2,052	2,085	1,503	1,503
Larvae	–	931	998	797	797
Juveniles	–	705	843	576	576
Total	–	3,689	3,926	2,876	2,876



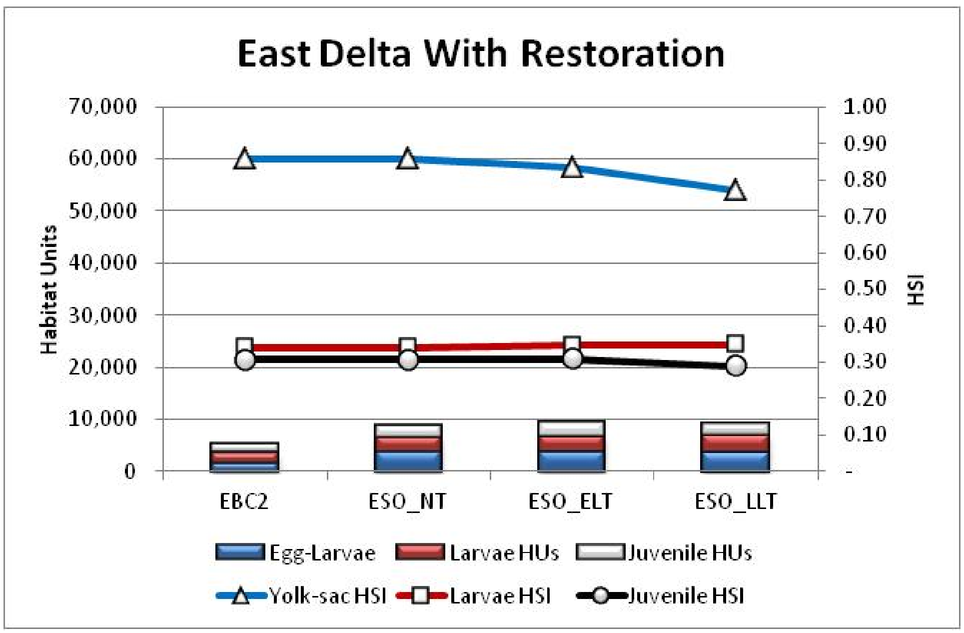


Figure 5.E.4-76. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Delta Smelt in the East Delta Subregion

Longfin Smelt

The East Delta does not appear to harbor substantial numbers of longfin smelt at the present time. Like delta smelt, longfin smelt do not appear to use the East Delta for spawning or rearing. The occasional catch of larvae in this area is attributable to larvae being passively transported into the area from the Sacramento River.

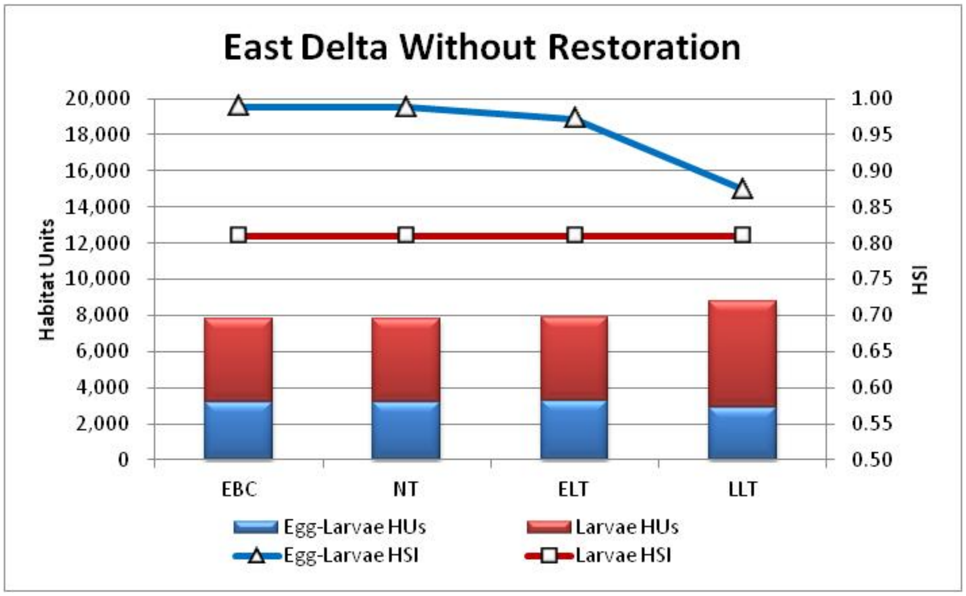
Habitat Suitability Analysis

Conditions in the East Delta subregion provided relatively good habitat for longfin smelt (Figure 5.E.4-77). This is somewhat surprising given the low HSI ratings for delta smelt in the subregion but it is due to the fact that longfin smelt were assumed to be present in the Delta primarily in the winter and early spring months (December–March for egg-larvae, January to April for larvae) when temperature and turbidity levels in the East Delta subregion were usually within preferred range for longfin smelt. Also, the subregion has a high proportion of the deeper habitat longfin smelt prefer. Suitability declined for the egg-larvae stage over time because of increasing water temperature but remained relatively high in the LLT.

CM4 increased habitat for longfin smelt in the East Delta subregion (Table 5.E.4-34). Most of the increased HUs were for the larval life stage that could use the increased tidal freshwater habitat for feeding whereas the egg-larvae stage benefited only from the small increase in deeper habitat.

Table 5.E.4-34. Habitat Units Estimated for Juvenile Longfin Smelt in the East Delta Subregion by Time Period, with and without the BDCP

East Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	3,179	3,179	3,239	2,930	(248)
Larvae	4,612	4,612	4,612	5,871	1,258
Total	7,791	7,791	7,851	8,801	1,010
ESO (Sea Level Rise + BDCP Restoration)					
Egg-Larvae	3,179	3,243	3,223	3,020	(159)
Larvae	4,612	6,885	6,885	7,713	3,100
Total	7,791	10,127	10,108	10,733	2,942
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	64	(16)	90	90
Larvae	–	2,272	2,272	1,842	1,842
Total	–	2,336	2,257	1,932	1,932



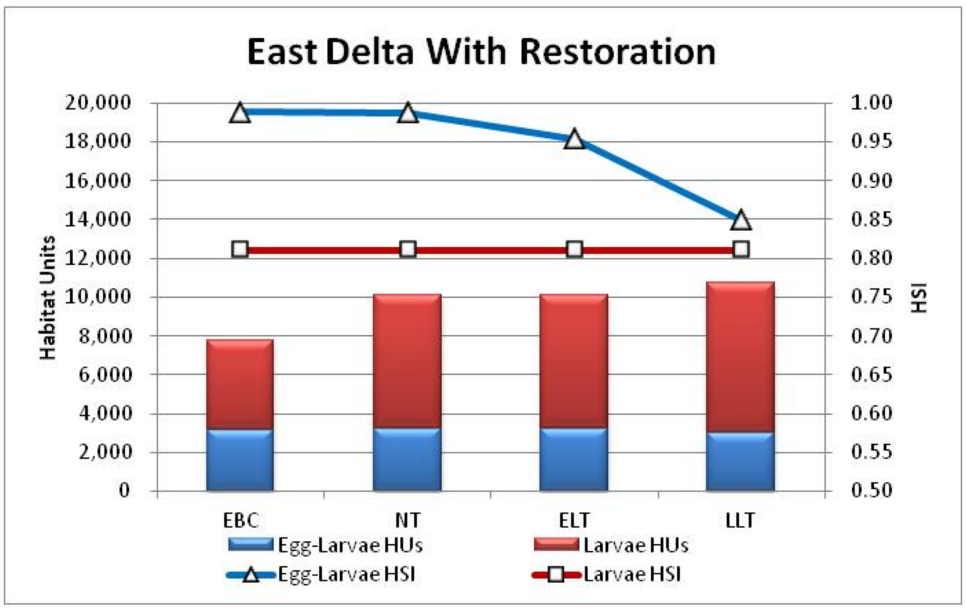


Figure 5.E.4-77. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Longfin Smelt in the East Delta Subregion

Salmonids

Migrating adult and juvenile Chinook and steelhead use the East Delta as a migratory pathway to spawning areas in the Cosumnes and Mokelumne Rivers.

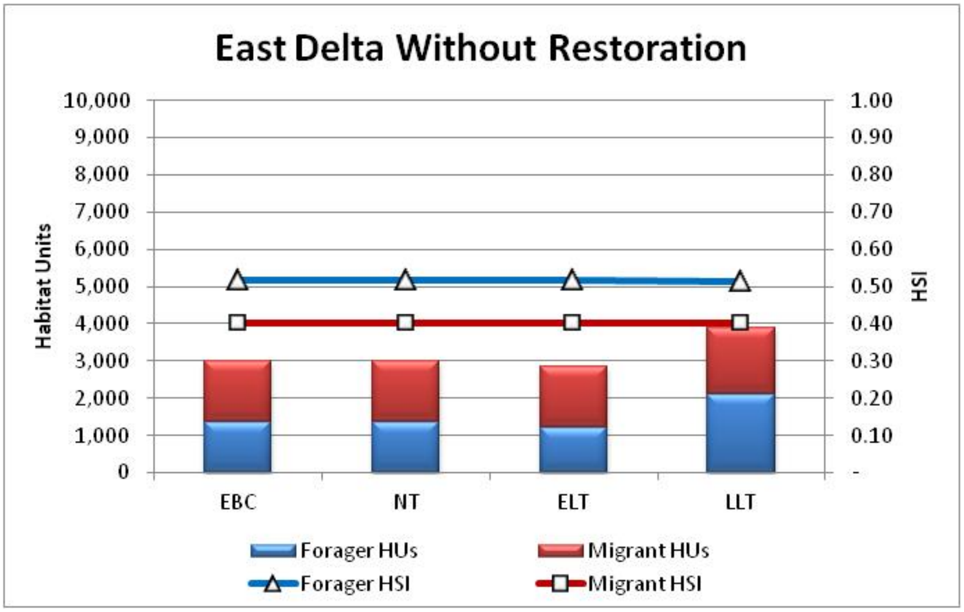
Habitat Suitability Analysis

The East Delta had relatively low suitability values for juvenile salmonids (Figure 5.E.4-78). This was the result of low turbidity conditions during summer and fall that affected both foraging and migrating forms. HSI values for migrant juvenile salmonids were lower than those for foragers because low turbidity conditions spanned the entire assumed period for migrants (April–May) whereas foragers were assumed to be present for a time prior to this (January–May) and benefited from the higher winter turbidity levels in the subregion.

Under current conditions (EBC) the majority of HUs are accounted to migrant juvenile salmonids because of the greater amount of deepwater habitat relative to shallow intertidal habitat. However, by the LLT, the majority of HUs accrued to foraging juvenile salmonids for both sea level rise only and with CM4 restoration (Table 5.E.4-35). Sea level rise increased tidal freshwater habitat which was further increased by CM4 with the result being that there were more HUs for the foraging behavior than there was for the migrant behavior by the LLT.

Table 5.E.4-35. Habitat Units Estimated for Juvenile Salmonid Behavior Patterns in the East Delta Subregion by Time Period, with and without the BDCP

East Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Foragers	1,346	1,346	1,192	2,106	760
Migrants	1,661	1,661	1,661	1,800	139
Total	3,007	3,007	2,853	3,906	899
ESO (Sea Level Rise + BDCP Restoration)					
Foragers	1,346	2,342	2,240	2,812	1,467
Migrants	1,661	2,242	2,242	2,352	691
Total	3,007	4,584	4,482	5,165	2,158
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Foragers	–	997	1,048	707	707
Migrants	–	580	580	552	552
Total	–	1,577	1,629	1,259	1,259



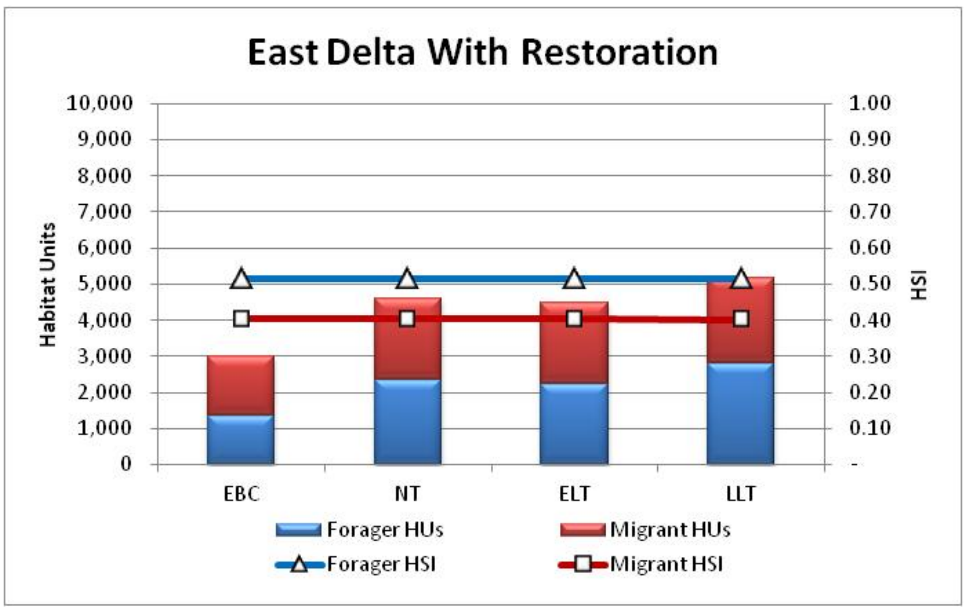


Figure 5.E.4-78. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Salmonid Behavior Patterns in the East Delta Subregion

South Delta

Delta Smelt

Habitat Suitability Analysis

HSI values for delta smelt in the South Delta were only slightly higher than those for the East Delta subregion (Table 5.E.4-36). This was because HSI for larval delta smelt was somewhat higher for the South Delta compared to the East Delta; HSI values for egg-larvae and juvenile delta smelt were similar in both areas. The analysis indicates that under current conditions (EBC), the south Delta provides small amount of habitats for larval spawning (egg-larvae) and juvenile delta smelt (Table 5.E.4-36). As in the East Delta subregion HSI values for delta smelt in the South Delta are limited by low turbidity especially during summer and fall periods. Suitability for spawning (egg-larvae) is relatively high in the South Delta because the evaluation period is prior to high summer water temperatures and suitability is not decreased by high water clarity. Over the BDCP period, however, suitability of the south Delta for delta smelt spawning is declined because of increasing water temperature from climate change.

All restoration under CM4 in the South Delta was assumed to occur in the LLT (Figure 5.E.4-79). Restoration added appreciably to the delta smelt HUs in the south Delta, especially for spawning (egg-larvae) and larval life stages (Table 5.E.4-36 and Figure 5.E.4-79). However, the benefits of CM4 in the south Delta are appreciably limited by low HSI values primarily related to high water clarity (low turbidity). The low HSI values, especially for juvenile delta smelt, make it unlikely that the increased quantity of habitat provided by restoration would compensate for the low habitat value (HSI).

Table 5.E.4-36. Habitat Units Estimated for Juvenile Delta Smelt in the South Delta Subregion by Time Period, with and without the BDCP

South Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	5,213	5,213	5,049	5,055	-158
Larvae	9,933	9,864	10,013	10,444	510
Juveniles	4,998	4,998	5,600	4,812	-185
Total	20,144	20,074	20,663	20,311	167
ESO (Sea Level Rise + BDCP Restoration)					
Egg-Larvae	5,213	5,016	4,862	18,484	13,271
Larvae	9,933	9,779	9,970	21,182	11,248
Juveniles	4,998	4,964	5,606	9,519	4,521
Total	20,144	19,759	20,437	49,184	29,040
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	-197	-188	13,429	13,429
Larvae	–	-85	-44	10,738	10,738
Juveniles	–	-34	6	4,706	4,706
Total	–	-316	-225	28,873	28,873

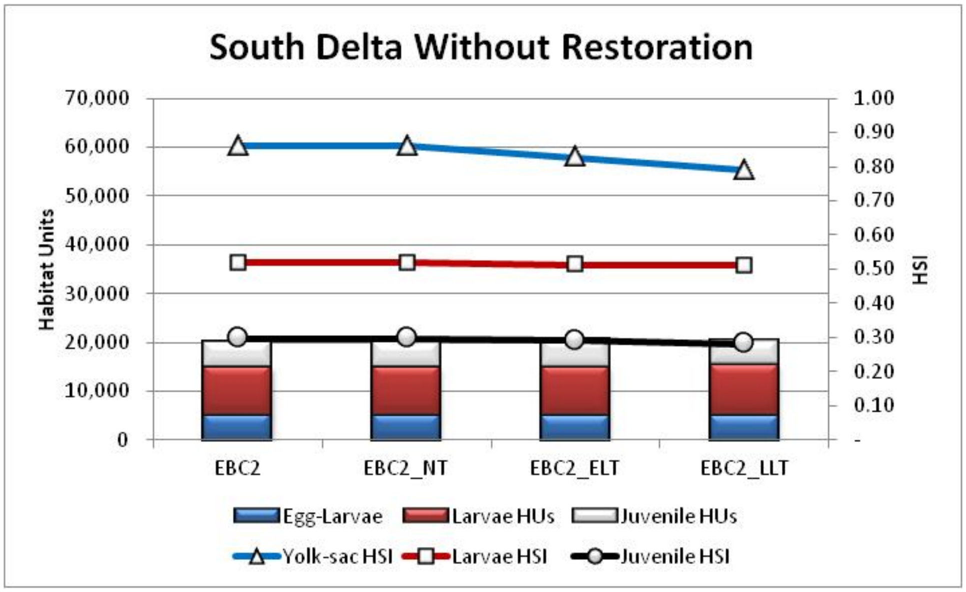


Figure 5.E.4-79A. Sea Level Rise Only: 1,025 Aquatic Acres Added to Subregion

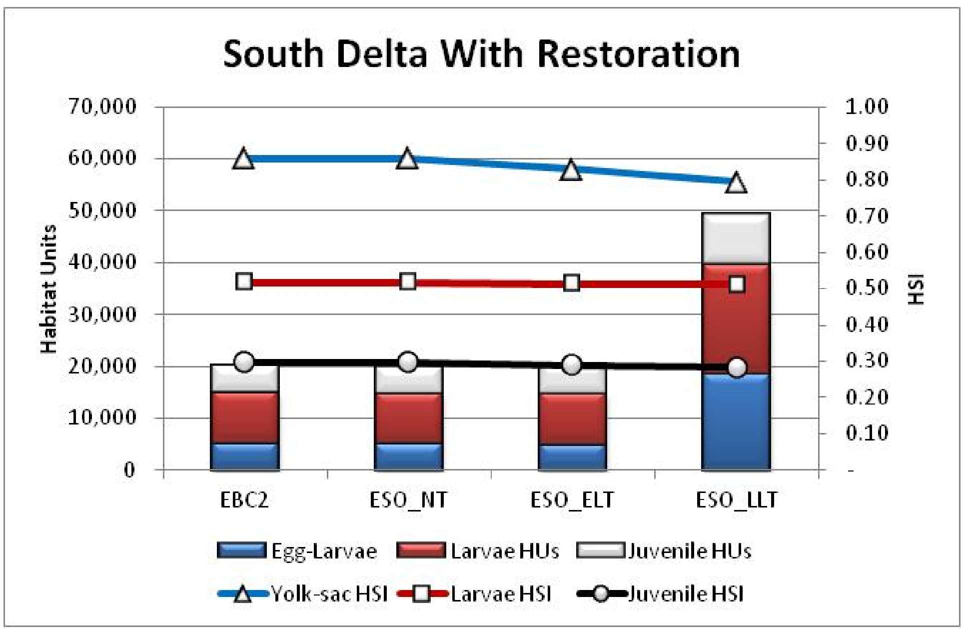


Figure 5.E.4-79B. Sea Level Rise + Restoration: 22,847 Aquatic Acres Added to Subregion

Figure 5.E.4-79. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Delta Smelt in the South Delta Subregion

Longfin Smelt

In the South Delta longfin smelt life stages are salvaged in the south Delta pumps, indicating that longfin smelt move or are drawn into the area. Generally, salinity is too low, temperature too high, and turbidity too low to provide suitable conditions.

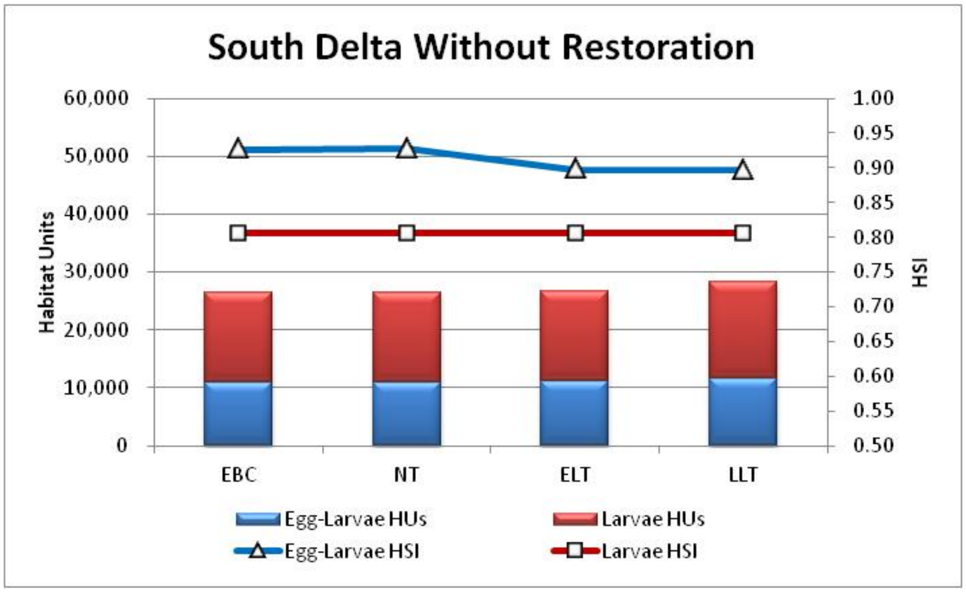
Habitat Suitability Analysis

Habitat suitability in the south Delta for longfin smelt was relatively high and appreciably better than for delta smelt (Figure 5.E.4-80). As in the East Delta subregion, this was because larval delta smelt were assumed to leave the south Delta by April, prior to the decreased turbidity of summer and fall. As for other species, suitability for spawning (egg-larvae) declined over time because of climate change–related increase in water temperature.

Sea level rise increased shallow freshwater tidal habitat and, to a lesser extent, the deeper subtidal habitat. This is seen in the larger increase in HUs for larval longfin smelt relative to the increase in habitat for the egg-larvae stage (Table 5.E.4-37). CM4 further increased the amount of shallow freshwater tidal habitat in the South Delta which greatly increased HUs for larval longfin smelt in the LLT (Figure 5.E.4-80).

Table 5.E.4-37. Habitat Units Estimated for Juvenile Longfin Smelt in the South Delta Subregion by Time Period, with and without the BDCP

South Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Egg-Larvae	11,012	11,012	11,199	11,685	672
Larvae	15,366	15,366	15,366	16,493	1,126
Total	26,379	26,379	26,565	28,177	1,799
ESO (Sea Level Rise + BDCP Restoration)					
Egg-Larvae	11,012	11,110	11,349	13,302	2,289
Larvae	15,366	15,234	15,234	33,396	18,029
Total	26,379	26,344	26,583	46,697	20,319
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Egg-Larvae	–	98	150	1,617	1,617
Larvae	–	(132)	(132)	16,903	16,903
Total	–	(34)	18	18,520	18,520



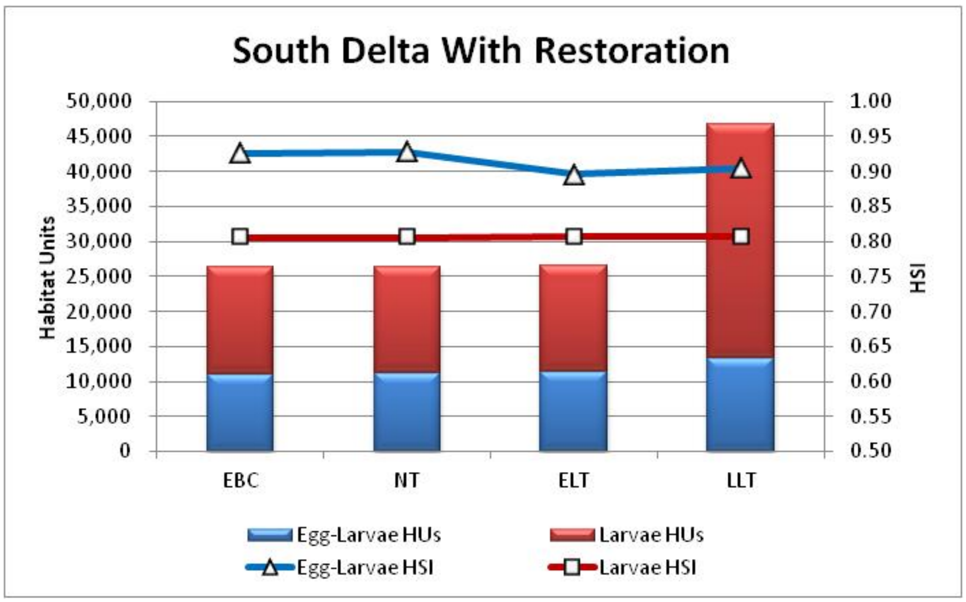


Figure 5.E.4-80. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Longfin Smelt in the South Delta Subregion

Salmonids

Restoring a wetland corridor in the South Delta may improve survival of salmonids from the San Joaquin River tributaries. Tidal wetland rearing habitat also would provide an improved migration corridor that would serve as an alternative to the main San Joaquin River route and may improve survival of salmonids from the San Joaquin River tributaries. Restoration in the South Delta ROA would be phased to occur after the construction of the north Delta diversion, in order to reduce entrainment risk for fish entering the interior Delta down Old River and the newly restored migration corridor.

Habitat Suitability Analysis

Conditions in the South Delta resulted in moderate HSI values for juvenile salmonids similar to those in the East Delta subregion (Figure 5.E.4-81). Suitability for both behavior forms was reduced by low turbidity levels.

Currently (EBC) the South Delta has more HUs for migrant juvenile salmonids than for foraging salmonids because of the greater amount of subtidal habitat. With sea level rise, shallow tidal habitat in the South Delta increased more than subtidal habitat resulting in a greater increase in HUs for foragers than for migrants by the LLT (Table 5.E.4-38).

CM4 further increased shallow tidal habitat in the South Delta resulting in a greater increase in HUs for foraging juvenile salmonids in the LLT relative to migrant salmonids (Figure 5.E.4-81). Although under current conditions (EBC) the South Delta had appreciably more HUs for migrants than for foragers, by the LLT there were similar proportions of habitat for the two behaviors as a result of sea level rise and CM4 restoration.

Table 5.E.4-38. Habitat Units Estimated for Juvenile Salmonid Behavior Patterns in the South Delta Subregion by Time Period, with and without the BDCP

South Delta	Current	NT	ELT	LLT	Total Change
EBC2 (Sea Level Rise Only)					
Foragers	4,363	4,363	3,604	5,036	674
Migrants	8,514	8,514	8,514	8,768	255
Total	12,876	12,876	12,118	13,805	929
ESO (Sea Level Rise + BDCP Restoration)					
Foragers	4,363	4,251	3,513	13,607	9,244
Migrants	8,514	8,511	8,511	14,609	6,095
Total	12,876	12,762	12,024	28,215	15,339
Change from BDCP Restoration Only (Sea Level Rise Removed)					
Foragers	–	(112)	(91)	8,570	8,570
Migrants	–	(3)	(3)	5,840	5,840
Total	–	(115)	(94)	14,410	14,410

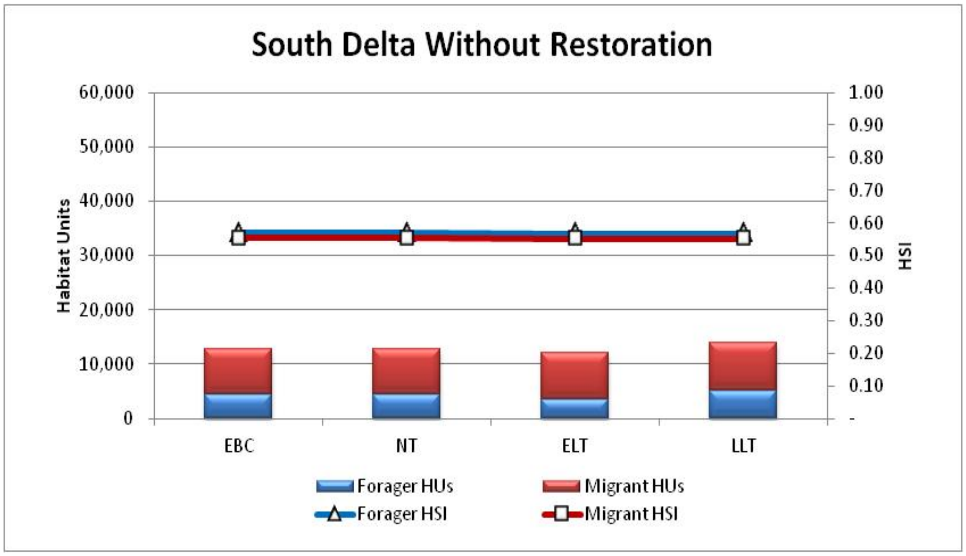


Figure 5.E.4-81A. Sea Level Rise Only: 1,025 Aquatic Acres Added to Subregion

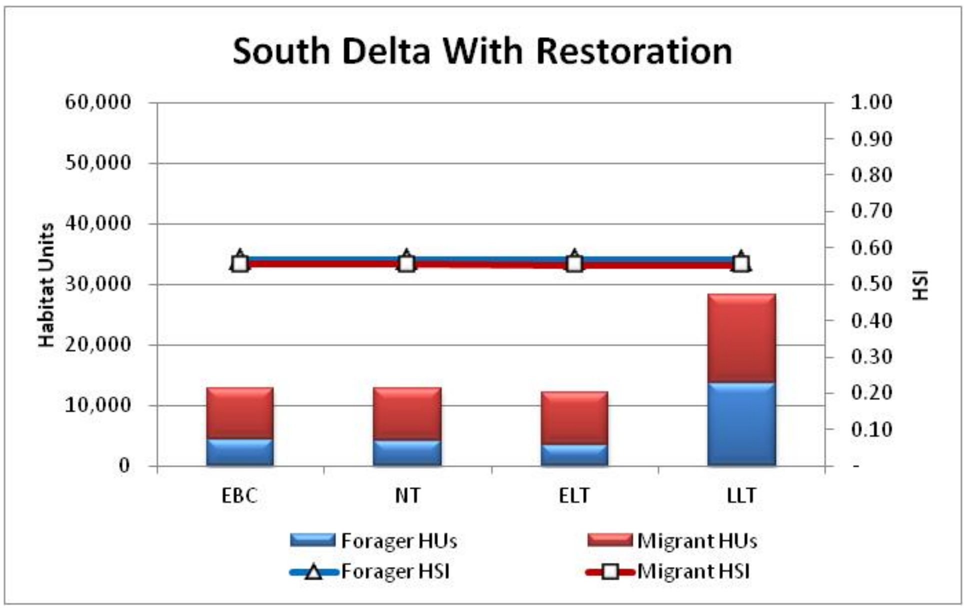


Figure 5.E.4-81B. Sea Level Rise + Restoration: 22,847 Aquatic Acres Added to Subregion

Figure 5.E.4-81. Habitat Suitability Index (HSI) and Habitat Unit (HU) Results for Juvenile Salmonid Behavior Patterns in the South Delta Subregion

Potential Impacts of Tidal Habitat Restoration on Splittail, Sturgeon, and Lamprey

Relatively little research has been conducted on the dietary, habitat and life-history requirements of green and white sturgeon in the Delta. Even less is known about the biology of lamprey and their use of aquatic habitat in the Plan Area. As a result an analysis of habitat suitability is not possible. Instead, a qualitative discussion of the potential use of the restored habitat for these species follows.

Splittail

Splittail occur throughout the Plan Area in a variety of habitats (Moyle et al. 2004). Splittail appear to be highly tolerant of a wide range of conditions likely to be encountered in the plan area (Young and Cech 1996). Year class strength of splittail is believed to be highly dependent on the extent and duration of flooding in areas such as the Yolo Bypass (Sommer et al. 1997).

The BDCP will benefit splittail in two major ways. First, in regard to CM4, once juvenile splittail have left the floodplain and move downward into the brackish areas of the Delta there will be more rearing habitat. Restoration in Suisun Marsh and the West Delta as well as Cache Slough is intended to provide habitat that has abundant food resources and sanctuary from predators. In diets of splittail, Feyrer et al. (2007) found that the majority of the diet was made of detritus, followed by mysids and clams. The increase in emergent marsh from BDCP restorations will increase substantially the amount of detrital surface area and is hoped to provide more of the valuable phytoplankton that mysids need to proliferate. Second, *CM2 Yolo Bypass Fisheries Enhancement* will inundate Yolo Bypass for a critical period of time (30 days) more often giving splittail more opportunity for spawning and larval rearing. In addition, floodplain restoration in CM5 could benefit splittail spawning to the extent that duration of inundation meets the critical 30 day criteria.

Sturgeon

Sturgeon spawn in riverine environments and appear to use the Delta for juvenile and adult rearing migration (Moyle 2002). The extreme loss of historical freshwater tidal marsh in the Delta may have lowered the carrying capacity of the entire system for sturgeon, so any increase in tidal habitat is likely to be beneficial (Israel and Klimley 2008). Habitat restoration under CM4 results primarily in an increase in shallow-water habitat that may augment feeding opportunities for sturgeon.

Little is known about juvenile sturgeon habitat use of floodplains and Delta habitats, although juvenile sturgeon on the Columbia River forage in riparian habitats, making it likely that they can use shallow vegetated habitats within the Plan Area (Van der Leeuw et al. 2006). Sturgeon typically consume tube-dwelling amphipods, mysids (*Neomysis* spp.), isopods, benthic invertebrates, and fish eggs or fry, including those of other sturgeon (Brannon et al. 1987; Pacific States Marine Fisheries Commission 1992). *Potamocorbula* is a major prey item in more saline waters (Moyle 2002). Prey species may benefit from increased phytoplankton and detritus from restored tidal wetland and add to the prey base for sturgeon. Tidal marsh restoration should result in increase in mud flats, which sturgeon are known to access for food (Israel and Klimley 2008). If this occurs, sturgeon juveniles and adults may benefit from the increased habitat.

Suitability of restored habitat for juvenile sturgeon rearing depends on water quality and food availability. High temperatures in the southern portion of the Delta may limit use by sturgeon in some months. Channelization and diking have negatively affected the amount of subtidal and intertidal habitat available for green sturgeon foraging. Invasive plant species in the southern Delta subregions likely have affected the quantity of shallow-water habitat available to coastal migrant and adult green sturgeon, and alterations of the foodweb brought about by the presence of invasive species also have likely shifted green sturgeon estuarine diet. Juveniles of other sturgeon species in other systems feed on drifting insects. Juvenile sturgeon may use the year-round tidal freshwater habitats for feeding.

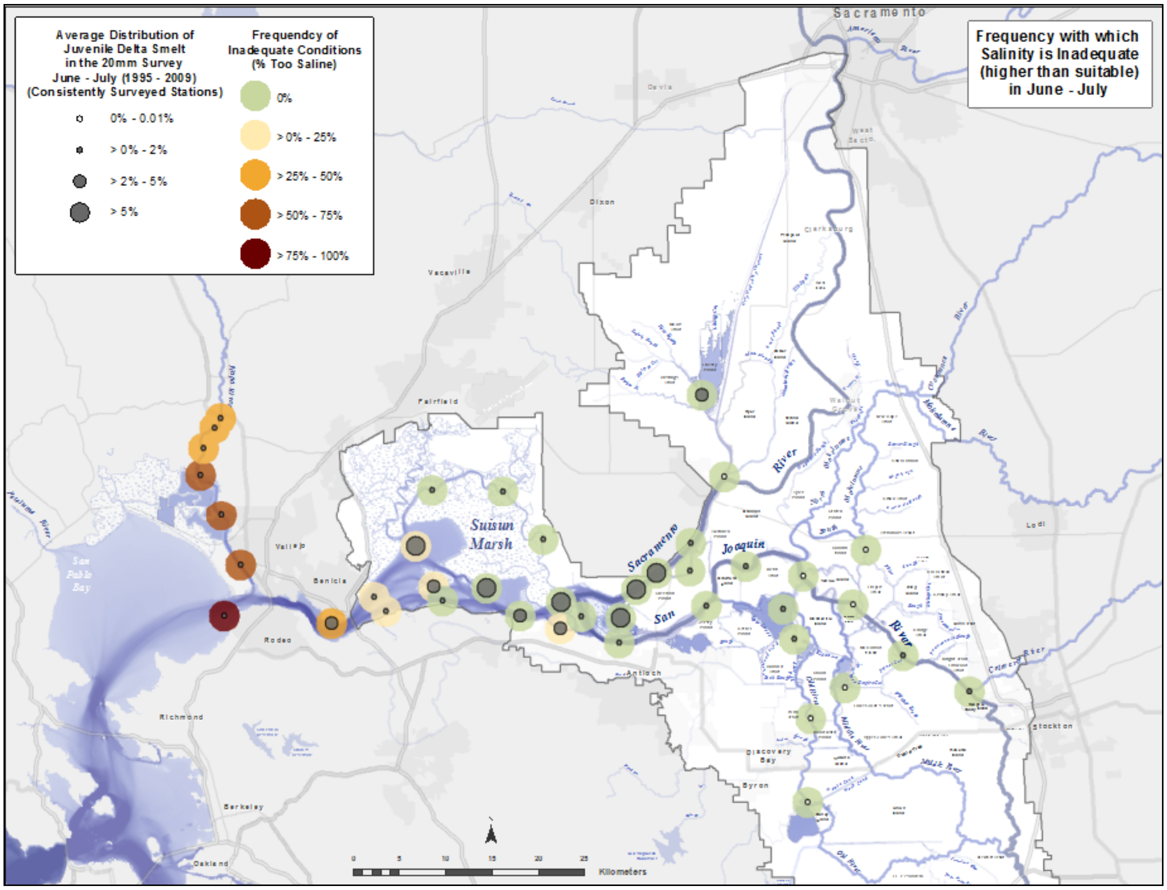
Lamprey

Lamprey have been little studied in the Plan Area and in California in general (Moyle 2002). Pacific and river lamprey appear in the Plan Area. Both species are anadromous, spawning in tributaries upstream of the Delta. Lamprey use the Plan Area primarily as a migratory route to access upstream areas for spawning and marine waters for adult feeding. In most years electrofishing studies catch lamprey ammocoetes (unidentified) in surveys in the Plan Area (Brown and Michniuk 2007), but the Delta likely represents a sink for individuals that have been swept downstream during high-flow events rather than a beneficial rearing area. Because lamprey appear to use the Plan Area mainly for migration, it seems unlikely that they would benefit from CM4 restoration beyond the value that restoration may provide to the Delta foodweb and ecology.

Scale of HSI Analysis Compared to Actual Restoration Projects

The HSI approach in this appendix has been applied at the scale of the geographic subregion and their ROAs and the hypothetical restoration footprint. Within each area, habitat suitability values were generated for each habitat type. Because of the scale of the analysis, habitat suitability ratings (e.g., temperature, turbidity) were necessarily limited to average or estimated values within an ROA for each of the three habitat types. The purpose of the analysis is to compare the expected beneficial effects of the ESO with the existing biological condition, with consideration of climate change effects. While this analysis suggests factors that are likely to be important in restoration design, it is not intended to determine where or how restoration projects are implemented. During Plan implementation, restoration projects will be designed at a much smaller scale than an ROA (i.e., multiple projects per ROA), which will provide the opportunity to design each project to best meet the habitat needs of the target covered species within the constraints of specific sites. Attachment 5E.B, *Review of Restoration in the Delta*, is an extensive review of restoration to date in the Delta and a synthesis of lessons learned that addresses restoration at a site-specific level. At the design scale (several hundred acres to low thousands of acres) and design level of detail, restoration projects will be able to account for physical and biological site conditions that could not be modeled by this analysis at the scale of an entire ROA and account for variables unavailable at the scale of an ROA. Furthermore, additional analysis will be conducted to select the best sites for restoration projects beyond what was performed at the regional planning level used in this appendix (i.e., the hypothetical restoration scenario) and described in Chapter 3, *Conservation Strategy*.

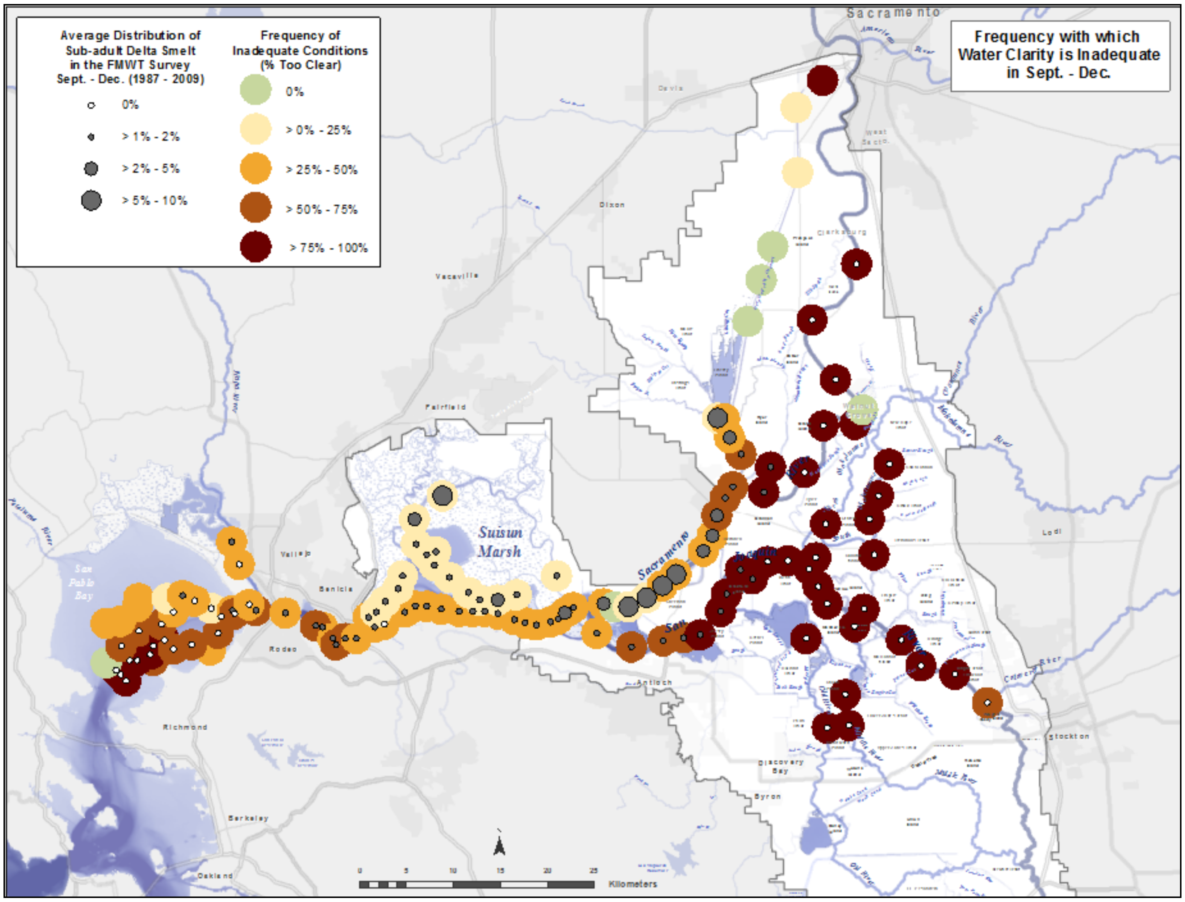
One effort that could be used to improve restoration planning in the future is new work conducted by Hamilton and Murphy (unpublished data 2012, in review), which could be used to help identify areas with high restoration potential and improve restoration planning for Plan implementation. Their work estimates affinities of delta smelt for various habitat parameters in and near the Plan Area. Hamilton and Murphy catalog nearly two dozen environmental variables that they evaluated as potentially useful to inform the process of identifying candidate actions and locations for restoration efforts to enhance the extent and value of habitat for delta smelt. Their approach uses a larger set of physical and biological parameters than have been applied to the large-scale habitat suitability approach used in this appendix. The preliminary results of the Hamilton and Murphy work are consistent with the results of the habitat suitability analysis used here; they include depth, food availability, and proximity to wetlands in addition to the attributes used in this appendix. Similar to the analysis in this appendix, Hamilton and Murphy use agency-generated data on the co-occurrence of delta smelt from four standard fish surveys and site-specific environmental data for the parameters described above to establish a range of variable conditions that appear to be preferred by delta smelt and, in so doing, identify environmental conditions both advantageous and adverse to delta smelt. The findings establish an operational definition of habitat similar to that developed for this analysis that is based on patterns of delta smelt occurrence across the surveyed estuary (Figure 5.E.4-82 and Figure 5.E.4-83). Hamilton and Murphy's results could be applied in Plan implementation to help prioritize and select optimal restoration sites among and within ROAs and to design effective restoration projects for delta smelt. Although these results apply only to delta smelt, they can be considered in the context of the multi-species benefits that tidal wetland restoration under the BDCP is intended to provide.



Gray circles indicate the across-years average of the percentage effort-corrected catch of juvenile delta smelt in the 20-mm survey during June and July at each monitoring station

Source: Hamilton and Murphy unpublished data.

Figure 5.E.4-82. Distribution of Delta Smelt from the 20-mm Trawl Surveys and the Frequency with Which Salinity Is Inadequate, with Salinity Too High



Gray circles indicate the average, across years, of the percentage effort-corrected catch of subadult delta smelt in the Fall Midwater Trawl Survey from September through December at each monitoring station. Source: Hamilton and Murphy, unpublished data.

Figure 5.E.4-83. Distribution of Subadult Delta Smelt from the Fall Midwater Trawl Surveys and the Frequency with Which Turbidity Is Inadequate

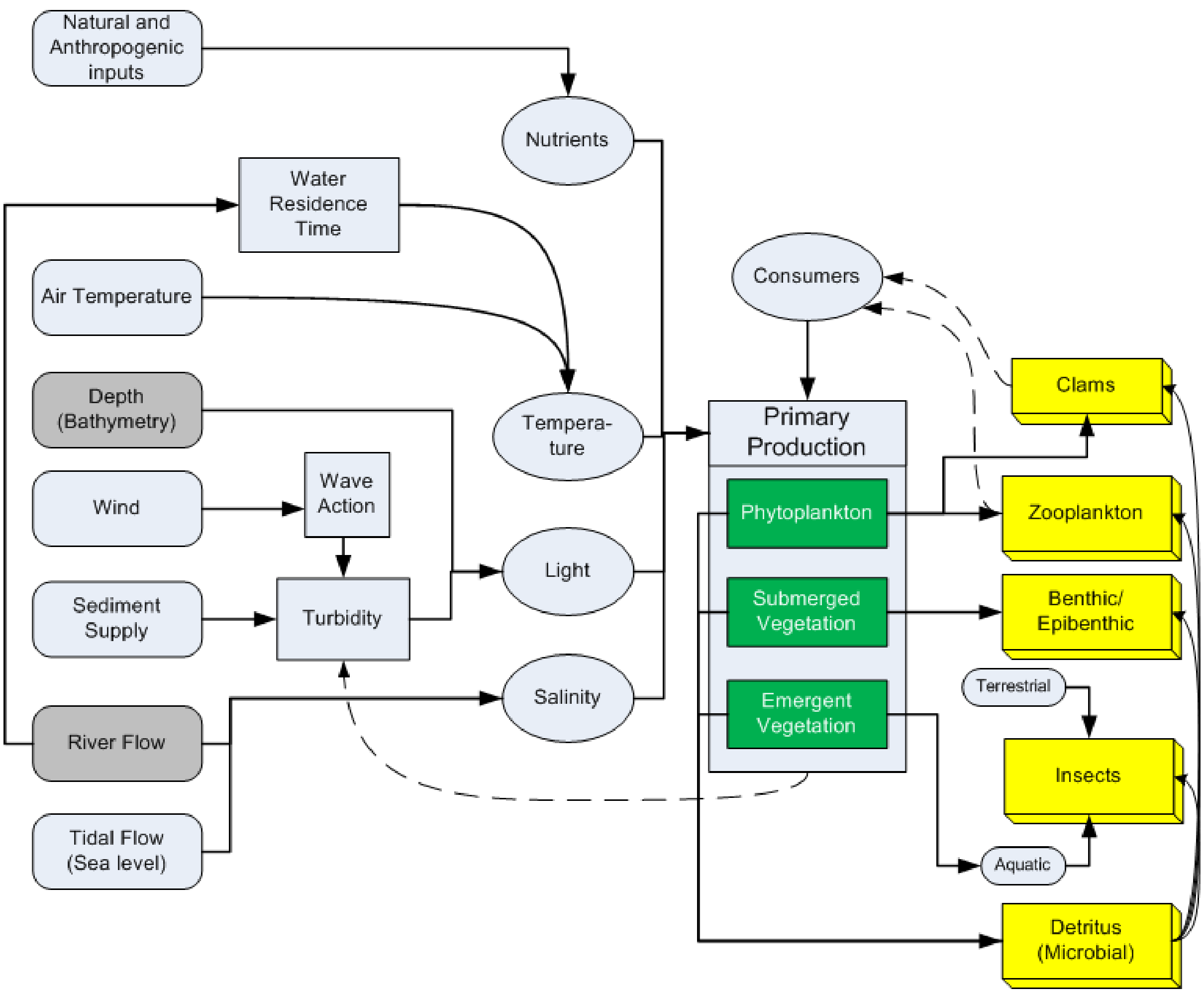
5.E.4.4.2.5 Food in the Delta and the Effect of the Conservation Measures on Food for Covered Fish Species

Introduction

A major purpose for *CM4 Tidal Natural Communities Restoration* is to increase food supply for covered fish species. The quantity, quality, and availability of food in the Delta is believed to be a significant limiting factor for covered fish species (Winder and Jassby 2011). Major changes in the species composition and abundance of zooplankton in the Delta are believed to be linked to the Pelagic Organism Decline (POD), which describes the abrupt and significant decline in several native fish species that occurred around 2000 (Sommer et al. 2007). The POD has been related to an ecological regime shift in the Delta (Sommer et al. 2007; Baxter et al. 2010). Causes of the ecological shift in the Delta include introduced species (plants, invertebrates, and fish) and a shift in nutrient dynamics supporting phytoplankton resulting in part from pollutant discharge (Sommer et al. 2007; Glibert et al. 2011; Parker et al. 2012).

Conceptual Model

The Delta foodweb is complex and includes a variety of food types that are potentially used by covered fish species (Durand 2008). Each fish species relies on a variety of types of food although each species has its own unique preferred prey and feeding strategies. For purposes of this discussion a simplified conceptual model of food production in the Plan Area is presented in Figure 5.E.4-84.



Ovals are physiological drivers on primary production; green boxes are types of primary production while yellow boxes are categories of food for covered fish species. Grey boxes denote controls that are influenced by BDCP. Dashed line indicates a feedback loop.

Figure 5.E.4-84. Simplified Conceptual Model for Delta Foodweb Supporting Covered Fish Species

Primary Production in the Delta

While there are many factors controlling the production of potential food (Durand 2008) all food used by covered fish species is ultimately derived from photosynthetic primary production in the form of phytoplankton, submerged aquatic vegetation (SAV), benthic algae or emergent macro-vegetation such as tules. Primary production, either alive or dead (detritus) is consumed by various organisms that are the prey of covered fish species. Primary production is in turn controlled by a number of physical, chemical, and biological drivers (Figure 5.E.4-84)

The four main types of aquatic plants are arrayed across the Delta in regard their abilities to exploit different environments.

- Phytoplankton are pelagic microscopic plants.
- SAV are macrophytes such as *Egeria* that are found within the water column.
- Benthic algae occur on shallow substrates.
- Emergent plants are rooted plants such as tules that occur in shallow environments.

Phytoplankton is generally considered the driver of the Delta foodweb (Jassby et al. 2003) and is directly eaten by secondary consumers such as zooplankton. SAV and rooted macrophytes produce detritus and provide substrate and habitat for secondary consumers that are eaten by fish (Grimaldo et al. 2009). The dominant SAV species in the Delta such as *Egeria* and water hyacinth are invasive. While they can provide detritus and substrates for epibenthic prey they are largely known for their negative impacts on the ecosystem of the Delta by providing shelter and habitat for nonnative pisciverous fish species (Nobriga and Feyrer 2007). SAV also decreases turbidity by slowing water velocity and trapping sediment which is generally bad for native pelagic fish species adapted to turbid conditions.

Phytoplankton

In the Delta, phytoplankton is the main source of organic matter for zooplankton and the foodweb supporting fish (Jassby and Cloern 2000; Müeller-Solger et al. 2002; Sobczak et al. 2002, 2005; Kimmerer 2005). Of the Delta habitats, tidal marsh sloughs have the highest phytoplankton concentrations and support the greatest zooplankton growth rate (Müeller-Solger et al. 2002; Sobczak et al. 2002). The Delta's phytoplankton community includes diatoms, cryptophytes, blue algae, green algae, and flagellates. Diatoms provide the most important food source for the zooplankton prey of native fish species because of their high nutritional value and accessibility (Brett and Müeller–Navarra 1997). In recent decades, diatom production in the Delta has declined dramatically (Jassby and Cloern 2000; Jassby et al. 2002, 2003), and there have been parallel declines in the zooplankton populations of the West Delta and Suisun Bay (Müeller-Solger et al. 2002; Sobczak et al. 2002; Kimmerer 2005). Since the mid-1990s, phytoplankton production has recovered to some extent in the Delta, although production remains low (Jassby 2008). At the same time, no trend has been apparent in phytoplankton in Suisun Bay, even though grazing by *Potamocorbula* remains a factor. Scientists hypothesize that export of phytoplankton production from the upper estuary is helping to maintain the Bay's zooplankton (Baxter et al. 2010).

Established tidal marsh habitat in the Delta contains the highest concentrations of phytoplankton (Müeller-Solger et al. 2002; Sobczak et al. 2002). Production of phytoplankton is high in some recently restored tidal wetlands in the Plan Area (e.g., Liberty Island) (Lehman et al. 2010b) and Mildred Island (Lucas et al. 2002). Local production of phytoplankton may be exported to adjacent channels and habitats with proper depth, residence time, hydraulic connection, and limited grazing by clams (Lucas et al. 2002; Lopez et al. 2006).

Emergent Vegetation

Tidal marshes are a unique part of estuarine wetlands that are categorized by the presence of emergent vegetation (Chapman 1960, 1976; Mitsch and Gosselink 1993). Tidal marshes are often defined by their range of salinity tolerance and the plants that are found within those salinity ranges. Tidal marshes can be found from coastal areas with full salinity to fresh water marshes found in estuarine river systems (Kneib et al. 2008).

Emergent vegetation is an important structural component of tidal marshes and when coupled with hydrology the interactions of the two influence ecological services. One service that is provided is that of essential habitats for biota (Visintainer et al. 2006). Emergent plants increase the complexity of habitat which is associated with high levels of diversity because there are a larger number of microhabitats per unit area (McCoy and Bell 1991) and variable microhabitats provide alternative resources. The architecture (plant stem area) of emergent vegetation often structures invertebrate communities because architecture influences a plant's surface-to-biomass ratio (Lalonde and Downing 1992). Emergent vegetation providing greater surface area creates favorable conditions for periphyton colonization which leads to more macroinvertebrates because there is increased habitat to use (Krecker 1939; Rosine 1955; Dvorak and Best 1982; McAbendroth et al. 2005). Another service provided by emergent vegetation is that of producing organic matter. Organic matter (decomposing emergent vegetation) can enter the detrital based foodweb through fungi and bacteria driven processes, although substantial production is lost to respiration by the microbial community (Kneib 2003). Another function of this mass of decomposing plant matter is the increase of surface area for periphyton to grow on as compared to a less variable sediment bottom.

Submerged Aquatic Vegetation (SAV)

The rapid expansion of SAV, especially *Egeria*, has caused changes in the physical habitat and water quality that have displaced native fish and favor a foodweb more suitable for nonnative centrarchid fish, such as largemouth bass. Invasive SAV can act as an ecosystem engineer, defined as "organisms that directly or indirectly modulate the availability of resources to other species by causing physical state changes in biotic or abiotic materials" (Jones et al. 1994). Specifically, invasive SAV fundamentally alters the aquatic environment by increasing sedimentation and reducing turbidity. The decreased turbidity increases the light penetration through the water column and further increases SAV growth. This positive feedback may be an important factor contributing to the ecological regime shift (Scheffer and Carpenter 2003) that has occurred in the Delta from a turbid phytoplankton-dominated system to the current clear-water SAV-dominated state of the Delta (Baxter et al. 2010). SAV can alter water quality, including parameters important for covered fish species such as DO, water velocity, turbidity, and nutrient flux and balance that may affect planktonic foodweb dynamics. The sedimentation caused by SAV affects phytoplankton and zooplankton abundance by sequestering nutrients, resulting in a decrease in phytoplankton in the water column. In lakes, dense SAV has been shown to serve as a refuge from predators for zooplankton (Stansfield et al. 1997). Dense patches of invasive aquatic vegetation (IAV) block light penetration into the water column in nearshore, shallow, freshwater habitat, which can create an undesirable and anoxic habitat for diatoms, phytoplankton, and zooplankton. Consequently, these organisms are less successful in areas occupied by SAV.

Because SAV species support distinct invertebrate assemblages that form the prey base for some covered fish species, removal of dense SAV may change productivity or food availability for covered species. The field evidence suggests that native SAV species may support a higher proportion of native invertebrates that are favored by, and available to, native fish (Toft 2000). It has been shown that macrophyte-epiphyte complexes are the most important primary producers in the littoral zone (Vis 2004), and large modifications of these plant assemblages can cause trophic cascades into higher trophic levels of the foodweb by altering the plant and periphyton eating macroinvertebrates (Healey 1984; Bertolo et al. 2005). In a stable isotope analysis of the pelagic and littoral foodwebs of the Delta, Grimaldo et al. (2009) found evidence that the SAV-epiphytic macroalgae pathway was important to the fishes of the Delta. There was also evidence that there was small to modest contributions from this pathway to open-water shoal habitats. Specifically it was found that amphipods (epiphytic-macroalgae grazers) were modeled to account for up to a third of the diet of American shad and threadfin shad, both of which are pelagic species.

Detritus

Many fish species are often found with detritus in their guts including splittail, sturgeon and, to lesser degrees salmonids and smelts. Detrital diets have been shown to support growth and reproduction in smaller invertebrate prey populations such as amphipods (Kneib 1997). Feyrer et al. (2003) found that detritus was the most prevalent food item found in splittail guts, although they also consumed bivalves (including *Potamocorbula*) and mysids.

Most Bay-Delta foodweb studies have focused on the phytoplankton-based pelagic foodweb, considering the detrital pathway to be relatively unimportant (Jassby et al. 1993; Jassby and Cloern 2000; Sobczak et al. 2002, 2005). However, the detrital pathway is important in many other estuaries and is poorly studied in the Delta. Grimaldo et al. (2009) showed that many marsh organisms are supported by a number of additional sources of primary production, including submerged aquatic vegetation, epiphytes, filamentous algae, and detritus. Howe (2006) and Howe and Simenstad (2007, 2011) found that marsh-derived organic matter contributed significantly greater amounts of organic matter to the base of the foodweb in the study’s shallow marsh environments than phytoplankton.

Decomposition of emergent vegetation may begin while the emergent plant is still upright, and fungi play an important role in this (Kneib 2008). Fungi conversion of live plant biomass is high, in the 50–60% range (Newell and Porter 2000). Consumers including gastropods and amphipods use fungi as an important food source (Kneib 1997; Newell and Porter 2000). This is an important pathway to consumers as it more efficiently captures marsh production before it enters the microbial pathway were bacteria can respire most of the marsh production into the atmosphere and re-mineralize nutrients that may become available to phytoplankton or benthic algae (Kneib 2008). Intertidal Marsh systems contain large amounts of plant material in varying stages of decomposition and it is not surprising that many consumers are commonly found with detritus in their guts (i.e., splittail). Detrital diets have been shown to show growth and reproduction in smaller invertebrate prey populations such as amphipods (Kneib 1997). The less direct pathway of consumption of microbial decomposers by invertebrates that are then available to fishes and other nekton seems the most likely pathway in which emergent marsh vegetation-detritus contributes to production of small fish and invertebrates (Kneib 2008).

Drivers of Photosynthesis in the Delta

Photosynthesis is controlled by a number of factors related to light availability and species physiology. Drivers are proximal controls that determine the amount and type of primary production available to secondary consumers (Figure 5.E.4-84).

Light

All photosynthetic processes are ultimately driven by light. The amount of light determines the production and distribution of phytoplankton, SAV, and emergent vegetation. Light available to aquatic photosynthesizers is dependent on turbidity and depth.

Turbidity

Turbidity decreases the amount of sunlight available for photosynthesis and is affected by any suspended material including sediment, detritus, and planktonic organisms. Wind-driven waves stir up and resuspend material and are an important contributor to turbidity. SAV such as *Egeria* slow water velocities and trap sediment increasing turbidity. The supply of sediment from the Sacramento–San Joaquin Rivers watershed to the Delta is limited and apparently declining (Wright and Schoellhamer 2004) due to trapping of sediment behind dams and diminishment of the hydraulic mining sediment pulse. As are result, water clarity is generally increasing in the Delta (Wright and Schoellhamer 2004).

Depth

Water depth affects primary production by limiting light penetration. Phytoplankton production is dependent on the amount of water that is photosynthetically active (the photic zone). The production of phytoplankton tends to be higher in the shallower portions of the Delta where phytoplankton cannot be mixed below the photic zone (Lopez et al. 2006). Important copepod species tend to be throughout the water column; thus in shallow areas with high primary productivity, secondary production tends also to be high (Durand 2008). Water depth also affects SAV and emergent vegetation colonization. Where the land surface elevation is greater than mean tide level, brackish emergent vegetation can colonize the site (Orr et al. 2003). Freshwater emergent vegetation colonizes down to 0.2 m below mean lower low water (Simenstad et al. 2000). Tidal inundation regime strongly influences zonation patterns in marsh plant communities (Batzer and Sharitz 2006).

Temperature

Phytoplankton growth varies directly as a function of temperature. Temperatures in the Delta range from 12°C in winter to 22°C in summer, with a corresponding variation in productivity by season. Water temperature in the Delta is primarily controlled by air temperature. The exchange of heat from water to air interacts with riverine movement and tidal dispersion to set the overall temperature distribution across the Delta. Temperature can be elevated by increased residence time, a function of flow, because slower water is able to absorb more solar energy at a location.

Salinity

Salinity is a major determinant on the distribution of plant species across the Delta (Batzer and Sharitz 2006). Water moves in the Delta as the result of fresh water inflow, exports, tides, and salinity gradient driven inflow all acting through the sloughs and channels of the Delta. The tides and density driven flow are the engines that move seawater into the Delta. Delta outflow (dependent on Delta inflow and diversions) pushes salinity out of the Delta. These two forces working against one another determine salinity gradients throughout the Delta.

Nutrients

Photosynthesis in the Delta is seldom limited by the lack of nutrients, although the nature of these nutrients can affect relative species success. In addition to natural influx of nutrients from upstream sources, the Delta receives inputs from anthropogenic sources such as sewage treatment facilities, agricultural areas, and urban runoff. The nature of nutrients delivered to the Delta is believed to affect the species composition of phytoplankton because species utilize different forms of nutrients such as nitrogen (Glibert et al. 2011). The nutrient composition of the Delta has shifted through time due to pollutant inputs. Sewage treatment plants, for example, release large quantities of the ammonium which can inhibit the uptake of nitrate which is the driver of larger phytoplankton blooms (Glibert et al. 2011). This appears to have shifted species compositions of phytoplankton from larger more nutritious diatoms to smaller flagellates, SAV and rooted vegetation.

Elevated ammonium from sewer plant discharge may contribute to increases in the cyanobacterium *Microcystis aeruginosa*, first observed in the Delta in 1999 (Lehman et al. 2005, 2008a, 2010a). *Microcystis* rapidly assimilates ammonium over nitrate (Jassby 2005). *Microcystis* has a number of adverse effects on the Delta's aquatic foodweb. The decline in calanoid copepods (*Eurytemora* and *Pseudodiaptomus*) occurred at the same time *Microcystis* increased (Sommer et al. 2007). Studies show that copepod survival is depressed with higher abundance of *Microcystis* relative to more palatable phytoplankton. *Microcystis* blooms have become more common in the past decade, principally in the south Delta and the uppermost portions of the west Delta (Lehman et al. 2010a).

Consumption

In the past, primary production, such as phytoplankton, would be food for secondary consumers, such as zooplankton that would be consumed by Delta fish species. However, the situation changed significantly with the proliferation of invasive clams in the Delta. The introduction of the *Potamocorbula* has had dramatic effects on phytoplankton production in the brackish portions of the estuary and the associated foodweb. The role of clams has received particular attention. *Potamocorbula* invaded the brackish portion of the estuary in 1986, and rapidly reached densities that allowed the clam to remove phytoplankton at levels exceeding the phytoplankton growth rate (Kimmerer and Orsi 1996). Phytoplankton blooms that had occurred annually in the upper estuary in earlier years essentially disappeared after *Potamocorbula* became established. Flooded Delta islands where introduced clams are scarce (Mildred Island) or abundant (Franks Tract) have been shown to be net sources and sinks, respectively, of phytoplankton biomass for the pelagic foodweb, suggesting that invasive clams can exert strong top-down control on food availability (Lucas et al. 2002). *Potamocorbula* also is an efficient predator on many zooplankton species, including ciliates, rotifers, and copepod nauplii, though it is not known to feed on cladocerans (Kimmerer 2004). High rates of phytoplankton grazing by *Potamocorbula* have been implicated in the decline of both *Eurytemora* and the native mysid shrimp, *Neomysis mercedis*, which primarily feeds on copepods (Kimmerer et al. 1994; Kimmerer and Orsi 1996; Orsi and Mecum 1996).

Secondary Production in the Delta

Secondary production describes consumers of primary production. For the most part, covered fish species consume secondary production in the form of zooplankton, other crustaceans and insects (Figure 5.E.4-84).

Zooplankton

Zooplankton are small pelagic crustaceans that consume phytoplankton. Zooplankton form the primary pelagic food for delta smelt and other covered fish species. Prior to the 1980s, phytoplankton production in the upper estuary supported a stable zooplankton assemblage dominated by calanoid copepods (*Eurytemora affinis* and *Pseudodiaptomus forbesi*) and cladocerans (*Daphnia* spp.), the primary food resources of fish species in the area. Between 1975 and 1995, phytoplankton production declined by 43% (Jassby et al. 2002) from a combination of factors, including grazing by introduced clams, changes in precipitation patterns, and changing trends in total suspended solids (Jassby et al. 2002).In recent decades, diatom production in the Delta has declined dramatically (Jassby and Cloern 2000; Jassby et al. 2002, 2003), and there have been parallel declines in the zooplankton populations of the West Delta and Suisun Bay (Müeller-Solger et al. 2002; Sobczak et al. 2002; Kimmerer 2005). Müeller-Solger et al. (2002) showed that zooplankton are food-limited when chlorophyll *a* concentration (a measure of phytoplankton biomass) drops below 10 micrograms per liter (μg/L); most regions of the Delta rarely reach this concentration (Kimmerer and Orsi 1996; Sobczak et al. 2002; Kimmerer 2005).

Benthic and Epibenthic Production

Benthic organisms live within the sediment and epibenthic organisms live near or in close association with substrate such as sediment, SAV or macrophytes. Benthic organisms include worms, insects and some clams while epibenthic organisms are usually small crustaceans such as mysids and amphipods. Benthic and epibenthic secondary production is supported by phytoplankton and detritus. The production that is exported includes insects, invertebrates, zooplankton, fish, and birds (Kneib et al. 2008). Algal biomass in general is grazed as live biofilms that grow on vascular plant stems and decomposing vegetation on the substrate (Kneib 2008). Most, 90% of emergent plant biomass that is produced goes into the detrital based foodweb that is driven by fungi and bacteria (Kneib 2008).

Insects

Wetland insects play a prominent role in the consumption and processing of primary production and associated detritus and serve as an important food source for higher trophic levels, including a delta smelt, juvenile salmonids, splittail, invertebrate, and avian species (Davies 1984; Stagliano et al. 1998). Studies at Liberty Island found that insect larvae (primarily Chironomid pupae) were an important component of the delta smelt diet (Whitley and Bollens 2013) where they are often associated with emergent vegetation (tules) that serves as substrate for larval insects. Chironomid midge pupae were found to be the primary food source of juvenile Chinook salmon and were found a dominant food source in many fishes by Grimaldo et al. (2009) in isotope studies. Chironomidae is commonly reported as the dominate insect group from many wetland and estuarine studies (Wrubleski 1987; Leeper and Taylor 1998; Stagliano et al. 1998; Whiles and Goldowitz 2001; MacKenzie and Kaster 2004; Williams and Williams 1998a; Strayer and Smith 2000; MacKenzie 2005).

Clams

While the food benefit for many species may be reduced because of invasive filter-feeding clams, benthic-feeding splittail and sturgeon may benefit from the increased presence of clams. Studies of white sturgeon gut contents indicate that the invasive *Potamocorbula* may now be a major component of white sturgeon diet (Kogut 2008). Additionally, Feyrer et al. (2003) found that splittail compensated for less mysids in their diets by eating more bivalves including *Potamocorbula* after its introduction lowered myisid abundance.

Food Needs for Covered Fish Species

Delta Smelt

Delta smelt are generally consideded pelagic feeders. They appear to especially target the calanoid copepod *Eurytemora*, although the nonnative *Pseudodiaptomus* is now a major part of the diet because of its greater relative abundance (Lott 1998; Moyle et al. 1992; Nobriga 2002). However, recent work has shown that delta smelt have a varied diet that can include insects (Whitley and Bollens 2013).

Delta smelt have been particularly vulnerable to the declines in calanoid copepods because they feed on copepods throughout their lives, mainly in the brackish waters of the western Delta and Suisun Bay (Nobriga 1998). Recent declines in calanoid copepods have been linked to reductions in delta smelt abundance in several studies. Kimmerer (2008) demonstrated a strong positive correlation between survival of juvenile delta smelt and density of calanoid copepods from summer to fall. Miller et al. (2012) found that minimum density of *Eurytemora* and *Pseudodiaptomus* during the spring larval period and their average density during the fall were significantly related to interannual trends in fall delta smelt relative abundance. MacNally et al. (2010) found some statistical evidence that summer calanoid copepod density was associated with annual trends in abundance of delta smelt in the fall.

Longfin Smelt

Lonfin smelt are also generally considered pelagic feeders on zooplankton. The published scientific literature strongly supports the conclusion that longfin smelt are food-limited (Durand 2008). A number of studies have shown a link between declining food availability and longfin smelt abundance in the Plan Area (Lopez et al. 2006; Baxter et al. 2010; Rosenfield and Baxter 2007; MacNally et al. 2010). Diet studies indicate that longfin smelt larvae feed extensively on *Eurytemora* and *Pseudodiaptomus* (Hobbs et al. 2006), while juveniles and adults feed primarily on mysid shrimp, including *Neomysis* and *Acanthomysis* spp. (Feyrer et al. 2003). Rosenfield and Baxter (2007) identified a decline in the survival of longfin smelt between Age-1 and Age-2 that may be the result of a decline in the abundance of prey items following establishment of *Potamocorbula*. MacNally et al. (2010) found some statistical evidence that spring/summer calanoid copepod biomass and summer mysid biomass were linked to annual trends in abundance of longfin smelt in the fall.

Sacramento Splittail

Splittail have a varied diet that included zooplankton, insects and detritus (Sommer et al. 2008). Little information exists regarding food-resource limitation of splittail. There is some indication that splittail are food-limited given that splittail growth rates declined following the invasion of *Potamocorbula* and the collapse of *Neomysis* due to high rates of grazing by *Potamocorbula* (Feyrer et al. 2003). Increased food production under the BDCP would be of importance in and adjacent to areas currently occupied by splittail (Cache Slough, West Delta, and Suisun Marsh ROAs).

Chinook Salmon

Salmonids that are seasonally present in the Plan Area include four runs of Chinook salmon along with steelhead. The juveniles of some salmonids may spend weeks or months rearing in the lower reaches of the rivers and the Delta prior to migrating to coastal marine waters (e.g., fall-run Chinook salmon) (Kjelson et al. 1982), and the use of tidal wetlands by foraging salmon fry is well-documented (Williams 2006; Shreffler et al. 1990, 1992; McLain and Castillo 2009).

Moyle (2008) cites food limitation as a factor for Chinook salmon in the Delta. Chironomids are the dominant prey item (Williams 2006). A number of studies in the Bay-Delta indicate that Chinook salmon and steelhead fry and juveniles forage in tidal marshes, channels, and sloughs (Williams 2006; Shreffler et al. 1990, 1992; Sommer et al. 2001a, 2001b; Moyle et al. 2002, 2004).

Sturgeon

White and green sturgeon are long-lived species that use the estuary as a migration corridor, feeding area, and juvenile rearing area. Individuals of both species spend the majority of their lives in brackish portions of the estuary in deep water, although a small number of individuals dwell in the ocean (Moyle 2002).

Information on juvenile sturgeon diet and physical habitat needs in the Delta is limited. Most of the available information on sturgeon diet is based on other species of sturgeon, located outside of the Delta (Israel and Klimley 2008; Israel et al. 2009). Nothing is known about the diet of white sturgeon larvae in the wild, although laboratory studies suggest that it consists of benthos, periphyton, and possibly pelagic fry and zooplankton (Brannon et al. 1987; Buddington and Christofferson 1985). Juvenile white sturgeon also may consume tube-dwelling amphipods, mysids (*Neomysis* spp.), isopods, benthic invertebrates, and fish eggs or fry, including those of other sturgeon (Brannon et al. 1987; Pacific States Marine Fisheries Commission 1992).

Evaluation of BDCP Restoration on Delta Food Production

The primary objective of tidal natural community restoration is to increase the quantity of high-value habitat for covered fish species, which includes enhancing the Delta foodweb for native fish species. Expansion of shallow tidal areas as a result of CM4 restoration is intended, in part, to enhance processes supplying food to covered fish.

Evaluation of the potential benefits of Delta restoration in regard to food production involves a combination of a quantitative index of primary production and qualitative evaluation based on scientific literature discussed above. At present, there is no comprehensive foodweb model for the Delta that could be used to evaluate the potential contribution of CM4 to the Delta foodweb. The quantitative index of primary production and the qualitative discussion of benefits to other components of food are intended to integrate the potential food benefits from CM4 based on the best available data and methods.

Phytoplankton Production

Method

The potential of CM4 restoration to contribute to the Delta foodweb was evaluated with a simple index of food production, termed prod-acres, that is based on potential phytoplankton growth rate calculated from water depth. Phytoplankton production is generally greater in shallow areas and declines with depth because light penetration attenuates with depth (Section 5.E.4.3.5.3, *Drivers of Primary Production in the Delta*). Because CM4 would increase the area of shallow environments in most of the subregions, the relationship between depth and potential phytoplankton production is relevant to the benefits of CM4. The depth relationship was used to create the prod-acres metric which is a the area weighted phytoplankton growth rate. As an area weighting of a biological effect of physical change, the prod-acres index is analogous to HUs used in the habitat suitability analysis. In both cases, the index is a relative value. That is, the index is used to compare across geographic areas (e.g., Restoration Opportunity Areas) and time periods (ELT, LLT) but not to calculate absolute metrics of phytoplantkton productivity.

The potential phytoplankton growth as a function of depth was calculated using a relationship developed by Lopez et al. (2006) from measured temperature, irradiance, and light attenuation in

Mildred Island in 2001 and Franks Track during 2002. Lopez et al. (2006) present a relationship between depth and daily phytoplankton growth rate as a function of depth in meters:

Phytoplankton growth rate/day = –0.86–0.27 ln (depth in meters) $(R^2 = 0.72)$ (Equation 3)

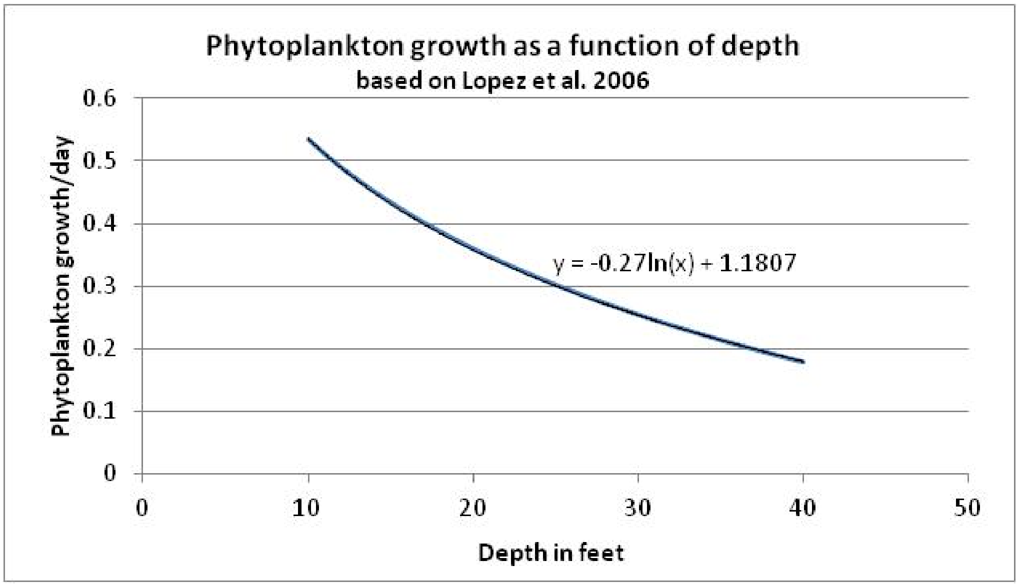
This relationship was modified to account for depth in feet rather than meters. The phytoplankton growth/depth relationship only incorporates one factor in the simplified food model in Figure 5.E.4-84 and is recognized to be a simplification of a complex ecological system leading to food production for covered fish species. For example, Lucas and Thompson (2012) have argued that while the depth relationship is valid, it is often compromised in the Delta by other factors affecting food production, especially clams (see Consumption in Figure 5.E.4-84). In some cases, clams can consume all of the phytoplankton in a water column and thereby limit the value of the production to secondary consumers and fish (Lucas and Thompson 2012). For this reason, shallower habitat is not always better in regard to food production in the Delta. However, in the absence of a comprehensive food model for the Delta, the depth relationship in Equation 3 is the best available method to estimate food production and is therefore used here as an index to compare the relative potential of the proposed CM4 restoration.

The Lopez model in Equation 3 was applied to the average depths and area[5] for each tidal-area stratum in Table 5.E.4-17 to compute the prod-acre index. Prod-acres index is calculated as follows:

$$\text{Prod-acres} = (\text{Phytoplankton growth rate/day})_{\text{average depth of stratum}} \times \text{Area of the stratum}$$ (Equation 4)

It was assumed that a larger area of a given phytoplankton growth rate has greater value than a smaller area with the same phytoplankton production rate. However, it should be noted that phytoplankton production is highly variable across the Delta; some areas of similar size are net producers of phytoplankton and others are net sinks (Lucas et al. 2002). To calculate the prod-acre index, the phytoplankton growth rate first was calculated from the estimated average water depth of each tidal-area stratum and then multiplied by the area of the stratum (Figure 5.E.4-85), *Prod-acres* is an index of potential phytoplankton growth as a function of depth and area in each geographic subregion.

[5] Average depth was calculated using the methods described in Section 5.E.4.2.3.2.



Source: Equation from Lopez et al. 2006, modified for depth in feet

Figure 5.E.4-85. Relationship between Phytoplankton Growth Rate and Depth

Results

Table 5.E.4-39 presents results of the phytoplankton analysis, including estimates of phytoplankton growth rate, depth, and the calculated prod-acre index by subregion and scenario. The table presents depth-averaged phytoplankton growth rates and prod-acres for existing conditions and for ESO_LLT with the effects of sea level rise removed. Figure 5.E.4-86 shows the change in prod-acres across scenarios and subregions.

Results suggest that the increase in shallow water areas in the Delta as a result of *CM4 Tidal Natural Communities Restoration* has the potential to increase phytoplankton growth in the Plan Area but with marked differences between subregions because of differing amounts of shallow water area provided by the proposed restoration. The change in the prod-acre index was highest in Cache Slough and the South Delta reflecting the amount of shallow intertidal area projected to be provided in these areas (Figure 5.E.4-86). The increase in the prod-acre index was less in the other subregions because of the differing amounts of shallow habitat provided.

Translation of the potential production implied by the prod-acre index into food for covered fish species is complicated by biological and physical conditions in the subregions discussed above. In particular in shallow areas grazing rates of clams can exceed phytoplankton production rates resulting in no augmentation of zooplankton or other food sources for covered fish species (Lucas et al. 2012). Hydrodynamics can affect water residence time and the movement of food from sources to potential fish feeding areas. Because clam grazing rates and hydrodynamics vary across the Delta, the potential of primary production changes in Table 5.E.4-39 and Figure 5.E.4-86 to effectively convert to food for covered fish species will likely vary significantly among and within subregions and will depend greatly on local conditions and by large scale drivers of conditions such as flow, salinity and temperature.

Based on the experience to date of the tidal natural community restoration at Liberty Island, it is reasonable to expect that the change in prod-acres shown in Figure 5.E.4-86 for the Cache Slough subregion will increase food for covered fish species. The restoration that is occurring at Liberty

Island appears to export food production (Lehman et al. 2010) while creating a localized foodweb that supports native species (Whitley and Bollens 2013). The juxtaposition of hydrology, wind fetch, diversity of habitat types and species occurrence that was seen at Liberty Island could be extended to restoration in the West Delta and Suisun Marsh subregions such that the phytoplankton production implied by the change in prod-acres in these areas might also be expected to benefit food production for covered fish species.

In other areas, the potential to effectively convert phytoplankton produced by restoration to zooplantkton (i.e., food) is more problematical. Although the South Delta produces considerable zooplankton at the present time (Hennessy 2010), the experience has been that dense areas of *Egeria*, water hyacinth, and invasive clams colonize the same areas and that these conditions could dampen the production provided by restoration. For example, the Delta lake created by the levee breaching at Mildred Island had higher net export of phytoplankton to surrounding channels than the Franks Tract lake, although Mildred Island is much smaller. The higher levels of phytoplankton export at Mildred Island was a result of less clam grazing, higher residence time, and greater hydrologic connectivity to surrounding channels at Mildred Island than at Franks Tract lake (Lucas et al. 2002). In addition, use of the South Delta by delta smelt and some other covered fish species is seasonal; for food production to benefit these species the food production (phytoplankton or zooplankton) must therefore be transported to other areas where feeding fish are present. The Habitat Suitability analysis of the South Delta restoration found conditions for delta smelt and juvenile salmonids in the South Delta to be less suitable than other areas during summer because of high temperatures and high water clarity. Thus, for the production benefits implied by the change in prod-acres for the South Delta to benefit covered fish species the food would have to be transported to other parts of the Delta where delta smelt feed during the summer without first being consumed by clams or other consumers (Lucas et al. 2002; Cloern 2007). Because of the complexity of the Delta foodweb and the effect of clams and other factors on food production, the results in Table 5.E.4-39 should be viewed as comparative indices of potential primary production that may result from CM4 and that the effective conversion to food for covered fish species will be affected by local physical and biological conditions and large scale drivers. The prod-acre result indicate the high potential of the CM4 restoration to contribute to food production but actual benefits will depend on local conditions, competition from clams and the ability deliver food to areas that support fish production.

Table 5.E.4-39. Depth-Averaged Phytoplankton Growth Rate and Prod-Acres under Existing Conditions and with BDCP in the Late Long-Term, Assuming No Sea Level Rise

Restoration Opportunity Area	Scenario	Phytoplankton Growth Rate (per day)	Prod-Acres Index	Hypothesized Foodweb Benefits for Covered Fish Species
Cache Slough	EBC2	0.89	10,100	Tidal habitat restoration in the Cache Slough ROA could increase local production of food for rearing salmonids, splittail, longfin smelt, delta smelt, and sturgeon, and increase export of food resources downstream of Rio Vista in the Delta and Suisun Marsh to benefit salmonids, splittail, delta smelt, and sturgeon. Marsh production is high in Liberty Island, a previously restored area in the Cache Slough Complex, and production from these marshes may be exported downstream.
	ESO_LLT minus sea level rise	0.97	29,569	
North Delta	EBC2	0.71	2,660	Sea level rise will increase the area of the North Delta and especially shallow-water areas. This may increase phytoplankton production in situ and export downstream to the Delta.
	ESO_LLT minus sea level rise	0.76	3,170	
West Delta	EBC2	0.78	22,591	Tidal habitat restoration in the West Delta ROA could increase local food production for rearing salmonids and splittail, and increase the availability and production of food in the western Delta and Suisun Bay by export via tidal flow.
	ESO_LLT minus sea level rise	0.78	26,670	
Suisun Marsh	EBC2	1.12	13,940	Sea level rise and restoration may decrease the amount of phytoplankton production in Suisun Marsh, although it remains high relative to other areas. Production from Suisun Marsh that is transported to Suisun Bay would benefit rearing salmonids, splittail, delta smelt, and longfin smelt.
	ESO_LLT minus sea level rise	1.09	24,420	
Suisun Bay	EBC2	1.13	14,010	Sea level rise decreases the area in the shallowest strata, thereby decreasing the projected phytoplankton production. However, production remains high relative to other areas.
	ESO_LLT minus sea level rise	1.00	24,670	
East Delta	EBC2	0.81	4,820	Transport of production from tidal habitat restoration in the Cosumnes/Mokelumne ROA could benefit juvenile salmonids, splittail, delta smelt, and sturgeon in the east and central Delta and fall-run Chinook salmon, steelhead, delta smelt, and splittail migrating to and from the Cosumnes and Mokelumne Rivers.
	ESO_LLT minus sea level rise	0.93	8,940	
South Delta	EBC2	0.76	15,060	Restoration of tidal habitat in the South Delta could increase local food production for rearing salmonids and splittail, and increase availability and production of food in the western Delta and Suisun Bay by export via tidal flow. The large area of restored habitat results in a high estimate of prod-acres for the South Delta.
	ESO_LLT minus sea level rise	0.89	38,090	

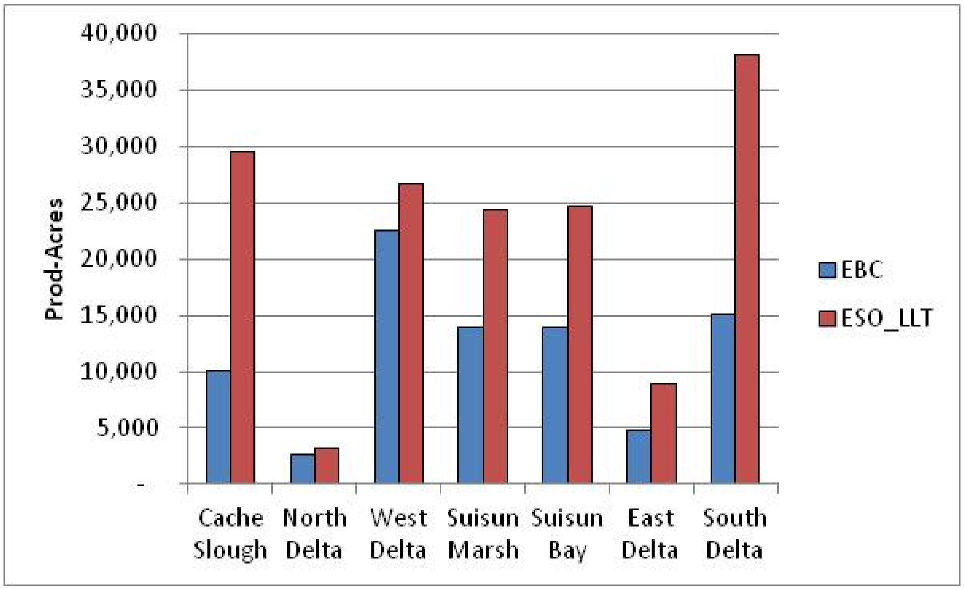


Figure 5.E.4-86. Change in Prod-Acres across Scenarios and Restoration Opportunity Areas

Emergent Vegetation Production

Emergent vegetation develops in shallow margins of delta waterways in areas of suitable substrate. Development of areas of tules and other emergent vegetation involves a feedback in which plants develop in shallow areas and in turn, these plants trap sediment and expand shallow areas and tule production. Ongoing restoration at Liberty Island and at other restoration sites show a pattern of initial rapid development of tules and then a tapering off of production presumably as substrate of suitable depth is occupied. Emergent plants contribute to production of detritus and provide substrates for aquatic insects and epibenthic organisms that are actively consumed by covered fish species. Restoration of shallow water areas under CM4 is expected to expand areas suitable for development of emergent vegetation. This, in turn, should augment food for covered fish species.

Submerged Aquatic Vegetation Production

Submerged aquatic vegetation, most of which is invasive in the Delta, dominates in some parts of the Delta. For the most part SAV is considered detrimental to native fish species because it provides habitat for nonnative pisciverous fishes and decreases turbidity. SAV also provides substrate for amphipods and other crustaceans eaten by native and non-native fish species (Grimaldo et al. 2009).

Because of its ubiquitous nature in the Delta, SAV will almost certainly increase as a result of CM4. However, although SAV can be locally dominant, it is not pervasive across the Delta and develops in some areas and not in others although the reasons for the differences are often unclear. Comparing the development of SAV at Liberty Island, Franks Tract and Mildred Island, however, indicates that local conditions of hydrology and bathymetry are important in determining whether nuisance levels of SAV develop. This indicates that SAV development can, perhaps, be controlled through restoration design features. Adaptive management and experimentation associated with CM4 should help elucidate the environmental conditions leading to SAV development and restoration techniques that discourage its spread. Implementation of the BDCP is expected to reduce the extent and biomass of *Egeria* and other SAV through aggressive control techniques that include herbicide treatment and mechanical removal in restoration sites and outside restoration sites throughout the Plan Area (*CM13 Invasive Aquatic Vegetation Control*).

Detritus Production

Detritus is derived from all other plant production especially emergent vegetation such as tules. Detritus especially results from the decomposition of emergent vegetation such as tules and development of shallow areas that enhance emergent vegetation should enhance detrital food as well.

As a result, restoration that increases shallow areas and emergent vegetation and enhances other forms of primary production can be expected to increase the supply of detritus in the Delta and benefit the detrital foodweb.

Food Benefits to Covered Fish Species

Delta Smelt

There is considerable evidence regarding the importance of food as a current constraint on the delta smelt population at both larval and juvenile life stages and it is concluded that food is a critical constraint on delta smelt life stages. Expansion of shallow environments in Cache Slough, West Delta and Suisun Marsh under CM4 should increase phytoplankton in these areas based on the reasoning above. The prod-acres index of phytoplankton production showed appreciable increases in these areas that co-occurs with generally high suitable habitat for delta smelt. The potential increase in phytoplankton should in turn benefit zooplankton production and increase food supply for delta smelt and other species with benefits to growth and survival of delta smelt.

The benefit of potential increases in phytoplankton production in the South Delta to delta smelt are less certain and would depend on the extent to which food could be exported to areas where delta smelt larvae and juveniles are more likely to occur. Suitability of habitat in the South Delta for delta smelt was low in the summer and fall and delta smelt abundance in the South Delta during these periods is very low. However, the South Delta is currently a high producer of zooplankton and this would be expected to increase if phytoplankton increases as result of restoration. *Eurytemora* and *Pseudodiaptomus* both frequently show their highest densities in the South Delta and Suisun Marsh (Hennessy 2010). Due to unsuitable conditions this production would not benefit delta smelt locally during the summer and fall periods but delta smelt could benefit indirectly to the extent food resources are exported to deeper habitats used by delta smelt (Lucas et al. 2002; Cloern 2007).

Longfin Smelt

As with delta smelt, longfin smelt would appreciably benefit from the increase in food potentially occurring due to expansion of shallow habitat in the Cache Slough, West Delta, and Suisun Marsh ROAs. To benefit longfin smelt, this food would need to be exported to deeper areas of these subregions. Except during spawning longfin smelt are generally found in deeper, open water of the Delta and may benefit more from transport of food resources produced in restored marsh areas. Longfin smelt occur infrequently near the Cosumnes and Mokelumne Rivers, and therefore increased diatom production from restoration of shallow-water environments in the East Delta subregion is unlikely to provide significant benefits. Likewise the south Delta does not generally provide favorable conditions for longfin smelt; therefore, the direct benefit of habitat restoration in the south Delta is likely to be low. However, longfin smelt could benefit indirectly to the extent food resources are exported to areas where longfin smelt larvae and juveniles are more likely to occur**.**

Sacramento Splittail

Little information exists regarding food-resource limitation of splittail. There is some indication that splittail are food-limited given that splittail growth rates declined following the invasion of *Potamocorbula* and the collapse of *Neomysis* due to high rates of grazing by *Potamocorbula* (Feyrer et al. 2003). Increased food production under the BDCP would be of importance in and adjacent to areas currently occupied by splittail (Cache Slough, West Delta, and Suisun Marsh ROAs). Splittail have a varied diet that includes secondary production (clams, insects, crustaceans) as well as detritus. The projected increase in emergent vegetation should increase insect, crustaceans and detrus that should benefit splittail feeding.

Chinook Salmon

Foraging juvenile Chinook salmon are expected to benefit from the expansion of shallow tidal marsh where they will be able to feed on Chironomids, amphipods and other food associated with emergent vegetation. Migrating juvenile Chinook salmon would benefit from the increased food supply as well although larger smolted fish would see less benefit because of their shorter residence time in the plan area. Restoration of tidal habitat in Suisun Marsh may be most important for juvenile salmonids during higher outflow years, when Chinook salmon fry may be dispersed farther downstream (Kjelson et al. 1982). Salmonids migrate down the Cosumnes and Mokelumne Rivers into the West Delta, and will benefit from increased food production in the West Delta. Restoration of wetland habitat in the South Delta is expected to contribute to improved rearing conditions for juvenile salmonids from the San Joaquin River mainstem and tributaries although use of this habitat by salmonids will be limited by less suitable habitat conditions especially in regard to temperature (Chapter 4, Section 4.4.2.4, *Suitability of Restored Habitat for Covered Fish Species*). Permanent tidal marshes in the South Delta ROA would contribute new holding and rearing areas for juvenile fish and help improve survival from the San Joaquin River system for foraging salmonids, particularly in combination with channel margin enhancements and floodplain restoration throughout this region. Restoration of marsh vegetation should enhance insect production that would be consumed by foraging juvenile salmonids.

Sturgeon

Tidal habitat restoration may create permanent year-round rearing habitat for juvenile white and green sturgeon. Because of the extreme loss of historical freshwater tidal marsh in the Delta, any increase in tidal habitat is likely to be beneficial to sturgeon. Tidal habitat restoration may indirectly benefit sturgeon through increased production of epibenthic organisms such as amphipods, mysids, bay shrimp, and bivalves, including the introduced clams, *Potamocorbula* and *Corbicula*. Israel et al. (2009) indicate that bivalves are now the principal food of white sturgeon, and Israel and Klimley (2008) note that *Potamocorbula* has replaced native mollusks and shrimp as food for green sturgeon.

The west Delta and Suisun Bay serve as a migratory corridor and feeding area for white sturgeon, and the increase in production supporting benthic invertebrates will increase food availability for sturgeon moving through the area. *CM4 Tidal Natural Communities Restoration* will increase the area of intertidal mud bottoms in the west Delta. Because sturgeon are highly adapted to prey on estuarine benthic invertebrates (Moyle 2002), they will benefit from increased soft bottom habitat. The phytoplankton growth model also indicates that tidal habitat restoration could increase food availability for juvenile sturgeon in the East Delta subregion. The former farm fields that would be flooded in the subtidal restoration site will remain comparatively hard for many years (such as occurred at Liberty Island and Little Holland Tract), but once the substrate softens, these benthic communities could become a substantial food resource for sturgeon. There is limited research to determine whether proposed restoration in the South Delta would benefit sturgeon. This area of the Delta would not provide extensive mud bottoms as found in lower portions of the estuary.

5.E.4.4.3 Limitations and Uncertainties of Habitat Restoration

Habitat restoration in the Delta to date is reviewed in Attachment 5E.B, *Review of Restoration in the Delta*, This attachment includes a discussion of the potential limitations and uncertainties of restoration that are summarized here. The review found that the success of restoration to date, most of which results from accidental breaching of dikes, has produced variable results. Liberty Island, for example, shows the potential for restoration to restore natural conditions and support native fish species. On the other hand Franks Tract shows how conditions can develop that support nonnative fish and plant species and do not appear to contribute to overall delta production. These examples provide guidance for CM4 restoration and illustrate the potential for restoration to contribute to the conservation of covered fish species.

Along side the indications of restoration potential at Liberty Island and elsewhere must lie the potential limitations and uncertainties of restoration. Much remains to be learned about restoration especially at the scale of CM4. The BDCP provides an adaptive approach to promote that learning as restoration is implemented. Some factors of potential qualifications and additional factors affecting restoration success under CM4 include the following:

1. *Potamocorbula* grazing could greatly reduce potential increases in food resources for native fishes. Excessive grazing by *Potamocorbula* is known to exert a strong influence on the foodweb in the upper estuary, reducing both phytoplankton and some zooplankton prey of native fish species (Kimmerer and Orsi 1996; Kimmerer et al. 2012).
2. Proposed changes to wastewater treatment plant discharges should benefit food production in the Delta by reducing ammonium in areas like Suisun Bay. This may increase diatom production above the level predicted by the Lopez et al. (2006) model (Parker et al. 2012). Tidal marsh restoration also may increase diatoms by increasing nitrate through nitrification (the conversion of ammonium to nitrate) (Ecosystem Restoration Program 2011). However, the relative importance of ammonium compared to clam grazing in primary production and trophic dynamics is a topic of continued debate (e.g., Glibert et al. 2011; Cloern et al. 2012; Lancelot et al. 2012; Kimmerer et al. 2012).
3. *Microcystis* blooms depress copepod feeding and survival, principally in the south Delta and the uppermost portions of the west Delta (e.g., Franks Tract) (Lehman 1996; Lehman et al. 2005, 2008a, 2010a).
4. The presence of SAV can exert a strong influence on the distance over which exported organic material can travel, potentially reducing transport of food resources from the South Delta and the Yolo Bypass to other areas of the estuary (Kneib et al. 2008).
5. There is evidence that invasive jellyfish consume calanoid copepods (Wintzer et al. 2011).
6. Climate change is resulting in a number of changes in the environmental attributes of the Delta that could affect phytoplankton production (e.g., timing of peak flows, salinity).

All of these factors could influence realized phytoplankton production in different ways, and render the potential benefits of tidal habitat restoration, especially for higher trophic levels, uncertain.

These factors are not easily accounted for, and it is likely that uncertainties can be resolved only by monitoring of the restored habitats and measuring actual food production. In the meantime, the basic relationship between depth and phytoplankton production developed by Lopez et al. (2006), which has a strong empirical foundation, provides a baseline estimate of phytoplankton production from which to estimate the relative importance of additional factors as more information becomes available.

5.E.5 Conservation Measure 5 Seasonally Inundated Floodplain Restoration

5.E.5.1 Description

Under *CM5 Seasonally Inundated Floodplain Restoration*, the Implementation Office will modify flood conveyance levees and infrastructure to restore 10,000 acres of seasonally inundated floodplain along river channels throughout the Plan Area. The floodplain restoration is separate from fisheries enhancement in the Yolo Bypass (*CM2 Yolo Bypass Fisheries Enhancement*). CM2 augments existing floodflows in the Yolo Bypass, whereas CM5 restores floodplains that historically existed elsewhere in the Plan Area but have been lost as a result of flood management and channelization activities. CM2 is fully evaluated in Appendix 5.C, *Flow, Passage, Salinity, and Turbidity*.

Under CM5 up to 10,000 acres of seasonally inundated floodplain will be restored:

- At least 1,000 acres restored by Year 15.
- At least 9,000 additional acres restored by Year 40.

The approximate total amounts of floodplain habitat in the Plan Area where enhancement will occur are:

- South Delta: up to 10,000 acres.

This conservation measure will be implemented through levee setbacks, removal of riprap, or grading of floodplain. The most promising opportunities for large-scale floodplain restoration that will have benefits for San Joaquin River salmonids and splittail by providing food resources and habitat complexity exist in the South Delta subregion.

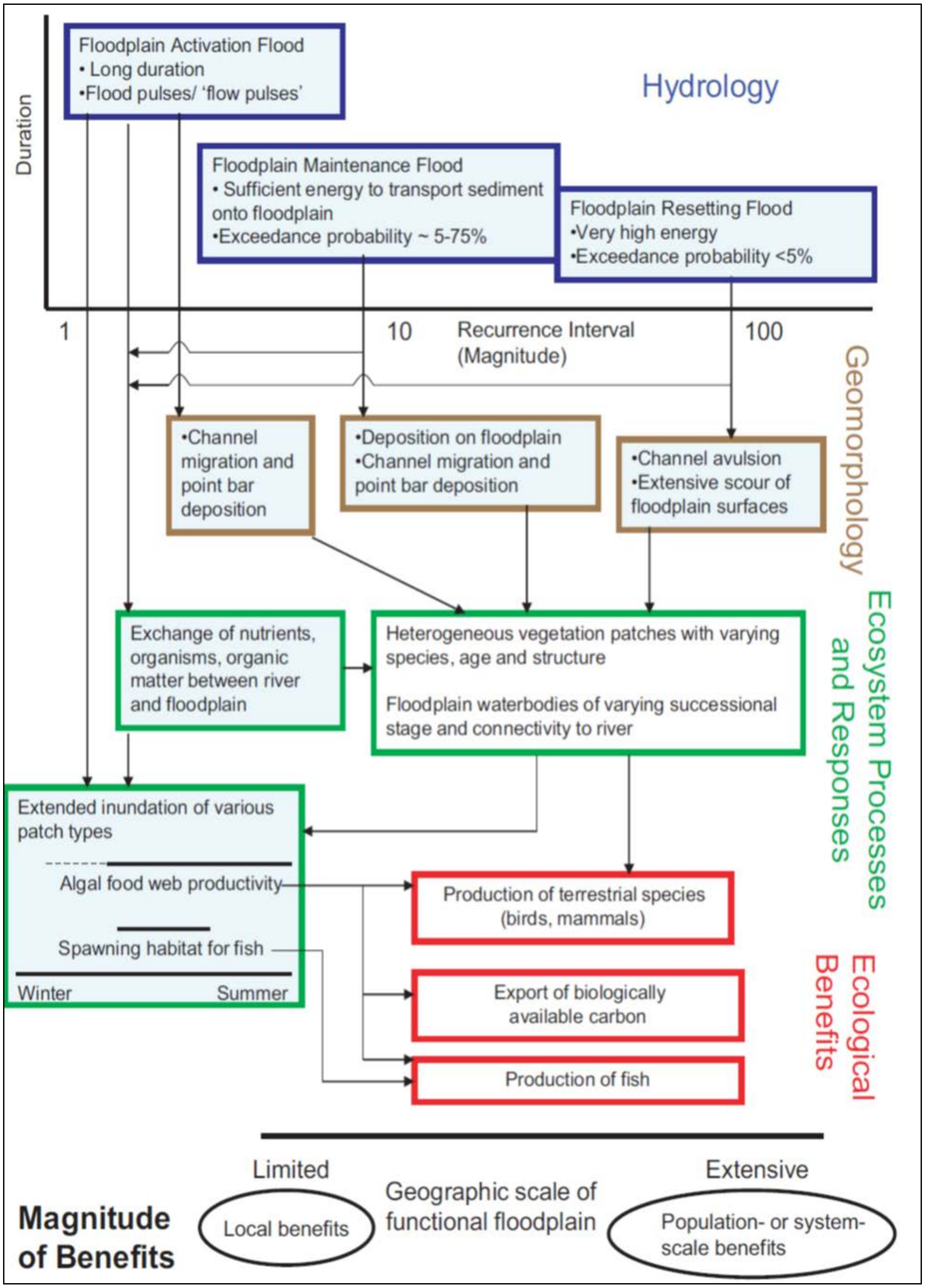
5.E.5.2 Conceptual Model

Many conceptual models of floodplain processes have been put forward. Some focus on geomorphology and riparian and landscape ecology (Whiting 1998; Florsheim and Mount 2002; Larsen et al. 2006). Others focus on floodplain topography and the development of vegetative communities with the influence of flow and disturbance regimes (Mahoney and Rood 1998; Ward 1998; Greco and Plant 2003).

Most relevant for understanding the potential benefits of floodplain restoration is the conceptual model of Opperman et al. (2010), which attempts to capture the complex interactions and processes that structure ecologically functional floodplains (Figure 5.E.5-1). Based on the flood pulse concept (Junk et al. 1989), the model considers rivers and their floodplains as one system of varying components. The model differs from other floodplain models in that it includes processes that occur during inundation, such as the production of food and fish in addition to processes that occur on longer time scales, such as the development of riparian forest and their communities (Opperman et al. 2010).

The Opperman model describes three key components of functioning floodplains.

1. Connectivity—a functional floodplain must be able to connect to its adjacent river to exchange flow, sediment, nutrients, and organisms (Amoros and Bornette 2002; Opperman et al 2010).
2. Flow regime—floodplain ecosystems are created, maintained, and disturbed by a variable hydrograph ranging from low flows to topography-changing high flows (Poff et al. 1997; Whiting 2002; Opperman et al. 2010). Ecosystem processes in the floodplain are highly dependent on this variable flow regime being available to drive these important processes (Opperman et al. 2010).
3. Spatial scale—a floodplain must be large enough to encompass dynamic processes such as erosion and deposition that drive floodplain topography when large floods occur (Richards et al. 2002; Rohde et al. 2005; Opperman et al. 2010). The floodplain or floodplains also must be of sufficient size to accrue measurable benefits to the ecosystem (Opperman et al. 2010).



Blue-shaded boxes indicate processes that occur during the period of inundation.
Note the temporal scale bar (Winter → Summer) in the box ''Extended inundation of various patch types,'' which indicates that the occurrence and magnitude of ecosystem processes vary with the season of inundation.
Source: Opperman et al. 2010.

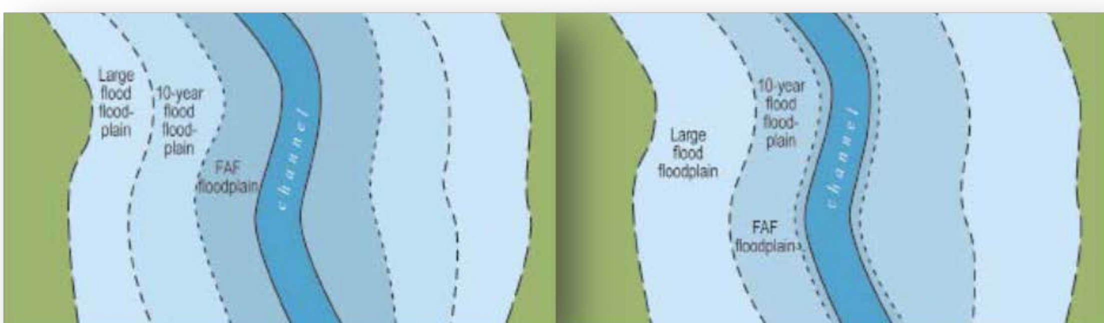
Figure 5.E.5-1. A Conceptual Model of Floodplain Processes in California's Central Valley

5.E.5.2.1.1 Floodplain Activation Flow

The floodplain activation flow (FAF) (Williams et al. 2009) is the smallest flood pulse event that initiates substantial beneficial ecological processes when associated with floodplain inundation. In a more natural river system, shallow floodplains that flood frequently are nested within larger floodplains that are flooded more deeply with less frequency (Williams et al. 2009). Because the smaller, more frequently inundated floodplains occur within the larger floodplain, they always will be more heavily inundated during larger floods, producing a different suite of processes than small floodplains that are not nested within larger floodplains (Williams et al. 2009).

The concept of FAF is useful for designing floodplain restorations. In the rivers of the Central Valley, small spring flows occur at a lower frequency than historically because the pulses are being captured in reservoirs. Even so, small floodplains still operate in modified form throughout Central Valley watersheds (Figure 5.E.5-2). Where spring flows are dampened by reservoir operations, the floodplain topography should be designed first to inundate under a minimum FAF pulse (Williams et al. 2009).

The definition of a specific FAF should incorporate the various ecological responses to a variable hydrological regime. For instance, increased growth and survival of Chinook salmon have been linked to floodplain processes, as have the spawning and rearing of splittail (Sommer et al. 1997; Sommer et al. 2001a; Crain et al. 2004; Moyle et al. 2007; Jeffres et al. 2008). The production of carbon in the form of microalgae and zooplankton has been linked to the duration of draining (i.e., residence time) and increases in temperature (Ahearn et al. 2006; Cushing and Allan 2001; Lehman et al. 2008b; Schemel et al. 2004; Sommer et al. 2004a), although extended periods of residence time can lead to lower rates of zooplankton export as phytoplankton biomass is grazed to low levels and larval and juvenile fish consume large quantities of production (Grosholz and Gallo 2006). The FAF must allow connectivity with the river during the period of flooding, it must be of the proper duration and timing to produce measurable ecological benefits, and it must occur often enough that the benefits are occurring on an interannual scale (Williams et al. 2009).



Source: Williams et al. 2009.

Figure 5.E.5-2. Depiction of Floodplain Activation Flow for a Natural Hydrograph (Left) and for a Regulated Stream (Right)

5.E.5.3 Consistency with the Biological Goals and Objectives

CM5 will advance the biological goals and objectives as identified in Chapter 3, *Conservation Strategy*, Table 3.4.5-3. The rationale for each of these goals and objectives is provided in Chapter 3, Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.5-3 also identifies the monitoring actions associated with each objective as it relates to CM5.

Restoration of freshwater and brackish tidal habitats (*CM4 Tidal Natural Communities Restoration*), in conjunction with channel margin (*CM6 Channel Margin Enhancement*) and floodplain enhancements implemented under CM5, is expected to reestablish an ecological gradient from river to floodplain to tidal estuary, and provide tidal freshwater wetland structure and functions adjacent to open-water habitat (Opperman et al. 2010). Connecting and improving function in seasonal floodplain (CM5) and tidal freshwater habitats (CM4) will help create a continuous pathway along the migration corridor of juvenile Chinook salmon. This will improve growth and survival across a range of environmental conditions, helping to promote population persistence (Bottom et al. 2005).

As shown on the Yolo Bypass and Cosumnes floodplains, increased floodplain inundation would help increase production of phytoplankton and other algae, particularly during reoccurring flood pulses with 2–3 weeks between pulses; this is typical of flooding that occurs in the spring. The shallow water depth and long residence time in floodplains facilitate settling of suspended solids, resulting in reduced turbidity and increased total irradiance available for phytoplankton growth in the water column. Because all restoration under CM5 is to be created in the South Delta subregion, it is likely that the production of phytoplankton noted on the Yolo Bypass and Cosumnes floodplains will be much less. This is due to the San Joaquin River hydrologic regime that allows for only partial inundation and limited duration of floodplain habitat accept during very wet years. Although management options for influencing inundation and residence time include manipulating floodplain topography to inundate at lower flows and the manipulation of vegetation and topography to alter hydraulic roughness and drainage connectivity (Opperman 2012). For instance, residence time can be controlled by the placement of internal levees (low berms) with breaches that control the drainage off the floodplain with their number and placement (Opperman 2012). Pulses of water instead of a long duration of flooding can also increase the amount of time that a floodplain experiences increased residence time draining (Opperman 2012).

Restored floodplains potentially can provide benefits to the larger estuary by exporting food resources to downstream systems, providing increased production for pelagic species such as delta smelt and longfin smelt (Schemel et al. 2004; Ahearn et al. 2006; Lehman et al. 2008b). Ahearn et al. (2006) found that floodplains that are connected and disconnected in pulses can act as a “productivity pump” for the lower estuary by exporting food resources, especially algae, to support foodwebs in downstream communities (Sommer et al. 2001b; Ahearn et al. 2006; Lehman et al. 2008a). Other studies indicate links between carbon produced on floodplains and the downstream foodweb (Sobczak et al. 2005; Opperman et al. 2010). On floodplains in the South Delta subregion, because of short inundation periods and less than full floodplain habitat inundation, the amount of primary production that can be exported downstream will be minor compared to that on the Yolo Bypass and Cosumnes floodplains. Although, as mentioned above benefits can be maximized by manipulating topography and the water that is available.

5.E.5.4 Explanation of the Conservation Measure

5.E.5.4.1 Descriptions of Current Floodplain Habitat

5.E.5.4.1.1 The Yolo Bypass

The 24,000-hectare Yolo Bypass is the largest floodplain of the Delta (Sommer et al. 2001a). This engineered floodplain (61 kilometers [km] long and 3 km wide) is not immediately adjacent to a main river but rather receives floodwaters through Fremont Weir, Sacramento Weir, and several westside streams: Knights Landing Ridge Cut, Cache Creek, Willow Slough Bypass, and Putah Creek (Sommer et al. 2001b). The floodplain is inundated during winter and spring in about 60% of years. During high-flow events, the Yolo Bypass can have a discharge of up to 14,000 cubic meters per second (m^3/s), representing 75% of total Sacramento River basin flow (Sommer et al. 2001a). Under typical flood events, water spills into the Yolo Bypass at Fremont Weir when Sacramento basin flows surpass approximately 2,000 m^3/s. At higher basin flows (>5,000 m^3/s), the Sacramento Weir also spills (Sommer et al. 2001a). When floodwaters recede, the basin empties through a permanent riparian fringed tidal channel along the eastern edge of the Yolo Bypass (Sommer et al. 2001a). The floodplain is relatively well-drained, but several isolated ponds remain perennially inundated (Sommer et al. 2001a, b; Feyrer et al. 2005). The Yolo Bypass supports fish and waterfowl in seasonally inundated habitats during winter and spring, and agriculture during summer (Sommer et al. 2001b).

The Yolo Bypass is beneficial to native fishes for the following reasons.

- It floods frequently with major inundation events.
- It floods during times of year that covered fishes can use it.
- It dries up, leaving very little permanent habitat for nonnative fishes to colonize and reproduce in.

5.E.5.4.1.2 Cosumnes River

The Cosumnes River drains from the Sierra Nevada into the east side of the Delta (Moyle et al. 2003). The Cosumnes River is one of the few Central Valley rivers without a major dam regulating its flows. As such, the river maintains a variable seasonal flow regime typical of Mediterranean systems, experiencing winter flooding from rainfall (November–February) with peak flows of up to 2,650 m^3/s (1997), smaller floods fed by snowmelt (March–May), and low to no late summer and fall flows (Booth et al. 2006). Levees constructed starting in the late 1800s still constrain much of the river channel (Swenson et al. 2003). The lowest reach of the river is influenced by freshwater tides of the Delta. Currently, more than 688 hectares of restored and remnant riparian forest, including stands of valley oak (*Quercus lobata*) forest, occur along the lower Cosumnes River (Griggs 2009).

At the Cosumnes River Preserve, approximately 100 hectares of floodplain were functionally reconnected to the river when levees were breached intentionally in October 1995 and in January 1997 (Swenson et al. 2003). Previously, the river overtopped its banks and established connectivity every 5 years when flows exceeded approximately 50 m^3/s. After the 1995 breach, this occurred earlier and more frequently (1.5-year recurrence interval) at half that flow (25 m^3/s) (Florsheim and Mount 2003; Florsheim et al. 2006). Variable floods produced a range of geomorphic and ecological outcomes. Flows exceeding 100 m^3/s deposited and eroded sediment on the floodplain. The January 1997 floods (2,650 m^3/s, 150-year recurrence interval) caused extensive levee failure along the river. These flows correlate to the floodplain activation, floodplain maintenance, and floodplain resetting flows (*sensu* Opperman et al. 2010).

5.E.5.4.1.3 Sacramento River

Much of the Sacramento River no longer has active floodplains. This reflects the fact that small, frequent spring flood events have been reduced since the construction and operation of large dams in the Sacramento Valley (Williams et al. 2009), as well as levee construction and channel incision. The FAF for the lower Sacramento River is the river stage that is exceeded in at least 2 out of 3 years and sustained for at least 7 days between March 15 and May 15 (Williams et al. 2009).

The biggest opportunities for floodplain restoration lie in the bypasses (Williams et al. 2009). Levee setbacks on the Sacramento River for improved flood conveyance could increase the amount of active floodplains, but only with increased release of small spring flood pulses from upstream reservoirs or grading of the newly established floodplains down to the current FAF stage. A recent example that applied the FAF concept is the flood control levee setback project at the confluence of the Bear and Feather Rivers, including a swale excavation to improve river-floodplain connectivity and reduce fish stranding (Williams et al. 2009).

5.E.5.4.1.4 San Joaquin River

The San Joaquin River, much like the Sacramento, is lacking the historical floodplains that it once had because of levee confinement and reduced flows due to reservoir management for water storage and flood control. Because the San Joaquin system historically had lower average flows than the Sacramento, the reduction of spring flood events is even more pronounced and limiting. The South Delta Habitat Working Group (SDHWG) was convened in 2011 to identify opportunities of improving habitat in the southern part of the Delta for integration into the BDCP. In Attachment 5E.A, *BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description & Assessment Document,* the SDHWG evaluates conceptual flood and habitat corridors to assess existing conditions, evaluate flood and ecosystem processes (including relative benefits and apparent risks), and spell out any data gaps that may need to be filled to clarify the assessment (ESA PWA 2012).

5.E.5.4.2 Post-Restoration Conditions

5.E.5.4.2.1 Aquatic Productivity

Currently, most Central Valley floodplains are severed from their rivers by levees, channelization, and flow regulation, restricting the high natural productivity of floodplain habitats (Mount 1995). Studies suggest that restoring river–floodplain connectivity in the Plan Area will enhance both primary production (Ahearn et al. 2006; Lehman et al. 2008a) and zooplankton growth (Grosholz and Gallo 2006; Müeller-Solger et al. 2002), potentially benefitting higher-level consumers like fish species.

Floodplain productivity and the export of primary and secondary food resources are very dependent on the amount of area flooded and how long it is flooded (Opperman et al. 2010). With the current hydrologic regime of the San Joaquin River (all tributaries flows managed by reservoir operations), it is likely that its floodplains will function with a lower capacity than the Yolo Bypass and the

Cosumnes floodplains described. This is not to say that there will not be benefit, but the benefit described for the other two floodplains will not be fully realized except possibly during very wet years. In particular, it is not expected that floodplains in the South Delta subregion will export primary production to the West Delta subregion or Suisun Bay.

Phytoplankton, zooplankton, and other food resources produced on inundated floodplains in the upper estuary provide subsidies to foodwebs downstream (Schemel et al. 1996; Jassby and Cloern 2000; Mitsch and Gosselink 2000; Moyle et al. 2007; Moss 2007; Lehman et al. 2008b). Floodplains can accomplish this in two ways; one is the trophic transfer of fish biomass downstream after accumulating floodplain food resources. Chinook salmon and splittail are good examples of this transfer. Another type of transference is the production of microalgae that is carried off the floodplain into adjacent channels and transported downstream, supporting primary production in pelagic foodwebs. This potentially would benefit delta smelt and longfin smelt, two species that feed primarily on zooplankton.

The connection and disconnection of pulsing small floodplain activation floods may pump varying concentrations of algae to downstream waters, but a minimum of 2 to 10 days' disconnection is required to develop higher levels of microalgae. If managed properly, restoration should export floodplain-produced algae to downstream aquatic ecosystems during flood events, but the dynamics are complex and reflect water residence time and local physical and biological conditions (Ahearn et al. 2006; Lehman et al. 2008a).

Central Valley floodplains potentially could produce high levels of phytoplankton and other algae, particularly during long-duration draining phases followed by flow pulses that move concentrated algal biomass into channels. The shallow water depth and long residence time in floodplains will facilitate settling of suspended solids, resulting in reduced turbidity and increased total irradiance available for phytoplankton growth in the water column. At the Cosumnes River Preserve, the inundated floodplain should progress from a physically driven system when connected to the river floods to a biologically driven pond-like system with increasing temperature and productivity. Periodic small floods should boost aquatic productivity of phytoplankton by delivering new pulses of nutrients, mixing waters, and exchanging organic materials with the river (Ahearn et al. 2006; Grosholz and Gallo 2006).

Providing river–floodplain connectivity should enhance production of lower trophic levels at relatively rapid time scales. In the Yolo Bypass, some foodweb organisms respond within days and attain high densities soon after inundation, including smaller fast-growing algae (e.g., picoplankton, small diatoms, nanoflagellates), vagile organisms such as drift insects, and organisms associated with wetted substrate such as chironomids (Benigno and Sommer 2007). These organisms, particularly chironomids, will provide a food source to fish that is available prior to the development of foodweb productivity (Schemel et al. 2004; Sommer et al. 2004a).

5.E.5.4.2.2 Spawning and Rearing Habitat for Native Fish

Floodplain inundation is intended to provide spawning (splittail) and rearing (juvenile Chinook salmon, larval and juvenile splittail) habitats that take advantage of the higher productivity on the floodplains (Sommer et al. 2001a, 2001b, 2004a; Crain et al. 2004; Moyle et al. 2007; Jeffres et al. 2008). During periods of connection to the river, fish should be able to move on and off the floodplain to spawn or forage. Further, the low-velocity, shallow, and vegetated habitats of the floodplain provide refuge from the fast, turbid waters of the river during high flows (Jeffres et al. 2008).

For salmon, the intent is to provide an alternative route that enhances growth and provides protection from predators, thus improving their survival rates as they migrate through the Delta. These expected potential benefits are supported by a number of studies (e.g., Sommer et al. 2001b; Jeffres et al. 2008, Whitener and Kennedy 1999; Moyle et al. 2007). Juvenile Chinook salmon also should benefit from restored floodplains as foraging and refuge habitat. Restoration will enable juveniles to migrate downstream onto floodplains in February to March to forage on the abundant invertebrates in the flooded vegetation before emigrating to the sea (Sommer et al. 2001a, 2001b; Moyle et al. 2007; Jeffres et al. 2008).

Sacramento splittail adults migrate onto the inundated floodplain to spawn on vegetation in January–June at both the Cosumnes floodplain and the Yolo Bypass (Crain et al. 2004; Moyle et al. 2004; Moyle et al. 2007). Juveniles should be able to rear on the floodplain and depart when it drains in April–June (Moyle et al. 2007; Sommer et al. 2001b).

Early spring inundation would facilitate development of habitat for floodplain-dependent native fishes and less hospitable for nonnative fish. Native fish species that evolved with California's pattern of seasonal precipitation typically used the floodplain earlier in the year. In contrast, nonnative species that evolved in temperate regions with year-round precipitation tend to arrive later and remain longer on the floodplain, spawn under warmer conditions, and are stranded more often when the floodplain drains and ponds dry out (Moyle 2002; Moyle et al. 2007).

Fish stranding in shallow ponds at the end of the flooding season is a concern for floodplain restoration. Perennial aquatic habitat such as ditches and floodplain ponds are dominated by nonnative fishes, as seen at the Cosumnes Preserve and the Yolo Bypass. A flood regime for native California fishes will include early season, coldwater events that persist long enough for bursts in algal and invertebrate productivity, followed by spring draining of the floodplain before it warms and favors nonnative species (Crain et al. 2004; Feyrer et al. 2005; Ahearn et al. 2006).

Predation is one mechanism that could lead to low native fish abundance in shallow-water habitats in the Delta. Predation is highest during spring and summer. Although there has been little investigation of predation of native fishes on floodplains, the observed seasonal use patterns and relative absence of piscivores suggest that floodplains offer native fishes a competitive advantage over nonnative predators. Habitat restoration should benefit native fishes (Moyle 2002; Moyle et al. 2007).

5.E.5.5 Evaluation

5.E.5.5.1 Method

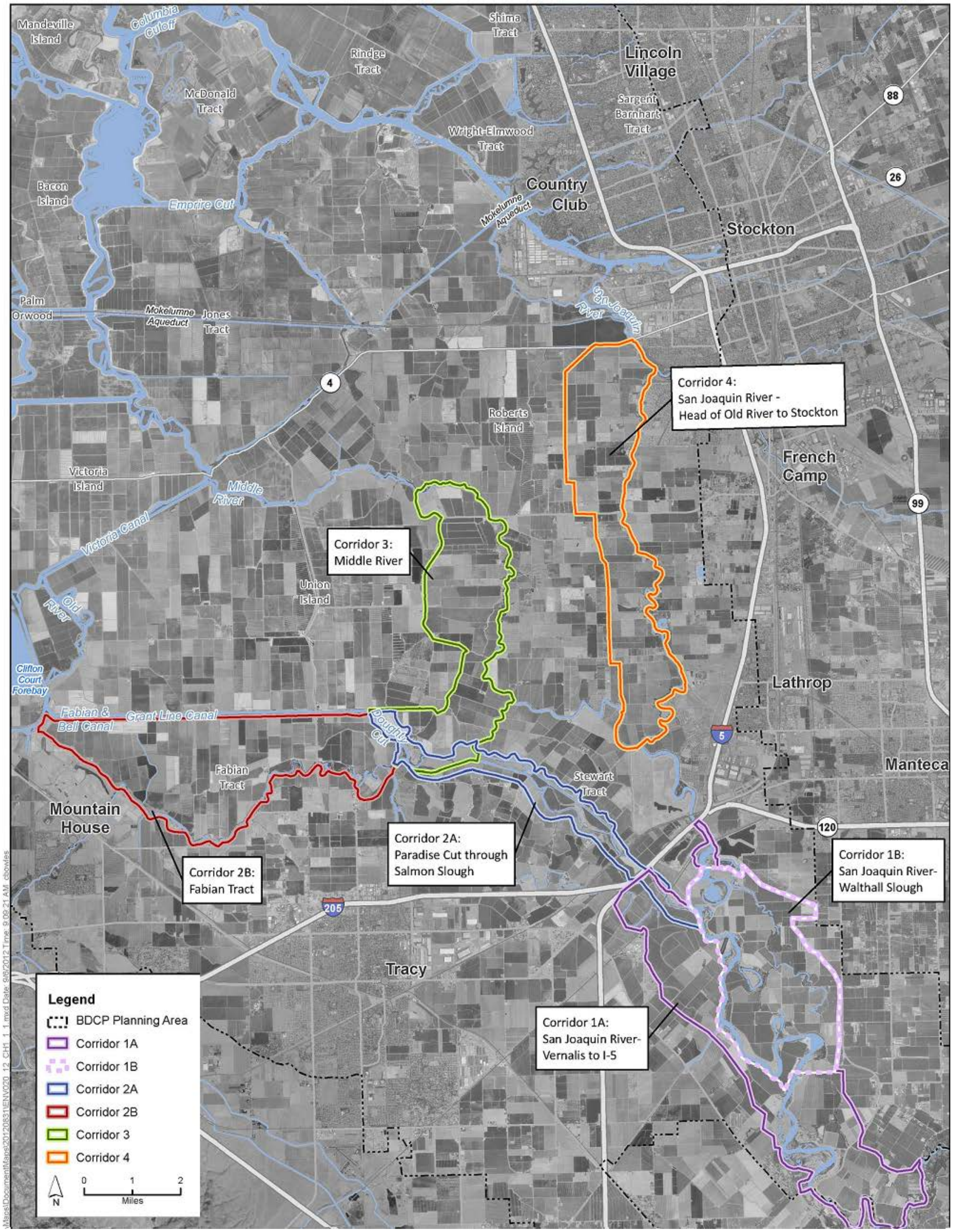
To assess the potential benefits of floodplain restoration on covered fish species, existing floodplain conditions were compared to those of conceptually restored corridors in the South Delta. Attachment 5E.A, *BDCP South Delta Habitat and Flood Corridor Planning: Corridor Description and Assessment Document,* details the process by which the existing conditions and conceptual restoration corridors were derived, the modeling methods used to quantify floodplain restoration benefits, and the results. In September 2013, an additional modeling effort was undertaken to better assess potential benefits for covered fish species (ESA PWA pers. comm.).

The south Delta floodplain evaluation method summarized in this section was developed over many months and included a number of long, sometimes complicated steps. Here, the process is summarized in five basic steps.

1. Define existing conditions and conceptual restoration corridors spatially is GIS.
2. Use hydraulic model to determine the discharge/floodplain inundation area relationship for the existing condition and conceptual corridors.
3. Develop ecologically-relevant flow criteria for two covered fish species: Sacramento splittail and Chinook Salmon.
4. Use ecosystem functions model to determine the discharge associated with assumed ecologically-relevant flow criteria.
5. Determine floodplain inundation acreages associated with ecologically-relevant flow criteria using the discharge/floodplain inundation area relationship created in Step 2.

When developing conceptual corridor configurations, various approaches for achieving the habitat and flood objectives were examined, including habitat and flood management corridors along the San Joaquin River upstream of Paradise Cut (Vernalis to Mossdale), the Paradise Cut/Old River area, the Middle River, and the mainstem San Joaquin River from Mossdale to Stockton. The potential actions identified were configured into a series of conceptual south Delta corridors, with each corridor being a delineation of actions such as levee setbacks, creation of flood bypasses, riparian planting, and channel margin enhancement. Work to date suggests that if implemented, these corridors would support achievement of CM5, CM6, and CM7 and simultaneously achieve ancillary benefits in flood risk reduction. However, only the benefits of floodplain restoration are evaluated in this section. The geographic corridors (Figure 5.E.5-3) are listed below.

- **Corridor 1A:** Levee setbacks on both banks of the San Joaquin River from Vernalis to Interstate 5.
- **Corridor 1B:** An alternative version of Corridor 1A along the San Joaquin that includes only a right-bank levee setback and connection of Walthall Slough with the San Joaquin River via a weir. Corridor 1B is assessed separately from Corridor 1A.
- **Corridor 2A:** Expansion of the Paradise Cut flood bypass and modifications to Paradise Cut weir.
- **Corridor 2B:** An expanded version of Corridor 2A that also includes levee removal around Fabian Tract. *Corridor 2B is essentially Corridor 2A plus Fabian Tract. Fabian Tract is not hydraulically modeled separately from Paradise Cut in terms of flood evaluations; however, the flood and ecological benefits of Corridor 2B are examined discretely*.
- **Corridor 3:** Selected levee setbacks along Middle River on Union Island.
- **Corridor 4:** Levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River.
- For a complete description of the conceptual corridors see Attachment 5E.A, *BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description & Assessment Document*, Section 5.E.A.3, *Corridor Description and Evaluation Assumptions*.



Source: ESA PWA 2012 (Attachment 5E.A).

Figure 5.E.5-3. Overview of the South Delta Subregion

The floodplain inundation (acres) to discharge (cfs) relationship for existing conditions and the conceptual corridors was calculated using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software—a one-dimensional river and floodplain hydraulics model. Two sets of geometric data were used in the modeling: an existing conditions configuration based on the HEC-RAS model originally developed for the USACE Sacramento and San Joaquin River Basins Comprehensive Study (Comp Study) and a set of corridor condition configurations that included modifications of levees and flood bypasses in each of the South Delta corridors described above. The hydrologic input used to assess existing and future floodplain inundation acreages was the daily flow time series from the Vernalis gage on the San Joaquin River for the time period January 1, 1985, through September 30, 2003.

The Hydrologic Engineering Center Ecosystem Functions Model (HEC-EFM) was used to determine ecologically-relevant discharges for covered fish species. Table 5.E.5-1 presents the important flow-related habitat criteria—seasonality, duration, and frequency—input into HEC-EFM to evaluate the range of ecologically-relevant discharges for Sacramento splittail and Chinook salmon. Table 5.E.5-1 also summarizes the sources used to determine appropriate flow-related habitat criteria. HEC-EFM inputs were revised in September 2013 to increase minimum inundation duration for Sacramento splittail from 20 days to 30 days and to decrease frequency/return period for Chinook salmon from 4 years to 3 years (ESA PWA pers. comm.). For a complete description of HEC-RAS and HEC-EFM modeling methods see Attachment 5E.A, *BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description & Assessment Document*, Section 5.E.A.7.3.1 (A), *South Delta Hydraulic and Hydrologic Modeling Methods and Assumptions* and Section 5.E.A.7.3.1.4, *Ecosystem Modeling Assessments*.

Table 5.E.5-1. Ecologically Relevant Flow-Related Habitat Criteria for HEC-EFM Scenarios, Original and Revised[a]

Model Results Source	Organism	Ecologically Relevant Flow Habitat Criteria: Life Stage	Season	Minimum Duration	Frequency/ Return Period	Sources
Revised HEC-EFM Inputs (ESA PWA pers. comm.)						
ESA PWA pers. comm.	Sacramento Splittail (*Pogonichthys macrolepidotus*)	Spawning and rearing	Feb 1–May 31	30 days	4-year	Moyle et al. 2004; Feyrer et al. 2005, 2006; Sommer et al. 1997
ESA PWA pers. comm.	Chinook salmon (*Oncorhynchus tshawytscha*)	Rearing	Dec 1–May 31	14 days	3-year	Sommer et al. 2001a; U.S. Army Corps of Engineers 2002.
Original HEC-EFM Inputs (Attachment 5E.A, Section 5.E.A.7.3.1.4, *Ecosystem Modeling Assessments*)						
ESA PWA 2012	Sacramento Splittail (*Pogonichthys macrolepidotus*)	Spawning and rearing	Feb 1–May 31	20 days	4-year	Sommer et al. 1997; U.S. Army Corps of Engineers 2002; Williams et al. 2009.
ESA PWA 2012	Chinook salmon (*Oncorhynchus tshawytscha*)	Rearing	Dec 1–May 31	14 days	4-year	Sommer et al. 2001a; U.S. Army Corps of Engineers 2002.

[a] The HEC-EFM was re-run in September 2013 (ESA PWA pers. comm.) to revise ecologically relevant criteria for Sacramento splittail and Chinook salmon. the existing conditions model was no re-run and so those results are based on the former ecologically relevant criteria. Because the former ecologically relevant criteria result in a slightly greater existing inundation acreage, the comparison between existing and restored conceptual corridors is assumed to produce a conservative estimate of increased inundation acreage.

The floodplain inundation and discharge relationship output from the HEC-RAS model was used to convert the HEC-EFM discharge output into an inundation acreage for both existing conditions and the conceptual corridors. See Attachment 5E.A, *BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description & Assessment Document*, Section 5.E.A.4, *Evaluation Results* to view the inundation to discharge curves for each conceptual corridor.

5.E.5.5.2 Results

Table 5.E.5-2 and Table 5.E.5-3 summarize the HEC-EFM outputs for the specified range of inundation duration scenarios in Table 5.E.5-1 for Sacramento splittail and Chinook salmon, respectively based on the criteria in Section 5.E.6-1. For each HEC-EFM scenario or run, seasonality and frequency were held constant while floodplain inundation duration was changed (see Table 5.E.5-1). Note, seasonality and frequency differ between Sacramento splittail and Chinook salmon.

Results suggest conceptual corridors 2B (Fabian Tract) and 4 have the greatest potential to increase the size of the inundated floodplain footprint. Corridor 2B While conceptual corridors 2B and 4 have the greatest potential to increase floodplain inundation acreage, it may not be feasible to do so. While restoration feasibility is not addressed in this analysis it is important to keep in mind that an increase in floodplain potential and covered species habitat is not the sole factor driving floodplain restoration placement or configuration. For instance, while the floodplain might be able to be expanded significantly in any one region, there may be land owner or other infrastructure constraints in another.

Table 5.E.5-4 and Table 5.E.5-5 compare the existing and restored condition HEC-EFM outputs—ecologically relevant discharge—and the associated inundation acreage, for one inundation duration scenario only. This is primarily because only one inundation duration scenario was run for existing conditions. The existing conditions floodplain inundation scenario for Sacramento splittail was 20 days (Attachment 5E.A, Section 5.E.A.7.3.1.4, *Ecosystem Modeling Assessments*), whereas the restored conditions scenario results are for 30 days (ESA PWA pers. comm.). For Chinook salmon, the floodplain inundation duration is the same between existing and restored conditions model runs, 14 days. However, the frequency/return period in the existing conditions model scenario was 4 years (Attachment 5E.A, Section 5.E.A.7.3.1.4, *Ecosystem Modeling Assessments*) and the restored conditions model scenario assumed a frequency/return period of 3 years (ESA PWA pers. comm.). Despite the differences in model inputs, the comparison between existing and restored conditions is still informative. In the case of Sacramento Splittail, the ecologically relevant discharge—HEC-EFM output—for 20 days versus 30 days was the same, 11,600 cfs. For Chinook Salmon, the change in frequency/return period from 4 years to 3 years resulted in the ecologically relevant discharge output decreasing from 15,500 cfs to 10,634 cfs (assuming 14 days inundation duration). As shown in Table 5.E.5-3, as the discharge decreases, so too does the floodplain inundation footprint. This means the discharge of 15,500 cfs used in the existing conditions model run produced a floodplain inundation footprint larger than if the new HEC-EFM model inputs had been used.

Table 5.E.5-2. HEC-EFM Inundation Acreage Results for Sacramento Splittail Ecologically Relevant Flow Criteria[a]

Duration of Inundation (days)	Discharge (cubic feet per second)	Corridor 1A		Corridor 1B		Corridor 2A		Corridor 2B (Fabian Tract)		Corridor 3		Corridor 4	
		Inundation Acres[b]	Percent of Floodplain Inundated[c]	Inundation Acres[d]	Percent of Floodplain Inundated[e]	Inundation Acres[f]	Percent of Floodplain Inundated[g]	Inundation Acres[h]	Percent of Floodplain Inundated[i]	Inundation Acres[j]	Percent of Floodplain Inundated[k]	Inundation Acres[l]	Percent of Floodplain Inundated[m]
30	11,600	1,924	16	1,064	19	275	11	3,668	51	1,517	19	2,307	37
31	11,600	1,924	16	1,064	19	275	11	3,668	51	1,517	19	2,307	37
32	11,600	1,924	16	1,064	19	275	11	3,668	51	1,517	19	2,307	37
33	11,500	1,887	15	1,050	18	269	11	3,662	51	1,505	19	2,294	37
34	10,800	1,627	13	953	17	232	9	3,615	50	1,417	18	2,204	36
35	10,500	1,516	12	911	16	216	9	3,594	50	1,380	18	2,165	35
36	10,200	1,404	11	870	15	200	8	3,574	49	1,342	17	2,126	34
37	10,200	1,404	11	870	15	200	8	3,574	49	1,342	17	2,126	34
38	10,200	1,404	11	870	15	200	8	3,574	49	1,342	17	2,126	34
39	10,100	1,367	11	856	15	194	8	3,568	49	1,330	17	2,113	34
40	8,530	1,191	10	783	14	185	8	3,551	49	1,299	17	2,275	37

[a] Assumes ecologically relevant inundation frequency of four years.
[b] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 1A*.
[c] Corridor 1A includes 12,318 acres.
[d] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 1B*.
[e] Corridor 1B includes 5,688 acres.
[f] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 2A*.
[g] Corridor 2A includes 2,444 acres.
[h] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 2B*.
[I] Corridor 2B includes 7,222 acres.
[j] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 3*.
[k] Corridor 3 includes 7,837 acres.
[l] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 4.*
[m] Corridor 4 includes 6,165 acres.

Table 5.E.5-3. HEC-EFM Inundation Acreage Results for Chinook Salmon Ecologically Relevant Flow Criteria[a]

Duration of Inundation (days)	Discharge (cubic feet per second)	Corridor 1A		Corridor 1B		Corridor 2A		Corridor 2B		Corridor 3		Corridor 4	
		Inundation Acres[b]	Percent of Floodplain Inundated[c]	Inundation Acres[d]	Percent of Floodplain Inundated[e]	Inundation Acres[f]	Percent of Floodplain Inundated[g]	Inundation Acres[h]	Percent of Floodplain Inundated[i]	Inundation Acres[j]	Percent of Floodplain Inundated[k]	Inundation Acres[l]	Percent of Floodplain Inundated[m]
7	11,668	1,949	16	1,074	19	278	11	3,673	51%	1,526	19	2,316	38
8	11,534	1,899	15	1,055	19	271	11	3,664	51%	1,509	19	2,298	37
9	11,334	1,825	15	1,027	18	261	11	3,650	51%	1,484	19	2,273	37
10	11,334	1,825	15	1,027	18	261	11	3,650	51%	1,484	19	2,273	37
11	11,001	1,702	14	981	17	243	10	3,628	50%	1,442	18	2,230	36
12	10,867	1,652	13	962	17	235	10	3,620	50%	1,425	18	2,212	36
13	10,834	1,640	13	958	17	234	10	3,617	50%	1,421	18	2,208	36
14	10,634	1,565	13	930	16	223	9	3,604	50%	1,396	18	2,182	35
15	10,425	1,488	12	901	16	212	9	3,589	50%	1,370	17	2,155	35
16	10,365	1,465	12	893	16	209	9	3,585	50%	1,363	17	2,147	35
17	10,068	1,355	11	851	15	193	8	3,565	49%	1,326	17	2,109	34
18	9,825	1,313	11	835	15	189	8	3,559	49%	1,315	17	2,442	40
19	9,648	1,297	11	828	15	188	8	3,559	49%	1,313	17	2,419	39
20	9,358	1,269	10	816	14	187	8	3,557	49%	1,309	17	2,382	39
21	9,235	1,257	10	811	14	187	8	3,556	49%	1,308	17	2,366	38

[a] Assumes ecologically relevant inundation frequency of three years.
[b] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 1A*.
[c] Corridor 1A includes 12,318 acres.
[d] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 1B*.
[e] Corridor 1B includes 5,688 acres.
[f] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 2A*.
[g] Corridor 2A includes 2,444 acres.
[h] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 2B*.
[I] Corridor 2B includes 7,222 acres.
[j] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 3*.
[k] Corridor 3 includes 7,837 acres.
[l] Based on Attachment 5E.A, Figure A.4.1-1, *Relation between Discharge and Floodplain Inundation: Corridor 4*.
[m] Corridor 4 includes 6,165 acres.

Table 5.E.5-4. HEC-EFM Inundation Acreage Results, Comparison between Existing Conditions and Conceptual Corridors for Sacramento Splittail Ecologically Relevant Flow Criteria[a]

Conceptual Corridors	Existing Inundated Floodplain Habitat (acres) *assuming 20 days inundation duration*	Inundated Floodplain Habitat for Conceptually Restored Corridors (acres) *assuming 30 days inundation duration*	Percent Increase over Existing
Corridor 1A[b]	412	1,924	467%
Corridor 1B[c]	213	1,064	500%
Corridor 2A[d]	11	275	2500%
Corridor 2B[e]	5	3,943	78860%
Corridor 3[f]	33	1,517	4597%
Corridor 4[g]	8	2,307	28838%

[a] Assumes 4 years inundation frequency and 11,600 cfs discharge.
[b] Existing Condition acreage from Table 5.EA.4.1-2.
[c] Existing Condition acreage from Table 5.EA.4.1-2.
[d] Existing Condition acreage from Table 5.EA.4.1-8.
[e] Existing Condition acreage from Table 5.EA.4.1-8 (Corridor 2B includes Fabian Tract).
[f] Existing Condition acreage from Table 5.EA.4.1-14.
[g] Existing Condition acreage from Table 5.EA.4.1-19

Table 5.E.5-5. HEC-EFM Inundation Acreage Results, Comparison between Existing Conditions and Conceptual Corridors for Chinook Salmon Ecologically Relevant Flow Criteria[a]

Conceptual Corridors	Existing Inundated Floodplain Habitat (acres) *assuming 15,500 cfs*	Inundated Floodplain Habitat (acres) *assuming 10,634 cfs*	Percent Increase over Existing
Corridor 1A[b]	910	1,565	172%
Corridor 1B[c]	532	930	175%
Corridor 2A[d]	46	223	485%
Corridor 2B[e]	29	3,827	13197%
Corridor 3[f]	88	1,396	1586%
Corridor 4[g]	26	2,182	8392%

[a] Assumes 14 days floodplain inundation duration.
[b] Existing Condition acreage from Table 5.EA.4.1-2.
[c] Existing Condition acreage from Table 5.EA.4.1-2.
[d] Existing Condition acreage from Table 5.A.4.1-8.
[e] Existing Condition acreage from Table 5.EA.4.1-8 (Corridor 2B includes Fabian Tract).
[f] Existing Condition acreage from Table 5.EA.4.1-14.
[g] Existing Condition acreage from Table 5.EA.4.1-19.

Results suggest each conceptual planning corridor has potential to significantly increase the ecologically relevant floodplain inundation footprint over existing, with Corridors 2A and 4 showing the greatest potential increase for both Sacramento splittail and Chinook Salmon. The potential increase in floodplain inundation is greater for Sacramento splittail because the frequency/return period criteria of 4 years is less than that for Chinook salmon, which requires a frequency of every 3 years to result in ecologically-relevant benefits. Stated another way, the potential for increased floodplain inundation in any given year increases as the required frequency (i.e., once every three years, once every four years) decreases.

Table 5.E.5-6 through Table 5.E.5-11 show the potential inundation frequencies for three inundation scenarios (30%, 60%, and 90%) combined with a range of duration scenarios (2 through 20 days in two day increments). An underlying assumption made in this analysis is that approximately 30% floodplain inundation is necessary to produce an ecologically meaningful foodweb response (see Attachment 5E.A, *BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description & Assessment Document*, Section 5.E.A.7.3.1.4, *Ecosystem Modeling Assessment* for additional details). While 30% is a somewhat arbitrary minimum inundation acreage, these results, combined with those species-specific results, provide an indication of the scale at which floodplain inundation is likely to have significant, beneficial effects on covered species.

Table 5.E.5-6. Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 1A (Season: December 1–May 31)

Duration (days)	Exceedance Probability		
	16,000 cfs (30% of the Corridor's Potential New Floodplain Is Inundated)	29,000 cfs (60% of the Corridor's Potential New Floodplain Is Inundated)	49,000 cfs (90% of the Corridor's Potential New Floodplain Is Inundated)
	Existing Hydrology	Existing Hydrology	Existing Hydrology
2	0.257	0.217	0.141
4	0.256	0.216	0.137
6	0.255	0.221	0.131
8	0.253	0.189	0.108
10	0.251	0.172	0.089
12	0.249	0.158	0.089
14	0.248	0.155	0.089
16	0.247	0.153	0.000
18	0.247	0.149	0.000
20	0.244	0.149	0.000

Source: ESA PWA 2012 (Attachment 5E.A).
Table created using area/discharge curves without sea level rise conditions. For sea level rise conditions, refer to the area/discharge curves to identify applicable acreages and percentages.
cfs = cubic feet per second; SJRRP = San Joaquin River Restoration Project.

Table 5.E.5-7. Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 1B (Season: December 1–May 31)

Duration (days)	Exceedance Probability		
	16,000 cfs (30% of the Corridor's Potential New Floodplain Is Inundated)	29,000 cfs (60% of the Corridor's Potential New Floodplain Is Inundated)	49,000 cfs (90% of the Corridor's Potential New Floodplain Is Inundated)
	Existing Hydrology	Existing Hydrology	Existing Hydrology
2	0.257	0.222	0.144
4	0.256	0.221	0.141
6	0.255	0.216	0.135
8	0.253	0.213	0.116
10	0.251	0.202	0.097
12	0.249	0.187	0.097
14	0.248	0.172	0.097
16	0.247	0.162	0.000
18	0.247	0.157	0.000
20	0.244	0.157	0.000

Source: ESA PWA 2012 (Attachment 5E.A).
Table created using area/discharge curves without sea level rise conditions. For sea level rise conditions, refer to the area/discharge curves to identify applicable acreages and percentages.
cfs = cubic feet per second; SJRRP = San Joaquin River Restoration Project.

Table 5.E.5-8. Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 2A (Season: December 1–May 31)

Duration (days)	Exceedance Probability		
	16,000 cfs (30% of the Corridor's Potential New Floodplain Is Inundated)	29,000 cfs (60% of the Corridor's Potential New Floodplain Is Inundated)	49,000 cfs (90% of the Corridor's Potential New Floodplain Is Inundated)
	Existing Hydrology	Existing Hydrology	Existing Hydrology
2	0.249	0.211	0.146
4	0.248	0.200	0.143
6	0.246	0.158	0.138
8	0.242	0.155	0.121
10	0.245	0.153	0.102
12	0.240	0.150	0.102
14	0.239	0.147	0.000
16	0.237	0.146	0.000
18	0.236	0.138	0.000
20	0.233	0.138	0.000

Source: ESA PWA 2012 (Attachment 5E.A).
Table created using area/discharge curves without sea level rise conditions. For sea level rise conditions, refer to the area/discharge curves to identify applicable acreages and percentages.
cfs = cubic feet per second; SJRRP = San Joaquin River Restoration Project.

Table 5.E.5-9. Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 2B (Season: December 1–May 31)

Duration (days)	Exceedance Probability		
	16,000 cfs (30% of the Corridor's Potential New Floodplain Is Inundated)	29,000 cfs (60% of the Corridor's Potential New Floodplain Is Inundated)	49,000 cfs (90% of the Corridor's Potential New Floodplain Is Inundated)
	Existing Hydrology	Existing Hydrology	Existing Hydrology
2	0.794	0.254	0.148
4	0.798	0.253	0.145
6	0.792	0.251	0.141
8	0.788	0.250	0.126
10	0.787	0.247	0.108
12	0.788	0.245	0.108
14	0.784	0.244	0.108
16	0.783	0.243	0.108
18	0.784	0.243	0.059
20	0.787	0.240	0.000

Source: ESA PWA 2012 (Attachment 5E.A).
Table created using area/discharge curves without sea level rise conditions. For sea level rise conditions, refer to the area/discharge curves to identify applicable acreages and percentages.
cfs = cubic feet per second; SJRRP = San Joaquin River Restoration Project.

Table 5.E.5-10. Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 3 (Season: December 1–May 31)

Duration (days)	Exceedance Probability		
	16,000 cfs (30% of the Corridor's Potential New Floodplain Is Inundated)	29,000 cfs (60% of the Corridor's Potential New Floodplain Is Inundated)	49,000 cfs (90% of the Corridor's Potential New Floodplain Is Inundated)
	Existing Hydrology	Existing Hydrology	Existing Hydrology
2	0.325	0.232	0.145
4	0.321	0.232	0.142
6	0.311	0.228	0.138
8	0.297	0.226	0.120
10	0.275	0.222	0.101
12	0.262	0.219	0.101
14	0.262	0.218	0.101
16	0.262	0.215	0.000
18	0.261	0.213	0.000
20	0.260	0.205	0.000

Source: ESA PWA 2012 (Attachment 5E.A).
Table created using area/discharge curves without sea level rise conditions. For sea level rise conditions, refer to the area/discharge curves to identify applicable acreages and percentages.
cfs = cubic feet per second; SJRRP = San Joaquin River Restoration Project.

Table 5.E.5-11. Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 4 (Season: December 1–May 31)

Duration (days)	Exceedance Probability		
	16,000 cfs (30% of the Corridor's Potential New Floodplain Is Inundated)	29,000 cfs (60% of the Corridor's Potential New Floodplain Is Inundated)	49,000 cfs (90% of the Corridor's Potential New Floodplain Is Inundated)
	Existing Hydrology	Existing Hydrology	Existing Hydrology
2	0.794	0.242	0.149
4	0.798	0.241	0.147
6	0.792	0.228	0.143
8	0.788	0.236	0.129
10	0.787	0.233	0.112
12	0.788	0.230	0.112
14	0.784	0.229	0.111
16	0.783	0.227	0.111
18	0.784	0.226	0.068
20	0.787	0.222	0.000

Source: ESA PWA 2012 (Attachment 5E.A).
Table created using area/discharge curves without sea level rise conditions. For sea level rise conditions, refer to the area/discharge curves to identify applicable acreages and percentages.
cfs = cubic feet per second.
SJRRP = San Joaquin River Restoration Project.

5.E.5.5.3 Anticipated Benefits

The HEC-EFM an analysis for salmon assumed that, at a minimum, floodplain inundation needed to occur every 3 years and inundation duration had to be at least 7 days, with significant food-web benefits likely being realized at a minimum of 14 days. Results suggest conceptually restored corridors in the South Delta could increase the amount of ecologically relevant floodplain for Chinook salmon by 172 to 13,197% depending on the conceptual corridor (Table 5.E.5-5). Significant increases in floodplain inundation are expected to increase the size of emigrating juvenile Chinook salmon and thus potentially increase through-Delta survival. The HEC-EFM analysis for splittail assumed a floodplain inundation occurrence of 4 years and an inundation period of 30 days. The analysis indicated an increase in ecologically relevant floodplain between 476% to 78,860% depending on the conceptual corridor. Below are the ecosystem mechanisms by which increased floodplain inundation could result in increased size and survival.

- Because of the shallow nature of floodplain habitat, irradiance of water is increased, thereby creating warmer temperatures than nearby channels. This increases metabolism in fish using the habitat, which increases feeding rates.
- Sediment drops out of the water column as floodwaters spread and slow, thus improving water quality within the adjacent channel.
- River channels are primary emigration corridors for juvenile salmon. Connection to adjacent floodplain habitat will greatly expand rearing habitat along migration corridors. This is especially important for emigrating Chinook fry, which will have increased survival through the Delta because of upstream growth before emigration.

- The creation of overland flows due to floodplain inundation could provide the additional benefit of flushing out FAV/SAV, thus providing more nearshore habitat for emigrating salmonids.
- Waters that spread out and interact with mosaics of floodplain vegetation are usually much slower than adjacent river channels. This could provide refugia during high-flow events that would reduce stress on juvenile salmonids.
- There is evidence that contact with vegetation reduces nonpoint sources of water pollution. Floodplain vegetation could reduce sources of nonpoint pollution and improve water quality in the adjacent river channel.
- Floodplain inundation supports the establishment of complex woody and scrub habitat along the river channel and floodplain. Woody and scrub habitat increase overhead cover and inputs large woody debris (LWD), creating topographic heterogeneity that drives the shifting of diverse habitat patches within the floodplain. This in turn drives productivity on many levels that increases food resources and provides rearing habitat for juvenile salmonids.
- Riparian habitat that forms with floodplain inundation increases the amount or organic carbon, provides leaf litter, and facilitates increased input of insects for aquatic foodweb support, in both the floodplain and the adjacent river channel.
- Complex habitats that form between floodplains and adjacent river channels provide refuge from predators for emigrating juvenile salmonids.
- The establishment of floodplain, riparian, and channel margin habitat creates a corridor of habitats for emigrating salmonids, allowing foraging, rest, and refuge from predators during emigration.
- Floodplain habitat will increase the amount of space between agriculture practices and the river corridor, thus providing a buffer zone that should increase aquatic insect communities and improve water quality.

The three-year frequency limits potential population-level benefits to approximately every third generation rearing on the floodplain in the South Delta. While there would be some increased floodplain inundation each year, especially in places like Corridor 2B and 4, it is unlikely that these increases would be large enough to result in significant increases in through-Delta survival for every year class.

Because the existing hydrological regime produces significant increases in floodplain inundation approximately every 3 years, CM5, as modeled, is likely to only produce low to medium benefits to emigrating salmonid juveniles. It is also important to note that enhanced growth may be offset by adverse conditions in the interior of the Delta such as the increased abundance and distribution of warm-water, predatory fishes.

CM5 has greater potential to provide population-level benefits to Sacramento splittail because of the increase in 30-day inundation of the floodplains. Sacramento splittail can live up to 9 years and therefore have potential for the same breeding generation to take advantage of one or two larger flood events where at least 20 to 30% of the floodplain is activated. In addition, Moyle et al. (2007) noted that even small amounts of floodplain inundation splittail recruitment can be quite large. The lower San Joaquin River, including the central and south Delta, are often sites of substantial splittail production (Sommer et al. 2007). Therefore splittail production from this area of the Delta may be more important than the modest amount of floodplain habitat would suggest.

CM5 also has potential to increase the geographic distribution of Sacramento splittail spawning habitats as the South Delta is not currently used by this species in any known, significant way. Increased distribution would have a number of potential benefits, including increased buffering from unforeseen future adverse environmental effects (including catastrophic events), potential increased genetic diversity, and additional rearing habitat for juvenile splittail emigrating from the spawning areas on the San Joaquin River floodplain upstream of the Delta.

Individual attributes from increased floodplain inundation that may increase splittail growth and survival are in general the same as those for salmonids with the addition that floodplain inundation will provide adult splittail access to floodplain vegetation for spawning substrate. Splittail use annual and perennial flooded vegetation for spawning. Increased spawning area in the San Joaquin River corridor will greatly enhance the San Joaquin River corridor for splittail spawning and rearing.

CM5 will also provide benefits to juvenile salmonids. Because of the existing hydrological regime that allows only periodic (every 4 years) and limited inundation (30%), CM5 overall as modeled will provide benefits to emigrating salmonid juveniles by increasing the upstream residence time, i.e., growth with increased food resources and complex habitats. As a result, through-Delta survival is expected to increase with larger emigrating size coupled with dual conveyance that is expected to lower entrainment. It is not known by how much survival will increase but the Yolo Bypass studies provide strong support to the idea that increased floodplain will enhance survival of juvenile salmonids; this increased growth is expected to increase through-delta survival. The enhanced growth may be offset by adverse conditions in the interior of the Delta. Individual attributes from increased floodplain inundation that may increase salmonid growth and survival are as follows.

5.E.5.5.4 Potential Impacts

The discussion of contaminants and their effects on fish can be found in Appendix 5.D, *Contaminants*.

- Release of toxins. Toxins built up from prior agricultural practices may be released to newly reconnected floodplains.
- Potential methylmercury release and resuspension. Fish and other aquatic species using recently reconnected/restored floodplain habitat would be exposed to potentially increased levels of methylmercury, and it may be transported downstream or result in local bioaccumulation affecting covered fish species, noncovered wildlife species, and human health.
- Increased fish stranding on the floodplain. Sommer et al. (2001b) and Moyle et al. (2007), however found that the amount of stranding was more than offset by the increase in growth and survival.
- Increased predation of covered fish by birds. Bird predation on floodplains is largely a function of anthropogenic structures that allow birds to prey on fish as they are funneled through narrow areas that increase their densities relative to open floodplain habitat (Crain unpublished data).
- Resuspension and export of contaminants to downstream areas.
- Production of organic matter that potentially could contribute to low DO conditions.

5.E.6 Conservation Measure 6 Channel Margin Enhancement

5.E.6.1 Description

The BDCP proposes to enhance 20 miles of channel margin along important salmonid migration routes in the Plan Area; most of this restoration is in the North Delta subregion. Channel margin enhancement would consist of constructing a shallow gradient from lower-elevation, submerged, shallow benches along existing river channels to higher-elevation riparian habitat. The design would involve modifying or setting back levees to create low benches with variable surface elevations to create hydrodynamic complexity and support emergent vegetation to provide an ecological gradient of habitat conditions, and higher elevation benches that support riparian and tidal marsh vegetation. CM6 includes but is not limited to the following actions.

- Modify the water side of levees or set back levees landward to create low floodplain benches. The floodplain benches would be constructed with variable surface elevations and water depths (laterally and longitudinally) to create hydrodynamic complexity, support emergent vegetation, and provide an ecological gradient of environmental conditions.
- Install LWD (e.g., tree trunks, logs, stumps) into constructed benches or into existing riprapped levees to provide physical complexity. Use finely branched material to minimize refuge for aquatic predators. LWD will be installed to replace debris lost during enhancement; woody debris also is expected to increase or be replaced over time through recruitment from adjacent riparian vegetation. It should be noted that LWD is controversial in that some believe that large smooth pieces provide hydraulic breaks for predators and little protection for juvenile salmonids. Finely branched LWD would provide both holding area and protection from predatory fishes, but more study is needed in the benefits and risks of LWD in the Plan Area.
- Plant native riparian and/or emergent wetland vegetation on constructed benches; open mudflat habitat may be appropriate too, depending on elevation and location.

Channel margin enhancement will be performed only along channels that provide rearing and outmigration habitat for juvenile salmonids. These include channels that are protected by federal project levees—such as the Sacramento River between Freeport and Walnut Grove, the San Joaquin River between Vernalis and Mossdale, and Steamboat and Sutter Sloughs—and channels in the interior Delta that are protected by nonfederal levees—such as the North and South Fork Mokelumne River.

The temporal targets for implementation of the 20 miles of channel margin enhancements are as follows.

- At least 5 miles enhanced by year 10.
- At least 5 more miles enhanced by year 20.
- At least 5 more miles enhanced by year 25.
- At least 5 more miles enhanced by year 30.

The primary objective of CM6 is to improve habitat conditions along important juvenile salmonid migration routes. CM6 is expected to increase rearing habitat; improve conditions along migration corridors by providing increased habitat complexity, overhead and in-water cover, and prey resources for covered fish species; and improve connectivity between patches of existing, higher-value channel margin habitat (Chapter 3, Section 3.4.6.1, *Purpose*). This conservation measure also has the potential to increase spawning habitat for covered fish that spawn in the Plan Area, primarily Sacramento splittail and possibly delta smelt and longfin smelt, as well as increase resting habitat in the Plan Area for migrating adult covered fish species. CM6 will advance specific biological goals and objectives, as described in Chapter 3, Section 3.4.6.5. Expected benefits of CM6 to covered fish species are discussed below.

5.E.6.2 Conceptual Model

Historically, the lower portions of tributaries to the Delta were a maze of channels and sloughs with complex channel margins composed of benches, beaches, and river bars supporting riparian forests and estuarine marsh vegetation. This created an array of habitats for native fish and wildlife species. Much of the development of the Delta has focused on simplifying these complex environments to create concentrated channels that are often armored to stabilize and protect river banks. As a result, resting and foraging habitat for juvenile salmonids and other species has been lost.

Restoring and enhancing channel margin in the Plan Area will add complexity to long, continuous stretches of aquatic and supratidal habitat adjacent to important migration corridors. Channel margin enhancement actions will attempt to improve the shallow-depth, slow–current velocity conditions within existing channel geometries that have been shown to play an important role in the survival of juvenile fish. These areas provide small juvenile fish areas of cover from predators with overhanging banks, instream woody material, and riparian vegetation; contribute invertebrates and organic material to the aquatic foodweb; and offer areas of low water-velocity where the larvae and protolarvae of target fish species can rest during outmigration (Bowen et al. 2003). Because the life cycle requirements of the target fish species are season-specific and environmental conditions (temperature, outflows) vary from year to year, as much variability as possible should be built into the channel margin to accommodate as many of the requirements as possible.

Enhanced channel margin will connect habitat patches throughout the Plan Area. Pringle (2003) defines connectivity as “the degree to which a landscape facilitates or impedes movement of organisms among resource patches.” The homogenous, riprap-lined river channels in the Plan Area, while not a physical hydrologic barrier to migration, do not ease the process for the target aquatic species and provide little direct habitat benefit. The channels identified for channel margin enhancement represent linear (as opposed to dendritic) migration corridors for the target aquatic species. Fagan (2002) and Cote (2009) demonstrated that disruptions in linear migration corridors have greater effects on populations compared to dendritic migration corridors because of the lack of multiple pathways. This concept reinforces the need to enhance channel margins in the Plan Area because of the unique role they serve in target fish species migration.

The importance of low-slope habitat without revetment has been found for smaller Chinook salmon that are rearing in the Delta (McLain and Castillo 2009; Zajanc et al. 2012). Zajanc and others (2012) found that where IWM (instream woody material) diversity was lower, IWM was larger and fine substrate was dominant Chinook salmon had a higher probability of holding (≥1 hour), and that the probability of holding for longer time was associated with increasing shade, lower IWM diversity, and absence of SAV (submerged aquatic vegetation). Some studies in the Plan Area indicate that larger, outmigrating juvenile Chinook salmon in the Delta may use channel margin habitat for holding during the day and then move offshore at night (Burau et al. 2007; Zajanc et al. 2012), whereas other studies suggest that nocturnal holding diminishes in the lower reaches of the Sacramento River as turbidity (and hence predator refuge) increases (Michel 2010) and that relatively little time is spent in enhanced channel margins by larger Chinook salmon and steelhead (H.T. Harvey and Associates with PRBO Conservation Science 2010; Zajanc et al. 2012). The extent to which the acoustically tagged, hatchery-origin fish used in such studies represent the behavior of wild fish, especially fry and pre-smolts, is uncertain.

5.E.6.3 Consistency with the Biological Goals and Objectives

CM6 will advance the biological goals and objectives as identified in Chapter 3, *Conservation Strategy*, Table 3.4.6-2. The rationale for each of these goals and objectives is provided in Chapter 3, Section 3.3, *Biological Goals and Objectives*. Through effectiveness monitoring, research, and adaptive management, described above, the Implementation Office will address scientific and management uncertainties and ensure that these biological goals and objectives are met. Table 3.4.6-2 also identifies potential monitoring actions associated with each objective as it relates to CM6.

5.E.6.3.1 Delta Smelt

CM6 is not expected to provide great benefit for delta smelt. The measure is directed primarily at restoring habitat for emigrating juvenile salmonids. It may provide some minor benefit to delta smelt if additional spawning habitat (e.g., shallow, sandy shoals) is restored. It is unknown whether spawning habitat is limiting for delta smelt.

5.E.6.3.2 Longfin Smelt

CM6 also is not expected to provide great benefit for longfin smelt. Similar to delta smelt, longfin smelt may gain spawning habitat as a result of CM6, but whether this type of habitat is limiting, given for longfin smelt in the North Delta subregion, is unknown.

5.E.6.3.3 Salmonids

Channel margin enhancement under the BDCP is generally expected to benefit covered salmonids by improving rearing habitat and connectivity along migration corridors. The primary benefit of CM6 will be an increase in high-value rearing habitat for juvenile salmonids, particularly for Chinook salmon fry, because of enhancement and creation of additional shallow-water habitat that will provide refuge from unfavorable hydraulic conditions and predation, as well as foraging habitat.

5.E.6.3.4 Splittail

CM6 is not expected to provide great benefit for splittail. The measure is directed primarily at restoring habitat for emigrating juvenile salmonids. It may provide some minor benefit to splittail if additional spawning habitat (e.g., submerged vegetation) is available. It is unknown whether spawning habitat is limiting for splittail.

5.E.6.3.5 Sturgeon (Green and White)

Channel margin enhancement may increase the availability and value of resting habitat for migrating adults by increasing channel margin complexity (e.g., woody material) that provides refuge from high flows. Although little is known about the use of channel margin habitat by white and green sturgeon, the DRERIP evaluations reported that there may be some rearing benefit from channel margin enhancement.

5.E.6.3.6 Lampreys (Pacific and River)

CM6 may provide a small net benefit to both Pacific and river lamprey. Although little is known about use of channel margin habitat by Pacific lamprey and river lamprey, these species may benefit from enhancement that increases the area of non-revetted, sandy-muddy substrate into which ammocoetes can burrow; recent monitoring suggests that ammocoetes may be present in substrates in the Plan Area.

5.E.6.4 Explanation of the Conservation Measure

5.E.6.4.1 Current Conditions

Existing channel margin conditions of importance to fish were summarized using the Sacramento River Bank Protection Project revetment database (U.S. Army Corps of Engineers 2007b). This database covers levees that are part of the Sacramento River Flood Control Project. In the Plan Area, the major channels important to covered fish species that are included in the database are:

- Sacramento River: full extent
- Georgiana Slough: full extent
- Sutter and Steamboat Sloughs: full extents
- Miner Slough: full extent
- Cache Slough: partial extent

Revetment database surveys consist of characterizing channel margin segments with relatively homogenous habitat features from a research vessel. Depending on the habitat features of a particular channel, it may consist of relatively few segments (indicating long stretches of homogenous habitat), or it may consist of numerous segments (indicating that habitat is quite heterogenous). The revetment database was used to summarize several features of existing habitat that may be important to covered fish species such as:

- Water depth
- Presence of revetment
- Emergent vegetation coverage
- Overhead cover (shade)
- Woody material

The revetment database consists of data collected during summer surveys between 2002 and 2007; therefore, there may be discrepancies between existing habitat conditions and habitat conditions when the data were collected (because of changes that have occurred over time and also because summer habitat may differ from habitat at other times of the year). It is assumed that the database offers a reasonable representation of existing channel margin habitat.

Data from the revetment database were summarized for each of the main channels described above for which coverage was available. The Sacramento River was subdivided into several ecological units in order to characterize conditions along this long reach in more detail.

- Upstream boundary of North Delta subregion (just south of Sacramento) to Freeport.
- Freeport to divergence with Georgiana Slough.
- Divergence with Georgiana Slough to downstream boundary of North Delta subregion (i.e., at the confluence of the Sacramento River and Cache Slough).
- Downstream boundary of North Delta subregion (near Rio Vista) to end of revetment database coverage (i.e., the eastern border the Suisun Marsh subregion and the West Delta subregion).

The U.S. Army Corps of Engineers revetment database provides information for around 240 miles of channel margin in the North Delta, West Delta, and Cache Slough subregions of the Plan Area (Figure 5.E.6-1 through Figure 5.E.6-6; Table 5.E.6-1 through Table 5.E.6-6). Revetted banks account for approximately 150 linear miles (62.5%) of channel margin, ranging from 5.5 miles in the Cache Slough subregion channels (11% of the shoreline in that subregion) to more than 39 miles in the Sacramento River between Freeport and Georgiana Slough (96% of the shoreline in that reach) (Figure 5.E.6-1, Table 5.E.6-1). Other important channels for fish in the North Delta subregion (Steamboat and Sutter Sloughs) also had quite extensive revetment coverage (more than 80%).

Reaches with a relatively large coverage of shallow water (<2.5 feet deep 5 feet away from shore) included the Cache Slough subregion channels (more than 44 miles, 93%), Steamboat Slough (more than 21 miles, 92%), and the Sacramento River from Georgiana Slough to Cache Slough (nearly 20 miles, 82%) (Figure 5.E.6-2, Table 5.E.6-2). These same channels, along with Miner Slough, also had water that was predominantly less than 5 feet deep at a distance of 12 feet from the shore. In contrast, the Sacramento River from Freeport to Georgiana Slough and Georgiana Slough itself had a relatively low proportion of shallow-water habitat, with Georgiana Slough being notable for the appreciable extent of water that was >10 feet deep at 10 feet away from the shore (more than 8 miles, 34%) (Figure 5.E.6-3, Table 5.E.6-3).

Emergent vegetation was absent, or nearly so, in the Sacramento River from the top of the North Delta subregion to Georgiana Slough, and in Sutter Slough (Figure 5.E.6-4, Table 5.E.6-4). Below Georgiana Slough on the Sacramento River, around 10% of the shoreline had emergent vegetation down to Cache Slough, whereas the farthest downstream reach within the revetment database coverage (Cache Slough to Suisun Marsh subregion) had more than 85% of shoreline with some emergent vegetation (mostly in the 6–25% and >75% of shoreline categories). The remaining channels had 12–40% of shoreline with emergent vegetation, with the Cache Slough subregion channels having the greatest extent of emergent vegetation (Figure 5.E.6-4, Table 5.E.6-4).

Woody material was particularly abundant in Georgiana Slough (less than 1 mile [3%] with no woody material and 13 miles [54%] of shoreline with >50% woody material) and in the Sacramento River from the top of the North Delta subregion to Freeport (nearly 9 miles [more than 40%] with woody material of 11–50% or >50%) (Figure 5.E.6-5, Table 5.E.6-5). Reaches with low quantities of woody material included the Cache Slough subregion channels (more than 43 miles [90%] with no woody material), and two segments of the Sacramento River from Freeport to Georgiana Slough and from Cache Slough to the Suisun Marsh subregion, both of which were mostly (around 90%) made up of no woody material or 1–10% woody material cover.

Overhead cover was most prominent in Georgiana Slough (nearly 20 miles [almost 80%] with >25% cover), Miner Slough (9 miles [80%] with >25% cover), and Sutter Slough (7.5 miles [nearly 60%] with >25% cover); all three of these channels had very little shoreline with no overhead cover (1–6%) (Figure 5.E.6-6, Table 5.E.6-6). In contrast, the Sacramento River in two reaches (Freeport to Georgiana Slough and Cache Slough to Suisun Marsh subregion) and the Cache Slough subregion channels had very little overhead cover (around 70–90% of shoreline with 5% cover or less).

Table 5.E.6-1. Linear Extent (Miles) of Revetted Channel Margin within Channels of the Plan Area

	Non-Revetment (Natural)	Revetment	Total
Sacramento River			
Top of North Delta subregion to Freeport	5.4 (26%)	15.3 (74%)	20.7
Freeport to Georgiana Slough	1.5 (4%)	39.3 (96%)	40.8
Georgiana Slough to Cache Slough	3.2 (13%)	20.9 (87%)	24.1
Cache Slough to Suisun Marsh subregion	14.0 (46%)	16.7 (54%)	30.8
Sutter Slough	2.3 (17%)	10.9 (83%)	13.1
Steamboat Slough	4.4 (19%)	18.9 (81%)	23.3
Georgiana Slough	14.3 (58%)	10.4 (42%)	24.7
Miner Slough	3.7 (24%)	11.6 (76%)	15.3
Cache Slough subregion channels	42.2 (89%)	5.5 (11%)	47.6
Total	90.9	149.4	240.3
Source: U.S. Army Corps of Engineers (2007b) Sacramento River Bank Protection Project Revetment Database.			

Table 5.E.6-2. Linear Extent (Miles) of Water Depth 5 Feet from Shore within Channels of the Plan Area

	<2.5 feet	2.5–5 feet	5–10 feet	Total
Sacramento River				
Top of North Delta subregion to Freeport	15.7 (76%)	5.0 (24%)	0.0 (0%)	20.7
Freeport to Georgiana Slough	23.6 (58%)	17.2 (42%)	0.0 (0%)	40.8
Georgiana Slough to Cache Slough	19.8 (82%)	4.3 (18%)	0.0 (0%)	24.1
Cache Slough to Suisun Marsh subregion	18.2 (59%)	12.5 (41%)	0.0 (0%)	30.8
Sutter Slough	8.2 (63%)	4.8 (37%)	0.1 (1%)	13.1
Steamboat Slough	21.4 (92%)	1.9 (8%)	0.0 (0%)	23.3
Georgiana Slough	11.0 (44%)	10.9 (44%)	2.8 (12%)	24.7
Miner Slough	11.1 (73%)	4.1 (27%)	0.0 (0%)	15.3
Cache Slough subregion channels	44.5 (93%)	1.6 (3%)	1.5 (3%)	47.6
Total	173.6	62.3	4.4	240.3
Source: U.S. Army Corps of Engineers (2007b) Sacramento River Bank Protection Project Revetment Database.				

Table 5.E.6-3. Linear Extent (Miles) of Water Depth 12 Feet from Shore within Channels of the Plan Area

	<2.5 feet	2.5–5 feet	5–10 feet	>10 feet	Total
Sacramento River					
Top of North Delta subregion to Freeport	7.3 (35%)	8.0 (39%)	4.9 (24%)	0.5 (2%)	20.7
Freeport to Georgiana Slough	2.9 (7%)	15.5 (38%)	21.7 (53%)	0.7 (2%)	40.8
Georgiana Slough to Cache Slough	15.9 (66%)	4.2 (17%)	4.0 (16%)	0.0 (0%)	24.1
Cache Slough to Suisun Marsh subregion	9.8 (32%)	17.6 (57%)	3.4 (11%)	0.0 (0%)	30.8
Sutter Slough	0.6 (5%)	3.1 (23%)	8.7 (66%)	0.8 (6%)	13.1
Steamboat Slough	8.9 (38%)	9.4 (40%)	4.6 (20%)	0.4 (2%)	23.3
Georgiana Slough	5.7 (23%)	1.6 (7%)	8.9 (36%)	8.4 (34%)	24.7
Miner Slough	7.3 (48%)	2.3 (15%)	5.7 (37%)	0.0 (0%)	15.3
Cache Slough subregion channels	11.2 (23%)	34.9 (73%)	0.1 (0%)	1.5 (3%)	47.6
Total	69.6	96.6	61.9	12.3	240.3

Source: U.S. Army Corps of Engineers (2007b) Sacramento River Bank Protection Project Revetment Database.

Table 5.E.6-4. Linear Extent (Miles) of Emergent Vegetation (% of Shoreline) within Channels of the Plan Area

	0%	1–5%	6–25%	26–75%	>75%	Total
Sacramento River						
Top of North Delta subregion to Freeport	20.7 (100%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	20.7
Freeport to Georgiana Slough	39.8 (98%)	0.0 (0%)	0.0 (0%)	0.7 (2%)	0.3 (1%)	40.8
Georgiana Slough to Cache Slough	21.6 (90%)	1.3 (5%)	0.0 (0%)	0.5 (2%)	0.6 (3%)	24.1
Cache Slough to Suisun Marsh subregion	5.0 (16%)	3.5 (11%)	7.2 (23%)	3.8 (12%)	11.3 (37%)	30.8
Sutter Slough	13.1 (100%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	0.0 (0%)	13.1
Steamboat Slough	16.6 (71%)	2.0 (9%)	0.7 (3%)	3.7 (16%)	0.3 (1%)	23.3
Georgiana Slough	16.8 (68%)	3.7 (15%)	2.4 (10%)	0.4 (2%)	1.4 (6%)	24.7
Miner Slough	13.5 (88%)	0.5 (3%)	0.3 (2%)	0.0 (0%)	1.0 (7%)	15.3
Cache Slough subregion channels	28.5 (60%)	5.9 (12%)	7.8 (16%)	4.6 (10%)	0.8 (2%)	47.6
Total	175.6	17.0	18.3	13.7	15.8	240.3

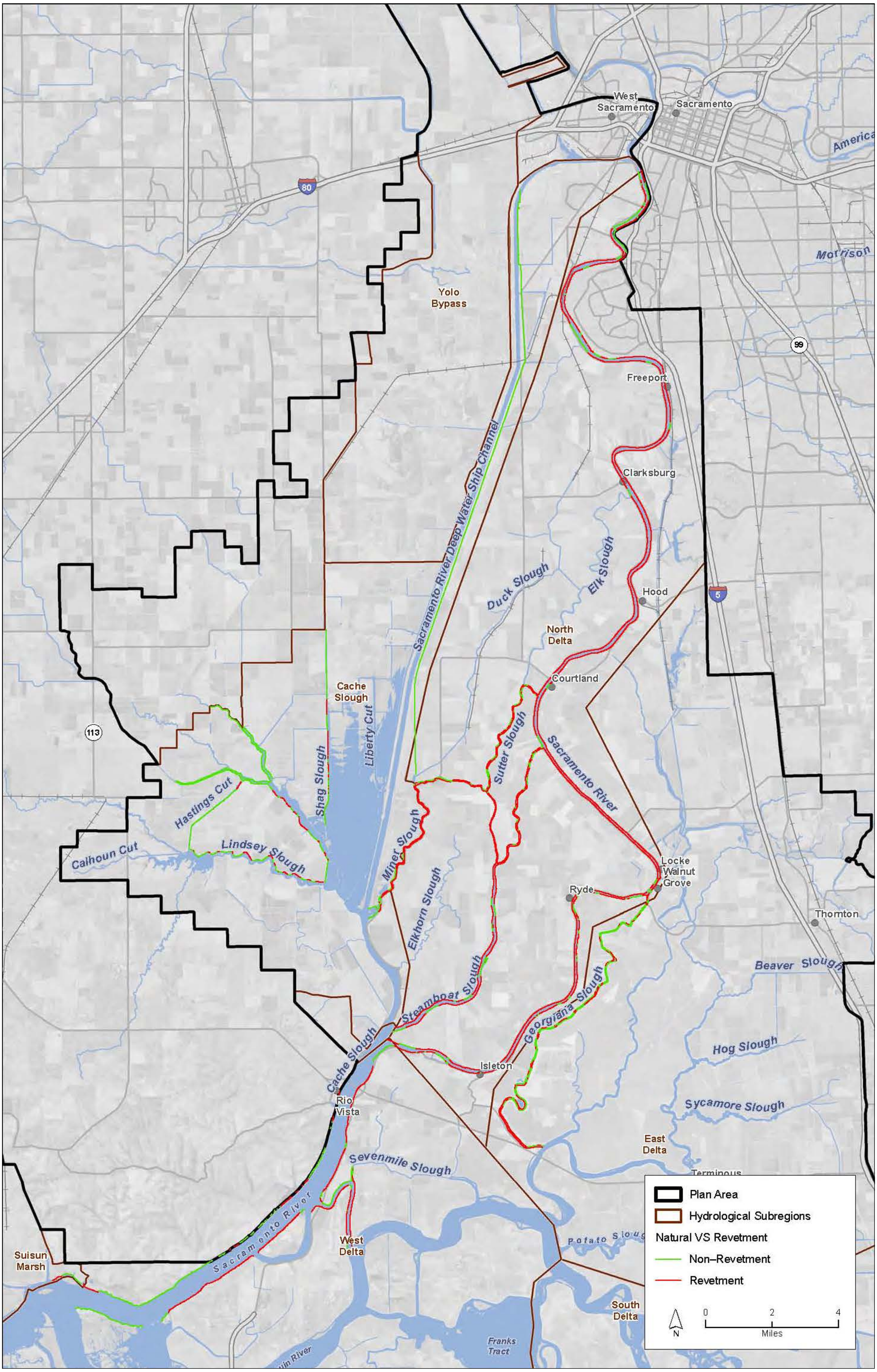
Source: U.S. Army Corps of Engineers (2007b) Sacramento River Bank Protection Project Revetment Database.

Table 5.E.6-5. Linear Extent (Miles) of Woody Material (% of Shoreline) within Channels of the Plan Area

	0%	1–10%	11–50%	>50%	Total
Sacramento River					
Top of North Delta subregion to Freeport	7.1 (34%)	4.8 (23%)	3.2 (15%)	5.5 (27%)	20.7
Freeport to Georgiana Slough	26.6 (65%)	10.2 (25%)	3.1 (8%)	0.8 (2%)	40.8
Georgiana Slough to Cache Slough	15.1 (63%)	2.4 (10%)	4.5 (19%)	2.0 (9%)	24.1
Cache Slough to Suisun Marsh subregion	11.2 (36%)	16.9 (55%)	2.7 (9%)	0.0 (0%)	30.8
Sutter Slough	6.1 (47%)	4.3 (33%)	0.9 (7%)	1.8 (14%)	13.1
Steamboat Slough	4.7 (20%)	11.2 (48%)	4.5 (19%)	2.9 (13%)	23.3
Georgiana Slough	0.8 (3%)	7.5 (30%)	3.3 (13%)	13.3 (54%)	24.7
Miner Slough	6.3 (42%)	5.4 (35%)	1.1 (7%)	2.4 (16%)	15.3
Cache Slough subregion channels	43.4 (91%)	4.2 (9%)	0.0 (0%)	0.0 (0%)	47.6
Total	121.3	66.9	23.2	28.9	240.3
Source: U.S. Army Corps of Engineers (2007b) Sacramento River Bank Protection Project Revetment Database.					

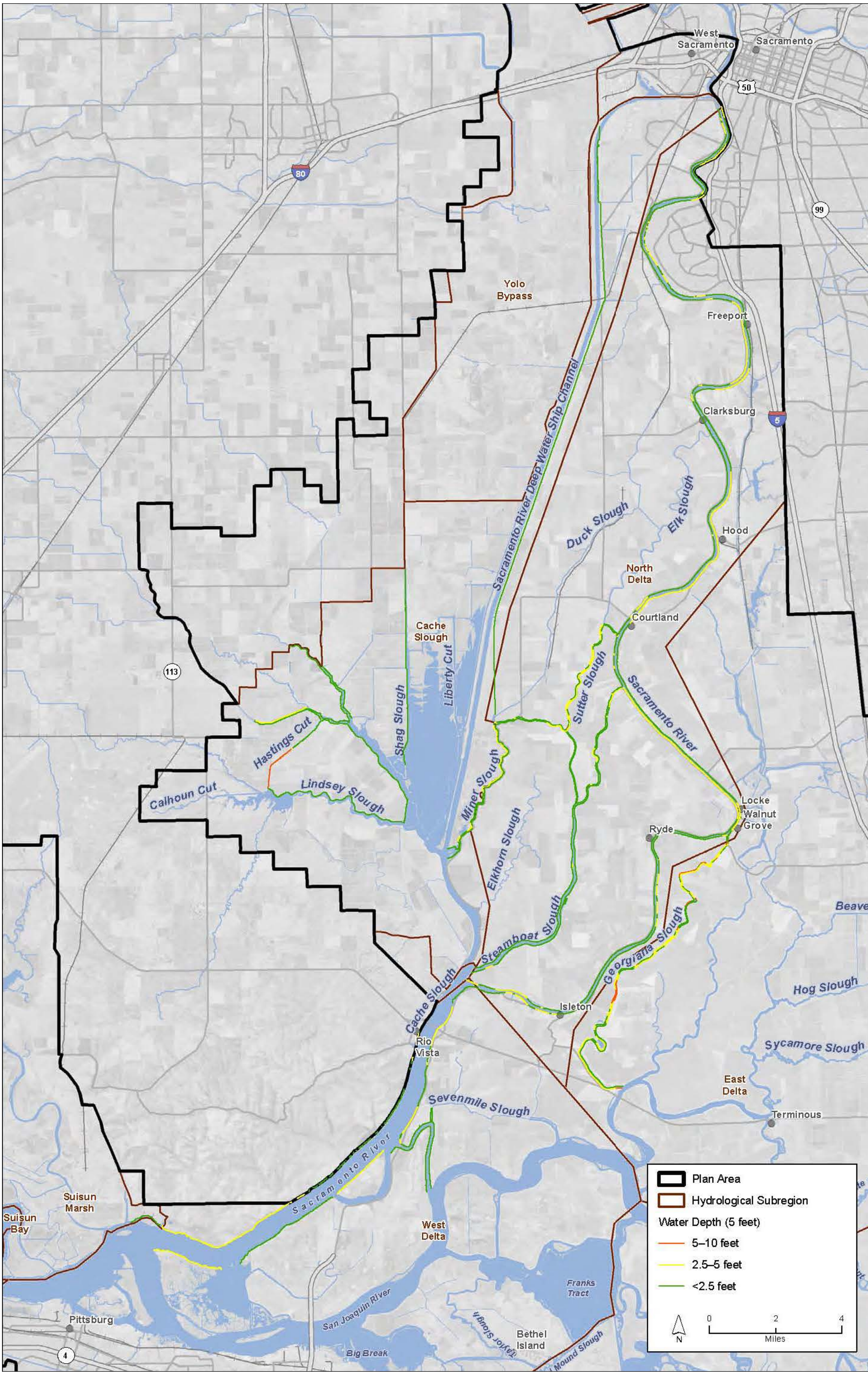
Table 5.E.6-6. Linear Extent (Miles) of Overhead Cover (% of shoreline) within Channels of the Plan Area

	0%	1–5%	6–25%	26–75%	>75%	Total
Sacramento River						
Top of North Delta subregion to Freeport	3.5 (17%)	5.3 (25%)	2.1 (10%)	9.0 (43%)	0.8 (4%)	20.7
Freeport to Georgiana Slough	17.9 (44%)	10.4 (26%)	8.2 (20%)	3.1 (8%)	1.1 (3%)	40.8
Georgiana Slough to Cache Slough	11.7 (49%)	2.2 (9%)	2.7 (11%)	3.1 (13%)	4.2 (18%)	24.1
Cache Slough to Suisun Marsh subregion	17.0 (55%)	7.0 (23%)	5.4 (18%)	1.2 (4%)	0.1 (0%)	30.8
Sutter Slough	0.1 (1%)	0.1 (1%)	5.4 (41%)	6.2 (47%)	1.3 (10%)	13.1
Steamboat Slough	7.3 (31%)	3.8 (16%)	2.4 (10%)	8.4 (36%)	1.5 (6%)	23.3
Georgiana Slough	1.5 (6%)	2.8 (11%)	1.4 (6%)	10.5 (43%)	8.5 (34%)	24.7
Miner Slough	0.2 (1%)	0.9 (6%)	5.2 (34%)	6.1 (40%)	2.8 (19%)	15.3
Cache Slough subregion channels	35.1 (74%)	8.0 (17%)	4.6 (10%)	0.0 (0%)	0.0 (0%)	47.6
Total	94.2	40.5	37.5	47.7	20.4	240.3
Source: U.S. Army Corps of Engineers (2007b) Sacramento River Bank Protection Project Revetment Database.						



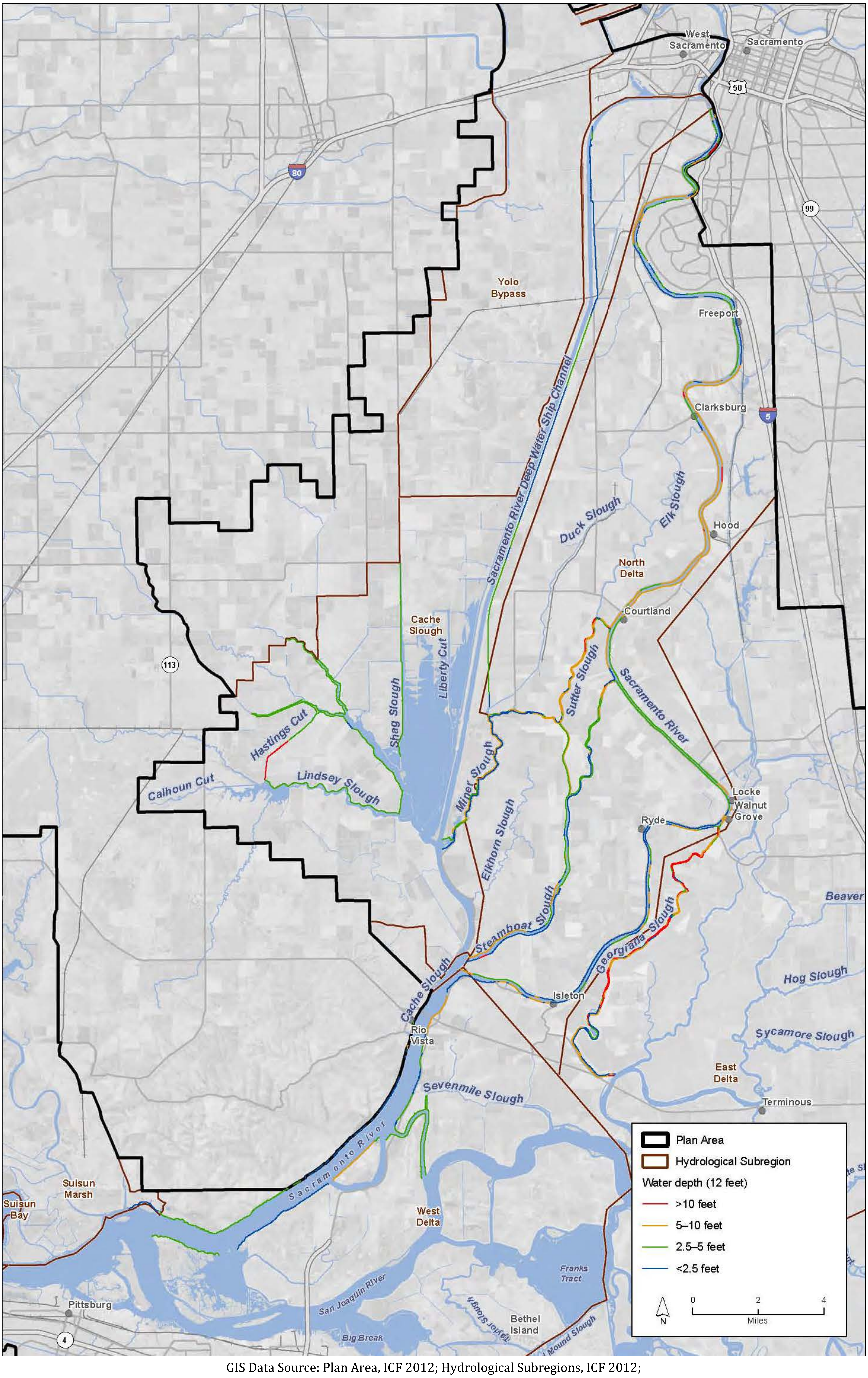
GIS Data Source: Conservation Zones, SAIC 2012; Plan Area, ICF 2012; Hydrological Subregions, ICF 2012; Sacramento River Bank Protection Project Revetment Database, USACDE 2007.

Figure 5.E.6-1. Revetment within Channels of the Plan Area



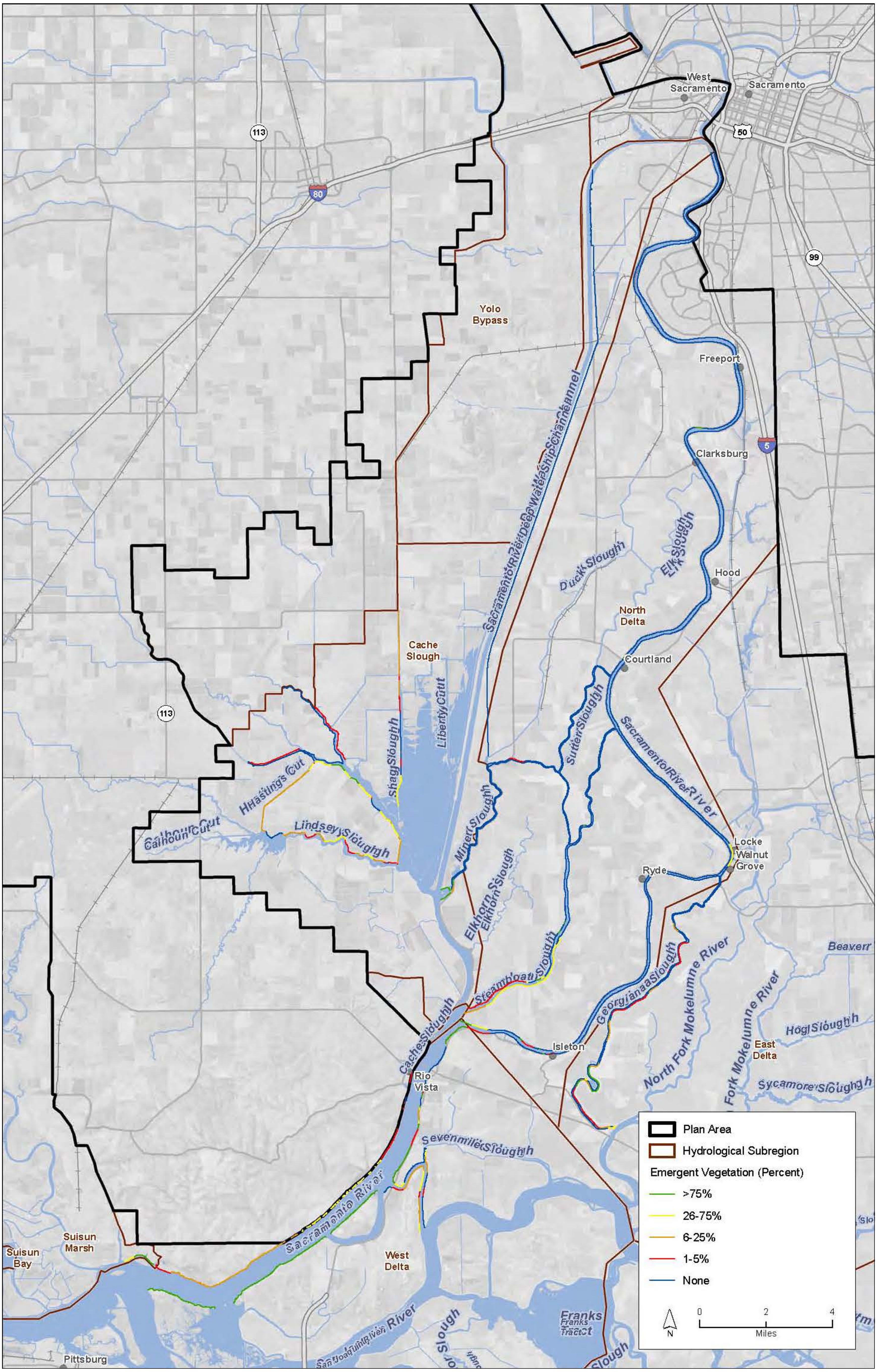
GIS Data Source: Plan Area, ICF 2012; Hydrological Subregions, ICF 2012;
Sacramento River Bank Protection Project Revetment Database, USACDE 2007.

Figure 5.E.6-2. Water Depth 5 Feet from Shore within Channels of the Plan Area



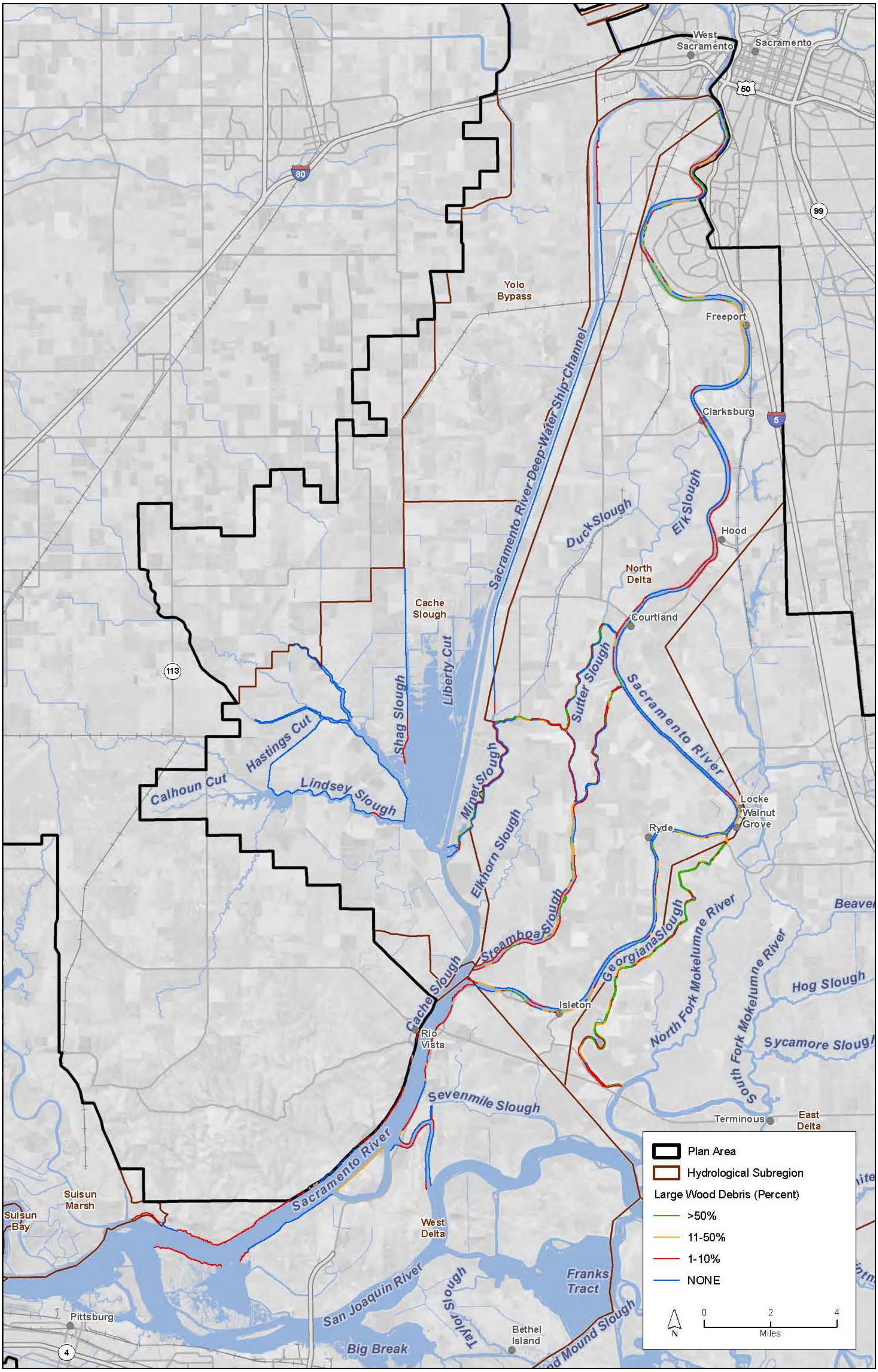
GIS Data Source: Plan Area, ICF 2012; Hydrological Subregions, ICF 2012;
Sacramento River Bank Protection Project Revetment Database, USACDE 2007.

Figure 5.E.6-3. Water Depth 12 Feet from Shore within Channels of the Plan Area



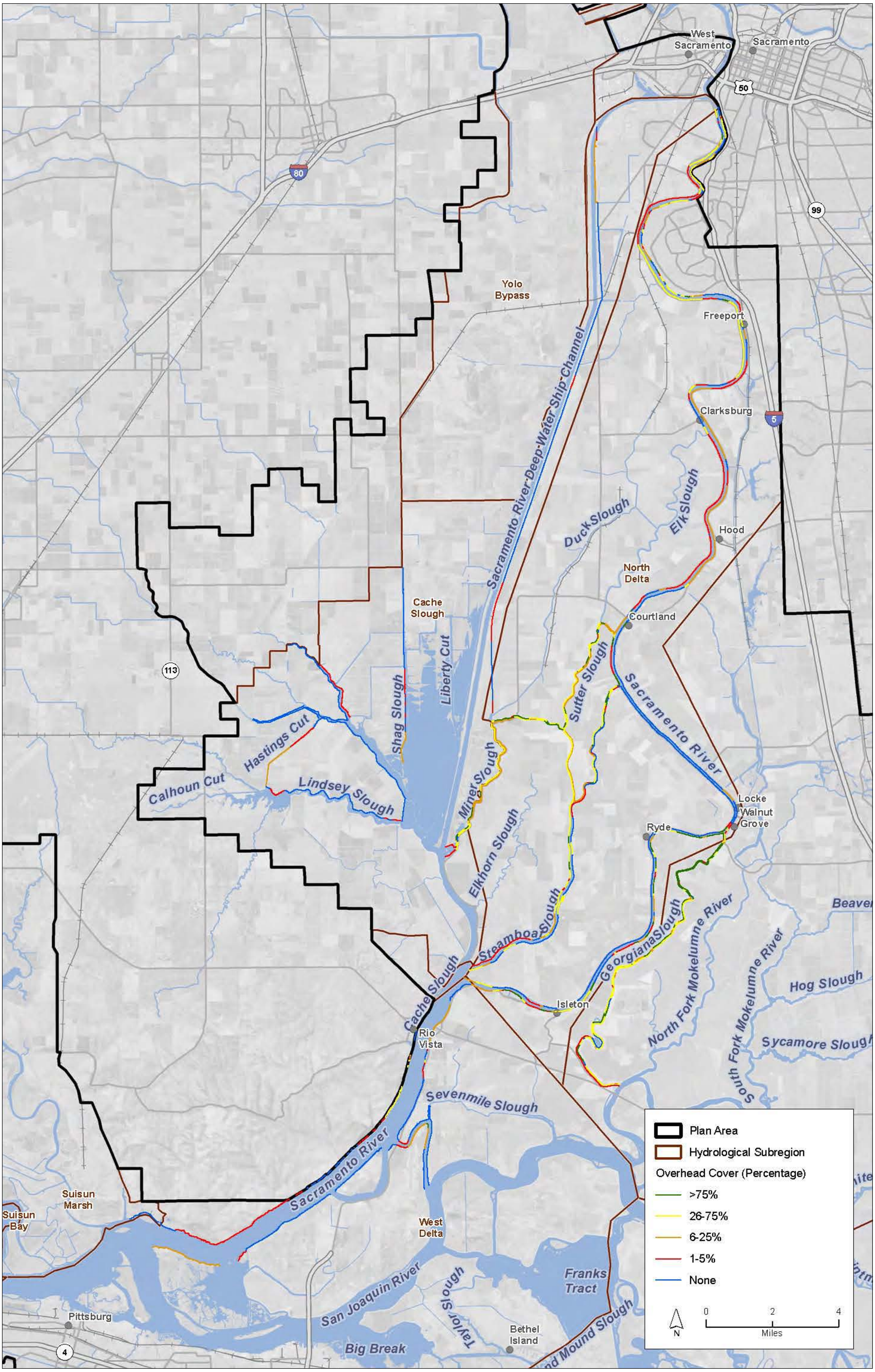
GIS Data Source: Plan Area, ICF 2012; Hydrological Subregions, ICF 2012; Sacramento River Bank Protection Project Revetment Database, USACDE 2007.

Figure 5.E.6-4. Emergent Vegetation (% of Shoreline) within Channels of the Plan Area



GIS Data Source: Plan Area, ICF 2012; Hydrological Subregions, ICF 2012; Sacramento River Bank Protection Project Revetment Database, USACDE 2007.

Figure 5.E.6-5. Woody Material (% of Shoreline) within Channels of the Plan Area



GIS Data Source: Plan Area, ICF 2012; Hydrological Subregions, ICF 2012;
Sacramento River Bank Protection Project Revetment Database, USACDE 2007.

Figure 5.E.6-6. Overhead Cover (Percent of Shoreline) within Channels of the Plan Area

5.E.6.4.2 Post-Restoration Conditions

Channel margin enhancement in the Plan Area under CM6 will include 20 linear miles of restoration. At least 15 miles of the enhancement will be sited along the channels of one or more of the following water bodies: the Sacramento River, Steamboat Slough, and Sutter Slough. The approximate total lengths of channel margin of the main water bodies in the Plan Area where channel margin enhancement could occur are as follows.

- Sacramento River (top of North Delta subregion to Sacramento–San Joaquin confluence in the West Delta subregion): 116 miles.
- Sutter Slough: 13 miles.
- Steamboat Slough: 23 miles.
- Miner Slough: 15 miles.
- Georgiana Slough: 24 miles.
- Mokelumne River (North and South Forks within the Plan Area): 77 miles.
- San Joaquin River (Vernalis to Sacramento–San Joaquin confluence in the West Delta subregion): 240 miles.

These water bodies represent around 500 linear miles of channel margin, and therefore CM6 has the potential to enhance approximately 4% of this total. The physical reconfiguration of channel margin under CM6 would create habitat that generally would have more natural substrates (and in particular less dominance by large-diameter riprap), lower slopes, more structural complexity (e.g., emergent vegetation, anchored woody material), and increased riparian vegetation. It is anticipated that any site grading, revetment removal/soil placement, emergent vegetation planting, and installation of woody material would affect covered fish species reasonably soon (following construction or within a few years) after restoration at a given site is completed. Development of riparian functioning, including overhanging shade, would be a more gradual process. Although site-specific differences occur because of planting, it is generally assumed to be 10–15 years before shoreline becomes appreciably shaded by riparian vegetation (U.S. Army Corps of Engineers 2007a). Following site enhancement, there inevitably will be changes in habitat, e.g., degradation of any anchored woody material and recruitment of new woody material (U.S. Army Corps of Engineers 2011) that will require monitoring and adaptive management to ensure that desirable site characteristics are being maintained.

5.E.6.5 Evaluation

5.E.6.5.1 Method

A qualitative assessment was made of the effects of CM6 on covered fish species based primarily on review of pertinent literature and other sources from the Plan Area and elsewhere pertaining to habitat features that may be enhanced. Fish occurrence along channel margins generally was characterized using available studies and beach seine data collected during 1976–2011 by USFWS's Juvenile Fish Monitoring Program. An available quantitative model, the U.S. Army Corps of Engineers (2004) Standard Assessment Methodology, which is an HSI-type approach used for assessing effects of bank protection projects in the Central Valley, was considered but was not used for this analysis because CM6 is described generally, without reference to specific locations and without specific details of channel margin enhancement activities that may occur. The DRERIP 2009 evaluations of the conservation measures related to channel margin proposed at that time were used to provide further context for the effects of CM6 to the extent it is still applicable.

The length of channel margin under consideration for enhancement under CM6 is 20 miles of restoration. This quantity of channel margin enhancement is similar to that assessed in the 2009 DRERIP evaluation, although CM6 specifies that only channels in the Plan Area that are used for rearing and outmigration by juvenile salmonids would be considered (e.g., Sacramento River, Sutter/Steamboat Sloughs, lower Mokelumne River, and lower San Joaquin River).

5.E.6.5.2 Results

5.E.6.5.2.1 Covered Fish Occurrence In Plan Area Channel Margin

Relatively few studies have been conducted in the Plan Area that sample littoral or channel margin habitat. Brown and Michniuk (2007) documented the occurrence of Chinook salmon, steelhead, Sacramento splittail, delta smelt, and lampreys from electrofishing in what amounts to the BDCP North Delta, East Delta, South Delta, West Delta, and Cache Slough subregions. Nobriga et al. (2005) found the same covered species (with the exception of lampreys) as Brown and Michniuk (2007) at several littoral sites (Sherman Island, Decker Island, Medford Island, Mildred Island, and Liberty Island). Seine data from the USFWS Delta Juvenile Fish Monitoring Program have been collected monthly since 1976 at a number of sites in the Plan Area. Collections of covered fish species within some of the channels that may be enhanced under CM6 were variable. Chinook salmon were highly abundant, followed by Sacramento splittail (as also noted by Feyrer et al. 2005, using the same dataset); both of these species were collected throughout the channels that were sampled. Delta smelt and steelhead/rainbow trout were collected in moderate abundance and were found mostly in the Sacramento River. There were rather few longfin smelt and lampreys collected relative to those species. No green or white sturgeon were collected during sampling. These data suggest considerable importance of channel margin habitat for juvenile Chinook salmon and Sacramento splittail. It should be noted that patterns of relative abundance are likely to reflect a mixture of species overall abundance (not just in channel margin habitat) and gear efficiency for different species and life stages.

5.E.6.5.2.2 Chinook Salmon and Steelhead

Expanded Rearing Habitat

Channel margin enhancement under CM6 is expected to create additional rearing habitat for juvenile salmonids, particularly Chinook salmon fry, which have a high affinity for channel margins. Water velocities and depth are increased along riprapped banks, which can fatigue fish in these constrained channels (U.S. Army Corps of Engineers 2004). Channel margin enhancements that create more shallow-water habitat are likely to provide hydraulic refuge. Increasing complexity and structure in channel margin habitat (e.g., woody material) can increase refuge from high flows. Chinook salmon fry are able to hide behind larger structures and to hold in lower-velocity environments out of the main current, which is a bioenergetic benefit.

LWD and boulders are examples of artificial structural elements used in channel margin habitat that have been shown to be beneficial to salmon fry (U.S. Army Corps of Engineers 2004); however, the

2009 DRERIP analysis of channel margin enhancement noted that evidence for the importance of LWD generally has been provided for riverine habitats upstream of the Plan Area rather than within the Plan Area. Much of the scientific literature supporting the role of large wood in enhancing salmonid habitat stresses the role of wood in creating geomorphic structures in streams such as pools, meanders, and cutbanks. The role of wood in large estuarine river systems has been poorly studied but is unlikely to have the same role as wood in smaller streams.

Enhanced channel margin may provide increased refuge from predation. The limited studies in the Delta generally show that low-slope habitat without revetment supports relatively high densities of smaller Chinook salmon juveniles (McLain and Castillo 2009; H.T. Harvey and Associates with PRBO Conservation Science 2010; Zajanc et al. 2012). Given the considerable extent of steeply sloping, revetted banks in the Study Area (e.g., in the Sacramento River between Freeport and Georgiana Slough) (Table 5.E.6-1 through Table 5.E.6-3), there may be a substantial increase in habitat value for this habitat function.

Channel margin enhancement also has the potential to create habitat for nonnative predatory fish such as largemouth bass that may prey on juvenile salmonids. A potential negative effect of large wood emplacements in the Delta could be that they provide habitat that enhances predation by nonnative fishes such as bass. The 2009 DRERIP evaluation of potential channel margin enhancement in Sutter/Steamboat Sloughs, the San Joaquin River from Vernalis to Mossdale, and Old River and the Sacramento River between Ryde and Isleton, suggested that predation (and competition) by nonnatives in enhanced channel margin had the potential to offset some of the benefits of the enhancement that were described above. The DRERIP evaluation further noted that the colonization of predatory fish may be influenced by flows through channels containing enhanced margins. Flows under the ESO generally would decrease relative to existing biological conditions downstream of the proposed north Delta diversions. Detailed recent and ongoing studies of channel margin in the Plan Area (described further in Section 5.E.6.3.2.3) are providing important information as to the habitat features used by juvenile salmonids and their potential predators.

Improved Connectivity along Migration Pathways

By enhancing channel margin, connectivity is expected to be improved for migrating juvenile salmonids. As described in Section 5.E.6.1.3.1, *Existing Conditions*, long stretches of habitat currently exist that are of very low habitat value. For example, between Freeport and Georgiana Slough, the Sacramento River consists of more than 20 miles (40 channel margin miles) of almost entirely (96%) revetted banks with relatively steep slopes. Strategic enhancement of channel margin along the main outmigration routes through the Delta (Sacramento River and associated larger channels, lower Mokelumne River, and San Joaquin River) has the potential to improve survival of outmigrating juvenile salmonids and increase spatial habitat diversity. Enhancement of channel margin may serve the important function of providing rest and recovery habitat upstream, between, and downstream of the proposed north Delta intakes. Data from the U.S. Army Corps of Engineers (2007a) revetment database indicate that the existing channel margin within the footprint of the intakes is steeply sloping, entirely revetted, and has little structural complexity (<10% woody debris; no emergent vegetation). This suggests that poor-value channel margin habitat for fish is being affected by the intake construction; the hydraulic effects of the north Delta intakes on juvenile salmonids migrating past the intakes are uncertain. Enhancement of channel margin in this river reach may limit mortality associated with migration through this reach.

The spatial extent of channel margin enhancement proposed under CM6 is a relatively small percentage (4%) of the main migratory corridors for juvenile salmonids in the Plan Area. It may be possible to achieve more than a 4% improvement in ecological conditions by targeting areas with very poor habitat value that have been shown to have poor biological performance (e.g., fish density and survival, other measures). The identification of reaches with poor biological performance will be aided by targeted research. Reach-specific survival studies have been made possible by acoustic tagging (e.g., Perry 2010; Del Real et al. 2011). Such studies are limited to larger fishes that are able to have tags implanted, and, as noted above, the extent to which these larger migrants use channel margin habitat is uncertain. Given the importance of Delta habitat for smaller Chinook salmon, it will be important to conduct studies on these smaller-sized fish to determine existing biological performance in important areas in order to inform channel margin enhancement activities.

Recent Studies of Channel Margin Habitat Use by Juvenile Salmonids in the Plan Area

This section briefly discusses some of the recent findings from research addressing channel margin habitat features in the Plan Area that are of importance in determining the value of enhanced channel habitat to juvenile salmonids. The findings from such studies will, along with other studies, inform consideration of site designs applied during channel margin enhancement.

Monitoring data collected in support of levee bank protection projects in the Central Valley provide useful context for the associations of covered fish species with restored habitat similar to the types of enhancement that could occur under CM6. H.T. Harvey and Associates with PRBO Conservation Science (2010) monitored fish along the Sacramento River at eight reference sites without riprap that were dominated by naturally recruited native vegetation and at 13 sites for which various bank protection designs had been applied as part of the repair of critical levees authorized in 2006.

The first 2 years of the study (2009–2010) indicated that the presence of both Chinook salmon fry <55 mm and juveniles >55 mm was positively related to the presence of submerged vegetation and the interaction of depth with instream woody material (IWM) and negatively associated with depth, among other habitat features (Table 5.E.6-7). The most suitable designs for fry were the bench/10:1 and natural sites, and for juveniles the most suitable design was the Dietl ditch. However, H.T. Harvey and Associates with PRBO Conservation Science (2010) noted that predatory bass also were found at the Dietl ditch sites, which may reduce the value of this habitat for Chinook salmon juveniles. Predatory bass were found most frequently at sites with greater slope, more boulder/cobble, and more aquatic vegetation, among other features (Table 5.E.6-7). Based on the observed relationships with habitat features, it was suggested that bench/10:1 designs could be made more beneficial for Chinook salmon juveniles >55 mm by placement of IWM at greater depths.

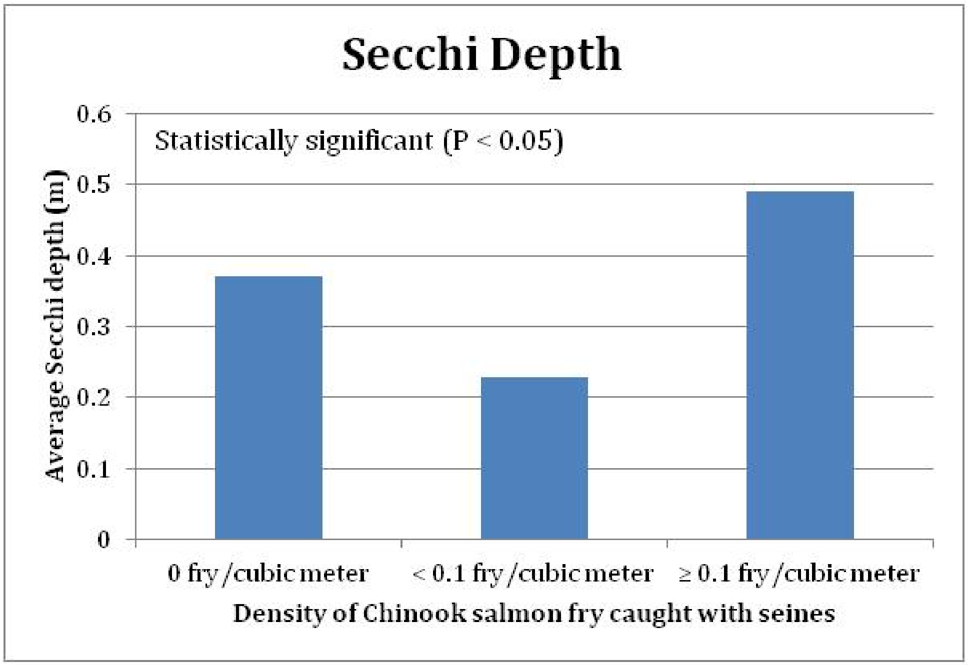
Table 5.E.6-7. Summary Interpretation of the Design Type and Habitat Feature Generalized Linear Models Based on Electrofishing at Reference and Bank Protection Sites in the Sacramento River

Species/Life Stage	"Best" Design Types	"Worst" Design Types	Habitat Features with Significant Positive Relationships to Fish Presence	Habitat Features with Significant Negative Relationships to Fish Presence
Chinook salmon/fry <55 mm (January, March)	Bench/10:1; natural	No bench	Submerged vegetation; depth × IWM diversity	% boulder/cobble; depth; IWM diversity
Chinook salmon/juvenile >55 mm (April)	Dietl ditch	Bench/10:1	Submerged vegetation; LWD density; depth × IWM density	Depth; IWM size; shade
Predatory bass (April)	Dietl ditch	Natural	Bank slope; % boulder/ cobble; aquatic vegetation; IWM size × LWM density; depth × IWM diversity	IWM size

Source: H.T. Harvey and Associates with PRBO Conservation Science 2010.
IWM = instream woody material; LWM = large woody material (IWM >4 inches diameter); IWM diversity = variation in density, size, and whether IWM was in/out of water).

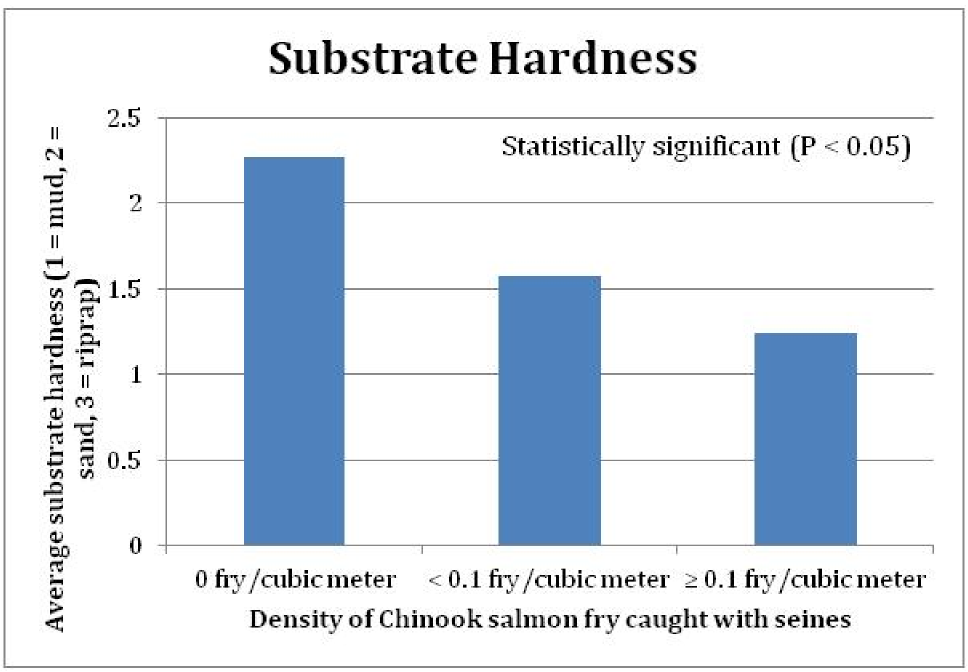
Telemetry data indicated that use of the repair sites by juvenile steelhead and larger (>100 mm) juvenile Chinook salmon was low, possibly because these were migrating smolts with relatively low shoreline use.

Another recent detailed study of channel margin habitat features in relation to covered fish species in the Plan Area was McLain and Castillo. Their study examined the density of fall-run Chinook salmon fry (generally smaller than 50 mm total length) collected in beach seines in relation to various channel margin habitat features in the lower Sacramento River. They found that density of fry was greatest in Steamboat Slough, intermediate in the Sacramento River, and low in the Cache Slough subregion, possibly because the Yolo Bypass had not been inundated and so fry had not passed down into Cache Slough. Channel margin features that were significantly related to Chinook salmon fry density included (in order of importance): Secchi depth (higher density in clearer water), substrate hardness (very low density in riprapped areas), and slope (higher density with gentler slopes) (Figure 5.E.6-7, Figure 5.E.6-8, and Figure 5.E.6-9); vegetation density and occurrence of riparian vegetation or woody debris were not statistically related to fry density. By removing rip-rap and increasing shallow water, CM6 has the potential to increase the area of channel margin habitat that would support higher density of rearing Chinook salmon fry.



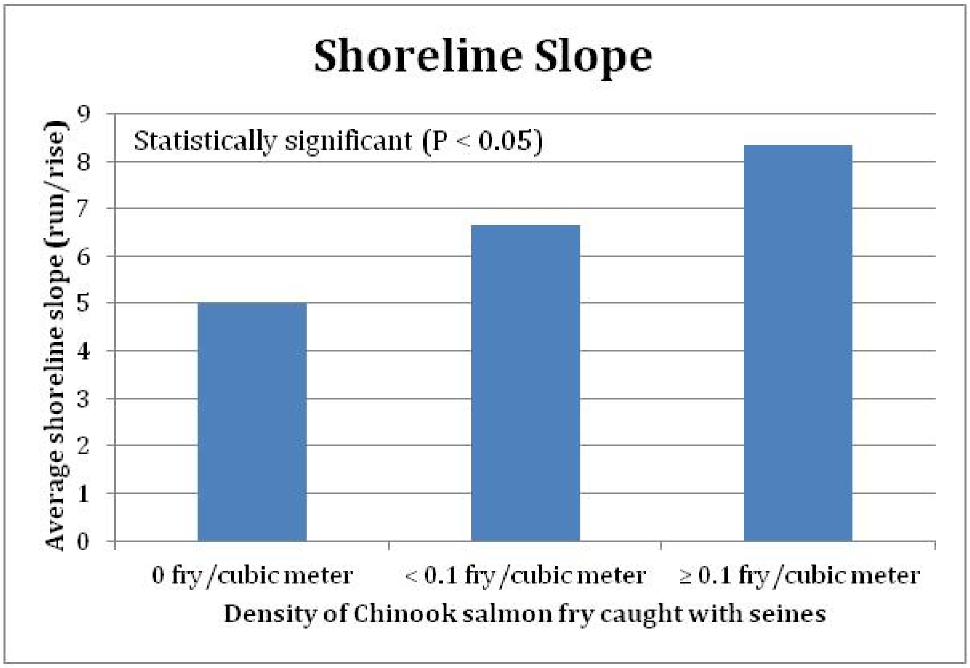
Source: McLain and Castillo 2009.

Figure 5.E.6-7. Average Secchi Depth at Three Levels of Fall-Run Chinook Salmon Fry Density in the Northwest Delta, with Statistical Significance from Multinomial Logistic Regression



Source: McLain and Castillo 2009.

Figure 5.E.6-8. Average Substrate Hardness at Three Levels of Fall-Run Chinook Salmon Fry Density in the Northwest Delta, with Statistical Significance from Multinomial Logistic Regression



Source: McLain and Castillo 2009.

Figure 5.E.6-9. Average Slope at Three Levels of Fall-Run Chinook Salmon Fry Density in the Northwest Delta, with Statistical Significance from Multinomial Logistic Regression

5.E.6.5.2.3 Delta Smelt and Longfin Smelt

Other than possibly during spawning, delta smelt and longfin do not appear to occupy channel margin habitats to any great extent and would not be expected to benefit from CM6. Although both smelt species occur in small numbers along the segments most likely to be targeted for channel margin enhancement, the main populations are typically well downstream. There may be little benefit from channel margin enhancement for rearing for these species. As noted for salmonids, channel margin enhancement that includes Dietl ditch design may increase susceptibility to predation from centrarchid bass species, although Delta and longfin smelt are unlikely to use this type of habitat for spawning where channel margin restoration is likely to occur.

Delta smelt have not been observed to spawn in the wild, but Bennett (2005) noted low-slope, sandy beaches typically are used by the most closely related species and possibly are used by delta smelt. Longfin smelt on the other hand are thought to spawn in deeper water, and this type of habitat may have little benefit to them. Any increase in these shallow sandy habitats because of channel margin enhancement in the Plan Area may increase spawning habitat, although it is likely to be a minimal increase because, as noted above, the majority of the delta smelt and longfin smelt populations occur well downstream of the main areas that would be considered for implementation of CM6.

5.E.6.5.2.4 Sacramento Splittail

Spawning Habitat

Most spawning of Sacramento splittail occurs in inundated floodplains such as the Yolo Bypass and Sutter Bypass (Feyrer et al. 2006a). Spawning habitat for Sacramento splittail also occurs in the lower reaches of rivers (Caywood 1974, as cited by Moyle et al. 1995), dead-end sloughs (Moyle 1976, as cited by Moyle et al. 1995), and in the larger sloughs such as Montezuma Slough (Wang

1986, as cited by Moyle et al. 1995). Splittail probably spawn on submerged vegetation in flooded areas (Moyle et al. 1995). Larvae remain in the shallow, weedy areas inshore close to the spawning sites and move into the deeper offshore habitat as they mature (Wang 1986).

Rearing Habitat

Sacramento splittail are abundant in channel margin habitat in the Plan Area. Channel margin enhancement measures may contribute to increased growth and survival of juvenile splittail and increased habitat availability. As noted for juvenile Chinook salmon, depending on design, channel margin enhancement also could provide habitat for nonnative centrarchid basses if a Dietl ditch design is used, which could enhance predation on juvenile Sacramento splittail emigrating from upstream floodplains and river backwaters.

Improved Connectivity along Migration Corridors

Channel margin habitat is especially important for splittail during migration to and from upstream spawning habitats. Channel margin habitat in the Delta is highly degraded (Feyrer et al. 2005), which likely reduces growth and survival of emigrating splittail juveniles and upmigrating adults. The location of channel margin habitat affects its significance and value. Channel margin enhancement on the Sacramento River and Sutter and Steamboat Sloughs would benefit splittail migrating to and from the Sacramento River, including the Sutter Bypass spawning area. Channel margin enhancement on the Mokelumne River would benefit splittail from the Cosumnes River floodplain, and the proposed restoration on the San Joaquin River would benefit splittail from the San Joaquin River floodplain.

Adult splittail migrate upstream to spawning habitats primarily during winter and early spring, and YOY emigrate downstream primarily from April through July (Feyrer et al. 2005, 2006a). During these migrations, they make use of off-channel habitats both upstream of and within the Delta (Feyrer et al. 2005). Adequate channel margin habitat in the Delta is highly limited, so restoring this habitat would provide some benefit to growth and survival of splittail.

5.E.6.5.2.5 Green Sturgeon and White Sturgeon

Sturgeon occurrence in channel margin habitats has not been found with long-term seining in the Plan Area, although this could be because of gear avoidance. The 2009 DRERIP evaluation of channel margin enhancement conservation measures noted that juvenile sturgeon are benthic feeders and therefore an increase in benthic habitat by lowering slopes may be beneficial. Another potential positive outcome that was suggested was the provision of resting habitat for migrating adults. Given the lack of information about occurrence of sturgeon in such habitats, the DRERIP (2009) evaluation noted that there was little certainty in the potential benefits of channel margin enhancement to sturgeon.

5.E.6.5.2.6 Pacific Lamprey and River Lamprey

Little is known about the occurrence of and potential function of channel margin habitat for Pacific lamprey and river lamprey in the Plan Area. As described above, there have been occasional catches of lamprey during seine surveys and more than 2,100 Pacific lamprey ammocoetes were collected during electrofishing at bank protection sites (H.T. Harvey and Associates with PRBO Conservation Science 2010). Lamprey ammocoetes generally are thought of as occurring upstream of the Plan Area, but there also appear to be appreciable numbers in the Plan Area. Enhancement of channel margin would increase the amount of ammocoete burial habitat where hardened substrates are removed or covered with soft substrate of a sufficient depth (at least 30 cm) (Close et al. 2003).

5.E.7 Conservation Measure 7 Riparian Natural Community Restoration

5.E.7.1 Description

Under *CM7 Riparian Natural Community Restoration*, the Implementation Office will restore 5,000 acres of native riparian forest and scrub in association with *CM4 Tidal Natural Communities Restoration*, *CM5 Seasonally Inundated Floodplain Restoration*, and *CM6 Channel Margin Enhancement*. CM7 actions will be phased, with 1,100 acres by Year 15 and 5,000 (cumulative) acres by Year 40.

The location of riparian restoration will be determined during implementation in order to meet specific geographic and species requirements. Site selection also will be guided, in part, by the needs of CM4, CM5, and CM6, which have goals overlapping riparian restoration.

At least 3,000 acres of the riparian restoration will take place in restored floodplains: concept-level planning has resulted in the identification of four south Delta corridors for potential implementation of floodplain restoration.

Native woody riparian vegetation will be allowed to reestablish naturally along the upper elevation margins of restored tidal natural communities in ROAs where soils and hydrology are suitable, including segments of stream channels that drain into restored marshes. Suitable soils for restoration are expected to be most extensive in the Cosumnes/Mokelumne and South Delta ROAs. In these ROAs, native riparian vegetation is expected generally to form as a band of variable width depending on site-specific soil and hydrologic conditions between high-marsh vegetation and herbaceous uplands.

Where compatible with site-specific objectives for channel margin enhancement, native woody riparian vegetation will be planted along channel margins on benches on the water side of existing levees to enhance covered fish and wildlife species habitat. Native riparian vegetation restored in these locations is expected to form narrow stringers of riparian forest and scrub along enhanced channel margins.

Riparian forest and scrub will be restored to include the range of conditions necessary to support habitat for each of the covered species that use riparian habitat. Restoration of channel margins (and floodplain margins) also, through natural hydrologic function and in some cases managed planting, will include the growth of riparian shrubs and trees. Leaves and other biomass are expected to be shed into the adjacent wet channel where they can be processed by bacteria into detritus.

CM7 is intended to restore riparian habitat within the context of flood control objectives and managed upstream hydrology to provide direct and indirect benefits to aquatic and terrestrial species along important migration corridors. These benefits can add to the functions and values provided by existing riparian habitat through enhancing structural (i.e., different landscape elements) and functional (distance or barriers between resource patches) connectivity and relationships (Bélisle 2005). Continuous riparian zones serve as transition zones between the upland and aquatic ecosystems (Ewel et al. 2001) by providing refugia and reciprocal foodweb subsidies for both aquatic and terrestrial organisms (Nakano and Murakami 2001). Holl and Crone (2004), in their study of natural recruitment within restored riparian areas along the Sacramento River, found that cover and species richness of native understory species were positively related to connectivity with remnant forest.

The objectives of riparian restoration for the BDCP are to create restored riparian zones that are characterized as follows.

- Resilient in the face of managed hydrology, including flooding interval and seasonality, geomorphic processes, and climate change.
- Designed for site-specific conditions such as soils and hydrology.
- Diverse in structure and spatial extent to provide habitat for target wildlife species.
- Compatible with surrounding land uses and regional flood control objectives.

5.E.7.2 Conceptual Model

Much of the scientific literature relating to the ecological role of riparian vegetation is based on studies of small streams and rivers. Based on the River Continnum Concept (Vannote et al. 1980), the influence of riparian vegetation declines as stream width increases and riparian vegetation has a relatively small overall impact on large rivers and likely the Delta. However, riparian vegetation can provide localized benefits such as cover for fish species, terrestrial insects for food and large wood for habitat structure. A clear understanding of the frequency, duration, and timing of flood events is critical to establishing resilient, heterogenous riparian habitat that will benefit target species during critical windows when they are present. The prevailing disturbance regime in a managed floodway may differ in critical ways from a similar natural condition, and design of the habitat needs to take this into account (Lake et al. 2007). In the Cosumnes River Preserve, researchers found that flood-induced disturbance is an important factor in promoting heterogenous riparian habitats, including woody and herbaceous species diversity (Viers et al. 2006). Maintaining and encouraging this diversity can help ensure habitat resilience in response to disturbance (Hooper 2005). Biodiversity is a key parameter for all BDCP habitat restoration actions because the number of species in a habitat directly relates to the variability, complexity, and connectivity of the foodweb (Martinez 1993, 1994; Martinez and Lawton 1995; Moyle et al. 2010).

Because the process of restoration begins with plantations of native plants, an important determination is whether or not these plantations eventually successfully transition into thriving riparian forests. There is debate over what is considered a forest vs. a plantation but two helpful working definitions include (after *Sacramento River Riparian Monitoring and Evaluation Plan* by Shilling et al. 2010) the following.

- Riparian forests are complex tree-dominated ecosystems with particular structural biotic and abiotic components, assembled within temporal and spatial limits and with a self-sustained successional dynamic determined by its biodiversity.
- Plantations are planted and managed tree-dominated systems, generally not self-successional and less complex both in structure and in biodiversity than forests.

Fremier et al. (2008) present a useful conceptual model for riparian function. Their model seeks to explain the potential pathways in understanding restoration implementation in light of the complexity of the natural system (Figure 5.E.7-1).

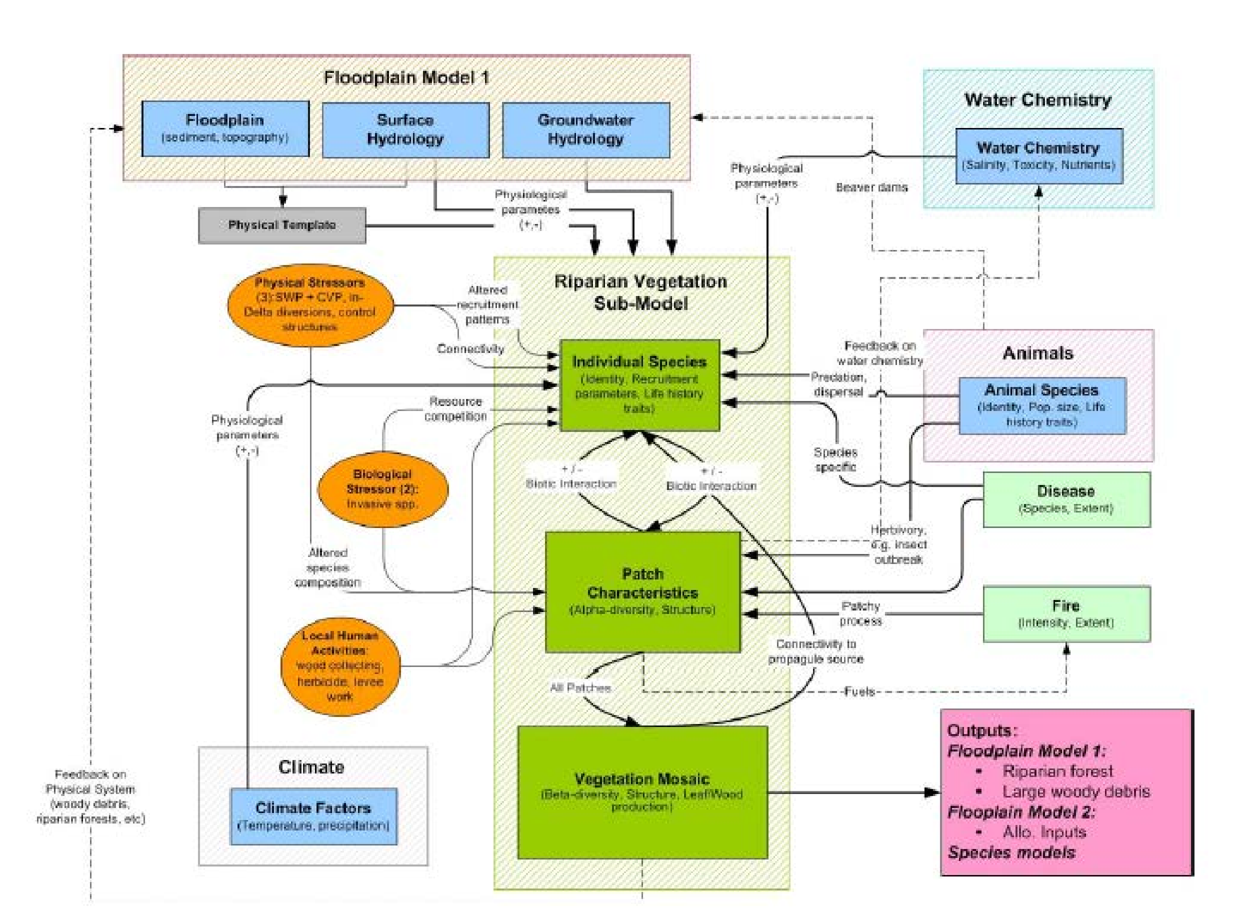


Figure 5.E.7-1. Riparian Vegetation Submodel

Riparian vegetation is but one of the natural systems of interest; others include fish, wildlife, and other plant communities. The conceptual model presented here deals exclusively with those physical, chemical, and ecological processes relevant to riparian vegetation. Riparian vegetation is important not only for biological conservation of the plant species themselves but also for the other flora and fauna species—and the physical and ecological processes—that depend on riparian vegetation. Although the restoration of riparian vegetation as a component of a healthy riverine landscape has cultural and economic importance, these aspects are not included in this model (Fremier et al. 2008).

The conceptual model of riparian vegetation presented is actually a submodel of the larger floodplain processes/habitat model. The Riparian Vegetation Submodel is general by design and is intended to provide a framework for potential expansion or adaptation to more-refined models of individual species, habitats, and/or entire landscapes. Spatially, focusing on the floodplain or land area beginning at the upper edge of the emergent vegetation zone, then moving up in elevation and inland from the water, ending when nonfloodplain areas, open water, or marsh is encountered. Together, the Floodplain Model and the Riparian Vegetation Submodel can be used to analyze various scenarios, ranging from potential restoration or research actions, to water management decisions, to placement of bank protection at a specific Delta levee site.

The modeling approach of Fremier et al. (2008) describes how ecosystem drivers (e.g., hydrology, sediment, fire, animals, patch configuration) affect the presence and character of riparian vegetation in the Delta, and how riparian vegetation feeds back into other components of the Floodplain Model. The Floodplain Model illustrates how hydrology (surface water and groundwater) and sediment characteristics form the floodplain—a process described here as *setting the physical template* upon which riparian vegetation establishes. Outputs from Floodplain Model 1 are routed to the Riparian Vegetation Submodel. Specifically, the changes in area of floodplain, sediment regime, inundation regime, and groundwater depth are all key inputs to the Riparian Vegetation Submodel. The Riparian Vegetation Submodel has two main inputs from Model 1, the sediment regime and the hydrologic regime. These inputs set the physical template upon which riparian vegetation establishes. Riparian vegetation outputs feedback into Floodplain Models 1 and 2 (overall vegetation mosaic of riparian forests, large woody material and leaf litter/carbon inputs into the aquatic system, hydraulic roughness, etc.) and also drive the formation of the vegetation patch/habitat mosaic. Restoration of the vegetation patch/habitat mosaic is a goal of the CALFED Bay-Delta Program's (CALFED's) DRERIP.

The riparian vegetation model assumes the physical drivers are the main first-order control on riparian vegetation. *Physical drivers* refers to the dynamic interrelationship between geomorphology and hydrology, including both the land-forming processes and floodwater inundation characteristics (including salinity). Secondary controls on vegetation presence and composition include invasive species, periodic fire, and animal population dynamics (Fremier et al. 2008).

5.E.7.3 Consistency with Biological Goals and Objectives

CM7 will advance the biological goals and objectives as identified in Chapter 3, *Conservation Strategy*, Table 3.4.7-4. The rationale for each of these goals and objectives is provided in Chapter 3, Section 3.3, *Biological Goals and Objectives.* Through effectiveness monitoring, research, and adaptive management, as described above, the Implementation Office will address scientific and management uncertainties and help ensure that these biological goals and objectives are met. Table 3.4.7-4 also identifies the monitoring actions associated with each objective as it relates to CM7.

5.E.7.3.1.1 Benefits to Covered Fish Species

Covered fish species that occur in the Plan Area and that rely on ecological attributes of valley/foothill riparian habitat include Chinook salmon, Central Valley steelhead, splittail, lamprey, and sturgeon. Salmonids benefit from contributions of the valley/foothill riparian natural community to the aquatic foodweb, in the form of terrestrial insects and leaf litter that that support salmonid growth directly and enhance the development of local foodweb processes. Riparian vegetation provides a source of large wood that serves as shelter from high velocity currents and predators. Riparian trees provide shade that serves as cover from avian predators and has been positively associated with Chinook salmon holding in shade covered areas (Zajanc et al. 2012). Splittail use low-velocity backwater habitats for spawning during low-flow years and inundated floodplains during higher flow years. Riparian habitat serves to slow water after inundation and increase residence time allowing floodplain foodwebs to form that are beneficial to larval and juvenile splittail. Coutant (2004) has postulated that there is increased spawning success of white sturgeon when flooded riparian habitat is available for embryos to adhere to newly wetted rocks and vegetation during incubation. Newly hatched embryos remain in the shallow waters using crevices as cover from predators. When the embryos have fully transitioned to exogenous feeding larvae the flooded riparian zone would then offer plentiful food resources. Receding water coinciding with lower river flow would then cue larvae to move lower into the adjacent channels. During high-flow years many white sturgeon larvae are flushed to the Delta and Suisun Bays, but are scarce in lower-flow years (Kohlhorst, 1976 as cited from Stevens and Miller 1970). White sturgeon larvae would benefit from riparian habitat especially during wet years. Although little is known about use of channel margin habitat containing riparian habitat by Pacific lamprey and river lamprey, these species may benefit from enhancement that increases the area of non-revetted substrate into which ammocoetes can burrow; recent monitoring suggests that ammocoetes may be present in substrates in the Plan Area.

5.E.7.3.1.2 Resilience

In general, the proposed riparian restoration aims to reestablish fluvial geomorphologic dynamics (Florsheim and Mount 2002) and regenerate native plant communities (Richter and Richter 2000; Stromberg 2001).

5.E.7.3.1.3 Restoration Construction and Site-Specific Design

Site-specific consideration and design of riparian restoration will consider factors such as spatiotemporal dynamics, prevailing disturbance regime, patch dynamics, seral composition of riparian vegetation, soil type, soil fertility, and depth to water table.

Restoration of large, continuous areas of riparian habitat would involve modifying or setting back levees to create low benches with variable surface elevations to create hydrodynamic complexity and that support emergent vegetation to provide an ecological gradient of habitat conditions, and higher elevation benches that support riparian vegetation.

Restoration techniques may include anchoring of large woody material (e.g., tree trunks, stumps) into constructed low benches or into existing riprapped levees to mimic natural habitat.

To the extent consistent with floodplain land uses and flood control requirements, if applicable, woody riparian vegetation will be allowed to establish naturally. Established woody riparian vegetation would support habitat for riparian-associated covered species and provide cover and hydrodynamic complexity for covered fish species during inundation periods. Riparian vegetation also would serve as sources of instream woody material for fish habitat, organic carbon in support of the aquatic foodweb, and macroinvertebrates (e.g., insects) that provide food for covered fish species.

5.E.7.3.1.4 Regional Compatibility

The restored riparian habitat should be designed to accommodate flood control objectives such as maintaining floodway conveyance and in a way that does not affect flood control structures such as levees, seepage berms, and maintenance corridors. The restored riparian areas also present opportunities for active and passive recreation, including hiking, boating, and bird watching.

5.E.7.4 Explanation of the Conservation Measure

5.E.7.4.1 Current Conditions

5.E.7.4.1.1 Native Vegetation

In the Central Valley, less than 5% of the once-broad riparian forests on the valley floor remain (Bay Institute 1998), and none are entirely unaltered by human use (Sands 1980; Warner and Hendrix 1984; Hunter et al. 1999). Using GIS analysis of the Central Valley, Warner and Hendrix (1984) showed that the remaining riparian vegetation is highly fragmented into small, unprotected patches (approximately 15% are in public ownership or managed for biological conservation). Riparian vegetation in the Delta is highly affected, and solutions should address not only the reduction but also fragmentation. Both of these impacts are addressed in the Riparian Vegetation Submodel.

Species composition in riparian stands has been altered. Along many of the tributary rivers into the Delta, researchers have documented a loss in cottonwood recruitment because of changed hydrology (Roberts et al. 2002; Stella et al. 2006). This pattern has been well-studied throughout most of the western United States (Johnson et al. 1976; Fenner et al. 1985; Bradley and Smith 1986; Stromberg and Patten 1996; Scott et al. 1997; Rood et al. 1999). In addition, sycamore distributions have been reduced. Keeler-Wolf et al. (1994) illustrated the continued decline of sycamore in California over the last 100 years; these authors suspected their observations could be partially explained by recruitment problems and drowning caused by elevated summer flows created by flow regulation. Willow (*Salix*) species grow with other pioneer species on point bars and newly formed lands (McBride and Strahan 1984; Jones 1997; Tu 2000). Later-seral species such as maple, ash, walnut, and oak (*Acer, Fraxinus, Juglans*, and *Quercus*) develop on older floodplains below an overstory canopy created by pioneer species such as cottonwood and willow (Strahan 1984; Cepello 1991; Tu 2000; Fremier 2003; Vaghti 2003). Comparing research conducted on the Cosumnes River to that completed on the Sacramento River shows that ash species are more abundant on the Cosumnes, and maple and walnut are more abundant on the Sacramento. It should be noted that maple, although clearly a common species now, was not mentioned by early explorers as summarized by Thompson's work (Fremier 2003; Vaghti 2003). All research has described valley oak forests as a later-seral stage of riparian forest in the Central Valley (Thompson 1961, 1980; Cepello 1991; Greco 1999; Tu 2000; Fremier 2003; Vaghti 2003; Williams 2006). Oak decline is attributed largely to land clearing for agriculture, and valley oak riparian forests are much reduced from their historical extent and represent a high conservation priority (Sacramento River Advisory Council 1998; Greco et al. 2007). Importantly, low regeneration success of valley oak appears to be limiting species abundance and recovery (Trowbridge et al. 2005).

Understory species (those plants living under the canopy of riparian trees) are also an important component of the riparian ecosystem. The recruitment requirements for individual species in relation to existing site conditions (e.g., open, bare mineral soil versus a dense, shaded overstory with heavy leaf litter) and associated soil moisture availability are understood to be deterministic in the establishment and evolution of understory vegetation through time (Vaghti and Greco 2007). Additionally, the interaction between understory vegetation and invasive species can inhibit natural patterns of vegetation succession and plant assemblages. Appendix 2.A, *Species Accounts*, includes a database of important species physiological tolerances and requirements that can be queried and sorted to support use of the Riparian Vegetation Submodel.

5.E.7.4.1.2 Invasive Species

Invasive, nonnative plant species can create serious problems for conservation, restoration, and management of riparian areas in the Delta. Ecological consequences from the establishment of invasive species include the alteration of ecosystem processes such as fire frequency (e.g., giant reed, Himalayan blackberry, tamarisk), nutrient cycling (e.g., Scotch broom), erosion and sedimentation rates (e.g., giant reed, *Egeria*), and hydrologic regimes (e.g., giant reed, tamarisk). Invasive species typically outcompete native species and are a major conservation concern. With invasions of nonnative species, native species diversity frequently declines because of the alteration of community structure and hybridization with native species, and because threatened and endangered plant species are outcompeted (Bossard et al. 2000; San Francisco Estuary Institute 1998). Large monospecific stands of invasive species push out native species and can fundamentally alter the system through physical feedbacks and trophic interactions. Holl and Crone (2004) found that invasive plant cover and species richness decreased with increased overstory cover and lower understory cover in areas closer to the base flow of the Sacramento River adjacent to their study areas.

The major nonnative invasive species that threaten the Delta occur across many riparian community types. In tree and shrub communities located in higher relative elevations, invasive species such as yellow star-thistle, poison hemlock, edible fig, and Himalayan blackberry displace native riparian species, deplete soil moisture, and increase fire hazard (Borman et al. 1992; Hoshovsky 2000; Randall 2000; Serpa 1989). Native shrub and herbaceous communities in lower relative elevation sites also are threatened by invasive species. Outcomes include the reduction of instream shading for fish, reptiles, and amphibians (e.g., giant reed [Franklin 1996]); the alteration of community composition (e.g., sweet fennel [Colvin 1996; Dash and Gliessman 1994; Granath 1992]); and the encroachment of rare plants (e.g., broad-leaved pepperweed [Skinner and Pavlik 1994]).

5.E.7.4.2 Post-Restoration Conditions

The approximate total amount and areas of riparian habitat in the Plan Area where enhancement will occur are as follows.

- At least 3,000 acres of the 5,000-acre riparian restoration requirement will occur in restored floodplains.
- Sacramento River (top of North Delta subregion to Sacramento–San Joaquin confluence in the West Delta subregion. Where compatible with site-specific objectives for channel margin enhancement, native woody riparian vegetation will be planted along channel margins on benches on the water side of existing levees to enhance covered fish and wildlife species habitat (20 miles total).
- Native woody riparian vegetation will be allowed to reestablish naturally along the upper elevation margins of restored tidal natural communities in ROAs where soils and hydrology are suitable, including segments of stream channels that drain into restored marshes.
- Mokelumne River (North and South Forks in the Plan Area). Maintain at least 250 acres of continuous valley/foothill riparian community (restored and protected).
- San Joaquin River (Vernalis to Sacramento–San Joaquin confluence in the West Delta subregion). Maintain at least 250 acres of continuous valley/foothill riparian community (restored and protected).

5.E.7.5 Evaluation

5.E.7.5.1 Method

There is currently no quantitative method to evaluate the benefits of restoring riparian conditions in the Plan Area. As a result, a qualitative approach was taken to evaluate the effectiveness of the proposed riparian restoration actions that draws from the general scientific literature related to riparian vegetation. The methods involved researching existing scientific literature and relying on professional expertise in implementing and monitoring riparian restoration projects in the Central Valley.

5.E.7.5.2 Results

The BDCP will restore 5,000 acres of riparian forest and scrub in the Delta, primarily in association with restoration of tidal natural communities and floodplains and enhancement of channel margins. Riparian natural community restoration is anticipated to provide many primary and secondary benefits to both terrestrial (Chapter 5, Section 5.6, *Effects on Covered Wildlife and Plant Species*) and aquatic species (Chapter 5, Section 5.5, *Effects on Covered Fish*), and provide positive influences on several environmental factors as well.

Expected results from habitat restoration included in the *South Delta Habitat and Flood Corridor Planning, Corridor Description & Assessment Document* (ESA PWA 2012) for the San Joaquin River that could be extrapolated to the Sacramento River and Cosumnes-Mokelumne Rivers include the following.

- Reduced nonpoint-source pollution and improved water quality (Craig et al. 2008).
- Reestablishing a mostly contiguous corridor of riparian habitat along the river channels to increase connectivity, providing cover for terrestrial species and facilitating genetic exchange (Bélisle 2005).
- Improving thermal regulation and improved dissolved oxygen levels.
- Supporting the establishment of a dynamic complex of woody and scrub habitat along the river channels and their associated floodplains over the long term to provide instream aquatic habitat in the form of overhead cover and inputs of large woody debris (U.S. Fish and Wildlife Service 2004).
- Providing an expanded buffer between agricultural practices and the river corridors that will enhance aquatic insect communities and improve water quality (Delaware Department of Natural Resources and Environmental Control and Brandywine Conservancy 1997).
- Providing areas of low velocity refugia for aquatic organisms during flood events by increasing hydraulic roughness (Gregory et. al 1991).
- Increasing organic carbon and aquatic foodweb contributions such as litter and insect inputs (Nakano and Murakami 2001) on site and possibly to downstream environments.
- Improved riparian habitat resilience during periodic perturbations and potentially to climate change (Seavy et al. 2009) by increasing overall habitat extent, improving connectivity, and allowing for plant community diversity.
- Providing additional cover for native fish from predatory fish (Bowen et al. 2003).

- Potential for phytoremediation of toxins in soil.
- Removal of SAV in off-channel areas following increased flow during flood events.

Potential impacts include the following.

- Increased fire hazard, particularly if nonnative species such as giant reed and tamarisk become established.
- Perception of increased land management activities and special-status species encroachment for adjacent agricultural land owners.
- Release of soil-borne toxins built up from prior agricultural practices from newly restored areas (See Appendix 5.D, *Contaminants*).
- Potential methylmercury release and resuspension (See Appendix 5.D, *Contaminants*).
- Establishment and proliferation of invasive nonnative vegetation (See Appendix 5.F, *Biological Stressors on Covered Fish*).
- Increased fish stranding on floodplains.

Success of the restored riparian habitat will be measured by how resilient it is and if natural successional dynamics take hold. The restoration will be assessed by monitoring structural, functional, and compositional characteristics. Short-term success will be determined by how many of the initial plantings survive during the establishment period and can survive without supplemental irrigation. Long-term success will be determined by whether natural recruitment of successive generations of plants takes place and whether vegetative complexity and structure develop through the establishment of understory riparian species. This will indicate that site-specific conditions are appropriate for sustained natural habitat development.

While many of the benefits to aquatic organisms are difficult to quantify at the project scale, their cumulative qualitative and quantitative effects are well-documented in scientific literature, and those findings could be carried forth and applied to these restoration efforts. Although the covered fish species do not rely primarily on riparian habitat, they are directly and indirectly supported by the habitat services and food sources provided by the highly productive riparian ecosystem, particularly during floodflows when riparian habitats are inundated. Riparian vegetation is a source of organic material (e.g., falling leaves), insect food, and woody debris in waterways and can influence the course of water flows and structure of instream habitat. This debris is an important habitat and food source for fish, amphibians, and aquatic insects (Opperman et al. 2005).

Selection of appropriate reference sites will be critical to accurately assessing the success of the restored riparian habitat for both vegetative performance and habitat functionality. The reference site should be located geographically close to the restoration site and share a similar landscape position in order to match such factors as geomorphic surface; flooding dynamics, including frequency, duration, and timing; tidal influence; and desired vegetative species composition as closely as possible.

5.E.8 Monitoring and Adaptive Management

Uncertainty is inherent in ecological systems, including habitats undergoing restoration. Uncertainties about restoration processes and the potential benefits of restoration have been highlighted throughout this document and in the many other documents that discuss potential conservation measures for the Delta (e.g., Brown 2003; Ecosystem Restoration Program 2011). Ecosystem Restoration Program (2011) summarizes the primary sources of uncertainty.

1. The inability to predict the future state of dynamic systems.
2. The degree to which future conditions depend upon unpredictable external drivers.
3. Incorrect or incomplete information about underlying processes.
4. Alternative interpretations of the available data.

Though some uncertainties are unavoidable (e.g., the future state of ecological systems), ongoing monitoring will help fill information gaps. It also will provide an opportunity to test hypotheses about mechanisms that govern habitat changes and foodweb processes in the Delta. Monitoring results will help guide adaptive management of the conservation measures, making it possible to adjust actions as more information becomes available.

5.E.9 References Cited

5.E.9.1 Literature Cited

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ATTACHMENT 5E.A
BDCP SOUTH DELTA HABITAT AND FLOOD CORRIDOR PLANNING

CORRIDOR DESCRIPTION AND ASSESSMENT DOCUMENT

REVISED ADMINISTRATIVE DRAFT
BAY DELTA CONSERVATION PLAN

PREPARED FOR:

California Department of Water Resources

PREPARED BY:

ESA PWA

March 2013

ESA PWA. 2012. *Attachment 5E.A: BDCP South Delta Habitat And Flood Corridor Planning Corridor Description And Assessment Document*. Attachment to *Appendix 5.E: Habitat Restoration*. Revised Administrative Draft. *Bay Delta Conservation Plan*. March. Sacramento, CA. Prepared for: California Department of Water Resources, Sacramento, CA.

Attachment 5E.A

BDCP South Delta Habitat and Flood Corridor Planning Corridor Description and Assessment Document

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Acronyms and Abbreviations

µg/L	micrograms per liter
AGR	agricultural irrigation and stock watering
BDCP	Bay Delta Conservation Plan
BIOS	Biogeographic Information and Observation System
BO	Biological Opinion
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CNRA	California State Natural Resources Agency
COLD	recreation, cold
CVFMPP	Central Valley Flood Management Protection Plan
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
DMC	Delta Mendota Canal
DMD	dredge material disposal ponds
DRERIP	Delta Regional Ecosystem Restoration Implementation Program
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
IND	service supply
LB	left bank or left overbank
mcl	maximum contaminant level
mg/L	milligrams per liter
MHHW	mean high high water
MHW	mean high water
MIGR	migration
MLLW	mean low low water
MUN	municipal and public water supply
NAV	navigation
ng/L	nanograms per liter
NHC	Northwest Hydraulic Consultants
NMFS	National Marine Fisheries Service
OMR	Old and Middle River
Preserve	Wing Levee Road Preserve
PROC	industrial process
RB	right bank or right overbank
REC-1	contact
REC-2	noncontact
ROA	restoration opportunity area

SDHWG	South Delta Habitat Working Group
SDWSC	Stockton Deep Water Ship Channel
SJMSCP	San Joaquin County Multi-Species Habitat Conservation and Open Space Plan
SJRRP	San Joaquin River Restoration Program
SLR	sea level rise
SPWN	spawning
SSC	suspended sediment concentrations
SWP	State Water Project
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WARM	recreation, warm
WILD	wildlife habitat

Attachment 5E.A
BDCP South Delta Habitat and Flood Corridor Planning Corridor Description and Assessment Document

EA.1 Introduction and Background

With an interest in developing habitat and flood improvements in the South Delta for the Bay Delta Conservation Plan (BDCP), the California Department of Water Resources (DWR) convened the South Delta Habitat Working Group (SDHWG) in summer 2011. The purpose of the SDHWG is to identify opportunities for improving habitat in the southern part of the Delta for integration into the BDCP. While flood management is not an objective of the BDCP process, the habitat improvements identified by the SDHWG were developed in a way that integrates flood management considerations and other economic benefits. The SDHWG has also assisted DWR and others to gain a broader understanding of public and interest group perspectives. The purpose of this document is to:

- describe the SDHWG process in the context of the BDCP;
- describe the conceptual flood and habitat "corridors" as developed by the SDHWG;
- provide information on existing conditions in the South Delta;
- explain the ecosystem, flood, terrestrial species, and water quality evaluations conducted to assess these conceptual corridors;
- present the outcomes of these evaluations (including the relative benefits and apparent risks of the corridors);
- note the uncertainties and data gaps in assessing the corridors; and
- describe how future efforts may refine the planning and design of these corridors to achieve ecosystem and flood management benefits.

EA.1.1 SDHWG Planning Process

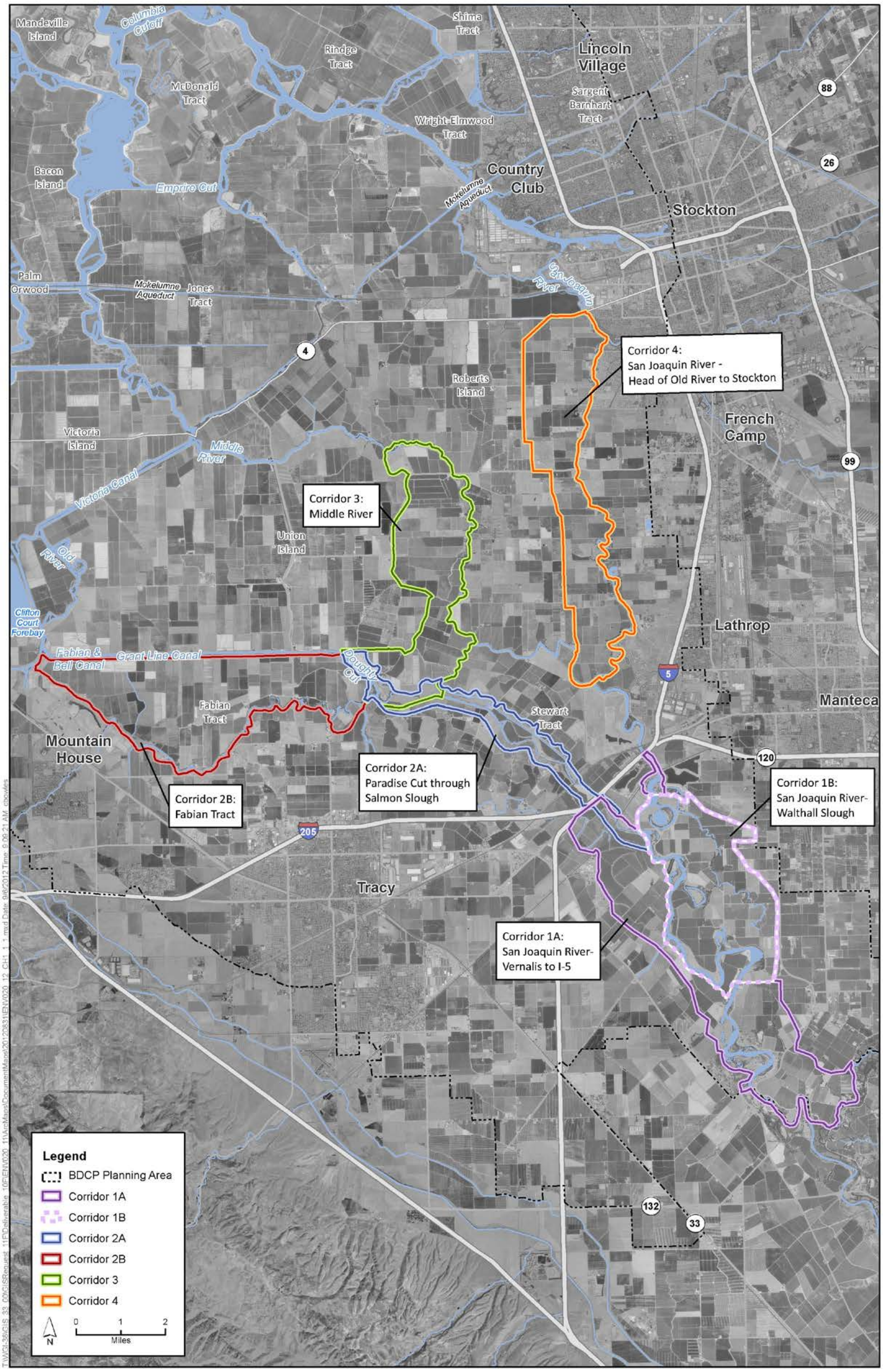
The South Delta is a likely location for the implementation of components of BDCP conservation measures CM 4 (Tidal Restoration), CM 5 (Seasonally-Inundated Floodplain Restoration), CM 6 (Channel Margin Enhancement), and CM 7 (Riparian Restoration). The life history and habitat needs of covered species, the suitability of existing conditions to create suitable habitat for these species, and the strong nexus between implementation of habitat actions and potential ancillary flood risk reduction benefits make the South Delta a potential location for implementation of BDCP conservation measures 4 through 7. In accordance with the SDHWG Charter[1] and based on identified problems, objectives, opportunities, and constraints, the SDHWG has compiled a suite of potential actions that would support achievement of the aforementioned BDCP conservation measures and simultaneously achieve ancillary benefits in flood risk reduction. These actions and

[1] Materials from the SDHWG, including the charter, are located at: http://baydeltaconservationplan.com/BDCPPlanningProcess/WorkingGroups/WorkingGroup-SouthDeltaHabitat.aspx

the geographic area in which they would occur are termed "corridors." The working group process also includes DWR's dialogue with, and presentation to, key stakeholders; a separate technical working group comprised mostly of agency scientists; and a supporting team of consultant engineers and scientists responsible for the development of conceptually-reconfigured South Delta corridors and the completion of an evaluation process to screen these corridors for benefits and risks. To date, the SDHWG includes the participation of the U.S. Army Corps of Engineers, South Delta Water Agency, Contra Costa Water District, San Joaquin County, San Joaquin Council of Governments, San Joaquin County Vector Control, North Delta Water Agency, American Rivers, Ducks Unlimited, PRBO Conservation Science, River Partners, Kern County Water Agency, Metropolitan Water District, Santa Clara Valley Water District, State Water Contractors, Westlands Water District, San Joaquin River Group Authority, River Islands, LLC, the Cities of Lathrop and Stockton, and other participants.

The SDHWG charter, provided in Section 7.1 of this document, states that that in developing approaches for achieving the habitat objectives, flood management objectives should be integrated. The approach of developing corridors along the San Joaquin River upstream of Paradise Cut (Vernalis to Mossdale), the Paradise Cut / Old River area, the Middle River, and the mainstem San Joaquin River from Mossdale to Stockton is consistent with the charter. The potential flood management and habitat restoration and enhancement actions identified by the SDHWG were configured by the support team into a series of conceptual South Delta corridors—with each corridor being a delineation of actions such as levee setbacks, creation of flood bypasses, riparian planting, and channel margin enhancement. While developed at an early, conceptual-level of detail, work to-date suggests that these corridors would support achievement of the BDCP conservation measures 4 through 7 and simultaneously achieve ancillary benefits in flood risk reduction. The four corridors (Figure EA.1.1-1) include:

- Corridor 1A: Levee setbacks on both banks of the San Joaquin River from Vernalis to I-5.
- Corridor 1B: An alternative version of Corridor 1A along the San Joaquin that includes only a right-bank levee setback and connection of Walthall Slough with the San Joaquin River via a weir. Corridor 1B is assessed separately from Corridor 1A.
- Corridor 2A: Expansion of the Paradise Cut flood bypass and modifications to Paradise Cut weir.
- Corridor 2B: An expanded version of Corridor 2A that also includes levee removal around Fabian Tract. *Corridor 2B is essentially Corridor 2A plus Fabian Tract. Fabian Tract is not hydraulically-modeled separately from Paradise Cut in terms of flood evaluations; however, the flood and ecological benefits of Corridor 2B are examined discretely.*
- Corridor 3: Selected levee setbacks along Middle River on Union Island.
- Corridor 4: Levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River.



Sources: Plan Area, ICF 2012; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.1.1-1: Overview of South Delta Study Area

The approach for developing the corridors, problem statements, and objectives are included in Section 7.1. A summary of the rationales for the configuration of the corridors is included in Section 7.2. More-detailed description of each corridor is presented in Section 3. However, it is important to note that such spatially-explicit definition of these actions was done *solely for the purpose of facilitating evaluation of the* *<u>relative potential benefits and risks</u>* of each these four geographic areas of the South Delta. This preliminary configuration of corridors was not an engineering-design exercise. Rather, the intent was to rapidly generate a collection of potential actions with a level of geographic specificity sufficient to support modeling and subsequent interdisciplinary assessment of potential flood and ecosystem benefits. After the SDHWG's initial evaluation of these corridors, further planning may expound on one or more corridor, as appropriate, for actual restoration planning and implementation.

EA.1.2 Overview of South Delta Screening-Level Assessments

Consisting of multiple river distributary channels in addition to the mainstem San Joaquin River, the South Delta is a hydrodynamically complex region in terms of considering major actions that have the potential to alter landscape-scale flood and ecosystem processes. Thus, to simplify the complexity, the support team developed the SDHWG evaluation process to define the outcomes (both positive and negative) for species, habitats, water quality, and flood conveyance as depicted in the conceptual corridors. The team used screening-level hydraulic modeling (see Section 7.3 and Section 7.4) and a conceptual-level assessment of the ecosystem to derive the outcomes. These outcomes were then reviewed, augmented or edited as necessary, and scored by a group of experts (listed in Section 7.5) using the Delta Regional Ecosystem Restoration Implementation Program (DRERIP) conceptual models and a modified version of the existing DRERIP evaluation process (see Section 7.6).

Most of the experts that completed the evaluations had some previous exposure to the DRERIP tools and process, either through involvement in development of the DRERIP ecosystem and species conceptual models[2], or through the DRERIP evaluation of potential BDCP conservation measures in 2009; however, the process was streamlined for use in these South Delta evaluations, and a new flood risk reduction evaluation process (separate from the species evaluations) was crafted to address the additional flood component of the SDHWG's objectives. The DRERIP evaluation process in general consists of a structured evaluation conducted by a multidisciplinary team of experts. The process is supported by conceptual models which describe the state of knowledge regarding ecosystem processes, habitats, stressors, and species. However, the process is also designed to draw upon other sources of information. Additionally, for the flood component, computational model results support the evaluations. In the end, the key is that the evaluations are transparent and well-documented.

This evaluation approach drew on the expertise of a group of agency, academic, and private-sector scientists and engineers, and generated conclusions that can focus implementation planning to locations where the relative benefits are high and the apparent risks are low. Perhaps more importantly, outcomes with high levels of engineering and/or scientific uncertainty or instances of professional disagreements where existing scientific literature or empirical data are lacking are

[2] The DRERIP Conceptual Models are posted to the CALFED Science Program Archives Website at http://www.science.calwater.ca.gov/drerip/drerip_index.html for review and use.

documented. This transparent depiction of the outcomes, identification of what remains uncertain, and outlining of issues where disagreement may remain allows subsequent planning and design efforts to concentrate on resolving that uncertainty through focused research or analysis prior to implementation.

In evaluating the corridors, the evaluators assumed a new dual conveyance strategy is in place, under which a substantial amount of water will be diverted from a new facility on the Sacramento River in combination with reduced, but continued diversions from state and federal pumping facilities in the South Delta, particularly in the summer months. Further, evaluators were also charged to consider:

- How the San Joaquin River Restoration Program restoration flow regime and future flows that may be ordered by the State Water Resources Control Board (SWRCB) or result from climate change influence key habitats such as ecologically relevant inundated floodplain;
- How sea level rise influences flooding and ecological outcomes;
- How the corridors will perform if several islands in the central and west Delta are permanently inundated in the future;
- How the corridors may be consistent with a barrier at the head of Old River, or how it can achieve the same or greater benefits without the barrier or with a barrier open more of the time than currently planned; and
- How the corridors might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants.

Lastly, while the evaluations were focused on the habitat benefits for salmonids and other native fish species, evaluators also sought to identify opportunities within the corridors for creating habitat for terrestrial species, including waterfowl, to the extent practicable. Similarly, recreational benefits of the corridors were also considered and noted as appropriate.

Each of the corridors was evaluated according to the objectives listed in Section 7.1 following the instructions included in Section 7.6. The results of those evaluations are summarized in Section 4. Sections 2 through 7 of this document include information supporting, and results from, a relatively rapid, screening-level assessment of South Delta habitat, water quality and flood conditions for both existing and “with corridor” conditions. The purpose of the information and results presented herein is to quickly and efficiently provide evaluators with what they need to support their screening-level evaluations. Thus, while some sections contain some narrative content, much of the information is in the form of tables and summary bullets.

EA.1.3 Future South Delta Habitat- and Flood-related Planning and Implementation

The multi-benefit synergy between habitat creation/restoration and flood risk reduction actions is a primary reason why the South Delta is a promising location to focus pre-project implementation planning efforts. After the SDHWG’s initial evaluation of these corridors (Phase 1), further planning may expound on one or more corridor, as appropriate, for actual restoration planning and implementation. This will include a more focused effort to plan and implement projects in those corridors/locations that were found to have the highest potential for benefits and the lowest apparent risk. This subsequent planning and implementation would be in accordance with the BDCP implementation schedule and may also be coordinated with implementation of the Central Valley Flood Protection Plan. All requisite permitting and project-level environmental documentation would be completed at that time.

It is envisioned that any future planning and design work would be advanced progressively. Phase 2 may involve the development of site-specific conceptual design alternatives that can be assessed for feasibility and potential benefits. A site-specific design alternative could then be selected based on the results of those assessments. Phase 3 would involve site-specific planning, design, restoration construction, restoration monitoring and management, and long-term monitoring and adaptive management. Clearly, the participation of additional individuals, organizations, and agencies would be necessary to advance implementation in the South Delta through these potential subsequent phases of planning and implementation.

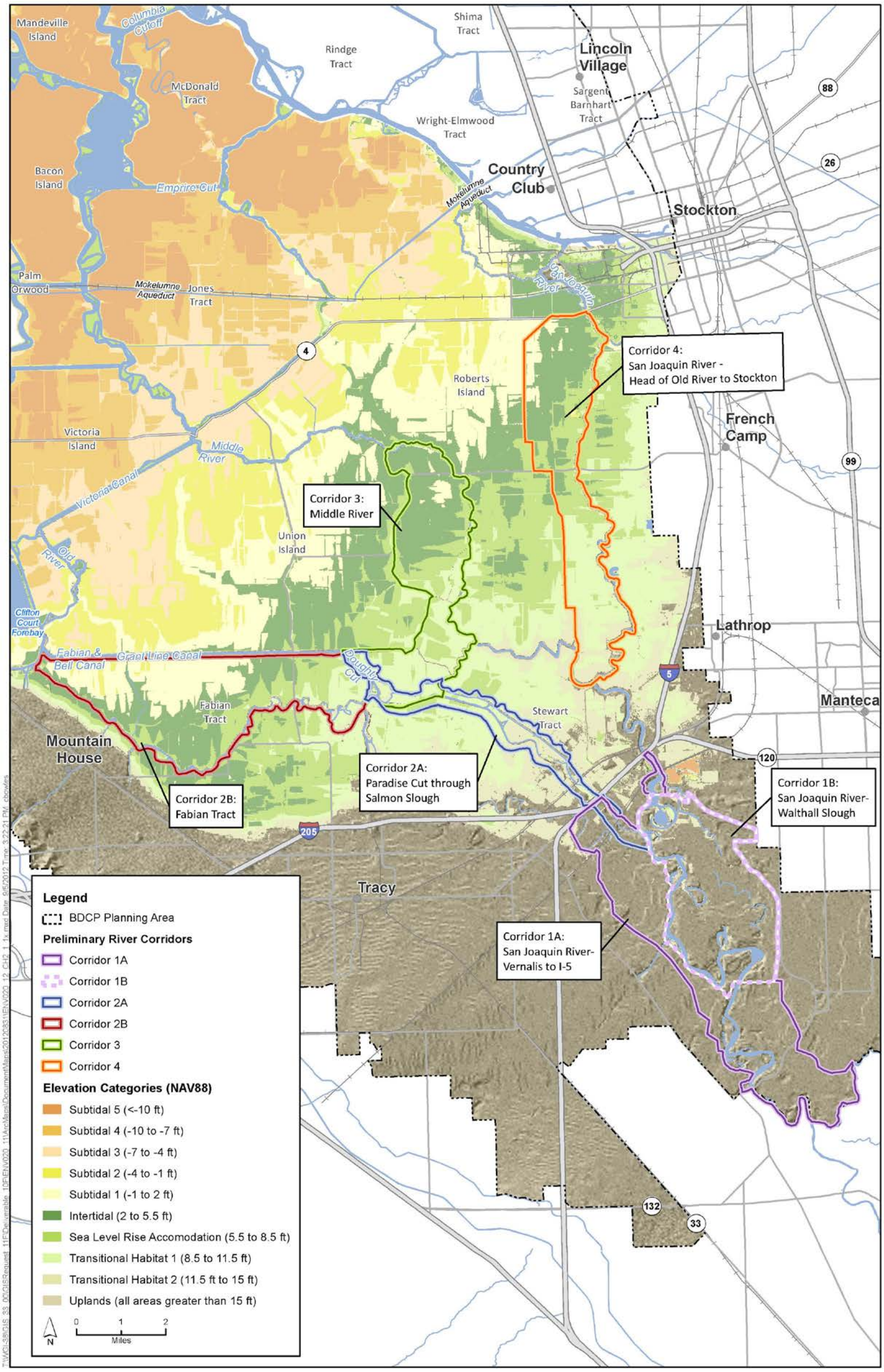
EA.2 Existing Corridor Conditions

EA.2.1 Introduction and Physical Setting

The objective of this section is to characterize existing infrastructure, levees, flood conveyance, habitat conditions, geomorphology, and water quality to inform the evaluations of the actions within each corridor as listed below. This section does not provide a comprehensive summary of existing conditions. At the time of the BDCP South Delta corridor evaluations (February 2012), a substantial literature regarding the Delta was publically available on the Internet, including documents that were in preparation at that time such as the Delta Plan and BDCP. During the evaluations, an extensive electronic library was made available to the evaluators.

Figure EA.2.1-1 illustrates the boundaries of the South Delta corridors, existing topography, and an extrapolation of tidal range across islands that are presently separated from South Delta waterways. Additional figures within this section depict levee issues and failures, hydraulic conveyance points of interest, urban and non-urban levee hazards, approximate extent of the 1997 floods in the South Delta, land uses, habitat types and acreages, and sediment and water quality data.

- Corridor 1A: Levee setbacks on both banks of the San Joaquin River from Vernalis to I-5.
- Corridor 1B: An alternative version of Corridor 1A along the San Joaquin that includes only a right-bank levee setback and connection of Walthall Slough with the San Joaquin River via a weir. Corridor 1B is assessed separately from Corridor 1A.
- Corridor 2A: Expansion of the Paradise Cut flood bypass and modifications to Paradise Cut weir.
- Corridor 2B: An expanded version of Corridor 2A that also includes levee removal around Fabian Tract. *Corridor 2B is essentially Corridor 2A plus Fabian Tract. Fabian Tract is not hydraulically-modeled separately from Paradise Cut in terms of flood evaluations; however, the flood and ecological benefits of Corridor 2B are examined discretely.*
- Corridor 3: Selected levee setbacks along Middle River on Union Island.
- Corridor 4: Levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River.



Sources: Plan Area, ICF 2012; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.1-1: South Delta Physical Setting

EA.2.2 Infrastructure & Operations

This section provides information on key human infrastructure as related to water use and management. Figure EA.2.2-1 illustrates the location of major and minor water diversions in the South Delta.

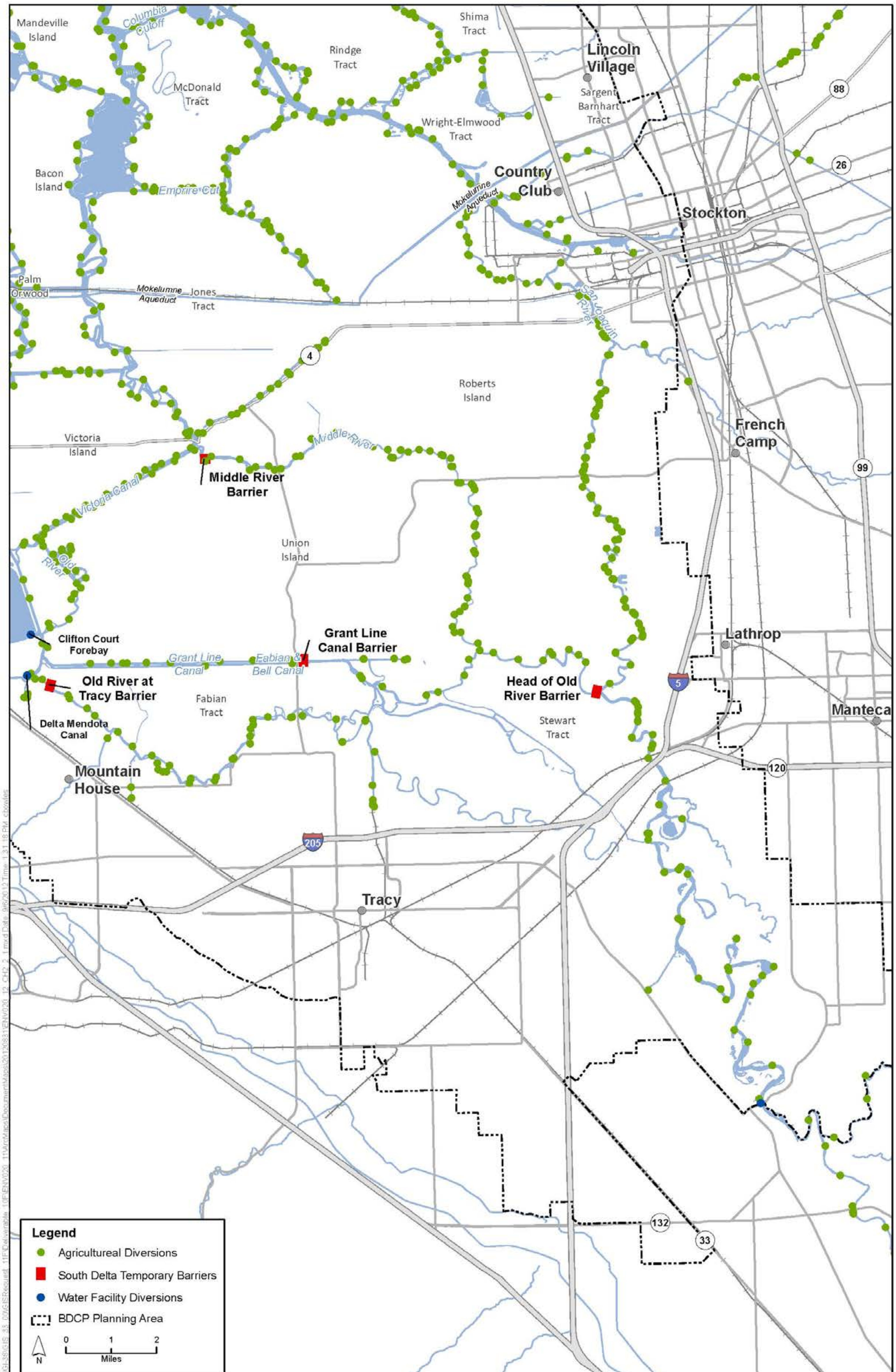
Specific information on agricultural land use and on publicly-owned and conservation-focused lands are addressed in Section 2.4, and presented in relation to other land covers types, notably existing habitat. Other human infrastructure (i.e., the number and location of homes, agricultural buildings and related infrastructure, etc.) is quantified for each corridor in Section 4.1.5.

To support management in the South Delta, the South Delta Temporary Barriers project consists of the installation of four rock barriers each spring at key locations in channels: the head of Old River, Old River at Tracy, Grant Line Canal, and Middle River (Figure EA.2.2-1). The purpose is to protect San Joaquin River fall-run Chinook salmon from the State Water Project (SWP) and Central Valley Project (CVP) south Delta export facilities and to benefit southern Delta agricultural diverters by increasing water elevations, improving circulation, and improving water quality. The head of Old River barrier is also installed during the fall for dissolved oxygen reasons. The head of Old River barrier is considered a fish barrier because it is installed to keep migrating juvenile Chinook salmon in the San Joaquin River. The other three barriers are agricultural barriers; meaning they are installed to maintain water quality for agricultural uses in the South Delta.

The barriers are installed at the following locations:

- Tidal control facilities with rock barriers and gated culverts to improve water elevations and water quality for agricultural diversions during the growing season are in place at the following locations:
  - Middle River near Victoria Canal, about 0.5 mile south of the confluence of Middle River, Trapper Slough, and North Canal.
  - Old River along the Fabian Tract, about 0.5 mile east of the Delta-Mendota Canal intake.
  - Grant Line Canal, about 400 feet east of the Tracy Boulevard Bridge.
- A rock barrier or nonphysical barrier is installed in the fall at the Head of Old River near the confluence with the San Joaquin River to improve dissolved oxygen in the San Joaquin River by reducing flows into Old River during salmon migration in the San Joaquin River.
- A rock barrier or nonphysical barrier is installed in the spring to reduce exposure of downstream migrating salmon to diversions at the SWP and CVP south Delta export facilities.

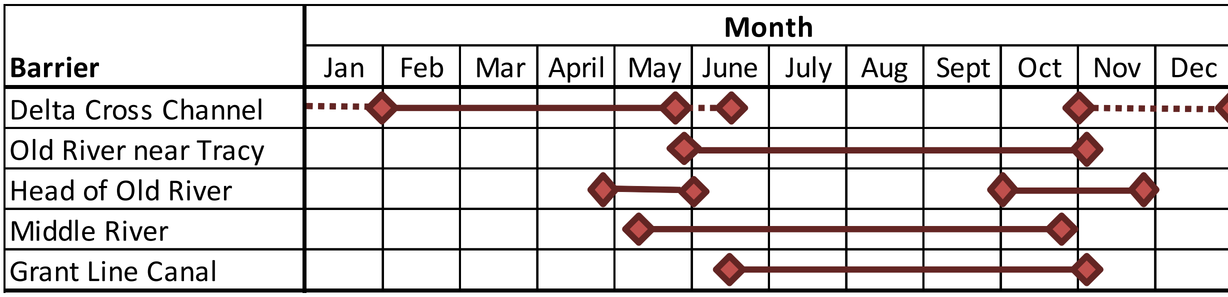
The head of Old River barrier was not installed in spring of 2009 or 2010 as the 2008 U.S. Fish and Wildlife Service (USFWS) Biological Opinion (BO) prohibited the installation of the barrier for the protection of delta smelt. The rock barriers are not installed in years when San Joaquin River flows are high (i.e., higher than 10,000 cubic feet per second (cfs) at Vernalis), such as during 1998. Table EA.2.2-1 depicts the approximate time of closure for these barriers, based on the sources noted.



Sources: Plan Area, ICF 2012; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.2-1: South Delta Temporary Barriers and Water Diversions

Table EA.2.2-1: Approximate Times of South Delta Barrier Closure



Average closure windows:	
Delta Cross Channel:	Nov 1 - Jan 31 (total of 45 days, may be closed on weekends), Feb 1 - May 20, May 21 - June 15 (total of 14 days, open on weekends)
Old River near Tracy:	May 26 - Nov 5
Head of Old River (spring):	Apr 22 - June 2
Head of Old River (fall):	Oct 1 - Nov 21
Middle River:	May 11 - Oct 20
Grant Line Canal:	June 16 - Nov 5
Sources: http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm http://www.usbr.gov/mp/cvo/vungvari/xcgtxt.html http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm#Grant http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm#Middle http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm#Fall http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm#Spring http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbsch.cfm#old	

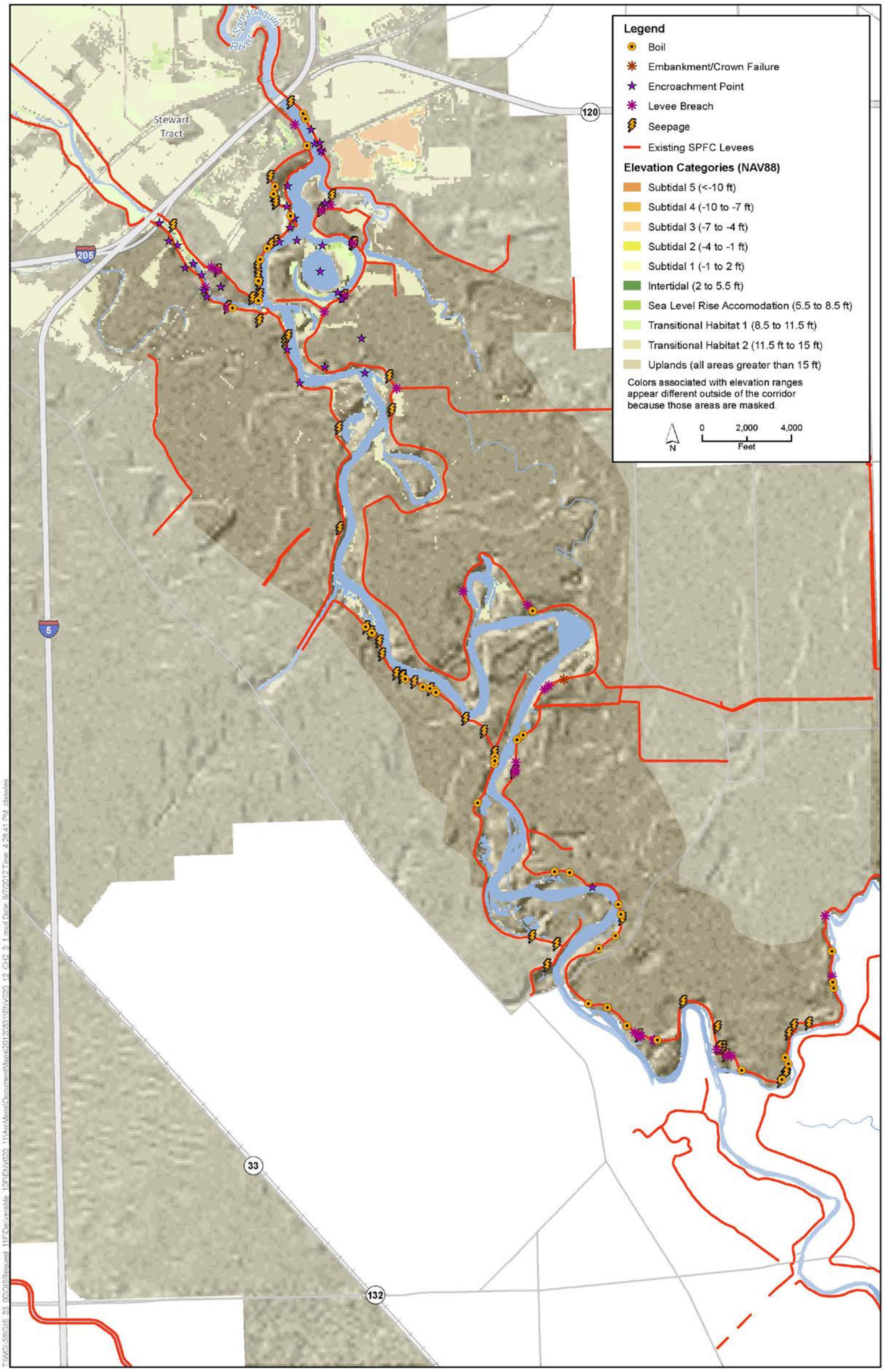
EA.2.3 Levees & Flood Conveyance

Figure EA.2.3-1 through Figure EA.2.3-6 provide a summary of levee conditions in the corridors with key locations related to river hydraulics and conveyance also identified. The locations of boils, embankment failures, encroachment points, levee breaches, and seepage were obtained from the California Levee Database, which is maintained by DWR. A more complete summary of existing flood conveyance conditions—presented in comparison to flood performance of the conceptual corridors—is included in Section 7.4.

Key elements of the levee / flood conveyance system in the South Delta channels area are as follows:

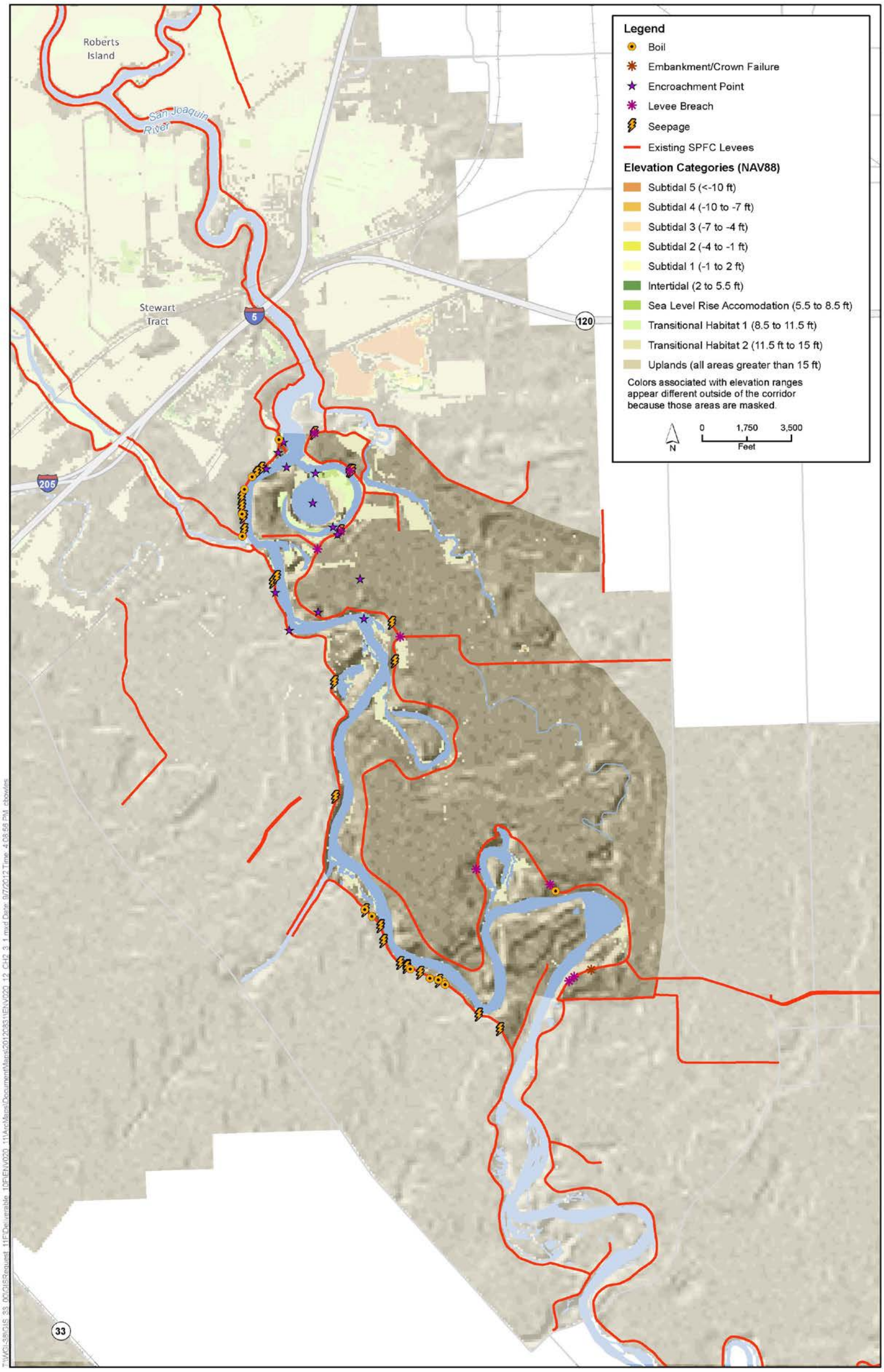
- The San Joaquin River routes flow in a northward direction from Vernalis. Existing project levees are located in this area. Condition information is noted on Figure EA.2.3-1 through Figure EA.2.3-6.
- The Paradise Cut bypass currently begins to draw water off of the San Joaquin at flows of approximately 18,000 cfs.

- Flood flows through Paradise Cut then route through Old River and Grant Line Canal, past Clifton Court Forebay and the pumping facilities, and into the interior Delta.
- Flows that continue down the San Joaquin River then bifurcate into Old River at the Head of Old River.
- Middle River accepts flood flows off of Old River, and routes towards Victoria Canal and the interior Delta.
- A network of levees runs adjacent to all channels in the South Delta. Most of these are "project" levees that were designed and built by the U.S. Army Corps of Engineers (USACE). In the 1960's these were raised where necessary in order to have three feet of free board above river stage when the flow at Vernalis was 52,000 cfs (Hildebrand and Foreman, 2004).
- Throughout the South Delta, these levees vary in terms of height, width, and condition, and so provide varying levels of flood protection.
- Floods have occurred frequently in this region due to levee overtopping and failure, most recently during the following events:
    - Dec 25th 1955 (City of Stockton flooded) San Joaquin River at Vernalis peaked at 50,900 cfs
    - April 5th, 1958 (City of Stockton flooded) San Joaquin River at Vernalis peaked at 41,400 cfs
    - March 7th, 1983 (widespread flooding along San Joaquin River) San Joaquin River at Vernalis peaked at 45,100 cfs
    - Jan 5th, 1997 (widespread flooding along San Joaquin River and South Delta) San Joaquin River at Vernalis peaked at 75,600 cfs
- The extent of inundation from the 1997 flood event in the South Delta is shown in Figure EA.2.3-7 below.
- The relative hazard of levee failure has been analyzed and rated by DWR for urban and non-urban levees in the South Delta by the recently released Central Valley Flood Management Protection Plan (CVFMPP) Flood Control System Status Report (Dec 2011; Figure EA.2.3-8 and Figure EA.2.3-9). An overall hazard category was assigned to each levee segment, considering the collective performance for the geotechnical failure modes, including under-seepage, through-seepage, slope stability, and erosion. A "high" rating means that when water reaches the assessment water surface elevation, there is a relatively high potential for levee failure or the need to flood-fight to prevent levee failure. These levees are in the most danger of failure.
- Additional information on the hydraulic and flood control performance of the South Delta is available in the 2001 Flood Control System Status report on the DWR website (http://www.water.ca.gov/cvfmp/docs/FCSSRDec2011_ExecSumSections1-3.pdf).



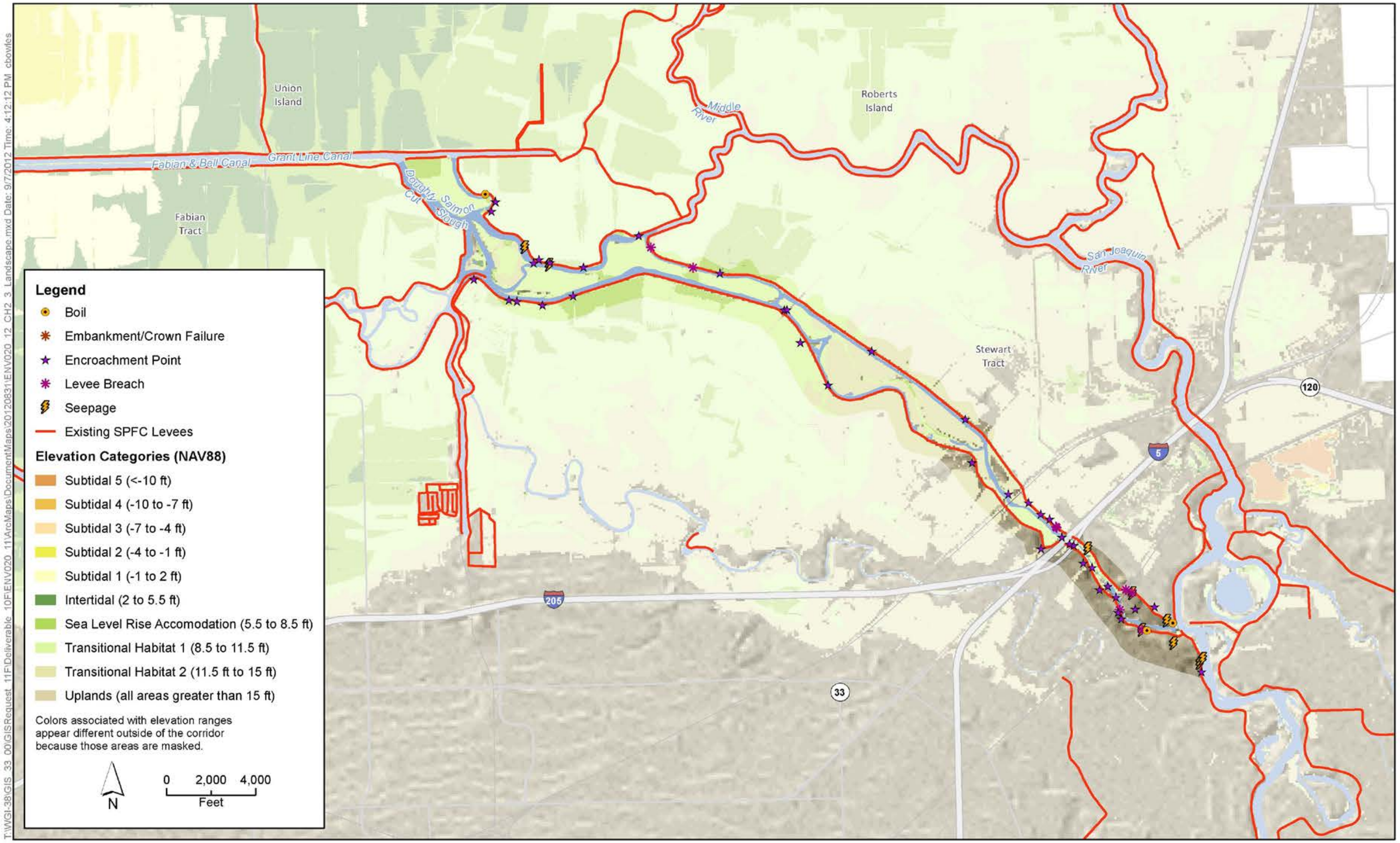
Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.3-1: Levee Issues & Failures; Hydraulic Conveyance Points of Interest: Corridor 1A



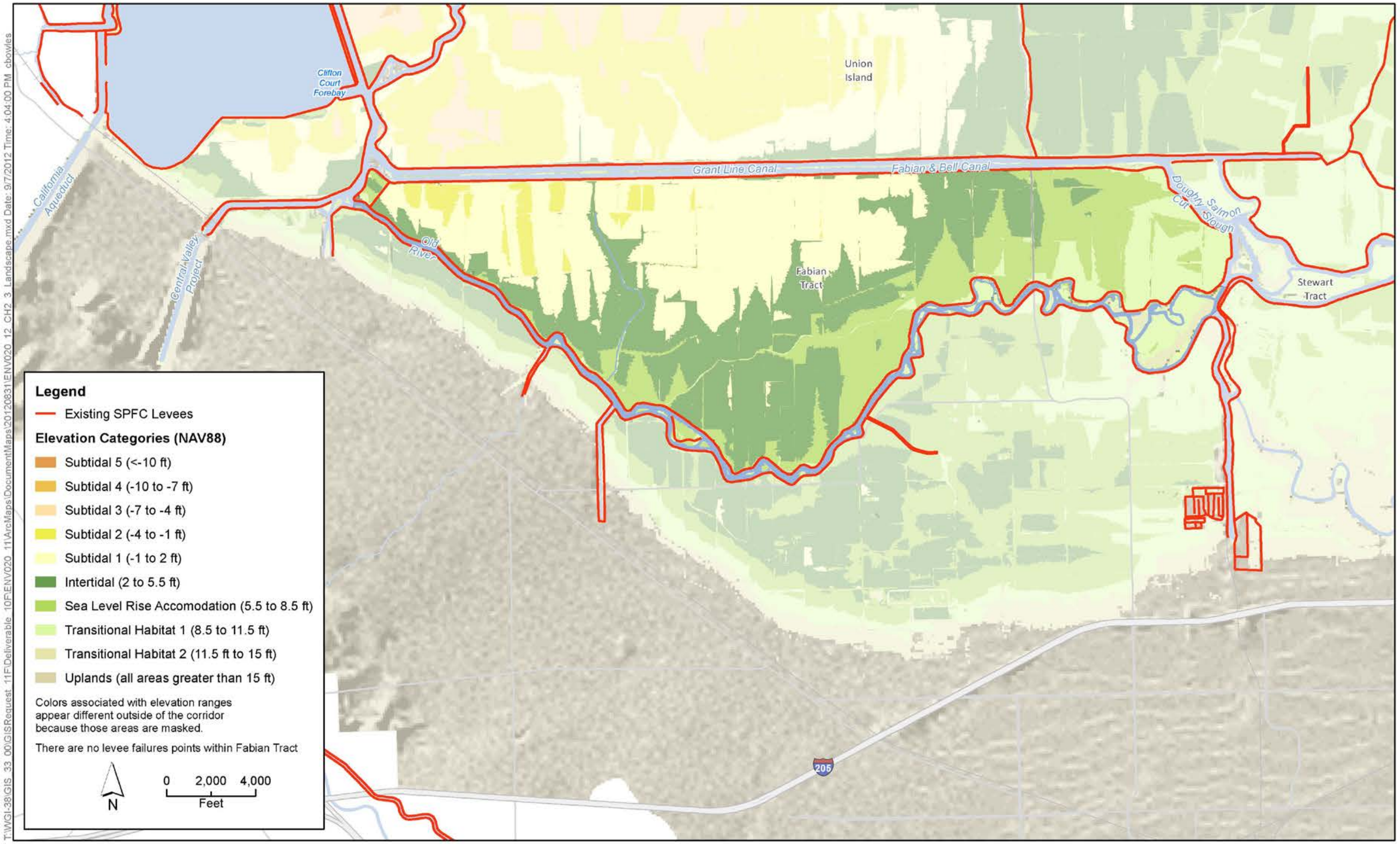
Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.3-2: Levee Issues & Failures; Hydraulic Conveyance Points of Interest: Corridor 1B



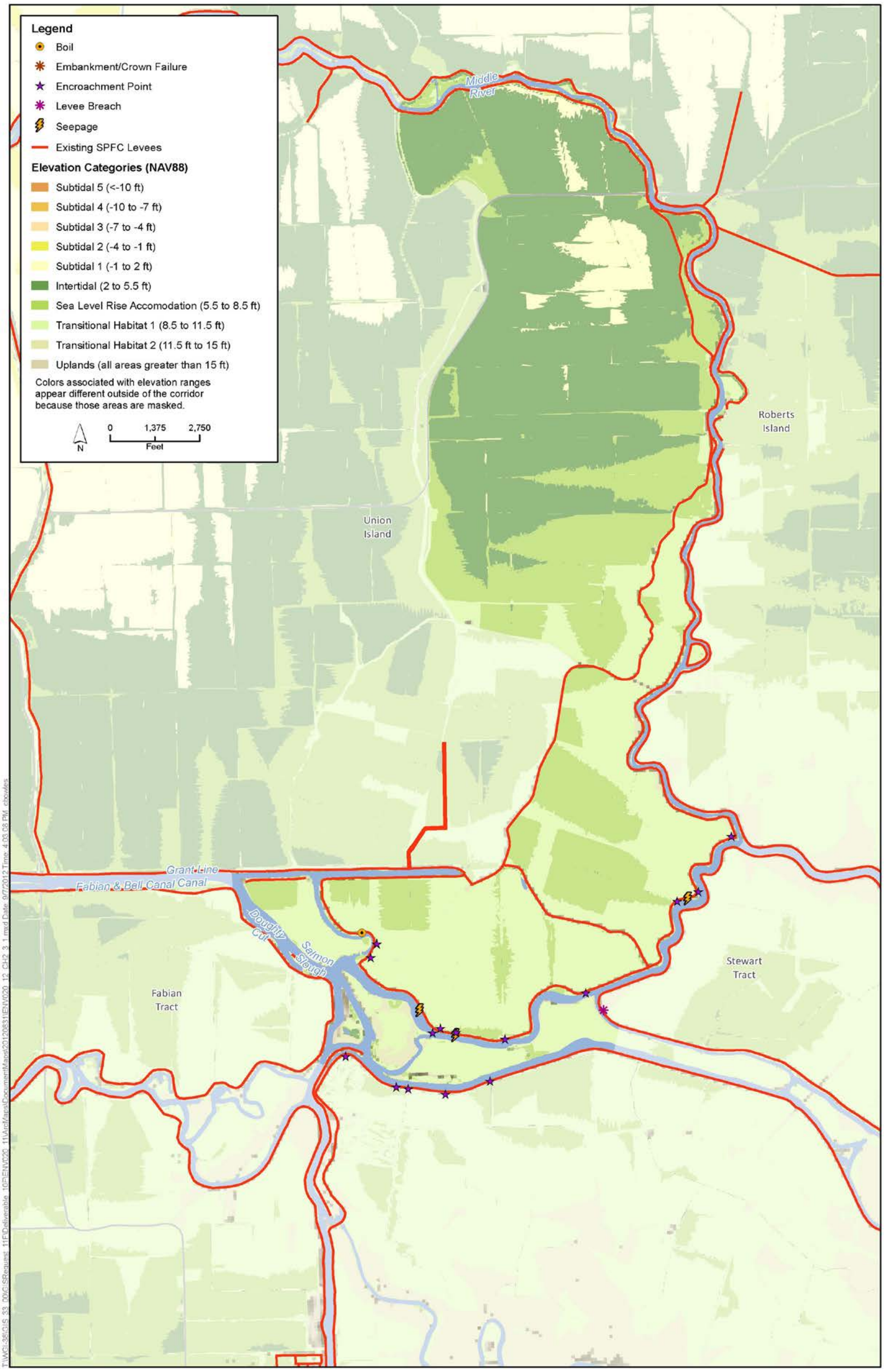
Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.3-3: Levee Issues & Failures; Hydraulic Conveyance Points of Interest: Corridor 2A



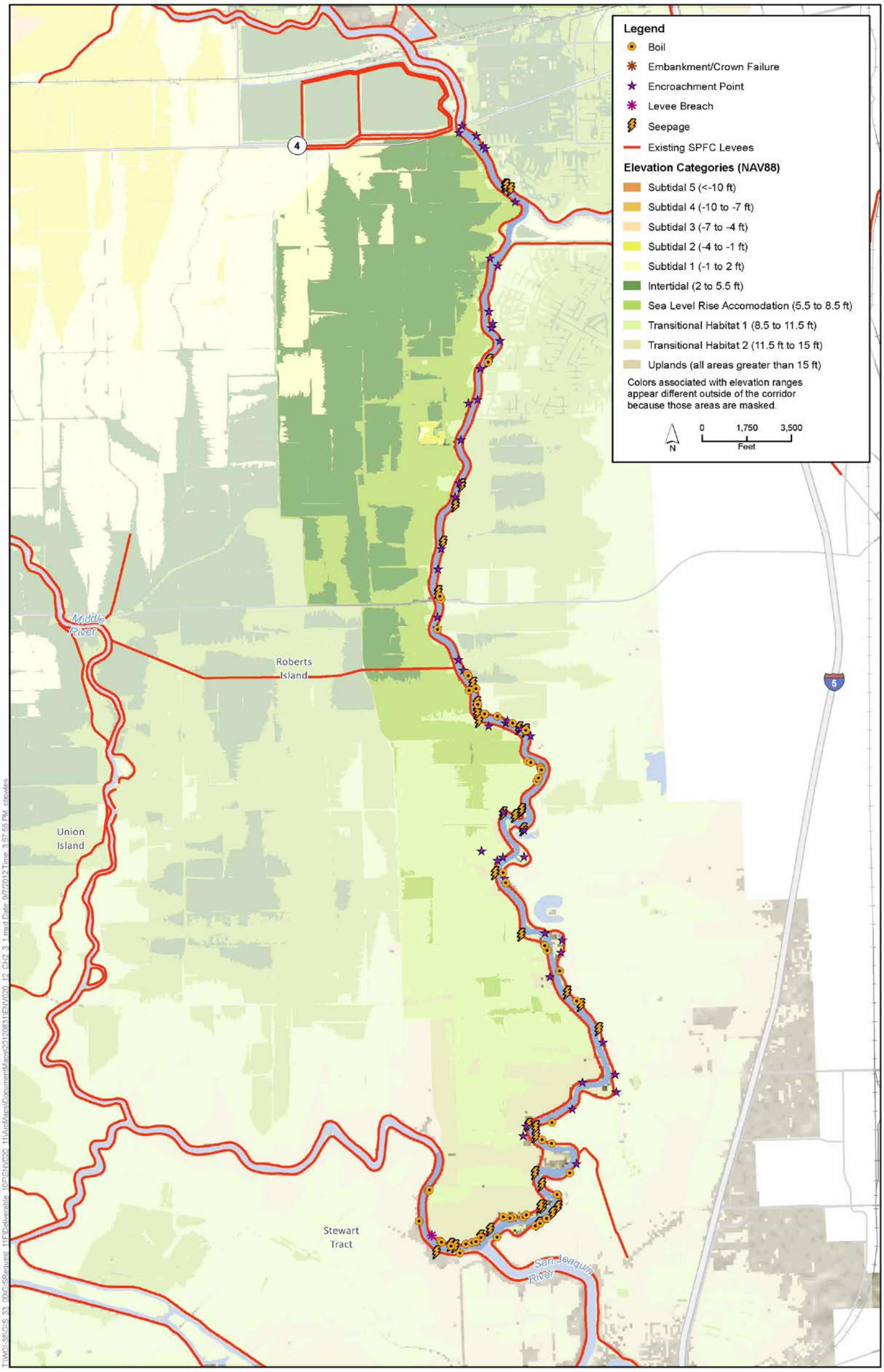
Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.3-4: Levee Issues & Failures; Hydraulic Conveyance Points of Interest: Corridor 2B



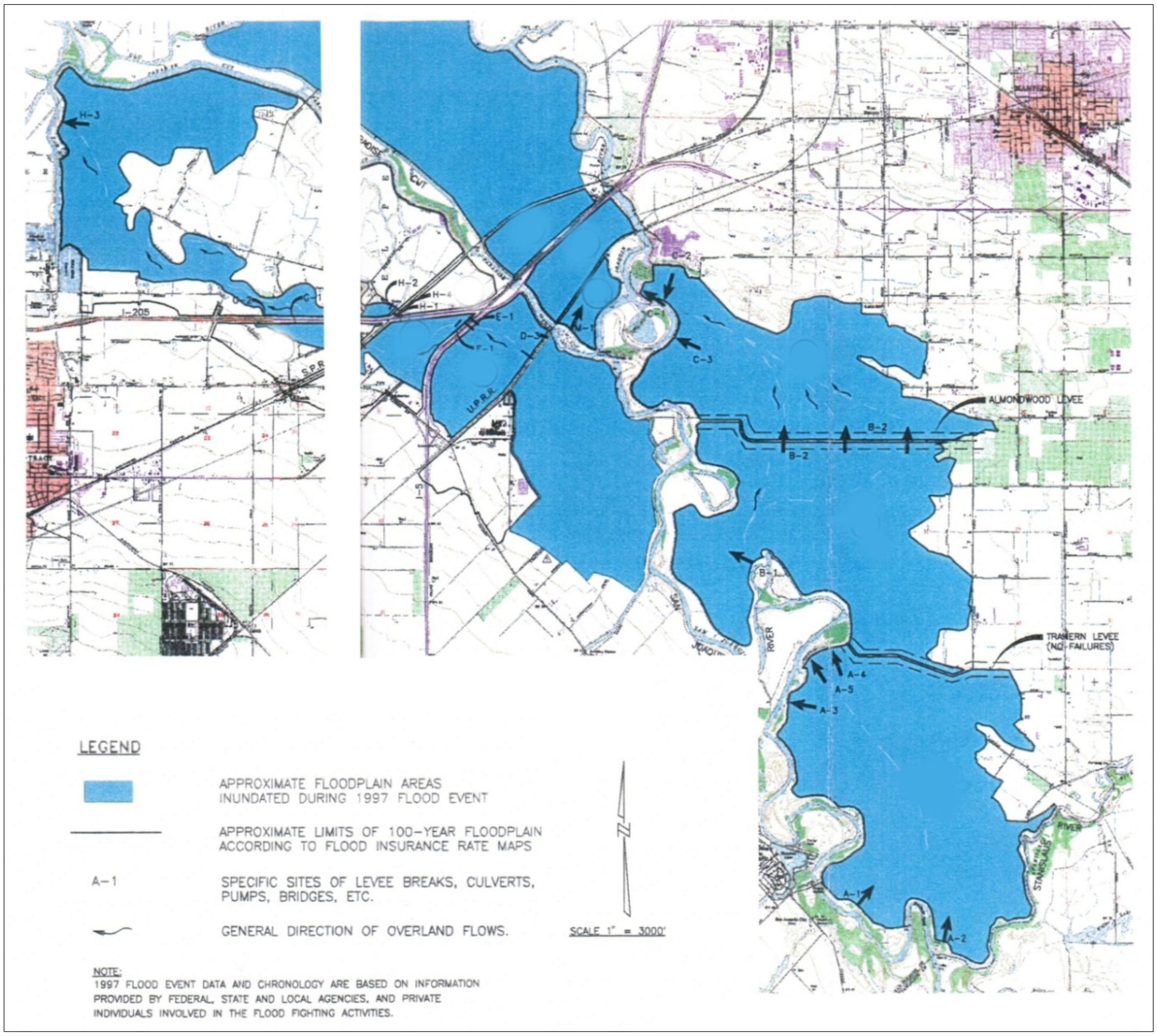
Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.3-5: Levee Issues & Failures; Hydraulic Conveyance Points of Interest: Corridor 3



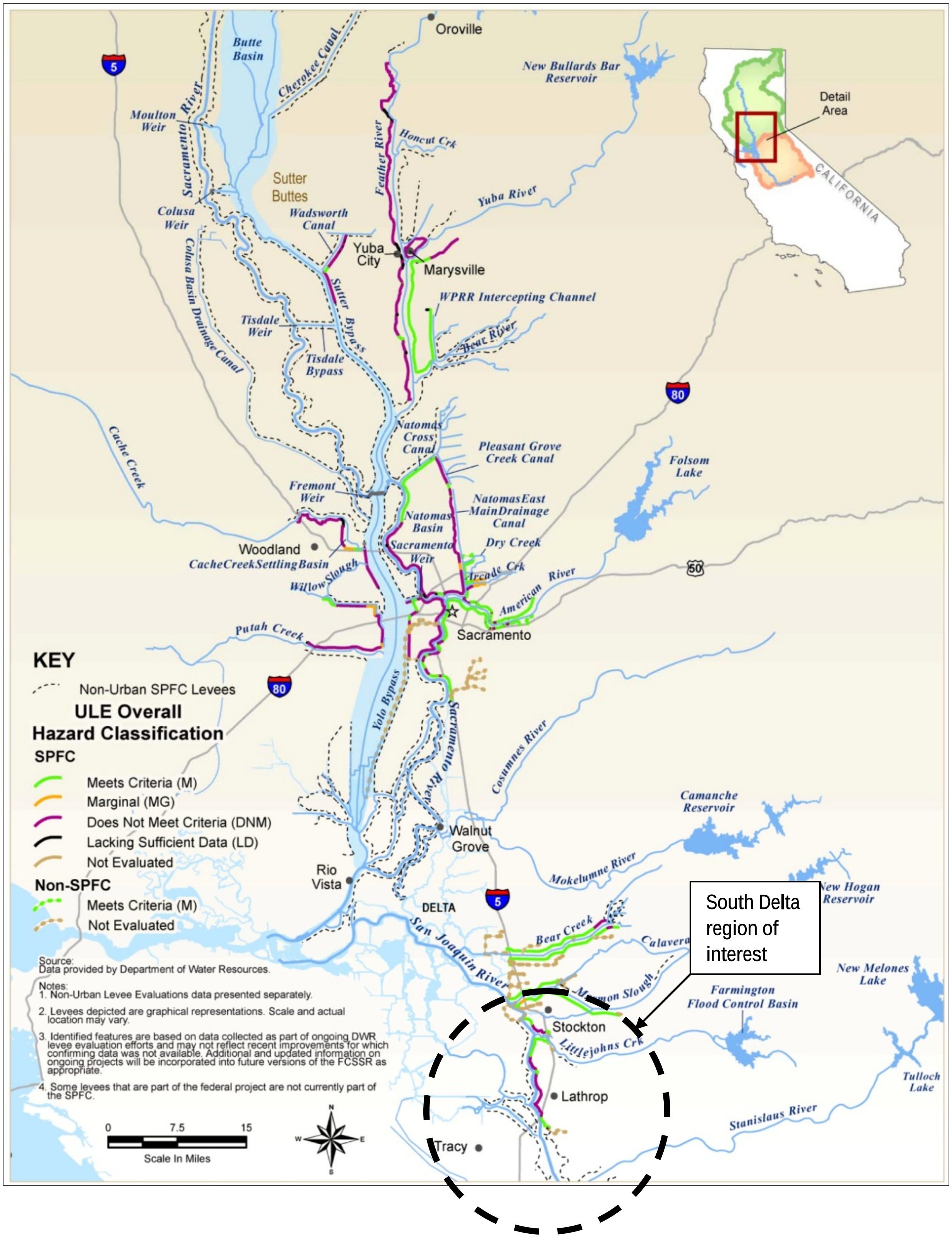
Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.3-6: Levee Issues & Failures; Hydraulic Conveyance Points of Interest: Corridor 4



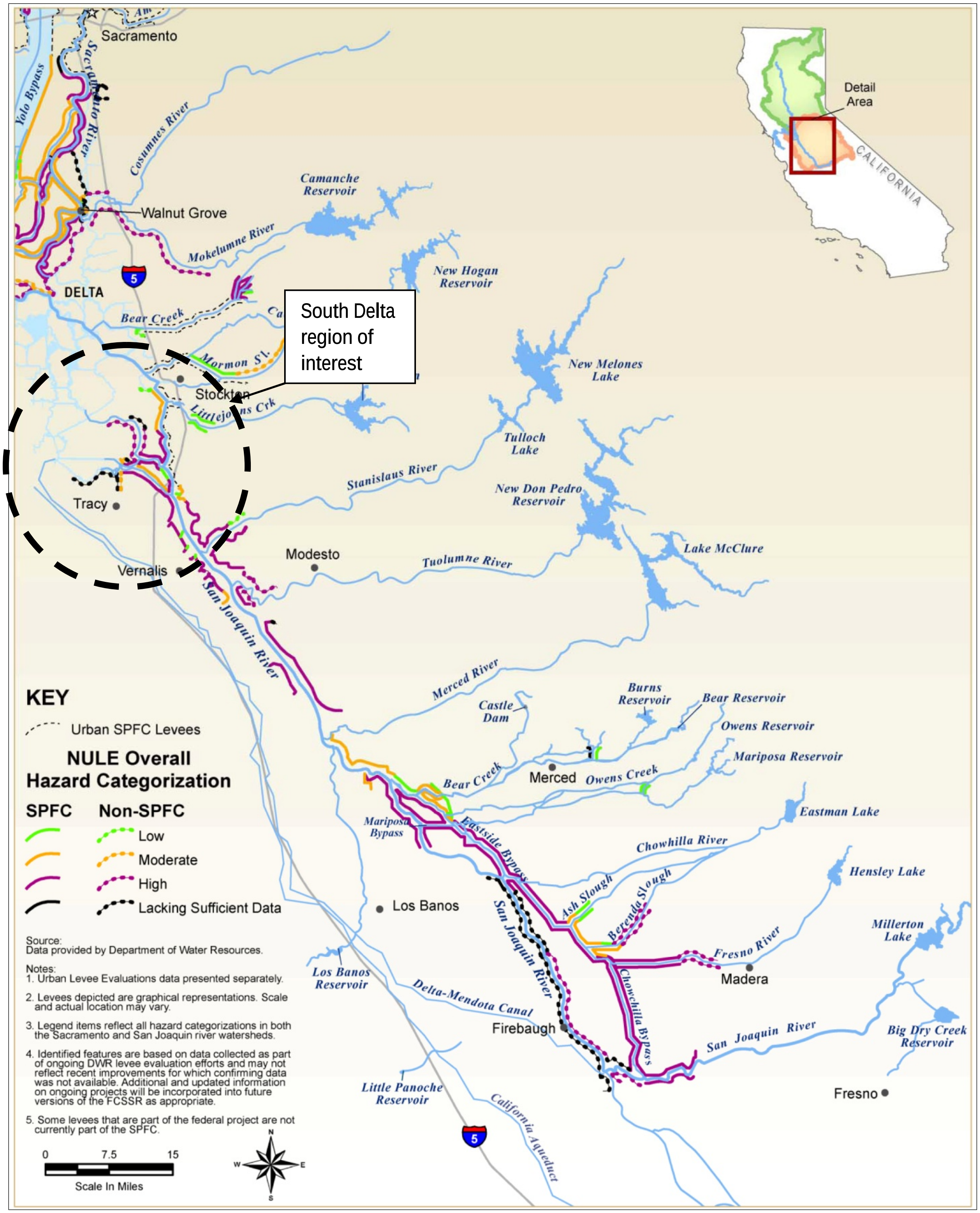
Source: Hildebrand and Foreman, 2004

Figure EA.2.3-7: Approximate Extent of 1997 Floods in the South Delta



Source: DWR, 2011

Figure EA.2.3-8: Urban Levee Hazards in the South Delta



Source: DWR, 2011

Figure EA.2.3-9: Non-Urban Levee Hazards in the South Delta

EA.2.4 South Delta Habitats

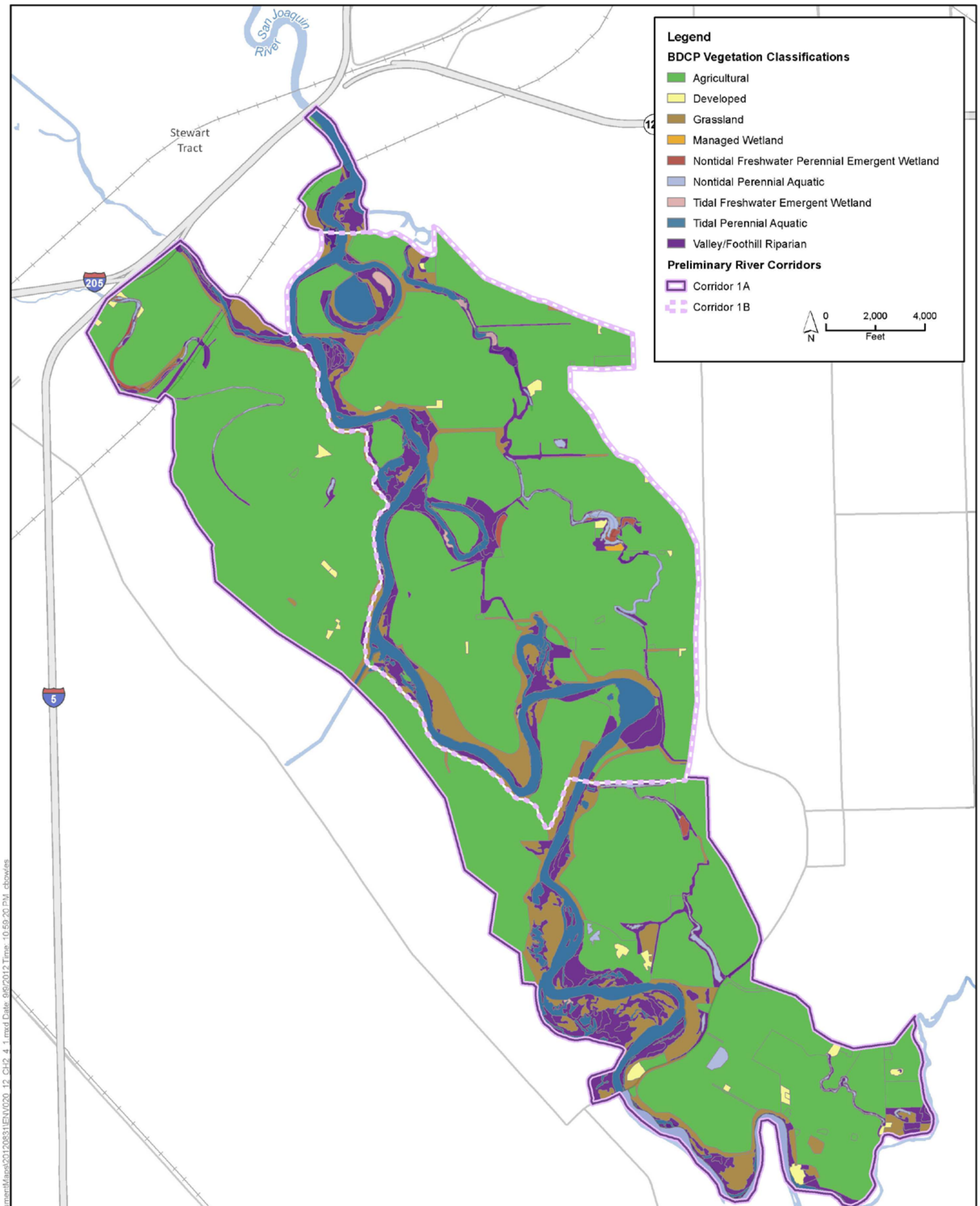
EA.2.4.1 Corridor 1

Habitats within Corridor 1 have been mapped as part of the BDCP planning process and their extent and distribution are provided in Figure EA.2.4-1 (CNRA, 2012). A vegetation and land use GIS dataset was created by the California State Natural Resources Agency (CNRA) in order to perform habitat conservation planning under the BDCP process. The sources of vegetation and land use data were primarily the CNRA and California Department of Fish and Wildlife (CDFW) (CNRA, 2012). The total acreages of habitat types and other land uses are provided in Table EA.2.4-1, below. In addition to the review of this spatial data, images from Google Earth (Google Inc, 2011) and delta vegetation and land use mapping on the CDFW Biogeographic Information and Observation System (BIOS) (VegCAMP, 2011) were reviewed to better characterize habitat quality and calibrate mapping accuracy. Limited field reconnaissance for this South Delta project was conducted from public access points.

In general, habitats that are important for ecosystem function, including tidal wetland, riparian, floodplain, and channel margin, are substantially limited within Corridor 1, as is similar to the overall South Delta study area. Agriculture is the dominant land use at approximately 70% of the entire acreage in Corridors 1A and 1B. Less than 2% of either corridor is mapped as developed land. Similar to other areas within the Central Valley, the extent of natural habitat along the San Joaquin River in Corridor 1 has been substantially reduced from historic conditions due to agricultural conversion, stream channelization, and flood protection (CNRA, 2010). According to parcel ownership data, there are 14 properties (either single parcels or contiguous blocks of parcels) within the South Delta Boundary that are either locally, state, or federally owned (Figure EA.2.4-2). In addition, there are seven properties that are under some type of conservation easement. Not all of these are under a conservation easement with the purpose of ecological protection; some of these are likely protected for agricultural or other land use purposes. Within Corridor 1, there are four properties that have some level of protection and two of these are publically owned lands. Protected lands include riparian corridors along the San Joaquin River. Overall, publically owned lands and lands protected for habitat conservation purposes within the entire South Delta region are lacking.

Table EA.2.4-1: BDCP Habitats in Corridor 1

BDCP Habitat Classification	Corridor 1A (Acres)	Percent of Corridor 1A Acreage	Corridor 1B (Acres)	Percent of Corridor 1B Acreage
Agricultural	8,902	72.27	3,976	69.89
Developed	84	0.69	21	0.36
Grassland	951	7.72	422	7.42
Managed Wetland	4	0.03	4	0.07
Nontidal Freshwater Perennial Emergent Wetland	36	0.29	14	0.25
Nontidal Perennial Aquatic	100	0.81	39	0.69
Tidal Freshwater Emergent Wetland	19	0.16	18	0.32
Tidal Perennial Aquatic	1,046	8.49	607	10.67
Valley/Foothill Riparian	1,176	9.54	588	10.33
Total Acres	**12,318**		**5,688**	

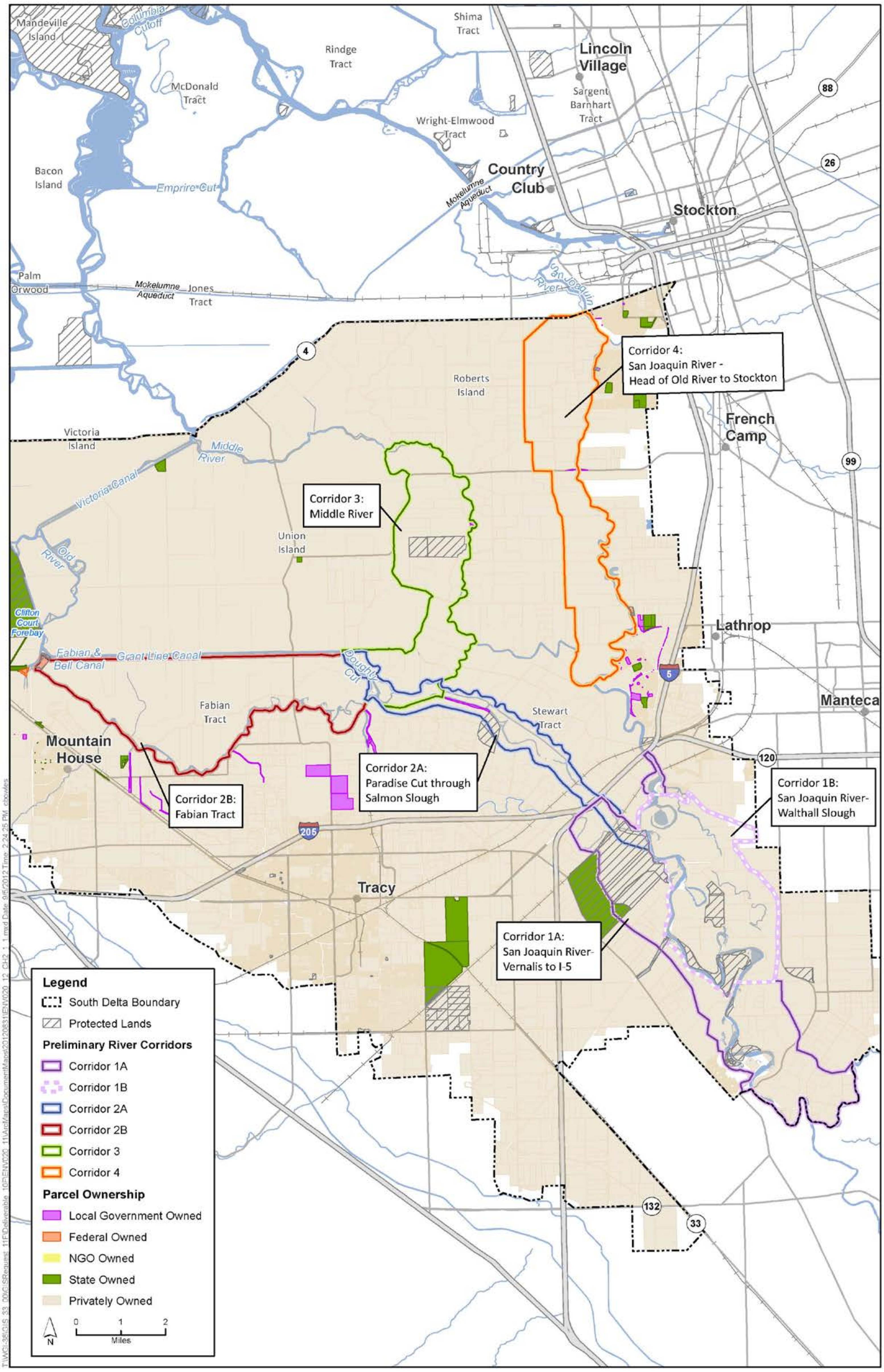


Existing Habitats in Corridors 1A and 1B

BDCP Vegetation Classification	Acres - 1A	% - 1A	Acres - 1B	% - 1B
Agricultural	8,902	72.27	3,976	69.89
Developed	84	0.69	21	0.36
Grassland	951	7.72	422	7.42
Managed Wetland	4	0.03	4	0.07
Nontidal Freshwater Perennial Emergent Wetland	36	0.29	14	0.25
Nontidal Perennial Aquatic	100	0.81	39	0.69
Tidal Freshwater Emergent Wetland	19	0.16	18	0.32
Tidal Perennial Aquatic	1,046	8.49	607	10.67
Valley/Foothill Riparian	1,176	9.54	588	10.33
Total	12,318	100.00	5,688	100.00

Sources: Plan Area, ICF 2012; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.4-1: Existing Corridor Habitats, Corridor 1



Sources: Plan Area, ICF 2012; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.4-2: Existing South Delta Conservation Lands

EA.2.4.1.1 Tidal Marsh and Tidal Perennial Aquatic

- Tidal marsh habitat is most commonly composed of tule (*Schoenoplectus acutus*) and cattail (*Typha spp.*). Other bulrush (*Schoenoplectus spp.*) and common reed (*Phragmites australis*) are associates.
- This habitat is generally located along fringes of oxbows, with the largest extent occurring within the oxbow at the northern end of Corridor 1.
- It is likely that the corridor supports slightly more tidal marsh habitat in narrow strips along the channels, but this habitat may not be reflected in the mapping because these areas were not visible due to limited size.
- The extent of tidal marsh habitat is limited by riprap armoring.
- Tidal perennial aquatic habitat occurs in the channels and supports open water habitat.
- Additional freshwater marsh habitat occurs within the corridor, but it is isolated from tidal influence.

Corridor 1A

- Very little tidal marsh habitat is supported in the entire corridor; only 19 acres mapped in total (less than 0.2% of total corridor acreage).

Corridor 1B

- Mostly lacking in the entire corridor, only 18 acres mapped in total (about 0.3% of total corridor acreage).

EA.2.4.1.2 Channel Margin

Channel margin habitat is defined as habitat along the edge of channels that provides cover for fish and contributes to the aquatic food web (CNRA, 2010). Ideally, channel margin habitat would be composed of soft natural river or slough edges occupied by native vegetation, especially riparian and emergent marsh associated species.

Data on the extent of existing channel margin habitat within Corridor 1 was not available for assessment. From a review of Google Earth images (Google Inc., 2011), it appears that a substantial portion of the San Joaquin River within the corridor has riprap along the levee banks. Some larger bends in the river, where the levees are further apart, may have natural river edges and slough channels outside of the federal levee system could support channel margin habitat; however, field observations at such locations would be required to confirm presence or absence of revetment and to further assess habitat quality.

EA.2.4.1.3 Floodplain Habitat and Food Production

Seasonally inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3) were assessed for existing conditions. Table EA.2.4-2 presents the results of the modeled estimate of existing habitat. Floodplain inundation related to food production was not directly modeled or assessed; however, given 1) the relatively-small areas of existing total floodplain in the corridors; and 2) that the floodplain inundation timing, duration and frequency characteristics related to the species that *were* assessed (salmon and splittail) are similar enough to food production criteria (see methods in Section 7.3), it appears that existing food production contributions by the floodplains in Corridor 1 are minimal.

Table EA.2.4-2: Ecologically-Relevant Floodplain Inundation in Corridor 1

Corridor	Existing Corridor Footprint (Total Existing Area between Levees; *river excluded)* *(acres)*	Inundated Floodplain Habitat assuming Salmon Threshold, 15,500 cfs (*river excluded*) *(acres)*	Inundated Floodplain Habitat assuming Splittail Threshold, 11,600 cfs (*river excluded*) *(acres)*
1A	2,524	910	412
1B	1,593	532	213

EA.2.4.1.4 Riparian

In addition to providing ecosystem function and habitat support for sensitive fisheries, riparian vegetation provides habitat for multiple BDCP-covered terrestrial species, including riparian brush rabbit, Swainson's hawk, white-tailed kite, yellow-breasted chat, yellow-billed cuckoo, and valley elderberry longhorn beetle (CNRA, 2010). Currently, habitat function is limited due to the substantial alteration and reduction of riparian vegetation. Within Corridor 1, riparian habitat quality varies considerably from a few scattered trees and shrubs to mature riparian communities with multi-tiered canopies and dense understories.

Riparian habitat within the leveed systems in the corridor is likely to undergo periodic levee and channel maintenance for flood management purposes; therefore, the extent of riparian habitat listed in Table EA.2.4-1 may be greater than current conditions as habitat may have been removed as a part of maintenance after the time of vegetation mapping efforts. In addition, there may be discrepancies in the total extent listed in Table EA.2.4-1 as a result of vegetation mapping inaccuracies. In many instances, a comparison of mapped vegetation with Google Earth images (Google Inc., 2011) and limited field observations suggest that some areas mapped as continuous bands of riparian, are in actuality perhaps better-characterized as scattered trees and shrubs. These few scattered trees and shrubs are likely not providing habitat in a meaningful way.

Corridor 1A

- Approximately 1,176 acres of riparian habitat has been mapped within Corridor 1A. Riparian habitat represents only 9.5% of the total acreage within Corridor 1A.
- Riparian habitat is a mix of native trees and shrubs including Fremont cottonwood (*Populus fremontii*), willow (*Salix spp.*), boxelder (*Acer negundo*), valley oak (*Quercus lobata*), and California rose (*Rosa californica*) interspersed with non-native invasives including Himalayan blackberry (*Rubus armeniacus* [*R. discolor*]).
- Generally, riparian habitat exists as a narrow, discontinuous corridor along the San Joaquin River. Smaller sloughs and channels within Corridor 1A support narrow, continuous bands of riparian vegetation.
- Relatively-more extensive stands of riparian vegetation along the San Joaquin River occur at river bends and within floodplain oxbows where the levees are further apart.

- Likely much of the existing riparian habitat within the narrower levee segments is periodically maintained for flood control purposes; therefore, some habitat may have been removed subsequent to vegetation mapping efforts.
- Conversely, a review of Google Earth images (Google Inc., 2011) shows a patch of riparian habitat that has established within the river on a sand splay (within a large bend) as well as in an area mapped as agriculture that is not reflected in the BDCP vegetation data.

Corridor 1B

- Approximately 588 acres of riparian habitat has been mapped within Corridor 1B. Riparian habitat represents only 10.3% of the total acreage within Corridor 1B.
- Along Walthall Slough, the riparian habitat corridor is narrow but fairly contiguous along the northern portion. South of E. McMullin Road, the slough banks appear maintained and support mostly scattered trees and shrubs.
- A review of Google Earth images (Google Inc., 2011) shows that portions of Walthall Slough just north of E. McMullin Road are lined by the non-native, invasive giant reed (*Arundo donax*).
- Riparian habitat along Walthall Slough is characterized by a mix of native trees and shrubs including Valley oak, Goodding's willow, boxelder, and California rose interspersed with stands of non-native invasives including Himalayan blackberry and giant reed.

EA.2.4.2 Corridor 2

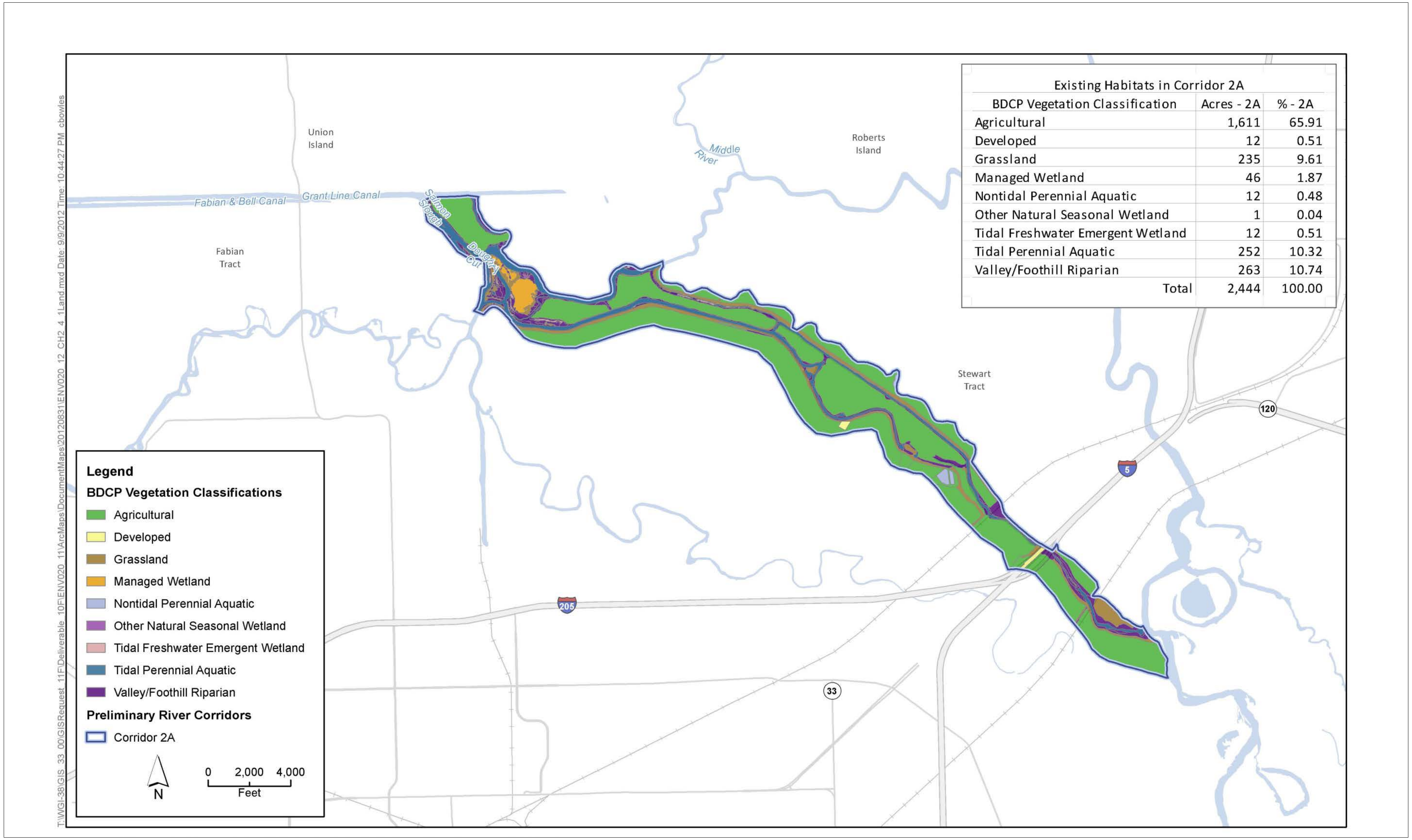
Habitats within Corridor 2 have been mapped as part of the BDCP planning process and their extent and distribution are provided in Figure EA.2.4-3 and Figure EA.2.4-4 (CNRA, 2012). A vegetation and land use GIS dataset was created by the CNRA in order to perform habitat conservation planning under the BDCP process. The sources of vegetation and land use data were primarily the CNRA and CDFW (CNRA, 2012). The total acreages of habitat types and other land uses are provided in Table EA.2.4-3, below. In addition to the review of this spatial data, images from Google Earth (Google Inc, 2011) and Delta vegetation and land use mapping on the CDFW BIOS (VegCAMP, 2011) were reviewed to better characterize habitat quality and calibrate mapping accuracy. Limited field reconnaissance for this South Delta project was conducted from public access points.

Table EA.2.4-3: BDCP Habitats in Corridor 2

BDCP Habitat Classification	Corridor 2A – Paradise Cut (Acres)	Percent of Corridor 2A Acreage	Corridor 2B – Fabian Tract (Acres)	Percent of Corridor 2B Acreage
Agricultural	1,611	65.91	6,391	88.50
Developed	12	0.51	81	1.12
Grassland	235	9.61	174	2.41
Managed Wetland	46	1.87	8	0.11
Nontidal Perennial Aquatic	12	0.48	7	0.09
Other Natural Seasonal Wetland	1	0.04	12	0.17
Tidal Freshwater Emergent Wetland	12	0.51	20	0.28
Tidal Perennial Aquatic	252	10.32	299	4.14
Valley/Foothill Riparian	263	10.74	229	3.17
Total Acres	**2,444**		**7,222**	

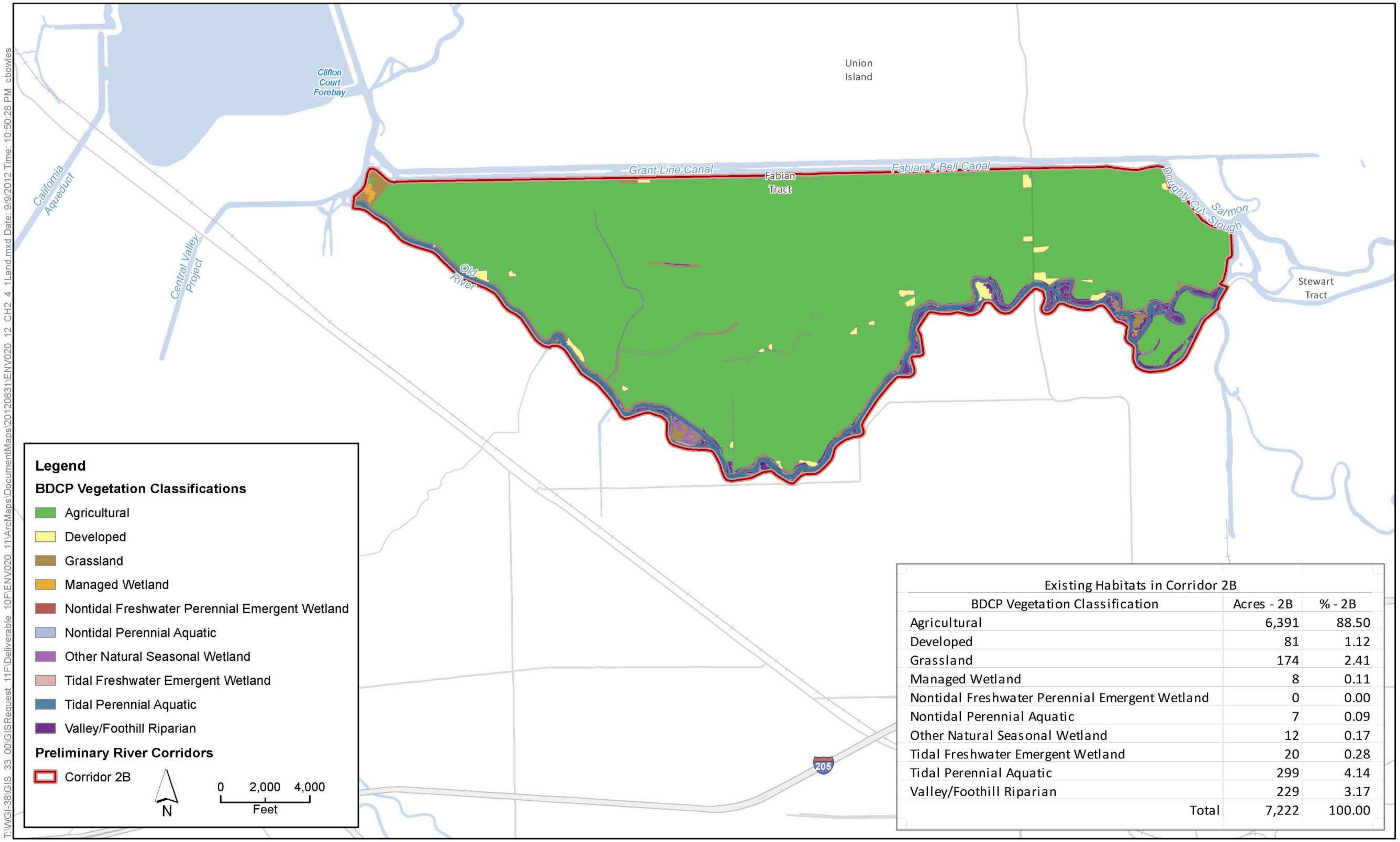
In general, habitats that are important for ecosystem function in the Delta, including tidal freshwater emergent wetland (tidal marsh), riparian, floodplain, and channel margin, are substantially limited within Corridor 2, as is similar to other BDCP Plan Areas. Agriculture is the dominant land use, comprising over 65% of Corridor 2A (Paradise Cut) and just under 90% of Corridor 2B (Fabian Tract). Only a very small percentage of both corridors is developed. Similar to other areas within the Central Valley, the extent of natural habitat along slough channels in Corridor 2 has been substantially reduced from historic conditions due to agricultural conversion, stream channelization, and flood protection (CNRA, 2010).

According to parcel ownership data, there are 14 properties (either single parcels or contiguous blocks of parcels) within the South Delta Boundary that are either locally, state, or federally owned (Figure EA.2.4-2). In addition, there are seven properties that are under some type of conservation easement. Not all of these are under a conservation easement with the purpose of ecological protection; some of these are likely protected for agricultural or other land use purposes. Within the southern portion of Corridor 2A, there is a large swath of land that has protected status, but is privately owned. In the western corner of Corridor 2B, on Fabian Tract, there is a state-owned property that has a protected status (mapped as grassland vegetation). It is unknown whether these properties are protected for the purposes of open space/habitat or other land uses. Overall, publically owned lands and lands protected for habitat conservation purposes within the entire South Delta region are lacking.



Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.4-3: Existing Corridor Habitats, Corridor 2A



Existing Habitats in Corridor 2B

BDCP Vegetation Classification	Acres - 2B	% - 2B
Agricultural	6,391	88.50
Developed	81	1.12
Grassland	174	2.41
Managed Wetland	8	0.11
Nontidal Freshwater Perennial Emergent Wetland	0	0.00
Nontidal Perennial Aquatic	7	0.09
Other Natural Seasonal Wetland	12	0.17
Tidal Freshwater Emergent Wetland	20	0.28
Tidal Perennial Aquatic	299	4.14
Valley/Foothill Riparian	229	3.17
Total	7,222	100.00

Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.4-4: Existing Corridor Habitats, Corridor 2B

EA.2.4.2.1 Tidal Marsh and Tidal Perennial Aquatic

- Tidal marsh habitat is most commonly composed of tule (*Schoenoplectus acutus*) and cattail (*Typha spp.*). Other bulrush (*Schoenoplectus spp.*) and common reed (*Phragmites australis*) are also associated with this habitat.
- Tidal perennial aquatic habitat within Corridor 2 supports submerged and floating aquatic vegetation in addition to providing open water habitat.

Corridor 2A

- Very little tidal marsh habitat is supported in the entire 2,444-acre corridor; only 12 acres are mapped in total (0.5% of total corridor acreage).
- Tidal perennial aquatic habitat occurs in slough channels and totals 252 acres within Corridor 2A (10.3% of the corridor).
- The extent of tidal marsh habitat is likely limited by levees and riprap, in addition to other factors.
- Tidal marsh habitat is mapped in the eastern channel north of the cross-channel connection (a complex of mixed tule/bulrush and submerged aquatics [*Egeria-Cabomba-Myriophyllum spp*]) –a result of slower water velocities through this channel.
- A small patch of tule-cattail marsh is mapped along western bank of Paradise Cut (western channel north of cross-channel connection).
- The majority of tidal marsh habitat occurs at the northern end of the corridor at the convergence point for several slough channels. There are also extensive stands of perennial pepperweed (*Lepidium latifolium*) mapped at this convergence point.

Corridor 2B

- Tidal marsh is mostly lacking in the entire 7,222-acre corridor, only 20 acres mapped in total (0.3% of total corridor acreage).
- Tidal perennial aquatic habitat occurs along the edges of Fabian Tract in slough and river channels and totals 300 acres within Corridor 2B (4.2% of the corridor).
- Tidal marsh habitat within Fabian Tract is primarily restricted to the outboard levee along the southern edge of the island in Old River. This habitat is dominated by a tule-cattail association.
- Old River along the southern edge of Fabian Tract also supports extensive stands of submerged aquatic vegetation dominated by *Egeria/Myriophyllum spp*. Smaller patches of water hyacinth (*Eichornia crassipes*) occur within the slough channel along the northern edge of the island.

EA.2.4.2.2 Channel Margin

Channel margin habitat is defined as habitat along the edge of channels that provides cover for fish and contributes to the aquatic food web (CNRA, 2010). Ideally, channel margin habitat would be composed of soft natural river or slough edges occupied by native vegetation, especially riparian and emergent marsh associated species.

Data on the extent of existing channel margin habitat within Corridor 2 was not available for assessment. From a review of Google Earth images (Google Inc., 2011), it appears that a substantial portion of the channels within the corridor have riprap or otherwise-modified levee banks. Some larger bends in the channel course, where the levees are further apart, may have natural river edges and slough channels outside of the federal levee system could support channel margin habitat.

EA.2.4.2.3 Floodplain and Food Production

Seasonally inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3) were assessed for existing conditions. Table EA.2.4-4 presents the results of the modeled estimate of existing habitat. Floodplain inundation related to food production was not directly modeled or assessed; however, given 1) the relatively-small areas of existing total floodplain in the corridors; and 2) that the floodplain inundation timing, duration and frequency characteristics related to the species that *were* assessed (salmon and splittail) are similar enough to food production criteria (see methods in Section 7.3), it appears that existing food production contributions by the floodplains in Corridor 2 are minimal.

Table EA.2.4-4: Ecologically-Relevant Floodplain Inundation in Corridor 2

Corridor	Existing Corridor Footprint (Total Existing Area between Levees; *river excluded)* *(acres)*	Inundated Floodplain Habitat assuming Salmon Threshold, 15,500 cfs (*river excluded*) *(acres)*	Inundated Floodplain Habitat assuming Splittail Threshold, 11,600 cfs (*river excluded*) *(acres)*
2A	1,189	46	11
Fabian Tract	484	29	5
2B	1,673	75	16

EA.2.4.2.4 Riparian

In addition to providing ecosystem function and habitat support for sensitive fisheries, riparian vegetation provides habitat for several BDCP-covered terrestrial species, including riparian brush rabbit, Swainson's hawk, white-tailed kite, yellow-breasted chat, yellow-billed cuckoo, and valley elderberry longhorn beetle (CNRA, 2010). Currently, habitat function is limited due to the substantial alteration and reduction of riparian vegetation. Within Corridor 2, riparian habitat quality varies considerably from a few scattered trees and shrubs to mature riparian communities with multi-tiered canopies and dense understories. Paradise Cut is known to provide important riparian brush rabbit habitat; however field observations suggest that this habitat is of a quality that could be improved.

Riparian habitat within the leveed systems in the corridor is likely to undergo periodic levee and channel maintenance for flood management purposes; therefore, the extent of riparian habitat listed in Table EA.2.4-3 may be greater than current conditions as habitat may have been removed as a part of maintenance after the time of vegetation mapping efforts. In addition, there may be discrepancies in the total extent listed in Table EA.2.4-3 as a result of vegetation mapping inaccuracies. In many instances, a comparison of mapped vegetation with Google Earth images (Google Inc., 2011) demonstrated that while areas were mapped as continuous bands of riparian, on the ground conditions were better characterized as scattered trees and shrubs. These few scattered trees and shrubs are not providing habitat in a meaningful way.

Corridor 2A

- Approximately 263 acres of riparian habitat has been mapped within Corridor 2A. Riparian habitat represents 10.7% of the total acreage within Corridor 2A.
- Riparian habitat south of the I-5/205 crossing is more extensive with a dense shrub understory and scattered large trees. The riparian community along this segment of the channel is a mix of Goodding's willow (*Salix gooddingii*), Fremont cottonwood (*Populus fremontii*), and valley oak (*Quercus lobata*) woodland and willow scrub dominated by sandbar willow (*S. exigua*), California rose (*Rosa californica*), and Himalayan blackberry (*Rubus armeniacus* [*R. discolor*]).
- North of the I-5/205 crossing, the riparian corridor becomes very narrow and is mostly limited to levee banks. This habitat primarily consists of scrub habitat with occasional oaks. Several long stretches of channel lack riparian habitat through this corridor.
- Along the eastern channel (north of the cross-channel connection), riparian vegetation persists and is mapped as arroyo willow (I) – mixed brambles (California rose – California grape [*Vitis californica*] – Himalayan blackberry)
- Periodic maintenance for flood control purposes likely restricts the persistence and maturation of riparian habitat.

Corridor 2B

- Approximately 229 acres of riparian habitat has been mapped within Corridor 2B. Riparian habitat represents 3.2% of the total acreage within Corridor 2B.
- Riparian habitat is confined to the outboard levees surrounding Fabian Tract. A fairly contiguous but narrow corridor of riparian habitat occurs along the northern, eastern and western edges of Fabian Tract. Along the southern boundary, in Old River, there are scattered patches of riparian habitat, but the slough is generally lined by a narrow band of marsh vegetation. As the levees widen near the southeastern edge of Fabian Tract, the extent of riparian habitat increases on in-river islands.
- Riparian habitat along the northern edge of the island is characterized by Valley oak and Goodding's willow woodland mixed with white alder (*Alnus rhombifolia*), sandbar willow, and California rose scrub habitat. There are substantial homogenous stands of Himalayan blackberry along the northern edge of the island within mapped riparian habitat.
- Riparian habitat established on islands within Old River, along the southern edge of Fabian Tract, is characterized by mature valley oak woodland.

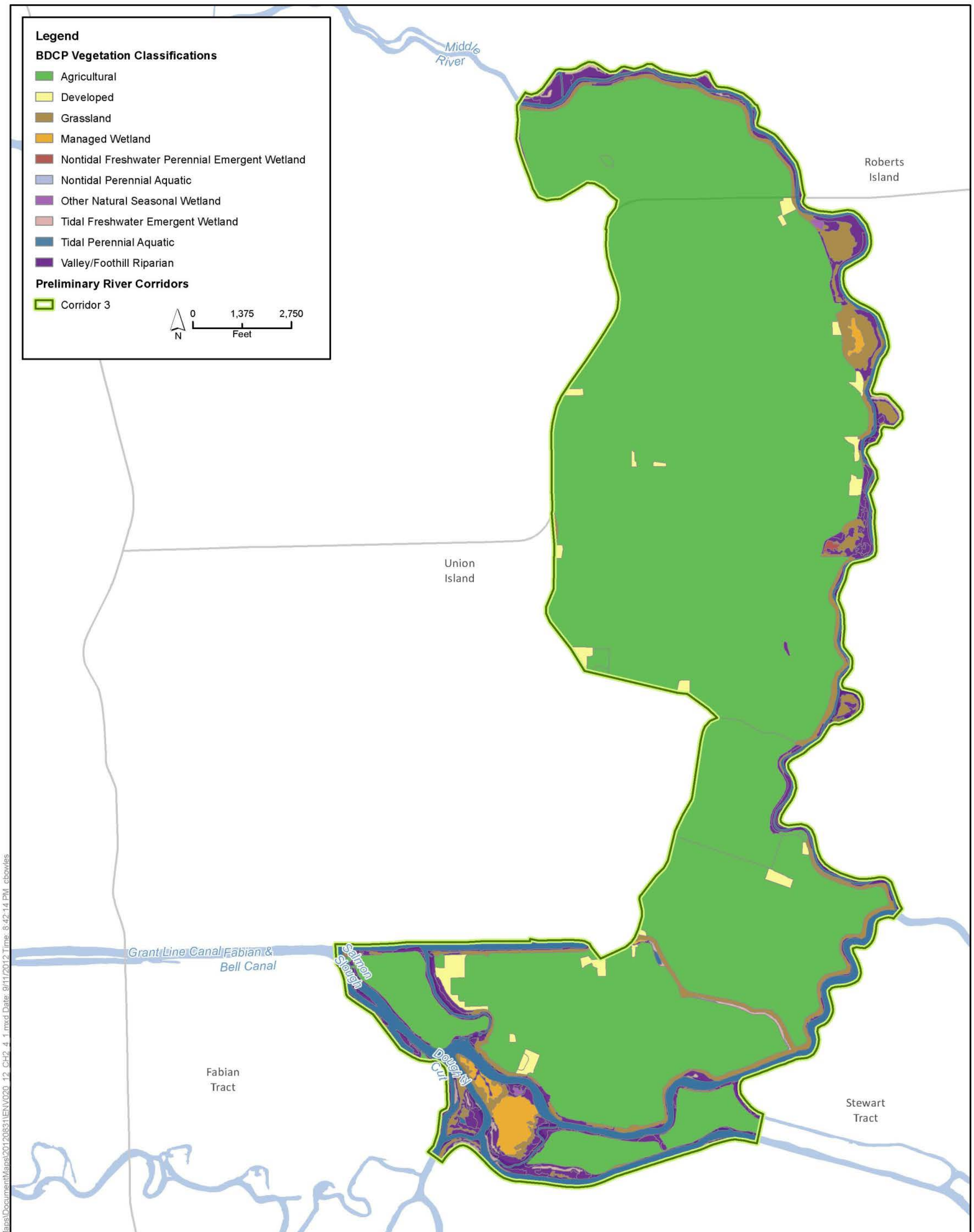
EA.2.4.3 Corridor 3

Habitats within Corridor 3 have been mapped as part of the BDCP planning process and their extent and distribution are provided in Figure EA.2.4-5 (CNRA, 2012). A vegetation and land use GIS dataset was created by the CNRA in order to perform habitat conservation planning under the BDCP process. The sources of vegetation and land use data were primarily the CNRA and CDFW (CNRA, 2012). The total acreages of habitat types and other land uses are provided in Table EA.2.4-5, below. In addition to the review of this spatial data, images from Google Earth (Google Inc, 2011) and delta vegetation and land use mapping on the CDFW BIOS (VegCAMP, 2011) were reviewed to better characterize habitat quality and calibrate mapping accuracy. Limited field reconnaissance for this South Delta project was conducted from public access points.

Table EA.2.4-5: BDCP Habitats in Corridor 3

BDCP Habitat Classification	Corridor 3 (Acres)	Percent of Corridor 3 Acreage
Agricultural	4,413	81.82
Developed	73	1.36
Grassland	255	4.72
Managed Wetland	49	0.90
Nontidal Freshwater Perennial Emergent Wetland	2	0.04
Nontidal Perennial Aquatic	2	0.03
Other Natural Seasonal Wetland	2	0.04
Tidal Freshwater Emergent Wetland	21	0.39
Tidal Perennial Aquatic	279	5.18
Valley/Foothill Riparian	297	5.51
Total Acres	**5,393**	

In general, habitats that are important for ecosystem function in the Delta, including tidal freshwater emergent wetland (tidal marsh), riparian, floodplain, and channel margin, are substantially limited within Corridor 3, as is similar to other BDCP Plan Areas. Agriculture is the dominant land use, comprising over 80% of Corridor 3. Only a small percentage (1.36%, 73 acres) of the corridor is developed. Similar to other areas within the Central Valley, the extent of natural habitat along Middle River has been substantially reduced from historic conditions due to agricultural conversion, stream channelization, and flood protection (BDCP, 2010). According to parcel ownership data, there are 14 properties (either single parcels or contiguous blocks of parcels) within the South Delta Boundary that are either locally, state, or federally owned (Figure EA.2.4-2). In addition, there are seven properties that are under some type of conservation easement. Not all of these are under a conservation easement with the purpose of ecological protection; some of these are likely protected for agricultural or other land use purposes. One parcel in Corridor 3 is permanently protected as part of the San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (SJMSCP), the Wing Levee Road Preserve (Preserve). This Preserve is a 354.7-acre agricultural parcel established to provide habitat for Swainson's hawk (*Buteo swainsoni*), burrowing owl (*Athene cunicularia*), and valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*). Overall, publically owned lands and lands protected for habitat conservation purposes within the entire South Delta region are lacking.



Existing Habitats in Corridor 3		
BDCP Vegetation Classification	Acres - 3	% - 3
Agricultural	4,413	81.82
Developed	73	1.36
Grassland	255	4.72
Managed Wetland	49	0.90
Nontidal Freshwater Perennial Emergent Wetland	2	0.04
Nontidal Perennial Aquatic	2	0.03
Other Natural Seasonal Wetland	2	0.04
Tidal Freshwater Emergent Wetland	21	0.39
Tidal Perennial Aquatic	279	5.18
Valley/Foothill Riparian	297	5.51
Total	5,393	100.00

Sources: Plan Area, ICF 2012; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.4-5: Existing Corridor Habitats, Corridor 3

EA.2.4.3.1 Tidal Marsh and Tidal Perennial Aquatic

- Tidal marsh habitat is characterized by tule (*Schoenoplectus acutus*) and cattail (*Typha spp.*). Other bulrush (*Schoenoplectus spp.*) and common reed (*Phragmites australis*) may occur as well. Approximately 21 acres of tidal freshwater emergent wetland habitat occurs in Corridor 2 (0.4% of the overall corridor)
- Tidal perennial aquatic habitat occurs with Middle River and tributary sloughs as open water and submerged aquatic vegetation. Approximately 279 acres of tidal perennial aquatic habitat occurs within Corridor 2 (5.2% of the overall corridor)
- More substantial stands of tidal marsh habitat occur at the southwestern end of the corridor at the convergence point for several slough channels and the northeastern end of the corridor where the levees are wider.
- Tidal habitat mapped in the southern portion of Corridor 3 in the vicinity of Paradise Cut includes a complex of mixed tule/bulrush and submerged aquatics [*Egeria-Cabomba-Myriophyllum spp*]. A small patch of tule-cattail marsh is mapped along western bank of Paradise Cut (western channel north of cross-channel connection).
- Submerged aquatic stands of *Egeria/Myriophyllum ssp.* also occur in Middle River along the northern portion of the corridor.
- Extensive stands of perennial pepperweed (*Lepidium latifolium*) occur near the slough convergence point at the southwestern end of the corridor.
- Tidal perennial aquatic habitat is characterized by … and occurs within Middle River, <list sloughs>.

EA.2.4.3.2 Channel Margin

Channel margin habitat is defined as habitat along the edge of channels that provides cover for fish and contributes to the aquatic food web (CNRA, 2010). Ideally, channel margin habitat would be composed of soft natural river or slough edges occupied by native vegetation, especially riparian and emergent marsh associated species.

Data on the extent of existing channel margin habitat within Corridor 3 was not available for assessment. From a review of Google Earth images (Google Inc., 2011), it appears that a substantial portion of the channels within the corridor have riprap along the levee banks. Some larger bends in the river, where the levees are further apart, may have natural river edges and slough channels outside of the federal levee system could support channel margin habitat.

EA.2.4.3.3 Floodplain and Food Production

Seasonally inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3) were assessed for existing conditions. **Table** EA.2.4-6 presents the results of the modeled estimate of existing habitat. Floodplain inundation related to food production was not directly modeled or assessed; however, given 1) the relatively-small areas of existing total floodplain in the corridors; and 2) that the floodplain inundation timing, duration and frequency characteristics related to the species that *were* assessed (salmon and splittail) are similar enough to food production criteria (see methods in Section 7.3), it appears that existing food production contributions by the floodplains in Corridor 3 are minimal.

Table EA.2.4-6: Ecologically-Relevant Floodplain Inundation in Corridor 3

Corridor	Existing Corridor Footprint (Total Existing Area between Levees; *river excluded)* *(acres)*	Inundated Floodplain Habitat assuming Salmon Threshold, 15,500 cfs (*river excluded*) *(acres)*	Inundated Floodplain Habitat assuming Splittail Threshold, 11,600 cfs (*river excluded*) *(acres)*
3	706	88	33

EA.2.4.3.4 Riparian

In addition to providing ecosystem function and habitat support for sensitive fisheries, riparian vegetation provides habitat for several BDCP-covered terrestrial species, including riparian brush rabbit, Swainson's hawk, white-tailed kite, yellow-breasted chat, yellow-billed cuckoo, and valley elderberry longhorn beetle (CNRA, 2010). Currently, habitat function is limited due to the substantial alteration and reduction of riparian vegetation. Within Corridor 3, riparian habitat quality is fairly low overall. Only a handful of more mature riparian communities with multi-tiered canopies and dense understories occur within this corridor.

The riparian community within this corridor ranges from Valley oak (*Quercus lobata*) dominated stands, to a mix of Valley oak and boxelder (*Acer negundo*), to willow dominated woodland (*Salix gooddingii and S. lasiolepis*) and willow-dominated scrub including sandbar willow (*S. exigua*) mixed with California rose (*Rosa californica*) and Himalayan blackberry (*Rubus armeniacus* [*R. discolor*]). A few stands of Fremont cottonwood (*Populus fremontii*) have also been mapped in this corridor. Scattered, homogenous patches of Himalayan blackberry also occur.

Riparian habitat within the leveed systems in the corridor is likely to undergo periodic levee and channel maintenance for flood management purposes; therefore, the extent of riparian habitat listed in Table EA.2.4-5, above, may be greater than current conditions as habitat may have been removed as a part of maintenance after the time of vegetation mapping efforts. In addition, there may be discrepancies in the total extent listed in Table EA.2.4-5 as a result of vegetation mapping inaccuracies. In many instances, a comparison of mapped vegetation with Google Earth images (Google Inc., 2011) demonstrated that while areas were mapped as continuous bands of riparian, on the ground conditions were better characterized as scattered trees and shrubs. These few scattered trees and shrubs are not providing habitat in a meaningful way.

- Approximately 297 acres of riparian habitat has been mapped within Corridor 3. Riparian habitat represents just over 5.5% of the total acreage within Corridor 3.
- The larger stands of riparian habitat occurring within Corridor 3 are located outside of the levee system, and are not connected to the river floodplain.
- Riparian habitat along Middle River is mostly lacking from Old River to West Undine Road. Through this stretch, riparian habitat occurs in small patches immediately adjacent to the river's edge. This portion of the corridor appears regularly maintained.
- More extensive stands of riparian habitat occur between the west levee of Middle River and the Wing Levee Road as well as a few bends along Middle River where the levee system is widened.

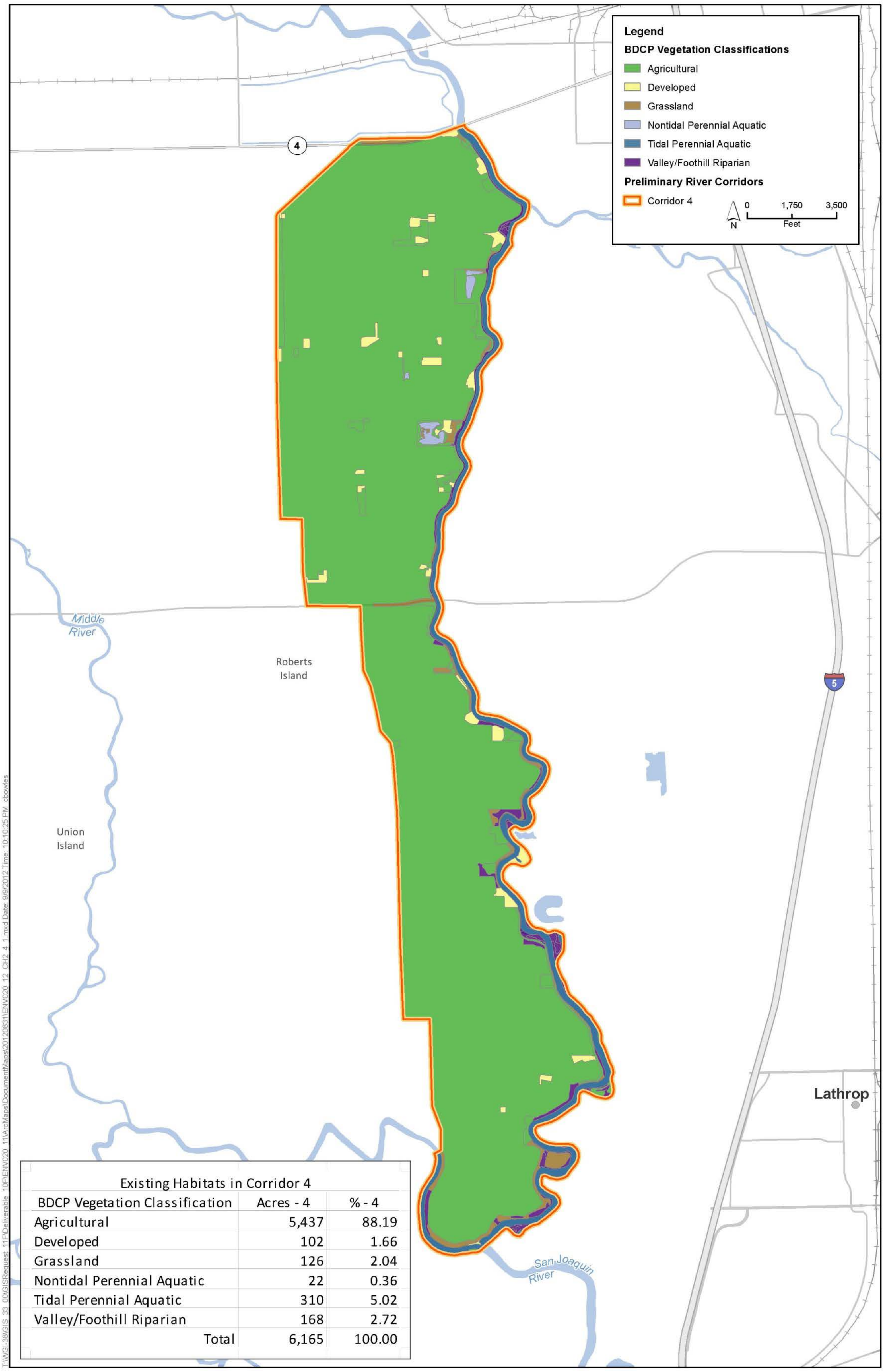
EA.2.4.4 Corridor 4

Habitats within Corridor 4 have been mapped as part of the BDCP planning process and their extent and distribution are provided in Figure EA.2.4-6 (CNRA, 2012). A vegetation and land use GIS dataset was created by the CNRA in order to perform habitat conservation planning under the BDCP process. The sources of spatial vegetation data were primarily derived from the CNRA and CDFW (CNRA, 2012). The total acreages of habitat types and other land uses) are provided in Table EA.2.4-7, below. In addition to the review of this spatial data, images from Google Earth (Google Inc, 2011) and Delta vegetation and land use mapping on the CDFW BIOS (VegCAMP, 2011) were reviewed to better characterize habitat quality and calibrate mapping accuracy. Limited field reconnaissance for this South Delta project was conducted from public access points.

In general, habitats that are important for ecosystem function, including tidal wetland, riparian, floodplain, and channel margin, are substantially limited within Corridor 4, as is similar to other BDCP Plan Areas. Agriculture is the dominant land useat almost 85% of the entire corridor acreage. Only approximately 102 acres (just over 1.5%) of the corridor is mapped as developed. Similar to other areas within the Central Valley, the extent of natural habitat along the San Joaquin River in Corridor 4 has been substantially reduced from historic conditions due to agricultural conversion, stream channelization, and flood protection (BDCP, 2009).

Table EA.2.4-7: BDCP Habitats in Corridor 4

BDCP Habitat Classification	Corridor 4 (Acres)	Percent of Corridor 4 Acreage
Agricultural	5,437	88.19
Developed	102	1.66
Grassland	126	2.04
Nontidal Perennial Aquatic	22	0.36
Tidal Perennial Aquatic	310	5.02
Valley/Foothill Riparian	168	2.72
Total Acres	6,165	



Existing Habitats in Corridor 4

BDCP Vegetation Classification	Acres - 4	% - 4
Agricultural	5,437	88.19
Developed	102	1.66
Grassland	126	2.04
Nontidal Perennial Aquatic	22	0.36
Tidal Perennial Aquatic	310	5.02
Valley/Foothill Riparian	168	2.72
Total	6,165	100.00

Sources: Plan Area, ICF 2012; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.2.4-6: Existing Corridor Habitats, Corridor 4

According to parcel ownership data, there are 14 properties (either single parcels or contiguous blocks of parcels) within the South Delta Boundary that are either locally, state, or federally owned (Figure EA.2.4-2). In addition, there are seven properties that are under some type of conservation easement. Not all of these are under a conservation easement with the purpose of ecological protection; some of these are likely protected for agricultural or other land use purposes. No publicly-owned or preserved parcels occur within Corridor 4, according to existing data sources. There are two locally owned properties that occur just east of Corridor 4, but neither of these have any protection status. Overall, there is a lack of lands protected for habitat conservation purposes within the entire South Delta region.

EA.2.4.4.1 Tidal Marsh and Tidal Perennial Aquatic

- There is essentially no existing tidal marsh occurring in Corridor 4. Any that occurs is dominated by tule (Schoenoplectus acutus). Some limited marsh area (1 acre; <0.1% of the total corridor area) occurs on French Camp Slough, just opposite the downstream end of the corridor.
- Little to no tidal marsh habitat is apparent along the San Joaquin River within Corridor 4, likely a result of bank armoring and periodic maintenance.
- Tidal perennial aquatic occurs primarily as open water habitat within the San Joaquin River. There is a total of 310 acres of tidal perennial aquatic habitat, which represents approximately 5% of Corridor 4.

EA.2.4.4.2 Channel Margin

Channel margin habitat is described as habitat along the edge of channels that provides cover for fish and contributes to the aquatic food web (CNRA, 2010). Ideally, channel margin habitat would be composed of soft natural river or slough edges occupied by native vegetation, especially riparian and emergent marsh associated species.

Data on the extent of existing channel margin habitat within Corridor 4 was not available for assessment. From a review of Google Earth images (Google Inc., 2011), it appears that a substantial portion of the San Joaquin River within the corridor has riprap along the levee banks. Some larger bends in the river, where the levees are further apart, may have natural river edges and slough channels outside of the federal levee system could support channel margin habitat.

EA.2.4.4.3 Floodplain and Food Production

Seasonally inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3) were assessed for existing conditions. Table EA.2.4-8 presents the results of the modeled estimate of existing habitat. Floodplain inundation related to food production was not directly modeled or assessed; however, given 1) the relatively-small areas of existing total floodplain in the corridors; and 2) that the floodplain inundation timing, duration and frequency characteristics related to the species that *were* assessed (salmon and splittail) are similar enough to food production criteria (see methods in Section 7.3), it appears that existing food production contributions by the floodplains in Corridor 4 are minimal.

Table EA.2.4-8: Ecologically-Relevant Floodplain Inundation in Corridor 4

Corridor	Existing Corridor Footprint (Total Existing Area between Levees; *river excluded)* *(acres)*	Inundated Floodplain Habitat assuming Salmon Threshold, 15,500 cfs (*river excluded*) *(acres)*	Inundated Floodplain Habitat assuming Splittail Threshold, 11,600 cfs (*river excluded*) *(acres)*
4	252	26	8

EA.2.4.4.4 Riparian

In addition to providing ecosystem function and habitat support for sensitive fisheries, riparian vegetation provides habitat for several BDCP-covered terrestrial species, including riparian brush rabbit, Swainson's hawk, white-tailed kite, yellow-breasted chat, yellow-billed cuckoo, and valley elderberry longhorn beetle (CNRA, 2010). Currently, habitat function is limited due to the substantial alteration and reduction of riparian vegetation. Within Corridor 4, riparian habitat quality is fairly low overall.

- Approximately 168 acres of riparian habitat has been mapped within Corridor 4. Riparian habitat represents less than 3% of the total acreage within Corridor 4.
- Riparian habitat is characterized by a mix of Fremont cottonwood (*Populus fremontii*), willow (*Salix spp.*), boxelder (*Acer negundo*), white alder (*Alnus rhombifolia*), valley oak (*Quercus lobata*), and California rose (*Rosa californica*) interspersed with stands of non-native Himalayan blackberry (*Rubus armeniacus* [*R. discolor*]).
- In general, riparian habitat is mapped more-often on the right bank of the San Joaquin River and was mostly lacking, occurring in small discontinuous patches, on the left bank.
- Unlike other corridors, riparian vegetation was lacking at some of the river bends where the levee system was wider and would appear to accommodate the establishment of riparian habitat. The lack of vegetation may be a result of prior land use (e.g., orchards), these areas could occur on terraces high above the water table that cannot support riparian vegetation, or the vegetation could be removed for the purposes of flood conveyance and levee maintenance.
- Riparian habitat within the leveed systems in the corridor is likely to undergo periodic levee and channel maintenance for flood management purposes; therefore, vegetation may have been removed as a part of maintenance after the time of vegetation mapping efforts. In addition, there may be discrepancies as a result of vegetation mapping inaccuracies. Photos taken from the Howard Road bridge crossing of the San Joaquin River show a maintained levee bank with very little habitat (Figure EA.2.4-7), while the vegetation data characterizes this area as riparian (including homogenous stands of Himalayan blackberry and riparian scrub). In particular, north of the Howard Road bridge crossing, riparian habitat is mapped as a continuous corridor, but a review of Google Earth images (Google Inc., 2011) demonstrates almost a complete lack of riparian habitat until the confluence with French Camp Slough. Only scattered trees and shrubs are visible along the majority of the San Joaquin River in Google Earth images (Google Inc., 2011). While vegetation data would indicate a continuous band of riparian vegetation along portions of the river corridor, the few scattered trees and shrubs are not providing habitat in a meaningful way.

PHOTOGRAPH 1. Looking north from the Howard Road bridge crossing of the San Joaquin River. Vegetation along the river is mostly absent, while the vegetation data identifies the left bank as Himalayan blackberry stands and the right bank as riparian scrub. This inaccuracy may be a result of periodic maintenance that removes vegetation or incorrect habitat mapping.

PHOTOGRAPH 2. Looking south from the Howard Road bridge crossing of the San Joaquin River. The right bank of the river in this location is mapped as riparian scrub, but these few shrubs do not provide much in the way of habitat.

Figure EA.2.4-7: Existing Bank Conditions, Corridor 4

EA.2.5 Geomorphology

The South Delta spans the network of channels and islands at the distributary-outlet of the San Joaquin River, at the easternmost tidal influence of the San Francisco Bay. The South Delta region is characterized by a series of river distributary channels branching off from the mainstem of the San Joaquin River. Historically, in contrast to the flood basins of the North Delta (Yolo Basin), these river distributary channel systems are generally dominated by fluvial processes (higher flows from snow-melt-driven, and to a lesser extend rain-on-snow floods), with more moderately-sized natural levees located in floodplains that were created by dynamic river processes (Whipple, Pers. Comm., 2010).

The geomorphology of the South Delta can be defined as the overall configuration, or shape of landforms along the lower San Joaquin River and within the estuary, as well as the reciprocating physical and ecological processes that have acted upon the landscape at different spatial and temporal scales. Underlying physical environmental controls on South Delta geomorphology include climate, hydrology, geology, sea level elevation, and sediment supply, which in turn influence the topography and composition of ecosystems within the Delta. Hydraulic and sediment transport processes have created distinct topography and bathymetry, which influence fundamental ecosystem drivers like tidal prism, salinity concentrations and residence times, and habitat formation (such as floodplains, shallow marshlands, channel margins, open water areas, and riparian areas).

Sediment is an important component of the South Delta ecosystem. It carries nutrients (and toxins), provides habitat for benthic organisms, reduces light penetration and limits photosynthesis in the water column, and sediment deposits on the bottom of channels, sub-embayments, shallow wetlands, and floodplains form the topography of the Delta. The distribution and composition of habitats throughout the Delta are in part defined by these factors, and geomorphic features adjust in response to changes in these factors.

In geologic context, the Delta estuary is a relatively recent ecosystem, with approximately 5,000-6,000 years of development into a state of relative geomorphic equilibrium prior to the introduction of human influence onto the landscape of the Delta and its watershed. Since the mid-1800's, rapid changes have occurred within the estuary and its contributing watersheds. Today, landforms within the estuary and associated sediment transport processes have been highly altered, and phenomena like sea level rise and climate change are expected to exert additional influences on regional hydraulics and geomorphology.

Historically, the South Delta was exposed to smaller flood flows and supplied with comparatively less inorganic sediment on intertidal wetlands than the North Delta (Atwater and Belknap, 1980; DWR, 2006). Most fine sediments eventually passed through the San Joaquin Delta and to the lower estuary before settling out. Natural levees in the South Delta were lower and less defined than in the North Delta, and high water was spread over a flatter topography (The Bay Institute, 1998). The plane of the swamps and marshes was therefore maintained through balanced deposition, erosion, and subsidence mechanisms. This set of conditions promoted accumulation and preservation of plant remains and peat formation. In the South Delta, peat soils formed up to 30 feet thick over layers of marine sedimentary muds, sands, shales, and rock. Many South Delta soils are typically at least 90 percent peat by wet volume, contrasting with the soil composition in the northern Delta, which contains a higher fraction of inorganic matter and a thinner layer of peat (Atwater and

Belknap, 1980; The Bay Institute, 1998). In the South Delta a complex layering of peat and sand is frequently encountered with progressive depth.

Three distinct sediment budgets and sediment routing studies have been performed for the lower San Joaquin River and South Delta, by Northwest Hydraulic Consultants (NHC) in 2003 and 2006, and Wright and Schoellhamer in 2005. These sediment budgets, as well as descriptions of current sediment transport processes, and other key data pertaining to the geomorphology of the South Delta is provided in brief as follows:

- The majority of sediment that enters and gets transported through the South Delta occurs as suspended sediment in the water column. Suspended sediment is predominantly less than 63 μm in diameter, cohesive, and flocculent (Schoellhamer et al., 2007).
- Last decade (2000-2010), average suspended sediment concentrations (SSCs) are 44.1 milligrams per liter (mg/L) in the Sacramento River at Freeport and 59.4 mg/L in the San Joaquin at Vernalis (Figure EA.2.5-1; USGS data reports). However, average flow of Sacramento River is much higher (~6 times that of San Joaquin River), so total sediment load higher in the Sacramento River.
- In the alluvial reaches of the major tributaries to the Delta, bed load is estimated at 4% to 20% of the total sediment load in the San Joaquin River (Shvidchenko et al., 2004).
- Within the tidally-influenced area of the Delta, bed load transport is thought to constitute 5% of the total sediment outflow to Suisun Bay (Dinehart, 2002; Shvidchenko et al., 2004). Despite this relatively low volume, bed load transport is believed to be the main factor determining channel evolution (fill and scour of the channel bed) in the Delta (NHC, 2006). This is likely due to the narrow channels and relatively high hydrodynamic velocities that occur within the Delta, which keep suspended sediments entrained and are sufficient to mobilize bed materials in Delta channels.
- In the South Delta, riprap and levees bound most channels, so in-channel (and floodplain) sediment erosion and supply are likely not significant sources (Wright and Schoellhamer, 2005).
- An NHC (2003) study concludes that the average annual suspended sediment inflow to the Delta from the Sacramento River and Yolo Bypass totals 3,120,000 tons and average annual bed load inflow is 150,000 tons. The San Joaquin River supplies annually an average of 340,000 tons of suspended sediment and 80,000 tons of bed load.
- An NHC (2006) study used a modified version of a MIKE11 hydrodynamic model originally developed by UC Davis to assess annual suspended sediment loads in the Delta. Annual suspended sediment loads were estimated using modeling and USGS suspended sediment data collected in 1998 (high-flow year) and 1999 (average-flow year) from the Sacramento, San Joaquin, Mokelumne, and Cosumnes Rivers, and from the Yolo Bypass, Delta-Mendota Canal, and Suisun Bay (Table EA.2.5-1).

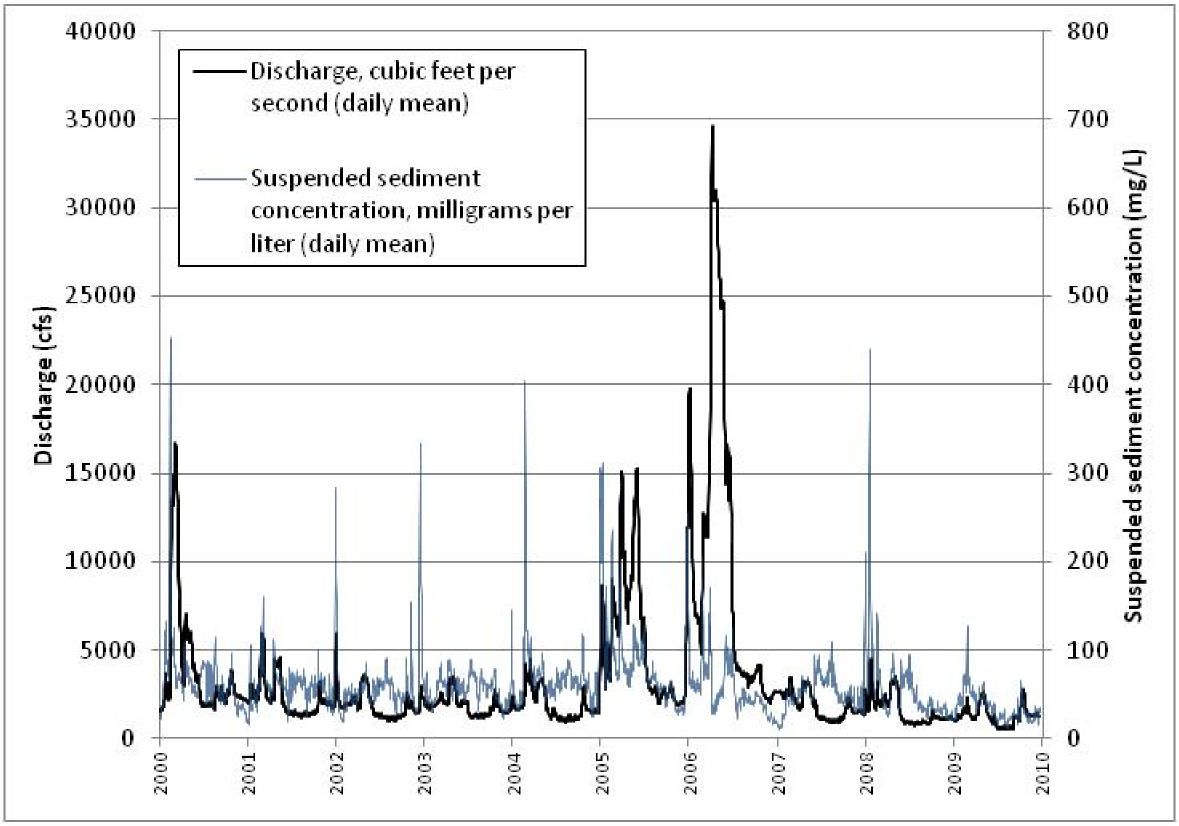


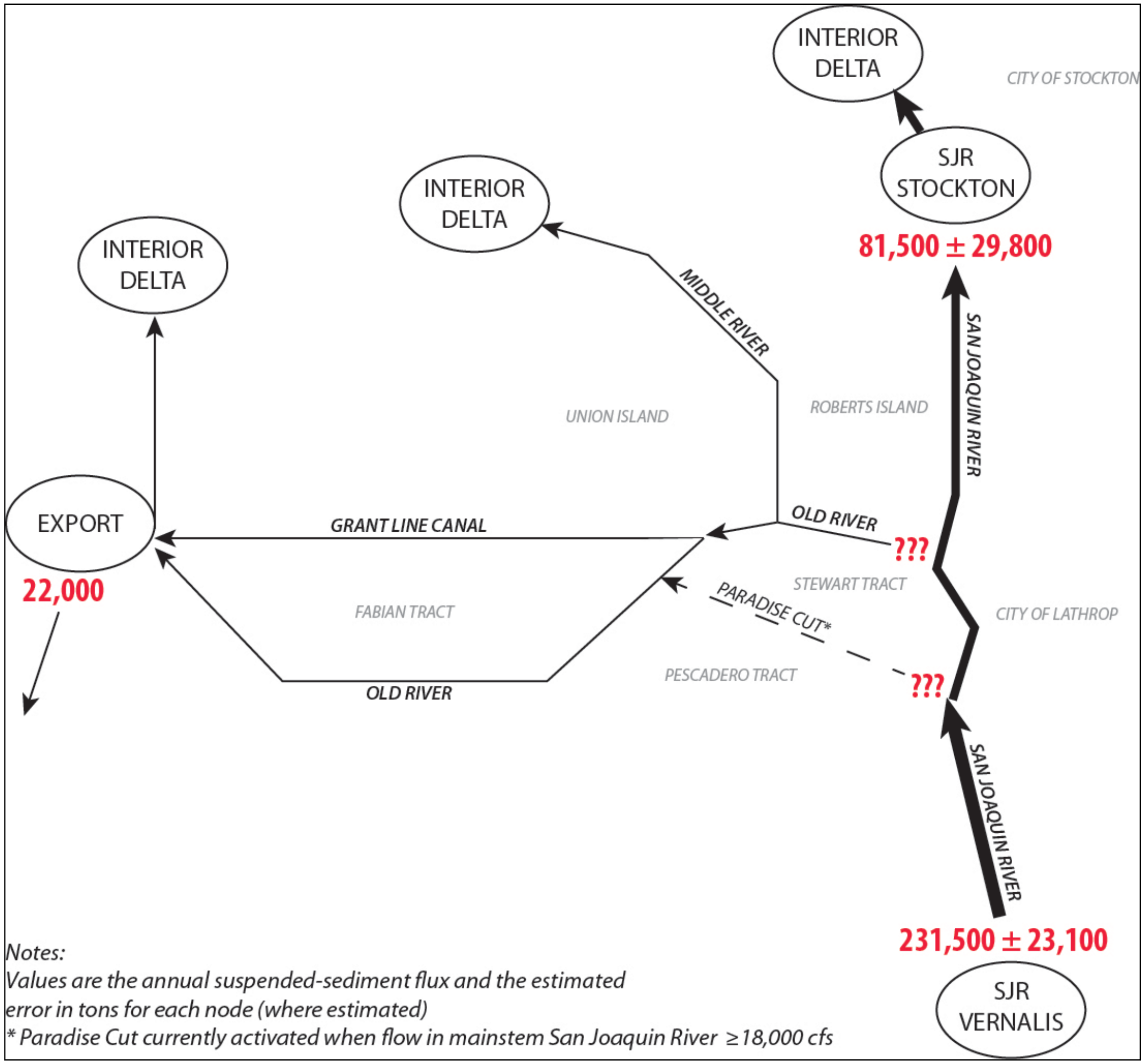
Figure EA.2.5-1: San Joaquin River at Vernalis – Mean Daily Discharge and Suspended Sediment Concentrations, 2000 – 2010

Table EA.2.5-1: Long Term Average Annual Sediment Budget Developed for DWR

Sediment Budget Components	Long-Term Average Annual Amount (Tons)	Percentage
Average Annual Inflow (TOTAL)	***4,200,000***	***100%***
Sacramento River with Yolo Bypass	3,530,000	84%
San Joaquin River	400,000	10%
Mokelumne and Cosumnes River	180,000	4%
Other Streams	90,000	2%
Average Annual Outflow/Export (TOTAL)	***3,930,000***	***94%***
Suisun Bay	2,290,000	54%
Dredging	910,000	22%
Delta Mendota Canal	330,000	8%
California Aqueduct	400,000	10%
Balance - Average Annual Net Deposition	***270,000***	***6%***
Source: Northwest Hydraulic Consultants, 2006		

- The 2006 NHC study estimated that approximately 270,000 tons (6%) of sediment per year on average would be deposited in the Delta. Based on analyses of cross sections and data published in DWR's Scour Monitoring Programs (DWR, 1993 and DWR, 2000), NHC concluded that the majority of this deposition occurs in the South Delta rather than in the north.

- Wright and Schoellhamer (2005) estimated an annual sediment budget and sediment routing through the South Delta based on data from water years 1999 – 2002, as shown in Figure EA.2.5-2.
- On the San Joaquin River, significant loss of sediment occurs over the reach between Vernalis and Stockton (64% over the 4 year period). This sediment is either deposited in the reach or enters the south delta channel complex through Old River, Middle River, and Paradise Cut (Wright and Schoellhamer, 2005).
- In the Wright and Schoellhamer (2005) study, for a four year period, the wet periods constituted 464 days of the 4 year record, or 31% of the total time, but the majority of sediment (82%) was delivered during these wet periods.
- Tidally averaged suspended-sediment flux at the delta sites indicates that the suspended-sediment signal of the San Joaquin River attenuates more rapidly than that of the Sacramento River (Wright and Schoellhamer, 2005).



(based on Wright and Schoellhamer, 2005)

Figure EA.2.5-2: Average Annual South Delta Sediment Budget and Routing for Water Years 1999–2002

EA.2.6 Water Quality

EA.2.6.1 Corridor 1

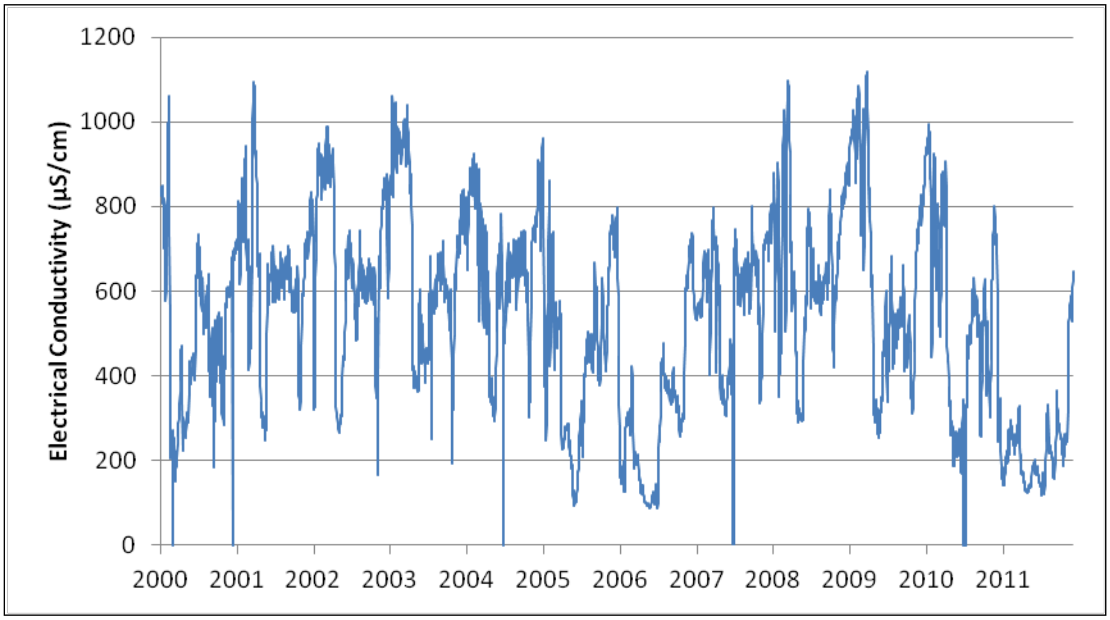
Water quality within the Delta, including Corridor 1, can be reasonably viewed through the lens of key beneficial uses. Beneficial uses are defined as end uses of water resources that provide a net benefit to humans or the environment, through a variety of individual uses. Maintaining water quality to the extent needed to protect identified beneficial uses is therefore a convenient way to characterize existing water quality conditions and potential changes to those conditions. Beneficial uses relevant to this study are defined by the Central Valley Regional Water Quality Control Board (CVRWQCB, 2011), and include municipal and public water supply (MUN), agricultural irrigation and stock watering (AGR), industrial process (PROC) and service supply (IND), contact (REC-1) and noncontact (REC-2) recreation, warm (WARM) and coldwater (COLD) freshwater habitat, migration (MIGR), spawning (SPWN), wildlife habitat (WILD), and navigation (NAV) (CVRWQCB, 2011). More specifically, AGR, MUN, and instream habitat (WARM and COLD) are most critically affected by water quality conditions in the corridor, and are therefore forwarded for discussion. The following discussion provides an overview of water quality conditions within Corridor 1, and reviews existing water quality conditions with respect to their influence on these select beneficial uses within the corridor.

EA.2.6.1.1 Salinity/Dissolved Solids

The salinity water quality parameter provides a summary of the total amount of dissolved inorganic ions (i.e., salts) that are contained within a water sample. Within freshwater systems, these are typically dominated by salts of calcium and magnesium, while sodium salts dominate in terms of total mass within ocean systems. The Delta, which represents an interface between freshwater and oceanic systems, is influenced by salts derived from both freshwater and saltwater. Freshwater profiles dominate the areas considered within this study, although increasing influence of saltwater can be observed in portions of the western Delta, including an increase in the occurrence of boron salts. Electrical conductivity, or the propensity of a sample of water to conduct electricity as a result of the dissolved ions that it contains, is commonly used as a convenient proxy to represent salinity concentrations. Electrical conductivity is measured in micro-Siemens per centimeter (μS/cm).

Salinity within Corridor 1 is monitored by a gauging station located along the San Joaquin River at Vernalis, which is located at the southern tip of Corridor 1. Salinity is measured automatically on at least a daily basis at the site. Figure EA.2.6-1 provides a summary of electrical conductivity measurements taken on a daily basis at Vernalis, from 2000 through 2011. These data reflect the salinity load flowing into the Delta from the San Joaquin River.

As shown, electrical conductivity at Vernalis ranges from less than 200 μS/cm to 1,062 μS/cm. This reflects salinity concentrations ranging from about 130 to 679 mg/L of dissolved salts. Peak values generally occur seasonally, during low flow periods in the summer and early autumn, while minimum values occur during runoff and flood events in the winter. As a point of comparison, the U.S. Environmental Protection Agency (USEPA) has set a secondary (nuisance) maximum contaminant level (MCL) for dissolved solids of 500 mg/L (USEPA, 2012). Above this value, municipal water taste may be affected, and the water may have an increased propensity to result in scaling within municipal systems (i.e., hard water). Salt-sensitive agricultural crops may also be affected by dissolved solids concentrations above 500 mg/L.

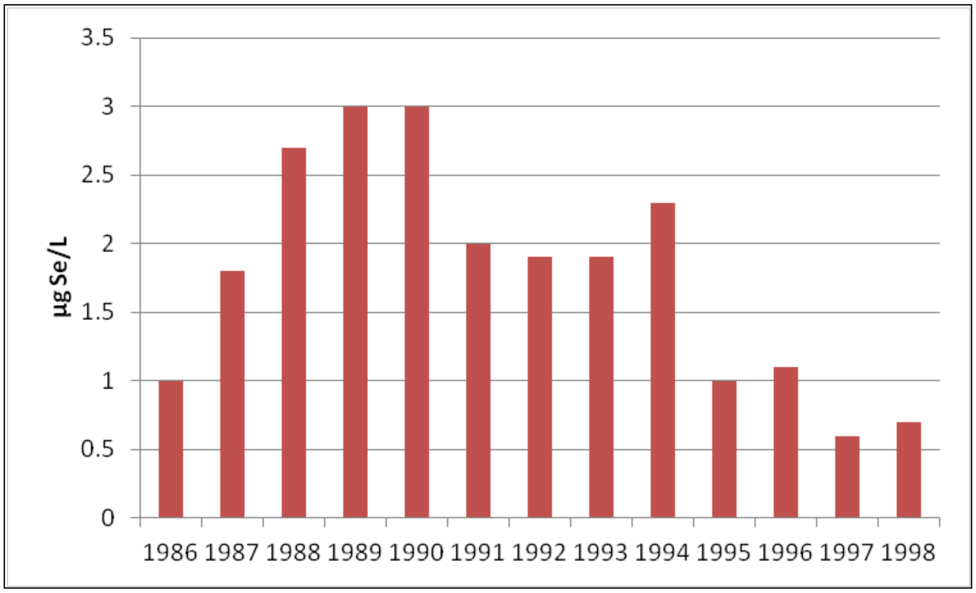


(DWR, 2011)

Figure EA.2.6-1: Electrical Conductivity of the San Joaquin River at Vernalis

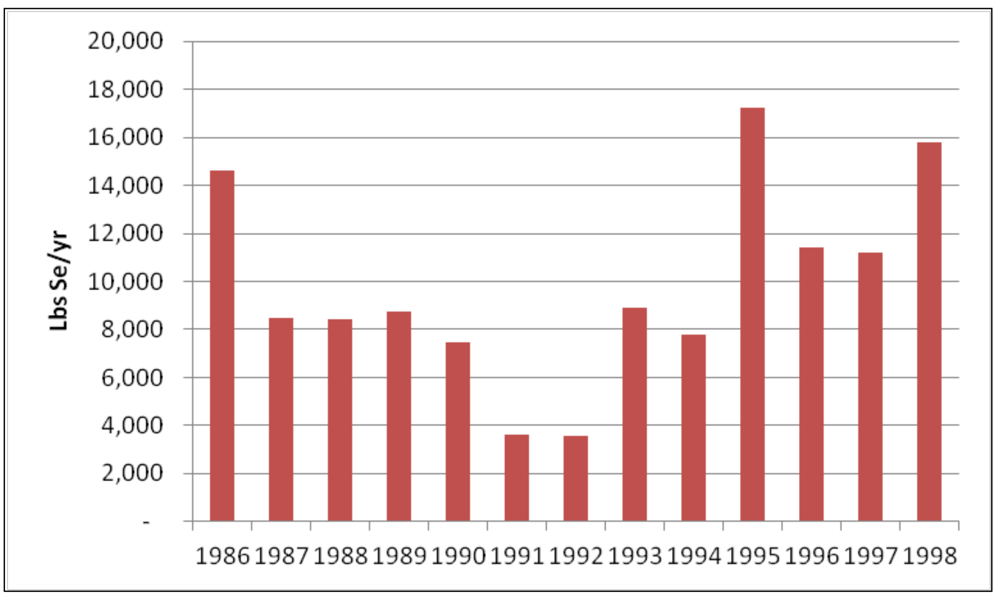
EA.2.6.1.2 Selenium

The CVRWQCB completed a Total Maximum Daily Load (TMDL) for selenium along the San Joaquin River in 2001. Selenium loading is primarily concentrated upstream in the river, but the effects of such loading have been observed by the monitoring station located at Vernalis. As shown in Figure EA.2.6-2 and Figure EA.2.6-3, selenium concentrations within the San Joaquin River at Vernalis ranged from 0.7 to 2.7 micrograms per liter (µg/L), while loads ranged from about 3,600 to 17,000 pounds per year (CVRWQCB, 2001).



Source: CVRWQCB, 2001. Total Maximum Daily Load for Selenium in the Lower San Joaquin River. August, 2001.

Figure EA.2.6-2: Selenium Concentrations at Vernalis



Source: CVRWQCB, 2001. Total Maximum Daily Load for Selenium in the Lower San Joaquin River. August, 2001.

Figure EA.2.6-3: Annual Selenium Loads at Vernalis

EA.2.6.1.3 Algae and Microcystis

Phytoplankton blooms have been documented in Delta waters. Some phytoplankton blooms result in the generation of toxic chemicals that are important to drinking water quality. Microcystis spp, a form of cyanobacteria, has been detected in the Delta since 1999 (CCWD, 2012), with sporadic/seasonal occurrences documented since that time. Microcystis blooms result in the generation of hepatotoxins termed Microcystins, which have the potential to affect Delta water quality and human health. Microcystis in the Delta has been studied by a handful of researchers, and blooms have been detected along Old River near Clifton Court (up to 20,000 cells per L) and along the lower San Joaquin River near Stockton (exceeding 20,000 cells per L on at least two occasions) (P. Lehman, Boyer, Satchwell, & Waller, 2008; P. W. Lehman, Boyer, Hall, Waller, & Gehrts, 2005; P. W. Lehman et al., 2010). A potential for temperature driven bloom events has been suggested by some researchers, although no study has yet confirmed this trend for the Delta.

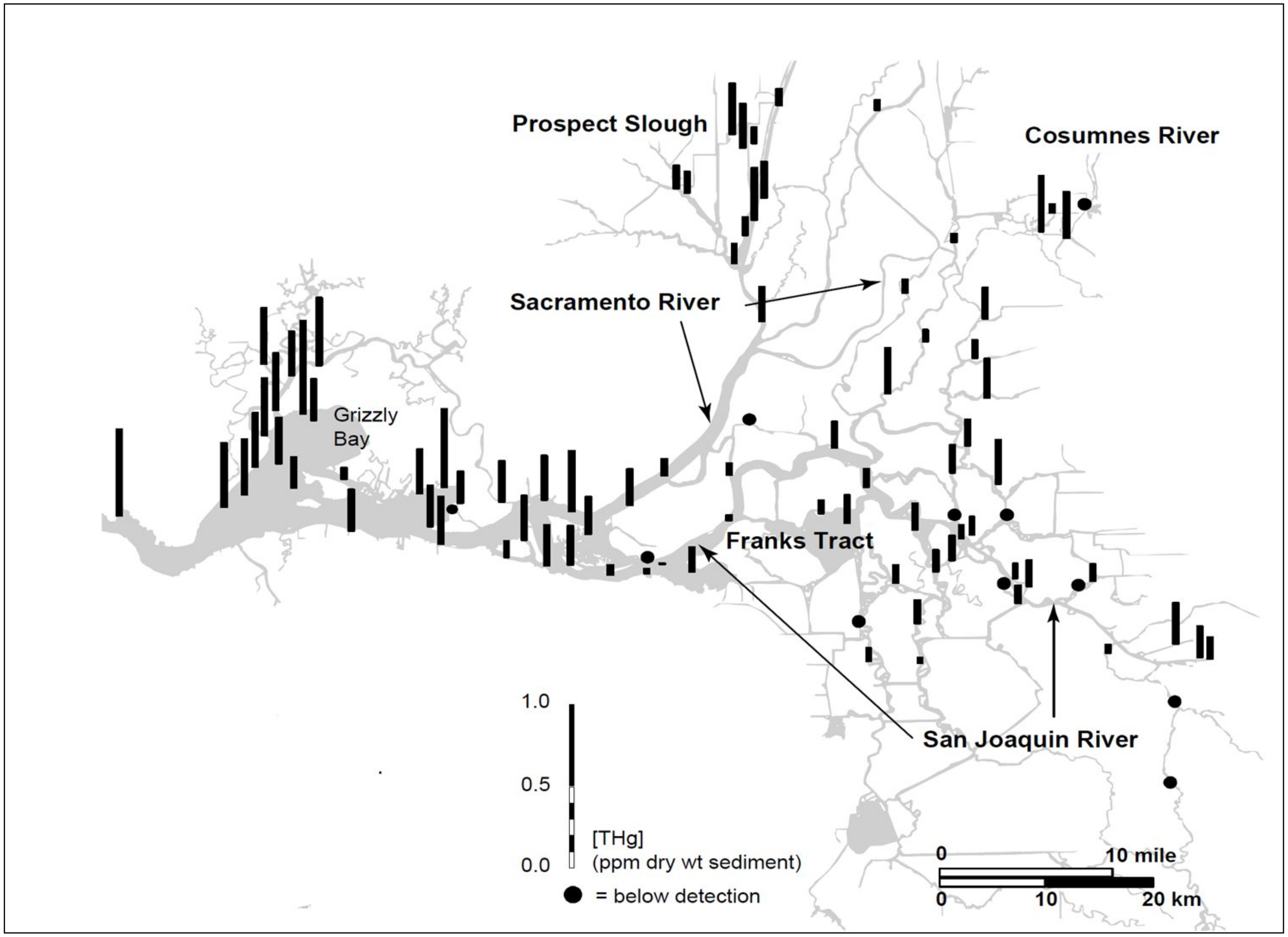
EA.2.6.1.4 Mercury and Methylmercury

Elemental mercury content within the Delta is believed to primarily result from legacy effects of placer mining for gold. Elemental mercury is a toxin to humans and wildlife, however, under certain environmental conditions, elemental mercury can be converted to methylmercury, a form that readily bioconcentrates and which has notable health effects. Intensive surveys for elemental and methylmercury have been completed in the eastern, northern, central, and western Delta. As shown in **Figure** EA.2.6-4 and Figure EA.2.6-5, elemental mercury concentrations are highest in the northern and western Delta, while methylmercury concentrations are highest in the central and western Delta. Sampling intensities within the south Delta, including Corridor 1, have been comparatively minimal. Available evidence indicates that elemental and methylmercury concentrations in the south Delta, including Corridor 1, are minor to below detection limits. As shown on **Figure** EA.2.6-4, sediment borne elemental mercury was not detected along the San Joaquin River downstream of Corridor 1, while sediment borne methylmercury concentrations were detected below 0.2 parts per billion (ppb or μg/L) (Heim, Coale, & Stephenson., 2002). However, sampling in these areas has been limited, and the presence of mercury across portions of the south Delta remains uncertain.

Waterborne mercury concentrations were sampled by DWR during a series of dredging projects near the Delta Mendota Canal (DMC) intake, just upstream of the fish screens and near the western end of Grant Line Canal (DWR, 2001). This location is also in close proximity to the Clifton Court Forebay. The samples were taking during dredging activities within south Delta channels. Dredging activities disturbed bottom sediments, causing elevated turbidity and suspension of mercury and other water quality constituents into the water column. The resulting data are not directly comparable to data presented by Heim, et al., (2002), because the latter reflect sediment-borne mercury concentrations. However, DWR's water quality data reflect the presence of mercury in bottom sediments within the area surveyed. Figure EA.2.6-6 provides a summary of waterborne mercury concentrations during dredging activity, within Old River at its intersection with Grant Line Canal (R3), Old River just south of its intersection with Grant Line Canal (R4), within the dredge material disposal ponds (DMD), and three sites along the Fabian-Bell Canal (T3, T4, and TDMD).

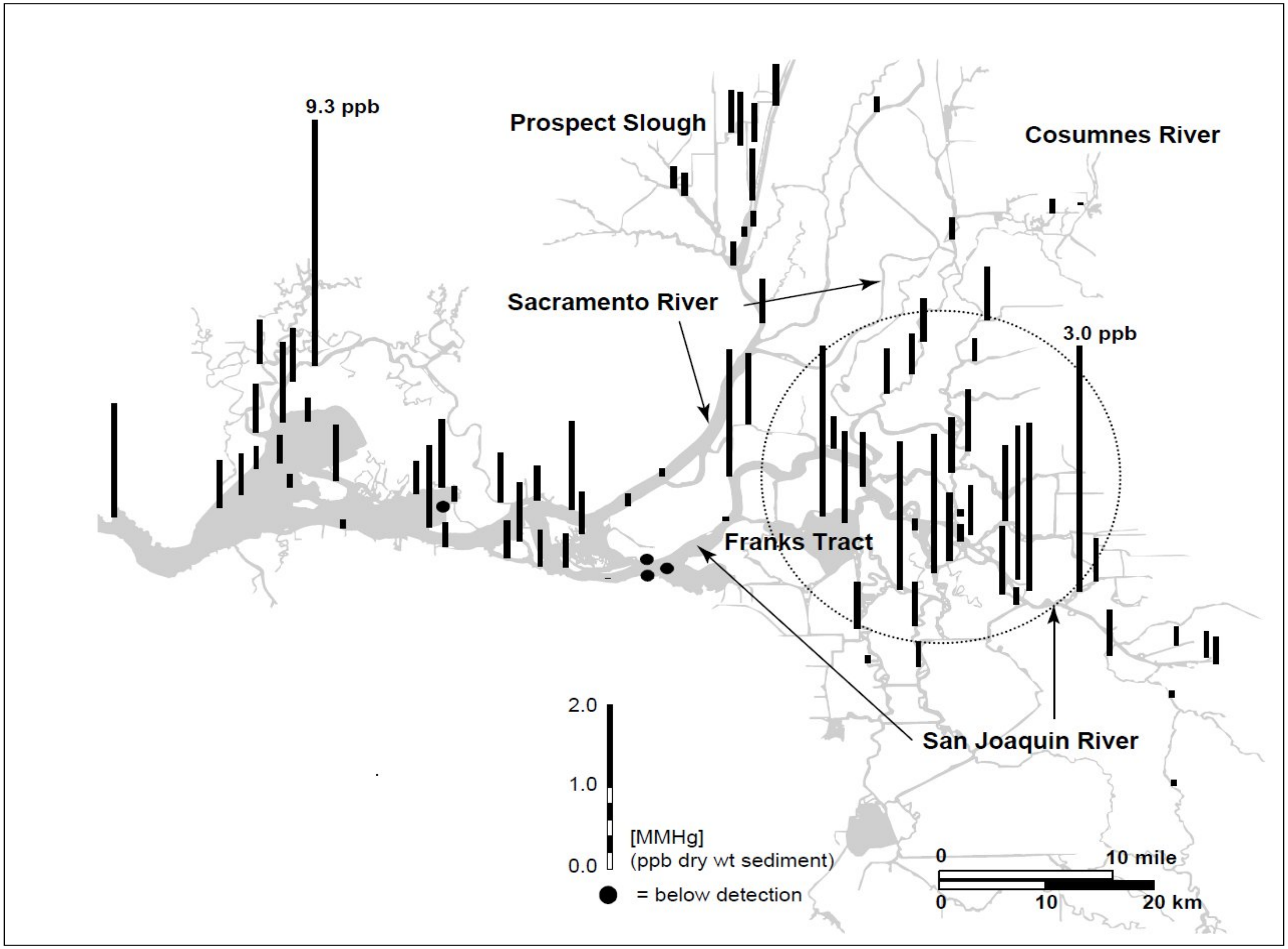
As shown, elemental mercury levels were considerably higher within dredge material disposal ponds (DMD and TDMD), with concentrations reaching 77.3 nanograms per liter (ng/L) in one instance. For reference, the maximum concentration allowable under the Section 401 permit applicable to this project was 50 ng/L (DWR, 2001). In general, these data indicate the presence of elemental mercury in sediments near the Tracy pumping plant and the Clifton Court Forebay, and in the general vicinity of some of the potential corridor activities. Thus, in the event that additional wetland areas capable of reducing mercury to methylmercury are implemented in the South Delta, production of methylmercury may be expected.

Movement of mercury within the San Francisco Bay-Delta system is largely a function of sediment transport dynamics, and waterborne mercury loads are strongly affected by suspended sediment concentrations (David et al., 2009). Methylmercury distribution is more complex. Methylation of elemental mercury occurs in the subsurface under anaerobic conditions, with relatively high rates of methylation occurring in wetland areas. A recent study reported dissolved methylmercury concentrations coming off of a wetland in the Petaluma Marsh at 0.136 ng/L during ebb tide, as compared to 0.083 ng/L on flood tide – equivalent to an increase of 0.053 ng/L during a single tidal cycle (Yee, McKee, & Oram, 2011).



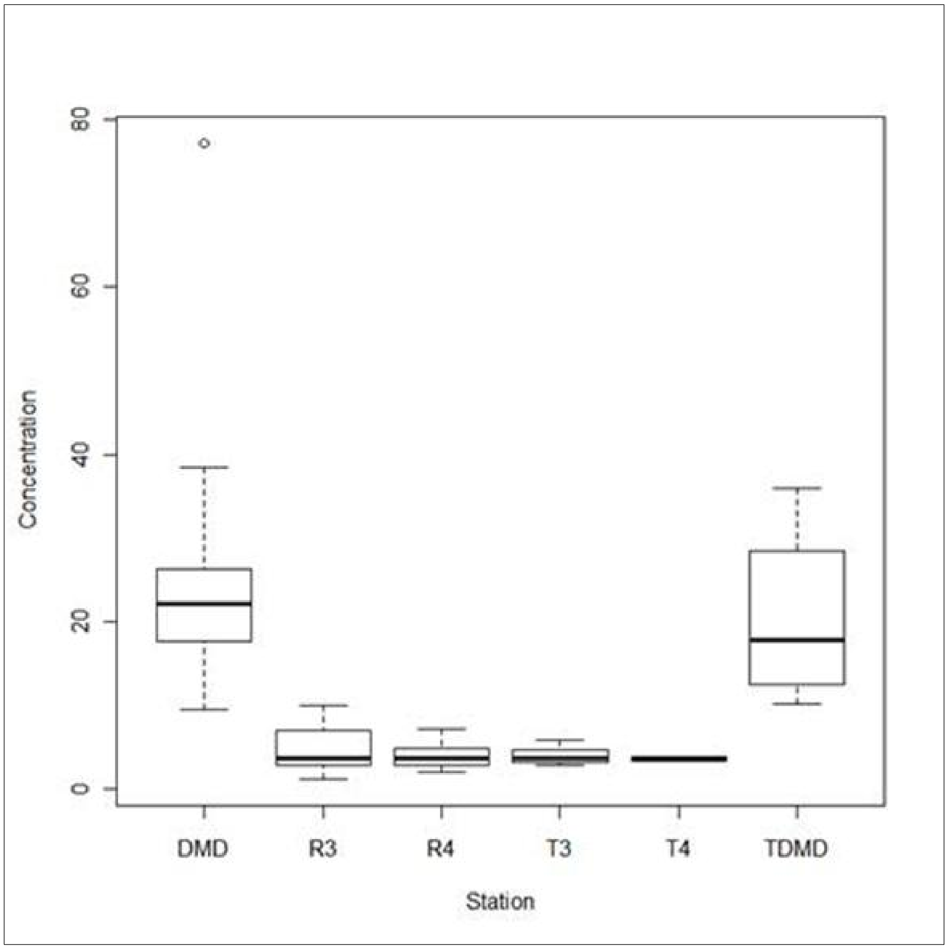
(Heim, et al., 2002)

Figure EA.2.6-4: Elemental Mercury Concentration in the Sacramento-San Joaquin Delta



(Heim, et al., 2002)

Figure EA.2.6-5: Methylmercury Concentration in the Sacramento-San Joaquin Delta



(DWR, 2011)

Figure EA.2.6-6: Waterborne Concentration of Elemental Mercury at South Delta Dredge Locations (ng/L)

EA.2.6.1.5 Dissolved Oxygen

Dissolved oxygen is a measurement of the amount of oxygen present in water, and maintenance of sufficient dissolved oxygen is critical to the support of fisheries. Dissolved oxygen varies on a seasonal and a daily basis. Factors that enhance dissolved oxygen concentration within a water body include diffusion from surface, artificial aeration, and photosynthetic production (typically near surface). Factors that reduce dissolved oxygen concentration result primarily from the activity of planktonic and microorganisms. When these organisms consume available organic matter, they draw oxygen from the water column to support their respiration process. As more readily consumable (labile) organic matter is available, the propensity for reduced dissolved oxygen conditions increases. Dissolved oxygen concentrations can become critically low in areas where high algal productivity at the surface is combined with low diffusion capacity and high rates of respiration lower in the water column.

Dissolved oxygen concentrations are not routinely monitored at Vernalis, and Corridor 1 is not indicated as a region where critically low dissolved oxygen is common. However, nutrients, planktonic organisms, and organic matter passing through Corridor 1 may eventually reach the

Stockton Deepwater Ship Channel, or portions of the southern Delta that have been identified as having periodic critically low or chronically low dissolved oxygen concentrations. These include the Old River at Tracy Wildlife Association, Middle River at Howard Road, and the Middle River at Union Point, as shown on Figure EA.2.6-7, which provides a summary of dissolved oxygen concentration for 2011. Therefore, potential changes in water quality within Corridor 1 could result in altered dissolved oxygen concentrations in these key downstream locations. Nutrient additions, in particular, can result in reduced dissolved oxygen downstream: under certain conditions, excess nutrients can result in phytoplankton blooms, which as they degrade down the water column, can result in critically low dissolved oxygen concentrations. Wetlands can in some cases reduce nutrient concentrations, which could support improved dissolved oxygen conditions downstream.

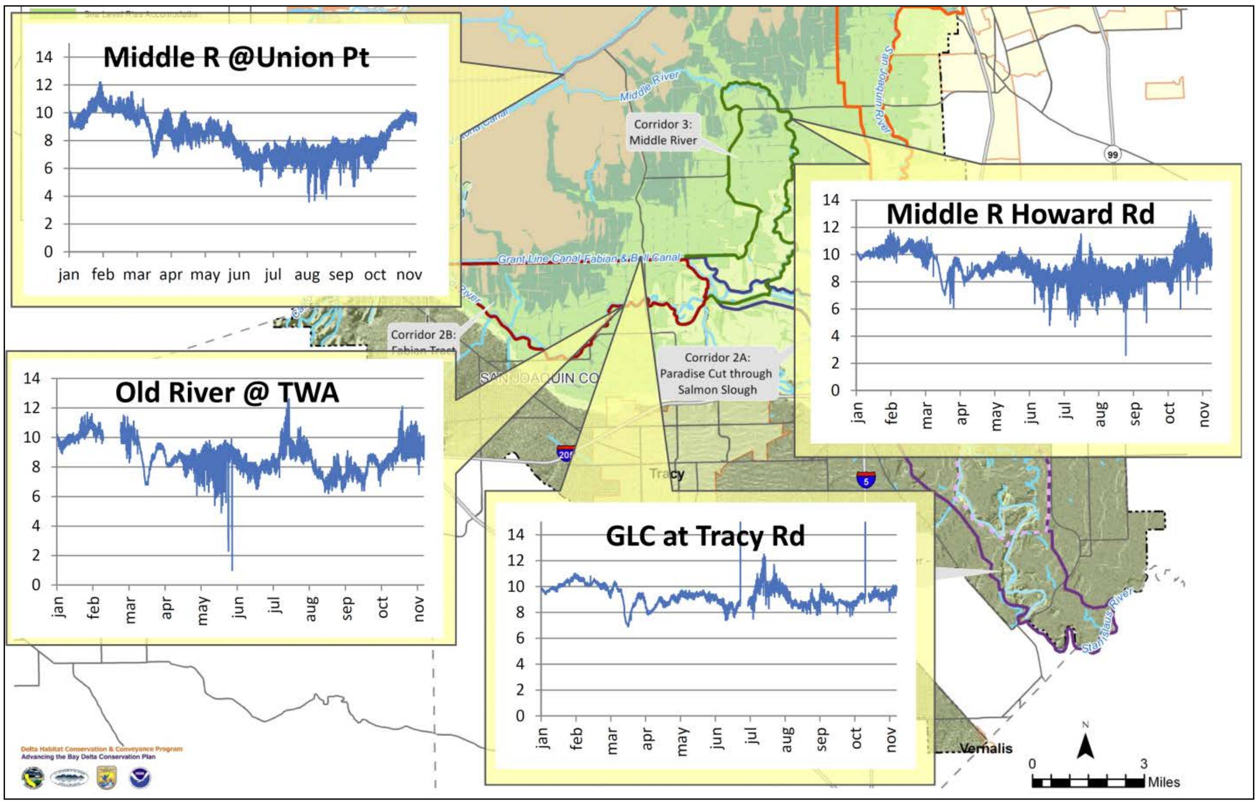


Figure EA.2.6-7: Dissolved Oxygen Concentrations in Key South Delta Locations (2011)

EA.2.6.1.6 Other Water Quality Considerations

Various other water quality constituents and pollutants are commonly found in south Delta waters. These include agricultural chemicals such as pesticides, herbicides, and nutrients (from fertilizers), as well as dissolved organic carbon. High levels of pesticides and herbicides can in some cases interfere with non-target plant and animal species including fish. Similarly, nutrients can alter productivity balances within Delta waterways, in some cases resulting in severely reduced dissolved oxygen concentrations, as discussed previously. Finally, dissolved organic carbon is a precursor to the formation of trihalomethanes, haloacetic acids, and various other drinking water disinfection by-products. Increases in dissolved organic carbon concentration can result in an associated increase in disinfection by-product formation. Delta wetlands have been shown to be significant exporters of dissolved organic carbon (Eckard, Hernes, Bergamaschi, Stepanauskas, & Kendall, 2007). Therefore construction of new wetlands could result in increased organic carbon export, and increased disinfection byproduct formation potential.

EA.2.6.1.7 Water Quality and Beneficial Uses

The following text provides a summary of potential effects that restoration could have on Corridor 1 or downstream portions of Delta waterways, as relevant.

Agricultural Irrigation (AGR)

Dissolved salts are the primary consideration for agricultural irrigation, including stock watering. Salt concentrations above 500 mg/L can in some cases result in reduced crop yields, with higher concentrations resulting in proportionally greater reductions in yield. Salt mixes conservatively, and is not easily removed from water – energy intensive procedures, such as reverse osmosis, are required. The potential restoration would result in the episodic inundation of additional land areas by San Joaquin/Delta waters. However, these lands are not anticipated to contain excessively high concentrations of salt. Additionally, in the event that additional salt is leached from sediments, leaching would primarily occur when emergent areas are flooded during high flow events. During such events, salinity in the Delta is generally reduced and would not result in a noticeable reduction in water quality. Therefore, the potential actions within Corridor 1a and Corridor 1b would not substantially affect agricultural irrigation.

Municipal and Public Water Supply, Including Export (MUN)

Municipal and public water supplies can be affected by an array of water quality constituents. Of those discussed here, key considerations include salinity, agricultural chemicals, dissolved organic carbon, and microcystis. As discussed previously, implementation of the potential actions within Corridors 1a and 1b is not expected to increase salt or selenium concentrations within Delta waters. Further, it would not result in an increase in agricultural production, or an increase in discharge from agricultural lands. Therefore, restoration of Corridors 1a and 1b would not result in an increase of agricultural chemicals. Most of the restoration work considered for this area would be inundated only during high water events. As a result, the potential actions would not result in large increases in Delta wetlands, which have been shown to be net exporters of dissolved organic carbon. Export of organic carbon may increase during flood events, but any increase from the project area would be overwhelmed by carbon from other sources. With respect to microcystis blooms, restoration along Corridors 1a and 1b would not result in increased nutrient loading or changes in temperature profiles, which could result in increased incidence of microcystis blooms. Therefore, restoration of Corridor 1a and 1b are not expected to result in increased disinfection byproduct formation potential.

Instream Habitat (WARM and COLD)

With respect to water quality, the corridor actions are not anticipated to result in the addition or reduction of nutrients or agricultural chemicals within Delta waters. Some agricultural production would be taken out of service. However, in comparison to the total load of agricultural pollutants contributed by Delta and upstream agriculture, reductions within the restoration area would likely be negligible. As discussed for municipal and public water supply, concentrations of organic carbon and selenium would not be substantially altered. Dissolved oxygen is a key consideration during low flow events. Because most of the restoration completed within corridors 1a and 1b would occur in areas that would only be periodically inundated (i.e., during high flow events), effects on downstream dissolved oxygen concentration during critical periods are expected to be minimal. Similarly, methylation potential for elemental mercury would be minimal, because Corridor 1 would not include extensive restoration of low lying wetlands. To the extent that the restoration would enhance channel fringe wetlands, a small degree of nutrient reduction could occur. The magnitude of effect on downstream dissolved oxygen is difficult to predict precisely, but would likely be minimal due to the limited extent of such wetlands.

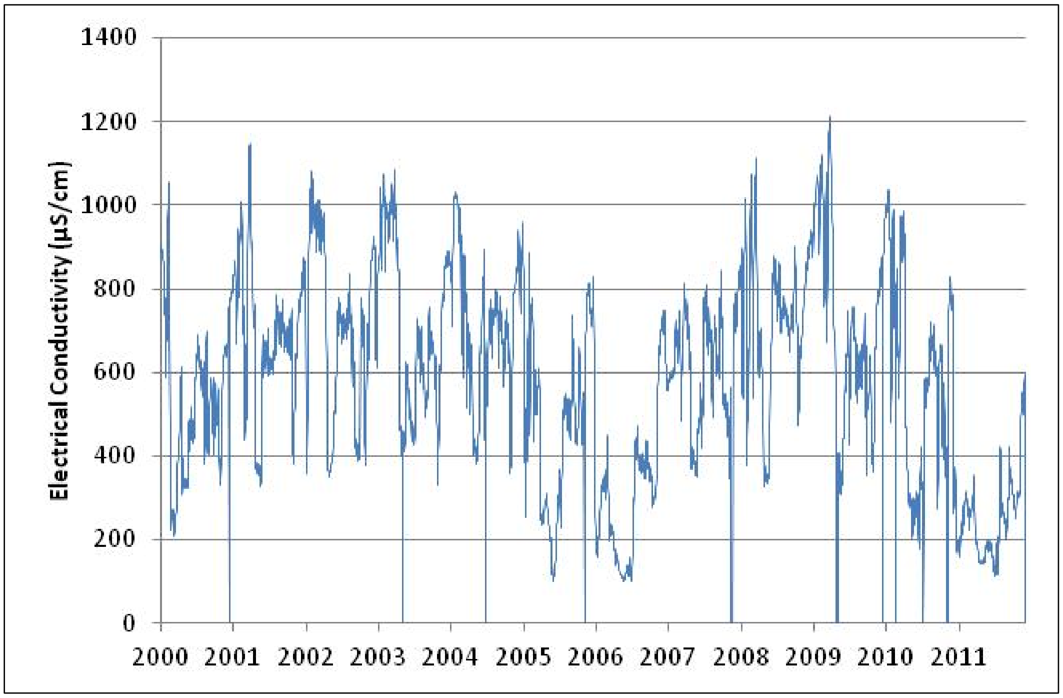
EA.2.6.2 Corridor 2

Water quality within the Delta, including Corridor 2, can be reasonably viewed through the lens of key beneficial uses. Beneficial uses are defined as end uses of water resources that provide a net benefit to humans or the environment, through a variety of individual uses. Maintaining water quality to the extent needed to protect identified beneficial uses is therefore a convenient way to characterize existing water quality conditions and potential changes to those conditions. The following discussion provides an overview of water quality conditions within Corridor 2, and reviews existing water quality conditions with respect to their influence on these select beneficial uses within the corridor.

EA.2.6.2.1 Salinity/Dissolved Solids

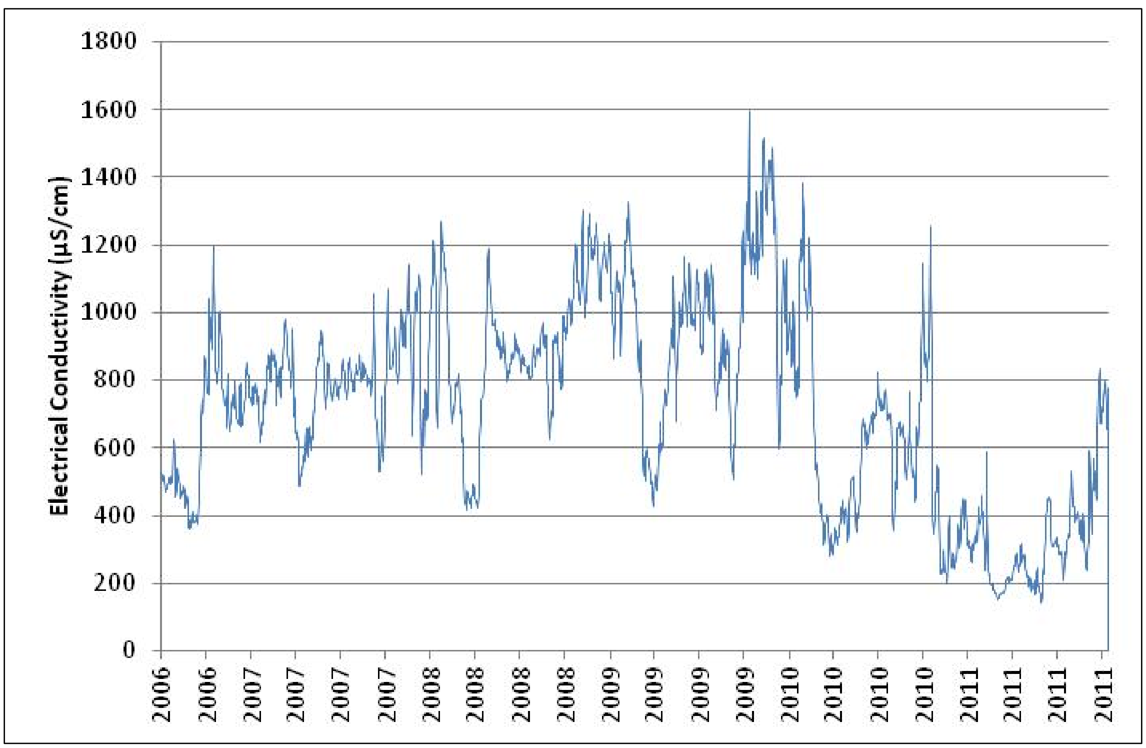
The salinity water quality parameter provides a summary of the total amount of dissolved inorganic ions (i.e., salts) that are contained within a water sample. For additional discussion and background, please refer to the water quality discussion for Corridor 1.

Salinity is not monitored within Corridor 2 on a daily basis, but is monitored at least daily at gauging stations located on the Old River near Middle River (Union Island), and downstream at the Old River near Tracy. Salinity is measured automatically on at least a daily basis at the site. Figure EA.2.6-8 and Figure EA.2.6-9 provide a summary of electrical conductivity measurements taken on a daily basis at these locations.



(DWR, 2011)

Figure EA.2.6-8: Electrical Conductivity of Old River Near Middle River (Union Island)



(DWR, 2011)

Figure EA.2.6-9: Electrical Conductivity of Old River Near Tracy

As shown, electrical conductivity at Old River at Middle River ranges from less than 200 µS/cm to 1,211 µS/cm. This reflects salinity concentrations ranging from about 130 to 775 mg/L of dissolved salts. These values are similar to that of the San Joaquin River (see Corridor 1 discussion), but slightly elevated, indicating a within Delta source of additional dissolved salts. Figure EA.2.6-9 indicates a stronger non-riverine source of electrical conductivity during low flow periods. Minimum high flow levels are similar to those indicated for the San Joaquin River and the Old River at Middle River. However, peak low flow values are considerably higher, reaching 1,595 µs/cm (1,020 mg/L of dissolved salts) during 2009. Studies of salinity within the south Delta have indicated that groundwater seeps along local waterways represent a key influx of salt into the south Delta system. Such inflows may contain groundwater that contains dissolved salts concentration as high as 2,100 to 2,600 mg/L, with flows in Sugar Cut providing a good example (DWR, 2007). Similar to that indicated for Corridor 1, peak values generally occur seasonally, during low flow periods in the summer and early autumn, while minimum values occur during runoff and flood events in the winter. For additional discussion regarding the effects of elevated salinity on beneficial uses, refer to the discussion for Corridor 1.

EA.2.6.2.2 Selenium

The most comprehensive and complete data set available on selenium is associated with the gauging station at Vernalis within Corridor 1. Therefore, please refer to Section 2.6.1.2 of this document for a discussion of selenium.

EA.2.6.2.3 Algae and Microcystis; Mercury and Methylmercury; Dissolved Oxygen; Other Water Quality Considerations

For discussions of microcystis, mercury and methylmercury, dissolved oxygen, and other water quality considerations relevant to Corridor 2, please refer to the appropriate discussion sections for Corridor 1.

EA.2.6.2.4 Water Quality and Beneficial Uses

The following text provides a summary of key issues relevant to water quality and concerning the restoration of Corridors 2a and 2b, with respect to beneficial uses.

Agricultural Irrigation (AGR)

Dissolved salts are the primary consideration for agricultural irrigation, including stock watering. Salt concentrations above 500 mg/L can in some cases result in reduced crop yields, with higher concentrations resulting in proportionally greater reductions in yield. Salt mixes conservatively, and is not easily removed from water – energy intensive procedures, such as reverse osmosis, are required. Based on available data, salt concentrations in Corridors 2a and 2b are expected to be somewhat higher than those anticipated for Corridor 1. Salt concentrations in these areas frequently exceed 500 mg/L. In the event that the corridor actions were to result in increases in salt concentration, agricultural use of water quality could be affected.

Municipal and Public Water Supply, Including Export (MUN)

Municipal and public water supplies can be affected by an array of water quality constituents. Of those discussed here, key considerations include salinity, agricultural chemicals, dissolved organic carbon, and microcystis blooms. Salt concentration is regulated via a secondary MCL, however, minimization of salt concentration is critical to exported municipal water supplies, because salt concentrations above 500 mg/L can result in aesthetic quality issues including taste and scaling.

Very high salt concentrations, such as those above 1,000 mg/L, are typically avoided for municipal supplies, or must be blended prior to distribution and utilization. Significant increases in the area of Delta wetlands, which have been shown to be net exporters of dissolved organic carbon (Eckard, Hernes, Bergamaschi, Stepanauskas, & Kendall, 2007), could result in a net increase in the production of disinfection byproduct precursors. This could in turn result in a net increase in exceedance events for disinfection byproducts in municipal supplies. Concentration of selenium and agricultural chemicals are not anticipated to be substantially affected. Changes in the frequency of occurrence for microcystis blooms could have corresponding effects on water quality. In the event that frequency or intensity of blooms increases, a net reduction in drinking water quality could occur.

Instream Habitat (WARM and COLD)

Dissolved oxygen concentration is a key water quality component with respect to habitat viability in the Delta. Reductions in factors leading to low dissolved oxygen could result in a reduced incidence of chronic and acute low dissolved oxygen events in the Delta, which can in extreme cases result in fish kills. Low dissolved oxygen can affect fish at all lifecycle stages, depending upon the timing of their exposure. Dissolved organic carbon exports from Delta wetlands may be linked to a healthy Delta food web, with additional production of organic carbon potentially resulting in increased bio-available carbon to support Delta food webs. To the extent that a restoration activity would result in increased dissolved organic carbon production, a net benefit in instream habitat may result. Note that this trend opposes the potential deleterious effects of increased dissolved oxygen concentration on drinking water quality. Biota, especially in higher trophic levels, are sensitive to bioconcentration of selenium and methylmercury, and processes that would result, directly or indirectly, in increased biotic uptake of these species could result in detrimental ecosystem effects.

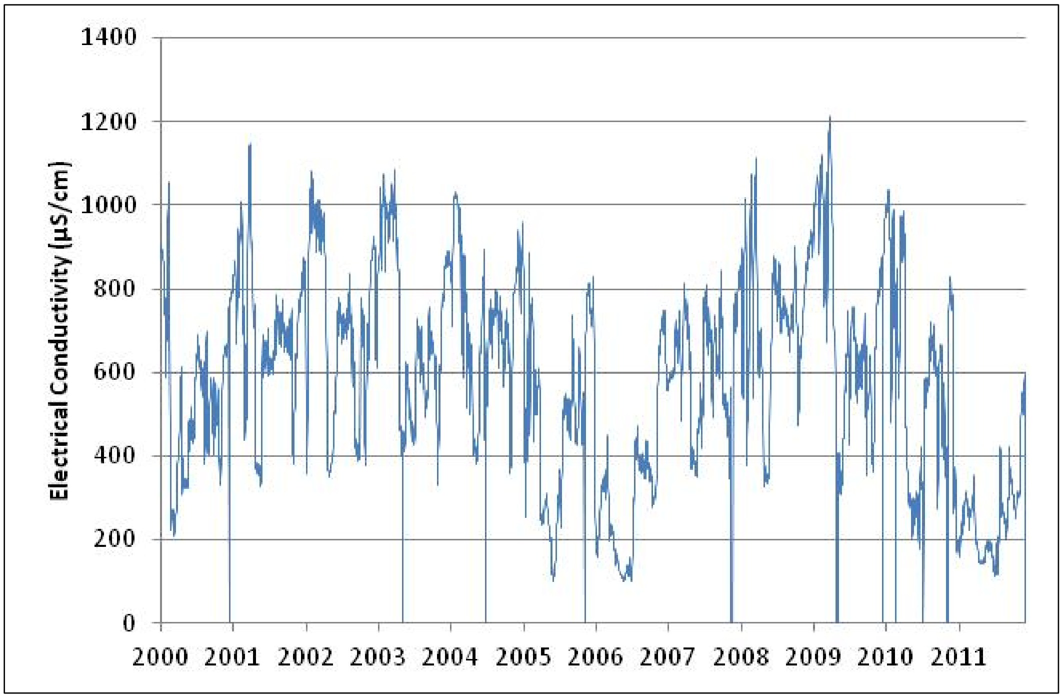
EA.2.6.3 Corridor 3

Water quality within the Delta, including Corridor 3, can be reasonably viewed through the lens of key beneficial uses. Beneficial uses are defined as end uses of water resources that provide a net benefit to humans or the environment, through a variety of individual uses. Maintaining water quality to the extent needed to protect identified beneficial uses is therefore a convenient way to characterize existing water quality conditions and potential changes to those conditions. The following discussion provides an overview of water quality conditions within Corridor 2, and reviews existing water quality conditions with respect to their influence on these select beneficial uses within the corridor.

EA.2.6.3.1 Salinity/Dissolved Solids

The salinity water quality parameter provides a summary of the total amount of dissolved inorganic ions (i.e., salts) that are contained within a water sample. For additional discussion and background, please refer to the water quality discussion for Corridor 1.

Salinity is monitored at the southeastern corner of Corridor 3, by a gauging station located on the Old River near Middle River (Union Island). Salinity is measured automatically on at least a daily basis at the site. Figure EA.2.6-10 provides a summary of electrical conductivity measurements taken on a daily basis at this location.



(DWR, 2011)

Figure EA.2.6-10: Electrical Conductivity of Old River Near Middle River (Union Island)

As shown, electrical conductivity at Old River at Middle River ranges from less than 200 µS/cm to 1,211 µS/cm. This reflects salinity concentrations ranging from about 130 to 775 mg/L of dissolved salts. These values are similar to that of the San Joaquin River (see Corridor 1 discussion), but slightly elevated, indicating a within Delta source of additional dissolved salts. As discussed in the evaluation for Corridor 2, saline groundwater influx within the south Delta has been identified as a key source of salt within the south Delta. Such inflows may contain groundwater that contains dissolved salts concentration as high as 2,100 to 2,600 mg/L, with flows in Sugar Cut providing a good example (DWR, 2007). Similar to that indicated for Corridor 1, peak values generally occur seasonally, during low flow periods in the summer and early autumn, while minimum values occur during runoff and flood events in the winter. For additional discussion regarding the effects of elevated salinity on beneficial uses, refer to the discussion for Corridor 1.

EA.2.6.3.2 Selenium

The most comprehensive and complete data set available on selenium is associated with the gauging station at Vernalis within Corridor 1. Therefore, please refer to Section 2.6.1.2 of this document for a discussion of selenium.

EA.2.6.3.3 Algae and Microcystis; Mercury and Methylmercury; Dissolved Oxygen; Other Water Quality Considerations

For discussions of microcystis, mercury and methylmercury, dissolved oxygen, and other water quality considerations relevant to Corridor 3, please refer to the appropriate discussion sections for Corridor 1.

EA.2.6.3.4 Water Quality and Beneficial Uses

The following text provides a summary of key issues relevant to water quality and concerning the restoration of Corridor 3, with respect to beneficial uses.

Agricultural Irrigation (AGR)

Dissolved salts are the primary consideration for agricultural irrigation, including stock watering. Salt concentrations above 500 mg/L can in some cases result in reduced crop yields, with higher concentrations resulting in proportionally greater reductions in yield. Salt mixes conservatively, and is not easily removed from water – energy intensive procedures, such as reverse osmosis, are required. Based on available data, salt concentrations in Corridor 3 are expected to be slightly higher than those anticipated for Corridor 1, but lower than those anticipated for Corridor 2. Salt concentrations in these areas frequently exceed 500 mg/L. In the event that the potential corridor actions were to result in increases in salt concentration, agricultural use of water quality could be affected.

Municipal and Public Water Supply, Including Export (MUN)

Municipal and public water supplies can be affected by an array of water quality constituents. Of those discussed here, key considerations include salinity, agricultural chemicals, dissolved organic carbon, and microcystis blooms. Salt concentration is regulated via a secondary MCL, however, minimization of salt concentration is critical to exported municipal water supplies, because salt concentrations above 500 mg/L can result in aesthetic quality issues including taste and scaling. Very high salt concentrations, such as those above 1,000 mg/L, are typically avoided for municipal supplies, or must be blended prior to distribution and utilization. Significant increases in the area of Delta wetlands, which have been shown to be net exporters of dissolved organic carbon (Eckard, Hernes, Bergamaschi, Stepanauskas, & Kendall, 2007), could result in a net increase in the production of disinfection byproduct precursors. This could in turn result in a net increase in exceedance events for disinfection byproducts in municipal supplies. Concentration of selenium, agricultural chemicals, and mercury are not anticipated to be substantially affected. Changes in the frequency of occurrence for microcystis blooms could have corresponding effects on water quality. In the event that frequency or intensity of blooms increases, a net reduction in drinking water quality could occur.

Instream Habitat (WARM and COLD)

Dissolved oxygen concentration is a key water quality component with respect to habitat viability in the Delta. Reductions in factors leading to low dissolved oxygen could result in a reduced incidence of chronic and acute low dissolved oxygen events in the Delta, which can in extreme cases result in fish kills. Low dissolved oxygen can affect fish at all lifecycle stages, depending upon the timing of their exposure.

Dissolved organic carbon exports from Delta wetlands may be linked to a healthy Delta food web, with additional production of organic carbon potentially resulting in increased bio-available carbon to support Delta food webs. To the extent that a restoration activity would result in increased dissolved organic carbon production, a net benefit in instream habitat may result. Note that this trend opposes the potential deleterious effects of increased dissolved oxygen concentration on drinking water quality. Biota, especially in higher trophic levels, are sensitive to bioconcentration of selenium and methylmercury, and processes that would result, directly or indirectly, in increased biotic uptake of these species could result in detrimental ecosystem effects.

EA.2.6.4 Corridor 4

Water quality within the Delta, including Corridor 4, can be reasonably viewed through the lens of key beneficial uses. Beneficial uses are defined as end uses of water resources that provide a net benefit to humans or the environment, through a variety of individual uses. Maintaining water quality to the extent needed to protect identified beneficial uses is therefore a convenient way to characterize existing water quality conditions and potential changes to those conditions. The following discussion provides an overview of water quality conditions within Corridor 2, and reviews existing water quality conditions with respect to their influence on these select beneficial uses within the corridor.

EA.2.6.4.1 Salinity/Dissolved Solids

The salinity water quality parameter provides a summary of the total amount of dissolved inorganic ions (i.e., salts) that are contained within a water sample. For additional discussion and background, please refer to the water quality discussion for Corridor 1.

Salinity is not directly monitored within Corridor 4. However, flows within this area are heavily influenced by flows emanating from the San Joaquin River at Vernalis. Therefore, salt concentrations within Corridor 4 are expected to be similar to those at the Vernalis station, as discussed in the evaluation of Corridor 1. For additional discussion of salt concentrations at Vernalis, please refer to the discussion for Corridor 1.

EA.2.6.4.2 Selenium

The most comprehensive and complete data set available on selenium is associated with the gauging station at Vernalis within Corridor 1. Therefore, please refer to Section 2.6.1.2 of this document for a discussion of selenium.

EA.2.6.4.3 Algae and Microcystis; Mercury and Methylmercury; Dissolved Oxygen; Other Water Quality Considerations

For discussions of microcystis, mercury and methylmercury, dissolved oxygen, and other water quality considerations relevant to Corridor 4, please refer to the appropriate discussion sections for Corridor 1.

EA.2.6.4.4 Water Quality and Beneficial Uses

The following text provides a summary of key issues relevant to water quality and concerning the restoration of Corridor 4, with respect to beneficial uses.

Agricultural Irrigation (AGR)

Dissolved salts are the primary consideration for agricultural irrigation, including stock watering. Salt concentrations above 500 mg/L can in some cases result in reduced crop yields, with higher concentrations resulting in proportionally greater reductions in yield. Salt mixes conservatively, and is not easily removed from water – energy intensive procedures, such as reverse osmosis, are required. Based on available data, salt concentrations in Corridor 4 are expected to be slightly higher than those anticipated for Corridor 1, but lower than those anticipated for Corridors 2 or 3. Salt concentrations in these areas frequently exceed 500 mg/L. In the event that the potential corridor actions were to result in increases in salt concentration, agricultural use of water quality could be affected.

Municipal and Public Water Supply, Including Export (MUN)

Municipal and public water supplies can be affected by an array of water quality constituents. Of those discussed here, key considerations include salinity, agricultural chemicals, dissolved organic carbon, and microcystis blooms. Salt concentration is regulated via a secondary MCL, however, minimization of salt concentration is critical to exported municipal water supplies, because salt concentrations above 500 mg/L can result in aesthetic quality issues including taste and scaling. Very high salt concentrations, such as those above 1,000 mg/L, are typically avoided for municipal supplies, or must be blended prior to distribution and utilization. Significant increases in the area of Delta wetlands, which have been shown to be net exporters of dissolved organic carbon (Eckard, Hernes, Bergamaschi, Stepanauskas, & Kendall, 2007), could result in a net increase in the production of disinfection byproduct precursors. This could in turn result in a net increase in exceedance events for disinfection byproducts in municipal supplies. Concentration of selenium, agricultural chemicals, and mercury are not anticipated to be substantially affected. Changes in the frequency of occurrence for microcystis blooms could have corresponding effects on water quality. In the event that frequency or intensity of blooms increases, a net reduction in drinking water quality could occur.

Instream Habitat (WARM and COLD)

Dissolved oxygen concentration is a key water quality component with respect to habitat viability in the Delta. Reductions in factors leading to low dissolved oxygen could result in a reduced incidence of chronic and acute low dissolved oxygen events in the Delta, which can in extreme cases result in fish kills. Low dissolved oxygen can affect fish at all lifecycle stages, depending upon the timing of their exposure.

Dissolved organic carbon exports from Delta wetlands may be linked to a healthy Delta food web, with additional production of organic carbon potentially resulting in increased bio-available carbon to support Delta food webs. To the extent that a restoration activity would result in increased dissolved organic carbon production, a net benefit in instream habitat may result. Note that this trend opposes the potential deleterious effects of increased dissolved oxygen concentration on drinking water quality. Biota, especially in higher trophic levels, are sensitive to bioconcentration of selenium and methylmercury, and processes that would result, directly or indirectly, in increased biotic uptake of these species could result in detrimental ecosystem effects.

EA.3 Corridor Description and Evaluation Assumptions

This section provides the approach, assumptions, and other information related to the flood management and habitat restoration actions that constitute the conceptual corridors. Aside from the flood infrastructure-related changes (i.e., levee setbacks), the corridors are described in relation to the four main BDCP habitat conservation measures relevant to the South Delta: CM 4 (Tidal Restoration), CM 5 (Seasonally-Inundated Floodplain Restoration), CM 6 (Channel Margin Enhancement), and CM 7 (Riparian Restoration). These descriptions and assumptions serve as a basis for evaluation of the conceptual corridors. The rationales for the overall corridor architecture (i.e., the levee setback and bypass-expansion locations) are included in Section 7.2. Also included in this section is a summary of the BDCP water operations (BDCP Alternative 1) that are assumed for the purposes of the South Delta corridor evaluations.

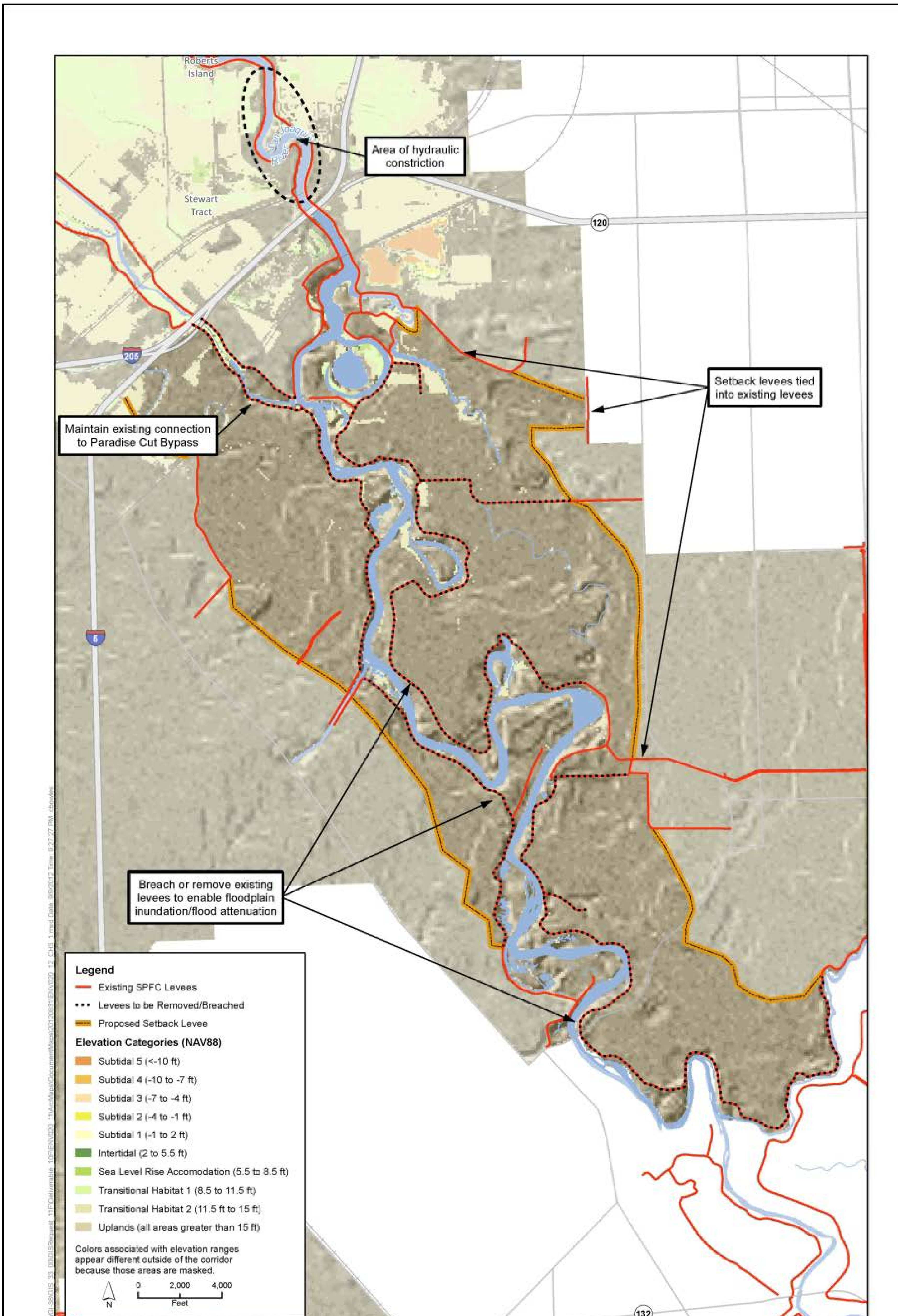
All general approach and habitat assumptions are contained in Sections 3.1 and 3.3, the first sections covering corridors (from upstream to downstream) that contain potential floodplain and wetlands habitat, respectively. Details specific to certain corridors are included in subsequent sections.

EA.3.1 Corridor 1 Description and Assumptions

EA.3.1.1 Corridor 1A

Corridor 1A is largely comprised of the development of setback levees on both sides of the San Joaquin River, as shown in Figure EA.3.1-1. The assumed corridor condition expands the floodway area (e.g., the corridor footprint between the levees, not including in-channel areas[3]) from 2,524 acres to 11,741 acres (an increase of 9,217 acres; 79% of the new corridor area). Table EA.3.1-1 and Table EA.3.1-2 summarizes estimated or assumed habitats and changes inland cover in all of the conceptual corridors.

[3] In-channel areas were estimated by running a hydraulic model of the San Joaquin River and measuring the inundated area at a discharge of 2,020 cfs (the 50% exceedance event at Vernalis).



Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.3.1-1: Configuration of South Delta Conceptual Corridor 1A

Table EA.3.1-1: Configuration of South Delta Conceptual Corridors

	Existing Conditions	**Corridor-Conditions**									
			Existing + Additional Corridor Footprint *(Total Area between Levees; river excluded)*	***Assumed Corridor Land Cover/Habitats***							
	Existing Footprint *(Total Existing Area between Levees; river excluded)*	**New Corridor Footprint *(Additional Area between Levees above Existing; river excluded)***		**Tidal Wetlands *(includes SLR accommodation, tidal marsh and shallow subtidal)***		**Riparian Forest**		**Flood-Tolerant Agriculture**		**Length of Channel Margin Habitat Created *(miles; RB vs LB defined; add active and passive for corridor totals)***	
Corridor	**acres**	**acres**	**acres**	**acres**	**percent of new corridor footprint**	**acres**	**percent of new corridor footprint**	**acres**	**percent of new corridor footprint**	**Passive**	**Active**
1A	2,524	9,217	11,741	-	-	8,219	70%	3,522	30%	16 on RB & 16 on LB (32 total both banks)	-
1B	1,593	3,787	5,380	-	-	3,228	60%	2,152	40%	8.5 (RB only)	-
2A	1,189	1,100	2,289	-	-	1,145	50%	1,145	50%	-	-
Fabian Tract	484	6,487	6,971	6,710	96%	235	3%	26	-	11.5 (one bank; multpl. chls.)	-
2B	1,673	7,587	9,260	6,710	72%	2,295	25%	255	3%	11.5 (one bank; multpl. chls.)	-
3	706	4,468	5,174	3,530	68%	1,480	29%	164	3%	11 on LB	11 on RB
4	252	5,629	5,881	3,820	65%	2,061	35%	-	-	12 on LB	12 on RB
Note: Because Corridor 2B is comprised of both Fabian Tract and Paradise Cut, areas for Fabian Tract are shown for clarity.											

Table EA.3.1-2: Assumed Percentages of Riparian versus Flood-Tolerant Agriculture*

	Assumed Riparian	Assumed Flood-Tolerant Agriculture	Rationale
Corridor 1A:	70%	30%	Flood-tolerant agriculture already exists. Existing ratios of agricultural to non-agricultural lands within the levees in this corridor were approximated and used to define these assumptions.
Corridor 1B:	60%	40%	Flood-tolerant agriculture already exists. Existing ratios of agricultural to non-agricultural lands within the levees in this corridor were approximated and used to define these assumptions.
Paradise Cut:	50%	50%	Flood-tolerant agriculture already exists in the bypass. Existing ratios of agricultural to non-agricultural lands within the levees in this corridor were approximated and used to define these assumptions.
Fabian Tract:	90%	10%	While most of this corridor would be converted to marsh, its relative flooding frequency is likely low. Riparian areas would fringe marsh lands and some smaller areas may remain as areas for flood-tolerant crops.
Corridor 3:	90%	10%	While most of this corridor would be converted to marsh, its relative flooding frequency is likely low-moderate. . Riparian areas would fringe marsh lands and some smaller areas may remain as areas for flood-tolerant crops
Corridor 4	100%	0%	Because this corridor would be inundated by relatively-frequent flows, continued agriculture appears difficult.
*Because tidal inundation dominates the Delta landscape, new landuse/landcover is assumed by calculating: total corridor, minus estimated tidal marsh, with the remaining new total divided among the percentages shown in Table EA.3.1-2.			

In creation of the corridor, it is assumed that all existing water-side riprap would be removed and levees breached and/or degraded sufficiently to allow more-dynamic channel migration processes. This action would also improve channel-margin habitat through passive restoration (i.e., the aforementioned removal of revetment /levees). The physical components (e.g., woody debris, undercut banks) and vegetation (emergent plants, woody riparian, and submerged aquatic vegetation) associated with channel margin habitat and adjacent shallow water and natural banks can serve as substrates for invertebrate communities that supports foraging fish. In Corridor 1A this would occur on *both* banks of the San Joaquin River for approximately 16 miles. The following bullets outline the results of estimation or assumptions for habitat in Corridor 1A:

- For the purposes of these evaluations, new corridor areas away from the channel margin are assumed to be either tidal marsh or floodplain, with floodplain areas either being vegetated by riparian vegetation or being retained in flood-tolerant agriculture.
- The potential for tidal marsh was estimated using relationships between existing ground elevation behind levees and existing tide range, with an acknowledgment of future for sea level rise. No tidal marsh potential was identified in Corridor 1A, and the new corridor area between

the levees is likely to function as seasonally-inundated floodplain covered in riparian habitats and flood-tolerant agriculture.

- Absent any tidal marsh, floodplain areas are assumed to cover 11,741 acres. Assuming a distribution of flood tolerant agriculture and riparian habitat as per Table EA.3.1-1, Corridor 1A may yield 8,219 acres of riparian and 3,522 acres of flood-tolerant agriculture.
- Results on seasonal floodplain inundation at specific ecologically-relevant discharge levels are included in Section 4.
- In these assumptions the general term 'riparian habitat' is used; however, the final composition of habitats may include mixed riparian vegetation, valley/upland riparian vegetation, and open grasslands depending on the mix of active and passive restoration and the soil and moisture conditions generated.
- No attempt was made to differentiate between the likely percent of riparian habitat that would be developed via active horticultural restoration or would be restored passively through natural recruitment.

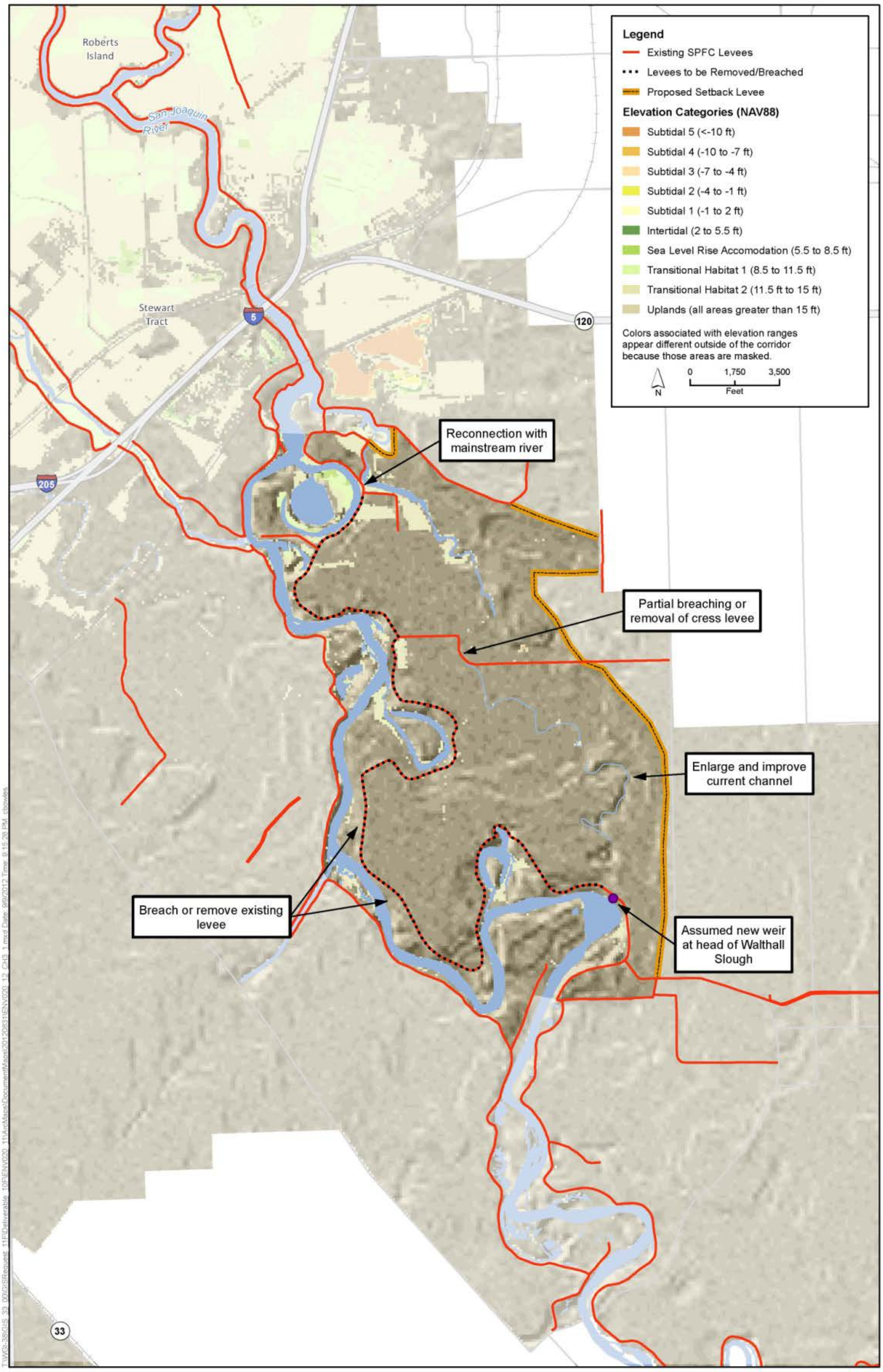
EA.3.1.2 Corridor 1B

Corridor 1B is comprised of the development of a setback levee on the east (right-bank) side of the San Joaquin River, as shown in Figure EA.3.1-2, as well as the construction of a weir at the upstream head of the currently-unconnected (blind) Walthall Slough, which under existing conditions is separated from the river by a levee. The new weir is defined in the modeling as a broad-crested v-notch weir with a crest width of 100 feet, top width of 500 feet, a crest elevation set at 25 feet (NAVD88), and weir side slopes set at 20 units horizontal to one unit vertical rising to the top of the weir structure. The new weir configuration at the head of Walthall Slough begins to flow at a San Joaquin River discharge of approximately 23,800 cfs (Model Run E, no Sea Level Rise (SLR); see Section 7.3). A downstream re-connection with the San Joaquin River is also assumed for Walthall Slough, as are some topographic modifications through the slough to account for existing infrastructure such as bridges.

- The assumed corridor condition expands the floodway area (e.g., the corridor footprint between the levees, not including in-channel areas[4]) from 1,593 acres to 5,380 acres (an increase of 3,787 acres; 70% of the new corridor area).
- In creation of the corridor, it is assumed that all existing water-side riprap would be removed and levees breached and/or degraded sufficiently to allow more-dynamic channel migration processes. This action would also improve channel-margin channel habitat through passive restoration (i.e., the aforementioned removal of revetment /levees). In Corridor 1B this would occur on *the right (east)* bank of the San Joaquin River for approximately 8.5 miles.
- The potential for tidal marsh in this corridor was estimated using relationships between existing ground elevation behind levees and existing tide range, with an acknowledgment of future for sea level rise. No tidal marsh potential was identified in Corridor 1B, and the new corridor area between the levees is likely to function as seasonally-inundated floodplain covered in riparian habitats and flood-tolerant agriculture.

[4] In-channel areas were estimated by running a hydraulic model of the San Joaquin River and measuring the inundated area at a discharge of 2,020 cfs (the 50% exceedance event at Vernalis).

- Absent any tidal marsh, floodplain areas are assumed to cover 5,380 acres. Assuming a distribution of flood tolerant agriculture and riparian habitat as per Table EA.3.1-2, Corridor 1B may yield 2,228 acres of riparian and 2,152 acres of flood-tolerant agriculture.
- Results on seasonal floodplain inundation at specific ecologically-relevant discharge levels are included in Section 4.
- In these assumptions the general term 'riparian habitat' is used; however, the final composition of habitats may include mixed riparian vegetation, valley/upland riparian vegetation, and open grasslands depending on the mix of active and passive restoration and the soil and moisture conditions generated.
- No attempt was made to differentiate between the likely percent of riparian habitat that would be developed via active horticultural restoration or would be restored passively through natural recruitment.



Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

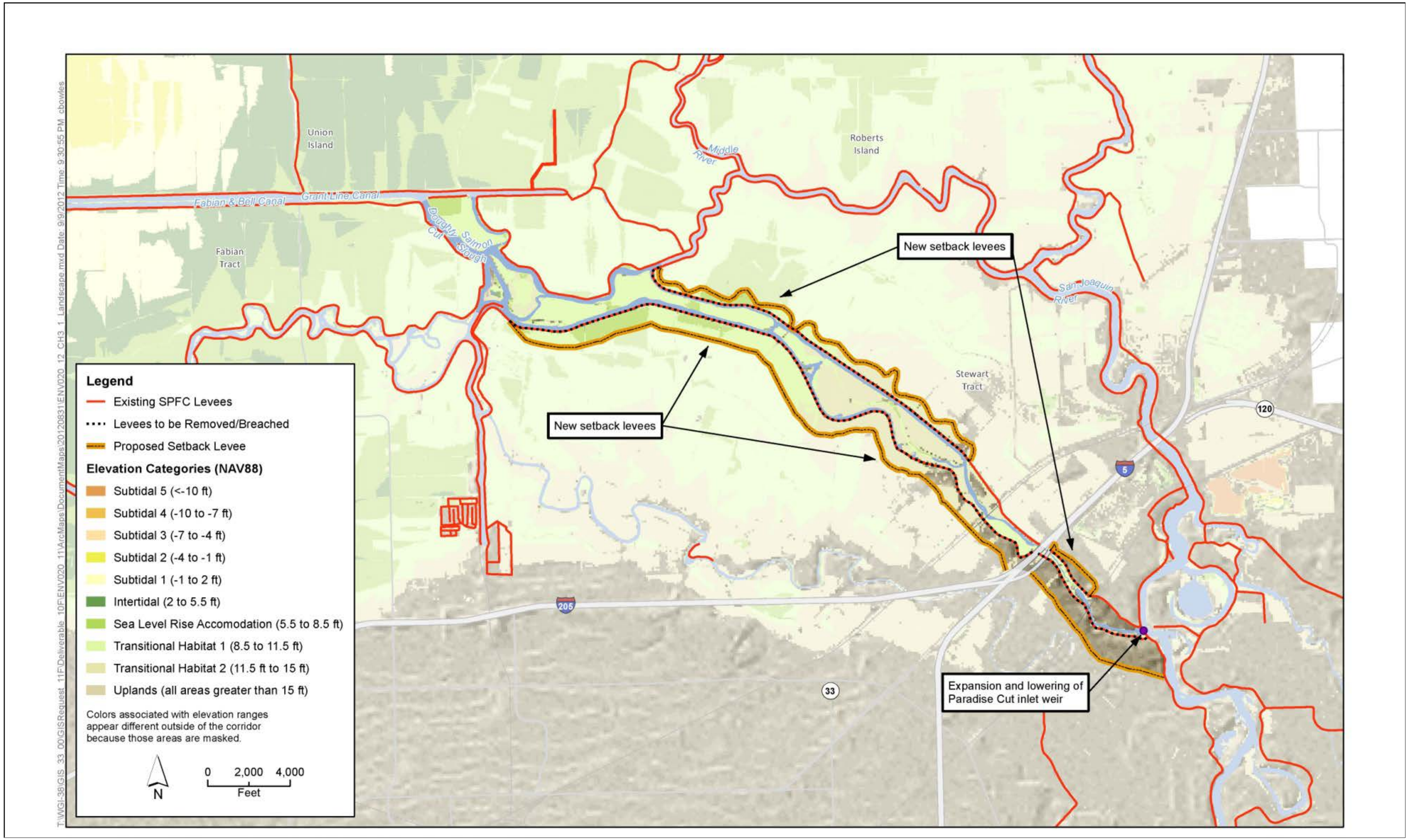
Figure EA.3.1-2: Configuration of South Delta Conceptual Corridor 1B

EA.3.2 Corridor 2

EA.3.2.1 Corridor 2A

Corridor 2A is comprised of an expansion of the Paradise Cut flood bypass as per the levee alignment shown in Figure EA.3.2-1 and modifications to the existing Paradise Cut weir. The weir crest width was assumed to increase to 400 feet (from an assumed 177 feet in the USACE Comprehensive Study model); crest height was assumed at 10.35 feet, (from an assumed 15.35 feet in the USACE Comprehensive Study model). In the hydraulic modeling, no other modeling settings for weir flow were changed from existing conditions. The new weir configuration begins to flow at a San Joaquin River discharge of approximately 6,040 cfs (assessed using Model Run F, no SLR; see Section 7.3). This compares to approximately 12,900 cfs for the existing conditions model run (Mean High Water (MHW), no SLR). Note that if different combinations of corridors are assumed, downstream and upstream hydraulic conditions change and weir spill occurs at different discharge levels. Bridge and railroad crossings in the vicinity of Interstate-5 were left in existing configuration and no dredging or reconfiguration of any channel geometry was assumed.

- The assumed corridor condition expands the floodway area (e.g., the corridor footprint between the levees, not including in-channel areas) from 1,189 acres to 2,289 acres (an increase of 1,100 acres; 48% of the new corridor area).
- In creation of the expanded flood bypass, it is assumed that all existing water-side riprap would be removed and levees breached and/or degraded sufficiently to allow more-dynamic channel migration processes. However, because most of the length of Paradise Cut is an ephemeral distributary of the San Joaquin River, it is assumed that this action would not improve channel-margin channel habitat.
- The potential for tidal marsh in this corridor was estimated using relationships between existing ground elevation behind levees and existing tide range, with an acknowledgment of future for sea level rise. No tidal marsh potential was identified in Corridor 2A, and the expanded bypass is likely to function as seasonally-inundated floodplain covered in riparian habitats and flood-tolerant agriculture. With sea level rise a very small amount of shallow sub-tidal habitat may be created (<50 acres), mostly fringing existing waterways at the downstream end of Paradise Cut.
- Absent any tidal marsh, floodplain areas are assumed to cover 2,289 acres. Assuming a distribution of flood tolerant agriculture and riparian habitat as per Table EA.3.1-2, Corridor 1B may yield 1,145 acres of riparian and 1,145 acres of flood-tolerant agriculture.
- Results on seasonal floodplain inundation at specific ecologically-relevant discharge levels are included in Section 4.
- In these assumptions the general term 'riparian habitat' is used; however, the final composition of habitats may include mixed riparian vegetation, valley/upland riparian vegetation, and open grasslands depending on the mix of active and passive restoration and the soil and moisture conditions generated.
- No attempt was made to differentiate between the likely percent of riparian habitat that would be developed via active horticultural restoration or would be restored passively through natural recruitment.



Sources: CA Levee Database v3.0 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

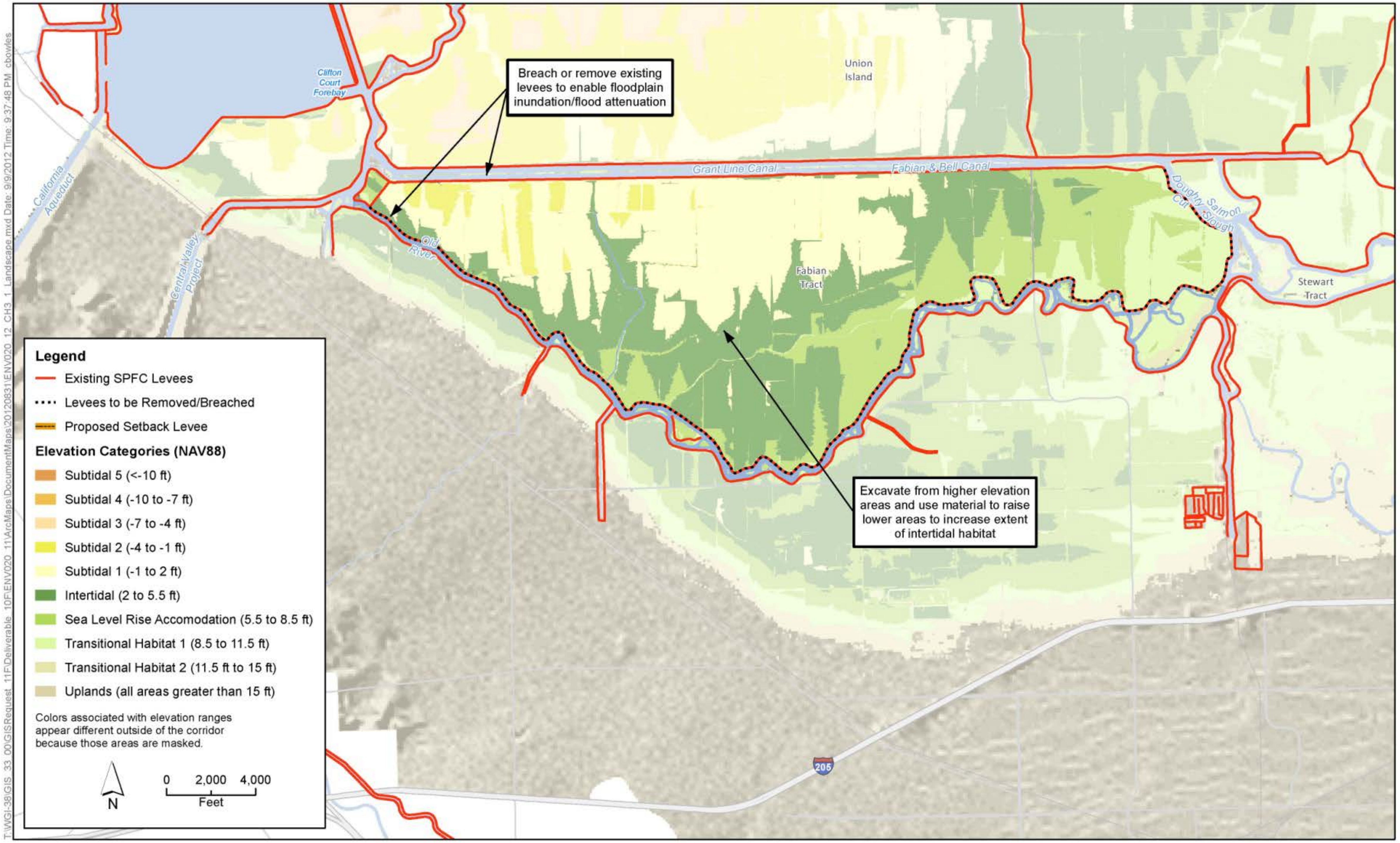
Figure EA.3.2-1: Configuration of South Delta Conceptual Corridor 2A

EA.3.2.2 Corridor 2B

Corridor 2B is comprised of both the footprint of Corridor 2A (Paradise Cut) with the addition of the entirety of Fabian Tract. To provide clarity on the assumptions related to Fabian Tract (with Paradise Cut covered in Corridor 2A, Section 3.2.1) this section only focuses upon Fabian Tract. Consult Table EA.3.1-1 for habitat totals for Corridor 2B that sum Paradise Cut and Fabian Tract.

Actions on Fabian Tract assume levee removal along portions of Old River (right bank), Daughty Cut (left bank), and Grant Line Canal (left bank), as shown in Figure EA.3.2-2. Removal of these levees is assumed to produce a downstream connection with the Old River and such that is also assumed for Walthall Slough, as are some topographic modifications through the slough to account for existing infrastructure such as bridges.

- The assumed corridor condition expands the floodway area (e.g., the corridor footprint between the levees, not including in-channel areas) from 484 acres under existing conditions (the island was mostly leveed from the river) to 6,971 acres (an increase of 6,487 acres; 93% of the new corridor area). Note that this is just for the Fabian Tract portion of Corridor 2B. Consult Table EA.3.1-1 for habitat totals for Corridor 2B that sum Paradise Cut and Fabian Tract.
- The removal of levees on Fabian Tract (as shown in Figure EA.3.2-2) is assumed to include removal of all existing water-side riprap sufficiently to allow more-dynamic channel migration processes. This action is assumed to improve channel-margin channel habitat along one bank for 11.5 miles of channels (including Old River right-bank; Grant Line Canal, left-bank).
- The potential for tidal marsh in this corridor was estimated using relationships between existing ground elevation behind levees and existing tide range, with an acknowledgment of future for sea level rise. Levee removal on Fabian Tract is estimated to produce 6,710 acres of tidal marsh, comprised of tidal habitat, shallow subtidal, and SLR accommodation space (assumed to be tidal habitat for the purposes of evaluations).



Sources: CA Levee Database v3 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.3.2-2: Configuration of South Delta Conceptual Corridor 2B

1 Tidal Marsh restoration approach details and assumptions are as follows:

- Marshplain grading approach:
  - Excavate from higher elevation areas and use material to raise lower areas, to increase the extent of intertidal acreage.
  - Note that the elevation bands shown in Figure EA.3.2-2 are based on existing topography and do not include the effects of grading.
- Grading assumptions:
  - Corridor 2b: Habitat acreages assume excavation of material from Mean High High Water (MHHW) to 1 ft above MHHW and placement of this material from 1 ft below Mean Low Low Water (MLLW) up to MLLW.
  - Actual extent of each habitat will depend on extent of grading.
- The tide range – MLLW to MHHW – is +2 to 5.5 ft NAVD88 for all corridors. This assumption is based on data for existing conditions that have been used previously for BDCP planning (Siegel 2007). These data have several important limitations: the data are of low quality, they do not include tidal damping associated with the restoration, and they do not include the effects of any seasonal barrier operations that may remain after restoration.
- Quality of data. The data supporting this assumption are limited and are being refined. Use of this assumption likely overestimates restored tidal marsh acreage and underestimates subtidal and SLR accommodation acreages. According to unpublished preliminary results of tidal datums with no barriers in place (DWR and WWR, unpublished):
  - Corridor 2b: existing tide range may be closer to 2.5 to 5 ft
- *Tidal damping.* With restoration, the tide range is expected to decrease due to tidal damping. Initial modeling (RMA 2010) simulates:
  - Corridor 2b: results not reported
- *Seasonal barriers.* The current practice of installing seasonal barriers in the south Delta significantly reduces the tide range upstream of the barriers. Under existing operations, barriers are typically in place during the dry season, from June to October. Low water levels, in particular, are higher with the barriers in place (RMA, 2010; DWR and WWR, unpublished).
  - Corridor 2b: low water increases on the order of 1 ft
- Establish tules prior to breaching, particularly within the lower intertidal areas. This may be achieved through water and vegetation management, both allowing vegetation to recruit on its own and active planting.
- Locate and size levee breaches/removal to maximize the development of intertidal marsh (full tidal exchange) and minimize connection to shallow subtidal areas that favor non-native predatory fish.
- Provide slope protection, preferably biotechnical, along levees to withstand wave-induced erosion. This can take the form of improving and maintaining

levees onsite or contributing to improvements and maintenance for adjacent off-site levees.

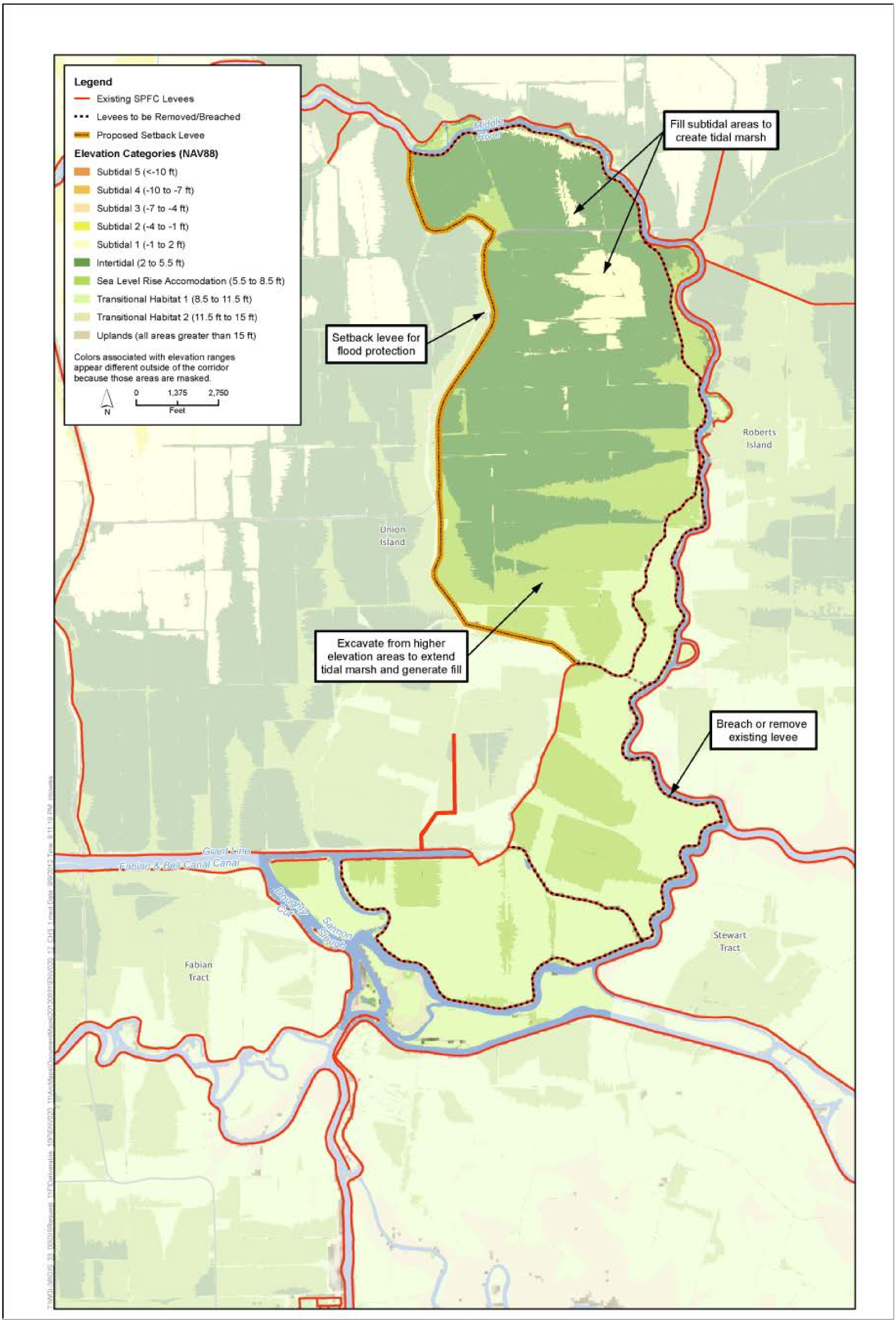
- Excavate to initiate development of tidal channel networks within restored marshes to provide tidal drainage and habitat for target fish species.
- Maximize the potential for natural sedimentation (tidal and episodic flood pulses) and vegetative colonization processes to slowly build land elevations.
- Create habitat heterogeneity by grading microtopography into cut and fill areas and by localized grading of existing homogeneous (farmed) areas. Maintain gentle slopes in excavated areas to facilitate gradual transgression of wetland habitats over sea level rise accommodation space and upstream floodplain habitat.
- No feasibility issues affect the approach or outcomes. For example, fill material (upland or dredged) will be identified and approved for use by the RWQCB. Water output from the site, post-restoration, will meet water quality standards. No legacy or other soil contaminants (i.e. mercury and pesticides) exist.
- No tule growing to raise ground elevations prior to breaching. Given sufficient time (years to decades prior to breaching) this approach could be used to increase the extent of tidal marsh above the acreages presented here. To avoid delaying restoration of an entire parcel, low-lying areas could be separated with new levees and reconnected to the rest of the site after subsidence reversal is accomplished.
- Emergent marsh vegetation will persist as low as MLLW where pre-vegetated and will rapidly (within seven years) colonize elsewhere within the intertidal zone (MLLW to MHHW) (Simenstad et al. 2000). Note that emergent vegetation may persist below MLLW in some locations.

- Given the assumed tidal marsh areas in Fabian Tract, floodplain areas on Fabian Tract are estimated to be approximately 261 acres. Assuming a distribution of flood tolerant agriculture and riparian habitat as per Table EA.3.1-2, Fabian Tract may yield about 235 acres of riparian and perhaps just 26 acres of space suitable for flood-tolerant agriculture.
- Results on seasonal floodplain inundation at specific ecologically-relevant discharge levels are included in Section 4.
- In these assumptions the general term ‘riparian habitat’ is used; however, the final composition of habitats may include mixed riparian vegetation, valley/upland riparian vegetation, and open grasslands depending on the mix of active and passive restoration and the soil and moisture conditions generated.
- No attempt was made to differentiate between the likely percent of riparian habitat that would be developed via active horticultural restoration or would be restored passively through natural recruitment.

EA.3.3 Corridor 3

Corridor 3 is comprised of levee removals and setbacks along portions of Middle River (left bank), Daughty Cut (right bank), and Old River (right bank), as shown in Figure EA.3.3-1.

- The assumed corridor condition expands the floodway area (e.g., the corridor footprint between the levees, not including in-channel areas) from 706 acres under existing conditions to 5,174 acres (an increase of 4,468 acres; 86% of the new corridor area).
- The removal of levees as shown in Figure EA.3.3-1 is assumed to include removal of all existing water-side riprap sufficiently to allow more-dynamic channel migration processes. This action is assumed to improve channel-margin channel habitat along one bank for 11 miles of channels including Middle River (left bank), Daughty Cut (right bank), and Old River (right bank). Active enhancement of channel margin habitat is assumed to occur on the banks opposite the setback levees, yielding an additional 11 miles of actively-enhanced channel margin habitat (22 miles total with a single bank measured; 11 miles total with both banks measured).
- The potential for tidal marsh in this corridor was estimated using relationships between existing ground elevation behind levees and existing tide range, with an acknowledgment of future for sea level rise. Levee removal in Corridor 3 is estimated to produce 3,530 acres of tidal habitat, comprised of tidal marsh, shallow subtidal, and SLR accommodation space (assumed to be tidal habitat for the purposes of evaluations).



Sources: CA Levee Database v3 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.3.3-1: Configuration of South Delta Conceptual Corridor 3

Tidal Marsh restoration approach details and assumptions are as follows:

- Marshplain grading approach:
  - Corridor 3: Excavate from higher elevation areas and use material to raise lower areas, to increase the extent of intertidal acreage and eliminate all shallow subtidal areas except those associated with the tidal channels.
  - All corridors: Note that the elevation bands shown in Figure EA.3.3-1 are based on existing topography and do not include the effects of grading.
- Grading assumptions:
  - Corridor 3: Habitat acreages assume excavation of material from MHHW to 1 ft above MHHW and placement of this material to raise all subtidal areas up to MLLW.
  - Actual extent of each habitat will depend on extent of grading.
- The tide range – MLLW to MHHW – is +2 to 5.5 ft NAVD88 for all corridors. This assumption is based on data for existing conditions that have been used previously for BDCP planning (Siegel 2007). These data have several important limitations: the data are of low quality, they do not include tidal damping associated with the restoration, and they do not include the effects of any seasonal barrier operations that may remain after restoration.
- Quality of data. The data supporting this assumption are limited and are being refined. Use of this assumption likely overestimates restored tidal marsh acreage and underestimates subtidal and SLR accommodation acreages. According to unpublished preliminary results of tidal datums with no barriers in place (DWR and WWR, unpublished):
  - Corridor 3: existing tide range may be closer to 3 to 5.5 ft
- *Tidal damping.* With restoration, the tide range is expected to decrease due to tidal damping. Initial modeling (RMA 2010) simulates:
  - Corridor 3: approximately 0.5 to 0.75 ft of damping
- *Seasonal barriers.* The current practice of installing seasonal barriers in the south Delta significantly reduces the tide range upstream of the barriers. Under existing operations, barriers are typically in place during the dry season, from June to October. Low water levels, in particular, are higher with the barriers in place (RMA, 2010; DWR and WWR, unpublished).
  - Corridor 3: low water increases on the order of 0.5 (observed) to 2 ft (modeled)

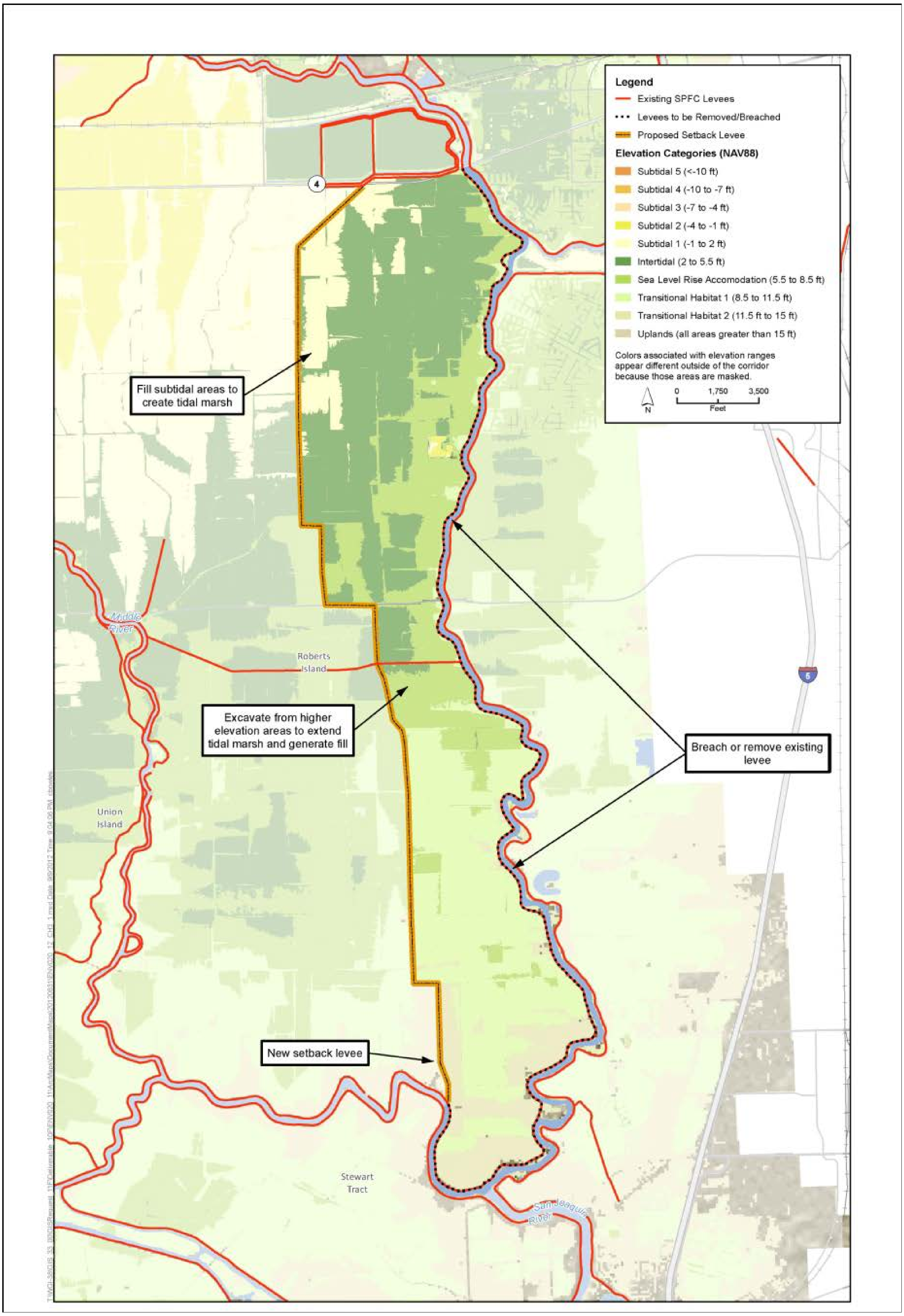
- Given the assumed tidal marsh areas in Corridor 3, floodplain areas in the new corridor are estimated to be approximately 1,644 acres. Assuming a distribution of flood tolerant agriculture and riparian habitat as per Table EA.3.1-2, Corridor 3 may yield about 1,480 acres of riparian and perhaps 160 acres of space suitable for flood-tolerant agriculture.
- Results on seasonal floodplain inundation at specific ecologically-relevant discharge levels are included in Section 4.

- In these assumptions the general term ‘riparian habitat’ is used; however, the final composition of habitats may include mixed riparian vegetation, valley/upland riparian vegetation, and open grasslands depending on the mix of active and passive restoration and the soil and moisture conditions generated.
- No attempt was made to differentiate between the likely percent of riparian habitat that would be developed via active horticultural restoration or would be restored passively through natural recruitment.

EA.3.4 Corridor 4

Corridor 4 is comprised of levee removal and setback along a reach of the San Joaquin River (left bank), with a short reach located along Old River (right bank), as shown in Figure EA.3.4-1.

- The assumed corridor condition expands the floodway area (e.g., the corridor footprint between the levees, not including in-channel areas) from 252 acres under existing conditions to 5,881 acres (an increase of 5,629 acres; 96% of the new corridor area).
- The removal of levees as shown in Figure EA.3.4-1 is assumed to include removal of all existing water-side riprap sufficiently to allow more-dynamic channel migration processes. This action is assumed to improve channel-margin channel habitat along one bank for 12 miles of channels including San Joaquin River (left bank) and Old River (right bank). Active enhancement of channel margin habitat is assumed to occur on the banks opposite the setback levees, yielding an additional 12 miles of actively-enhanced channel margin habitat (24 miles total with a single bank measured; 11 miles total with both banks measured).
- The potential for tidal marsh in this corridor was estimated using relationships between existing ground elevation behind levees and existing tide range, with an acknowledgment of future for sea level rise. Levee removal in Corridor 4 is estimated to produce 3,820 acres of tidal marsh, comprised of tidal habitat, shallow subtidal, and SLR accommodation space (assumed to be tidal habitat for the purposes of evaluations).



Sources: CA Levee Database v3 r1 2011; South Delta Preliminary River Corridors, ESA 2012.

Figure EA.3.4-1: Configuration of South Delta Conceptual Corridor 4

Tidal Marsh restoration approach details and assumptions are as follows:

- Marshplain grading approach:
  - Corridor 4: Excavate from higher elevation areas and import fill. Use fill material to raise lower areas, increasing the extent of intertidal acreage and eliminating all shallow subtidal areas except those associated with the tidal channels.
  - All corridors: Note that the elevation bands shown in Figure EA.3.4-1 are based on existing topography and do not include the effects of grading.
- Grading assumptions:
  - Corridor 4: Habitat acreages assume excavation of material from MHHW to 1 ft above MHHW and placement of this material plus imported fill to raise all subtidal areas up to MLLW. This would require a moderate amount (~140,000 CY) of imported fill. Possible sources include dredged material from the Stockton Shipping Channel.
  - Actual extent of each habitat will depend on extent of grading.
- The tide range – MLLW to MHHW – is +2 to 5.5 ft NAVD88 for all corridors. This assumption is based on data for existing conditions that have been used previously for BDCP planning (Siegel 2007). These data have several important limitations: the data are of low quality, they do not include tidal damping associated with the restoration, and they do not include the effects of any seasonal barrier operations that may remain after restoration.
- Quality of data. The data supporting this assumption are limited and are being refined. Use of this assumption likely overestimates restored tidal marsh acreage and underestimates subtidal and SLR accommodation acreages. According to unpublished preliminary results of tidal datums with no barriers in place (DWR and WWR, unpublished):
  - Corridor 4: existing tide range may be closer to 2.5 or 3 to 5.5 ft
- *Tidal damping.* With restoration, the tide range is expected to decrease due to tidal damping. Initial modeling (RMA 2010) simulates:
  - Corridor 4: approximately 0.5 ft of damping
- *Seasonal barriers.* The current practice of installing seasonal barriers in the south Delta significantly reduces the tide range upstream of the barriers. Under existing operations, barriers are typically in place during the dry season, from June to October. Low water levels, in particular, are higher with the barriers in place (RMA, 2010; DWR and WWR, unpublished).
  - Corridor 4: no notable effect

- Given the assumed tidal marsh areas in Corridor 4, floodplain areas in the new corridor are estimated to be approximately 2,061 acres. Assuming a distribution of flood tolerant agriculture and riparian habitat as per Table EA.3.1-2, riparian habitat is anticipated to occupy all of the floodplain area in Corridor 4 (2,061 acres).

- Results on seasonal floodplain inundation at specific ecologically-relevant discharge levels are included in Section 4.
- In these assumptions the general term 'riparian habitat' is used; however, the final composition of habitats may include mixed riparian vegetation, valley/upland riparian vegetation, and open grasslands depending on the mix of active and passive restoration and the soil and moisture conditions generated.
- No attempt was made to differentiate between the likely percent of riparian habitat that would be developed via active horticultural restoration or would be restored passively through natural recruitment.

EA.3.5 Applicable BDCP Alternative

For the purposes of completing the South Delta evaluations, evaluators are to assume BDCP Alternative 1A (Dual Conveyance with Tunnel and Intakes 1–5 [15,000 cfs; Scenario A Operations]). A summary of related assumptions and details are summarized below; however, the draft BDCP EIR/EIS "Chapter 3 – Description of Alternatives" document (dated 12/07/11, located at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Chapter_3_-_Description_of_Alternatives.sflb.ashx) shall serve as the definitive source of reference for operations and related information, and is incorporated herein via reference. Modeling results from CalSIM II and DSM2 for Alternative 1A were made available to evaluators at the modified-DRERIP evaluation workshop.

- Alternative 1A would primarily convey water from the north Delta to the south Delta through pipelines/tunnels.
- Alternative 1A also includes restoration in the South Delta after the dual conveyance has been established. Actions in the South Delta would contribute toward these habitat conservation components:
  - 65,000 acres of restored freshwater and brackish tidal habitat within the BDCP Restoration Opportunity Areas (ROAs) (CM 4, Tidal Restoration);
  - 10,000 acres of seasonally inundated floodplain habitat within the north, east, and/or south 6 Delta (CM5, Seasonally-Inundated Floodplain Restoration);
  - 20 linear miles of channel margin habitat enhancement in the Delta (CM6, Channel Margin Enhancement), and
  - 5,000 acres of restored valley/foothill riparian habitat (CM7, Riparian Restoration).
- Modified-DRERIP evaluations of the corridors assume these conservation measure actions, as configured in the restored corridors described above in Section 3.1 through 3.5, in the BDCP late long-term.

EA.3.5.1 South Delta Barrier Operations

- Alternative 1A does not include installation of physical or nonphysical barriers at the junction of channels with low survival of outmigrating juvenile salmonids to deter fish from entering these channels. As such, the South Delta Temporary Barriers Project is assumed to <u>not</u> be in place for the purposes of the modified-DRERIP evaluations.

- Alternative 1A does not include any operable barriers to support water conveyance (see Section 3.6.1.3 Operable Barriers, Draft BDCP EIR/EIS). However,
  - Conservation Measure 16 (CM16, Nonphysical Fish Barriers), which is assumed as a part of Alternative 1A, is also an assumed for the purposes of the modified-DRERIP evaluations. CM16 seeks to improve the survival of out-migrating juvenile salmonids by using nonphysical barriers to direct them away from channels in which survival is lower. Locations would include the Head of Old River, the Delta Cross Channel, and Georgiana Slough, and could possibly include Turner Cut, Columbia Cut, the Delta Mendota Canal intake, and Clifton Court Forebay. Such a nonphysical barrier would include a combination of sound, light, and bubbles; and would be installed and operated during October to June or when monitoring by the Fishery Agencies determines that salmonid smolts are present in the areas where barriers are to be installed. Nonphysical barrier placement may also be accompanied by methods to reduce local predator abundance described in CM15 (Predator Control), if monitoring finds that barriers attract predators. Until the time of BDCP implementation, existing nonphysical fish barrier serving as a pilot project at the head of Old River is assumed to continue to be operated.
- The SDHWG charter requests that evaluators assess how corridors may be consistent with a barrier at the head of Old River (physical or nonphysical), or how the corridor can achieve the same or better benefits without the barrier or with a barrier open more of the time than currently planned. This is not a base assumption, and is considered and noted during the evaluations.
- How the conservation measure might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants. This is not a base assumption, and is considered and noted during the evaluations.

EA.3.5.2 South Delta Water Operations

The operational criteria for the BDCP alternatives are summarized and assigned letters as operational scenarios. The operational criteria for Alternative 1A are based on those guidelines set forth in the BDCP Steering Committee handout of 2/11/10, and are identified as Operation Scenario A.

Scenario A, described in detail in Section 3.6.4.2 of the draft BDCP EIR/EIS, includes specific criteria guiding water supply parameters at a variety of locations and facilities. This includes criteria for: north Delta diversion bypass flows; south Delta channel flows; Fremont Weir / Yolo Bypass operations; Delta inflow and outflow; Delta Cross Channel gate operations; Rio Vista minimum instream flows; Delta water quality and residence time, and in-Delta agricultural, municipal, and industrial water quality requirements. Highlighted below are some of the South Delta Water Conveyance Operational Criteria relevant to the modified-DRERIP evaluations.

EA.3.5.2.1 South Delta Channel Flows Criteria

The objectives of the south Delta channel flows criteria are to minimize take at south Delta pumps by reducing incidence and magnitude of reverse flows during critical periods for pelagic species. The south Delta channel flows criteria use two parameters: Old and Middle River (OMR) flow criteria and South Delta Export–San Joaquin River Inflow Ratio, as summarized below.

EA.3.5.2.2 OMR Flows

The criteria are based on concepts addressed in the 2008 USFWS and 2009 National Marine Fisheries Service (NMFS) BOs related to adaptive restrictions for temperature, turbidity, salinity, and presence of delta smelt. The criteria, presented in draft BDCP EIR/EIS Table 3-10, are considered to be an estimate of "most likely" water operations under the BOs for modeling purposes.

EA.3.5.2.3 South Delta Export–San Joaquin River Inflow Ratio

This ratio uses a sliding scale for flows in excess of the OMR flow criteria, as presented in draft BDCP EIR/EIS Table 3-11, to share additional San Joaquin River flows between diversions at the SWP and CVP south Delta export facilities and environmental requirements. The export proportions would increase with rising San Joaquin River flows. This criteria also considers the time value of the benefit from using this ratio, including crediting outside of the period of time when the flows are acquired.

EA.3.5.2.4 Operations for Delta Water Quality and Residence Criteria

The objectives of the operations for Delta water quality and residence criteria, summarized below, are to (1) maintain a minimum level of pumping from the south Delta during summer to provide limited flushing to reduce residence times and improve water quality; (2) provide salinity improvements for municipal, industrial, and agricultural water users; and (3) allow operational flexibility during other periods to operate either north or south diversions based on real-time assessments of benefits to fish and water quality.

- July–September. Preferentially operate SWP and CVP south Delta export facilities up to 3,000 cfs of diversions before diverting from north Delta intakes.
- October–June. Preferentially operate north Delta intakes.

EA.3.5.2.5 In-Delta Municipal, Industrial, and Agricultural Water Quality Requirements Criteria

The in-Delta municipal, industrial, and agricultural water quality requirements criteria would require the SWP and CVP to comply with existing agreements with water rights holders related to operations of the SWP and CVP. These requirements include water operations in accordance with State Water Board D-1641 related to north Delta and western Delta agricultural and municipal and industrial requirements, except that the Sacramento River compliance point for the agreement with the North Delta Water Agency would be moved from Emmaton to Three mile Slough.

EA.4 Evaluation Results

This section provides the anticipated changes in habitats and physical and ecosystem processes that would be the result of implementing the corridors described in Section 3. It also provides summaries of the species-based outcomes generated by the modified-DRERIP evaluations completed on February 1 and 2, 2012. The section is presented in two parts: Section 4.1 presents the expected "intermediate outcomes" as estimated, modeled, and assumed based on technical work by the support team. Section 4.2 presents a summary of the results of the modified-DRERIP and flood evaluations.

The intermediate outcomes described in Section 4.1 were used in the subsequent modified-DRERIP evaluations and are based on technical work completed by the support team. This work included hydrologic and hydraulic modeling and identifying potential areas of restored tidal marsh and tidal perennial aquatic habitats using elevation data. The intermediate outcomes provide as much quantitative information as was feasible and appropriate during this screening-level assessment to support the evaluation of outcomes for target species during the modified-DRERIP evaluations. Detailed descriptions of the development of the four corridors and technical analyses conducted to reach the intermediate outcomes are provided in Section 7. While not specific to the South Delta area, the draft BDCP Appendix 5.E, *Habitat Restoration*, provides additional scientific information and rationale for the expected intermediate outcomes presented in Section 4.1 and the species-based outcomes presented in Section 4.2. Appendix 5.E of the BDCP is incorporated by reference. However, it is important to note that the BDCP Effects Analysis (Chapter 5) and some information in Appendix 5.E include different assumptions for habitat actions, areas and even different modeling tools and assumptions. Thus, the following ecological outcomes (this South Delta work) may not be completely consistent with what is presented in Chapter 5 and Appendix 5.E.

A few notes on sea level rise and hydrology in relation to Section 4:

- Tidal marsh outcomes are considered with a sea level rise of 16 inches, assumed to occur by mid-century.
- Floodplain habitat outcomes are considered with and without sea level rise. When sea level rise is considered, 55-inches of sea level rise was assumed to occur by the end of the century.
- Flooding outcomes were assessed with and without sea level rise. When sea level rise is considered, 55-inches of sea level rise was assumed to occur by the end of the century.
- Foodweb production outcomes were evaluated under the historic flow regime and, as per the SDHWG charter, with the assumption of a San Joaquin River Restoration Program (SJRRP) restoration hydrograph (i.e., increased flows on the San Joaquin River).

EA.4.1 Intermediate Habitat- and Process-Based Outcomes

Intermediate outcomes are described for channel margin habitat, floodplain habitat and food production, riparian habitat, and water quality. In the following subsections, a series of tables and graphs summarize the intermediate outcomes for each corridor.

EA.4.1.1 Corridor 1

The following subsections provide a series of tables and bullet statements that outline some of the key potential benefits and impacts that would result if Corridor 1 were implemented. Table EA.4.1-1 summarizes key habitat changes. Generally, Corridor 1A would increase floodplain and riparian habitat extent along the San Joaquin River, which is a primary migratory corridor for salmonids where habitat is considerably lacking. No new tidal marsh is estimated. Habitat improvements would occur under potential actions in Corridor 1B, but to a lesser extent given the smaller corridor size.

Table EA.4.1-1. Habitat Changes in Corridor 1

	New Corridor Footprint (Total Area between Levees; *river excluded*)	**Tidal Freshwater Emergent Wetland, *assuming grading and SLR (acres)***		**Tidal Perennial Aquatic, *assuming grading* and SLR (acres)**		**Riparian (acres)**		**Length of Channel Margin Habitat (miles; Right Bank [RB] vs Left Bank [LB] defined; *totals are the sum of active and passive*)**	
Corridor	**acres**	**Existing Conditions**	**New Corridor**	**Existing Conditions**	**New Corridor**	**Existing Conditions**	**New Corridor**	**Passive**	**Active**
1A	11,741	19	–	1,046	–	1,176	8,219	16 RB & LB (32 total both banks)	–
1B	5,380	18	–	607	–	588	3,228	8.5 (RB only)	–

EA.4.1.1.1 BDCP Covered Species

By creating and expanding habitats, BDCP Covered Species benefitting from Channel Margin and Tidal Marsh Habitat improvements in the South Delta include:

- All fish (improved thermal regulation, improved water quality, food web support)
- California black rail
- California clapper rail
- California least tern
- Tricolored blackbird
- Giant garter snake
- Western pond turtle
- Delta mudwort
- Delta tule pea
- Legenere
- Mason's lilaeopsis
- Slough thistle
- Suisun marsh aster

BDCP Covered Species benefitting from Riparian and Floodplain Habitat Enhancements in the South Delta include:

- All fish (either directly or from food web support to downstream areas)
- Riparian brush rabbit and riparian woodrat
- Townsend's big-eared bat – prefers dense wooded areas for foraging
- Swainson's hawk nesting habitat increased with increases in riparian woodland. Swainson's hawk foraging could be supported by infrequently inundated floodplain areas (grasslands).
- White tailed kite - nesting
- Western yellow-billed cuckoo – nesting and foraging
- Valley elderberry longhorn beetle
- Delta button celery (currently known to occur along the San Joaquin River in Corridor 1, occupies floodplain habitat with clay soils)

EA.4.1.1.2 Channel Margin

Current data wasn't available to quantify the extent of existing channel margin habitat; however, it is anticipated that the overall extent and quality would increase where levees are breached and natural channel processes and vegetation are allowed to re-establish along the banks of the San Joaquin River. Some improvements would be expected along Walthall Slough as well, but were not estimated. Channel margin habitat is estimated to increase by 16 miles along the San Joaquin River (or 32 miles if both banks are considered) through physical components such as woody debris and undercut banks, and in shaded riverine vegetation, both of which serve as cover for foraging fish and substrates for aquatic invertebrates. In some instances these areas may be suitable for splittail spawning. These near shore environments also provide cover during high flow events.

Anticipated Benefits

- Increased in-channel foraging habitat for covered fish
- Increased cover habitat for covered fish
- Improved thermal regulation and increased dissolved oxygen levels
- Increased organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.

Potential Impacts

- Increased predation of covered fish by birds
- Potential for increased predation of covered fish by non-native fish
- Establishment and proliferation of invasive non-native vegetation.

EA.4.1.1.3 Floodplain Habitat and Food Production

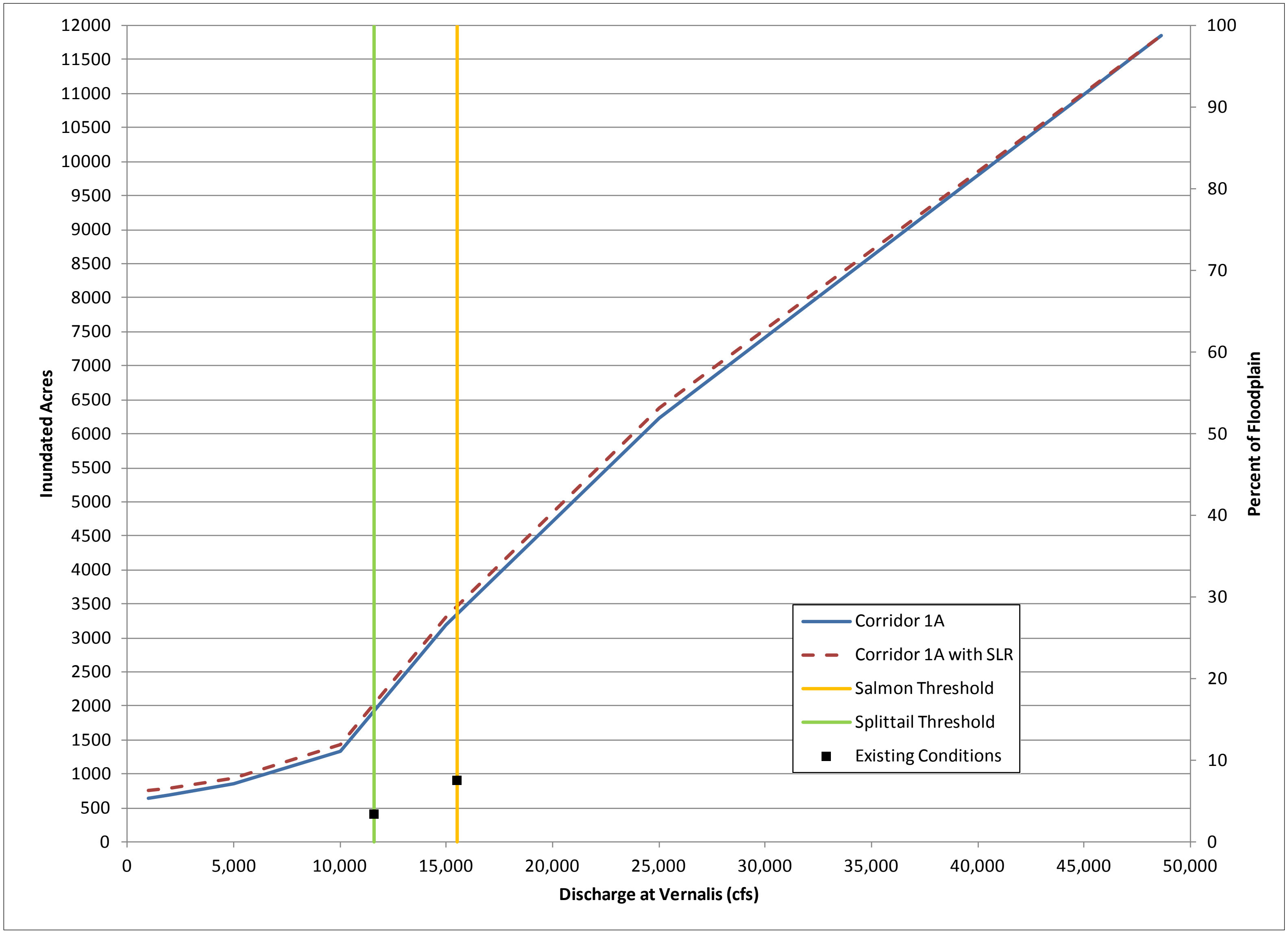
An increase in the extent and frequency of floodplain inundation is expected to occur along the San Joaquin River and areas in between the San Joaquin River and Walthall Slough following the removal of levees. Floodplain habitat will likely support a mosaic of vegetation types depending on a variety of factors including depth to groundwater, frequency of inundation, and soil properties. The anticipated benefits for both corridors are similar, but differ by extent and to some extent ecosystem function support. The more-extensive floodplain reconnection activities along the San Joaquin River in Corridor 1A will likely have a greater effect on re-establishing key ecosystem processes and result in a more dynamic mosaic of grassland, riparian woodland, and riparian scrub floodplain habitats and interfaces.

Table EA.4.1-2 presents the estimated changes in seasonally-inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3). Figure EA.4.1-1 and Figure EA.4.1-2 illustrate the relationship between river discharge (as measured at Vernalis) and floodplain inundation with and without assumed sea level rise for Corridors 1A and 1B, respectively. These curves can be used to assess other discharge levels that evaluators may find to be potentially relevant to species outcomes. Of note, the assumed Walthall Slough weir begins to overtop at 23,805 cfs (assuming Model Run E conditions; see Section 7.3). Though other floodplain inundation along the San Joaquin River in Corridor 1B may occur at other discharge levels, a direct upstream connection is not made until that discharge level.

Floodplain inundation related to food production was assessed using the methods described in Section 7.3. Table EA.4.1-3 and Table EA.4.1-4 illustrate the probability that specified percentages of the corridor floodplains are inundated assuming different inundation durations. These results are presented graphically in Figure EA.4.1-3 and Figure EA.4.1-4, and include results for existing and “with San Joaquin River Restoration flow regime” hydrology.

Table EA.4.1-2: Changes in Ecologically-Relevant Floodplain Inundation in Corridor 1

	Existing Conditions			**Corridor Conditions - with Sea Level Rise**								
					Existing Flow Regime				**SJRRP Flow Regime**			
	Existing Corridor Footprint *(Total Existing Area between Levees; river excluded)*	**Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs***	**Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs***	**New Corridor Footprint *(Total Area between Levees; river excluded)***	**Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs (river excluded)***		**Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs (river excluded)***		**Inundated Floodplain Habitat *assuming Salmon Threshold(river excluded)***		**Inundated Floodplain Habitat *assuming Splittail Threshold (river excluded)***	
Corridor	**Acres**	**acres**	**acres**	**acres**	**acres**	**Percent of new corridor footprint**	**acres**	**Percent of new corridor footprint**	**acres**	**Percent of new corridor footprint**	**acres**	**Percent of new corridor footprint**
1A	2,524	910	412	11,741	3,500	28%	2,000	16%	3,500	28%	2,200	19%
1B	1,593	532	213	5,380	1,750	31%	1,200	21%	1,800	33%	1,250	23%



1
2 **Figure EA.4.1-1: Relation between Discharge and Floodplain Inundation: Corridor 1A**

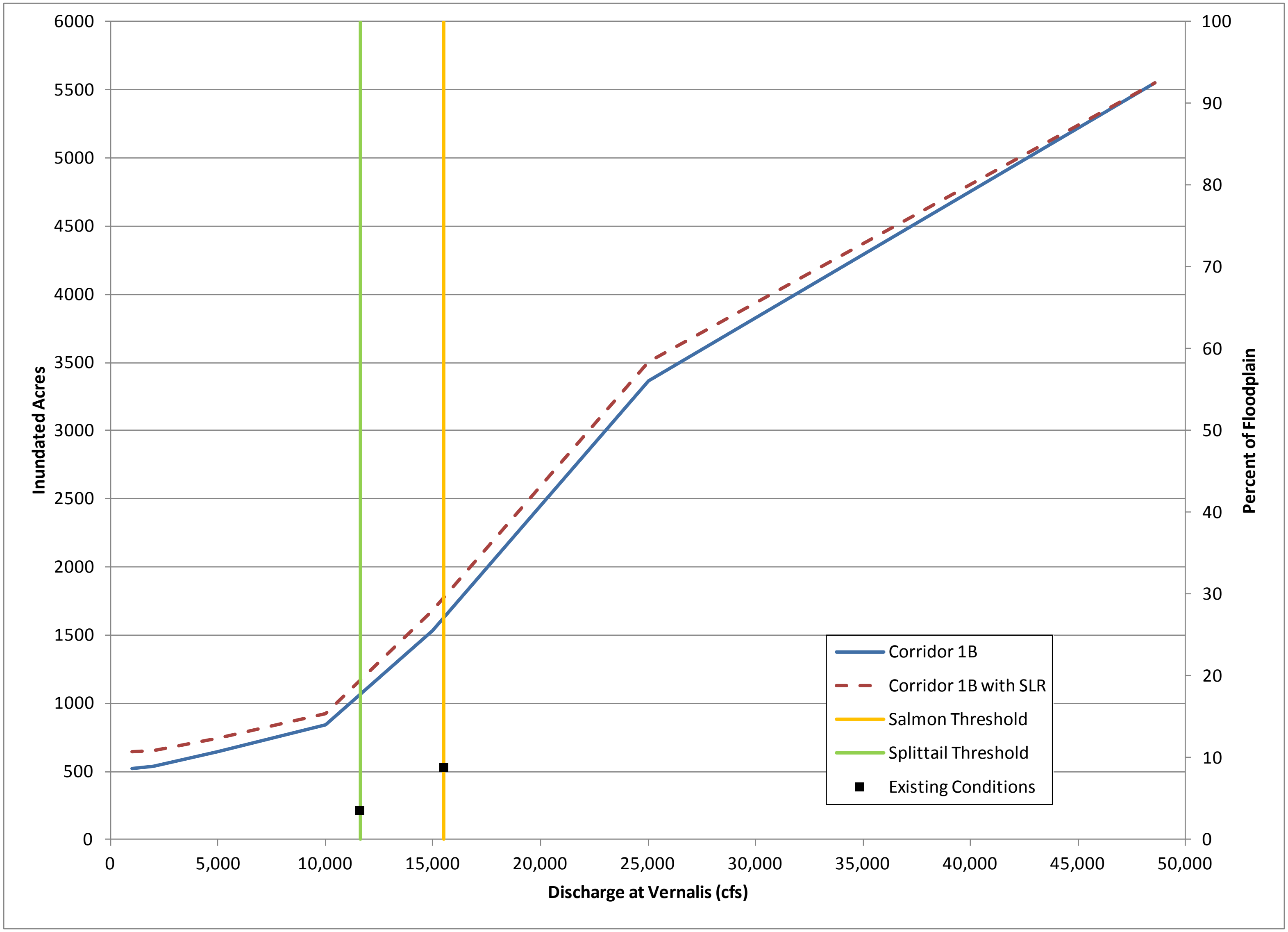


Figure EA.4.1-2: Relation between Discharge and Floodplain Inundation: Corridor 1B

Table EA.4.1-3: Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 1A

Season: Dec. 1 – May 31						
	Exceedance Probability					
	16,000 cfs (30% of the corridor's potential new floodplain is inundated)		29,000 cfs (60% of the corridor's potential new floodplain is inundated)		49,000 cfs (90% of the corridor's potential new floodplain is inundated)	
Duration (days)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)
2	0.257	0.257	0.217	0.211	0.141	0.139
4	0.256	0.256	0.216	0.208	0.137	0.134
6	0.255	0.255	0.221	0.157	0.131	0.111
8	0.253	0.254	0.189	0.154	0.108	0.092
10	0.251	0.252	0.172	0.153	0.089	0.091
12	0.249	0.249	0.158	0.152	0.089	0.090
14	0.248	0.249	0.155	0.151	0.089	0.090
16	0.247	0.247	0.153	0.150	0.000	0.000
18	0.247	0.247	0.149	0.145	0.000	0.000
20	0.244	0.245	0.149	0.142	0.000	0.000
Created using area/discharge curves under without SLR conditions. For SLR conditions, refer to the area/discharge curves to identify applicable acreages and percentages.						

Table EA.4.1-4: Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 1B

Season: Dec. 1 – May 31						
	Exceedance Probability					
	16,000 cfs (30% of the corridor's potential new floodplain is inundated)		27,500 cfs (60% of the corridor's potential new floodplain is inundated)		46,000cfs (90% of the corridor's potential new floodplain is inundated)	
Duration (days)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)
2	0.257	0.257	0.222	0.216	0.144	0.142
4	0.256	0.256	0.221	0.216	0.141	0.137
6	0.255	0.255	0.216	0.214	0.135	0.118
8	0.253	0.254	0.213	0.211	0.116	0.100
10	0.251	0.252	0.202	0.166	0.097	0.098
12	0.249	0.249	0.187	0.157	0.097	0.098
14	0.248	0.249	0.172	0.156	0.097	0.097
16	0.247	0.247	0.162	0.155	0.000	0.000
18	0.247	0.247	0.157	0.152	0.000	0.000
20	0.244	0.245	0.157	0.150	0.000	0.000
Created using area/discharge curves under without SLR conditions. For SLR conditions, refer to the area/discharge curves to identify applicable acreages and percentages.						

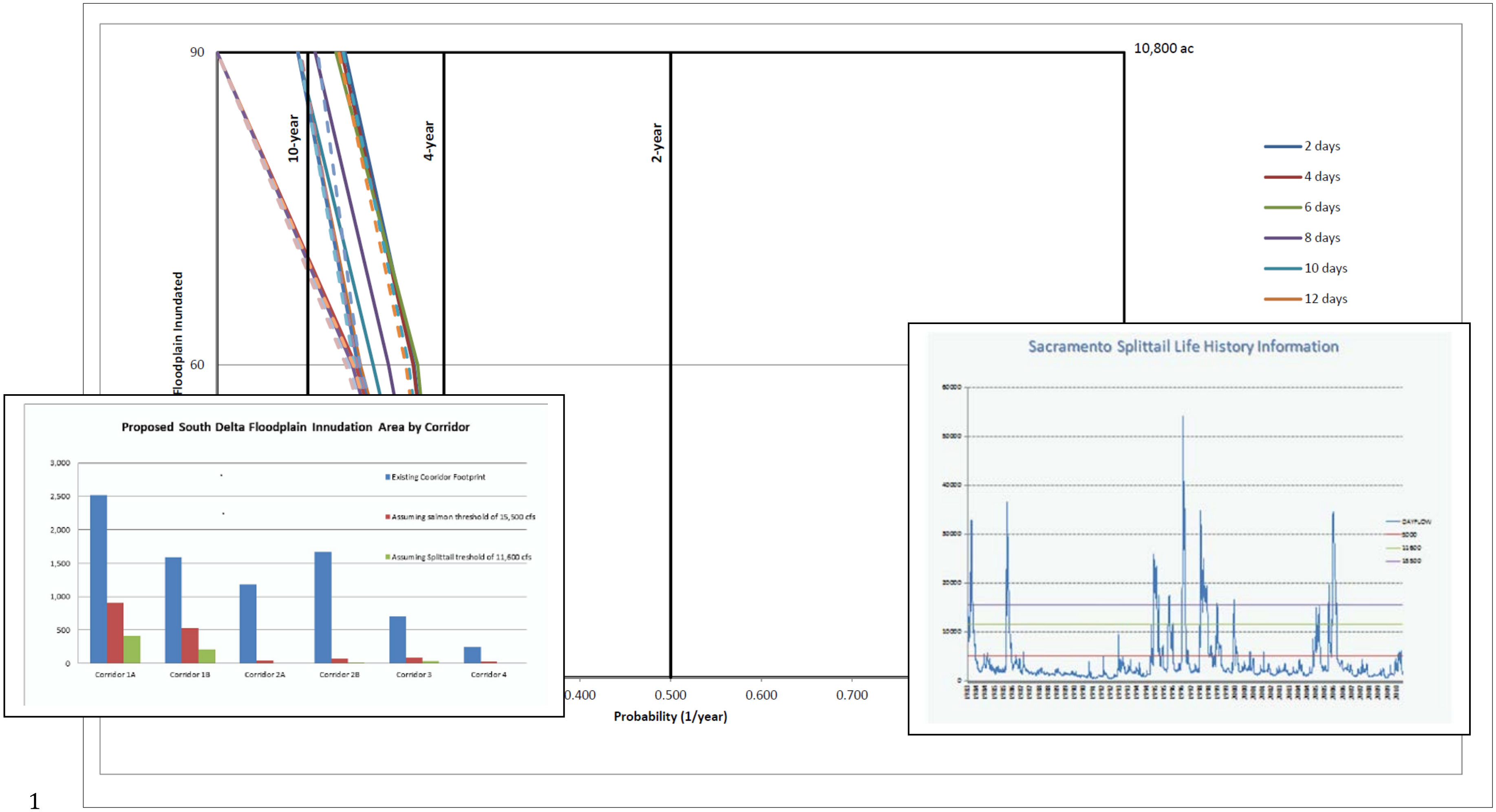


Figure EA.4.1-3: Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 1A

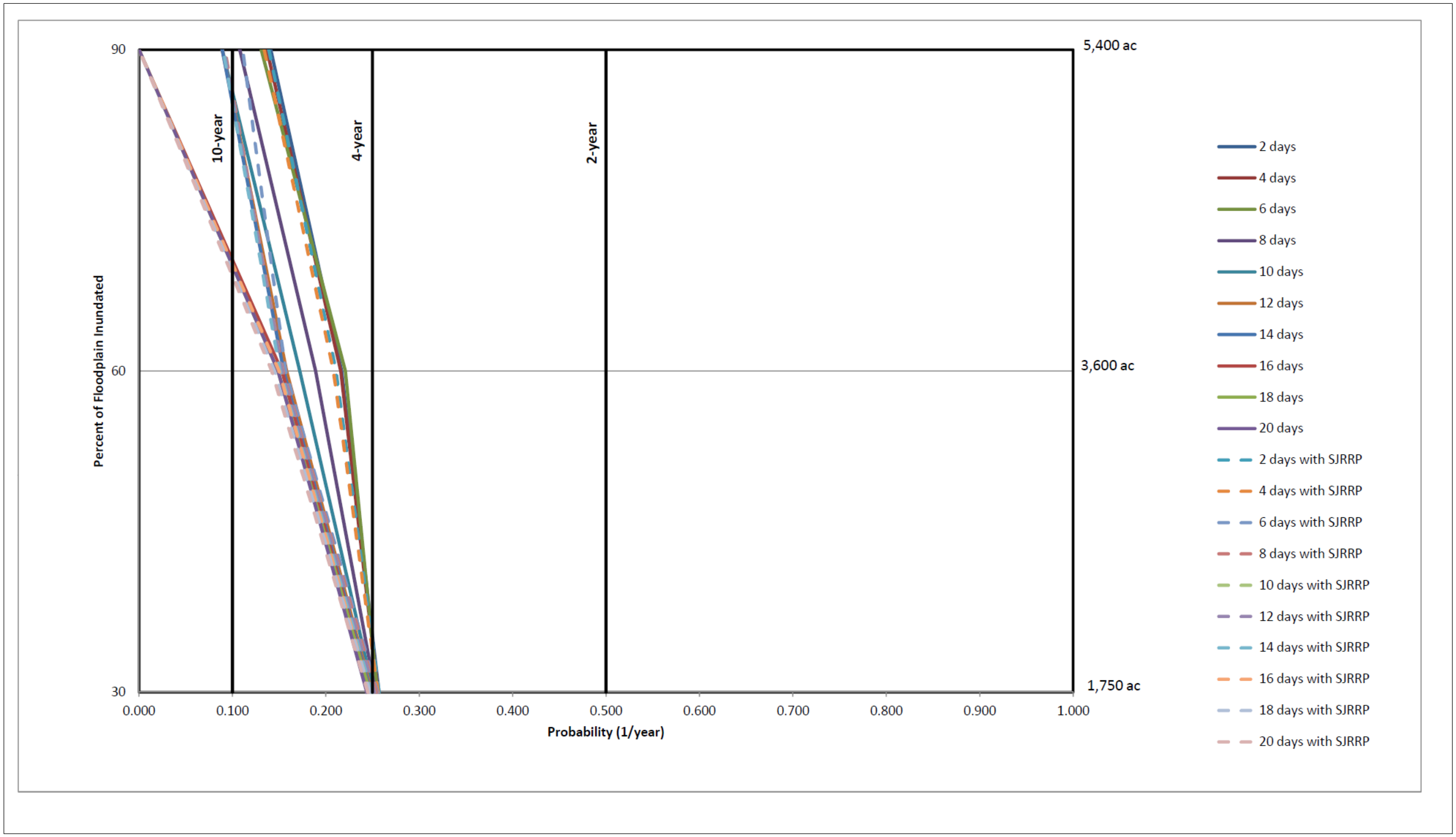


Figure EA.4.1-4: Range of Frequencies and Durations for Flows Relevant to Foodweb Production, Corridor 1B

The anticipated benefits and potential negative impacts for reconnecting the San Joaquin River to an expanded floodplain are listed below. Some of the benefits and impacts listed below also apply and are repeated below under the riparian ecosystem discussion, in the subsection below

Anticipated Benefits

- Water temperatures on the floodplain are warmer than in-channel temperatures during large winter events, a benefit to juvenile fish utilizing this habitat.
- Water quality improvements for in-stream conditions as sediments in flood waters are dropped out of the water column and are deposited on the floodplain.
- An expanded floodplain with direct connection to a prime migratory corridor for salmonids.
- Improved access to seasonally inundated floodplain habitat creates additional spawning habitat for splittail and additional rearing habitat for salmonids, splittail, and steelhead.
- Seasonally inundated habitats with the cycles of wetting and drying act are believed to act as a "productivity pump" to the lower estuary (CNRA, 2011).
- Flushing of backwaters to remove floating and submerged aquatic vegetation opens up habitat for use of shallow, near shore habitat for salmonids and smelt.
- Reduce non-point source pollution for improved water quality.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Access to slower floodplain water velocities reduces stress on juvenile fish during extreme water events.

Potential Impacts

- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension. Fish and other aquatic species utilizing recently reconnected/restored floodplain habitat would be exposed to these increased levels of methylmercury and it may be transported downstream.
- Establishment and proliferation of invasive non-native vegetation.
- Potential for fish stranding on the floodplain.
- Reduced turbidity in downstream waters may have a negative impact on delta smelt, which are commonly found in turbid waters.

EA.4.1.1.4 Riparian

Additional riparian habitat is expected to establish along the San Joaquin River and areas in between the San Joaquin River and Walthall Slough following the removal of levees and reactivation of the floodplain. It is estimated that potential corridor actions will provide an additional 7,028 acres of riparian habitat in Corridor 1A. In comparison, with the more limited actions in Corridor 1B, only an additional 2,640 acres of riparian habitat is estimated to have potential to re-establish. The anticipated benefits for both corridors are similar, but primarily differ by extent and ecosystem function support.

Anticipated Benefits

- Reduced non-point source pollution and improving overall water quality.
- Re-establishing a fairly contiguous corridor of riparian habitat along San Joaquin River increases connectivity providing cover for terrestrial species and facilitates genetic exchange.
- Improved thermal regulation and improved dissolved oxygen levels.
- Supports the establishment of a dynamic complex of woody and scrub habitat along the river channel and in the floodplain over the long-term provide in stream aquatic habitat in the form of overhead cover and inputs of large woody debris.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Riparian vegetation slows water velocities in the floodplain for salmonids and splittail reducing stress on juvenile fish during extreme water events.
- Riparian habitat increases organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.
- Improved riparian habitat resilience during periodic perturbations and potentially to climate change (Seavy et al., 2009) by increasing overall habitat extent, improving connectivity, and allowing for plant community diversity.
- Additional cover for native fisheries from predatory fish.
- Potential for phytoremediation of toxins within soil (not well understood at this time, but Poplar hybrids are commonly used and some willow species have shown promise).
- Removal of submerged aquatic vegetation in back-channel/oxbow areas following increased flow.

Potential Impacts

- Increased fire hazard, particularly in non-native species such as giant reed and tamarisk become established.
- Perception of increased 'weed' control needs for adjacent agricultural land owners (not necessarily an ecological impact, but something that will likely be an issue).
- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension.
- Establishment and proliferation of invasive non-native vegetation.
- Increased fish stranding on the floodplain.

EA.4.1.1.5 Water Quality

Anticipated water quality benefits and impacts are listed below. Note that no modeling was completed and these are conceptualized process-based outcomes.

- Water temperatures on the floodplain are warmer than in-channel temperatures during large winter events, which benefits juvenile fish utilizing inundated floodplains.

- Reduced in-stream turbidity as sediments in flood waters are dropped out of the water column and are deposited on the floodplain.
- Reduce non-point source pollution for improved water quality.
- A slight benefit to downstream dissolved oxygen could occur as a result of fringe wetland enhancement.
- Similarly, a small increase in organic carbon exports from the channel could occur during flood events, however, these would likely be masked organic carbon from overbank sources during flood events.
- Minimal nutrient load reductions may occur due to Corridor 1a and 1b implementation, as a result of reduced agricultural use and processes in channel fringe wetlands.

EA.4.1.2 Corridor 2

The following subsections provide a series of tables and bullet statements related to some of the key potential benefits and impacts resulting from the assumed actions comprising Corridor 2. Table EA.4.1-5 summarizes key habitat changes. Within Corridor 2A, there is potential for an increase in floodplain and riparian habitat, especially on Pescadero Tract. The lower portion of Corridor 2A has higher elevations and is not likely to support riparian, but would provide seasonally inundated floodplain habitat. Within Corridor 2B, there is potential for a substantial increase in tidal habitat including subtidal and tidal marsh within Fabian Tract. Riparian vegetation establishment would likely be confined to the eastern end of Fabian Tract.

Table EA.4.1-5: Habitat Changes in Corridor 2

	New Corridor Footprint (Total Area between Levees; *river excluded)*	**Tidal Freshwater Emergent Wetland, *assuming grading and SLR (acres)***		**Tidal Perennial Aquatic, *assuming grading* and SLR (acres)**		**Riparian (acres)**		**Length of Channel Margin Habitat (miles; RB vs LB defined; *totals are the sum of active and passive)***	
Corridor	**acres**	**Existing Conditions**	**New Corridor**	**Existing Conditions**	**New Corridor**	**Existing Conditions**	**New Corridor**	**Passive**	**Active**
2A	2,289	12	12	252	252	263	1,145	0.0	-
Fabian Tract	6,710	20	4,220	299	2,060	229	235	11.5 (one bank; multpl. chls.)	-
2B	8,999	32	4,230	551	2,310	492	2,295	11.5 (one bank; multpl. chls.)	-

Note: Tidal freshwater emergent includes sea level rise accommodation area (not all of which will be tidal freshwater emergent by mid-century) and assumes no loss of emergent wetland with sea level rise.

EA.4.1.2.1 BDCP Covered Species

By creating and expanding habitats, BDCP Covered Species benefitting from Channel Margin and Tidal Marsh Habitat improvements in the South Delta include:

- All fish (improved thermal regulation, improved water quality, food web support)
- California black rail
- California clapper rail
- California least tern
- Tricolored blackbird
- Giant garter snake
- Western pond turtle
- Delta mudwort
- Delta tule pea
- Legenere
- Mason's lilaeopsis
- Slough thistle
- Suisun marsh aster

BDCP Covered Species Benefitting from Riparian and Floodplain Habitat Enhancements in the South Delta:

- All fish (either directly or from food web support to downstream areas)
- Riparian brush rabbit and riparian woodrat
- Townsend's big-eared bat – prefers dense wooded areas for foraging
- Swainson's hawk nesting habitat increased with increases in riparian woodland. Swainson's hawk foraging could be supported by infrequently inundated floodplain areas (grasslands).

Primarily benefited species in Corridor 2A may include:

- White tailed kite - nesting
- Western yellow-billed cuckoo – nesting and foraging
- Valley elderberry longhorn beetle
- Delta button celery (potentially, existing habitat not identified, generally occupies floodplain habitat with clay)

EA.4.1.2.2 Channel Margin

Current data wasn't available to quantify the extent of existing channel margin habitat; however, it is anticipated that the overall extent and quality would increase where levees are breached and natural channel processes and vegetation is allowed to re-establish along the banks of channels in Pescadero Tract and along Fabian Tract. Potentially, there would be additional channel margin habitat established along dendritic channels within restored tidal marsh. In Corridor 2B, 11.5 miles of channel margin habitat is assumed to form passively, where the channel margin in the location of former levees would be allowed to naturalize and "soften." Importantly, the channel margin habitat created along Paradise Cut is ephemeral and would only be created during flood bypasses (discharges over 6,000 cfs); as such the totals assumed to increase in Corridor 2A is zero. Despite the ephemeral nature in Corridor 2A; in Corridor 2B (and in 2A, when inundated) the benefits and impacts may include:

Anticipated Benefits

- Increased in-channel foraging habitat for covered fish
- Increased cover habitat for covered fish
- Improved thermal regulation and increased dissolved oxygen levels
- Increased organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.

Potential Impacts

- Increased predation of covered fish by birds
- Potential for increased predation of covered fish by non-native fish
- Establishment and proliferation of invasive non-native vegetation.

EA.4.1.2.3 Tidal Marsh and Tidal Perennial Aquatic

The estimated extent of restored marsh-related habitats for Corridor 2B (Corridor 2A is not anticipated to include any such habitat) is presented in Table EA.4.1-6. Without grading, the restoration would result in less tidal marsh habitat and more sea level rise accommodation and subtidal habitat. The acreages if no grading were to occur are shown in Table EA.4.1-7 for comparison.

Table EA.4.1-6: Tidal Habitat Areas by Corridor, With Grading

Habitat	Elevation Range	Corridor 2b (Fabian Tract)
Uplands	> +15	140
transitional 2	+11.5 → +15	120
transitional 1	+8.5 → +11.5	700
SLR accommodation	+5.5 →+8.5	850
Intertidal	+2 → +5.5	3,370
subtidal 1	-1 →+2	1,630
subtidal 2	-4 → -1	340
subtidal 3	-7 → -4	70
subtidal 4	-10 → -7	20
subtidal 5	< -10	-
Total all habitats/elevations		**7,230**
Total SLR, intertidal, and subtidal		**6,270**
Notes: area listed in acres		

Table EA.4.1-7: Tidal Habitat Areas by Corridor, With Grading

Habitat	Elevation Range	Corridor 2b (Fabian Tract)
uplands	> +15	140
transitional 2	+11.5 → +15	120
transitional 1	+8.5 → +11.5	700
SLR accommodation	+5.5 →+8.5	1,430
intertidal	+2 → +5.5	2,200
subtidal 1	-1 →+2	2,210
subtidal 2	-4 → -1	340
subtidal 3	-7 → -4	70
subtidal 4	-10 → -7	20
subtidal 5	< -10	-
Total all habitats/elevations		**7,230**
Total SLR, intertidal, and subtidal		**6,270**
Notes: area listed in acres		

The following assumptions were assumed in estimating these habitats:

- For Corridor 2B, the restoration approach could be modified to breach areas only downstream of existing temporary barriers, limiting the effects of the barriers on tide range. This may relate only to phased implementation as BDCP Alternative 1A does not include the South Delta Temporary Barriers Project.

- Restoration will have spatially varying positive and negative effects. For example, some areas may be more efficient at the methylization of mercury and so may have a higher magnitude score for an associated negative outcome.
- No significant increases in salinity compared to current conditions. The restored areas remain fresh water.
- Accretion rates will be on the same order as rates of sea level rise during the planning horizon (2050). This assumption may cease to hold toward the end of the 50-year planning horizon, when some of the lowest marsh areas may convert to subtidal habitat. The accretion rate depends on sediment supply and biomass accretion, which depend on site-specific conditions. Sediment supply in the Delta is generally very low (Schoellhamer et. al., 2007). The few available empirical data on Delta marsh accretion suggest accretion rates of 9 to 18 mm yr-1 (Goman and Wells 2000; D. Reed, personal communication).
- Restored acreages in Table EA.4.1-6 and Table EA.4.1-7 are for current sea level conditions. Areas categorized as Sea Level Rise Accommodation show areas that would be tidal marsh with 3 ft of sea level rise, similar to BDCP's planning assumptions.
- There is a hypothesis that shallow open water regions located contiguous to emergent tidal marsh provide enhanced ecosystem complexity and functions compared to those tidal marsh habitats located directly adjacent to deeper sloughs. Although this hypothesis has not been tested, preliminary information on current conditions at Liberty Island and Little Holland Tract suggest support. However, the details of these sites are not readily available to the broad research community at this time and so the information is anecdotal.

Anticipated Benefits

- Increase rearing habitat area and food production for Sacramento splittail, Chinook salmon produced in the San Joaquin River and other eastside tributaries, and possibly steelhead.
- Increase the availability and production of food in the Delta by export from the south Delta of organic material via tidal flow from the new marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in new intertidal channels.
- Locally provide areas of cool water refugia for Delta smelt, as possible.
- In conjunction with dual conveyance operations, marsh restoration in the south Delta could expand the current distribution of Delta smelt into formerly occupied habitat areas.

Potential Impacts

- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension. Fish and other aquatic species utilizing recently reconnected/restored floodplain habitat would be exposed to these increased levels of methylmercury and it may be transported downstream or result in local bioaccumulation affecting covered fish species, non-covered wildlife species, and human health.
- Local effects of contaminants including toxicity from residual pesticides and herbicides.
- Increased fish stranding on the floodplain.
- Increased predation of covered fish by birds.

- Reduced turbidity in downstream waters may have a negative impact on delta smelt, which are commonly found in turbid waters.
- Establishment of harmful invasive species: submerged aquatic vegetation, non-native centrarchids, corbicula, inland silversides effects on Delta and Longfin Smelt
- Resuspension and export of contaminants to downstream areas
- Creation of a population sink due to longer residence times with associated increased exposure to predators and entrainment
- Production of organic matter that will contribute to low DO conditions

EA.4.1.2.4 Floodplain Habitat and Food Production

An increase in the extent and frequency of floodplain inundation is expected to occur in Paradise Cut (Corridor 2A) and areas in Fabian Tract (Corridor 2B) following the removal of levees. Floodplain habitat will likely support a mosaic of vegetation types depending on a variety of factors including depth to groundwater, frequency of inundation, and soil properties. The anticipated benefits for both corridors are similar, but differ by extent and to some extent ecosystem function support. In Corridor 2A, it is expected that the floodplain would support more riparian and upland habitat whereas Corridor 2B would support more subtidal and tidal marsh habitat. The anticipated benefits for both corridors are similar, but differ by extent and ecosystem function support. The floodplain reconnection in Corridor 2B would result in different species benefits and ecosystem function associated with a broad expanse of homogenous marsh habitat while Corridor 2A is likely to support a more dynamic mosaic of riparian, upland, and marsh habitat.

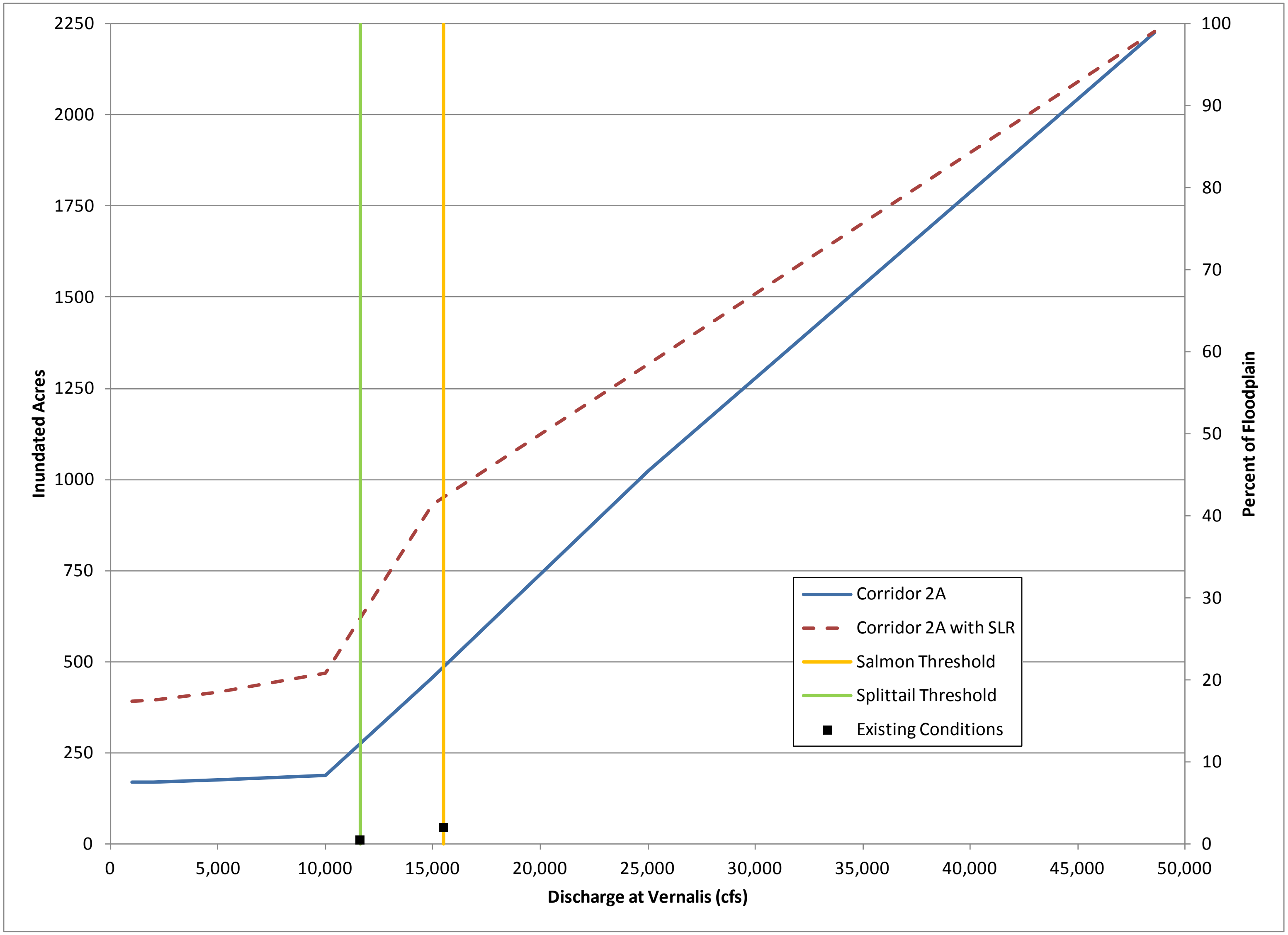
Of note, the assumed changes to the Paradise Cut weir result in the San Joaquin River beginning to overtop at 6,040 cfs (assuming Model Run F conditions, no SLR; see Section 7.3). In comparison, the existing Paradise Cut weir is modeled (using a MHW downstream boundary condition without SLR), to begin to overtop at 12,957 cfs.

Table EA.4.1-8 presents the estimated changes in seasonally-inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3). Figure EA.4.1-5 and Figure EA.4.1-6 illustrates the relationship between river discharge (as measured at Vernalis) and floodplain inundation with and without assumed sea level rise for Corridors 2A and 2B, respectively.

1 **Table EA.4.1-8: Changes in Ecologically-Relevant Floodplain Inundation in Corridor 2**

	Existing Conditions			Corridor Conditions - with Sea Level Rise								
					Existing Flow Regime				SJRRP Flow Regime			
	Existing Corridor Footprint *(Total Existing Area between Levees; river excluded)*	Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs*	Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs*	New Corridor Footprint *(Total Area between Levees; river excluded)*	Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs (river excluded)*		Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs (river excluded)*		Inundated Floodplain Habitat *assuming Salmon Threshold(river excluded)*		Inundated Floodplain Habitat *assuming Splittail Threshold (river excluded)*	
Corridor	acres	acres	acres	acres	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint
2A	1,189	46	11	2,289	950	39%	625	26%	950	39%	650	28%
Fabian Tract	484	29	5	6,971	6,150	88%	6,125	88%	6,250	90%	6,250	90%
2B	1,673	75	16	9,260	7,100	77%	6,750	73%	7,200	78%	6,900	75%

2



1
2 **Figure EA.4.1-5: Relation between Discharge and Floodplain Inundation: Corridor 2A**

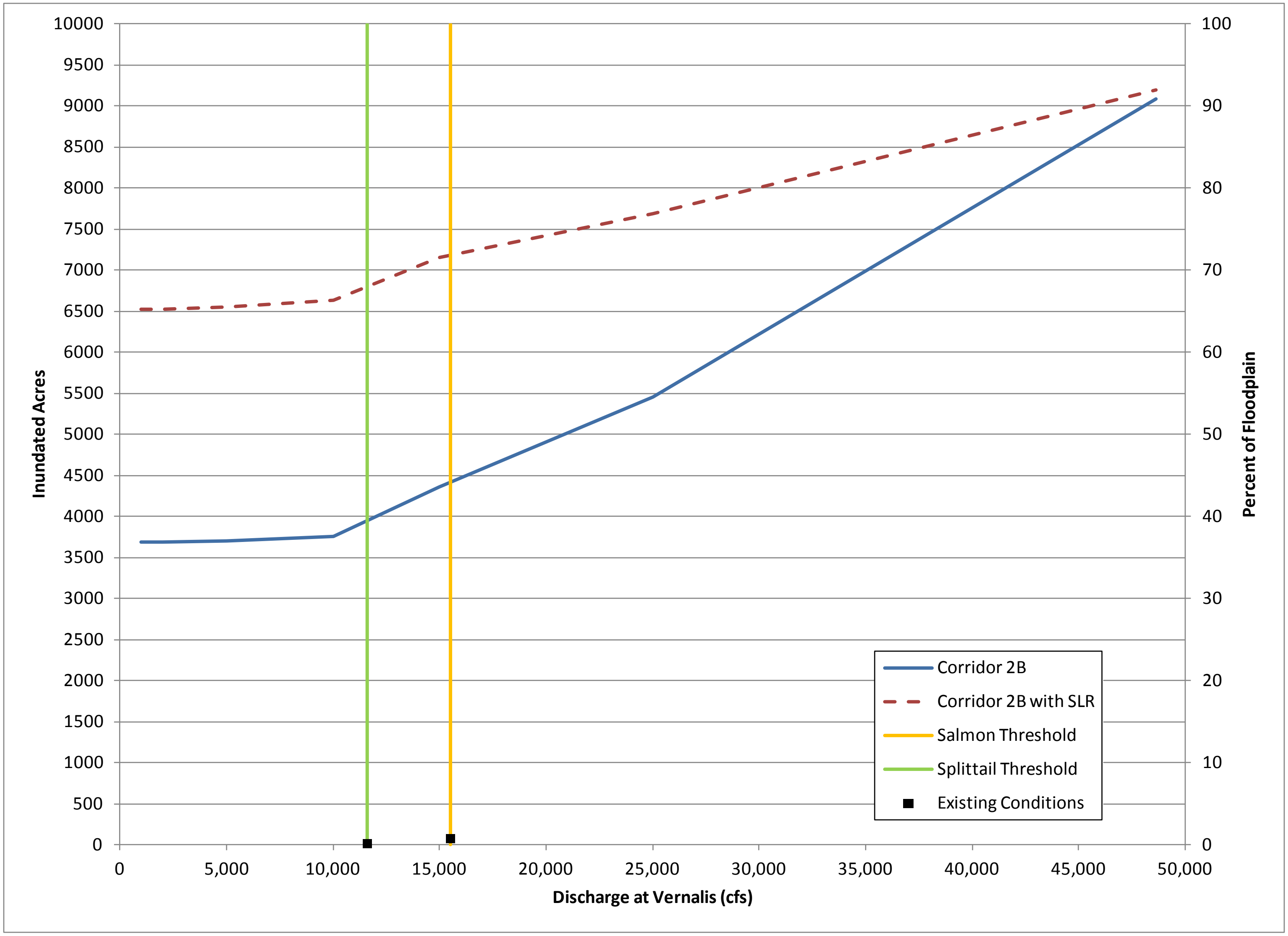


Figure EA.4.1-6: Relation between Discharge and Floodplain Inundation: Corridor 2B

Floodplain inundation related to food production was assessed using the methods described in Section 7.3. Table EA.4.1-9 and Table EA.4.1-10 illustrate the probability that specified percentages of the corridor floodplains are inundated assuming different inundation durations. These results are presented graphically in Figure EA.4.1-7 and Figure EA.4.1-8 and include results for existing and "with San Joaquin River Restoration flow regime" hydrology.

Table EA.4.1-9: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 2A

Season: Dec. 1 – May 31						
	Exceedance Probability					
	18,500 cfs (30% of the corridor's potential new floodplain is inundated)		31,000 cfs (60% of the corridor's potential new floodplain is inundated)		44,000 cfs (90% of the corridor's potential new floodplain is inundated)	
Duration (days)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)
2	0.249	0.248	0.211	0.157	0.146	0.144
4	0.248	0.247	0.200	0.156	0.143	0.140
6	0.246	0.246	0.158	0.152	0.138	0.123
8	0.245	0.244	0.155	0.147	0.121	0.105
10	0.242	0.242	0.153	0.146	0.102	0.104
12	0.240	0.240	0.150	0.145	0.102	0.103
14	0.239	0.239	0.147	0.144	0.102	0.102
16	0.237	0.236	0.146	0.143	0.000	0.000
18	0.236	0.235	0.138	0.135	0.000	0.000
20	0.233	0.232	0.138	0.133	0.000	0.000
Created using area/discharge curves under without SLR conditions. For SLR conditions, refer to the area/discharge curves to identify applicable acreages and percentages.						

Table EA.4.1-10: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 2B

Season: Dec. 1 – May 31						
	Exceedance Probability					
	1,000 cfs (30% of the corridor's potential new floodplain is inundated)		17,000 cfs (60% of the corridor's potential new floodplain is inundated)		42,000 cfs (90% of the corridor's potential new floodplain is inundated)	
Duration (days)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)
2	0.794	0.864	0.254	0.253	0.148	0.146
4	0.798	0.865	0.253	0.252	0.145	0.142
6	0.792	0.865	0.251	0.252	0.141	0.127
8	0.788	0.864	0.250	0.250	0.126	0.111
10	0.787	0.863	0.247	0.248	0.108	0.111
12	0.788	0.863	0.245	0.246	0.108	0.108
14	0.784	0.863	0.244	0.245	0.108	0.108
16	0.783	0.866	0.243	0.243	0.108	0.108
18	0.784	0.866	0.243	0.242	0.059	0.060
20	0.787	0.864	0.240	0.240	0.000	0.000
Created using area/discharge curves under without SLR conditions. For SLR conditions, refer to the area/discharge curves to identify applicable acreages and percentages.						

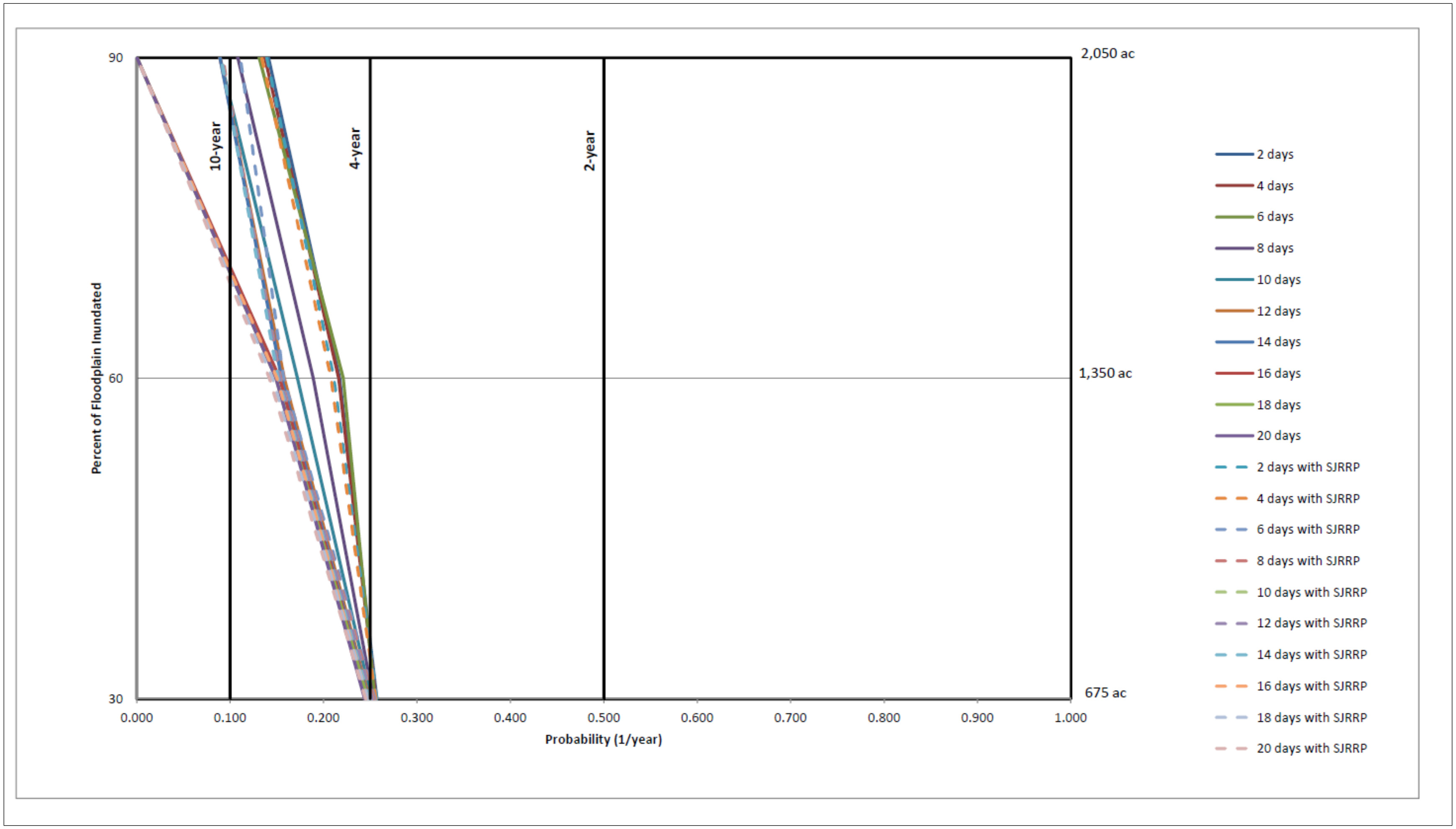


Figure EA.4.1-7: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 2A

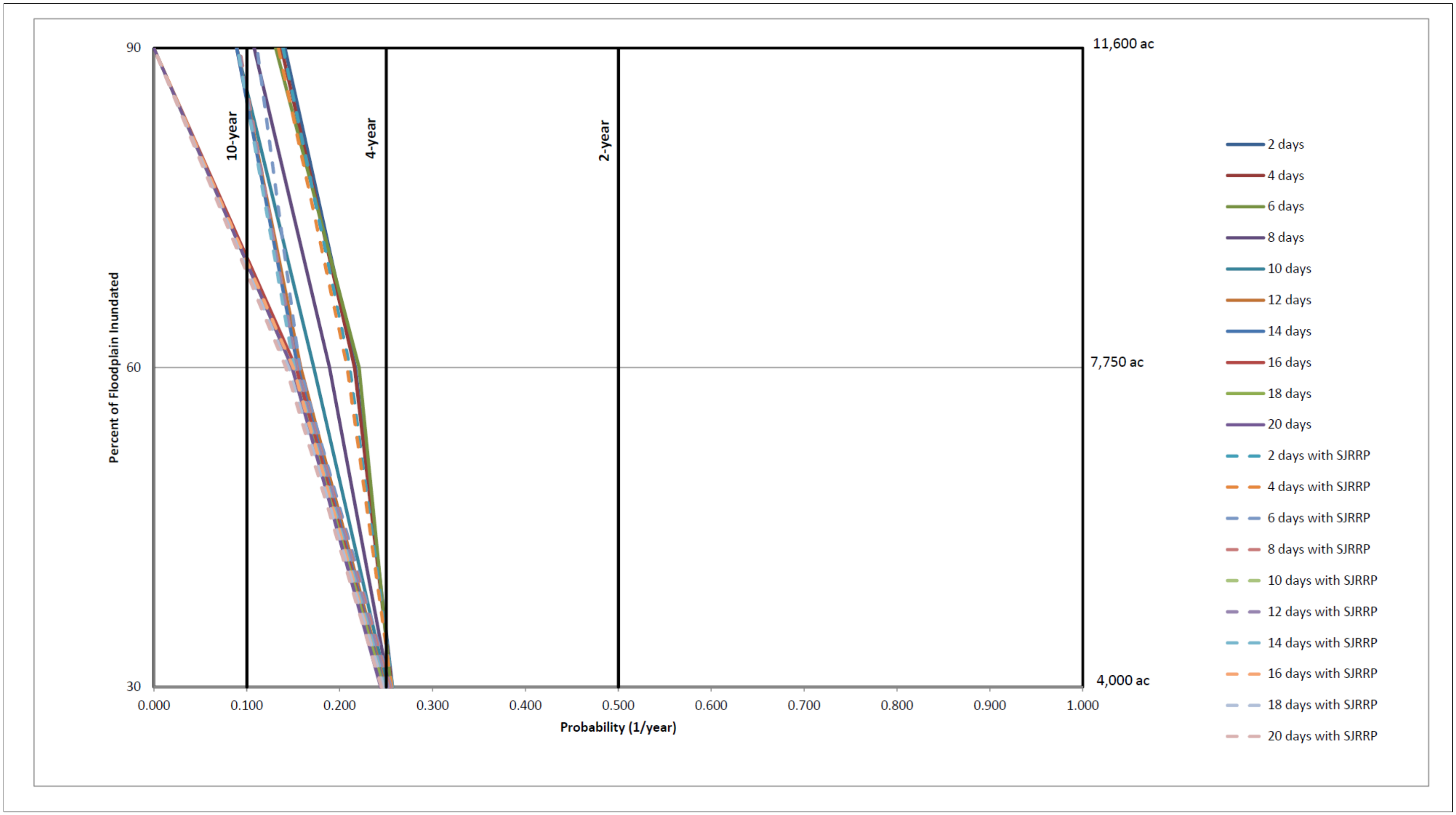


Figure EA.4.1-8: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 2B

The anticipated benefits and potential negative impacts for reconnecting the San Joaquin River to an expanded floodplain are listed below. Some of the benefits and impacts listed below also apply and are repeated below under the riparian ecosystem discussion, in the subsection below.

Anticipated Benefits

- Water temperatures on the floodplain are warmer than in-channel temperatures during large winter events, a benefit to juvenile fish utilizing this habitat.
- Water quality improvements for in-stream conditions as sediments in flood waters are dropped out of the water column and are deposited on the floodplain.
- An expanded floodplain with direct connection to a prime migratory corridor for salmonids.
- Improved access to seasonally inundated floodplain habitat creates additional spawning habitat for splittail and additional rearing habitat for salmonids, splittail, and potentially steelhead.
- Seasonally inundated habitats with the cycles of wetting and drying act are believed to act as a productivity pump to the lower estuary (CNRA, 2011).
- Flushing of backwaters to remove floating and submerged aquatic vegetation opens up habitat for use of shallow, near shore habitat for salmonids and smelt.
- Reduce non-point source pollution for improved water quality.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Access to slower floodplain water velocities reduces stress on juvenile fish during extreme water events.

Potential Impacts

- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension. Fish and other aquatic species utilzing recently reconnected/restored floodplain habitat would be exposed to these increased levels of methylmercury and it may be transported downstream.
- Establishment and proliferation of invasive non-native vegetation.
- Increased fish stranding on the floodplain.
- Reduced turbidity in downstream waters may have a negative impact on delta smelt, which are commonly found in turbid waters.

EA.4.1.2.5 Riparian

Additional riparian habitat is expected to establish along the channels and reconnected floodplain in Pescadero Tract under Corridor 2A actions while a limited area of riparian vegetation has potential to establish along the eastern margin of Fabian Tract. It is estimated that Corridor 2A will provide an increase of 882 acres of riparian habitat (for a total of 1,145 acres). In comparison, only an additional 46 acres of riparian habitat is estimated to have potential to re-establish in Corridor 2B (for a total of 235 acres).

Anticipated Benefits

- Reduced non-point source pollution and improving overall water quality.
- Re-establishing a fairly contiguous corridor of riparian habitat along San Joaquin River increases connectivity providing cover for terrestrial species and facilitates genetic exchange.
- Improved thermal regulation and improved dissolved oxygen levels.
- Supports the establishment of a dynamic complex of woody and scrub habitat along the river channel and in the floodplain over the long-term provide in stream aquatic habitat in the form of overhead cover and inputs of large woody debris.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Riparian vegetation slows water velocities in the floodplain for salmonids and splittail reducing stress on juvenile fish during extreme water events.
- Riparian habitat increases organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.
- Improved riparian habitat resilience during periodic perturbations and potentially to climate change (Seavy et al., 2009) by increasing overall habitat extent, improving connectivity, and allowing for plant community diversity.
- Additional cover for native fisheries from predatory fish.
- Potential for phytoremediation of toxins within soil (not well understood at this time, but Poplar hybrids are commonly used and some willow have shown promise)
- Removal of submerged aquatic vegetation in back-channel/oxbow areas following increased flow.

Potential Impacts

- Increased fire hazard , particularly is non-native species such as giant reed and tamarisk become established.
- Perception of increased 'weed' control needs for adjacent agricultural land owners (not necessarily an ecological impact, but something that will likely be an issue).
- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension.
- Establishment and proliferation of invasive non-native vegetation.
- Increased fish stranding on the floodplain.

EA.4.1.2.6 Water Quality

Anticipated water quality benefits and impacts are listed below. Note that no modeling was completed and these are conceptualized process-based outcomes.

- With respect to agriculture, the potential corridor actions are estimated to result in the inundation of additional land areas by San Joaquin/Delta waters. However, these lands are not anticipated to contain excessively high concentrations of salt. Implementation of corridor actions and the BDCP as a whole could potentially result in increased residence time within Corridor 2. Increased residence time could result in a net increase in evaporation within Corridor 2. This could result in an unknown but perhaps minimal increase in salt concentration, but would not increase net salt loading.

- As discussed previously, salt concentrations in this area of the Delta are affected by surfacing of comparatively salty groundwater from a number of locations in the south Delta. Reductions in flow within this area, as a result of BDCP implementation, could result in an overall concentration of these flows in the south Delta, which could potentially result in further elevation of salt concentrations and salt loading. Salt concentrations are currently high during the summer irrigation season. Additional increases in salt concentration associated with reduced flow in the south Delta could deleteriously affect agricultural irrigation beneficial use. Restoration alone (without consideration of the effects of BDCP operations) may not result in a net change in salt concentration or loading associated with salty groundwater inflows.
- With respect to water supply, increases in salt concentration could occur, as discussed above, which could affect drinking water quality. Increases in Delta wetlands coverage could also result in increased dissolved organic carbon output, which could cause increased occurrence of disinfection byproduct production. Because Corridor 2b would include restoration of a large area of land to tidal wetlands, altered flow rates could occur, which could result in increased incidence of algal blooms, including toxic blooms such as microcystis.
- With respect to habitat quality, potential increases in particulate and dissolved organic carbon could potentially support Delta food webs. The potential corridor actions could also result in a net reduction in dissolved oxygen depletion, both through the removal of nutrients within wetland processes, and also via increased diffusion capacity due to increased water surface area. Countering this trend, to the extent that increased surface area would result in increased temperature, temperature sensitive species may be affected. Additionally, if increased incidence of algal bloom conditions occur, reduced dissolved oxygen could result in localized areas. Therefore, based on counteracting factors, potential effects on dissolved oxygen concentration are considered uncertain.
- Increases in tidal wetlands could result in an increase in mercury methylation potential. Increased methylation within anoxic layers could result in increased bioconcentration of methyl mercury in fish and other aquatic organisms. However, the distribution of elemental mercury and methylmercury is not well known in the South Delta. Therefore, potential effects associated with methylmercury remain uncertain within Corridors 2a and 2b.

EA.4.1.3 Corridor 3

Corridor 3 appears especially-suited for tidal marsh restoration given existing land elevations. Currently, native vegetation and habitat within the corridor is limited to the narrow river channel. By breaching and removing levees along the east bank of Middle River, there is potential for substantial gains in tidal marsh habitat, and potentially riparian habitat. The increase in floodplain and riparian habitat extent would occur primarily along Middle River near the outlet of Paradise Cut in the southern portion of Corridor 3.

EA.4.1.3.1 BDCP Covered Species

The following subsections provide a series of tables and bullet statements related to some of the key potential benefits and impacts resulting from the assumed actions comprising Corridor 3. Table EA.4.1-11 summarizes key habitat changes.

By creating and expanding habitats, BDCP Covered Species benefitting from Channel Margin and Tidal Marsh Habitat improvements in the South Delta include:

- All fish (improved thermal regulation, improved water quality, food web support)
- California black rail
- California clapper rail
- California least tern
- Tricolored blackbird
- Giant garter snake
- Western pond turtle
- Delta mudwort
- Delta tule pea
- Legenere
- Mason's lilaeopsis
- Slough thistle
- Suisun marsh aster

BDCP Covered Species Benefitting from Riparian and Floodplain Habitat Enhancements in the South Delta:

- All fish (either directly or from food web support to downstream areas)
- Riparian brush rabbit and riparian woodrat
- Townsend's big-eared bat – prefers dense wooded areas for foraging
- Swainson's hawk nesting habitat increased with increases in riparian woodland. Swainson's hawk foraging could be supported by infrequently inundated floodplain areas (grasslands).

Table EA.4.1-11: Habitat Changes in Corridor 3

Corridor	New Corridor Footprint (Total Area between Levees; *river excluded)*	Tidal Freshwater Emergent Wetland, *assuming grading and SLR (acres)*		Tidal Perennial Aquatic, *assuming grading* and SLR (acres)		Riparian (acres)		Length of Channel Margin Habitat (miles; RB vs LB defined; *totals are the sum of active and passive)*	
	acres	Existing Conditions	New Corridor	Existing Conditions	New Corridor	Existing Conditions	New Corridor	Passive	Active
3	5,174	21	3,530	279	0*	297	1,480	11 on LB	11 on RB

* Will have some subtidal associated with tidal channels within the restored emergent marsh.
Note: Tidal freshwater emergent includes sea level rise accommodation area and assumes no loss of emergent wetland with sea level rise.

EA.4.1.3.2 Channel Margin

Current data wasn't available to quantify the extent of existing channel margin habitat; however, it is anticipated that the overall extent and quality would increase where levees are breached and natural channel processes and vegetation is allowed to re-establish along the banks of Union Island along Middle River. Potentially, there would be additional channel margin habitat established along dendritic channels within restored tidal marsh. This corridor does not serve as a primary migration corridor for salmonids. Active channel margin enhancement is assumed along 11 miles of the corridor, located on the existing-levee side of the corridor where that levee is to remain. Those areas may include large wood placement and plantings. An additional 11 miles of channel margin habitat is assumed to form passively, where the channel margin in the location of former levees would be allowed to naturalize and "soften."

The benefits and impacts in Corridor 3 may include:

Anticipated Benefits

- Increased in-channel foraging habitat for covered fish
- Increased cover habitat for covered fish
- Improved thermal regulation and increased dissolved oxygen levels
- Increased organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.

Potential Impacts

- Increased predation of covered fish by birds
- Potential for increased predation of covered fish by non-native fish
- Establishment and proliferation of invasive non-native vegetation.

EA.4.1.3.3 Tidal Marsh and Tidal Perennial Aquatic

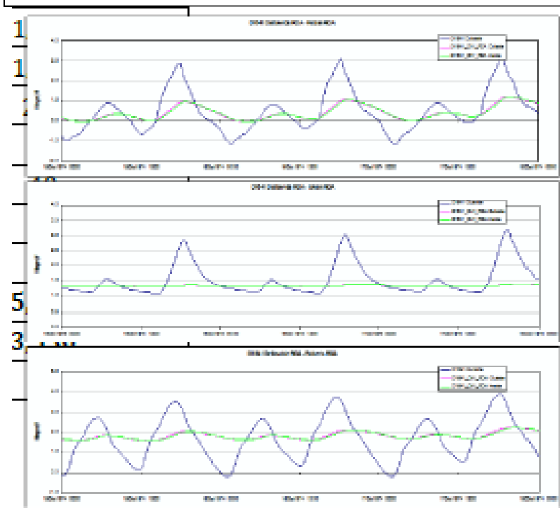
The estimated extent of restored marsh-related habitats for Corridor 3 is presented in Table EA.4.1-12. Note that Corridor 3 will have some subtidal habitat associated with tidal marsh channels (not included in Table EA.4.1-12). Without grading, the restoration would result in less tidal marsh habitat and more sea level rise accommodation and subtidal habitat. The acreages if no grading were to occur are shown in Table EA.4.1-13 for comparison.

Table EA.4.1-12: Tidal Habitat Areas by Corridor, With Grading

Habitat	Elevation Range	Corridor 3
uplands	> +15	210
transitional 2	+11.5 → +15	140
transitional 1	+8.5 → +11.5	1,510
SLR accommodation	+5.5 →+8.5	930
intertidal	+2 → +5.5	2,600
subtidal 1	-1 →+2	0
subtidal 2	-4 → -1	0
subtidal 3	-7 → -4	0
subtidal 4	-10 → -7	0
subtidal 5	< -10	0
Total all habitats/elevations		**5,390**
Total SLR, intertidal, and subtidal		**3,530**
Note: Area listed in acres Corridors 3 and 4 will have some subtidal associated with tidal channels		

Table EA.4.1-13: Tidal Habitat Areas by Corridor, No Grading

Habitat	Elevation Range	Corridor 3
uplands	> +15	210
transitional 2	+11.5 → +15	140
transitional 1	+8.5 → +11.5	1,510
SLR accommodation	+5.5 →+8.5	1,340
intertidal	+2 → +5.5	1,780
subtidal 1	-1 →+2	260
subtidal 2	-4 → -1	60
subtidal 3	-7 → -4	40
subtidal 4	-10 → -7	30
subtidal 5	< -10	30
Total all habitats/elevations		**5,390**
Total SLR, intertidal, and subtidal		**3,530**
Note: Area listed in acres		



Anticipated Benefits

- Increase rearing habitat area and food production for Sacramento splittail, Chinook salmon produced in the San Joaquin River and other eastside tributaries, and possibly steelhead.
- Increase the availability and production of food in the Delta by export from the south Delta of organic material via tidal flow from the new marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in new intertidal channels.
- Locally provide areas of cool water refugia for Delta smelt, as possible.
- In conjunction with dual conveyance operations, marsh restoration in the south Delta could expand the current distribution of Delta smelt into formerly occupied habitat areas.

Potential Impacts

- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.

- Potential methylmercury release and resuspension. Fish and other aquatic species utilizing recently reconnected/restored floodplain habitat would be exposed to these increased levels of methylmercury and it may be transported downstream or result in local bioaccumulation affecting covered fish species, non-covered wildlife species, and human health.
- Local effects of contaminants including toxicity from residual pesticides and herbicides.
- Increased fish stranding on the floodplain.
- Increased predation of covered fish by birds.
- Reduced turbidity in downstream waters may have a negative impact on delta smelt, which are commonly found in turbid waters.
- Establishment of harmful invasive species: submerged aquatic vegetation, non-native centrarchids, corbicula, inland silversides effects on Delta and Longfin Smelt
- Resuspension and export of contaminants to downstream areas
- Creation of a population sink due to longer residence times with associated increased exposure to predators and entrainment
- Production of organic matter that will contribute to low DO conditions

EA.4.1.3.4 Floodplain Habitat and Food Production

An increase in the extent and frequency of floodplain inundation is expected to occur along Middle River and Doughty Cut following the removal of levees. Floodplain habitat will likely support a mosaic of vegetation types depending on a variety of factors including depth to groundwater, frequency of inundation, and soil properties. The floodplain reconnection activities in Corridor 3 will likely have a greater effect on re-establishing key ecosystem processes related to tidal marsh and result in less grassland, riparian woodland, and riparian scrub floodplain habitats and interfaces.

Table EA.4.1-14 presents the estimated changes in seasonally-inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3). Figure EA.4.1-9 illustrates the relationship between river discharge (as measured at Vernalis) and floodplain inundation with and without assumed sea level rise for Corridor 3. This curve can be used to assess other discharge levels that evaluators may find to be potentially relevant to species outcomes.

Table EA.4.1-14: Changes in Ecologically-Relevant Floodplain Inundation in Corridor 3

	Existing Conditions			Corridor Conditions - with Sea Level Rise								
					Existing Flow Regime				SJRRP Flow Regime			
	Existing Corridor Footprint *(Total Existing Area between Levees; river excluded)*	Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs*	Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs*	New Corridor Footprint *(Total Area between Levees; river excluded)*	Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs (river excluded)*		Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs (river excluded)*		Inundated Floodplain Habitat *assuming Salmon Threshold(river excluded)*		Inundated Floodplain Habitat *assuming Splittail Threshold (river excluded)*	
Corridor	Acres	acres	acres	acres	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint
3	706	88	33	5,174	4,250	82%	3,800	73%	4,250	82%	3,900	75%

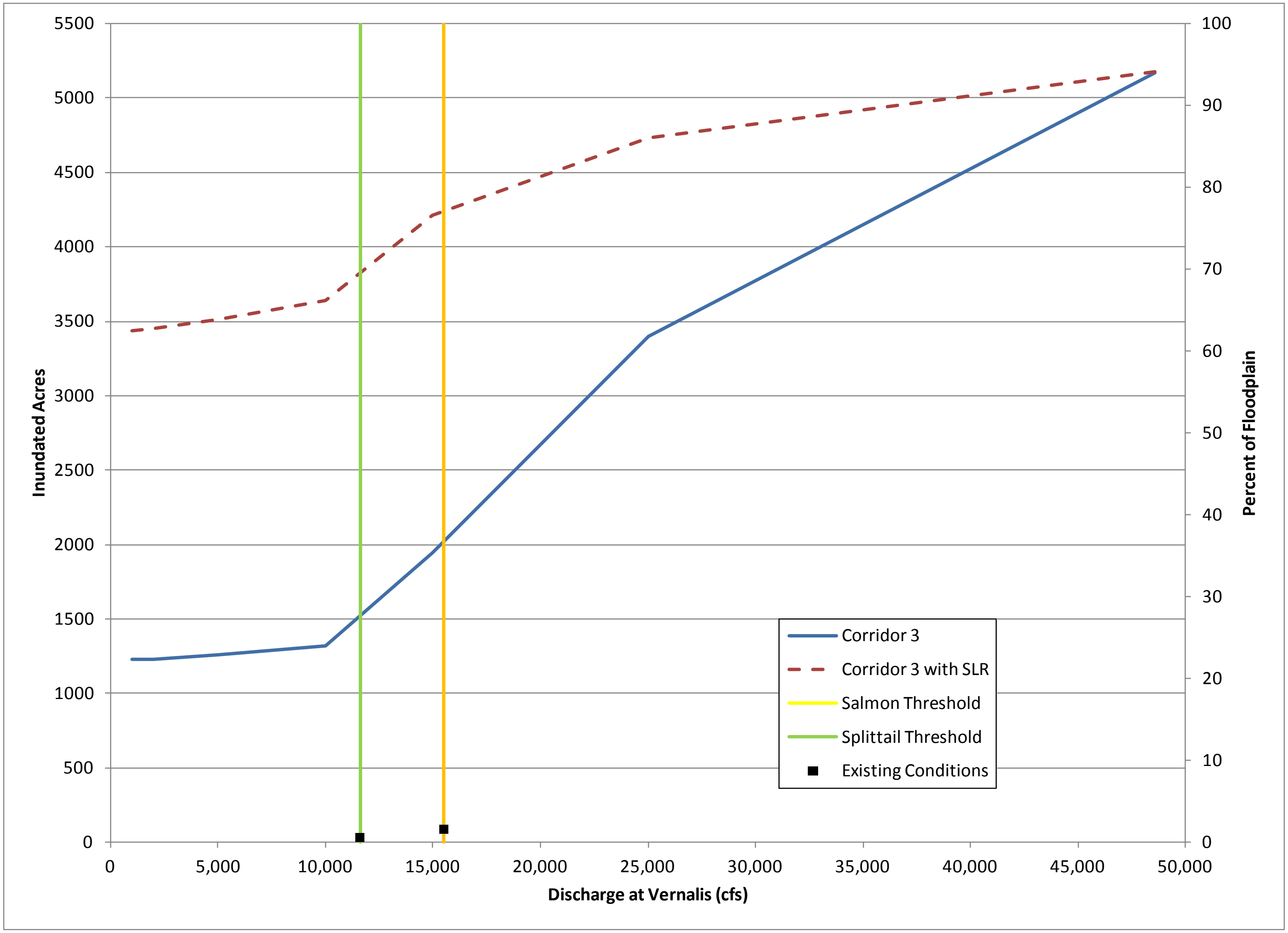


Figure EA.4.1-9: Relation between Discharge and Floodplain Inundation: Corridor 3

Floodplain inundation related to food production was assessed using the methods described in Section 7.3. Table EA.4.1-15 illustrates the probability that specified percentages of the corridor floodplains are inundated assuming different inundation durations. These results are presented graphically in Figure EA.4.1-10, and include results for existing and "with San Joaquin River Restoration flow regime" hydrology.

Table EA.4.1-15: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 3

Season: Dec. 1 – May 31						
	Exceedance Probability					
	12,500 cfs (30% of the corridor's potential new floodplain is inundated)		24,000 cfs (60% of the corridor's potential new floodplain is inundated)		44,500 cfs (90% of the corridor's potential new floodplain is inundated)	
Duration (days)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)
2	0.325	0.333	0.232	0.229	0.145	0.144
4	0.321	0.327	0.232	0.228	0.142	0.139
6	0.311	0.318	0.228	0.226	0.138	0.122
8	0.297	0.314	0.226	0.224	0.120	0.104
10	0.275	0.286	0.222	0.222	0.101	0.102
12	0.262	0.263	0.219	0.219	0.101	0.101
14	0.262	0.263	0.218	0.218	0.101	0.101
16	0.262	0.263	0.215	0.212	0.000	0.000
18	0.261	0.263	0.213	0.211	0.000	0.000
20	0.260	0.263	0.205	0.190	0.000	0.000
Created using area/discharge curves under without SLR conditions. For SLR conditions, refer to the area/discharge curves to identify applicable acreages and percentages.						

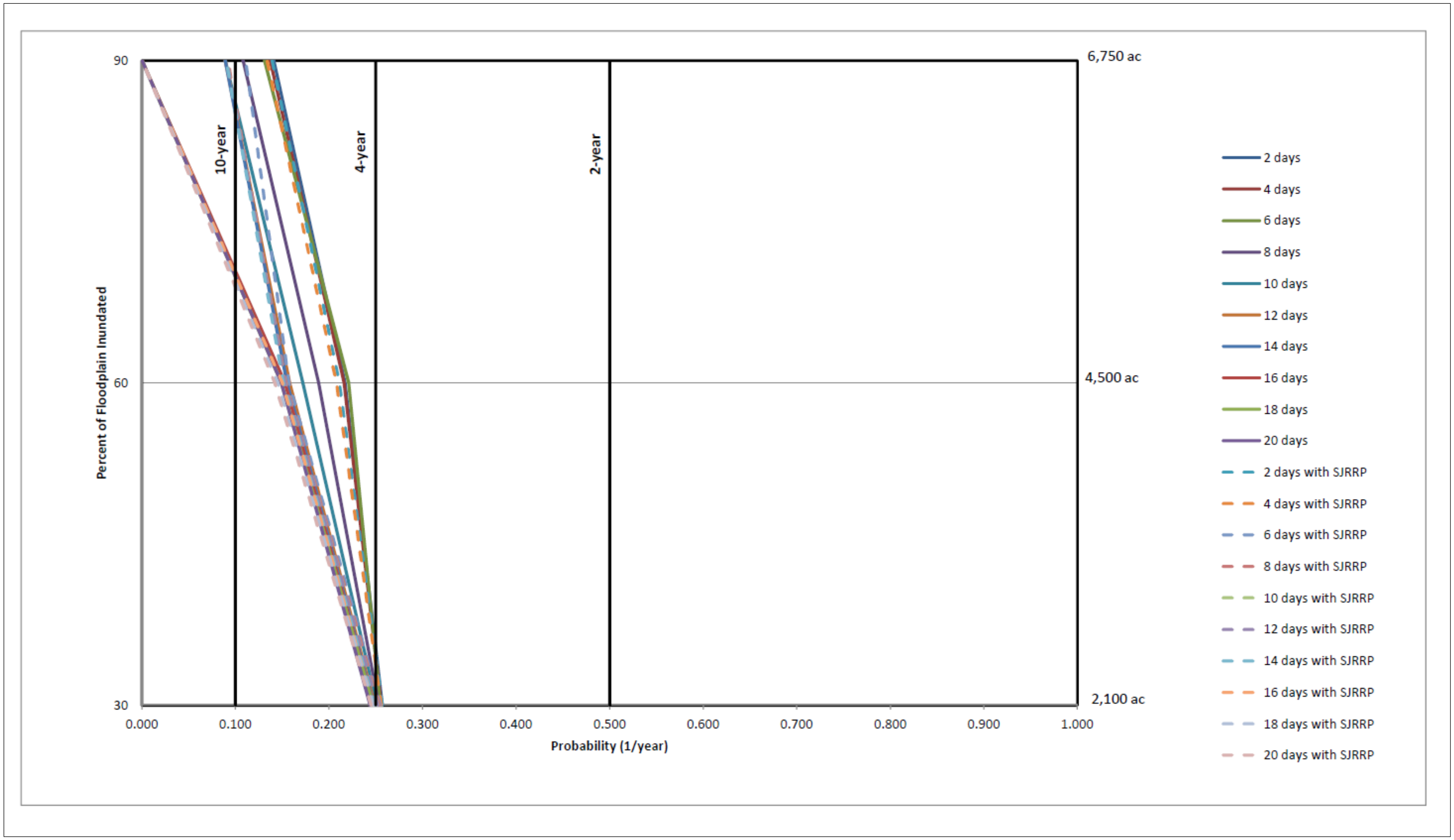


Figure EA.4.1-10: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 3

The anticipated benefits and potential negative impacts for reconnecting the San Joaquin River to an expanded floodplain are listed below. Some of the benefits and impacts listed below also apply and are repeated below under the riparian ecosystem discussion, in the subsection below

Anticipated Benefits

- Water temperatures on the floodplain are warmer than in-channel temperatures during large winter events, a benefit to juvenile fish utilizing this habitat.
- Water quality improvements for in-stream conditions as sediments in flood waters are dropped out of the water column and are deposited on the floodplain.
- An expanded floodplain with direct connection to a prime migratory corridor for salmonids.
- Improved access to seasonally inundated floodplain habitat creates additional spawning habitat for splittail and additional rearing habitat for salmonids, splittail, and steelhead.
- Seasonally inundated habitats with the cycles of wetting and drying act are believed to act as a "productivity pump" to the lower estuary (CNRA, 2011).
- Flushing of backwaters to remove floating and submerged aquatic vegetation opens up habitat for use of shallow, near shore habitat for salmonids and smelt.
- Reduce non-point source pollution for improved water quality.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Access to slower floodplain water velocities reduces stress on juvenile fish during extreme water events.

Potential Impacts

- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension. Fish and other aquatic species utilizing recently reconnected/restored floodplain habitat would be exposed to these increased levels of methylmercury and it may be transported downstream.
- Establishment and proliferation of invasive non-native vegetation.
- Potential for fish stranding on the floodplain.
- Reduced turbidity in downstream waters may have a negative impact on delta smelt, which are commonly found in turbid waters.

EA.4.1.3.5 Riparian

Additional riparian habitat is expected to establish along the tidal channels and reconnected floodplain under Corridor 3 actions. It is anticipated that Corridor 3 restoration actions may provide an additional 1,183 acres of riparian habitat (for a total of 1,480 acres).

Anticipated Benefits

- Reduced non-point source pollution and improving overall water quality.

- Re-establishing a fairly contiguous corridor of riparian habitat along San Joaquin River increases connectivity providing cover for terrestrial species and facilitates genetic exchange.
- Improved thermal regulation and improved dissolved oxygen levels.
- Supports the establishment of a dynamic complex of woody and scrub habitat along the river channel and in the floodplain over the long-term provide in stream aquatic habitat in the form of overhead cover and inputs of large woody debris.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Riparian vegetation slows water velocities in the floodplain for salmonids and splittail reducing stress on juvenile fish during extreme water events.
- Riparian habitat increases organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.
- Improved riparian habitat resilience during periodic perturbations and potentially to climate change (Seavy et al., 2009) by increasing overall habitat extent, improving connectivity, and allowing for plant community diversity.
- Additional cover for native fisheries from predatory fish.
- Potential for phytoremediation of toxins within soil (not well understood at this time, but Poplar hybrids are commonly used and some willow have shown promise)
- Removal of submerged aquatic vegetation in back-channel/oxbow areas following increased flow.

Potential Impacts

- Increased fire hazard , particularly is non-native species such as giant reed and tamarisk become established.
- Perception of increased ‘weed’ control needs for adjacent agricultural land owners (not necessarily an ecological impact, but something that will likely be an issue).
- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension.
- Establishment and proliferation of invasive non-native vegetation.
- Increased fish stranding on the floodplain.

EA.4.1.3.6 Water Quality

Anticipated water quality benefits and impacts are listed below. Note that no modeling was completed and these are conceptualized process-based outcomes.

- With respect to agriculture, the potential corridor actions are estimated to result in the inundation of additional land areas by San Joaquin/Delta waters. However, these lands are not anticipated to contain excessively high concentrations of salt. Implementation of Corridor 3 and the BDCP as a whole could potentially result in increased residence time within Corridor 3. Increased residence time could result in a net increase in evaporation within Corridor 3. This could result in an unknown but perhaps minimal increase in salt concentration, but would not increase net salt loading.

- As discussed previously, salt concentrations in this area of the Delta are affected by surfacing of comparatively salty groundwater from a number of locations in the south Delta. Reductions in flow within this area, as a result of BDCP implementation, could result in an overall concentration of these flows in the south Delta, which could potentially result in further elevation of salt concentrations and salt loading. Salt concentrations are currently high during the summer irrigation season. Due to increased mixing between the area of known salty groundwater influx, this effect is anticipated to be muted within Corridor 3, as compared to Corridor 2. However, additional increases in salt concentration associated with reduced flow in the south Delta could deleteriously affect agricultural irrigation beneficial use. Restoration alone (without consideration of the effects of BDCP operations) may not result in a net change in salt concentration or salt loading associated with salty groundwater inflows.
- With respect to water supply, increases in salt concentration could occur, as discussed above, which could affect drinking water quality. Increases in Delta wetlands coverage could also result in increased dissolved organic carbon output, which could cause increased occurrence of disinfection byproduct production. Because Corridor 3 would include restoration of a large area of land to tidal wetlands, altered flow rates could occur, which could result in increased incidence of algal blooms, including toxic blooms such as microcystis.
- With respect to habitat quality, potential increases in particulate and dissolved organic carbon could potentially support Delta food webs. The potential corridor actions could also result in a net reduction in dissolved oxygen depletion, both through the removal of nutrients within wetland processes, and also via increased diffusion capacity due to increased water surface area. Countering this trend, to the extent that increased surface area would result in increased temperature, temperature sensitive species may be affected. Additionally, if increased incidence of algal bloom conditions occur, reduced dissolved oxygen could result in localized areas. Therefore, based on counteracting factors, potential effects on dissolved oxygen concentration are considered uncertain within Corridor 3.
- Increases in tidal wetlands could result in an increase in mercury methylation potential. Increased methylation within anoxic layers could result in increased bioconcentration of methyl mercury in fish and other aquatic organisms. However, the distribution of elemental mercury and methylmercury is not well known in the South Delta. Therefore, potential effects associated with methylmercury remain uncertain within Corridor 3.

EA.4.1.4 Corridor 4

The following subsections provide a series of tables and bullet statements related to some of the key potential benefits and impacts resulting from the assumed actions comprising Corridor 4. Table EA.4.1-16 summarizes key habitat changes. Generally, Corridor 4 would increase floodplain and riparian habitat extent along the San Joaquin River, where habitat is considerably lacking, and this habitat would occur along a primary migratory corridor for salmonids. This corridor is also anticipated to provide tidal marsh habitat. The increase in floodplain, channel margin, riparian and tidal marsh habitat along the San Joaquin River, where habitat is notably lacking, would occur along a primary migratory corridor for salmonids.

EA.4.1.4.1 BDCP Covered Species

By creating and expanding habitats, BDCP Covered Species benefitting from Channel Margin and Tidal Marsh Habitat improvements in the South Delta include:

- All fish (improved thermal regulation, improved water quality, food web support)
- California black rail
- California clapper rail
- California least tern
- Tricolored blackbird
- Giant garter snake
- Western pond turtle
- Delta mudwort
- Delta tule pea
- Legenere
- Mason's lilaeopsis
- Slough thistle
- Suisun marsh aster

BDCP Covered Species benefitting from Riparian and Floodplain Habitat Enhancements in the South Delta include:

- All fish (either directly or from food web support to downstream areas)
- Riparian brush rabbit and riparian woodrat
- Townsend's big-eared bat – prefers dense wooded areas for foraging
- Swainson's hawk nesting habitat increased with increases in riparian woodland. Swainson's hawk foraging could be supported by infrequently inundated floodplain areas (grasslands).
- White tailed kite - nesting
- Western yellow-billed cuckoo – nesting and foraging
- Valley elderberry longhorn beetle
- Delta button celery

Table EA.4.1-16. Habitat Changes in Corridor 4

	New Corridor Footprint (Total Area between Levees; *river excluded)*	Tidal Freshwater Emergent Wetland, *assuming grading and SLR (acres)*		Tidal Perennial Aquatic, *assuming grading* and SLR (acres)		Riparian (acres)		Length of Channel Margin Habitat (miles; RB vs LB defined; *totals are the sum of active and passive)*	
Corridor	Acres	Existing Conditions	New Corridor	Existing Conditions	New Corridor	Existing Conditions	New Corridor	Passive	Active
4	5,881	0	3,820	310	0*	168	2,061	12 on LB	12 on RB

* Will have some subtidal associated with tidal channels within the restored emergent marsh.
Note: Tidal freshwater emergent includes sea level rise accommodation area (not all of which will be tidal freshwater emergent by mid-century) and assumes no loss of emergent wetland with sea level rise.

EA.4.1.4.2 Channel Margin

Current data wasn't available to quantify the extent of existing channel margin habitat; however, it is anticipated that the overall extent and quality would increase where levees are breached and natural channel processes and vegetation is allowed to re-establish along the banks of Roberts Island along the San Joaquin and Middle Rivers. Potentially, there would be additional channel margin habitat established along dendritic channels within restored tidal marsh. Active channel margin enhancement is assumed along 12 miles of the corridor, located on the existing-levee side of the corridor (the east, or right-bank, side of the San Joaquin River) where that levee is to remain. Those areas may include large wood placement and plantings. An additional 12 miles of channel margin habitat is assumed to form passively, where the channel margin in the location of former levees would be allowed to naturalize and "soften."

The benefits and impacts in Corridor 4 may include:

Anticipated Benefits

- Increased in-channel foraging habitat for covered fish
- Increased cover habitat for covered fish
- Improved thermal regulation and increased dissolved oxygen levels
- Increased organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.

Potential Impacts

- Increased predation of covered fish by birds
- Potential for increased predation of covered fish by non-native fish
- Establishment and proliferation of invasive non-native vegetation.

EA.4.1.4.3 Tidal Marsh and Tidal Perennial Aquatic

The estimated extent of restored marsh-related habitats for Corridor 4 is presented in Table EA.4.1-17. Note that Corridor 4 will have some subtidal habitat associated with tidal marsh channels (not included in Table EA.4.1-17). Without grading, the restoration would result in less tidal marsh habitat and more sea level rise accommodation and subtidal habitat. The acreages if no grading were to occur are shown in Table EA.4.1-18 for comparison.

Table EA.4.1-17: Tidal Habitat Areas by Corridor, With Grading

Habitat	Elevation Range	Corridor 4
uplands	> +15	190
transitional 2	+11.5 → +15	580
transitional 1	+8.5 → +11.5	1,570
SLR accommodation	+5.5 →+8.5	720
intertidal	+2 → +5.5	3,100
subtidal 1	-1 →+2	0
subtidal 2	-4 → -1	0
subtidal 3	-7 → -4	0
subtidal 4	-10 → -7	0
subtidal 5	< -10	0
Total all habitats/elevations		**6,160**
Total SLR, intertidal, and subtidal		**3,820**
Note: Area listed in acres Corridors 3 and 4 will have some subtidal associated with tidal channels		

Table EA.4.1-18: Tidal Habitat Areas by Corridor, No Grading

Habitat	Elevation Range	Corridor 4
uplands	> +15	190
transitional 2	+11.5 → +15	580
transitional 1	+8.5 → +11.5	1,570
SLR accommodation	+5.5 →+8.5	1,200
intertidal	+2 → +5.5	1,920
subtidal 1	-1 →+2	460
subtidal 2	-4 → -1	80
subtidal 3	-7 → -4	80
subtidal 4	-10 → -7	60
subtidal 5	< -10	30
Total all habitats/elevations		**6,160**
Total SLR, intertidal, and subtidal		**3,820**
Note: area listed in acres		

Anticipated Benefits

- Increase rearing habitat area and food production for Sacramento splittail, Chinook salmon produced in the San Joaquin River and other eastside tributaries, and possibly steelhead.

- Increase the availability and production of food in the Delta by export from the south Delta of organic material via tidal flow from the new marsh plain and organic carbon, phytoplankton, zooplankton, and other organisms produced in new intertidal channels.
- Locally provide areas of cool water refugia for Delta smelt, as possible.
- In conjunction with dual conveyance operations, marsh restoration in the south Delta could expand the current distribution of Delta smelt into formerly occupied habitat areas.

Potential Impacts

- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension. Fish and other aquatic species utilizing recently reconnected/restored floodplain habitat would be exposed to these increased levels of methylmercury and it may be transported downstream or result in local bioaccumulation affecting covered fish species, non-covered wildlife species, and human health.
- Local effects of contaminants including toxicity from residual pesticides and herbicides.
- Increased fish stranding on the floodplain.
- Increased predation of covered fish by birds.
- Reduced turbidity in downstream waters may have a negative impact on delta smelt, which are commonly found in turbid waters.
- Establishment of harmful invasive species: submerged aquatic vegetation, non-native centrarchids, corbicula, inland silversides effects on Delta and Longfin Smelt
- Resuspension and export of contaminants to downstream areas
- Creation of a population sink due to longer residence times with associated increased exposure to predators and entrainment
- Production of organic matter that will contribute to low DO conditions

EA.4.1.4.4 Floodplain Habitat and Food Production

An increase in the extent and frequency of floodplain inundation is expected to occur along the San Joaquin River following the removal of levees. Floodplain habitat will likely support a mosaic of vegetation types depending on a variety of factors including depth to groundwater, frequency of inundation, and soil properties. There is likely to be a continuum from riparian-dominated floodplain in the upstream end of the corridor, to a more tidal marsh-dominated area between the levees on the downstream end of the corridor.

Table EA.4.1-19 presents the estimated changes in seasonally-inundated floodplain meeting the assumed criteria to benefit salmon and splittail (see methods in Section 7.3). Figure EA.4.1-11 illustrates the relationship between river discharge (as measured at Vernalis) and floodplain inundation with and without assumed sea level rise for Corridor 4. This curve can be used to assess other discharge levels that evaluators may find to be potentially relevant to species outcomes.

Table EA.4.1-19: Changes in Ecologically-Relevant Floodplain Inundation in Corridor 4

	Existing Conditions			Corridor Conditions - with Sea Level Rise								
					Existing Flow Regime				SJRRP Flow Regime			
	Existing Corridor Footprint *(Total Existing Area between Levees; river excluded)*	Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs*	Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs*	New Corridor Footprint *(Total Area between Levees; river excluded)*	Inundated Floodplain Habitat *assuming Salmon Threshold, 15,500 cfs (river excluded)*		Inundated Floodplain Habitat *assuming Splittail Threshold, 11,600 cfs (river excluded)*		Inundated Floodplain Habitat *assuming Salmon Threshold(river excluded)*		Inundated Floodplain Habitat *assuming Splittail Threshold (river excluded)*	
Corridor	acres	acres	acres	acres	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint	acres	Percent of new corridor footprint
4	252	26	8	5,881	4,600	78%	4,200	71%	4,650	79%	4,250	72%

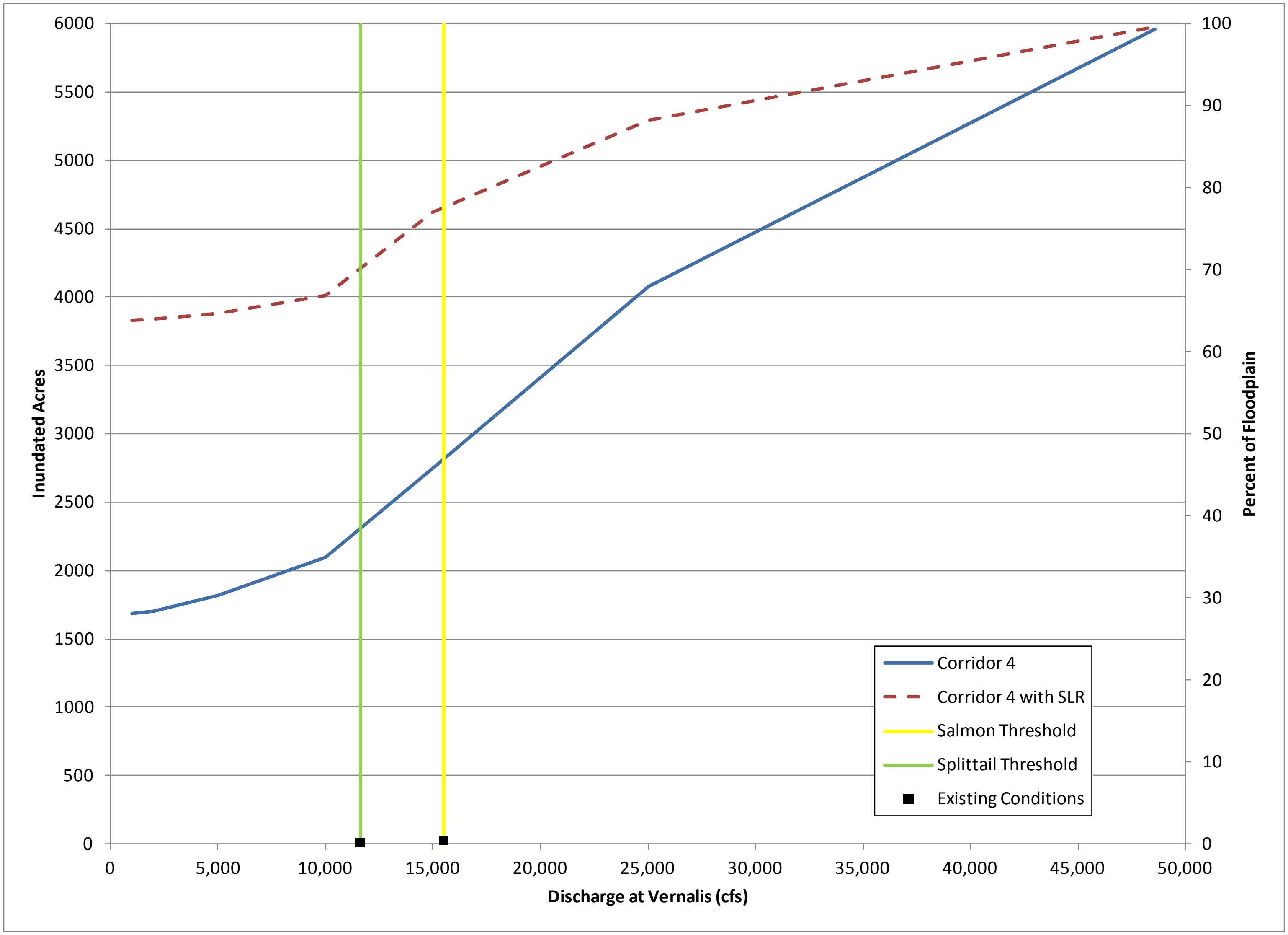
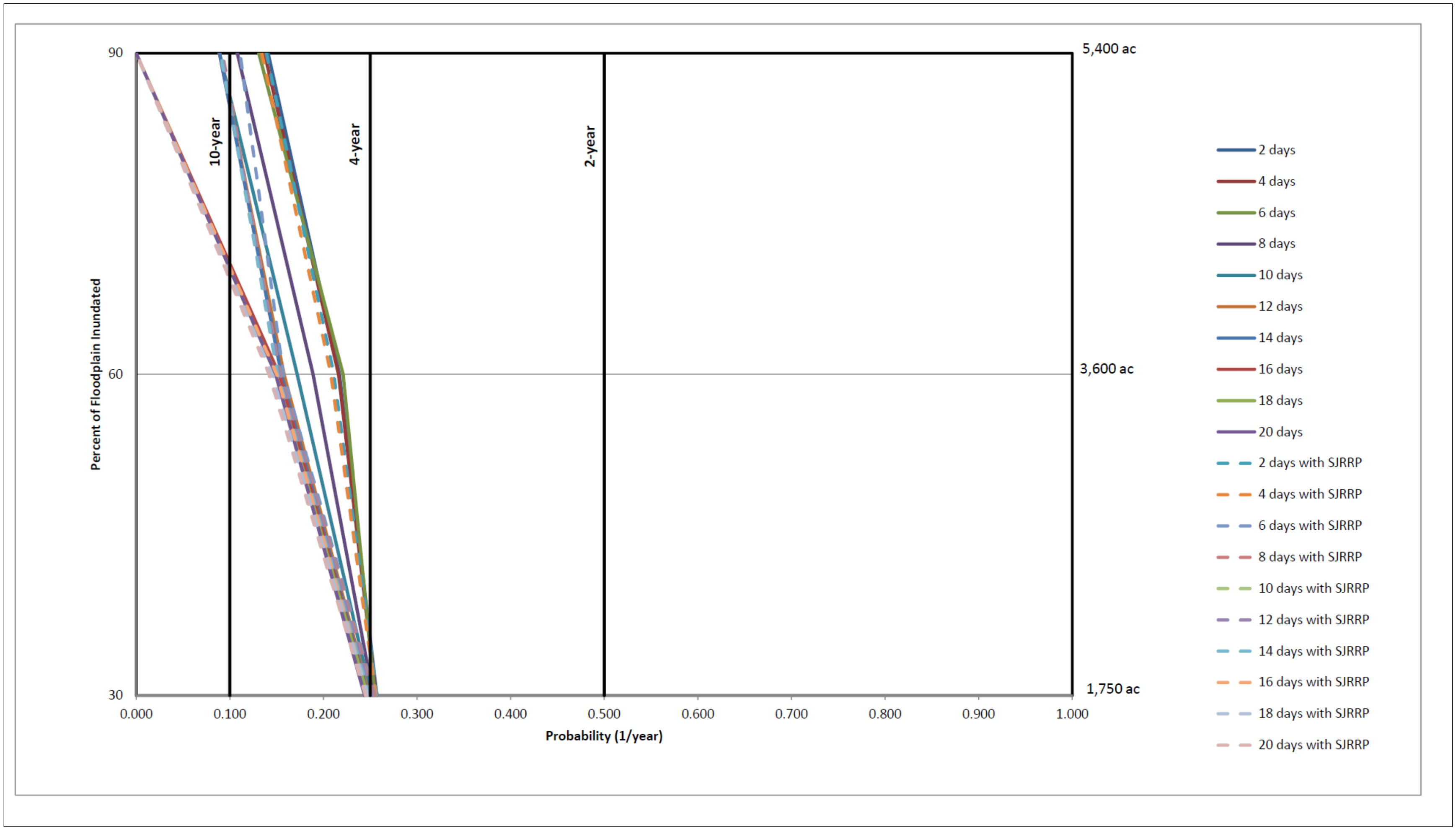


Figure EA.4.1-11: Relation between Discharge and Floodplain Inundation: Corridor 4

Floodplain inundation related to food production was assessed using the methods described in Section 7.3. Table EA.4.1-20 illustrates the probability that specified percentages of the corridor floodplains are inundated assuming different inundation durations. These results are presented graphically in Figure EA.4.1-12, and include results for existing and “with San Joaquin River Restoration flow regime” hydrology.

Table EA.4.1-20: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 4

Season: Dec. 1 – May 31						
	Exceedance Probability					
	1,000 cfs (30% of the corridor’s potential new floodplain is inundated)		21,000 cfs (60% of the corridor’s potential new floodplain is inundated)		41,000 cfs (90% of the corridor’s potential new floodplain is inundated)	
Duration(days)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)	(Existing Hydrology)	(SJRRP Hydrology)
2	0.794	0.864	0.242	0.239	0.149	0.147
4	0.798	0.865	0.241	0.238	0.147	0.144
6	0.792	0.865	0.238	0.237	0.143	0.130
8	0.788	0.864	0.236	0.235	0.129	0.115
10	0.787	0.863	0.233	0.233	0.112	0.113
12	0.788	0.863	0.230	0.231	0.112	0.112
14	0.784	0.863	0.229	0.229	0.111	0.111
16	0.783	0.866	0.227	0.225	0.111	0.111
18	0.784	0.866	0.226	0.224	0.068	0.069
20	0.787	0.864	0.222	0.220	0.000	0.000
Created using area/discharge curves under without SLR conditions. For SLR conditions, refer to the area/discharge curves to identify applicable acreages and percentages.						



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2 **Figure EA.4.1-12: Range of Frequencies and Durations for Flows Relevant to Food Production, Corridor 4**

The anticipated benefits and potential negative impacts for reconnecting the San Joaquin River to an expanded floodplain are listed below. Some of the benefits and impacts listed below also apply and are repeated below under the riparian ecosystem discussion, in the subsection below

Anticipated Benefits

- Water temperatures on the floodplain are warmer than in-channel temperatures during large winter events, a benefit to juvenile fish utilizing this habitat.
- Water quality improvements for in-stream conditions as sediments in flood waters are dropped out of the water column and are deposited on the floodplain.
- An expanded floodplain with direct connection to a prime migratory corridor for salmonids.
- Improved access to seasonally inundated floodplain habitat creates additional spawning habitat for splittail and additional rearing habitat for salmonids, splittail, and steelhead.
- Seasonally inundated habitats with the cycles of wetting and drying act are believed to act as a "productivity pump" to the lower estuary (CNRA, 2011).
- Flushing of backwaters to remove floating and submerged aquatic vegetation opens up habitat for use of shallow, near shore habitat for salmonids and smelt.
- Reduce non-point source pollution for improved water quality.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Access to slower floodplain water velocities reduces stress on juvenile fish during extreme water events.

Potential Impacts

- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension. Fish and other aquatic species utilizing recently reconnected/restored floodplain habitat would be exposed to these increased levels of methylmercury and it may be transported downstream.
- Establishment and proliferation of invasive non-native vegetation.
- Potential for fish stranding on the floodplain.
- Reduced turbidity in downstream waters may have a negative impact on delta smelt, which are commonly found in turbid waters.

EA.4.1.4.5 Riparian

Additional riparian habitat is expected to establish along the southern portion of the San Joaquin River within Corridor 4. It is anticipated that Corridor 4 restoration actions may provide an additional 1,807 acres of riparian habitat (for a total of 2,061 acres).

Anticipated Benefits

- Reduced non-point source pollution and improving overall water quality.

- Re-establishing a fairly contiguous corridor of riparian habitat along San Joaquin River increases connectivity providing cover for terrestrial species and facilitates genetic exchange.
- Improved thermal regulation and improved dissolved oxygen levels.
- Supports the establishment of a dynamic complex of woody and scrub habitat along the river channel and in the floodplain over the long-term provide in stream aquatic habitat in the form of overhead cover and inputs of large woody debris.
- Providing an expanded buffer between agricultural practices and the river corridor will enhance aquatic insect communities and improve water quality.
- Riparian vegetation slows water velocities in the floodplain for salmonids and splittail reducing stress on juvenile fish during extreme water events.
- Riparian habitat increases organic carbon, litter and insect inputs for aquatic food web support both on site and may be exported to downstream environments.
- Improved riparian habitat resilience during periodic perturbations and potentially to climate change (Seavy et al., 2009) by increasing overall habitat extent, improving connectivity, and allowing for plant community diversity.
- Additional cover for native fisheries from predatory fish.
- Potential for phytoremediation of toxins within soil (not well understood at this time, but Poplar hybrids are commonly used and some willow have shown promise)
- Removal of submerged aquatic vegetation in back-channel/oxbow areas following increased flow.

Potential Impacts

- Increased fire hazard, particularly is non-native species such as giant reed and tamarisk become established.
- Perception of increased 'weed' control needs for adjacent agricultural land owners (not necessarily an ecological impact, but something that will likely be an issue).
- Release of toxins built up from prior agricultural practices may be release to newly reconnected floodplains.
- Potential methylmercury release and resuspension.
- Establishment and proliferation of invasive non-native vegetation.
- Increased fish stranding on the floodplain.

EA.4.1.4.6 Water Quality

Anticipated water quality benefits and impacts are listed below. Note that no modeling was completed and these are conceptualized process-based outcomes.

- With respect to agriculture, the potential corridor actions are estimated to result in the inundation of additional land areas by San Joaquin/Delta waters. However, these lands are not anticipated to contain excessively high concentrations of salt. Implementation of the potential restoration could result in increased residence time within Corridor 4. Increased residence time could result in a net increase in evaporation within Corridor 4. This could result in an unknown but likely minimal increase in salt concentration, but would not increase net salt loading. Increases in salt concentration could deleteriously affect agricultural irrigation beneficial use.

- With respect to water supply, minor increases in salt concentration could occur, as discussed above, which could affect drinking water quality. Increases in Delta wetlands coverage could also result in increased dissolved organic carbon output, which could cause increased occurrence of disinfection byproduct production. Because Corridor 3 would include restoration of a large area of land to tidal wetlands, altered flow rates could occur, which could result in increased incidence of algal blooms, including toxic blooms such as microcystis.
- With respect to habitat quality, potential increases in particulate and dissolved organic carbon could potentially support Delta food webs. The potential restoration could also result in a net reduction in dissolved oxygen depletion, both through the removal of nutrients within wetland processes, and also via increased diffusion capacity due to increased water surface area. Countering this trend, to the extent that increased surface area would result in increased temperature, temperature sensitive species may be affected. Additionally, if increased incidence of algal bloom conditions occur, reduced dissolved oxygen could result in localized areas. Therefore, based on counteracting factors, potential effects on dissolved oxygen concentration are considered uncertain within Corridor 4
- Increases in tidal wetlands could result in an increase in mercury methylation potential. Increased methylation within anoxic layers could result in increased bioconcentration of methyl mercury in fish and other aquatic organisms. However, the distribution of elemental mercury and methylmercury is not well known in the South Delta. Therefore, potential effects associated with methylmercury remain uncertain within Corridor 4.

EA.4.1.5 Land Use

In general, the land use changes that would be associated with implementation of any of the conceptual South Delta corridors would result in the relocation or removal of some existing structures and infrastructure. Through any further progression of the conceptual corridors toward implementation, the exact configuration of the corridors may change as engineering design is completed in advance of implementation (i.e., the footprint of the corridor may expand or contract). Thus, at this time it is useful to examine the existing structures and infrastructure that are contained both within the corridors themselves, and within the area of a 1,000-foot buffer surrounding the corridors—examined to account for the potential of a wider corridor footprint.

Table EA.4.1-21 and Table EA.4.1-22 display the results of a comprehensive review of aerial imagery of the conceptual South Delta corridors to identiy agricultural infrastructure, boating-related facilities, utility towers, houses, and assorted other infrastructure. Figure EA.4.1-13 thru Figure EA.4.1-17 depict the identified locations and types of features identified within the corridors. The 1,000-foot buffer was completed based on the corridor boundary and in some areas (e.g., Corridor 4 near French Camp Slough) captures infrastructure or homes on the river bank opposite the corridor itself. Further, becaues corridors were developed to work synergistically with existing levees, in some areas the buffers capture homes behind levees that are in locations where the corridor width is not likely to expand (e.g., homes of South kasson Road near Vernalis). Thus, the totals including a buffer must be assessed carefully.

Table EA.4.1-21: Identified South Delta Infrastructure

Corridor	Ag Infrastructure	Boat Facility	House	Utility Tower	Other*
Corridor 1A (inside corridor)	76	1	72	9	30
Outside of corridor, 1,000 foot buffer	62	1	305	4	30
Corridor + 1,000 foot buffer	138	2	377	13	60
Corridor 1B (inside corridor)	35	1	31	1	2
Outside of corridor, 1,000 foot buffer	24	0	54	1	3
Corridor + 1,000 foot buffer	59	1	85	2	5
Corridor 2A (inside corridor)	3	0	2	4	4
Outside of corridor, 1,000 foot buffer	59	0	19	3	3
Corridor + 1,000 foot buffer	62	0	21	7	7
Corridor 2B (inside corridor)	66	13	34	10	11
Outside of corridor, 1,000 foot buffer	73	23	65	14	10
Corridor + 1,000 foot buffer	139	36	99	24	21
Corridor 3 (inside corridor)	46	0	16	31	0
Outside of corridor, 1,000 foot buffer	47	0	29	14	3
Corridor + 1,000 foot buffer	93	0	45	45	3
Corridor 4 (inside corridor)	97	2	67	16	5
Outside of corridor, 1,000 foot buffer	25	1	999	7	21
Corridor + 1,000 foot buffer	122	3	1066	23	26

Table EA.4.1-22: Observed types of features within the "Other" category from Table A.4.1-21

-Abandoned House	-Industrial/warehouse
-Business/Retail	-Major facility (unknown)
-Campground	-Mining Facility
-Commercial	-Office/Retail
-Community Center	-Park
-Dairy manure ponds	-Public Boat Launch
-Durham Ferry State Rec Area	-Public facility
-Fairgrounds-type facility	-Trailer Park
-Golf Course, with Club House and Maintenance	-Union Mills Conference/Wedding Center
-Gun Club	-Water Diversion Facility
-Hydro-Canal Feature	-Water Treatment Facility
-Industrial	-Water Treatment Plant

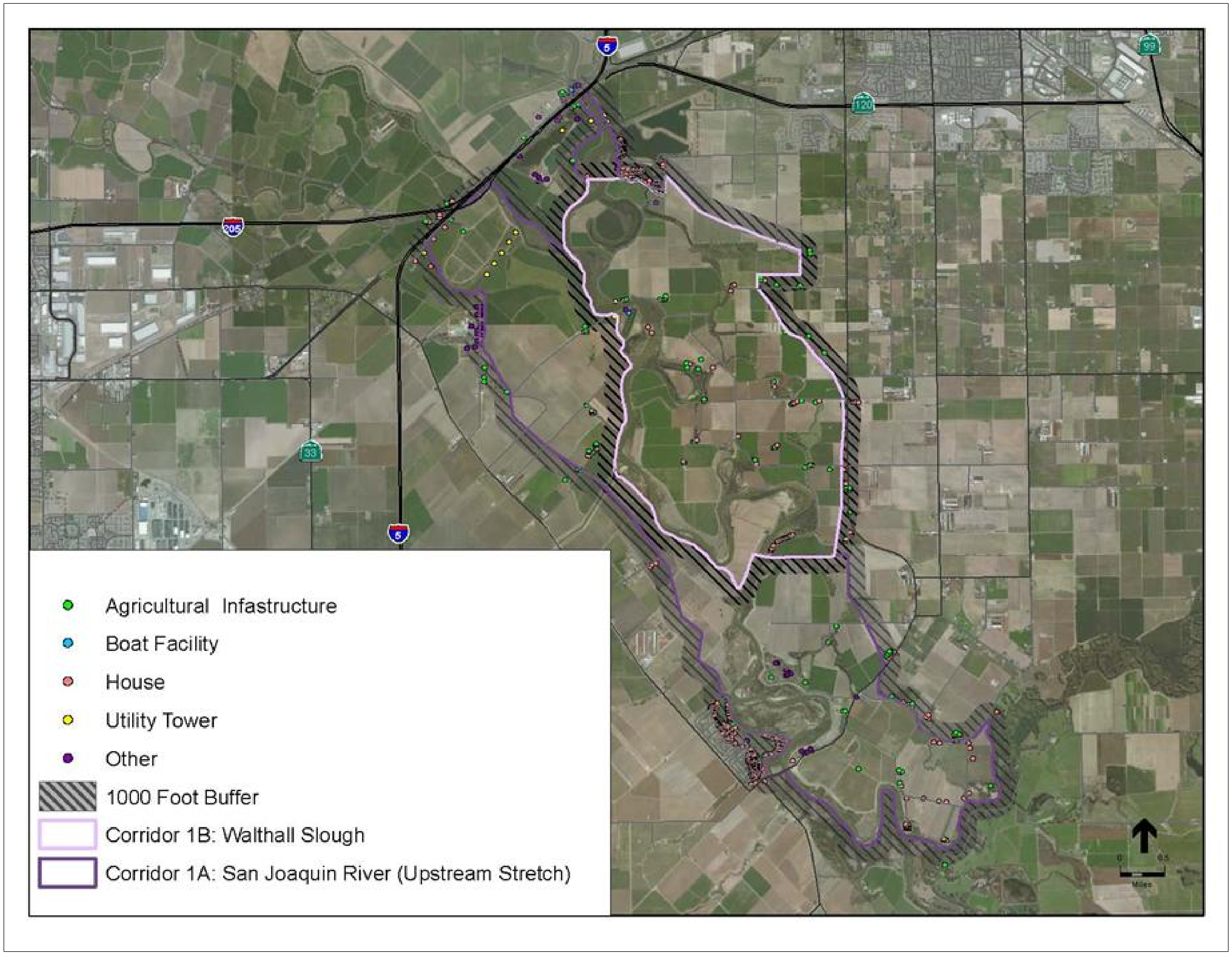


Figure EA.4.1-13: Identified Infrastructure, Corridors 1A and 1B

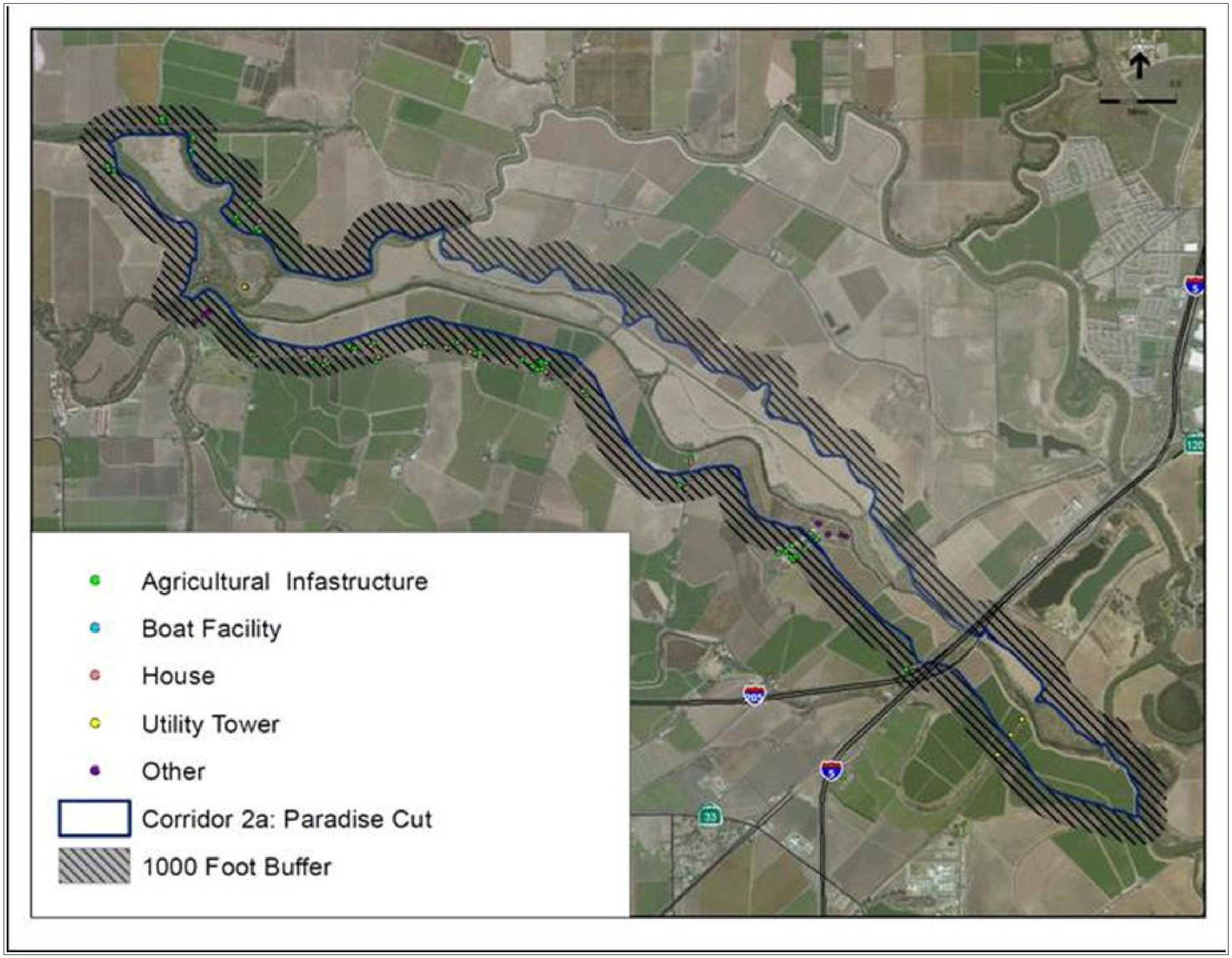


Figure EA.4.1-14: Identified Infrastructure, Corridors 2A

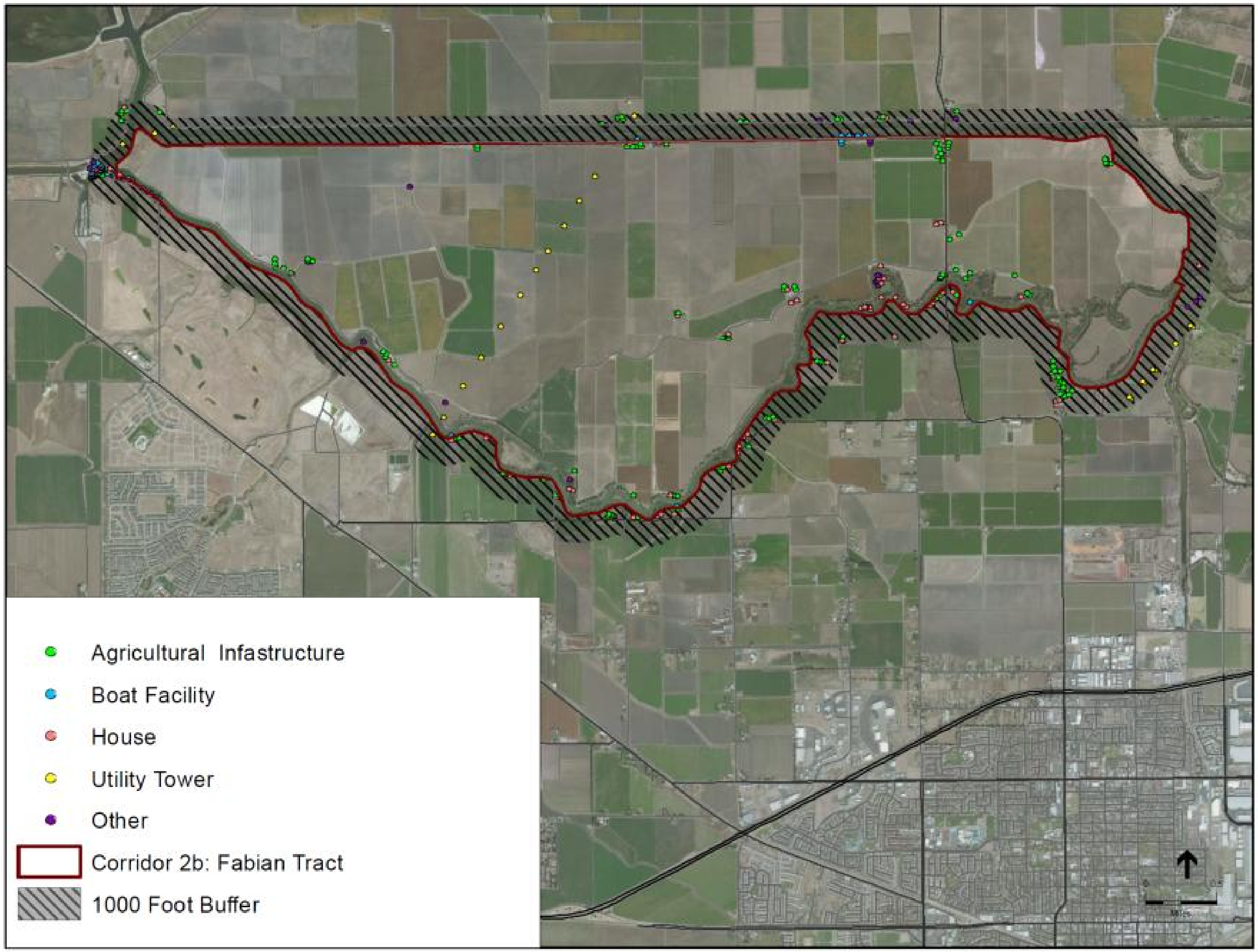


Figure EA.4.1-15: Identified Infrastructure, Corridors 2B

Figure EA.4.1-16: Identified Infrastructure, Corridors 3

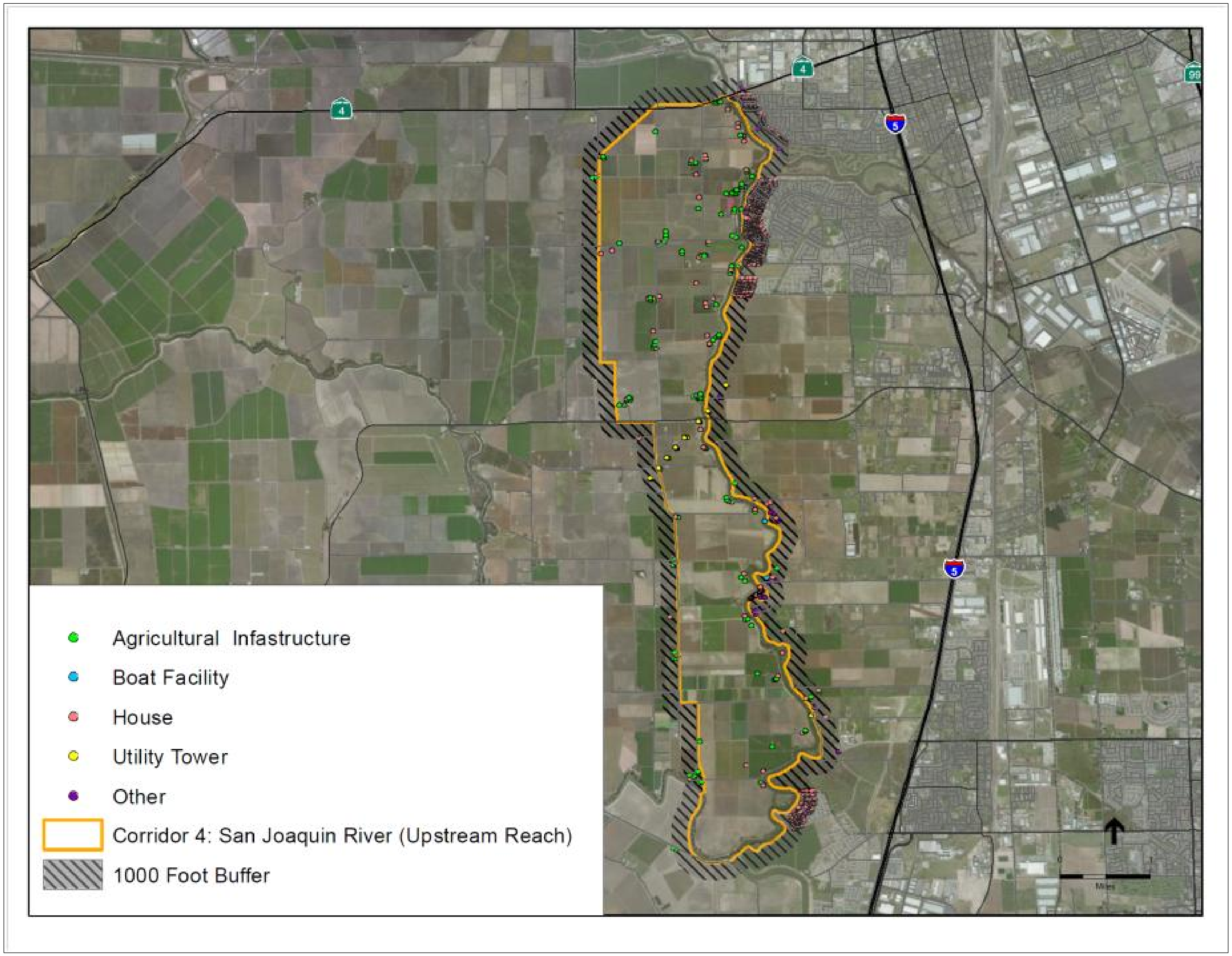


Figure EA.4.1-17: Identified Infrastructure, Corridors 4

EA.4.2 Evaluation Results

EA.4.2.1 Modified-DRERIP Evaluations

The objective of the modified DRERIP evaluation evaluations was to determine which corridors hold the greatest opportunity to achieve the habitat-related objectives stated in the SDHWG charter. Through this process, a group of technical experts evaluated the corridors to determine the relative "worth" (based on the positive outcomes) and the potential "risk" (based on negative outcomes) of focusing any future planning upon, and/or ultimately selecting and implementing, any of the corridors. In short, this process was a screening-level evaluation to identify potential opportunities and identify data gaps and uncertainties so they can be resolved in the future, depending on what actions are deemed appropriate.

As included in Section 7.1, there are ten objectives focused on restoration of native aquatic, terrestrial and avian habitats and geomorphic processes:

Native Aquatic Habitat Restoration

1. Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.
2. Create or restore critical habitats for splittail, sturgeon, and other native fishes along the mainstem of the San Joaquin River, with an emphasis on increasing flow-related survivorship.
3. Increase frequency of floodplain inundation to support Sacramento splittail reproduction and viability.
4. Improve conditions for other native resident fish species including Hitch, Blackfish, Hardhead, and Tule Perch.
5. Create a natural gradient of fluvial and tidal habitats and water quality constituents along one or more corridors in the South Delta to improve the upstream and downstream migration of native fishes between Vernalis and the Western Delta to:
    a. facilitate the upstream and downstream migration of native fishes between Vernalis and the western Delta.
    b. provide habitat that will increase the survival and numbers of native fish species
6. Reduce entrainment mortality of juvenile salmonids, smelt, sturgeon, splittail, and other native fishes

Terrestrial and Avian Species Habitat Restoration

7. Restore tidal marshes and riparian corridor habitat for terrestrial and avian species including waterfowl.

Geomorphic Processes

8. Restore more natural channel morphology to create more diverse and complex channel habitats, increase the frequency of side channel inundation, and restore hyporheic flow.
9. Create conditions that allow physical processes to generate suspended sediment and turbidity.

10. Create habitat and/or hydrodynamic conditions that do not favor macrophytes and degrade the sediment pool, but rather promote marsh building processes.

The modified-DRERIP evaluations of the South Delta corridors took place over two days on February 1st and 2nd, 2012. The evaluation team included Bruce DiGennaro (Facilitator; ESSEX Partnership); Eric Ginney (Coach; ESA PWA); Jeremy Thomas (NewFields); Michelle Orr (ESA PWA); Ted Sommer (DWR); Cathy Marcinkevage (NOAA Fisheries); Josh Israel (USBR); Christine Joab (CVRWQCB); Will Stringfellow (UOP); Mike Hoover (USFWS); John Cain (AR); Ron Melcer (DWR); Shengjun Wu (DWR); and Deanna Sereno (CCWD).

Evaluators were provided with a draft portion of this document in advance of the evaluations workshop to become familiar with the South Delta conceptual corridor configurations, existing conditions in these areas of the South Delta, and the modeling and assessment work performed by the consultant team to consider potential conditions assuming the conceptual flood and conservation actions were to be implemented in these corridors. Additional sections of this document outlining the results of these evaluations were prepared after the evaluation workshop took place.

EA.4.2.1.2 Methodology

The evaluation workshop began with a review of Modified-DRERIP Instructions document provided in Section 7.6. As this modified-DRERIP evaluation process was novel and, therefore, new to these volunteer participants (some had experience with the 2007 DRERIP evaluation of the initial BDCP conservation measures), an initial briefing was provided at the onset. During work on February 1st, it was determined by the group that it would be advantageous to link all of the positive and negative outcomes back to the SDHWG Objectives (as listed in Section 7.1). This change was made after the evaluation of Corridor 1A was completed, and the consultant team revised the framework and note taking methods before the workshop on February 2nd. Outcomes for Corridor 1A were subsequently adapted into the "objective-based framework" after the workshop ended and the notes were being edited for clarity.

The edited workshop evaluation notes and outcome tabulation are included in Section 7.7. The group of evaluators that participated in the February workshop was smaller than the confirmed invitation list because multiple participants became ill. This required that the group be kept together instead of breaking into sub-teams, which limited the productivity of the effort. Thus, Corridor 1B and Corridor 3 were not explicitly evaluated. The group did comment on the similarities between Corridors 1A and 1B, and also mentioned how Corridor 3 seemed in some respects not as desirable as Corridor 2B or 4 in terms of the likely flood benefits (even though this group was not considering flood outcomes) and benefit of marsh habitat given the corridor's proximity to other portions of the interior Delta. Results of the workshop were summarized and circulated to reviewers for comment, with revisions made accordingly. The edited workshop evaluation notes are included in Section 7.7.

EA.4.2.1.3 Summary of Results

The complete listing of the workshop evaluation notes and outcome tabulation are included in Section 7.7; however, the following sections outline some of the key ecological outcomes, positive and negative, as related to species and habitats for the corridors that were evaluated. In this summary, key outcomes are not presented with linkage to their respective objectives. That detail is provided in Section 7.7. Outstanding issues, questions and uncertainties; data gaps; and future considerations and refinements to restoration areas are presented in Section 5.

Corridor 1A

- New floodplain areas are available for inundation that would benefit splittail and salmonids, including additional food export from this corridor into critical habitat areas. There is a relatively low risk of: floodplain stranding, increased mortality due to water quality degradation, mercury methylation, selenium, or resuspension of toxics.
- There is a very high probability that channel complexity will increase and natural geomorphic processes will be restored between the new levee setbacks in this corridor.
- There is a very low potential for invasive species colonization (SAV, Clams). Invasive riparian vegetation is a concern if active management is not employed.

Corridor 2A

- New floodplain areas could improve channel complexity and the new floodplain would be available for inundation and would benefit splittail and salmonids.
- A lowered Paradise Cut weir could increase export of juveniles and food to other parts of the South Delta.
- The corridor presents a relatively-low risk of floodplain stranding or increased mortality due to water quality degradation or mercury methylation. There is more uncertainty with microcystis and selenium.

Corridor 2B

- New floodplain areas (that transition into marsh habitat) would be available for inundation that would benefit splittail and salmonids, and levee removal would increase channel complexity.
- The new marsh area would be well-connected to upstream floodplains, but without other habitat work downstream of Fabian Tract, the downstream connection into the Delta would be a linkage to poor habitat.
- Minimal habitat for smelt; some habitat for splittail spawning and salmonid rearing and white sturgeon rearing.
- Invasive species (clams, SAV) will certainly occur, but adverse effect on fish species is uncertain and likely low magnitude
- Water quality (especially temperature, potentially DO) may be an issue, but numerical modeling data is lacking.
- Potential for entrainment is an issue yet to be examined quantitatively/with modeling, but conceptually is a large factor that needs to be addressed.

Corridor 4

- New floodplain areas (that transition into marsh habitat) would be available for inundation that would benefit splittail and salmonids—and all outmigrating fish would go through this corridor if the HORB is in place. Low risk of stranding.

- New marsh area would be well connected to upstream floodplains, but downstream connection into the Delta links to poor habitat in the Stockton Deep Water Ship Channel (SDWSC).
- Minimal habitat for smelt; some habitat for splittail spawning and salmonid rearing and white sturgeon rearing.
- Water quality (especially DO and temperature) is likely an issue with the downstream SDWSC , but numerical modeling data for water quality is lacking.
- The risk of invasive species (clams, SAV) similar to other corridors.

EA.4.2.2 Summary of Flood Evaluations

EA.4.2.2.1 Introduction

The objective of the flood evaluations was to determine which corridors or combinations of corridors could provide the greatest potential benefit to flood management. As stated in Section 7.1, South Delta Habitat and Flood Corridor Development and Sizing Process, the flood management objectives for the South Delta conceptual corridors are:

1. Substantially reduce flood stage on the mainstem San Joaquin River between Mossdale and Stockton. This can be via a bypass of flows to another area, or a reduction of flow via attenuation upstream or in the reach. Specifically, seek to provide for a substantial reduction in flood stage on the mainstem San Joaquin River between Vernalis and Stockton for the 50-year flood peak[5], with the understanding that numerical modeling results are assumed to have accuracy within +/- 0.5 foot, though this is less relevant because relative model results were compared for trend analysis during the evaluations rather than model results to stage data.
2. Reduce the probability of catastrophic urban flooding and loss of life in the communities of Lathrop, Manteca, Stockton, and unincorporated San Joaquin County.
3. Substantially increase flood conveyance capacity through a constrained reach of the San Joaquin River floodway. This objective seeks to reduce backwater conditions within the project area, for particular benefits in upstream reaches/the broader region.
4. Maintain consistency with regional flood management plans (i.e., the CVFPP).
5. Reduce maintenance costs and conflicts with listed species.
6. Cause no significant increases in flood stage during the 50-year event and identify locations where risk evaluations are merited in future investigations.

The flood evaluations of the South Delta corridors took place over two days on February 1st and 2nd, 2012. The evaluation team included Betty Andrews (ESA PWA, coach), Mark Tompkins (NewFields River Basin Services), Mike Archer (MBK Engineers), Michael Mierzwa (DWR), Joe Bartlett (DWR), Samson Haile-Selassie (DWR), Ray McDowell (DWR), Scott Woodland (DWR), Steve Cimperman (DWR), Chris Neudeck - Feb 1 only (KSN, Inc.), Bob Scarborough (DWR, Feb 2 only) Minta Schaefer (ESA PWA, note taker), Lucy Croy (NewFields River Basin Services, modeling support, Feb 1 only). Evaluators were provided with the following sections of this document in advance of the evaluations workshop to become familiar with the South Delta conceptual corridors: 1, Introduction and

[5] The Settlement Agreement between River Islands, NRDC, and NHI (2007) references a 1.75-foot stage reduction at Mossdale for the 100-year flood peak.

Background; 2, Existing Corridor Conditions; 3, Corridor Description and Evaluation Assumptions; 7.1, South Delta Habitat and Flood Corridor Development and Sizing Process; 7.2, South Delta Habitat and Flood Corridor Rationales Summary; 7.3, Hydraulic and Hydrologic Modeling Methods and Assumptions; 7.4, Flood Modeling Results; and 7.6, Methods and Materials for Modified-DRERIP, Flood, Terrestrial Species, and Water Quality Evaluations. All remaining sections of this document were prepared after the evaluations took place as they summarize the results of the evaluation process.

EA.4.2.2.2 Methodology

The flood evaluations began with a review of the Flood Evaluation Instructions document provided in Section 7.6 of this document. As this type of evaluation process was novel, it became necessary both before and during the evaluations to revise the Flood Evaluation Instructions to document the approach that the group agreed would best achieve the objectives of the flood evaluations and was logistically feasible. The steps in the Flood Evaluation Instructions are listed below and this Section 4.2.2.2, Methodology, will follow the same structure.

- Step 1, Review the Modeling Approach and Results;
- Step 2, Develop the Positive and Negative Outcome(s) to be Scored;
- Step 3, Assign a Spatial Scale;
- Step 4, Score Magnitude and Certainly of Potential Positive and Negative Outcomes; and
- Step 5, Identify Potential Refinements for Phase 2 of South Delta Habitat Planning.

Step 1, Review the Modeling Approach and Results

The methods and results of the one-dimensional unsteady hydraulic modeling using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) that would be used to evaluate each corridor were presented to the group per Step 1. A detailed description of the hydraulic modeling is provided in this document in Section 7.3, Hydraulic and Hydrologic Modeling Methods and Assumptions. The six model runs that were used to evaluate the corridors are listed below. All six model runs considered the event with an annual exceedance probability (AEP) of 0.02, or the 50-year flood. See Figure EA.3.1-1 through Figure EA.3.4-1 for a depiction of each corridor.

<u>Model Run A (Corridor 1A)</u> - Levee setbacks on both banks of the San Joaquin River from Vernalis to I-5.

<u>Model Run B (Corridor 4)</u> - Levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River.

<u>Model Run C (Corridors 1A and 2A)</u> - Levee setbacks on both banks of the San Joaquin River from Vernalis to I-5 and expansion of the Paradise Cut flood bypass and modifications to Paradise Cut weir.

<u>Model Run D (Corridors 1A and 4)</u> - Levee setbacks on both banks of the San Joaquin River from Vernalis to I-5 and levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River.

<u>Model Run E (Corridors 1B and 2B)</u> – Corridor 1B is an alternative version of Corridor 1A along the San Joaquin that includes only a right-bank levee setback and connection of Walthall Slough with the

San Joaquin River via a weir. Corridor 2B is an expanded version of Corridor 2A that includes the expansion of the Paradise Cut flood bypass and removes or breaches levees between the flood bypass and Fabian Tract.

Model Run F (Corridors 2A and 3) - Expansion of the Paradise Cut flood bypass and modifications to Paradise Cut weir and selected levee setbacks along Middle River on Union Island.

Model output was reported as the difference in stage as well as the difference in flow at maximum stage between existing and corridor conditions at key locations on maps as shown in Figure EA.4.2-1 and Figure EA.4.2-2 through Figure EA.4.2-8. The following is the list of selected model output locations:

- San Joaquin River near Red Bridge Slough
- San Joaquin River Upstream of Paradise Cut
- San Joaquin River at Mossdale
- San Joaquin River Downstream of Old River
- San Joaquin River at Brandt Bridge
- San Joaquin River Downstream of Old River
- San Joaquin River near Highway 4
- Paradise Cut at I-5
- Paradise Cut at Paradise Road
- Old River at Tracy Boulevard
- Old River near Grant Line Canal
- Old River at Heard of Old River
- Gland Line Canal at Tracy Boulevard
- Old River at Middle River
- Middle River at Howard Road

In addition to the results reported in Figure EA.4.2-1 and Figure EA.4.2-2 through Figure EA.4.2-8, water surface elevation profiles for each model run for the group of four scenarios that included existing, corridor, existing with sea level rise (SLR), and corridor with SLR conditions were used to assess potential benefits in the evaluation process. These profiles are provided in Section 7.4, Flood Modeling Results. Specific potential benefits are described below.

Step 2, Develop the Positive and Negative Outcome(s) to be Scored

After the model results were presented to the group per Step 1, the positive and negative outcomes were identified by the group under Step 2. The Scientific Evaluation Worksheet found in Section 7.6 of this document was used to record the identified outcomes during the evaluation process. The worksheet was set up prior to the evaluation workshop with four positive and four negative potential outcomes that the group was to evaluate. The worksheet included the following four positive outcomes: P1F, Decreased Stage; P2F, Decreased Flow; P3F, Decreased duration of flow against levees; and P4F, Decreased frequency of flow against levees. The potential negative outcomes included: N1F, Increased Stage; N2F, Increased Flow; N3F, Increased duration of flow against levees; and N4F, Increased frequency of flow against levees.

The water surface elevation profiles provided in Section 7.4 were used to determine what effect the corridor actions would have on river stage during the event with an annual exceedance probability of 0.02, or the 50-year flood. As each profile was examined by the evaluators, the approximate identified change in stage was recorded in the flood outcomes worksheets found in Section 7.6 of this document. If stage decreased in a given area, it was noted in the positive outcomes portion of the worksheet and if stage increased, it was recorded as a negative outcome in the worksheet. When evaluating differences in stage, the approximate maximum difference in the profile plots was identified. Particular attention was focused on the flood objective areas (FOAs), which are the mainstem San Joaquin River between Mossdale and Stockton, including the communities of Lathrop, Manteca, Stockton, and unincorporated San Joaquin County, Old River between San Joaquin and Middle Rivers, and Paradise Cut (see Figure EA.4.2-9). After the change in stage was examined, the group discussed the implications to flood management and the potential to mitigate negative outcomes, which were also noted in the flood evaluations worksheet.

As the evaluations progressed, it was clear that it would not be feasible to address each of the eight potential outcomes for each of the six model runs within the time available. Therefore, the group agreed that outcomes P1F and N1F, which address changes in stage, were where the evaluations would focus. Additionally, the group was aware that the outcomes that were not addressed during this workshop would be slated for examination during the next phase of work. Each model run was evaluated in terms of changes in stage, and outcomes P2F through P4F and N2F through N4F were not evaluated, except for a single informal review of the full time series of model results throughout the model domain for Model Run C by a small sub-group led by Mark Tompkins. The purpose of this informal review was to assess whether certain stage reductions observed in the peak flow results were supported by changes in flow distribution and attenuation that could only be assessed by looking at these results. The consensus of the sub-group was that attenuation occurred and that the peak flow results were indeed consistent with the complete time series of results throughout the model domain.

Step 3, Assign a Spatial Scale

The relative spatial scale of each of the outcomes were defined in Step 3 based on the model results and specific criteria included in the Flood Evaluation Instructions. Scale was assigned in relation to the results of the other corridors (and corridor combinations, i.e., the other model runs). The purpose of establishing scale was to assist with determining the magnitude of the outcome, which was defined in Step 4 of the process.

Step 4, Score Magnitude and Certainty of Potential Positive and Negative Outcomes

Tables 1 and 2 in the Flood Evaluation Instructions contain the criteria used to inform the magnitude and certainty scores that were developed in Step 4. The magnitude and certainty scores were tracked in an Excel spreadsheet and used in the conversion matrices in Tables 3 and 4 in the Flood Evaluation Instructions, which indicate the degree of worth (positive outcomes) and risk (negative outcomes) of the corridor actions included in the model run being evaluated. Note that these terms relate to the *decision of choosing to implement the flood system modifications in the corridors being evaluated*, and the term “risk” should not be confused with the traditional definition of risk used in flood management.

Step 5, Identify Potential Refinements for Phase 2 of South Delta Habitat Planning

Under Step 5, the data gaps/future planning table at the end of the evaluation worksheet was completed by the group. The discussion led to elucidation and documentation of important data needs, key uncertainties, additional analysis necessary to resolve outstanding uncertainties, new ideas or understanding, and potential corridor reconfigurations or combinations that would increase worth or decrease risk, and restoration design considerations. Data gaps identified in Step 5 are listed in Section 5 of this document.

Post Evaluation

After the flood evaluations were complete, the results were summarized, the structure of the Scientific Evaluation Worksheet was modified to allow for more clear presentation of the identified outcomes, and the Flood Evaluation Instructions document was revised to reflect the methodology implemented during the evaluations. After this summary was prepared and all supporting materials were updated, the following items were sent to all members of the flood evaluation team for review: Section 4.2.2, Flood Evaluation Summary (this section); South Delta Flood Evaluation Instructions; the completed Scientific Evaluation Worksheet; the completed magnitude and certainty scoring spreadsheet; and Section 7.3, Hydraulic and Hydrologic Modeling Methods and Assumptions. Comments provided by the evaluators were then incorporated and each document was finalized.

In addition to finalizing the documentation as described above, a review of the hydraulic model was conducted subsequent to the flood evaluations, but before the evaluation summary materials were sent to the evaluators for comment. During the review of the hydraulic model, three errors were discovered and the models were corrected and rerun. A technical memorandum that describes these changes to the hydraulic model and how the results were affected is provided in this document in Section 7.3, Hydraulic and Hydrologic Modeling Methods and Assumptions. As shown in Table EA.7.3-3 in Section 7.3, when the stage increases and decreases that were reported during the evaluations based on the original model results are compared to increases and decreases under the new model results, changes range from 0.1 to 0.9 feet. As a result of these changes, some magnitude and certainty scores needed to be revised, but the worth and risk scores were not affected. The flood evaluation team received versions of the documents listed in the paragraph above that reflected the updated model results.

EA.4.2.2.3 Results

Model Run A

Model Run A corresponds to Corridor 1A and includes levee setbacks on both banks of the San Joaquin River from Vernalis to I-5. According to the stage profiles and model results in spreadsheet form, Corridor 1A would result in stage decreases of less than 0.5 feet throughout the FOA under with- and without-SLR conditions. The magnitude score assigned is 1 because stage increases within the FOA were less than 0.5 feet. The certainty score of 4 was chosen because the understanding is high for flood hydraulics. Based on professional judgment, the model results seem to logically predict the reduction in water surface elevation (WSE) that would be expected to occur in the upper portion of the San Joaquin River under corridor conditions.

Under Outcome NF1, Increased Stage, a minimal WSE increase of approximately 0.02 feet on the San Jaoquin River at Mossdale was observed. A magnitude of 1 was chosen because WSE increase was less than 0.5 feet. A certainty of 3 was chosen because while the understanding for flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, the modeling precision does not exist to support a high level of certainty.

When magnitude and certainty are considered together, Model Run A and, therefore, Corridor 1A, has a **worth** of **medium** and a **risk** of **low** under both with- and without-SLR conditions.

Model Run B

Model Run B corresponds to Corridor 4 and includes Levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River. According to the stage profiles and model results in spreadsheet form, Corridor 4 would result in a WSE decrease of up to 1.8 feet in the FOA along Paradise Cut (up to 1.5 feet under with-SLR conditions) and Old River of up to 2.25 feet under with and without-SLR conditions. The magnitude score assigned is 3 because decreases in stage typically reached a maximum between 1.5 and 3 feet in the FOA along Old River and exceeded 2.5 feet outside of the FOA. A certainty of 4 was chosen because based on professional judgment, model results seem to logically predict the reduction in WSE that would be expected to occur under corridor conditions.

Under Outcome NF1, Increased Stage, WSE increases within the FOA were up to approximately 3.2 feet along the downstream-most 22,000 feet of the San Joaquin River. Under with-SLR conditions, WSE increases were up to approximately 2.4 feet. In evaluating the potential to mitigate WSE increases documented under Outcome NF1, the group agreed that mitigation would be potentially difficult due to existing infrastructure (e.g., Hwy 4, railroad, wastewater treatment plant ponds, and urban development). The Stockton Deepwater Ship Channel and turning basin could provide additional conveyance, if flows could be successfully routed through the constricted area just upstream. Additional analysis would be required to evaluate the feasibility and benefit of using the Stockton Deepwater Ship Channel to mitigate for WSE increases associated with Corridor 4. Therefore, a magnitude score of 4 was chosen for Outcome NF1. The certainty score of 3 was chosen because while the understanding of flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, boundary effects may be influencing the model result.

When magnitude and certainty are considered together, Model Run B and, therefore, Corridor 4, has a **worth** of **high** and a **risk** of **high** under both with- and without-SLR conditions.

Model Run C

Model Run C corresponds to Corridors 1A and 2A and includes levee setbacks on both banks of the San Joaquin River from Vernalis to I-5, the expansion of the Paradise Cut flood bypass, and modifications to Paradise Cut weir. According to the stage profiles and model results in spreadsheet form, the combination of Corridors 1A and 2A would result in WSE decreases within the FOA of up to 1.25 feet along the San Joaquin River, 0.9 along and Old River, and 0.85 feet along Paradise Cut. Under with-SLR conditions, WSE decreases were up to 1.25 feet along the San Joaquin River, 0.85 along Old River, and 0.8 feet along Paradise Cut. The magnitude score assigned is 2 because decreases in stage typically reached a maximum between 0.5 and 1.5 feet. The certainty score chosen was 4 because based on professional judgment, model results seem to logically predict the reduction in WSE that would be expected to occur under corridor conditions.

When magnitude and certainty are considered together, Model Run C and therefore, the combination of Corridors 1A and 2A, has a **worth** of **high** and a **risk** of **null** because the model results indicated that no increases in stage would occur under this scenario. This is the case under both with- and without-SLR conditions.

Model Run D

Model Run D corresponds to Corridors 1A and 4 and includes levee setbacks on both banks of the San Joaquin River from Vernalis to I-5 as well as levee setbacks on Roberts Tract along the left bank side of the San Joaquin River and on a short reach of the right bank of Old River. According to the stage profiles and model results in spreadsheet form, the combination of Corridors 1A and 4 would result in WSE decreases within the FOA of more than 3 feet in the San Joaquin River, up to 2.25 feet along Old River, and up to 1.75 feet along the upstream-most 2.7 miles of Paradise Cut. Under with-SLR conditions, WSE decreases were up to 2.5 feet along the San Joaquin River, up to 2.25 feet along Old River, and 1.65 feet along Paradise Cut. The magnitude score assigned is 4 because stage decreases exceed 3 feet in portions of the FOA. For with-SLR conditions, a magnitude score of 3 was chosen because stage decreases within the FOA typically reached a maximum between 1.5 and 3 feet. The certainty score chosen was 4 because based on professional judgment, model results seem to logically predict the reduction in WSE that would be expected to occur under corridor conditions.

Under Outcome NF1, Increased Stage, WSE increases within the FOA of up to approximately 2.4 feet along the downstream-most 27,000 feet of the San Joaquin River. In evaluating the potential to mitigate WSE increases, the group agreed that mitigation would be potentially difficult due to existing infrastructure (e.g., Hwy 4, railroad, wastewater treatment plant ponds, and urban development). The Stockton Deepwater Ship Channel and turning basin could provide additional conveyance, if flows could be successfully routed through the constricted area just upstream. Additional analysis would be required to evaluate the feasibility and benefit of using the Stockton Deepwater Ship Channel to mitigate for WSE increases associated with the combination of Corridors 1A and 4. Therefore, a magnitude score of 4 was chosen for Outcome NF1. A certainty score of 3 was chosen because while the understanding of flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, boundary effects may be influencing the model results.

When magnitude and certainty are considered together, Model Run D and therefore, the combination of Corridors 1A and 4, has a **worth** of **high** and a **risk** of **high** under both with- and without-SLR conditions.

Model Run E

Model Run E corresponds to Corridors 1B and 2B and includes only a right-bank levee setback and connection of Walthall Slough with the San Joaquin River via a weir and allowing flow to access Fabian Tract. According to the stage profiles and model results in spreadsheet form, the combination of Corridors 1B and 2B would result in WSE decreases within the FOA of up to approximately 1.9 feet along the San Joaquin River, 2 feet along Old River, and 2.5 feet along Paradise Cut. Under with-SLR conditions, WSE decreases within the FOA of up to approximately 1.9 feet along the San Joaquin River, 2.2 feet along Old River, and 2.6 feet along Paradise Cut. The magnitude score assigned is 3 because stage decreases typically reached a maximum between 1.5 and 3 feet within the FOA under both with- and without-SLR conditions. A certainty score of 4 was chosen because based on professional judgment, the model results seem to logically predict the reduction in WSE that would be expected to occur under corridor conditions.

Under Outcome NF1, Increased Stage, increases in WSE were up to a 2 feet without SLR and approximately 0.75 feet with SLR along lower Old River. In evaluating the potential to mitigate WSE increases documented under Outcome NF1, the group agreed that mitigation would likely have fewer constraints in this non-project levee, non-urban setting. Uncertainty exists about such factors as soil types and the scope of infrastructure modifications, etc. The group identified the possibility of using Walthall Slough to store water as a method to regulate WSE in the San Joaquin River. Additional analysis would be required to evaluate potential options for mitigating the WSE increases associated with the combination of Corridors 1B and 2B. A magnitude score of 2 was chosen for without-SLR conditions because stage increases are expected to be mitigable with moderate investment. A magnitude score of 1 was chosen for with-SLR conditions because stage increases are expected to be mitigable with minor investment. A certainty score of 3 was chosen for both the with-SLR and without-SLR conditions because, while the understanding of flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, boundary effects may be influencing the model result.

When magnitude and certainty are considered together, Model Run E and therefore, the combination of Corridors 1B and 2B, has a **worth** of **high** and a **risk** of **medium** under with-SLR conditions and a worth of high and risk of low under with-SLR conditions.

Model Run F

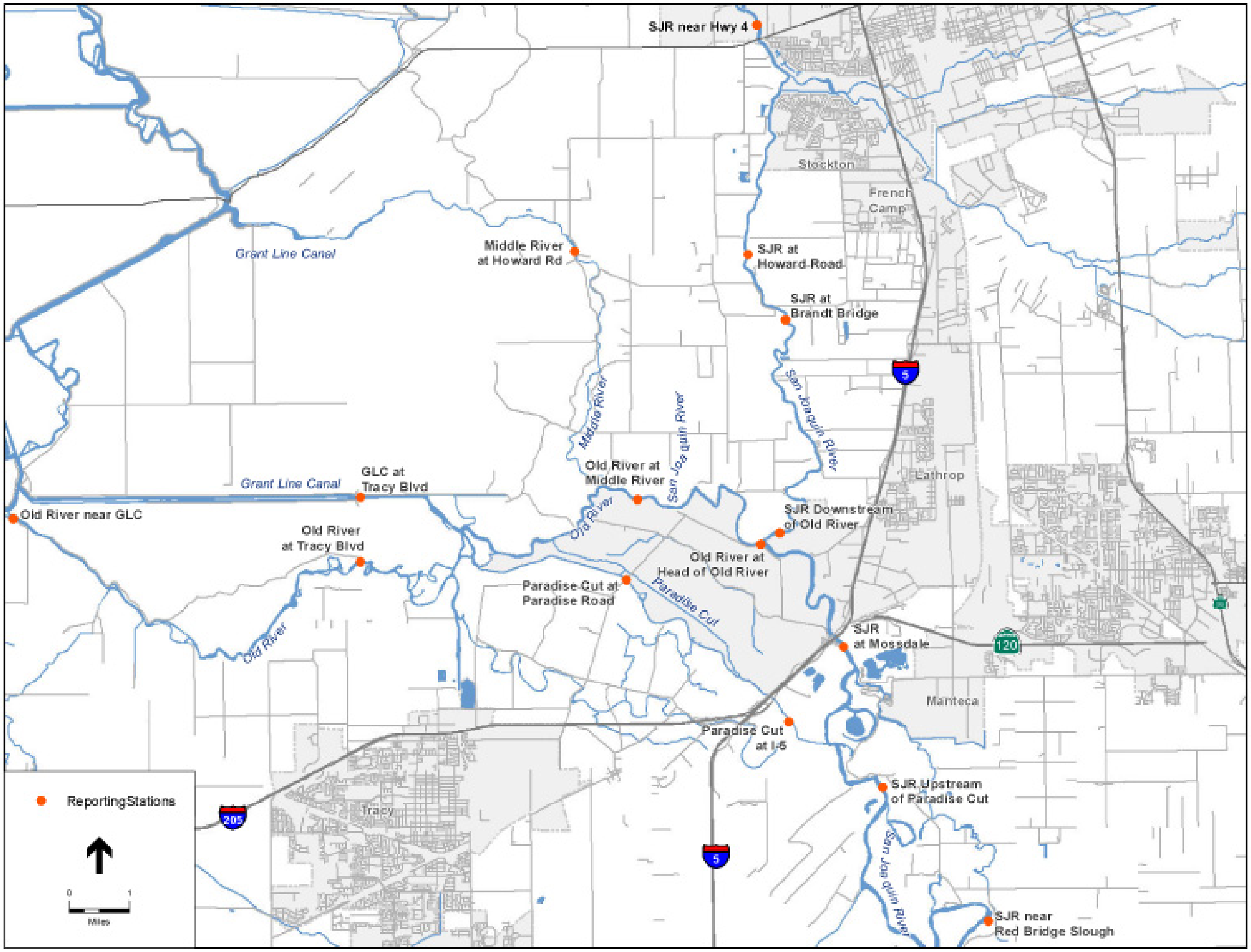
Model Run F corresponds to Corridors 2A and 3 and includes Expansion of the Paradise Cut flood bypass and modifications to Paradise Cut weir and selected levee setbacks along Middle River on Union Island. According to the stage profiles and model results in spreadsheet form, the combination of Corridors 2A and 3 would result in WSE decreases within the FOA of up to approximately 2.1 feet along the San Joaquin River, 2.4 feet along Old River, and 2.1 feet along Paradise Cut. Under with-SLR conditions, WSE decreases within the FOA of up to approximately 2 feet along the San Joaquin River, Old River, and Paradise Cut. The magnitude score assigned is 3 because decreases typically reached a maximum between 1.5 and 3 feet within the FOA. A certainty score of 4 was chosen because based on professional judgment, the model results seem to logically predict the reduction in WSE that would be expected to occur under corridor conditions.

Under Outcome NF1, Increased Stage, there were large increases in WSE at the downstream model boundary along Middle River of up to approximately 5.25 and 4.0 feet without and with SLR, respectively. In evaluating the potential to mitigate WSE increases documented under Outcome NF1, the group agreed that mitigation is possible, but may require large investment due to the spatial extents of the improvements that may be needed. Additionally, the group identified uncertainty about levee overtopping potential downstream of Corridor 3. Additional analysis would be required to evaluate potential options for mitigating the WSE increases associated with the combination of Corridors 2A and 3. A magnitude score of 4 was chosen because stage increases are large and extensive and mitigation may require significant investment. A certainty score of 3 was chosen for both the with-SLR and without-SLR conditions because it is very likely that boundary effects are influencing the model result.

When magnitude and certainty are considered together, Model Run F and therefore, the combination of Corridors 2A and 3, has a **worth** of **high** and a **risk** of **high** under both with- and without-SLR conditions.

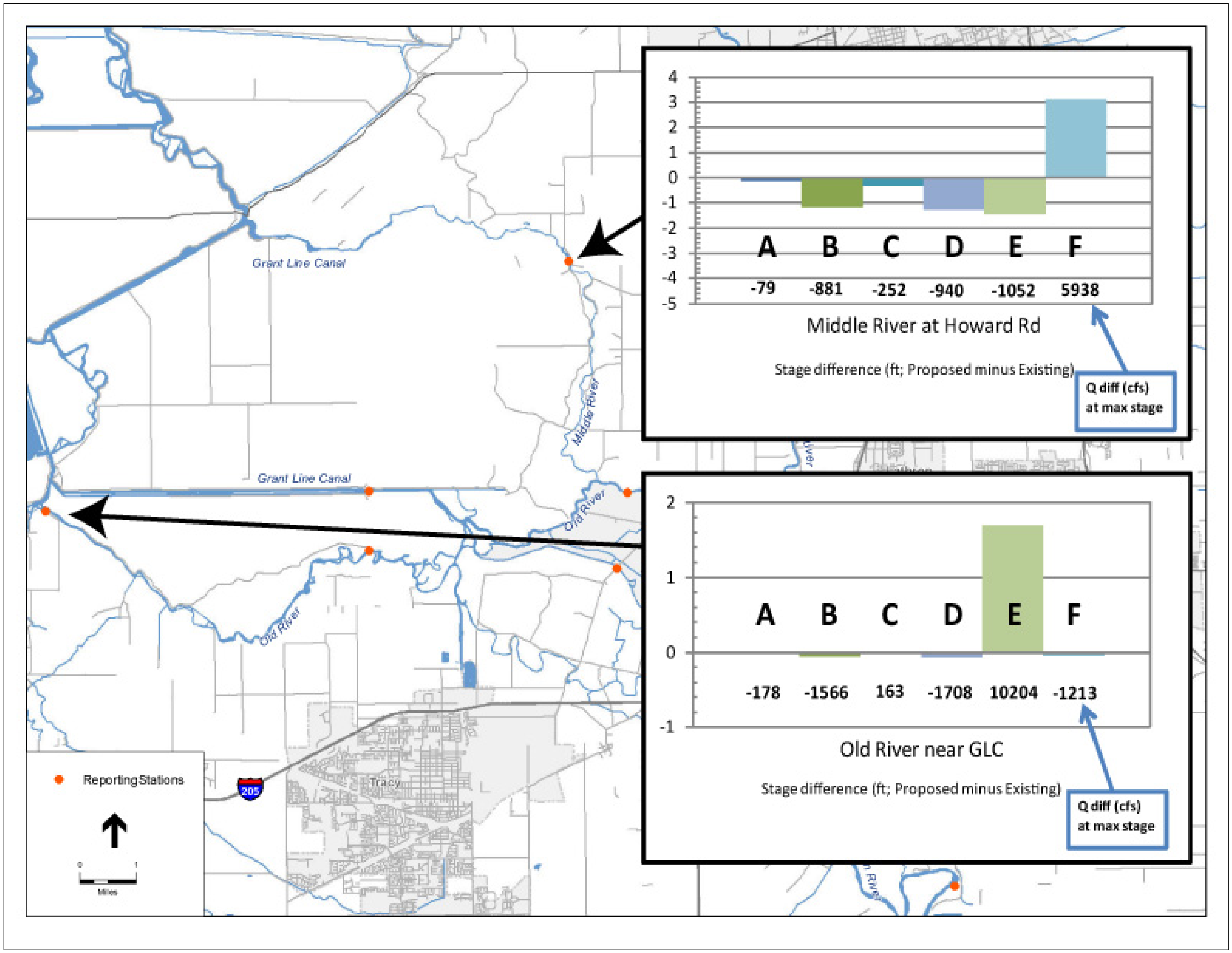
Overall Results Summary

The scoring worksheet and summary is provided in Section 7.7, Modified-DRERIP, Flood, Terrestrial Species, and Water Quality Evaluation Worksheets, as developed in Evaluation Workshops. As shown in the scoring summary and described in this section, model run A has a worth score of medium and model runs B through F have a worth score of high. The only model run that did not show increases in stage was model run C and, therefore, it is the only run that does not have a risk score. Model runs A, A with SLR, and E with SLR have risk scores of low. Model run E is the only run that has a risk score of medium. Model runs B, D, and F have risk scores of high under both under with- and without-SLR conditions.

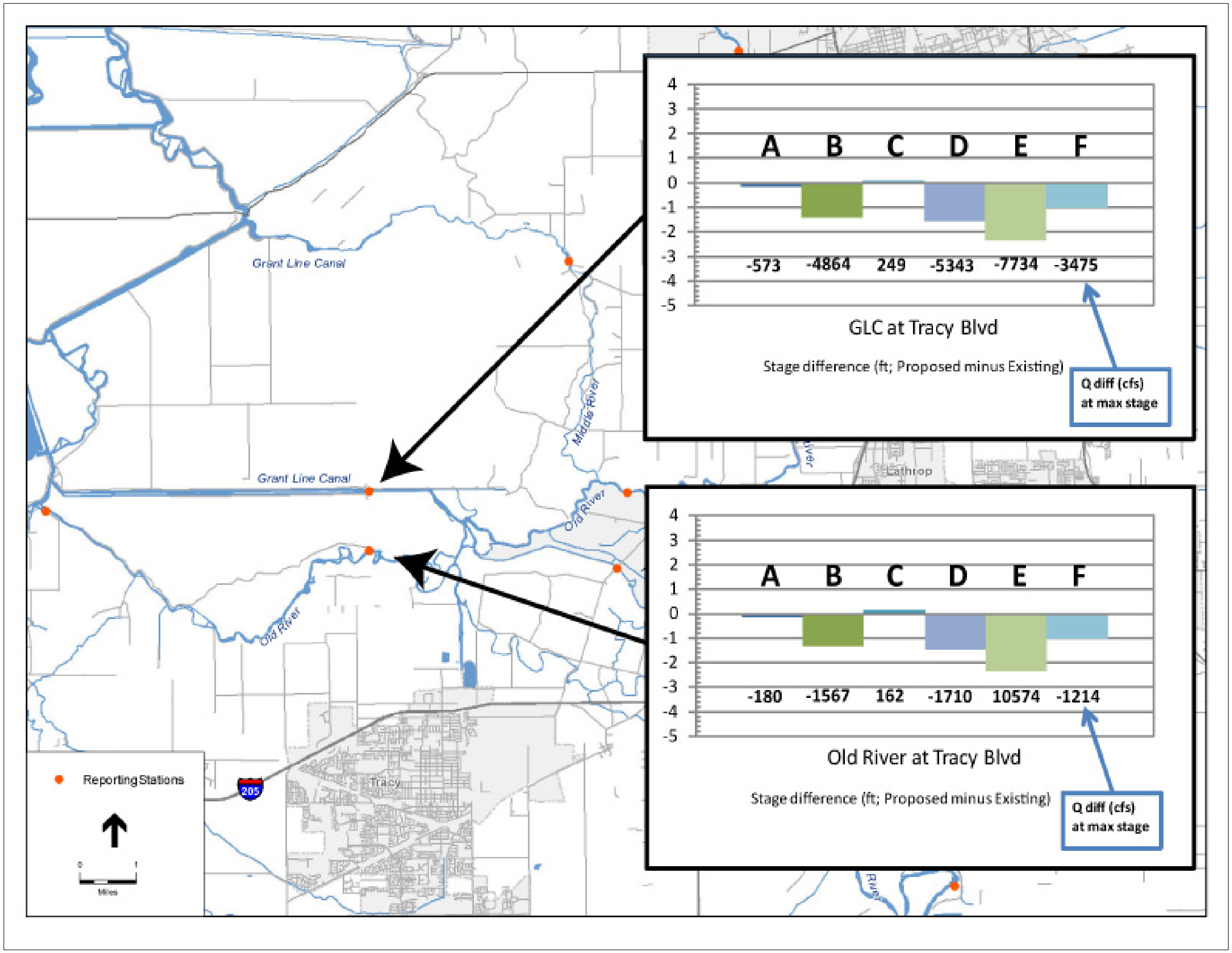


1
2 **Figure EA.4.2-1: Hydraulic Model Output Locations**

1



2 **Figure EA.4.2-2: Reported Hydraulic Model Results by Node**



1

2 **Figure EA.4.2-3: Reported Hydraulic Model Results by Node**

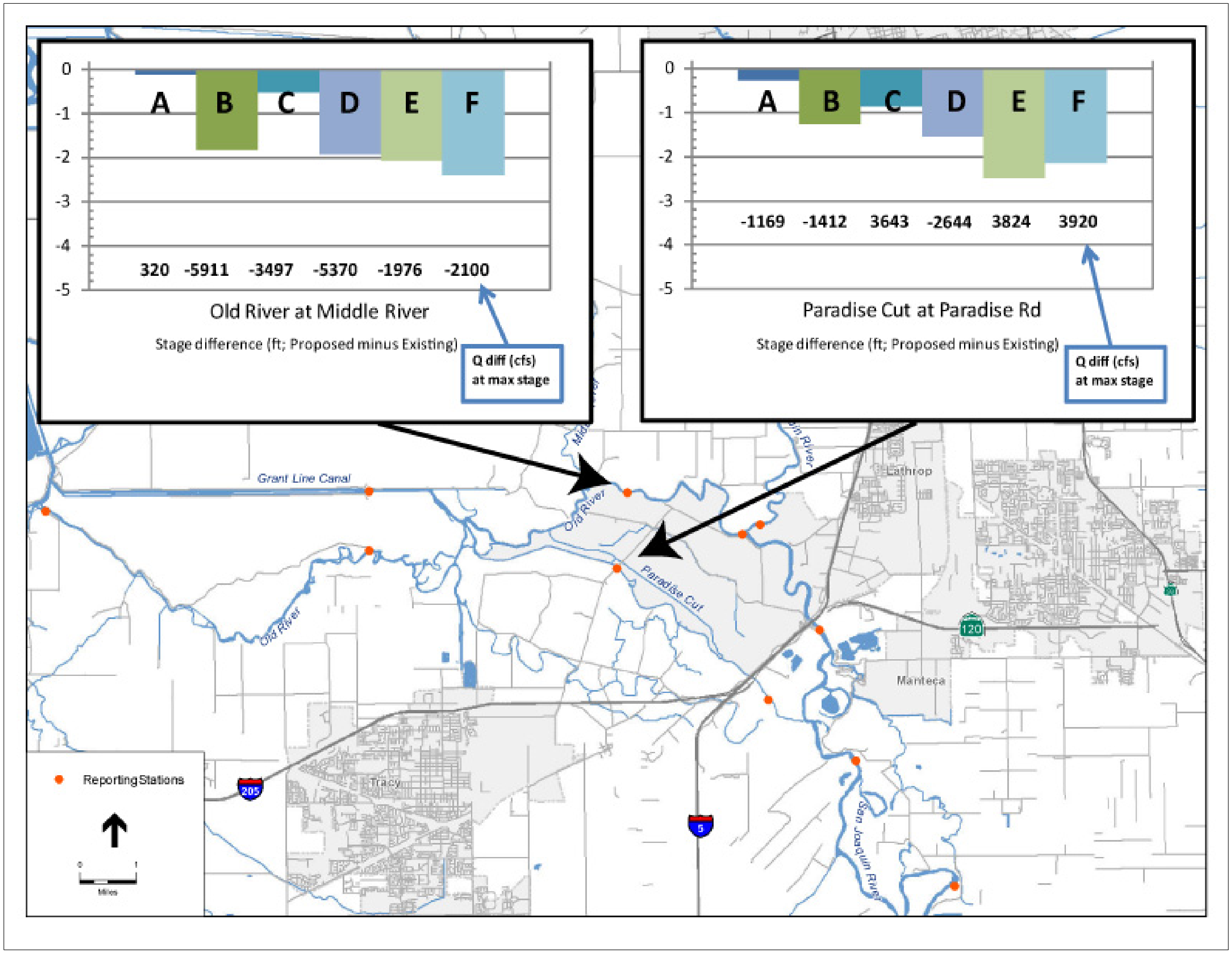
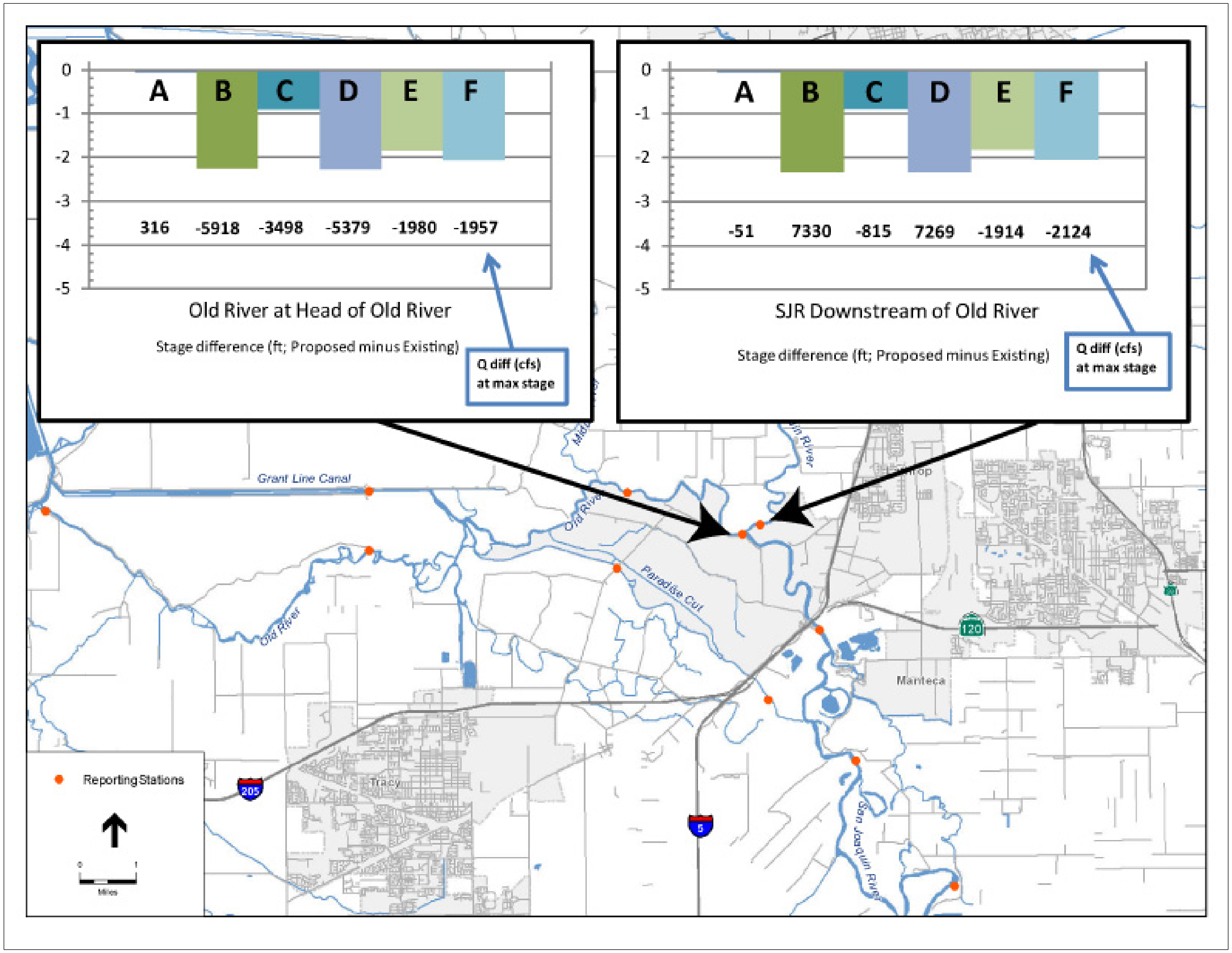


Figure EA.4.2-4: Reported Hydraulic Model Results by Node

1


2 **Figure EA.4.2-5: Reported Hydraulic Model Results by Node**

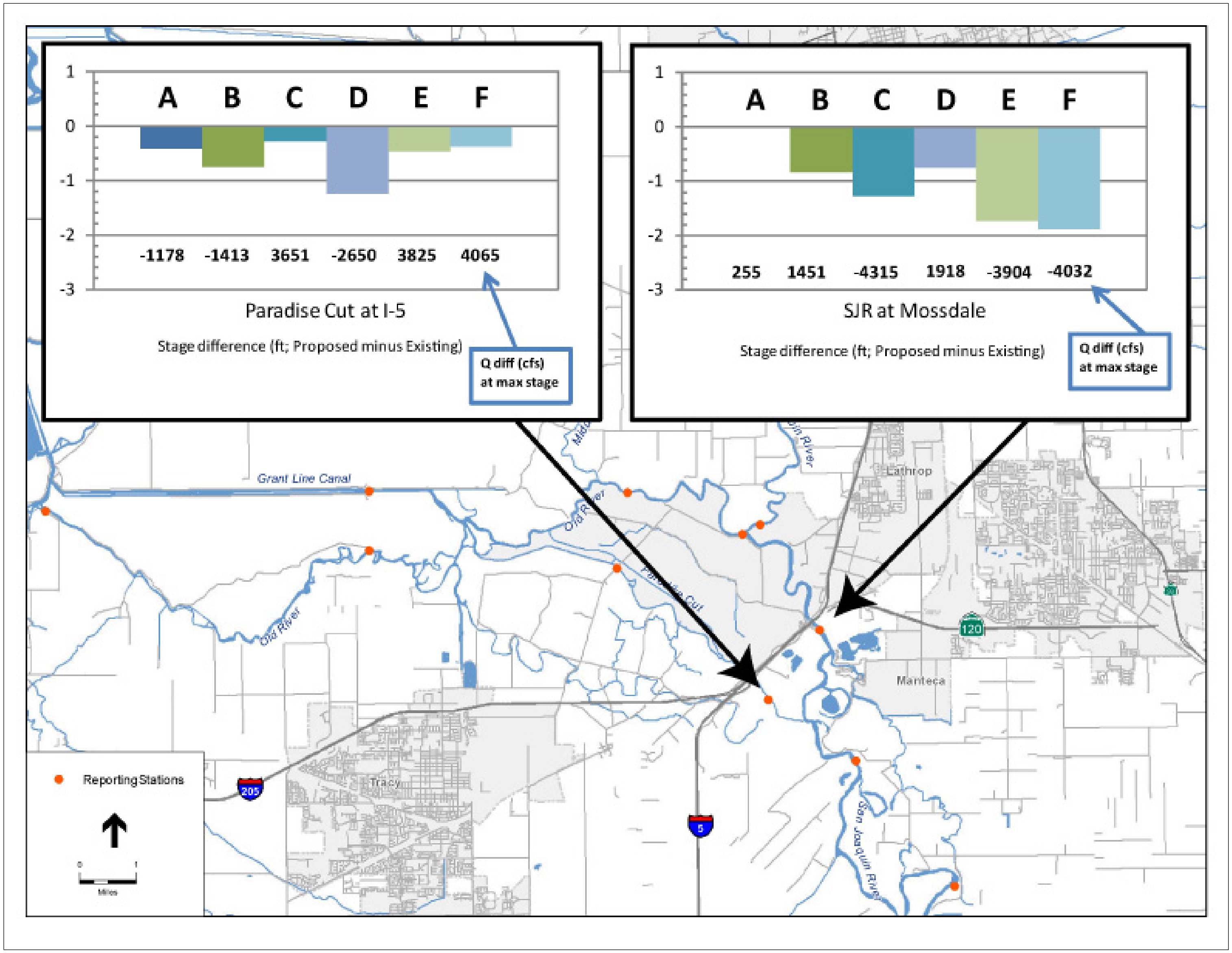


Figure EA.4.2-6: Reported Hydraulic Model Results by Node

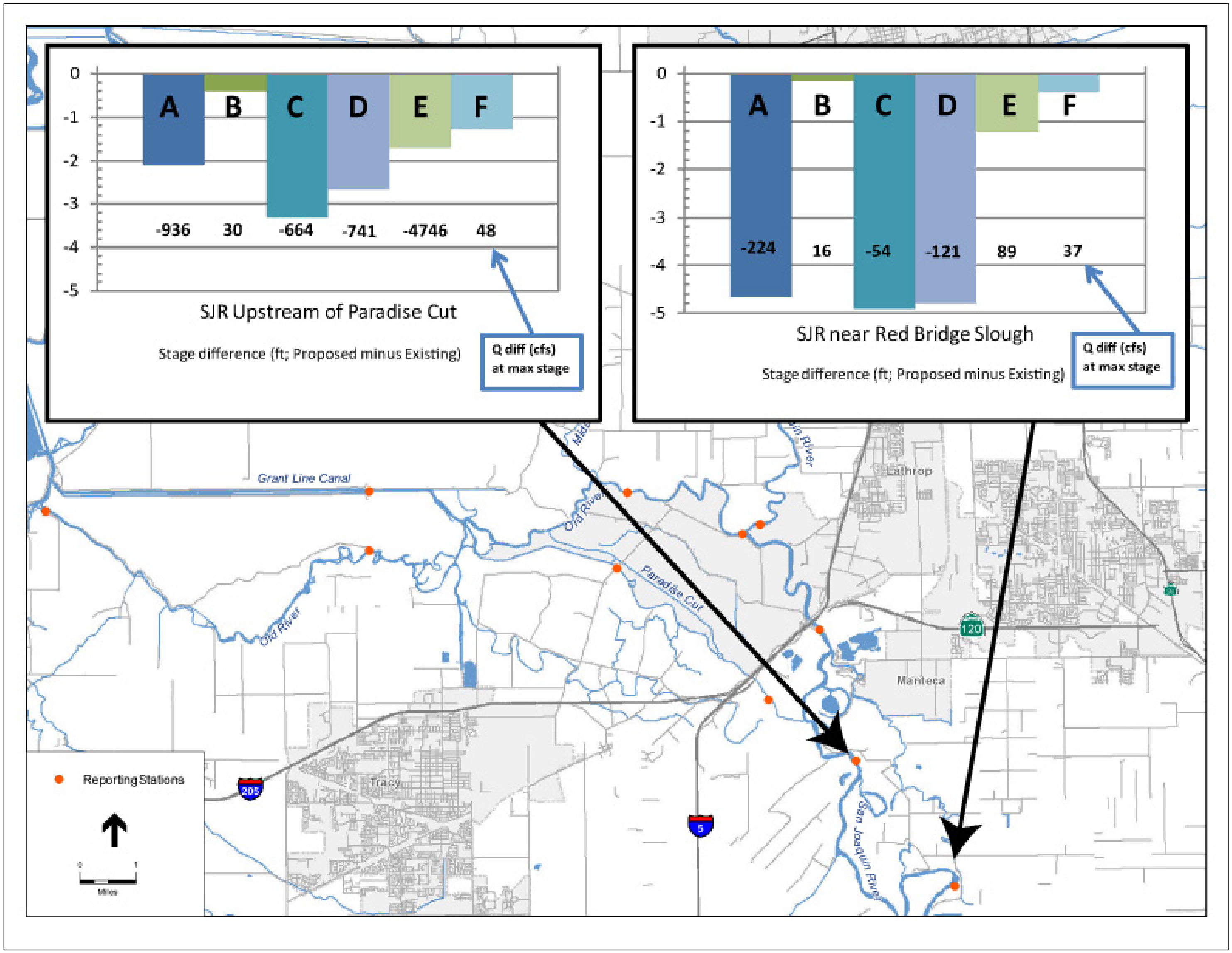
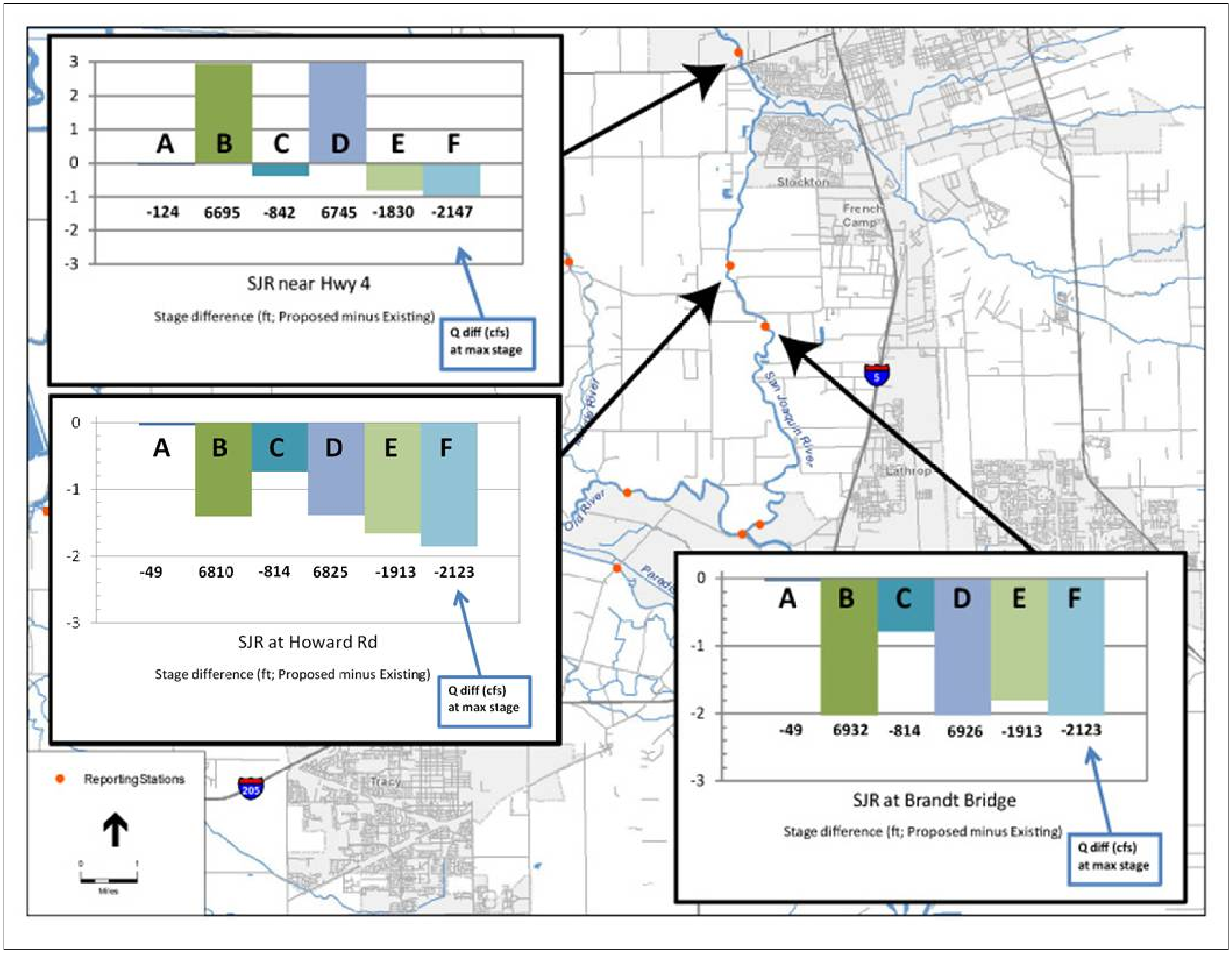


Figure EA.4.2-7: Reported Hydraulic Model Results by Node

1



2 **Figure EA.4.2-8: Reported Hydraulic Model Results by Node**

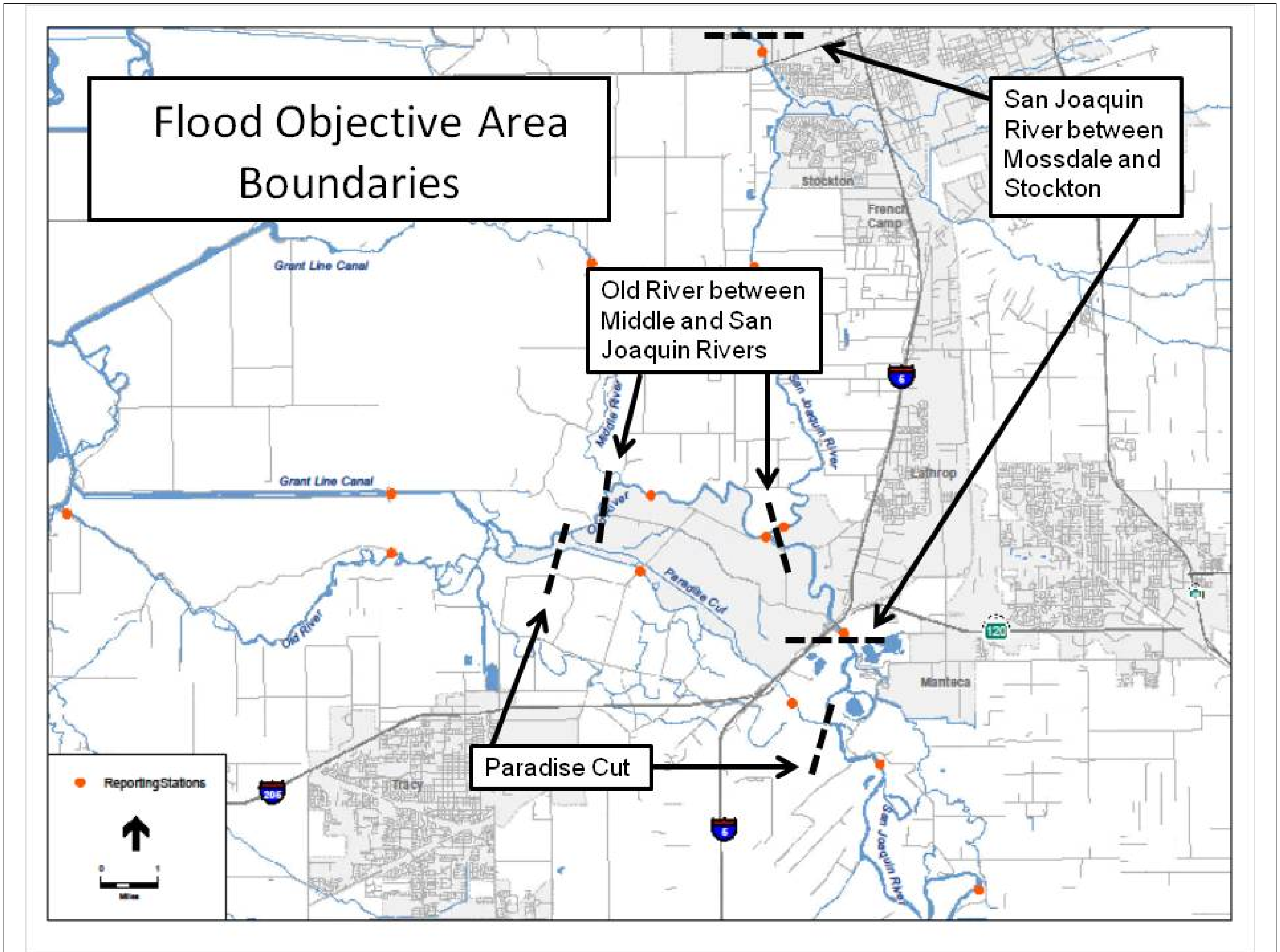


Figure EA.4.2-9: Flood Objective Area Boundaries

EA.4.2.3 Terrestrial Species Screening Evaluation

The BDCP covers approximately 60 terrestrial species. The charter for the SDHWG requests that technical experts seek to identify opportunities within the corridors for creating habitat for terrestrial species, including waterfowl, to the extent practicable.

Clearly, changes in the landscape as assumed for the South Delta under "corridor conditions" would have an influence on terrestrial habitat for the BDCP covered terrestrial species. However, evaluation of potential outcomes for terrestrial species in the assumed South Delta corridors is difficult because the site-specific planning for riparian restoration and other revegetation (active or passive) and an assessment of terrestrial landscape evolution in the corridors is not to be completed in this initial screening-level evaluation of the conceptual South Delta corridors. Further, there are no DRERIP conceptual models for the BDCP terrestrial species. For these reasons, scoring outcomes for terrestrial species is not possible in the full DRERIP evaluation process.

To support further consideration of the potential outcomes for terrestrial species, a screening-level evaluation process was developed (see Section 7.6 for full evaluation process instructions) to identify issues and concerns associated with the assumed South Delta corridors, as identified by state and federal fish and wildlife agencies and the BDCP consultant team. This included gaining a better understanding of how terrestrial habitat may change, what sorts of key questions and uncertainties surround these changes, and what are the data gaps. Additionally, evaluators were asked to provide input on restoration design criteria and considerations related to habitat configuration in restoring terrestrial habitat in the corridors so that it can be integrated into future planning and design at the corridor- and sub-corridor-level.

EA.4.2.3.1 Methods

The evaluation workshop began with a review of the evaluation process instructions document provided in Section 7.6. Prior to the workshop held on June 13th, the group was provided with worksheets and was broken into smaller working groups to provide advance thinking and content for the workshop. Results of the June 13th workshop were summarized and circulated to reviewers for comment, with revisions made accordingly. The edited workshop evaluation notes are included in Section 7.7. Outstanding issues, questions and uncertainties, future considerations, and refinements to restoration areas are presented in Section 5.

EA.4.2.4 Municipal, Industrial, and Agricultural Use Water Quality Screening Evaluation

Changes in water quality in the assumed South Delta "corridor conditions" have an influence on aquatic species and human uses. The effects on aquatic species are covered by the modified-DRERIP evaluations, with outcomes listed for each of the key species being evaluated. The evaluation of potential changes in water quality and how they may influence the use of water in the South Delta for municipal, industrial and agricultural uses[6] is covered by the evaluation process described below.

[6] Hereto, any reference to water quality in this section is in relation to M&I and Agricultural uses unless otherwise noted.

Evaluation of potential water quality changes that may occur in the assumed South Delta corridors is difficult because multi-dimensional hydrodynamic modeling dedicated to assessing water quality is not to be completed in this initial screening-level evaluation of the conceptual South Delta corridors. Further, there is no DRERIP conceptual model for M&I/Ag water quality. For these reasons, scoring outcomes for water quality are not possible in any sort of DRERIP-type evaluation process. Additionally, the evaluation of water quality is complicated by conflicting benefits and detriments associated with certain changes in anticipated water quality. Therefore, this screening-level evaluation of the corridors seeks to promote a better understanding of: 1) key process-based changes, 2) potential issues, 3) outstanding questions and uncertainties, and 4) data gaps. Systematically developing a greater understanding of these items for each corridor will support development of appropriate technical investigations in any future planning work, which would focus upon a single corridor or a combination of corridors based on the outcomes of this evaluation and the modified-DRERIP evaluations for species and flood.

To support further thinking and consideration of the potential outcomes for water quality, a screening-level evaluation process was developed (see Section 7.6 for full evaluation process instructions) to identify issues and concerns associated with the assumed corridors in the South Delta, as identified by water quality experts and the BDCP consultant team. This included gaining a better understanding of how water quality may change, what sorts of key questions and uncertainties surround these changes, and what are the data gaps. Additionally, evaluators were asked to provide input on restoration design criteria and considerations related to habitat configuration and how it may influence water quality for human uses so that this information can be integrated into future planning and design at the corridor- and sub-corridor-level.

EA.4.2.4.1 Methods

The evaluation workshop began with a review of the evaluation process instructions document provided in Section 7.6. Prior to the workshop held on June 13th, the group was provided with worksheets and was broken into smaller working groups to provide advance thinking and content for the workshop. Results of the June 13th workshop were summarized and circulated to reviewers for comment, with revisions made accordingly. The edited workshop evaluation notes are included in Section 7.7. Outstanding issues, questions and uncertainties; data gaps; and future considerations and refinements to restoration areas are presented in Section 5.

EA.5 Gaps in Information and/or Understanding

EA.5.1 Modified-DRERIP Evaluations

EA.5.1.1 Data Gaps

- Multi-dimensional hydrodynamic modeling (particularly as related to entrainment and water quality) is of particular interest as it is a key driver in many of the important processes and outcomes considered.
- Stage/discharge relationships for key nodes that are currently un-gauged.
- Sediment transport data, modeling and sediment budgeting for the Lower San Joaquin River.
- Sturgeon population / habitat data for the South Delta.
- Additional information/research on site-specific marsh habitat design options that can improve water quality conditions/mitigate potential adverse conditions that might be generated by creation of tidal marsh habitats in the South Delta. (See also the separate M&I and Agriculture WQ Evaluations summary, below in Section 5.4)
- Examine runoff into Corridor and evaluate potential for water quality impacts.
- Extent of existing channel margin habitat within corridor is needed. Baseline conditions are necessary to measure potential increases in channel margin habitat under each corridor.
- Extent and location of additional protected lands within the South Delta corridors as well as those under the Williamson Act.
- Location of municipal infrastructure such as sewer and water lines.

EA.5.1.2 Outstanding Issues, Questions and Uncertainties, Future Considerations, and Refinements to Restoration Areas

- Entrainment modeling and/or particle tracking analysis should be completed for Head of Old River Barrier (HORB) in/out operations and habitat restoration impacts. This should also be considered in relation to various Paradise Cut and Fabian Tract configurations. Key question are: Will habitat restoration effect OMR entrainment? Will HORB operations affect OMR and entrainment? Is particle tracking analysis an appropriate method?
- Gain a better understanding of habitat conditions and outmigration success for fishes that may rear in an inundated Fabian Tract. Also, the relationship between successful outmigration downstream of Corridor 2B compared to that of Corridor 4. Consider all of these aspects in relation to an isolated Old River corridor.
- Corridor 2B refinement suggestion: this corridor would achieve greater habitat value and connectivity if portions of Stewart Tract were to be included as a part of restoration actions.
- Consider how future geomorphic response of a less-confined San Joaquin River may result in changes in sediment transport and potentially aggradation of the channel bed. This may modify the stage-discharge relationships for floodplain inundation more-generally. (Note that this would be a positive trend for inundated floodplain habitat).

- Consider the expected / predicted channel meander potential of the reach with levee setbacks in relation to corridor refinement.
- Consider how the San Joaquin River Restoration Program restoration flow regime and future flows that may be ordered by the SWRCB or result from climate change may influence key habitats and species outcomes.
- If Paradise Cut modifications are further considered:
  - A foundational aspect of future planning is the hydrodynamics (spatially, and temporally [within each water year and by water year type]) of the flow split from the San Joaquin River to a widened / lowered Paradise Cut weir. This split influences the distribution of food and outmigrating fishes.
  - Additional detail (i.e., sensitivity analyses) for the configuration of the Paradise Cut weir and the Old River Corridor (i.e. the presence or absence of an isolated Old River Corridor) needs to be further defined such that alternatives can be developed.
- If Fabian Tract modifications are further considered: The hydrodynamics (spatially, and temporally [within each water year and by water year type]) of how flows come in from the San Joaquin River as well as how tidal action works within an opened-Fabian Tract. These dynamics influence water quality, residence time of fishes for spawning and rearing, and the distribution of food and out-migrating fishes.
- Tidal habitat restoration design must consider how sub-tidal habitat areas within a restored marsh area are either managed or modified in the restoration designs such that they are eliminated, in order to reduce undesirable habitat areas.
- Additional research and site-specific design “gaming” and sensitivity analysis should be completed for site-specific marsh habitat design options in order to that can improve water quality conditions/mitigate potential adverse conditions that might be generated by creation of tidal marsh habitats in the South Delta. (See also the separate M&I and Agriculture WQ Evaluations results; below).
- Related to the above, a key question is: Are sub-tidal areas located in the South Delta beneficial for native fish?
- In preparing additional background to support restoration design, use SFEI’s historical ecology information and other sources to better-understand what were the historical ecological functions of the South Delta for smelt? Is it feasible to re-create those processes/habitats within the context of BDCP South Delta restoration? Use this understanding to refine design criteria.
- A “landscape-scale processes” conceptual model would be helpful in understanding ecosystem dynamics (physical and ecological) that occur across the transition between habitat types (i.e., the gradation from floodplain to marsh). Use such a model to refine design criteria and perhaps even project site scoping/identification.
- Evaluators in both the modified-DRERIP and terrestrial species evaluations (covered below in Section 5.3) identified priority questions in relation to uncertainties in geomorphology, habitat, entrainment, and water quality effects including:
  - Will the frequency and timing of inundation provide meaningful/significant habitat quantity and quality for the covered BDCP species?

- Will productivity from new South Delta habitat restoration areas actually be more vulnerable to entrainment, and therefore become unavailable to native fishes?
- Will creation of channel and floodplain habitat create sinks for selenium and other contaminants that could influence terrestrial and aquatic species?

EA.5.2 Flood Management

EA.5.2.1 Data Gaps

- Confidence in downstream boundary conditions: propagation of SLR throughout the Delta that accounts for changes to tidal prism would support development of a modeling tool without a steady-state downstream boundary condition
- USACE 1992 stage/frequency analysis using tidal gages in the Delta or updated version of the analysis as was described in the December 2, 2009 San Joaquin Area Flood Control Agency board meeting agenda, if that updated analysis has been completed
- Floodplain inundation maps showing depth and extent
- Top of levee profiles for identification of potential overtopping locations (note that DWR data covering a portion of the study area with levee elevation values spaced 10 meters apart, longitudinally, was used to refine model output reporting locations that were used in these evaluations)
- Anticipated future land use changes (note that some geospatial data on projected urban development is available and was used in developing the corridors and that the San Joaquin County General Plan will provide useful information)
- Data on levee stability/failure, fragility curves
- Location of infrastructure - both major infrastructure and that which is particularly relevant to key locations within the corridors

EA.5.2.2 Key Uncertainties and Research Needs

EA.5.2.2.1 Sensitivity Analysis

- Evaluate the change in flood risk associated with each corridor throughout study area
- Evaluate the need to extend the model domain to reduce sensitivity to the downstream boundary condition
- Analyze the relative performance of modeled scenarios under a range of flood events
- Evaluate sensitivity to existing and proposed channel and floodplain roughness values
- Evaluate sensitivity to the lateral extent of setbacks

EA.5.2.2.2 Other Uncertainties

- Long-term sediment management issues in central Delta (fixed-bed model unable to evaluate changes in sediment distributions)
- Scour potential of any proposed projects in central Delta

- Ability of HEC-RAS to capture needed hydrodynamics when levees are set back (e.g., use of ineffective flow areas within HEC-RAS to account for a braided channel? Use of a 2D model?)

EA.5.2.3 Important New Ideas or Understandings

- Paradise weir currently spills at approximately 18,000 cfs per Chris Neudeck and Mike Archer.
- New Environmental Fluid Dynamics Code (EFDC) estuary model is being developed by USACE through firm out of Knoxville, Tennessee called Dynamic Solutions, LLC; not likely ready in next year; Gene Mack is the Sacramento District contact.
- Corridor 2A – Locals view Paradise weir as being fixed and that modifying the weir is not an option (wider weir would be good for flood conveyance and a lower weir would be good for the ecosystem by allowing more frequent inundation).
- Corridor 1B – Wetherby community (250-300 homes) near Walthall Slough was raised after 97 event – per Chris Neudeck
- Data on SLR in Stockton available through DWR

EA.5.2.4 Additional Model Runs

Additional model runs that would be useful for the next phase of work include:

- An expanded Corridor 2A that includes an additional weir, perhaps at Tom Paine Slough. The intent is to test if 2A alone with such a weir has similar worth and risk as 2A + 1A (Model Run C). Model Run C has worth and risk scores of high and null, respectively.
- A run that combines 1A and 2B. Model run E looks promising and this run would substitute 1A for 1B to further explore the potential benefits.
- Walthall Slough with downstream control and/or Corridor 4 with downstream control to evaluate managed detention.

EA.5.3 Terrestrial Species

EA.5.3.1 Outstanding Issues, Questions and Uncertainties, Future Considerations, and Refinements to Restoration Areas

- Evaluators emphasized that a main caveat to this review process was that there wasn't enough time for each species to be addressed for this review deadline, but eventually each species will need to be analyzed critically through this process
- Considering multiple species issues evaluators questioned how conclusions on the net benefit of each corridor to the system will be determined and what would be the basis to choose preferred corridors and the restoration actions?
- Evaluators identified priority questions in relation to uncertainties in geomorphology, habitat, entrainment, and water quality effects including:
    - Will the frequency and timing of inundation provide meaningful/significant habitat quantity and quality for the covered BDCP species?
    - Will productivity from new South Delta habitat restoration areas actually be more vulnerable to entrainment, and therefore become unavailable to native fishes?

  - Will creation of channel and floodplain habitat create sinks for selenium and other contaminants that could influence terrestrial and aquatic species?
- Evaluators emphasized that future studies may be necessary to understand the best way to achieve the BDCP goals and objectives. For example there is a BDCP objective to create 1,000 acres of early succession habitat. Which corridor would be best to obtain that? In order to make this recommendation, evaluators emphasized that it is essential to understand corridor inundation frequencies, land elevations, soil and water quality, locations of upstream riparian seed sources, and if the action commitment includes any active restoration components.
- There was several restoration design criteria that evaluators emphasized should be considered in future planning. These include:
  - Consider which corridor or combination of South Delta corridors most-efficiently meets the BDCP Goals and Objectives, while still achieving the habitat requirements and the species needs.
  - Consider how to reconcile the issue of immediate short term impacts to some species vs. long term benefits (i.e. riparian brush rabbit and woodrat).
  - Some species, natural communities, and/or ecological processes have conflicting conservation needs. Analysis of the benefits and impacts to the system is needed as a basis to integrate the overall conservation approach.
  - Don't assume that agricultural lands don't have wildlife habitat value.
  - Technical experts should be involved in the development of restoration plans so that species-specific habitat requirements can be incorporated.
  - Consider whether floodplain habitat restoration would necessitate more armored levees and their associated mitigations on reaches of the river in other locations, either upstream or downstream.
  - In developing levee setbacks, consider that levees or portions of levees can provide refugia from flooding for terrestrial species.
  - Terrestrial habitats should be designed to link and be complimentary to existing and planned adjacent land uses
  - Consider climate change projected sea level rise and estuarine transgression scenarios. At a minimum use web tools developed by PRBO to understand projected scenarios at project sites. http://data.prbo.org/apps/sfbslr/

EA.5.4 Water Quality

EA.5.4.1 Data Gaps

- Data on mercury or methylmercury in the south Delta. Baseline conditions needed to estimate potential increase in methylmecury formation.

EA.5.4.2 Outstanding Issues, Questions and Uncertainties, Future Considerations, and Refinements to Restoration Areas

- Additional research and site-specific design “gaming” and sensitivity analysis should be completed for site-specific marsh habitat design options in order to that can improve water quality conditions/mitigate potential adverse conditions that might be generated by creation of tidal marsh habitats in the South Delta.
- What restoration practices and/or plant assemblages support the production of beneficial organic carbon (bioavailable/beneficial to food webs) versus detrimental organic carbon (detrimental to water quality), to the extent that these functions can be separated?
- Identify specifics of physical restoration activities, such as levee removal locations, that will affect circulation and flows, and thereby will affect water quality. Constituents of concern include salts, dissolved oxygen, nutrients, and phytoplankton (including cyanobacteria).
- For corridors located upstream of the Stockton Deep Water Ship Channel (DWSC), processes that increase residence time in the DWSC, or that contribute to plankton blooms and elevated nutrients, could exacerbate low dissolved oxygen levels in the DWSC. The extent to which restoration along such corridors could affect the DWSC should be evaluated more closely and mitigated via design or other measures as warranted.

EA.5.5 Recreation

EA.5.5.1 Outstanding Issues, Questions and Uncertainties, Future Considerations, and Refinements to Restoration Areas

- The potential for the corridors to impact recreation should be analyzed in subsequent stages of habitat restoration and flood management planning in the South Delta.

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EA.7 Attachments

EA.7.1 South Delta Habitat Working Group Charter; Problem and Objectives Statement; and Corridor Development and Sizing Process

The following charter was developed to help guide the work of the South Delta Habitat Working Group.

EA.7.1.1 South Delta Habitat Working Group Charter

DWR is interested in developing actions for improving habitat in the San Joaquin River corridor in the southern part of the Delta for integration into the BDCP. Many opportunities for improving habitat in the South Delta provide flood management benefits. Development of potential flood management and conservation actions will allow examination of ways to reduce flooding for communities along the San Joaquin River. The purpose of the South Delta Habitat Working Group is to provide input to DWR to be used in development of potential flood management and conservation actions. The SDHWG will also assist DWR and others to gain a broader understanding of public and interest group perspectives.

While BDCP is not responsible for paying for flood management programs, the potential flood management and conservation actions should be developed in a way that integrates flood hazard reduction and other economic benefits where consistent with meeting BDCP objectives. In developing the potential flood management and conservation actions, the working group will assume a new dual conveyance strategy under which a substantial amount of water will be diverted from a new facility on the Sacramento River in combination with reduced, but continued diversions from state and federal pumping facilities in the S. Delta, particularly in the summer months. The potential flood management and conservation actions will focus on providing habitat benefits for salmonids and other native fish species, but should also identify opportunities for creating habitat for terrestrial species, including waterfowl, to the extent practicable.

The potential flood management and conservation actions should also be developed to protect access to water rights and water quality for South Delta agriculture and municipal and industrial uses. The potential flood management and conservation actions will recognize the need to minimize disruption to existing agricultural operations, especially perennial crops, and will minimize the need for relocation of residential structures to the maximum extent practicable. While not a primary purpose of the potential flood management and conservation actions, recreational benefits of the plan will also be considered and created where possible.

The South Delta Habitat Working Group will provide input to develop potential flood management and conservation actions consistent with this charge and BDCP plan objectives and will examine several alternative approaches for achieving those objectives, including habitat and flood management corridors along the San Joaquin River upstream of Paradise Cut, the Paradise Cut / Old River corridor, the Middle River corridor, as well as the mainstem San Joaquin River corridor.

The South Delta Habitat Working Group will also consider:

- How the potential flood management and conservation actions will be phased-in over time, including how adaptive management will be incorporated as a key principle.

- How various potential flood management and conservation concepts perform under the San Joaquin River Restoration Program restoration flow regime and future flows that may be ordered by the SWRCB or result from climate change.
- Specific guidance from regulatory agencies regarding development of levee side vegetation, large woody debris, quantifying the benefits of floodplain and tidal habitats, and best management practices for avoiding conditions that favor exotic species.
- How the potential flood management and conservation actions will perform under a scenario that assumes 55 inches of sea level rise by the end of the century.
- How the potential flood management and conservation actions will perform if several islands in the central and west Delta are permanently inundated in the future.
- How the potential flood management and conservation actions may be consistent with a barrier at the head of Old River, or how it can achieve the same or better benefits without the barrier or with a barrier open more of the time than currently planned.
- How the potential flood management and conservation actions might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants.

The working group will have access to a technical work group for scientific information regarding the development of the potential flood management and conservation actions. The technical work group will evaluate the extent to which various types and configurations of habitat advance the overall objectives of BDCP in the South Delta.

EA.7.1.2 South Delta Base Condition Problem Statements

EA.7.1.2.1 Flood Management

- The existing flood infrastructure in the South Delta is aging, insufficient in many areas, and contributes to degraded habitat conditions and restriction of natural physical processes.

EA.7.1.2.2 Native Species Habitat

- Spawning and rearing habitats for native fishes are limited or of poor quality in the south Delta.
- Rearing habitat for salmonids is very limited along the main corridor of the San Joaquin River, particularly between Mossdale and Jersey Island, but also between Vernalis and Mossdale.
- Conditions in the S. Delta favor invasive fish species that prey on native fishes. Predation may be a large source of indirect mortality for native fishes. Indirect mortality in the S. Delta is associated with the hydrodynamic conditions, which draw juvenile fish into high predation zones. Predation is the proximal cause of entrainment, while habitat alteration (including hydrodynamic changes due to exports) and exotic species are the ultimate causes.
- Lack of habitat continuity and a natural ecological gradient between upper rivers and the Bay make it more difficult for migratory species to successfully migrate up or down stream.
- Altered and unnatural channel morphology along the San Joaquin and Delta channels results in lack of channel habitat complexity and cover for native fish, hydraulics that favor exotic species, infrequent overbank flows, and limited riparian habitat.

EA.7.1.2.3 Natural Processes

- Substantial reductions in ***flow***, particularly ***channel altering and floodplain inundating high flows*** in the winter and spring, has resulted in degraded habitat and water quality.
- Lack of ***floodplain inundation*** due to levees, berms, ditches, and hydrologic alteration.
- Limited ***groundwater recharge and hyporheic flow*** due to unnatural channel morphology combined with infrequent floodplain inundation reduces the potential for pockets of cool upwelling water that would otherwise serve as thermal refugia for migrating salmonids in lower flow conditions.
- As the frequency of ***prolonged inundation*** is 1 in 7 years, these areas are generally unavailable for two successive generations of Chinook salmon.

EA.7.1.2.4 Entrainment

- The benefit of aquatic habitat restoration in the S. Delta is currently limited by entrainment effects associated with existing S. Delta diversions and operations. High potential for entrainment of fish species (salmon, Delta smelt, longfin smelt, splittail, sturgeon), even with a new dual conveyance system in the future, may still limit or constrain the potential for restored ecosystem function in the south Delta.
- Food resources produced in the south Delta are vulnerable to entrainment, and therefore, may become unavailable to native fishes.
- Juvenile fish and production of native species in the south Delta are vulnerable to entrainment at the SWP and CVP and other smaller diversions.

EA.7.1.2.5 Water Quality and Flow

- Reduced San Joaquin River inflows, mainly in the summer and fall, create poor water quality conditions such as low dissolved oxygen and microcystis blooms in the main stem of the San Joaquin River near Stockton and interior channels of the south Delta, which have adverse effects (direct and indirect) on native fishes and drinking water quality.
- Poor water quality resulting from agricultural and urban discharges in the San Joaquin River system, other tributaries to the south Delta, and local sources increases the exposure of aquatic organisms to contaminants and adversely impacts human use of water in the South Delta for municipal, agricultural, and industrial purposes.
- Unnatural channel features including the deep water ship channel and barriers reduce circulation resulting in low dissolved oxygen levels in some areas of the S. Delta during lower flow conditions.
- Poor water quality in the interior South Delta channels (Old and Middle rivers, and Grant Line canal can occur with the proposed operations of the Agricultural Barriers and the Head of Old River Barrier. This results in increased salinity and reduced dissolved oxygen conditions.
- Average daily temperatures exceed 20-21^{o}C during May in approximately 1/3 of years. In June, average daily temperatures exceed this critical threshold in almost every year. With warming that may occur under climate change projections, high temperatures may become more frequent and more extreme, even during April.

- Unnaturally clear water inflow from the San Joaquin River may also contribute to increased predation of juvenile salmon. Upstream reservoirs trap suspended sediment and release clear water. Low to moderate releases from the reservoirs in most years are not large enough to recruit suspended sediment downstream of the reservoirs.

EA.7.1.2.6 Non-Native Invasives

- Tidal channels are colonized by non-native macrophytes, which provides limited rearing space for most native fishes and favors predators that might consume native fishes. Macrophytes, such as Egeria densa and Myriophyllum spicatum, also increase sedimentation rates, resulting in high water clarity (i.e., less turbidity) that degrades habitat conditions for pelagic and anadromous species in the south Delta. Higher water clarity can either reduce feeding success for pelagic species or increase predation upon juvenile salmonids.
- Many non-native species were introduced for sportfishing, such as striped bass, largemouth bass, smallmouth bass, bluegill sunfish, common carp, brown bullhead, white catfish threadfin shad, golden shiner and fathead minnow.

EA.7.1.3 Objectives for the South Delta

EA.7.1.3.1 Native Aquatic Habitat Restoration

1. Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.
2. Create or restore critical habitats for splittail, sturgeon, and other native fishes along the mainstem of the San Joaquin River, with an emphasis on increasing flow-related survivorship.
3. Increase frequency of floodplain inundation to support Sacramento splittail reproduction and viability.
4. Improve conditions for other native resident fish species including Hitch, Blackfish, Hardhead, and Tule Perch.
5. Create a natural gradient of fluvial and tidal habitats and water quality constituents along one or more corridors in the South Delta to improve the upstream and downstream migration of native fishes between Vernalis and the Western Delta to:
    a. facilitate the upstream and downstream migration of native fishes between Vernalis and the western Delta.
    b. provide habitat that will increase the survival and numbers of native fish species
6. Reduce entrainment mortality of juvenile salmonids, smelt, sturgeon, splittail, and other native fishes

EA.7.1.3.2 Terrestrial and Avian Species Habitat Restoration

1. Restore tidal marshes and riparian corridor habitat for terrestrial and avian species including waterfowl.

EA.7.1.3.3 Geomorphic Processes

1. Restore more natural channel morphology to create more diverse and complex channel habitats, increase the frequency of side channel inundation, and restore hyporheic flow.
2. Create conditions that allow physical processes to generate suspended sediment and turbidity.
3. Create habitat and/or hydrodynamic conditions that do not favor macrophytes and degrade the sediment pool, but rather promote marsh building processes.

EA.7.1.3.4 Flood Management

1. Substantially reduce flood stage on the mainstem San Joaquin River between Mossdale and Stockton. This can be via a bypass of flows to another area, or a reduction of flow via attenuation upstream or in the reach. Specifically, seek to provide for a substantial reduction in flood stage on the mainstem San Joaquin River between Vernalis and Stockton for the 50-year flood peak[7], with the understanding that numerical modeling results are typically assumed to have a range of accuracy of approximately 0.5 foot.
2. Reduce the probability of catastrophic urban flooding and loss of life in the communities of Lathrop, Manteca, Stockton, and unincorporated San Joaquin County.
3. Substantially increase flood conveyance capacity through a constrained reach of the San Joaquin River floodway. This objective seeks to reduce backwater conditions within the project area, for particular benefits in upstream reaches/the broader region.
4. Maintain consistency with regional flood management plans (i.e., the CVFPP).
5. Reduce maintenance costs and conflicts with listed species, increase flood management system resilience / sustainability through the use of more-natural/less-structural approaches such as a corridor management strategy (CMS).
6. Cause no significant increases in flood stage during the 50-year event, and identify locations where risk evaluations are merited in future investigations.

EA.7.1.3.5 Water Quality

1. Increase export of nutrients from the San Joaquin and south Delta habitats in a manner that does not create eutrophication or dissolved oxygen problems.
2. Avoid the degradation of water quality for municipal, agricultural, industrial users in the South Delta and aquatic species.

EA.7.1.3.6 Recreation

1. Improve or create recreational opportunities for the general public.

EA.7.1.3.7 Cultural Preservation

1. Preserve and protect the Delta's sense of place and its local economy, including agriculture.

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[7] The Settlement Agreement between River Islands, NRDC, and NHI (2007) references a 1.75-foot stage reduction at Mossdale for the 100-year flood peak.

EA.7.1.4 Corridor Development and Sizing Process

Based on the intent of the charter, conceptual corridors were developed for further consideration. The intent of the following description of the corridor development process is to document the assumptions and techniques used to rapidly generate the conceptual-level corridors that allowed subsequent analysis of flood management and ecosystem benefits.

Corridors are comprised of specific actions placed within that corridor—e.g., a setback levee on the right bank of a certain section of river; planting of riparian vegetation on a floodplain; enlargement of an overflow weir to increase flood conveyance.

Preliminary configuration of the corridors is not an engineering-design exercise. Rather, the intent is to rapidly generate a configuration of potential actions with a level of geographic specificity that is sufficient to support subsequent analysis to estimate the corridor's potential flood and ecosystem benefits. The technical team preparing the corridors is aware of many of the important considerations that would be integral to developing these various corridor actions into actual engineering design plans and specifications for implementation; however, those considerations are not integrated into this process at this time because generating such design-level plans is not necessary to achieving this effort's goal of evaluating the relative level of potential flood and ecosystem benefits that these corridors may provide. In the future, a larger and more-detailed planning and engineering effort, integrating many additional considerations into the planning and design process, may be completed to progress the most-promising corridor toward implementation.

The technical team preparing the corridors is also aware that, on the landscape, there are inherent interactions between the four corridors being developed and evaluated discretely. For example, in assessing the hydraulic effects of the corridors, the downstream boundary conditions of one corridor dictate the upstream boundary conditions of another corridor. Those interactions are captured in the corridor combinations that were modeled for the flood evaluations (see Section 7.3).

A. Assumptions

1. The South Delta Working Group charter provides direction for development of a conservation measure for inclusion in BDCP. Corridors developed in this process should be consistent with the charter.
2. Target acreages for ecosystem restoration in the Delta are defined by BDCP, including some specific assumptions with respect to habitat in the South Delta. Currently, these targets are:
    a. Tidal Marsh: 5,000 acres within the South Delta.
    b. Floodplain: 10,000 acres across entire Delta, with most promising locations in the South Delta along the San Joaquin River, Old River, and Middle River channels.
    c. Channel Margin: 20 miles across entire Delta with at least 5 miles along the San Joaquin River between Vernalis and Mossdale.
    d. Riparian: 5,000 acres across entire Delta, with natural re-establishment in floodplain and tidal marsh restoration areas.
3. We assume that the main objectives for these corridors are:
    a. Improve Flood Management:

i. Substantially reduce flood stage on the mainstem San Joaquin River between Mossdale and Stockton. This can be via a bypass of flows to another area, or a reduction of flow via attenuation upstream or in the reach. Specifically, seek to provide for a substantial reduction in flood stage on the mainstem San Joaquin River between Vernalis and Stockton for the 50-year flood peak[8], with the understanding that numerical modeling results are typically assumed to have a range of accuracy of approximately 0.5 foot.

ii. Reduce the probability of catastrophic urban flooding and loss of life in the communities of Lathrop, Manteca, Stockton, and unincorporated San Joaquin County.

iii. Substantially increase flood conveyance capacity through a constrained reach of the San Joaquin River floodway. This objective seeks to reduce backwater conditions within the project area, for particular benefits in upstream reaches/the broader region.

iv. Maintain consistency with regional flood management plans (i.e., the CVFPP).

v. Reduce maintenance costs and conflicts with listed species.

vi. Cause no significant increases in flood stage during the 50-year event, and identify locations where risk evaluations are merited in future investigations.

b. Improve the Ecosystem:

i. Ecosystem enhancement actions will include creation of the following habitat types: Tidal Habitat; Seasonally Inundated Floodplain Habitat; Channel Margin Habitat; and Riparian Habitat.

ii. Habitat creation can be facilitated by a flood action (i.e., a setback levee in the elevation range suitable for tidal marsh), or a purposeful action (i.e., horticultural restoration of riparian forest).

1. Corridor development will build on past and present efforts related to flood management and ecosystem restoration in the South Delta, as appropriate.
2. Corridor 1 and Corridor 4 are, by definition, not viable as flood bypasses because they are comprised by mainstem river segments that contain most of the river's discharge at lower flows. Flood bypasses are only viable in Corridors 2 & 3.

B. Developing the Configuration of Actions in the Corridor

The following process was used to define the suite of actions that comprise the corridor, and in some instances, corridor options.

1. If a corridor includes an existing proposal; assess viability for use as a starting point. Integrate components of that proposal if appropriate and/or with modification.
2. Identify major fixed constraints (sewer plants; communities with populations over 10k people) that cause flow constrictions (so-called "pinch points").

[8] The Settlement Agreement between River Islands, NRDC, and NHI (2007) references a 1.75-foot stage reduction at Mossdale for the 100-year flood peak.

3. Examine the reach relative to the assumptions and flood objectives to determine the potential for development of a bypass or setback levees:
    a. Has the corridor been previously studied, and has it demonstrated the potential for achieving flood goals with a bypass?
    b. Does the river channel and locations of upstream distributary flow currently have the configuration / capacity to allow the corridor to function as a bypass?
    c. If a flood bypass is applicable, assess viability of setbacks on one or both banks based on screening above.
    d. If a bypass is not applicable, assess levee setbacks for one or both banks to increase conveyance and/or storage.
    e. If neither setbacks nor a bypass appear to be applicable to meeting flood objectives, consider habitat enhancement actions in Steps 6 and 7, below.
4. Based on the outcomes from Step 3, above, locate (longitudinally) the extent of the setback or bypass within the corridor (i.e., define the upstream and downstream extents for one or both banks).
5. Consider sea level rise (55 inches; see charter) relative to tidal boundary conditions and associated flooding hazard. Refine longitudinal extent accordingly.
6. Using the tidal range map (including the sea level rise accommodation), identify potential restoration areas along the setback/bypass reaches that could function as tidal marsh habitat.
7. Define the ecosystem enhancement actions:
    a. Consider the seasonality of flow through the corridor relative to inundation of floodplains and other physical processes.
    b. Consider and integrate assumptions on pumping, gate operations, and any additional topographic or infrastructure-related modifications that would need to be made to address stage-dependencies related to corridor function in different water year types, etc.
    c. Based on these considerations and the work in Step 6, above, delineate habitat actions.

The steps in the process described above result in partial delineation of actions within a corridor (i.e., there is an upstream and downstream extent, but no width). The following steps were taken to define the width of these actions, and thus at a conceptual level provide a spatial definition of the corridor. This width sizing process is sufficient to generate corridors that allow subsequent examination of the potential benefits of actions in the four river reaches in the project area. The width sizing is not meant to be absolute and it is acknowledged that if any of the corridors are progressed on toward the level of project implementation, more-detailed investigations will result in refinements to these configurations.

8. If a corridor includes an existing proposal that contains a specific width of levee change, use if appropriate and/or with modification.
9. Consider corridor width based on any assumed changes to weirs, river distributary points, etc. (see Step 7, above). Size corridor widths to (at a minimum) accommodate new flood flows coming through those changed structures.

10. Locate tie-in points for new levees by favoring natural curves in river meanders and larger radii curves in existing levees. Avoid sharp angles which may cause hydraulic conditions conducive to scour. For new levee setbacks, utilize the footprints of existing (smaller) levees or other linear infrastructure (roads, canals) to minimize impacts and utilize any existing easements.
11. If no existing information is available to suggest a levee width configuration, examine geological, soils and historical maps relative to historical channel locations (which may be pathways for levee underseepage). Locate levees outside any such areas. NOTE: this is merely a rudimentary method to integrate some geotechnical information. It is acknowledged that it is not a geotechnical analysis, but it provides some information in instances where no prior investigation is available.
12. For areas NOT suitable for a bypass:
    a. Assess feasibility of area to act as conveyance / storage
    b. Set corridor width based on:
        i. Ability to provide additional conveyance / storage, or
        ii. Target habitat acreages (e.g. if tidal habitat is main focus, adjust width of corridor to show footprint for 5,000 acres; reassess as appropriate)
13. Undertake initial hydraulic modeling; examine flood dynamics.
14. Summarize acreages of new habitat areas within corridor levees.
15. Iterate as necessary to adjust widths of the corridors to better attain the flood and ecosystem objectives.

EA.7.2 South Delta Habitat and Flood Corridor Rationales Summary

Based on the Corridor Identification and Sizing Process (described above in Section 7.1) a total of six different corridors were identified and delineated with specific actions such as flood bypasses, levee setbacks, removal / replacement of infrastructure, dredging and/or earthmoving, and habitat restoration.

These corridors are:

- **Corridor 1A**: Levee setbacks on both banks of the San Joaquin River from Vernalis to I-5.
- **Corridor 1B**: An alternative version of Corridor 1A along the San Joaquin River that includes only a right-bank levee setback and connection of Walthall Slough.
- **Corridor 2A**: Expansion of Paradise Cut through to approximately Salmon Slough
- **Corridor 2B**: An expanded version of Corridor 2A that also includes all of Fabian Tract. Corridor 2B is essentially Corridor 2A plus Fabian Tract.
- **Corridor 3**: Selected levee setbacks along Middle River on Union Island.
- **Corridor 4**: Levee setbacks on the left-bank side of the San Joaquin River on Roberts Tract.

Many of the details on the habitat-centric corridor actions are covered in Section 3 under the respective corridor descriptions. The broader, overarching rationales for the architecture of the corridors are described in the following table.

Table EA.7.2-1. Notes on Rationales for South Delta Corridor Selection and Footprint Delineation

Corridor	Existing Study / Planning Effort	Physical Viability	Flood Management Potential	Ecological Restoration Potential	Socio-Economic Considerations
1A San Joaquin River Vernalis to I-5	River Islands / NRDC / NHI detention basin concepts at Mainstone Property and Mitten Property (MBK, 2008)	SDWA (2004) provides a map of the extent of flooding from the 1997 event – this provides a reference to the currently active floodplain for this magnitude of event (defined both by topography, as well as levee condition).	San Joaquin River hydraulic pinch point at I-5 suggests that large scale flood conveyance improvements likely limited in this corridor. However, potential for improving regional flood performance, especially when combined with a Paradise Cut Bypass (Corridors 2A or 2B).	Potential for restoring large tracts of terrestrial, floodplain, and riparian habitats in this area, along a variety of topographic gradients (i.e. varying frequencies of inundation).	The area currently supports agriculture and residences. Proposed levee setbacks tie into existing levee network where feasible.
	American Rivers large footprint concept for Vernalis to I-5 (American Rivers, in progress).	Floodplain is constrained topographically through this reach.	Potential for local flood attenuation / storage benefits throughout the footprint of Corridor 1A.		
		The setback area corresponds with a "floodplain sediments" geologic unit which defines the extent of the historic floodplain through this reach of the SJ River.			

Corridor	Existing Study / Planning Effort	Physical Viability	Flood Management Potential	Ecological Restoration Potential	Socio-Economic Considerations
1B San Joaquin River, right-bank levee setback that includes Walthall Slough	American Rivers (2011) / Mary Mattela (UCB, 2011) concepts on Walthall Slough	Walthall Slough is a relic floodplain channel and the topographic low point in the right-bank floodplain – potential for inundation of existing habitats through levee setbacks and weir design.	San Joaquin River hydraulic pinch point at I-5 suggests that large scale flood conveyance improvements likely limited in this corridor. However, potential for flood attenuation / storage benefits may exist.	Design Walthall Slough as a secondary low-flow channel, with floodplain areas accessed by higher flows. Requires weir control at upstream junction with SJ River. Because this is a remnant channel, relative amount of grading necessary to construct is lower than in a floodplain without a relic channel.	The area currently supports agriculture and residences.
		Entire footprint within the “floodplain sediment” geologic unit (within the historic, geomorphically active floodplain).		Potential for restoration of aquatic, riparian, floodplain, terrestrial habitats within corridor.	Proposed levee setbacks tie into existing levee network where feasible.
2A Paradise Cut Through Salmon Slough	DWR Paradise Cut Bypass Investigation (DWR, 2010), Alternative 1A and Alternative 2.	DWR RMA modeling of levee setback / flood bypass scenarios has demonstrated physical viability and benefits / impacts associated with various flood management scenarios.	DWR RMA modeling of levee setback / flood bypass scenarios has demonstrated benefits / impacts associated with various flood management scenarios.	Potential for restoration of aquatic, riparian, floodplain, tidal wetland, channel margin and terrestrial habitats within corridor.	The Pescadero Tract area supports agriculture and residences. Stewart Tract (River Islands) side already designated for levee setbacks.
	River Islands Paradise Cut Flood Bypass concepts (MBK, 2008).	MBK HEC-RAS hydraulic modeling of levee setback / flood bypass scenarios has demonstrated physical viability and benefits / impacts associated with various flood management scenarios.	MBK HEC-RAS hydraulic modeling of levee setback / flood bypass scenarios has demonstrated benefits / impacts associated with various flood management scenarios.		Avoid designated urban limits of City of Lathrop on Stewart Tract, except where River Islands has agreed to levee setbacks along Stewart Tract.
	Lower San Joaquin River Bypass Proposal (South Delta Channel and Levee Maintenance Authority, 2011).				

Corridor	Existing Study / Planning Effort	Physical Viability	Flood Management Potential	Ecological Restoration Potential	Socio-Economic Considerations
2B Expansion of Corridor 2A to include Fabian Tract	None known.	Topography / tidal range conducive for inundation.	Potential to provide flood conveyance / storage for flood waters routed through Paradise Cut, as suggested by the DWR and MBK Paradise Cut bypass flood modeling	Topography / tidal range appears conducive to restoration of tidal wetland, floodplain, channel margin and terrestrial habitats.	Fabian Tract currently supports agriculture and residences, of varying density throughout island.
3 Middle River / Union Island	None known.	Topography / tidal range conducive for inundation.	Potential to provide attenuation and/or flood storage for increased stages that result of routing flood waters through Paradise Cut, as demonstrated by the DWR and MBK Paradise Cut bypass flood modeling	Topography / tidal range appears conducive for restoration of floodplain, tidal wetland, riparian, and channel margin habitats.	Union Island currently supports agriculture and residences, of varying density throughout island. Proposed levee setbacks tie into existing levee network where feasible.
4 San Joaquin River / Roberts Island	Communications with DWR about levee setback flood performance modeling on Roberts Island (Mierzwa, 2011).	Topography / tidal range conducive for inundation.	Hydraulic constrictions at City of Lathrop and Stockton (upstream and downstream extents of corridor) limit opportunities. Potential for flood attenuation / storage on Roberts Island.	Topography / tidal range appears conducive for restoration of floodplain, tidal wetland, riparian, channel margin, and terrestrial habitats.	Roberts Island currently supports agriculture and residences, of varying density throughout island. Proposed levee setbacks tie into existing levee network where feasible.

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EA.7.3 (A) South Delta Hydraulic and Hydrologic Modeling Methods and Assumptions and (B) Technical Memorandum—Hydraulic Model Revisions Subsequent to the South Delta Evaluations

EA.7.3.1 (A) South Delta Hydraulic and Hydrologic Modeling Methods and Assumptions

We conducted one-dimensional numerical modeling of river and floodplain hydraulics using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software to support ecosystem and flood management performance evaluations of the South Delta corridors. The flood management objectives of this project include:

1. Substantially reduce flood stage on the mainstem San Joaquin River between Mossdale and Stockton. This can be accomplished via a bypass of flows to another area, or a reduction of flow via attenuation upstream, and may include water surface elevation reductions in the reach. Specifically, the project seeks to provide a substantial reduction in flood stage on the mainstem San Joaquin River between Vernalis and Stockton for the 50-year flood peak[9], with the understanding that numerical modeling results can typically be assumed to have a range of accuracy of approximately +/-0.5 foot.
2. Reduce the probability of catastrophic urban flooding and loss of life in the communities of Lathrop, Manteca, Stockton, and unincorporated San Joaquin County.
3. Substantially increase flood conveyance capacity through a constrained reach of the San Joaquin River floodway. This objective seeks to reduce backwater conditions within the project area, for particular benefits in upstream reaches/the broader region.
4. Maintain consistency with regional flood management plans (i.e., the CVFPP).
5. Reduce maintenance costs and conflicts with listed species.
6. Cause no significant increases in flood stage during the 50-year event, and identify locations where risk evaluations are merited in future investigations.

Two sets of geometric data were used in the modeling: an “existing conditions” configuration based on the HEC-RAS model originally developed for the United States Army Corps of Engineers (USACE) Sacramento and San Joaquin River Basins Comprehensive Study (Comp Study) and a set of “corridor condition” configurations that included modifications of levees and flood bypasses in each of four South Delta corridors (described below) to increase flood conveyance capacity and improve ecosystem conditions.

Corridor 1A: Levee setbacks on both banks of the San Joaquin River from Vernalis to I-5.

[9] The Settlement Agreement between River Islands, NRDC, and NHI (2007) references a 1.75-foot stage reduction at Mossdale for the 100-year flood peak.

Corridor 1B: An alternative version of Corridor 1A along the San Joaquin that includes only a right-bank levee setback and connection of Walthall Slough. *Corridor 1B can be modeled separately from Corridor 1A for flood evaluations.*

Corridor 2A: Expansion of Paradise Cut through to approximately Salmon Slough.

Corridor 2B: An expanded version of Corridor 2A that also includes all of Fabian Tract. *Corridor 2B is essentially Corridor 2A plus Fabian Tract. Fabian Tract alone as a corridor is not modeled separately in any hydraulic evaluations (flood or ecosystem).*

Corridor 3: Selected levee setbacks along Middle River on Union Island.

Corridor 4: Levee setbacks on the left bank side of the San Joaquin River on Roberts Tract.

Specific details on the development of the existing and corridor model configurations, flood modeling runs, and ecological modeling runs are provided below. Details on the development of the conceptual configurations of the corridors are included in Section 7.1.

The vertical datum used in all modeling and reporting is the North American Vertical Datum of 1988 (NAVD88). Model development and post-processing of model results was supported with Geographic Information Systems (GIS) using the Lambert Conformal Conic projection and the North American Datum 1983 State Plane, California, Zone III, feet (NAD83) coordinate system. Sources of topographic and bathymetric data used in the GIS and hydraulic model are provided in the following sections.

EA.7.3.1.1 Existing Conditions Model Development

We developed a new hydraulic model for existing conditions using an approach similar to other recent evaluations of river hydrodynamics in this region (e.g., the Comp Study and the HEC-RAS analysis developed by MBK Engineers for the proposed River Islands development). The Comp Study HEC-RAS model for the San Joaquin River served as the base model and was modified to address the questions of interest for this project. The fundamental difference between the Comp Study model and the model developed for this project was the lateral extension of model cross sections to allow simulation of overbank flows in the expanded floodways established by the conceptual corridors. Previous HEC-RAS models of this area have been limited to the area between the existing levees and could only consider overbank flows into or out of “storage areas.”

The following changes were necessary to produce a model to evaluate overbank flows. First, the model was truncated to have an upstream boundary on the San Joaquin River at Vernalis and downstream boundaries on the San Joaquin River near Rough and Ready Island, and on Middle River near Trapper Slough. The model was then extended longitudinally downstream on Grant Line Canal and Old River to a location near Clifton Court. Next, the storage areas and lateral structures were removed from the model, and new topographic (LiDAR data collected by DWR in 2006 and 2007; vertical accuracy of 95% at 0.6 feet and 90% at 0.5 feet; horizontal accuracy of 1 foot) and bathymetric data provided by DWR was used to update the Comp Study geometry in the project area. In addition, all of the model cross sections were extended laterally to include the entire area potentially encompassed by the proposed corridor conditions considered in this effort. Vertical “levees” were imposed at areas where the original Comp Study model included a blocked obstruction that prevented flow outside of levees, forcing water into storage areas to simulate floodplain storage. Lastly, the Manning’s roughness coefficient, or *n*-values, for the channel, levees, and overbank areas were replicated from the Comp Study model.

This new model was validated by comparing its flow distribution and water surface profile results to flow distribution and water surface profile results of the original Comp Study model with the same unsteady hydrograph (see unsteady hydrograph description below). Translation errors in model geometry and roughness were refined until the new model produced results with differences from the Comp Study that could be reasonably explained by the new topography and bathymetry and the changes in flow distribution that such changes cause in hydraulic models. It is important to note that the new existing conditions model created for this project does not exactly replicate results of the original Comp Study model for two primary reasons:

1. The longitudinal extensions of the model fundamentally change downstream boundary conditions because flow conveyance in these areas is lower, which influences the flow distribution and water surface profiles simulated by the model; and
2. Minor changes in geometry resulting from updating the Comp Study geometry with the most currently available topography and bathymetry influences flow distributions and water surface profiles simulated by the model.

We used this existing conditions model configuration to assess 1) existing flood performance and future flood performance with assumed sea level rise (SLR) of 55 inches or 140 centimeters, but without corridor implementation; and 2) existing inundated floodplain habitat. The purpose of the inundated floodplain habitat assessment was to compare the relative ecosystem benefit between the corridors rather than to evaluate the difference between implementation and no action. Therefore, future floodplain habitat with SLR, but without corridor implementation was not considered. Assumptions and boundary conditions information related to SLR are described below.

EA.7.3.1.2 Corridor Conditions Model Development

Development of HEC-RAS models for each corridor was largely a process of relocating the levees in the existing conditions model to the conceptual corridor boundaries. In addition, floodplain (or overbank) *n*-values were changed to 0.12 to conservatively represent the development of more natural riparian and floodplain vegetation assemblages in reconnected floodplain areas. In general, n-values appropriate for a floodplain range from 0.025 for a pasture with short grass to 0.160 when dense vegetation exists (Chow, 1959).

The conceptual corridors include many locations where existing levees would be removed or substantially breached such that they no longer impeded floodplain connectivity. For the purposes of modeling, however, existing levees were not removed from the one-dimensional model cross-sections. Instead, "virtual levees" within the model architecture were configured *outside* the existing levees (at the new setback levee locations), and the model was allowed to route flow *outside* of the existing levees, in effect simulating a "virtual removal" or "virtual breach." The corridor conditions model configurations were used to assess each corridor relative to: 1) flood performance under corridor conditions with and without assumed SLR; and 2) inundated floodplain habitat under corridor conditions with and without assumed SLR.

EA.7.3.1.3 Boundary Conditions

Boundary conditions are user-defined flow and stage conditions, typically specified at the downstream and upstream extents of a hydraulic model.

Downstream Boundary Conditions

All downstream boundary conditions from the original Comp Study model were converted from stage-discharge relationships to fixed water surface elevations at mean high water (MHW) for evaluating flood performance and Mean Tide Level (MTL) for analyzing potential ecosystem improvement using available data (DWR and Wetlands and Water Resources, unpublished). Additionally, boundary conditions for analysis of SLR were established using UnTRIM modeling results (MacWilliams and Gross, 2010).To develop these boundary conditions, the following process was used. First, a cumulative probability distribution of the UnTRIM output time series was generated from model reporting stations that correspond to the each of the three downstream boundaries in the HEC-RAS model under both the existing condition and the with 140 centimeters (cm) of SLR scenarios analyzed in the 2010 MacWilliams and Gross study. The current MHW values for the downstream locations were estimated to be 1.4 meters for Old River, 1.5 meters for Middle River, and 1.7 meters for the San Joaquin River (DWR and Wetlands and Water Resources, unpublished). The probability values that correspond to the 1.4, 1.5, and 1.7 meter MHW values were identified in the existing conditions cumulative probability distribution as 0.84, 0.87, and 0.91, respectively. The water levels in the "with 140 cm of SLR" cumulative probability distribution that correspond to the 0.84, 0.87, and 0.91 probability values were identified as 2.90, 2.98, and 3.16 meters, respectively. Finally, the difference between the water surface elevations under the with SLR and existing conditions values were calculated as 1.5, 1.48, and 1.46 meters, respectively. Based on the modest difference from 1.4 meters displayed by these results, we concluded that simply adding the anticipated amount of SLR, 1.4 meters or 140 cm, to the existing water surface elevations at each location was a reasonable method to account for SLR. The combinations of boundary conditions for various assessment purposes are identified in Table EA.7.3-1.

Table EA.7.3-1: Boundary Conditions for Flood and Inundated Floodplain Assessments

Assessment Type	Flood				Inundated Floodplain Habitat		
Boundary Condition:	**Existing Conditions No SLR**	**Existing Conditions With SLR**	**Corridor Conditions No SLR**	**Corridor Conditions With SLR**	**Existing Conditions No SLR**	**Corridor Conditions No SLR**	**Corridor Conditions With SLR**
Upstream Inflow	50-Year AEP Vernalis Unsteady Hydrograph	50-Year AEP Vernalis Unsteady Hydrograph	50-Year AEP Vernalis Unsteady Hydrograph	50-Year AEP Vernalis Unsteady Hydrograph	50-Year AEP Vernalis Unsteady Hydrograph	50-Year AEP Vernalis Unsteady Hydrograph	50-Year AEP Vernalis Unsteady Hydrograph
Downstream WSEL	Estimated MHW	Estimated MHW plus 140 cm	Estimated MHW	Estimated MHW plus 140 cm	Estimated MTL	Estimated MTL	Estimated MTL plus 140 cm

Upstream Boundary Conditions

Unsteady Flow Hydrograph

We used a synthetic hydrograph representing the two percent annual exceedance probability (AEP) storm (50-year recurrence interval) for San Joaquin River inflows at the upstream model boundary (i.e., at the upstream end of Corridor 1, or the San Joaquin River at Vernalis). This 2-percent AEP hydrograph was developed and used by DWR in the assessments and planning for the Central Valley

Flood Protection Plan (CVFPP) and is based on a "storm centering" focused on Vernalis. The synthetic hydrograph and its centering were formulated using the trends identified in the historical storm analysis and the Composite Floodplain concept described in the Hydraulic Technical Documentation of the Comp Study (USACE and DWR, 2002). A flood runoff centering is defined simply as a set of synthetic exceedence frequencies assigned to a mainstem and/or set of tributaries. The 2-percent AEP synthetic hydrograph (see Figure EA.7.3-1) used in this assessment is 21-days in duration, is expressed with an hourly timestep, and includes a peak flow of 48,602 cfs.

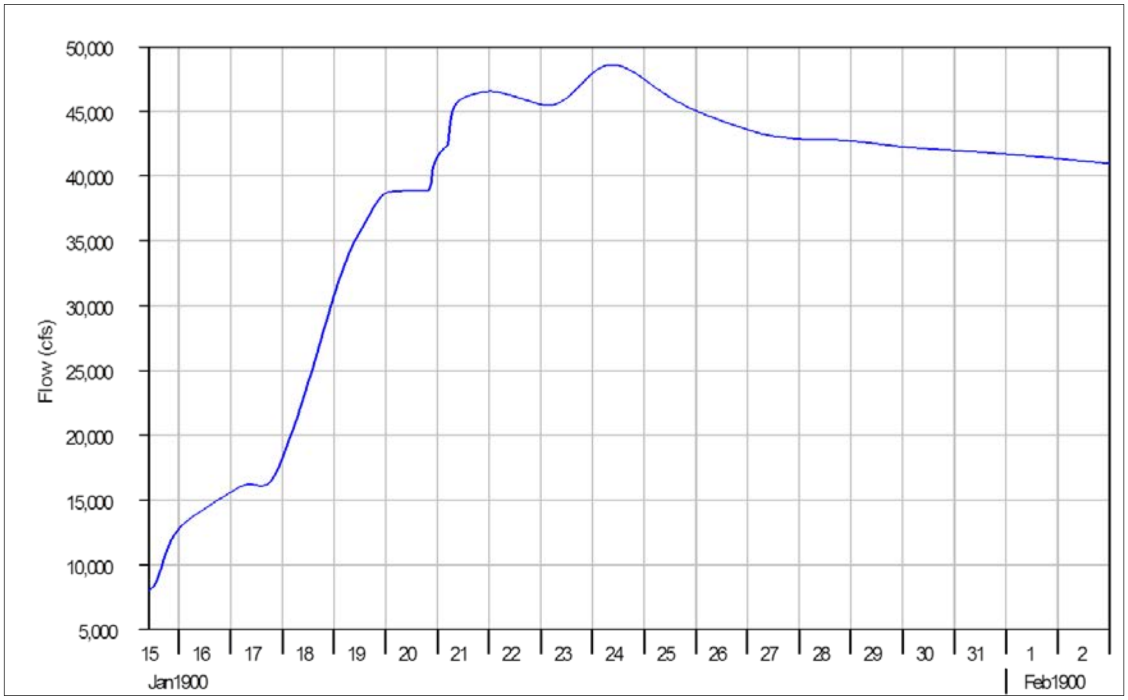

Figure EA.7.3-1. Synthetic 2-percent AEP (50-year) Hydrograph, Centered at Vernalis

Steady-Flow Discharge Sensitivity Analysis

Both the flood modeling runs and the floodplain habitat inundation modeling runs were completed with the unsteady flood hydrograph as described above. The sensitivity of water surface elevation predictions to travel time for flows at Vernalis to reach the downstream model boundaries was evaluated by modeling a steady flow of 15,000 cfs and comparing the water surface profile results to the results for the time step in the unsteady hydrograph at 15,000 cfs. The steady flow water surface elevations were less than 0.5 feet higher than the unsteady flow water surface elevations throughout nearly the entire model domain. While using the floodplain inundation areas from the unsteady inflow hydrograph may slightly underestimate floodplain inundation at a given flow, it was determined that for the relative comparison purposes of this effort this would not significantly influence evaluation results. Additional model runs with steady flow periods appended to the unsteady inflow hydrograph could be completed at a later date to refine the calculation of absolute floodplain inundation areas.

Flood Modeling Assessments

Flood performance was evaluated by running the models under a series of corridor combinations for which results would be useful in evaluating each corridor against flood management objectives.

We assessed the effects of the corridors relative to these objectives using a combination of hydraulic modeling and professional engineering judgment based on experience in evaluating similar flood management schemes. More specifically, our evaluation of flood management conditions is characterized as follows:

- This is a rapid, screening-level assessment that does not incorporate fragility curves and assumes that levees perform as designed (i.e., no levee failures).
- We focused on stage reduction at key locations, including identified locations where freeboard is limited (see description of the methods used to identify these low points, below).
- We reported results from the peak stage from the unsteady flood modeling assessments, regardless of timestep in the flood hydrograph. In other words, we have reported the highest flood stage at each modeled cross section regardless of its relationship to peak flow or how the flood is routed through the corridor.
- We assumed that hydraulic model results are equivalent if they differ by 0.5 feet or less.
- Locations of lowest levee freeboard were identified by evaluating a DWR-supplied geodatabase of South Delta levee elevations for a subset of the study area in comparison to this study's water surface profile results for existing conditions. The levee elevation data points are 32.8 feet (10 meters) apart and were derived from DWR's Delta LiDAR dataset, described above. The elevation points and corresponding distance along each levee were extracted from the geodatabase and plotted against the profile of peak water surface elevations when the HEC-RAS model was run for the 2% AEP (50-year) hydrograph. As a result of this analysis, three locations were added to the reporting locations for the HEC-RAS analysis developed by MBK Engineers for the proposed River Islands development for use as model output reporting locations, including Paradise Cut at Paradise Road, Middle River at Howard Road, and Jan Joaquin River downstream of Old River. Flood modeling results are presented in Section 7.4.

There are four main South Delta conceptual corridors; two of these corridors (Corridors 1 and 2) include "A" or "B" optional configurations. Because any potential implementation in the South Delta may involve a solution that includes habitat restoration and/or flood reduction activities in one or more of these corridors, it is important to evaluate channel conveyance for some of the most-likely corridor combinations. Further, evaluating just one corridor on its own (i.e., just Corridor 1 without enlarging any downstream reaches) would not fully explore the potential to enhance conveyance through the study area. Selecting the corridor combinations to evaluate required judgment, as there are a large number of potential corridor combinations that could be assessed. **As highlighted in gray** in Table EA.7.3-2, only certain corridor combinations were conducted in this screening level assessment. Model runs for flood assessments utilize the boundary conditions from Table EA.7.3-1. As the flood model runs are interrelated and cannot easily be placed into the individual corridor documents, all of the flood assessment modeling results are located in Section 7.4.

Table EA.7.3-2: Possible Combinations of Corridors

Model Run	Corridors						Basis for Choice of Modeled Corridor Combinations
	1A	1B	2A	2B	3	4	
FLOOD PERFORMANCE (Runs completed for this study highlighted in gray)							
A	X						Does not transfer risk away from the Mossdale to Stockton reach, but may appreciably attenuate flows for the Mossdale to Stockton reach.
		X					May attenuate flows, but Model Run A was selected to test sensitivity of that result.
			X				While this model run would likely demonstrate a beneficial flood outcome, this single-corridor option is unlikely because it would create minimal habitat.
				X			This model run only includes opening Fabian Tract to flooding, which alone is unable to meet Flood Objective 1 (i.e., no way to route additional floodwaters away from Mossdale to Stockton).
					X		This model run only expands Middle River and provides no way to route additional floodwaters away from Mossdale to Stockton.
B						X	This model run directly influences the Mossdale to Stockton reach.
	X	X					Not Applicable: Corridor 1B is an alternative (and partial) version of Corridor 1A
C	X		X				This combination combines the flood attenuation potential of Corridor 1A with the bypass function of Corridor 2A.
	X			X			To reduce model runs, the similar Model Run E was selected to examine Corridor 2B performance relative to upstream attenuation.
	X				X		This combination does not provide any means to route additional flood flows to Corridor 3.
D	X					X	This combination leverages the flood attenuation potential of Corridor 1A with water surface profile lowering on the Mossdale to Stockton reach (Corridor 4).
		X	X				To reduce model runs, the similar Model Run E was selected to examine how Corridor 2A (Paradise Cut) bypass performance relates to upstream attenuation.
E		X	X	X			Uses the moderate attenuation potential of Corridor 1B to evaluate the conveyance and water surface profile lowering performance of Corridor 2B.
		X			X		This combination does not provide any means to route additional flood flows to Corridor 3.

Model Run	Corridors						Basis for Choice of Modeled Corridor Combinations
	1A	1B	2A	2B	3	4	
FLOOD PERFORMANCE (Runs completed for this study highlighted in gray)							
		X				X	To reduce model runs, the similar Model Run D was selected to examine Corridor 1 performance related to downstream dynamics.
			X	X			Not Applicable: Corridor 2B is just an extension of Corridor 2A, into Fabian Tract
F			X		X		Corridor 2A provides a means to route floodwaters into Corridor 3, which may include attenuation benefits.
			X			X	Not modeled because the outputs of similar Model Runs B and F can be considered to examine the potential for screening purposes.
				X	X		Not modeled because the outputs of the similar Model Run F and other model runs can be considered to examine this potential for screening purposes.
				X		X	Not modeled because the outputs of Model Runs B and E can be considered to examine the potential for screening purposes.
					X	X	Not a logical combination because flood routing to Corridor 3 is not facilitated by Corridor 4.

EA.7.3.1.4 Ecosystem Modeling Assessments

Estimation of Ecologically-Relevant Discharges for Modeling

As per the SDHWG charter, future conditions were assessed with and without the assumption of a San Joaquin River Restoration Program (SJRRP) restoration hydrograph (i.e., increased flows on the San Joaquin River). The assessment to compare the two different hydrologic assumptions was conducted using the Hydrologic Engineering Center Ecosystem Functions Model (HEC-EFM). The hydrologic inputs for the “without SJRRP restoration hydrograph” assessment used the daily flow time series from the San Joaquin River at Vernalis gage for the time period January 1, 1985 through September 30, 2003. This time series was downloaded from the Department of Water Resources (DWR) Water Data Library (WDL) website. The “SJRRP restoration hydrograph” is still under development by the USBR; however a preliminary version was provided by the USBR for use in this assessment. A daily flow time series for the time period January 1, 1985 through September 30, 2003 was developed using the preliminary SJRRP hydrograph. This time series was used in the HEC-EFM calculations for the “with SJRRP” condition.

Based on the focal species of the BDCP and for the purposes of rapidly screening all of the South Delta corridors relative potential ecosystem improvements, the flow-related habitat criteria for floodplain spawning of splittail and rearing of salmon along with riverine and delta food production (phytoplankton and zooplankton production on inundated floodplains) were selected as key indicator species/processes to assess. The functional relationships between the seasonality, duration, and frequency of flows and their relation to species life stages or ecosystem processes were specified in HEC-EFM based on existing studies and are included in Table EA.7.3-3. The ecologically-relevant flows included in Table EA.7.3-3 are the HEC-EFM output values, derived from an evaluation of the existing hydrologic regime at Vernalis (1985-2003).

While the seasonality and duration of floodplain inundation are important for generating food production from a restored floodplain, it is our working assumption that *a substantial amount of floodplain* must be inundated for an ecologically-meaningful increase in the production of phytoplankton and zooplankton to occur. In this regard, it is useful to examine the extremes of a hypothetical inundated-floodplain scenario to highlight the dynamics of this process: clearly, if the timing and duration of inundation are ideal from an ecological perspective, a fully-inundated floodway of many thousands of acres is very likely to provide meaningful inputs to the foodweb; at the other extreme if only a small part of the floodplain is inundated, say just 50 acres—even if it clearly meets the duration and timing criteria—it is tenuous at best to define the output as significant. Defining a level of significance (and one that is appropriate for the goals and assessment needs of the project in question) is an unresolved topic in the emerging field of floodplain restoration planning. Thus, for the purposes of this rapid evaluation of the potential new floodplain habitat in the conceptual South Delta corridors, an arbitrary minimum threshold was set where it was assumed that 30% of a corridor's new floodplain areas needed to be inundated (along with the seasonality and duration requirements) in order for meaningful outputs to accrue. Using this assumption, the relationship between river discharge and floodplain inundation area for each corridor was queried to identify the discharge that causes 30%, 60% and 90% of the available floodplain to be inundated. Note that these discharge values are unique to each corridor as related to the total floodplain size available. Subsequently, the seasonality and duration criteria shown in Table EA.7.3-3 were applied using the reverse lookup function in HEC-EFM, which results in the identification of the *frequency* with which the various seasonality, duration, and discharge criteria are met. This assessment was applied to both the "with" and "without" SJRRP restoration hydrographs. A range of durations from 2 days through 20 days were considered. This allows evaluators to consider the relevance of the results as related to phytoplankton production (which can occur in as few as 2 days of inundation) and zooplankton production (which has been shown to peak with longer inundation durations of 14 days or more) (Baranyi et al, 2002; Grosholz and Gallo, 2006). The identified discharges and the results of the assessment (i.e., the frequencies at which the various sets of criteria shown in Table EA.7.3-3 are met) are shown in the Section 4 of the corridor description and assessment document in Table EA.4.1-3, Table EA.4.1-4, Table EA.4.1-9, Table EA.4.1-10, Table EA.4.1-15, and Table EA.4.1-20.

Table EA.7.3-3: Functional Habitat Relationships and HEC-EFM Results

Organism	Life Stage	Season	Minimum Duration	Frequency/ Return Period	Ecologically-Relevant Flow (cfs) *Without*-SJRRP	Sources
Sacramento Splittail (*Pogonichthys macrolepidotus*)	Spawning and rearing	Feb. 1 – May 31	21 days	4-year	11,600	Sommer et al., 1997; ACOE, 2002;
Chinook salmon (*Oncorhynchus tshawytscha*)	Rearing	Dec. 1 – May 31	14 days	4-year	15,550	Sommer et al., 2001a; ACOE, 2002

Hydraulic Modeling for Ecologically-Relevant Discharges

Table EA.7.3-4 depicts the hydraulic modeling runs used as a basis to examine the potential increase in floodplain inundation and the various species and ecosystem benefits that may manifest. To better understand the relationship between river discharge and floodplain inundation, plots similar to the hypothetical example in Figure EA.7.3-2 were developed and are included in each Corridor Description and Assessment Document. These inundation area- discharge plots clarify each corridor's inundation dynamics, with the series of discharge data plotted encompassing the discharges identified in Table EA.7.3-3. The plots were developed by extracting modeled water surface profile results from the HEC-RAS model at time steps of the hydrograph which correspond to ecologically-relevant discharges. Subsequently, those modeled water surface profiles were integrated into GIS using HEC-GeoRAS. The floodplain inundation areas for each corridor were subsequently tallied and plotted versus discharge in figures similar to the example in Figure EA.7.3-2.

Evaluations related to the foodweb were completed by using the data referenced in Table EA.7.3-3 and the approach described above as related to steady-state flow identification. The percentages of inundation of the floodplains (i.e., 30%, 60% and 90%, and the related discharges) were derived from an understanding of the total floodplain area for each corridor (100%) and relating it to the various acreages (and discharges) displayed in the plots exemplified by Figure EA.7.3-2.

Table EA.7.3-4: Hydraulic Modeling Runs Used to Examine Floodplain Inundation at Ecologically-Relevant Discharges

Model Run	Corridors						Notes
	1A	1B	2A	2B	3	4	
G	X						Ecological outcomes of each of the corridors are evaluated individually.
H		X					Ecological outcomes of each of the corridors are evaluated individually.
I			X				Ecological outcomes of each of the corridors are evaluated individually.
J			X	X			Ecological outcomes of each of the corridors are evaluated individually.
K			X		X		Ecological outcomes of each of the corridors are evaluated individually.
L						X	Ecological outcomes of each of the corridors are evaluated individually.

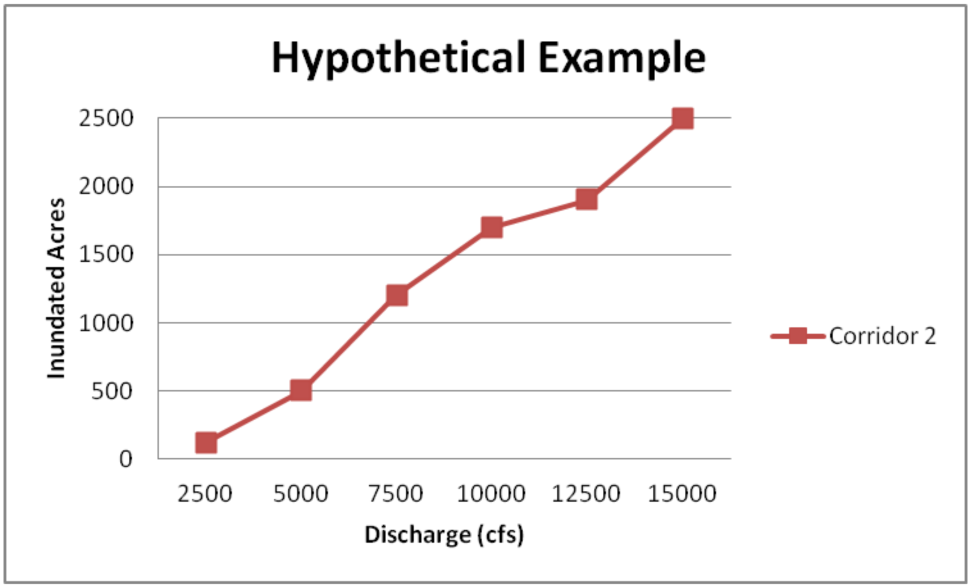

Figure EA.7.3-2. Hypothetical Example of Floodplain Inundation in Relation to Discharge

EA.7.3.1.5 Literature Cited

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EA.7.3.2 (B) Technical Memorandum—Hydraulic Model Revisions Subsequent to the South Delta Evaluations, 9/6/2012

NEWFIELDS

TECHNICAL MEMORANDUM

TO: Scott Woodland; Dale Hoffman-Floerke

CC: Betty Andrews; Jeremy Thomas

FROM: Mark Tompkins; Paul Frank; Lucy Croy

DATE: 9/6/2012

SUBJECT: Hydraulic Model Revisions Subsequent to the South Delta Evaluations

Introduction

We developed a HEC-RAS model of the San Joaquin River downstream of Vernalis based on the Comprehensive Study (USACE 2002) model of the lower San Joaquin River. Prior to final QA/QC, results generated by this model were used to inform the evaluations (conducted on February 1 and 2, 2012) of the flood management and ecosystem implications of changes to flood corridor geometry in this region of the San Joaquin River. Subsequent to the evaluations, we completed final QA/QC of the model and identified three minor errors in the model construction. This technical memorandum describes each error, how each error was corrected, and how the revised model output impacts results presented for each corridor at the evaluations.

Revision #1: Existing Conditions Channel Roughness in Old River

In general, channel roughness values range from 0.025 for clean, straight channels at full stage without rifts or deep pools to 0.150 in reaches with heavy vegetation and deep pools (Chow, 1959). In the existing conditions model, several cross sections in Old River had channel roughness values that were higher than the values used in the proposed conditions models (0.042 vs. 0.035). This occurred when we longitudinally extended this portion of the original Comprehensive Study model. To correct this error, we adjusted channel roughness values in the existing conditions model to match those in the proposed conditions models. This error, in combination with the other two errors identified during final QA/QC, contributed to both overestimations and underestimations of stage reduction in some locations during the evaluations. When the stage increases and decreases that were reported during the evaluations based on the original model results are compared to increases and decreases under the new model results, changes range from 0.1 to 0.9 feet. The effect of these changes on the magnitude and certainty scores assigned to each model run during the flood evaluation workshop is described below.

This error did not have a significant impact on the existing conditions floodplain area calculations.

Revision #2: Existing Conditions Channel Margin Roughness in Paradise Cut

In general, the range of roughness values that are appropriate for a stream channel can be applied to the channel margin. In the existing conditions model, several cross sections in Paradise Cut had channel margin roughness values that were higher than the values used in the proposed conditions models (0.07 vs. 0.035). This occurred when we modified the Paradise Weir portion of the original Comprehensive Study model. To correct this error, we adjusted channel margin roughness values in the existing conditions model to match those in the proposed conditions models. This error, in combination with the other two errors identified during final QA/QC, also contributed to both overestimations and underestimations of stage reduction in some locations during the evaluations. When the stage increases and decreases that were reported during the evaluations based on the original model results are compared to increases and decreases under the new model results, changes range from 0.1 to 0.9 feet. The effect of these changes on the magnitude and certainty scores assigned to each model run during the flood evaluation workshop is described below.

This error did not have a significant impact on the existing conditions floodplain area calculations.

Revision #3: Proposed Conditions Floodplain Roughness in Corridor 4

In the proposed conditions models that included changes to Corridor 4 (runs B,D, and L), all setback cross sections had floodplain roughness values that were lower than the values used for all other floodplains in areas with proposed setbacks (0.055 vs. 0.12). This occurred when we laterally extended the original Comprehensive Study model cross sections in Corridor 4. To correct this error, we adjusted floodplain roughness values in proposed conditions models B, D, and L to 0.12. This error, in combination with the other two errors identified during final QA/QC, also contributed to both overestimations and underestimations of stage reduction in some locations during the evaluations.

This error had no impact on the existing conditions floodplain area calculations.

Along with the revisions to n-values described above, additional information on water surface elevations (WSEs) and Model Run E should be conveyed to the evaluators. Maximum WSEs at cross sections (XSs) traversing the area between Walthall Slough and the San Joaquin River (SJR26) vary by up to 3 feet between the two channels, though the levee between them would be breached or removed as a part of Corridor 1B. At Fabian Tract, while the left levees along Grant Line Canal are described as being breached or removed, maximum water surface elevations differ significantly from Grant Line Canal to Old River (OLD10). Spot checks show up to +1 or -2ft lower maximum WSEs on Old River. These differences in WSE between parallel channels influence the WSEs that were examined during the flood evaluations as well as the revised WSEs that are presented in the flood evaluations summary.

Summary of Implications by Model Run

As noted above, none of the errors identified through our final QA/QC process resulted in significant changes to the existing conditions floodplain inundation area. Therefore, only the changes in stage associated with model runs A through F were affected by model construction errors.

After the model was corrected, it was provided to ESA PWA so that the model results could be reevaluated according to the methodology applied during the evaluation workshop in February 2012. Changes in stage reduction caused by the model error corrections resulted in changes to the magnitude score for model run B with respect to Outcome PF1 under without-sea level rise (SLR) conditions. Under with-SLR conditions, changes include the magnitude score for model run B with respect to Outcome PF1 along with the magnitude score for model run D with respect to Outcome PF1.

The original and final magnitude and certainty scores for both with- and without-SLR conditions are provided in Tables 1 and 2. While some of the magnitude and certainty scores changed with the revised modeling results, the overall worth and risk scores that are meant to rank the relative benefit and risk of each South Delta corridor did not change. Table 3 summarizes how decreases (Outcome PF1) and increases (Outcome NF1) in stage differ between the model results used during the February 2012 evaluations and the final results. As shown, magnitude scores changed from a 4 to a 3 under with- and without-SLR conditions for Model Run B and under with-SLR conditions for Model Run D. According to the magnitude scoring criteria included in the South Delta Flood Instructions document, a score of 4 is assigned when stage would be reduced by 3 feet or more. In each instance, the maximum stage reduction was 3 feet or greater under the original model results, but fell within the range (greater than 1.5, but under 3 feet) for a score of 3 per the results of the revised model. The certainty score change for Model Run F under with-SLR conditions resulted from a consistency review by the consultant team, not the revision of modeling results.)

Table 1. Changes in Magnitude and Certainty Scores without SLR

Model Run	Outcome*	Original Magnitude Score	Final Magnitude Score	Scoring Change?	Original Certainty Score	Final Certainty Score	Scoring Change?
A	PF1	1	1	No	4	4	No
	NF1	1	1	No	3	3	No
B	PF1	4	3	**Yes**	4	4	No
	NF1	4	4	No	3	3	No
C	PF1	2	2	No	4	4	No
	NF1	n/a	n/a	n/a	n/a	n/a	n/a
D	PF1	4	4	No	4	4	No
	NF1	4	4	No	3	3	No
E	PF1	3	3	No	4	4	No
	NF1	2	2	No	3	3	No
F	PF1	3	3	No	4	4	No
	NF1	4	4	No	2	3	**Yes**
***Outcome PF1 – Decreased stage; Outcome NF1 – Increased Stage**							

Table 2. Changes in Magnitude and Certainty Scores with SLR

Model Run	Outcome*	Original Magnitude Score	Final Magnitude Score	Scoring Change?	Original Certainty Score	Final Certainty Score	Scoring Change?
A	PF1	1	1	No	4	4	No
	NF1	1	1	No	3	3	No
B	PF1	4	3	**Yes**	4	4	No
	NF1	4	4	No	3	3	No
C	PF1	2	2	No	4	4	No
	NF1	n/a	n/a	n/a	n/a	n/a	n/a
D	PF1	4	3	**Yes**	4	4	No
	NF1	4	4	No	3	3	No
E	PF1	3	3	No	4	4	No
	NF1	1	1	No	3	3	No
F	PF1	3	3	No	4	4	No
	NF1	4	4	No	2	3	**Yes**
***Outcome PF1 – Decreased stage; Outcome NF1 – Increased Stage**							

Table 3. Comparison of Stage Increases and Decreases under Original and Final Model Results

Model Run	Outcome*	Original Maximum Stage Change (feet)	Final Maximum Stage Change (feet)	Location
A	PF1	<0.5	<0.5	Throughout FOA
	NF1	0.01	0.02	SJR at Mossdale
B	PF1	>3; >3; 2	2.6; 2.25; 1.8	FOA - SJR; OR; PC
	NF1	4	3.2	Downstream-most 22,000 feet of SJR
C	PF1	0.8; 0.75; 1.1	1.25; 0.9; 0.85	FOA - SJR; OR; PC
	NF1	n/a	n/a	n/a
D	PF1	>3; >3; 2	2.6; 2.25; 1.75	FOA - SJR; OR; PC
	NF1	4	2.4	Downstream-most 27,000 feet of SJR
E	PF1	1.9; 1.9; 2.25	1.9; 2; 2.5	FOA - SJR; OR; PC
	NF1	2	2	Lower OR
F	PF1	2.1; 2.4; 2.1	2.1; 2.4; 2.1	FOA - SJR; OR; PC
	NF1	5.5	5.25	Downstream-most 9.25 miles along MR

***Outcome PF1 – Decreased stage; Outcome NF1 – Increased Stage**

EA.7.4 South Delta Flood Modeling Results

This section includes hydraulic modeling results from the analysis described in Section 7.3, Hydraulic and Hydrologic Modeling Methods and Assumptions. This section contains:

1. A map showing river reach names as assigned in HEC-RAS;
2. Stage profile plots created from the output of model runs A through F; and
3. Histograms showing results by model run.

EA.7.5 List of Experts that Participated in the Modified-DRERIP, Flood, Terrestrial Species, and Water Quality Evaluations

EA.7.5.1 Modified-DRERIP

- Bruce DiGennaro (ESSEX Partnership; Facilitator)
- Eric Ginney (ESA PWA; Coach)
- Jeremy Thomas (NewFields)
- Michelle Orr (ESA PWA)
- Ted Sommer (Department of Water Resources [DWR])
- Cathy Marcinkevage (NOAA Fisheries)
- Josh Israel (United States Bureau of Reclamation [USBR])
- Christine Joab [Central Valley Regional Water Quality Control Board [CVRWQCB])
- Will Stringfellow (University of the Pacific [UOP]/Lawrence Berkeley National Laboratory [LBNL])
- Mike Hoover (United States Fish and Wildlife Service [USFWS])
- John Cain (American Rivers)
- Ron Melcer (DWR)
- Shengjun Wu (DWR)
- Deanna Sereno (Contra Costa Water District [CCWD])

EA.7.5.2 Flood

- Betty Andrews (ESA PWA, Coach)
- Mark Tompkins (NewFields)
- Mike Archer (MBK Engineers)
- Michael Mierzwa (DWR)
- Joe Bartlett (DWR)
- Samson Haile-Selassie (DWR)
- Ray McDowell (DWR)
- Scott Woodland (DWR)
- Steve Cimperman (DWR)
- Chris Neudeck (KSN, Inc.) - Feb 1 only
- Bob Scarborough (DWR) - Feb 2 only
- Minta Schaefer (ESA PWA, note taker)
- Lucy Croy (NewFields River Basin Services, modeling support) - Feb 1 only

EA.7.5.3 Terrestrial Species

- Bruce DiGennaro (ESSEX Partnership; Facilitator)
- Eric Ginney (ESA PWA; Coach)
- Nat Seavy (PRBO Conservation Science)
- Tom Griggs (River Partners)
- Ron Melcer (DWR FESSRO)
- Laura Cholodenko (California Department of Fish and Wildlife [CDFW])
- Ellen Berryman (ICF)
- Heather Webb (USFWS)
- Lori Rinek (USFWS)
- Michael Hoover (USFWS)
- Rebecca Sloan (ICF)
- Neil Clipperton (CDFW)
- Amy Richey (Mosaic Associates)
- Junko Hoshi (CDFW)
- Judy Bendix (Mosaic Associates)
- Minta Schaefer (ESA PWA, note taker)

EA.7.5.4 Water Quality

- Bruce DiGennaro (ESSEX Partnership; Facilitator)
- Eric Ginney (ESA PWA; Coach)
- Scott Woodland (DWR)
- Subir Saha (DWR)
- Parviz Nader (DWR)
- Deanna Sereno (CCWD)
- Will Stringfellow (UOP/LBNL)
- Frances Brewster (Santa Clara Valley Water District [SCVWD])
- Christine Joab (CVRWQCB)
- Stephanie Fong (CVRWQCB)
- Val Connor (State and Federal Contractors Water Agency [SFCWA])
- Minta Schaefer (ESA PWA, note taker)
- Robert Eckard (ESA PWA, note taker)

EA.7.6 Methods and Materials for Modified-DRERIP, Flood, Terrestrial Species, and Water Quality Evaluations

South Delta

Scientific Evaluation Instructions

Key assumptions:

- BDCP Alternative 1A (Dual Conveyance with Tunnel and Intakes 1–5 [15,000 cfs; Scenario A Operations]).
- Dual-conveyance from a location on the Sacramento River.
- No South Delta Temporary Barriers Project; CM 16 may include a non-physical barrier at CCF and/or HOR
- Assessment assumes restoration is complete and is at some time in the BDCP late-long term.
- All ecological outcomes are assessed *with* Sea Level Rise (16 inches at 2050), with consideration of any changes from the San Joaquin River Restoration Program flow regime. (Note: Flood considers 55 inches at 2100).
- Full assumptions on corridor configuration are included in Section 3, *Corridor Descriptions and Assumptions*.

Step 1: Review the Scale *[in Excel]*

Review the relative scale of the corridor based on the following criteria and in relation to the other corridors. The purpose of establishing scale is to assist with determining the magnitude of effect on the ecosystem. Large, medium and small should be considered relative to the overall Delta area, the other corridors, and the temporal dynamics of processes being manipulated.

Large: Broad spatial extent, significant duration and/or frequency, and/or major reversal compared to existing conditions. Landscape scale.

Medium: Moderate spatial extent, moderate duration and/or frequency, and/or moderate change compared to existing conditions. Regional scale.

Small: Small acreage, short duration or only occasionally, and/or small change compared to existing conditions. Local scale.

Step 2: Review Positive and Negative Outcomes to be Evaluated; Verify/Confirm *[in Excel]*

Review the standardized list of expected positive and negative outcomes. Outcomes should not be evaluated at this step, just reviewed. List additional outcomes, as appropriate.

Step 3: Score Magnitude and Certainty of Potential Positive and Negative Ecological Outcomes *[in Excel; record rationale in Word document]*

Using the conceptual models and other relevant source materials, identify and score the expected magnitude and certainty of the identified positive and negative ecological outcomes, *assuming sea level rise conditions from the technical information in the supporting documents*. The overall “Worth” (generated by the positive outcomes) and “Risk” (generated by the negative outcomes) for species is automatically-tabulated in the worksheets based on the conversion matrices attached, below.

- Record the magnitude and certainty for each outcome on the evaluation worksheet. Use the definitions, criteria, listed at the end of these instructions to guide the scoring determination.
- *If magnitude and certainty are different for conditions without SLR, provide alternative scoring in that column of the worksheet.*
- Document a rationale for how scores for magnitude and certainty were arrived at, including citation of specific model sections and page numbers, and/or additional information used in the rationale section.

Step 4: Identify Data Gaps and Potential Refinements for future South Delta Habitat Planning *[in Word Document]*

Based on the evaluation process, for each corridor reflect back on the evaluation and identify any important new ideas or understandings, any identified data gaps, or future analysis or research needs. This includes additional (or new) analysis necessary to resolve outstanding uncertainty and noting any potential to change assumptions or corridor configurations (or corridor combinations) to increase the worth /decrease the risk of potential implementation. Record ideas in the appropriate boxes on the evaluation worksheet.

Step 5: *After* developing scores for all species in all corridors, consider and add any caveats related to the following items. Complete this for each corridor:

- How the San Joaquin River Restoration Program restoration flow regime and future flows that may be ordered by the SWRCB or result from climate change may influence key habitats and species outcomes and associated scoring.
- How the corridors will perform if several islands in the central and west Delta are permanently inundated in the future.
- How the corridors may be consistent with a barrier at the head of Old River, or how it can achieve the same or better benefits without the barrier or with a barrier open more of the time than currently planned.
- How the corridors might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants.

Definitions, Criteria and Conversion Matrices

The following definitions, criteria, and conversion matrices, are provided to aid the Scientific Evaluation process. Some of the definitions pertain to terms used in the conceptual models, such as understanding and predictability. Other definitions relate directly to completion of the Scientific Evaluation worksheet.

Scientific Evaluation Terms

The terms ***scale, magnitude, and certainty*** are scientific evaluation terms used to characterize the cumulate "path" or "chain" found between the restoration in each corridor being evaluated and each outcome being considered within the evaluation.

The terms ***worth and risk*** are Scientific Evaluation terms that combine considerations of magnitude and certainty to assess the consequences of an action.

> ***Scale*** - Scale addresses temporal and spatial considerations, quantity and/or degree of change contained within the Action.
>
> ***Magnitude*** – Magnitude assesses the size or level of the outcome, either positive or negative, in terms of population or habitat effects on a given species. Magnitude is not the same as the scale of the action, however, higher magnitude scores require consideration of scale.
>
> ***Certainty*** - Certainty describes the likelihood that a given Restoration Action will achieve a certain Outcome. Certainty considers both the predictability and understanding of linkages in the DLO pathway from the action to the outcome. Generally, high importance-low predictability linkages drive the scoring; it is important to ensure that certainty is not unduly weighted by a comparatively low-importance, albeit low-predictability linkage.
>
> ***Worth*** - Combines the ***magnitude*** and ***certainty*** of positive outcomes to convey the cumulative "value" of a Restoration Action toward achieving an Outcome.
>
> ***Risk*** - Combines the ***magnitude*** and ***certainty*** of negative outcomes to convey the overall degree of risk associated with implementing a corridor. Note that the term "risk" here applies to the *risk of the decision*, not the degree of the potential impact. High magnitude, high certainty outcomes are considered less "risky" than high magnitude, low certainty outcomes because it is assumed that the ability to manage and mitigate for the former is greater due to the high certainty (i.e. greater understanding and knowledge).

Conceptual Model Terms

The terms ***importance, predictability, and understanding*** are used in the conceptual models to characterize individual linkages (depicted as arrows in the models) between a driver and an outcome. The terms pertain to specific processes or mechanisms *within a given model* (e.g. how important is the supply of organic matter to mercury methylation?). The graphical forms of the conceptual models apply line color, thickness, and style to represent these three terms. See the following link for more information regarding the DRERIP conceptual models: http://www.dfg.ca.gov/ERP/conceptual_models.asp.

Importance - The degree to which a linkage controls the outcome *relative to* other drivers and linkages affecting that same outcome. Models are designed to encompass all identifiable drivers, linkages and outcomes but this concept recognizes that some are more important than others in determining how the system works. If a driver is potentially more important under particular environmental conditions, the graphic should display the maximum level of importance of this driver with the narrative describing the range of spatial and temporal conditions associated with this driver.

Predictability - The degree to which the performance or the nature of the outcome can be predicted from the driver. Predictability seeks to capture the variability in the driver-outcome relationship. Predictability can encompass temporal or spatial variability in conditions of a driver (e.g., suspended sediment concentration or grain size), variability in the processes that link the driver to the outcome (e.g., sediment deposition or erosion rate as influenced by flow velocity), or our level of understanding about the cause-effect relationship (e.g., magnitude of sediment accretion inside vs. outside beds of submerged aquatic vegetation). Any of these forms of variability can lead to difficulty in predicting change in an outcome based on changes in a driver.

Understanding – A description of the known, established, and/or generally agreed upon scientific understanding of the cause-effect relationship between a single driver and a single outcome. Understanding may be limited due to lack of knowledge and information or due to disagreements in the interpretation of existing data and information; or because the basis for assessing the understanding of a linkage or outcome is based on studies done elsewhere and/or on different organisms, or conflicting results have been reported. Understanding should reflect the degree to which the model that is used to represent the system does, in fact, represent the system.

Scientific Evaluation Scoring Criteria

The following tables should be used to inform ***magnitude and certainty*** scores for Scientific Evaluation. These entail looking holistically at the cumulative value (positive or negative) of an outcome.

Table 1 - Criteria for Scoring Magnitude of Ecological Outcomes (positive or negative)

4 - High: expected sustained major population level effect, e.g., the outcome addresses a key limiting factor, or contributes substantially to a species population's natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or has a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics. Requires a large-scale.
3 - Medium: expected sustained minor population effect or effect on large area (regional) or multiple patches of habitat. Requires at least a medium-scale.
2 - Low: expected sustained effect limited to small fraction of population, addresses productivity and diversity in a minor way, or limited spatial (local) or temporal habitat effects.
1 - Minimal: Conceptual model indicates little effect.

Table 2 - Criteria for Scoring Certainty of Ecological Outcomes (positive or negative)

4 - High: Understanding is high (based on peer-reviewed studies from within system and scientific reasoning supported by most experts within system) and nature of outcome is largely unconstrained by variability (i.e., predictable) in ecosystem dynamics, other external factors, or is expected to confer benefits under conditions or times when model indicates greatest importance.
3 - Medium: Understanding is high but nature of outcome is dependent on other highly variable ecosystem processes or uncertain external factors or understanding is medium (based on peer-reviewed studies from outside the system and corroborated by non peer-reviewed studies within the system) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
2 - Low: Understanding is medium and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors or understanding is low (based on non peer-reviewed research within system or elsewhere) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
1 - Minimal: Understanding is lacking (scientific basis unknown or not widely accepted), or understanding is low and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors

Conversion Matrices

The following two matrices are designed to combine scores for magnitude and certainty to develop overall values for Worth and Risk.

Table 3. Conversion Matrix for Determining Worth from the Criteria Scores for Positive Outcomes.

Is It Worthwhile?

Combining Magnitude and Certainty

		Certainty			
		1	2	3	4
Magnitude	1	***Low***	***Low***	***Med***	***Med***
	2	***Low***	***Med***	***Med***	***High***
	3	***Med***	***Med***	***High***	***High***
	4	***Med***	***High***	***High***	***High***

Table 4. Conversion Matrix for Determining Risk from the Criteria Scores for Negative Outcomes.

Is It Risky?

Combining Magnitude and Certainty

		Certainty (understanding + predictability)			
		1	2	3	4
Magnitude	1	***Med***	***Med***	***Low***	***Low***
	2	***High***	***Med***	***Med***	***Low***
	3	***High***	***High***	***Med***	***Med***
	4	***High***	***High***	***High***	***Med***

Scientific Evaluation Worksheet
Corridor Xx

Evaluation Team:

Date:

Note: Magnitude and Certainty scoring is tracked in an accompanying Excel spreadsheet.

Corridor Scale: *Insert corridor scale rationale statement (developed by support team; reviewed by evaluators).*

SALMON OUTCOMES

Potential Positive Ecological Outcome(s)

Outcome #	***Px (short name)***
Clarifying Assumptions: *List them here*	
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*	
Literature Cited: *Insert here.*	

Potential <u>Negative</u> Ecological Outcome(s)

Outcome #	***Nx (short name)***
Clarifying Assumptions: *List them here*	
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*	
Literature Cited: *Insert here.*	

Data Gaps, Key Uncertainties, New Ideas, and Suggestions for Future South Delta Planning

(Complete this section for each species)

Data Needs *(indicate specific models, DLO relationships, or other information indicating the need):*
Key Uncertainties and Research Needs *(describe specific research activities that could be employed to increase understanding):*
Important New Ideas or Understandings *(describe these items here):*
Potential corridor re-configurations (or corridor combinations) to increase the worth /decrease the risk of potential implementation. Also add comments on any restoration design considerations. *(Describe those new configurations or changes here):*

The templates above will be copied into a series of sections with the following headings (in this order):

SALMON OUTCOMES

STEELHEAD OUTCOMES

SPLITTAIL OUTCOMES

GREEN STURGEON OUTCOMES

WHITE SURGEON OUTCOMES

DELTA SMELT OUTCOMES

LONGFIN SMELT OUTCOMES

Standardized Outcomes for South Delta Corridors DRERIP Evaluations		
Standard Outcome Code	**DRERIP Outcomes (long text)**	**Outcome (brief descriptor)**
Habitat - Spatial Extent		
P1	Increased habitat extent and connectivity	Connectivity of habitat
P2	Additional spawning habitat	Spawning
P3	Additional rearing habitat	Rearing
P4	Potential for expanded spatial distribution into formerly (historically) occupied habitat areas	Expand Spatial Distribution
P5	Increased upstream migration opportunities	Upstream Migration
P6	Reduced habitat for non-native predatory fish.	Reduce Habitat for Predatory Fish
N1	Increased habitat for non-native predators/competitors to covered species	Habitat for Predators/Competitors
Habitat Quality		
P7	Increased establishment of woody riparian vegetation providing shaded channel habitat, increased channel margin complexity, and export of large woody debris (LWD)	Shaded Channels /Channel Margin/LWD
P8	Increased establishment of emergent vegetation providing high quality rearing habitat	Emergent Vegetation

Standardized Outcomes for South Delta Corridors DRERIP Evaluations

Standard Outcome Code	DRERIP Outcomes (long text)	Outcome (brief descriptor)
P9	Reduced periodic low dissolved oxygen events	DO
P10	Increased delivery of readily-suspendable sediments providing increased turbidity downstream, improved habitat conditions, and greater feeding success, and reduced predation	Suspended Sediments
N2	Decrease in turbidity downstream	Decreased Turbidity
N3	Increased mortality of covered species due to degradation of water quality	Mortality Because of Water Quality
N4	Increased frequency, duration and extent of low DO (perhaps due to an increase in algae/POM)	Low DO
N5	Establishment of undesirable species (such as Egeria/SAV, Corbula, Corbicula, other invasives) that will prey or compete or alter habitat conditions for covered fish.	Establishment of Invasive Species
Food		
P11	Increased production and local availability of aquatic food resouces (POM, phytoplankton, zooplankton, small fish, etc).	Increased Local Aquatic Primary and Secondary Production
P12	Increased production of terrestrial invertebrates put into the aquatic ecosystem for rearing covered fish species.	Increased Terrestrial Invertebrates

Standardized Outcomes for South Delta Corridors DRERIP Evaluations

Standard Outcome Code	DRERIP Outcomes (long text)	Outcome (brief descriptor)
P13	Food resources produced on the restored habitat will be exported and contribute to food availability in downstream aquatic areas. (Note: food resouces could include organic carbon, phytoplankton, zooplankton, and other organisms).	Food Export
P14	Increased or decreased nutrients (NPK, etc).	Nutrients
N6	Detritus POC is temporally and spatially limited	Limited Detritus and POC
N7	Increased concentrations of microcystis due to decreased circulation	Microcystis from stagnation
N8	Increased blooms of microcystis due to a reduction in competition for nutrients	Microcystis bloom
Mortality		
P14	Reduced predation mortality (i.e. due to striped bass, black bass, and other non-native predatory species).	Reduced Predation
P15	Increased survival of out-migrating juveniles by providing migration route with lower predation	Route for Out-Migration
P16	Reduced entrainment mortality	Reduced Entrainment
P17	Reduced mortality due to stranding, illegal harvest and/or blocked/delayed passage	Reduced Stranding and Blocked Passage

Standardized Outcomes for South Delta Corridors DRERIP Evaluations		
Standard Outcome Code	**DRERIP Outcomes (long text)**	**Outcome (brief descriptor)**
N9	Restoration site creates a population sink for covered fish species (Provides rearing habitat that becomes a one-way trip (to entrainment or predation?)	Sink
Contaminents		
P18	Reduced sublethal effects (genetic, tissue/organ damage, development, reproductive, growth, and immune) of mercury on covered fish species.	Sublethal Effects
P19	Reduced direct mortality of covered fish species from pesticides.	pesticides
N10	Increased phytoplankton productivity will increase clam biomass and uptake of selenium, impairing reproduction in benthic foraging fish species	Selenium
N11	Potential for increased mercury methylation, local bioaccumulation and impact on covered species (on floodplain and downstream)	Mercury Methylation
N12	Increased resuspension/mobilization and export of toxic compounds w/impact on covered species	Resuspension/Mobilization of Toxics
N13	Increased exposure risk to contaminants (including Selinium) due to longer residence times	Longer Residence Time Increases Exposure Risk

Standard Species Codes for DRERIP Worksheet	
A	Fall-run Chinook salmon (but note any differences for Spring Chinook)
B	Steelhead
C	splittail
D	green sturgeon
E	white surgeon
F	Delta smelt
G	Longfin smelt

South Delta
Flood Evaluation Instructions

Note: The entire evaluation process should be completed by comparing existing and corridor conditions <u>assuming existing sea level</u>. The evaluation process should then be repeated to provide scoring for conditions assuming sea level rise.

Step 1: Review the Modeling Approach and Results

Evaluators will begin with a review of the approach to modeling existing conditions, followed by the corridor model runs (i.e., single corridors and corridor combinations, as per the modeling run matrix in Section 7.3 of the Corridor Description and Assessment Document). Evaluators shall review the results of the model run to agree on the "signals" indicated by the stage results at the reporting nodes. Changes in attenuation shall also be reviewed. In this review, particular attention shall be focused on the flood objective areas (FOAs) as per their importance in the magnitude scoring. The FOAs are the mainstem San Joaquin River between Mossdale and Stockton, including the communities of Lathrop, Manteca, Stockton, and unincorporated San Joaquin County, Old River between San Joaquin and Middle Rivers and Paradise Cut **(**see in Section 7.3 of the supporting documents).

Step 2: Develop the Positive and Negative Outcome(s) to be Scored

Review results for each model run in order to identify specific outcomes. Define outcomes in relation to locations (including reaches or sub-regions). One outcome must address the relation of the modeling results to the FOA. Consider changes in stage and attenuation, and examine reaches upstream and downstream of the corridor(s) being evaluated.

Step 3: Assign a Spatial Scale

Define the relative spatial scale of the outcomes based on the results of the model run and the following criteria. Scale is assigned in relation to the results of the other corridors (and corridor combinations, i.e., the other model runs). The purpose of establishing scale is to assist with determining the magnitude of the outcome.

Large: Broad spatial extent. Includes the entire FOA and much of the study area.

Medium: Moderate spatial extent. Includes most of **the** FOA, but little or no area beyond.

Small: Small extent. Includes part of the FOA.

N/A: Outside the flood objective location area.

Step 4: Score Magnitude and Certainty of Potential Positive and Negative Outcomes

Develop a magnitude and certainty for both positive and negative outcomes. Using the model results and other relevant materials from the Corridor Documents, score the expected magnitude and certainty of the identified positive and negative outcomes. The overall "Worth" (generated by the positive outcomes) and "Risk" (generated by the negative outcomes) will be automatically-tabulated in the worksheets. Note that these terms relate to the *decision of choosing to implement the flood system modifications in the corridors being evaluated*, and the term "risk" should not be confused with the traditional definition of risk used in flood management.

Use the definitions and criteria in the Flood Evaluation Definitions and Scoring Criteria section, below, to guide the scoring determination. Document how scores for magnitude and certainty were arrived at and note anything about this rationale that can provide information to subsequent efforts.

Step 5: Identify Potential Refinements for Phase 2 of South Delta Habitat Planning

Based on the evaluation process, identify important data, analysis, or research needs. This includes: identifying important gaps in information; specifying additional (or new) analysis necessary to resolve outstanding uncertainty; and noting any potential to change assumptions or corridor configurations (or corridor combinations) to increase the worth/decrease the risk . Complete the data gaps/future planning table at the end of the Scientific Evaluation Worksheet.

Flood Evaluation Definitions and Scoring Criteria

Definitions (defined specifically for use in this these evaluations)

Understanding – A description of the known, established, and/or generally agreed upon scientific/engineering understanding of the cause-effect relationship between a single driver and a single outcome. Understanding may be limited due to lack of knowledge and information or due to disagreements in the interpretation of existing data and information; or because the basis for assessing the understanding of a process is based on conflicting results that have been reported (i.e., the use of different modeling tools for the same location or corridor option). Understanding should reflect the degree to which the model that is used to represent key dynamics and processes in question does, in fact, represent those key processes and dynamics.

Scale - Scale addresses spatial considerations of the outcome relative to the objectives.

Magnitude – Magnitude assesses the size or level of the outcome, either positive or negative, in terms of the effect. Magnitude is not the same as the scale of the action, however, higher magnitude scores require consideration of scale.

Certainty - Certainty describes the likelihood that a given change in the flood system will achieve a certain outcome. Certainty considers both the predictability and understanding of linkages in the pathway from the action to the outcome.

Worth - Combines the ***magnitude*** and ***certainty*** of positive outcomes to convey the cumulative "value" of corridor implementation toward achieving the flood objectives.

Risk - Combines the ***magnitude*** and ***certainty*** of negative outcomes to convey the overall degree of risk associated with implementing a corridor. Note that the term "risk" here applies to the *risk of the decision*, not the degree of the potential impact. High magnitude, high certainty outcomes are considered less "risky" than high magnitude, low certainty outcomes because it is assumed that the ability to manage and mitigate for the former is greater due to the high certainty (i.e., greater understanding and knowledge).

Criteria Tables

The following criteria tables should be used to inform ***magnitude and certainty*** scores for the Flood Evaluation. These entail looking holistically at the cumulative value (positive or negative) of outcomes.

Table 1 - Criteria for Scoring Magnitude of Flood Outcomes (positive or negative)

4 – High: Positive (scale must be large): Evaluation results indicate a large (3 ft or more) decrease in WSE *within the FOA*. Attenuation benefits are large. Negative: Evaluation results indicate an increase in WSE in any location and /or redirected impacts are large and increase flood risk[1]. Existing attenuation benefits in FOA are greatly reduced. Not generally mitigable.
3 – Medium: Positive (scale must be at least medium): Evaluation results indicate a medium decrease (1.5 ft to 3 ft) in WSE *within the FOA*. Attenuation benefits are moderate to large. Negative: Evaluation results indicate an increase in WSE in any location and /or redirected impacts are moderate and increase flood risk. Existing attenuation benefits in FOA are moderately reduced. Mitigable with a large investment.
2 – Low: Positive (scale must be small): Evaluation results indicate a low WSE decrease (0.5 to 1.5 feet) in WSE *within the FOA*. Attenuation benefits are small. Negative: Evaluation results indicate an increase in WSE in any location and/or redirected impacts are small and increase flood risk. Existing attenuation benefits in FOA are slightly reduced. Mitigable with moderate investment.
1 - Modest: Evaluation indicates little effect, though WSE decreases or increases exist. Little or no change in attenuation benefit. Mitigable with minor investment or mitigation not anticipated.
[1] It's important to note that flood risk and the overall risk score are distinct. The negative outcomes describe increased flood risk due to an increase in WSE. The scores applied to the negative outcomes are what determine the final risk score for each model run. The concept of the risk score is described later in this instructions document, and is consistent with that for the ecosystem/species, terrestrial, and water quality evaluations. It just happens that the analysis of the potential for flooding also involves the analysis of risk.

Table 2 - Criteria for Scoring <u>Certainty</u> of Flood Outcomes (positive or negative)

4 - High: Understanding is high for both flood hydraulics and mitigation. Corridor option was explicitly modeled and the assumptions in boundary conditions are well-developed to assess critical processes that have a strong influence on the outcomes. Future modeling and analysis is likely to be well-positioned because most or all of the variability in hydrodynamic processes or other external factors (including relation to other corridors) were examined.
3 - Medium: Understanding is high for flood hydraulics but modeling of corridor option includes assumptions in boundary conditions or other factors that are potentially variable or not well understood. Mitigation understanding is medium.
2 - Low: Understanding is low for either flood hydraulics or mitigation. Modeling of corridor option includes assumptions in boundary conditions or other factors that are potentially variable, not well understood, or require additional intermediate investigations to resolve inconsistent results from previous efforts.
1 - Modest: Understanding is lacking for both flood hydraulics and mitigation. Corridor option was not explicitly modeled and/or the assumptions in boundary conditions are not consistent with other modeling in this effort. Future modeling and analysis will require substantial sensitivity analysis because of highly-variable factors.

Conversion Matrices

The following two matrices combine scores for magnitude and certainty to develop overall values for Worth and Risk. These terms relate to the *decision of choosing to implement the flood system modifications in the corridors being evaluated*, and the term "risk" should not be confused with the traditional definition of risk used in flood management. High-worth and low-risk decisions on implementation are desirable.

Table 3. Conversion Matrix for Determining Worth from the Criteria Scores for <u>Positive</u> Outcomes

Is It Worthwhile?

Combining Magnitude and Certainty

		Certainty			
		1	2	3	4
Magnitude	1	***Low***	***Low***	***Med***	***Med***
	2	***Low***	***Med***	***Med***	***High***
	3	***Med***	***Med***	***High***	***High***
	4	***Med***	***High***	***High***	***High***

Table 4. Conversion Matrix for Determining Risk from the Criteria Scores for <u>Negative</u> Outcomes

Is It Risky? (rev 6-28-07)

Combining Magnitude and Certainty

		Certainty			
		1	2	3	4
Magnitude	1	***Med***	***Med***	***Low***	***Low***
	2	***High***	***Med***	***Med***	***Low***
	3	***High***	***High***	***Med***	***Med***
	4	***High***	***High***	***High***	***Med***

Scientific Evaluation Worksheet

Evaluation Team:

Date:

FLOOD OUTCOMES – MODEL RUN A

Potential Positive Flood Outcome(s)

Outcome P1F: Decreased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P2F: Decreased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P3F: Decreased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P4F: Decreased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN A

Potential Negative Flood Outcome(s)

Outcome N1F: Increased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N2F: Increased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N3F: Increased duration of flow against levees
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N4F: Increased frequency of flow against levees
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

FLOOD OUTCOMES – MODEL RUN B

Potential Positive Flood Outcome(s)

Outcome P1F: Decreased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*
Outcome P2F: Decreased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P3F: Decreased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P4F: Decreased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN B

Potential Negative Flood Outcome(s)

Outcome N1F: Increased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*
Outcome N2F: Increased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N3F: Increased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome N4F: Increased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN C

Potential Positive Flood Outcome(s)

Outcome P1F: Decreased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P2F: Decreased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P3F: Decreased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P4F: Decreased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN C

Potential Negative Flood Outcome(s)

Outcome N1F: Increased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N2F: Increased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N3F: Increased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome N4F: Increased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN D

Potential Positive Flood Outcome(s)

Outcome P1F: Decreased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P2F: Decreased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P3F: Decreased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P4F: Decreased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN D

Potential Negative Flood Outcome(s)

Outcome N1F: Increased stage

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome N2F: Increased flow

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome N3F: Increased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome N4F: Increased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN E

Potential Positive Flood Outcome(s)

Outcome P1F: Decreased stage

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P2F: Decreased flow

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P3F: Decreased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P4F: Decreased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN E

Potential Negative Flood Outcome(s)

Outcome N1F: Increased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N2F: Increased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N3F: Increased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome N4F: Increased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN F

Potential Positive Flood Outcome(s)

Outcome P1F: Decreased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P2F: Decreased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome P3F: Decreased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome P4F: Decreased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

FLOOD OUTCOMES – MODEL RUN F

Potential Negative Flood Outcome(s)

Outcome N1F: Increased stage
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N2F: Increased flow
Clarifying Assumptions: *List them here.*
Scientific Justification: *Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.*
Literature Cited: *Insert here.*

Outcome N3F: Increased duration of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

Outcome N4F: Increased frequency of flow against levees

Clarifying Assumptions:
List them here.

Scientific Justification:
Insert rationale statement(s) for magnitude and certainty scores here. Document any differences in viewpoints here.

Literature Cited:
Insert here.

DATA GAPS, KEY UNCERTAINTIES, NEW IDEAS, AND SUGGESTIONS FOR FUTURE SOUTH DELTA PLANNING

Data Needs *(indicate specific models, DLO relationships, or other information indicating the need):*
Key Uncertainties and Research Needs *(describe specific research activities that could be employed to increase understanding):*
Important New Ideas or Understandings *(describe these items here):*
Potential corridor re-configurations (or corridor combinations) to increase the worth /decrease the risk of potential implementation. Also add comments on any restoration design considerations. *(Describe those new configurations or changes here):*

South Delta Flood and Habitat Planning

Modified DRERIP Evaluation Process for Evaluating Terrestrial Habitat

The BDCP covers approximately 60 terrestrial species. The charter for the South Delta Habitat Working Group requests that DRERIP evaluators seek to identify opportunities within the corridors for creating habitat for terrestrial species, including waterfowl, to the extent practicable.

Clearly, changes in the landscape as assumed for the South Delta under "corridor conditions" would have an influence on terrestrial habitat for the BDCP covered terrestrial species. However, evaluation of potential outcomes for terrestrial species in the assumed South Delta corridors is difficult because the site-specific planning for riparian restoration and other revegetation (active or passive) and an assessment of terrestrial landscape evolution in the corridors is not to be completed in this initial screening-level evaluation of the conceptual South Delta corridors. Further, there are no DRERIP conceptual models for the BDCP terrestrial species. For these reasons, scoring outcomes for terrestrial species is not possible in the full DRERIP evaluation process.

To support further thinking and consideration of the potential outcomes for terrestrial species, there is utility in assessing terrestrial *habitat* as a surrogate for the many species that use this habitat. The evaluation of potential changes in terrestrial habitat is covered by the modified-DRERIP evaluation process described below.

At this stage of screening-level evaluation of the corridors, it is important to gain a better understanding of how terrestrial habitat may change, what sorts of key questions and uncertainties surround these changes, and what are the data gaps. Additionally, gaining input on restoration design criteria and considerations related to habitat configuration in restoring terrestrial habitat in the corridors is also important to gain at this time so that it can be integrated into future planning and design at the corridor- and sub-corridor-level. Such meso- and micro-scale design consideration is important for future planning work, which would focus upon increasing the level of design for a single corridor or a combination of corridors based on the outcomes of this evaluation and the DRERIP evaluations for species and flood.

INSTRUCTIONS:

In the following tables, develop responses to the prompts. Support this work with process-based outcomes from Section 4 of the Corridor Documents, as appropriate. All input should be focused upon terrestrial habitat; however, note any instances where there is a potential interaction with aquatic species that is not being covered by the full DRERIP evaluations of those species. In completing the tables, consider that the charter for the South Delta Habitat Working Group specifies an assessment of several additional hypothetical considerations relative to the corridors. These considerations should be integrated into the evaluation of each corridor, in the tables below, in whichever category is appropriate. Not all may be applicable to terrestrial species; if not, mark as N/A.

1. How 55 inches of sea level rise (assumed to occur by the end of the century) influences flooding and ecological outcomes.
2. How the corridors will perform if several islands in the central and west Delta are permanently inundated in the future (note which islands may have a particular influence and/or are being assumed in the evaluation).

3. How the corridors may be consistent with a barrier at the head of Old River, or how it can achieve the same or better benefits without the barrier or with a barrier open more of the time than currently planned.
4. How the corridors might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants.

Also, assess the corridor to determine if its implementation would have the potential to change system dynamics (either within the Delta or as inputs to the Delta) beyond the existing range conditions (i.e. change in inflows to the Delta, modified hydrodynamic conditions, or salinity regimes) such that the current understanding of how the system works may no longer hold. Consider how the changes may affect the ability to evaluate the corridor using the recommended models methods in response #5.

Corridor 1A

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 1B

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

<u>Corridor 2A</u>

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

__Corridor 2B__

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 3

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 4

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

South Delta Flood and Habitat Planning

Modified DRERIP Evaluation Process for Evaluating Water Quality for Municipal, Industrial and Agricultural Uses

Changes in water quality in the assumed South Delta “corridor conditions” have an influence on aquatic species and human uses. The affects on aquatic species are covered by the DRERIP evaluations, with outcomes listed for each of the key species being evaluated. The evaluation of potential changes in water quality and how they may influence the use of water in the South Delta for municipal, industrial and agricultural uses[1] is covered by the modified-DRERIP evaluation process described below.

Evaluation of potential water quality changes that may occur in the assumed South Delta corridors is difficult because multi-dimensional hydrodynamic modeling dedicated to assessing water quality is not to be completed in this initial screening-level evaluation of the conceptual South Delta corridors. Further, there is no DRERIP conceptual model for M&I/Ag water quality. For these reasons, scoring outcomes for water quality are not possible in the formal DRERIP evaluation process. Perhaps more important at this stage of screening-level evaluation of the corridors is to gain a better understanding of: 1) key process-based changes, 2) potential issues, 3) outstanding questions and uncertainties, and 4) data gaps. Systematically developing a greater understanding of these items for each corridor will support development of appropriate technical investigations in any future planning work, which would focus upon a single corridor or a combination of corridors based on the outcomes of this evaluation and the DRERIP evaluations for species and flood.

INSTRUCTIONS:

In the following tables, develop responses to the prompts. Support this work with process-based outcomes from Section 4 of the Corridor Documents, as appropriate. All input should be focused upon M&I/Ag water quality; however, note any instances where there is a potential interaction with covered species. In completing the tables, consider that the charter for the South Delta Habitat Working Group specifies an assessment of several additional hypothetical considerations relative to the corridors. These considerations should be integrated into the evaluation of each corridor, in the tables below, in whichever category is appropriate. Not all may be applicable to water quality; if not, mark as N/A.

1. How 55 inches of sea level rise (assumed to occur by the end of the century) influences flooding and ecological outcomes.
2. How the corridors will perform if several islands in the central and west Delta are permanently inundated in the future (note which islands may have a particular influence and/or are being assumed in the evaluation).
3. How the corridors may be consistent with a barrier at the head of Old River, or how it can achieve the same or better benefits without the barrier or with a barrier open more of the time than currently planned.

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[1] Hereto, any reference to water quality in this evaluation worksheet is in relation to M&I and Agricultural uses unless otherwise noted.

4. How the corridors might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants.

Also, assess the corridor to determine if its implementation would have the potential to change system dynamics (either within the Delta or as inputs to the Delta) beyond the existing range conditions (i.e. change in inflows to the Delta, modified hydrodynamic conditions, or salinity regimes) such that the current understanding of how the system works may no longer hold. Consider how the changes may affect the ability to evaluate the corridor using the recommended models methods in response #5.

__Corridor 1A__

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Changes in system dynamics that alter current understanding of the system	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 1B

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Changes in system dynamics that alter current understanding of the system	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 2A

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Changes in system dynamics that alter current understanding of the system	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 2B

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Changes in system dynamics that alter current understanding of the system	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 3

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Changes in system dynamics that alter current understanding of the system	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the "additional considerations" listed in the instructions.

References:

Corridor 4

Evaluators Names:

Date:

1. Process-based Outcomes	State the outcome and provide rationale, including literature references cited.
2. Key Potential Issues	
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	
6. Changes in system dynamics that alter current understanding of the system	
7. Data Gaps	Note any data that the evaluators are aware is missing/unavailable.

NOTE: be sure to cover all four of the “additional considerations” listed in the instructions.

References:

EA.7.7 Modified-DRERIP, Flood, Terrestrial Species, and Water Quality Evaluation Worksheets, as developed in Evaluation Workshops

Corridor 1A - Modified-DRERIP Evaluation Summary

- Assumptions/Changes to Corridor Description made During Evaluation
  - Assume that restoration actions include levee setbacks, but no “active” restoration to enhance channel, floodplain, or riparian habitats or grading. However, fish stranding on the floodplain was assumed to be a “non-issue” because it can be minimized via restoration design.
  - The timeline for passive restoration to mature is late long term (30 – 50 years); this evaluation assumes late long term conditions.
  - Evaluations are based on the existing hydrology of the San Joaquin River and potential changes to hydrology associated with the San Joaquin River Restoration Program. It was acknowledged that the charter for the group also directs evaluators to consider changes to hydrology to improve ecological benefits. Specifically, the charter says the group “will consider how alternatives perform with San Joaquin restoration flows and future flows that result from Water Board orders or climate change.” These additional flow scenarios were not analyzed as part of this evaluation.
  - As part of the original DRERIP evaluations, outcomes and their scores were targeted for physical processes and/or attributes that occur throughout the corridor, and fish species of concern. Outcomes for terrestrial species are not included in the following evaluations.

- Summary of Key Outcomes Related to Objectives
  - *Objective: Increase the extent of ecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead*
    - Positive Outcomes
      - New floodplain areas available for inundation that would benefit splittail and salmonids
      - Additional food export from this Corridor into critical habitat areas (this would be minimal).
    - Negative Outcomes
      - Relatively-low risk of: floodplain stranding, increased mortality due to water quality degradation, mercury methylation, selenium, or resuspension of toxics.

  - *Objective: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes*
    - Positive Outcomes

            - There is a very high probability that channel complexity will increase and natural geomorphic processes will be restored with levee setbacks.
        - Negative Outcomes
            - Very low potential for invasive species colonization (SAV, Clams). Invasive riparian vegetation is a concern.

- Key Uncertainties
    - How future geomorphic response of a less-confined San Joaquin River may result in changes in sediment transport and potentially aggradation of the channel bed. This may modify the stage-discharge relationships for floodplain inundation more-generally. (Note, this would be a positive trend for inundated floodplain habitat).
    - The expected / predicted channel meander potential of the reach with levee setbacks.
    - The presence / absence of sturgeon in this corridor, and the potential for sturgeon habitat benefits / impacts.
    - How the San Joaquin River Restoration Program restoration flow regime and future flows that may be ordered by the SWRCB or result from climate change may influence key habitats and species outcomes and associated scoring. The river's hydrology drives habitat benefits coming from newly-connected floodplain areas.

- Data Gaps
    - Sediment transport data, modeling and sediment budgeting for the Lower San Joaquin River.
    - Sturgeon population / habitat data for this area.

- Potential corridor re-configurations or combinations to increase the worth /decrease the risk of potential implementation.
    - Some evaluators felt that the floodplain inundation frequencies / ecological conditions required to benefit target fish species could be refined. Additional sensitivity analysis will provide additional information on benefits.
    - Some evaluators felt that additional sensitivity analysis should be performed to: a) determine the potential benefits and impacts associated with altered flow regimes, and b) enhance ecological benefits by evaluating different configurations and widths of levee setbacks in this corridor.
    - Active riparian forest restoration will increase the certainty of ecological benefits, and this should be considered in refining this corridor.

Corridor 1A – Detailed Evaluation Notes

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Scientific Evaluation Worksheet & Notes
Corridor 1A

Evaluation Team:
Facilitator: Bruce DiGennaro
Participants: Josh Israel, Mike Hoover, Christine Joab, John Cain, John Clerici, Jeremy. Ron, Ted Sommer, Josh Israel, Michelle Orr, Will Stringfellow, Cathy Marcinkevage.
Note – taker: Kateri Harrison
Revisions: Jeremy Thomas, Eric Ginney

Workshop Date: Wednesday, February 1, 2012

Notes about Corridor 1A:

1) Take home message: San Joaquin River flow regime limits potential ecological benefits.
2) There are four ways to increase floodplain inundation: lower floodplain, change hydrology, raise the channel; block/backwater the channel at a downstream location
3) Sturgeon are not found in this location in significant numbers.
4) One suggestion is to maximize and accelerate benefits by using active restoration techniques such as horticultural riparian vegetation restoration.
5) With a levee corridor this wide, natural geomorphic processes (i.e., floodway expansion and contraction) can reverse channel incision and may lead to enhanced riffle stability---all things that would improve floodplain connectivity even given the existing flow regime.

Notes on revisions to the Corridor 1A Evaluation Worksheet:
Corridor 1A was the first corridor to be evaluated on February 1, 2012, the first of the two-day evaluation workshop. Subsequent to working through the evaluations for Corridor 1A, the group decided to refocus the approach and organize the structure of the evaluation to be consistent with the Problems and Objectives Statement as defined by the South Delta Working Group in the meeting on September 13, 2011. Therefore, the format of the outcomes and objectives originally used in the evaluation of Corridor 1A were changed and standardized for all of the corridors subsequently evaluated. The following evaluation notes were

revised to reflect the reorganization of the objectives and outcomes utilized in all of the other corridor evaluations. Because of this change, Corridor 1A did not have all of the same standardized outcomes available during this evaluation, and thus not all of the outcomes examined in the other corridor evaluations are available here.

OBJECTIVE: INCREASE THE EXTENT OF ECOLOGICALLY-RELEVANT FLOODPLAIN HABITAT TO SUPPORT REPRODUCTION AND VIABILITY OF SACRAMENTO SPLITTAIL AND CHINOOK SALMON & STEELHEAD

Potential Positive Ecological Outcomes

Outcome P1: Increased frequency of inundation

Scientific Justification:
Most of the salmon returning to California rivers display a 3 year life cycle. The inundation frequency assumed in the modeling of the corridors is once every four years---this seems too infrequent to some evaluators based on the common salmon life history. Under existing conditions, approximately 900 acres are flooded. With restoration as defined for Corridor 1A, inundation will increase to approximately 2,600 acres of inundation.

It is assumed that hydrology will not change as a result of BDCP implementation. This is an important thing to recognize in regard to the benefits of floodplain restoration as a part of BDCP: that if the flows are not there, the benefits do not accrue.

In the San Joaquin River, during the large inundation (i.e. wet) years, splittail abundance increases and this relates to outcome P2 below.

Key Understanding: San Joaquin River hydrology drives habitat benefits coming from newly-connected floodplain areas.

Magnitude:
Score is a Low "2", but with some disagreement about whether a 4-yr occurrence interval is an appropriate minimum threshold. BDCP should also integrate factors (i.e. compare to the inundation threshold in Yolo Bypass) to be consistent. Also, the 4-year inundation timeframe is a statistical average, the actual time between inundation events may be much more or less. Magnitude Score: **Low "2"**

Misc. Notes: If better hydrology were provided, the magnitude would increase. Evaluation team experts recommend inundation on an average of once every 2 years, optimally.

Certainty: Evaluation team is very certain that this magnitude will be low. There is a high level of uncertainty because it is not clear whether the once every four years inundation timeframe is representative. Although scientific understanding is high, this situation is dependent on a variable environment. Certainty Score: **Medium "3"**

Certainty of physical habitat on its own merits. **High "4"**, based on the increase in spatial area.

Magnitude for Splittail: There is redundancy with Outcome #P2. Splittail have a 5-7 year life cycle. **Medium "3".**

Certainty for Splittail: Same as Outcome #P2. **Score is Medium"3".**

Notes: Not applicable to sturgeon or smelt

Literature Cited:

- DRERIP Salmonid conceptual models (for salmon life cycle of 3 years).
- Cosumnes River and Yolo Bypass work on inundated floodplains.
- 2009 DRERIP evaluation worksheets have relevant literature citations.

Outcome P2: Increased Spawning Habitat for Splittail and White Sturgeon

Clarifying Assumptions:
Assuming a 21-day inundation period between Feb 1 and May 31 (source: Section 7 Table 3).

Magnitude for Splittail: Splittail have a seven year life-cycle and they spawn every year. Corridor 1A provides a lot of acreage for restoration. Existing inundated floodplain for splittail within existing levees is 412 acres. Assuming the existing flow continues, the restored habitat would be 1,023 acres with another 400 extra acres with the San Joaquin restoration flow regime. See Table 4.12 for Corridor 1A on page 102 in the corridor document. Magnitude is **Medium, Score: "3".**

If the hydrology were to change, then a larger area would be inundated with more frequency of inundation and this would then change the magnitude. In past discussions, Dr. Peter Moyle indicated that an inundation occurrence every 2 years would be satisfactory for native fish.

Certainty for Splittail: The magnitude score is based on peer reviewed studies in the Delta system. However, flooding is unpredictable. There is variability in the human-controlled hydrology of the San Joaquin River. If flows were managed to allow more inundation, then this certainty score would increase. There is a close relationship between floodplain inundation and splittail. **Score is Medium"3".**

Green Sturgeon: No spawning in the San Joaquin River. Historical evidence and current monitoring does not find green sturgeon on the San Joaquin River. Not present.

Magnitude for White Sturgeon: White Sturgeon spawn in the Tuolumne River. Would white sturgeon spawn if their habitat were provided? Scientists do not have enough information about white sturgeon spawning habitat. Some studies indicate spawning habitat needs to be "in-channel" and have a sandy bottom (not floodplain). White sturgeon were spotted spawning on the San Joaquin River last year. White sturgeon likely use flow as the main characteristic of their spawning habitat. However, there is no indication that flows on San Joaquin River will change as a result of BDCP. Corridor 1A has a more naturalized channel bed, compared to other corridors. Magnitude is **Low "2".**

Certainty for White Sturgeon: Certainty is **Low "2".**

Literature Cited:

Sommer, Baxter, and Herbold 2000 "Resiliency of splittail" paper

Outcome P5: Increased Food Export

Notes about Food Production:

Food production is listed a positive outcome. An increase in primary production would yield many benefits for fish species. How much food resources might drift downstream and benefit species in the Delta? See draft corridor document Table 4.1.3a, Figure 4.1.2a, and page 105. When you increase the amount and frequency of floodplain inundation, is that significant for downstream food export? It depends on the size of the floodplain. See HEC-EFM floodplain inundation modeling and assumptions in Section 7.3. The duration of inundation is Dec 1 to May 31, between 2 to 20 days (see Tables 3 and 4 in Section 7.3). Every 4 years at least 30% of the floodplain is inundated.

The San Joaquin River flow regime will not be different as a result of BDCP implementation. Higher flows will not occur with any increase in frequency. Floodplain inundation is only one mechanism by which you get food production. However, the improvements in ecosystem level nutrient production (i.e. food production) are limited for this floodplain creation because of the lack of changes in the San Joaquin River's hydrology.

The restoration description prescribes 16 river miles of soft banks with trees. This will yield an increase in riparian-based food production. We anticipate that riparian vegetation (assuming passive restoration) will be young fringe trees. At the San Joaquin River wildlife refuge, very rapid riparian growth has occurred. For some ecosystem functions, it is not about big wood, it is about development of a canopy (i.e., for leaf and insect drop).

There is a risk that invasive plants will move into the restoration area. Studies along the Sacramento River show that prior to Shasta Dam (i.e., under normal hydrology) a flow event that drives riparian vegetation recruitment occurs on average every 5 years . However, for the San Joaquin River, the present conditions for riparian recruitment are not good. Using passive restoration techniques and assuming inundation every 4 years, there would not be sufficient re-vegetation. It is recommended that more areas with active riparian revegetation occur as part of the levee setback process.

Clarifying Assumptions:

- Assume passive restoration along the channel margin where levees are removed.
- There is a risk of low riparian plant recruitment, unless there is active intervention to increase inundation.

Note that no one has mapped existing conditions channel margin habitat.

The Delta is a big filter with complex habitats. Nutrients are continually processed during a range of flows. Although there might be a periodic flush of nutrients into the Delta, overall this will not make a significant difference. There is a concern that tidal marsh creation would cause eutrophication. The classic location for eutrophication and low dissolved oxygen is near Stockton.

Evaluators considered whether the corridor improvements would lead to a greater export of more nutrients or algae. In the past when the floodplains are inundated (during high flows), then dilution occurs and the intakes would not divert water.

Studies by the CA Water Board suggest riparian leaf litter creates microbial activity that reduces the nutrients sent downstream. If the levees are set back and trees grow into large woody debris, then this changes habitat along miles of river. But even so, it is not expected that this would substantially alter nutrient export.

Scientific Justification:

Overall Magnitude: very low, score is **Minimal "1".**

Overall Certainty: certainty score is **High"4".**

Magnitude for salmonid food: Assumes passive restoration. Control strategies for Himalayan blackberries and other non-natives, etc needed. See notes above. **Low "2".** With active re-vegetation, the magnitude score would increase.

Certainty for salmonid food: The processes are understood, however this is a highly variable ecosystem, **Medium "3".**

Potential Negative Ecological Outcome(s)

Outcome N2: Increased Mortality Due to Water Quality Degradation (Including Water Temperature, DO, Eutrophication)

General Notes: Soil constituents are not known. Water from natural floodplain and agricultural areas will drain into the river.

Magnitude: The action might benefit water quality given the cold high flows and riparian / floodplain shading. Dam releases in May and June could inundate the floodplain and some evaluators had concerns regarding temperature. However, overall, summer releases will be infrequent. Score: **Low "2".**

Certainty: The length of time inundation will occur on the floodplain is not certain and may be dependent upon the timing of dam releases. Although not a large problem, it is not certain. **Low certainty "2".**

Magnitude for dissolved oxygen (DO): Low "1".

Certainty for dissolved oxygen (DO): High "4".
(NOTE: the "risk" for the DO score is much lower than the overall scoring, so the 'more conservative" score of 2/2 was retained in the spreadsheet).

Outcome N4: Increased Exposure to Selenium

Magnitude: Low "2". This restoration will increase phytoplankton production that contains higher levels of selenium and gets carried up the food chain. Heavy selenium loading from San Joaquin watershed will be available to clams. Sturgeon eat clams and via the food chain may bioaccumulate selenium. However, overall effect on native fish species is **Low "2"**

Certainty: Low "2"

Outcome N5: Increased Mercury Methylation

Clarifying Assumptions:
Effects of mercury on terrestrial species, birds, and humans were not discussed during the workshop.

Magnitude: For fish, the effect is minimal because fish are relatively low on the food chain. **Minimal "1"**

Certainty: Medium "3"

Rationale is the same as 2009 DRERIP analysis.

Outcome N6: Increased Mobilization or Re-suspension of Toxics (including pesticides)

Magnitude: If riparian vegetation is established, it could make previously existing toxics bioavailable. If pesticides/herbicides are used in the corridor on non-native vegetation this could be a concern; although they break down fairly quickly. RWQCB does have 303d listings for agricultural areas in the San Joaquin areas. **Low "2"**

Certainty: If there are agricultural easements and agricultural chemicals are being used on the land, this adds to the uncertainty. There is also a data gap because we do not know what toxics exist on the soil. **Low "2"**

OBJECTIVE: RESTORE HABITATS AND RIVER CONDITIONS (I.E., THE MAGNITUDE AND DIRECTION OF FLOW IN FLUVIAL REGIMES) THAT FAVOR SURVIVAL AND GROWTH OF JUVENILE SALMONIDS, STURGEON, DELTA SMELT, LONGFIN SMELT, AND OTHER NATIVE FISHES

Potential Positive Ecological Outcomes

Outcome P16: Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)

Clarifying Assumptions:
The evaluation team made the following assumptions:

- No grading of the floodplain or in-channel work. The project includes removal of the levee and passive vegetation restoration.
- The timeline for passive restoration to mature is late long term (30 – 50 years); assume evaluation is for the late long term.
- Once levees are removed, natural geomorphic sediment depositional and erosional processes will occur.
- Within 20 years, some vegetation and trees would be established along the channel corridor.
- When the bank becomes more naturalized, channel complexity will increase.

General Notes on Channel Complexity:
If we restore the physical configuration of this corridor with no change in hydrology, then the biological benefits will not be as large as if a change in hydrology were also made (as discussed in Outcome 1A). The proposed restoration may increase channel complexity. There are intrinsic benefits such as micro-scale effects and the creation of more natural interfaces.

Flow is one of many variables. Pushing out the banks or raising the channel invert would allow woody vegetation establishment. If the channel invert were raised, this would increase the frequency of inundation.

Concern that since BDCP alternative #1A is late-long term, the timeframe for realizing ecological / biological benefits would be very long from now. Upstream hydrology may change due to climate change, such that the peak discharges occur earlier in the year. Under climate change, there may be different timing for inundation and this timing may not synchronize with species life cycle. Additional modeling of these assumptions is recommended.

Two ways channel complexity can help salmon: 1) high flows spread out across floodplain, lower velocities, fish less likely to get washed downstream; 2) flows create a complex channel that creates beneficial fish habitat. Fish will use these channels even during lower flows. Ability of downstream migrating smolts to hide from predators was considered. The Vernalis Adaptive Management Plan (VAMP) shows high predation rates near the Stockton wastewater treatment plan. Complex habitat provides hiding spots for native fish. If the habitat is restored, then more sediment will be generated/ mobilized and this will provide additional hiding opportunities for salmonid juveniles.

This outcome also includes the potential beneficial impacts of suspended sediment and turbidity on channel complexity and habitat conditions for affected fish species. Sediment transport generates turbidity, creates complex habitats, and is beneficial for native fish species. This outcome is vague because it intends to create all these benefits. Even with dams, the San Joaquin River has enough energy and enough sediment supply to provide some of these benefits. Ideally, the sediment would move into the Delta to benefit habitats there. Flows in a 4 year event may be over 15,000 cfs. Evaluators wondered: How much can you generate within this reach from those types of flow events? Would this benefit native fish species? Flow is not normally distributed, due to climate and human management of reservoirs etc. A metric could be the average number of days with suspended sediments during a 2-week period. It is anticipated that we would not see a big change in sediment conditions as a result of implementation. An evaluator postulated that if flows are high enough to move sediment downstream over a series of many years, then the beneficial downstream effects could be significant.

Scientific Justification:
River is still eroding activity and there is interface with vegetation. This interface will be beneficial. In a situation that is completely channelized then improvement would be significant.

Overall Magnitude: This outcome pertains to physical habitat conditions. Score is **High "4".**

Note: The Evaluation team has not evaluated outcomes here for splittail, salmon, steelhead, white sturgeon. It likely does not apply to smelt or green sturgeon. For salmon, there is a medium benefit arising from increased complexity of habitat.

Overall Certainty: Not scored by the group (assumed Medium "3" based on sediment processes only and that those processes are a key driver in this outcome).

Magnitude for sediment processes only: This is a physical process outcome. Biological resources are not rated here. The corridor is about 16 miles along both banks (i.e. 32 linear miles). Some of the sediment will be eroded and deposited within the reach. Over time, more riparian habitat will develop. **Medium "3"**

Certainty for sediment processes only: Understanding of the process is high; however, there is considerable uncertainty about the sediment budget and where the sediment will go. The nature of outcome is dependent on variable ecosystem process, such as hydrology. Scientists do understand the physical processes so based on theory alone, the certainty would be high. However, there is natural and human variability associated with the sediment dynamics and hydrology. **Medium "3"**

(NOTE: only the overall score was retained in the spreadsheet; sediment processes not broken out).

Literature Cited:

- DRERIP sediment model

Potential Negative Ecological Outcome(s)

Outcome N12: Establishment of Invasive Species (SAV, Clams, invasive competitors)

Scientific Justification:
Corbicula is moderately common in the San Joaquin River. Restoration activities will result in the digging up and moving of *Corbicula* more frequently. Are we creating a new template upon which the invasives will establish? Threadfin shad likes deep channels but we are not creating deep channels here, so this is more applicable to other corridors.

Magnitude: Minimal "1"

Certainty: **Medium "3"**

DATA GAPS & KEY UNCERTAINTIES

Data Needs:

- A better understanding of sediment transport dynamics and sediment budgets for each corridor for the range of flow conditions is necessary.
- Assess the meander potential of the reach based on current channel configuration, geology, and soils. Corridor 1A has high potential for channel migration.
- Determine the presence/absence of sturgeon. Studies last year found evidence of white sturgeon spawning in the lower San Joaquin River. We need to know what kind of habitat sturgeon spawn on. From a population perspective, perhaps high velocity habitats limit sturgeon spawning. High velocity in this case means 25,000 cfs (i.e. wet years). The Bay Study has done carrying capacity studies. There are spawning adults; however flows are not large enough for those adults to produce eggs that survive. VAMP flows are either low or high. Are intermediate flow years sufficient? Perhaps to get adults to spawn, but not enough for eggs to survive. For example, in the Columbia River, during intermediate years, predators eat the young sturgeon. It is hypothesized that sturgeon need good nursery habitat to avoid predators and this type of habitat is not presently found in Corridor 1A. Changes in channel morphology associated with the levee setbacks will produce variations in velocities through the channel. This may result in increased sediment deposition, increasing stage through the reach for a given discharge.
- Sediment deposition may also create some areas where velocities increase and that could benefit sturgeon. Sturgeon are long-lived fish. If there is a really wet year, 70,000 eggs could be spawned with a 5% survival ratio.
- Even with dams, the San Joaquin River has enough energy and enough sediment supply to provide some ecosystem benefits. How much turbidity can be generated within Corridor 1A from those types of flow events? Would this benefit native fish species (in the corridor and downstream)? A suggested metric could be the average number of days with suspended sediments during a 2-week period. It is anticipated that we would not see a big change in sediment conditions as a result of implementation. An evaluator postulated that if flows are high enough to move sediment downstream over a series of many years, then the beneficial downstream effects could be significant.

FOR FUTURE SOUTH DELTA PLANNING

Important New Ideas or Understandings:

- One way to improve hydrology would be to consider operational issues on the San Joaquin River. Ecological benefits relate to flow timing, magnitude, frequency, and durations.
- The charter for the South Delta Workgroup directs evaluators to consider changes to hydrology to improve ecological benefits. Specifically, the charter says the group "will consider how alternatives perform with San Joaquin restoration flows and future flows that result from Water Board orders or climate change." These additional aspects should be considered as South Delta planning continues.
- Communication between ecologists and DWR engineers is a key aspect of successful water planning in this region.
- American Rivers is leading a study on the lower San Joaquin River to quantify the potential benefits for flood management, water supply and ecosystem improvements in this portion of the Delta from expanded floodplains and bypasses.
- Sensitivity analysis with different hydrologic regimes would be interesting and illustrative of potential future benefits if flow regimes were to be altered.

Scoring Summary
Corridor 1A

Species Name	SCORING			
	WORTH		RISK	
Corridor Score (Habitat; Physical Process)	Med	2.3	Med	2.0
Salmonids	High	2.5	--	--
Splittail	High	3.0	--	--
Green sturgeon	--	--	--	--
White surgeon	High	2.5	--	--
Delta smelt	--	--	--	--
Longfin smelt	--	--	--	--
	High	**2.6**	Med	**2.0**

Scoring Key

WORTH	High	(green circle)
	Medium	(yellow circle)
	Low	(red circle)
RISK	Low	(green circle)
	Medium	(yellow triangle)
	High	(red diamond)

Scoring Weights

Value between..	..and	Rank
1	1.5	Low
1.5	2.5	Med
2.5	3	High

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		CORRIDOR SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
P1	Increased Frequency of Inundation	2	3	Med	2		
P5	Increased Food Export	1	4	Med	2		
N2	Increased Mortality Due to Water Quality Degradation (including water temperature, DO, eutrophication)	2	2			Med	2
N4	Increased Exposure to Selenium	2	2			Med	2
N5	Increased Mercury Methylation	1	3			Low	1
N6	Increased Mobilization or Re-suspension of Toxics (including pesticides)	2	2			Med	2
OBJECTIVE: Increase the extent and connectivity of tidal marsh.							
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.		3	3				
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	4	3	High	3		
N12	Establishment of Invasive Species (SAV, Clams, invasive competitors) (need to separate clams, competition, and SAV)	1	3			Low	1

WORTH		RISK	
Med	2.3	Med	2.0

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		SALMONID SCORING		WORTH		RISK	
Standard Outcome Code	Outcome (brief descriptor)	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
P5	Increased Food Export	2	3	Med	2		
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	4	3	High	3		

WORTH			RISK		
High	●	2.5	#N/A	●	0.0

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		SPLITTAIL SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
P2	Increased Spawning Habitat for Splittial	3	3	High	3		
OBJECTIVE: Increase the extent and connectivity of tidal marsh.							
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	4	3	High	3		
				SCORING with SLR			
				WORTH		**RISK**	
				High	**3.0**	#N/A	**0.0**

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		WHITE STURGEON SCORING		WORTH		RISK	
Standard Outcome Code	Outcome (brief descriptor)	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
P2	Increased Spawning Habitat for WHITE STURGEON	2	2	Med	2		
OBJECTIVE: Increase the extent and connectivity of tidal marsh.							
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	4	3	High	3		

SCORING with SLR					
WORTH			RISK		
High	●	2.5	#N/A	●	0.0

Corridor 2A – Modified-DRERIP Evaluation Summary

- <u>Assumptions/Changes to Corridor Description made During Evaluation</u>
  - The Evaluation Team agreed to evaluate Corridor 2A assuming an Isolated Old River Corridor (IROC) to decrease uncertainty related to the lack of available information.
  - Passive riparian restoration is assumed, which lowers certainty on benefits coming from riparian.
  - The timeline for passive restoration to mature is late long term (30 – 50 years); this evaluation assumes late long term conditions.
  - Fish stranding on the floodplain was assumed to be a “non-issue” because it can be minimized via restoration design.
  - The group decided not to evaluate the entrainment/export issue because the uncertainty is very high (i.e. there is no certainty at all; lack of data). The group considered coming back to re-visit the entrainment issue later, but never did, feeling it more important to move on to other corridors.

- <u>Summary of Key Outcomes Related to Objectives</u>
  - *Objective: Increase the extent of ecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead*
    - Positive Outcomes
      - New floodplain areas available for inundation that would benefit splittail and salmonids
      - Lower Paradise Cut weir could increase export of juveniles and food to other parts of the South Delta
    - Negative Outcomes
      - Relatively-low risk of: floodplain stranding, increased mortality due to water quality degradation or mercury methylation; more uncertainty with microcystis and selenium

  - *Objective: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes*
    - Positive Outcomes
      - Channel complexity will increase with wider bypass
    - Negative Outcomes
      - Potential for additional invasive species colonization in downstream end of expanded Paradise Cut bypass.

- Key Uncertainties
  - The hydrodynamics (spatially, and temporally [within each water year and by water year type]) of the flow split from the San Joaquin River to a lowered Paradise Cut weir. This split influences the distribution of food and outmigrating fishes.
  - How the San Joaquin River Restoration Program restoration flow regime and future flows that may be ordered by the SWRCB or result from climate change may influence key habitats and species outcomes and associated scoring.
  - How future geomorphic response of a less-confined San Joaquin River may result in aggradation of the channel bed and thus modify the stage-discharge relationships at the weir and for floodplain inundation more-generally. (Note, this would be a positive trend for inundated floodplain habitat).

- Data Gaps
  - Multi-dimensional hydrodynamic modeling (as related to entrainment and water quality) is of particular interest as it is a key driver in many of the important processes and outcomes considered.
  - Details regarding the configuration of the weir, the Old River Corridor (i.e. the presence or absence of an IROC) need to be further refined (including sensitivity analysis) to enable additional evaluation of this corridor, especially as it relates to other corridors.
  - Additional information/research on site-specific marsh habitat design options that can improve water quality conditions/mitigate potential adverse conditions that might be generated by creation of tidal marsh habitats in the South Delta. (See also the separate M&I and Agriculture WQ Evaluations in June, 2012)

- Potential corridor re-configurations or combinations to increase the worth /decrease the risk of potential implementation.
  - Salmon and splittail could potentially end up in Fabian Tract (after being routed through a lowered Paradise Cut weir) which would have marsh habitat. The combination of Corridors 2A and 2B should be considered as a coupled pair if in the future this corridor shows promise.
  - If in future South Delta Planning this corridor appears a promising option, it will be important to evaluate Corridor 2A with and without an IROC.
  - Some evaluators felt that the December date in the assumed ecologically-relevant hydrology for salmonids (Dec. 1 – May 31) is too broad. Additional sensitivity analysis will provide additional information on benefits.
  - Active riparian forest restoration will increase the certainty of ecological benefits, and this should be considered in refining this corridor.

Corridor 2A– Detailed Evaluation Notes

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Scientific Evaluation Worksheet & Notes
Corridor 2A

Evaluation Team:
Facilitator: Bruce DiGennaro
Participants: Eric Ginney, Coach; Jeremy Thomas, Ray McDowell, John Cain, Steve Cimperman, Sheng Jun Wu, Christine Joab, Deanna Sereno, Mike Hoover, Michelle Orr, Andrea Thorpe, Cathy Marcinkevage, Ted Sommer, Val Connor, Josh Israel, Ray McDowell, John Cain
Note-taker: Kateri Harrison

Date: Thursday, February 2, 2012

Corridor Scale: Large

Introductory notes:

- Evaluators asked if this Bypass significantly different from DWR's Central Valley Flood Protection Plan? Answer: DWR's Central Valley Flood Protection Plan contains placeholder maps; however, it does not contain any specific modeling. The CVFPP did not make specific assumptions, and did not make any specific proposals for an assumed expansion of the Paradise Cut weir. The specific assumptions in the Corridor Document, upon which the modeling of the corridors is based, are an amalgamation of previous proposals and modeling efforts from the River Islands' bypass expansion proposal and other modeling. Corridor 2A is an initial placeholder configuration that is not a final configuration—simply something to test the outcomes of an expanded weir/bypass. If a project evolves that might include Paradise Cut, additional refinement and alternatives development would be required.

- Corridor 2A includes the following:
    - The assumed changes to the Paradise Cut weir result in the San Joaquin River beginning to overtop at 6,040 cfs (assuming Model Run F conditions, no SLR; see Section 7.3). In comparison, the existing Paradise Cut weir is modeled (using a MHW downstream boundary condition, without SLR), to begin to overtop at 12,957 cfs. Flow

stays in channel until ~10,000 cfs (i.e., floodplain inundation in Paradise Cut begins when river discharge is above 10,000 cfs).

- The group noted that to make Fabian Tract (Corridor 2B) most effective, consider routing more flow through Old River rather than Grant Line Canal. Old River doesn't get much flow under existing conditions, most flow goes through Grant Line. Terrestrial species of interest such as brush rabbit, swainson hawk, waterfowl and general migratory birds were not covered in today's evaluation but can be considered later.

OBJECTIVE: INCREASE THE EXTENT OF ECOLOGICALLY-RELEVANT FLOODPLAIN HABITAT TO SUPPORT REPRODUCTION AND VIABILITY OF SACRAMENTO SPLITTAIL AND CHINOOK SALMON & STEELHEAD.

Potential Positive Ecological Outcomes

Outcome P1: Increased Frequency of Inundation

Scientific Justification:
The restoration seems to create a reliable floodplain inundation. Inundation of this magnitude (for salmonids: 777 acres compared to 46 acres for existing conditions) happens every 4 years, for at least 14 days, sometime between December 1 and May 31 and is a sustained, but minor effect. Lower magnitude levels of inundation occur more frequently or for a longer duration.

Magnitude: Medium "3".

Certainty: The team felt certain that these flows would happen infrequently—but were also reminded that the outcome is based on real data and historical operations. Thus, while the magnitude of the acres is low, and the frequency is only every 4 years, there is some statistical certainty of that occurring. Overall, the group agreed that the San Joaquin River's flows are highly-altered, and that benefits will only manifest during times with high variability and flooding; this is unpredictable. The flows are beyond the control of BDCP and are reliant on meteorology and the river's hydrology. Understanding is high but outcome is dependent of highly variable process. It is hard to predict when the flood flows will occur. **Medium "3".**

Outcome P2: Increase Spatial Extent of Spawning Habitat for Splittail

Clarifying Assumptions:
The Evaluation Team discussed how/whether Old River would be isolated from pumps. *It was agreed to evaluate assuming an Isolated Old River Corridor (IROC) to decrease uncertainty in available information.* However, it will be important to evaluate this corridor in the future without an IROC if the corridor appears promising.

Scientific Justification:
Splittail need a minimum duration of flooding for 21-days. Page 10 of Section 7 document states 11,600 cfs is the ecologically significant flow w/out SJRRP needed to achieve this. Under existing conditions 11 acres would be flooded. Post-restoration corridor condition is modeled to be 445 acres. So, 400+ acres will be flooded every 4 years. Essentially doubling splittail spawning acreage from 413 ac (Corridors 1a and 2) to add 445 in corridor 2A. This flooding will occur from Feb to May. However, the temperature during this timeframe will obviously be variable.

Magnitude for splittail: Currently, very little floodplain gets wet (11 acres). This proposed 2A will be a significant improvement. **Medium "3".**

Certainty for splittail: Group discussed how much or whether BDCP can control the hydrology. The timing, frequency and duration of the assumed hydrology used by the consultants to identify the inundated area for splittail is based on peer reviewed studies in the Delta system. However, flooding is unpredictable. There is variability in the human-controlled hydrology of the San Joaquin River. If flows were managed to allow more inundation, then this certainty score would increase. There is a close relationship between floodplain inundation and splittail. **Medium "3".**

Outcome P3: Increased Rearing Habitat for Salmon

Note: Some evaluators felt that the December date in the assumed ecologically-relevant hydrology for salmonids (Dec. 1 – May 31) is too broad. There is some variation in the timing for juvenile (spring-run) out-migration; however, it may be a mistake to say that inundation in December would necessarily benefit salmon. In the future, sensitivity analyses would be informative. The consultant team noted they were more "inclusive" than "exclusive" in terms of the time period examined for the ecologically-relevant flows.

There is a 20-fold increase, from 46 acres to 845 acres; however, this occurs only once every 4 years. In comparison, corridor 1A's reach improves 910 acres. Corridor 2A will double the amount of physical habitat, in combination with corridor 1A. Frequency of inundation drives the score. Salmon cohorts have a 3-year life cycle; however, inundation occurs only once every 4 years, and other frequencies should be examined in the future if this corridor shows promise.
Notes, salmon could potentially end up in Fabian Tract which could have marsh. The combo of 2A and 2B should be considered as a coupled pair if in the future this corridor shows promise.

Magnitude: Score is a "2", but with some disagreement about whether a 4-yr occurrence interval is an appropriate minimum threshold. BDCP should also integrate factors as compared to the Yolo Bypass, to be consistent. What is the threshold in Yolo? **Low "2"**

Certainty: The Evaluation Team is very certain that this magnitude will be low. There is a high level of uncertainty because it is not known how representative this once every four years inundation is. The EMF model could be re-run to sort this out. Unnaturally reduced flows on the San Joaquin are a problem. Scientific understanding is high; however this situation is dependent on a variable environment. **Medium "3".**

Outcome P4: Increased Local Aquatic Primary and Secondary Production

Scientific Justification:
Notes about Food Production - Food production is listed a positive outcome. An increase in primary production would yield many benefits for fish species. How much food resources might drift downstream and benefit species in the Delta? See draft corridor document Table 4.1.3a, Figure 4.1.2a, and page 105. When you increase the amount and frequency of floodplain inundation, is that significant for downstream food export? It depends on the size of the floodplain. See HEC-EFM floodplain inundation modeling and assumptions in Section 7.3. The duration of inundation is Dec 1 to May 31, between 2 to 20 days (see Tables 3 and 4 in Section 7.3). Every 4 years at least 30% of the floodplain is inundated.

The San Joaquin River flow regime will not be different as a result of BDCP implementation. Higher flows will not occur with any increase in frequency. Floodplain inundation is only one mechanism by which you get food production. However, the improvements in ecosystem level nutrient production (i.e. food production) are limited for this floodplain creation because of the lack of changes in the San Joaquin River's hydrology.

The restoration description prescribes 16 river miles of soft banks with trees. This will yield an increase in riparian-based food production. We anticipate that riparian vegetation (assuming passive restoration) will be young fringe trees. At the San Joaquin River wildlife refuge, very rapid riparian growth has occurred. For some ecosystem functions, it is not about big wood, it is about development of a canopy (i.e., for leaf and insect drop).
There is a risk that invasive plants will move into the restoration area. Studies along the Sacramento River show that prior to Shasta Dam (i.e., under normal hydrology) a flow event that drives riparian vegetation recruitment occurs on average every 5 years . However, for the San Joaquin River, the present conditions for riparian recruitment are not good. Using passive restoration techniques and assuming inundation every 4 years, there would not be sufficient re-vegetation. It is recommended that more areas with active riparian revegetation occur as part of the levee setback process.

Magnitude: Assumes passive restoration. Control strategies for Himalayan blackberries and other non-natives, are needed.
Low "2"

Certainty: The processes are understood, however there is a highly variable ecosystem, **medium "3"**

Outcome P5: Increased Food Export

Clarifying Assumptions:
The weir will be lower, so there is a higher likelihood that food will be pushed downstream through this corridor. However, the export would go down Grant Line and into an isolated Old River corridor (i.e. if in this evaluation Fabian Tract is not assumed). There is a concern that any food production would be exported to the pumping facilities if an IROC is not assumed. However, dual conveyance is assumed, so in some operation scenarios this might be a lesser concern (i.e., in the wet years, there would not be a lot of south Delta pumping during December to May).

Several evaluators recommended modeling of OMR flows with an IROC. However modeling is not currently available to assess this. Also, general entrainment modeling is not currently available. Modeling would need to consider operations year-by-year etc. Modeling should consider with and without the barrier. This type of modeling is recommended in order to thoughtfully analyze these issues.

During wet years, not much pumping will occur in the south Delta facilities. However, foodweb productivity in normal or dry years might be a concern (export of primary productivity via the pumps during dry years). The entrainment issue is speculative. South Delta pumping (i.e. level of diversions) is directly related to the pumping allowed from the north Delta.

The group decided not to evaluate the entrainment/export issue because the uncertainty is very high (i.e. there is no certainty; lack of data). The group considered coming back to re-visit this outcome later, but never did, feeling it more important to move on to other corridors.

Potential Negative Ecological Outcomes

Outcome N1: Increased Stranding on the floodplain

Clarifying Assumptions:

Stranding on the floodplain can be minimized via design. The evaluation team assumed the aquatic habitats, including the floodplain and marsh would be designed such that the site functions and operates in a manner that avoids stranding. Designers should allow for mostly complete drainage behind the Paradise Cut weir. Although it is recognized that microhabitats such as pools will develop and this might create minimal stranding. This type of minimal fish stranding due to microhabitat is acceptable. Designers should think about areas upstream and downstream. Also, designers should review the SFEI historical ecology materials

Assumption: the potential for stranding will be designed out of this floodplain.

Scientific Justification:

Magnitude: Conceptually stranding is an issue **Low "2".** There is project level mitigation (good design) that needs to happen.

Certainty: High "4".

Outcome N2: Increased Mortality Due to Water Quality Degradation (including water temperature, DO, eutrophication)

General Notes: The downstream area is tidally influenced so might have longer residence time. Between 6,000 to 10,000 cfs water is simply flushing thru the system. Above 10,000 cfs the water is held on the floodplain. There was a lot of speculation about these processes by the evaluators and the consensus was that more modeling is needed.

RWQCB has water bodies on 303d list of impaired water bodies. Also, the soil constituents (residue pesticides) on the restoration site are not currently known.

Above 10,000 cfs temperature might be better or worse, depending on residence time etc. However in corridor 2B, residence time will increase and so water temperatures might be a concern under that other alternative. Floodplain dynamics are not well defined here.

Scientific Justification:

Magnitude for general water quality: The action might benefit water quality given the cold high flows and riparian / floodplain shading. Dam releases in May and June could inundate the floodplain and some evaluators had concerns regarding temperature. However, overall, summer releases will be infrequent. **Low "2"**

Certainty general water quality: The length of time inundation will occur on the floodplain is not certain and may be dependent upon the timing of dam releases. Although not a large problem, it is not certain. **Low "2"**

Outcome N3: Increased Microcystis

Scientific Justification:

Magnitude: The spatial extent is minimal (a few hundreds of acres). **Low "2".**

Certainty: Very little information is available on the dynamics of this floodplain. **Low "2".**

Outcome N4: Increased Exposure to Selenium

Scientific Justification:

Magnitude: Low "2". This restoration will increase phytoplankton production that contains higher levels of selenium and gets carried up the food chain. Heavy selenium loading from San Joaquin watershed will be available to clams. Sturgeon eat clams and via the food chain may bioaccumulate selenium. However, overall effect on native fish species is **Low "2"**

Certainty: Low "2"

Outcome N5: Increased Mercury Methylation

Clarifying Assumptions:
Effects of mercury on terrestrial species, birds, and humans were not discussed during the workshop.

Magnitude: For fish, the effect is minimal because fish are relatively low on the food chain. **Minimal "1"**

Certainty: Medium "3"

Rationale is the same as 2009 DRERIP analysis.

OBJECTIVE: RESTORE HABITATS AND RIVER CONDITIONS (I.E., THE MAGNITUDE AND DIRECTION OF FLOW IN FLUVIAL REGIMES) THAT FAVOR SURVIVAL AND GROWTH OF JUVENILE SALMONIDS, STURGEON, DELTA SMELT, LONGFIN SMELT, AND OTHER NATIVE FISHES

Potential Positive Ecological Outcomes

Outcome P16: Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)

Clarifying Assumptions:
The evaluation team made the following assumptions:

- No grading of the floodplain (except to mitigate for potential fish stranding) or in-channel work. The project includes removal of the levee and passive vegetation restoration.
- The timeline for passive restoration to mature is late long term (30 – 50 years); assume evaluation is for the late long term.
- Once levees are removed, natural geomorphic sediment depositional and erosional processes will occur.
- Within 20 years, some vegetation and trees would be established along the channel corridor.
- When the bank becomes more naturalized, channel complexity will increase.

Magnitude: High "4". **Certainty: Medium "3".**

Potential Negative Ecological Outcomes

Outcome N12: Establishment of Invasive Species (SAV, Clams, invasive competitors)
General Notes: This site waters from the back end, up the channel in direction of Fabian Tract. So, the bottom half of Paradise Cut would be wet and top half dry. It will be dry for 3 out of 4 years. When wet it will be from flooding.
Magnitude for SAV: Minimal "1" **Certainty SAV: High "4"** **Magnitude for Clams:** the bottom half has tidal influence and perennially wet. However, this restoration will not change this situation. Corbicula dies off due to contaminants. If high flows dilute the contamination, the clams may increase in population abundance. San Joaquin River currently has stretches that are clam-free due to contamination. Scoring this is too speculative. Not rated.

Data Gaps & Key Uncertainties

Data Needs *(indicate specific models, DLO relationships, or other information indicating the need):* • Entrainment and water quality (as related to multi-dimensional hydrodynamics) are of particular interest as they are a key

driver in many of the important processes and outcomes considered.

- Details regarding the configuration of the weir, the Old River Corridor (ie the presence or absence of an IROC).

Key Uncertainties and Research Needs *(describe specific research activities that could be employed to increase understanding):*

- Additional information/research on site-specific habitat design considerations that can improve water quality conditions/mitigate potential adverse conditions, generated by creation of tidal marsh habitats in the altered hydrologic conditions of the South Delta. (See also the separate M&I and Agriculture WQ Evaluations in June, 2012)
- Notes, salmon could potentially end up in Fabian Tract which could have marsh. The combo of 2A and 2B should be considered as a coupled pair if in the future this corridor shows promise.

Scoring Summary

Corridor 2A

Species Name	SCORING			
	WORTH		RISK	
Corridor Score (Habitat; Physical Process)	High	2.7	Med	2.0
Salmonids	Med	2.0	--	--
Splittail	High	3.0	--	--
Green sturgeon	--	--	--	--
White surgeon	--	--	--	--
Delta smelt	--	--	--	--
Longfin smelt	--	--	--	--
	High	**2.6**	Med	**2.0**

Scoring Key

WORTH	High	
	Medium	
	Low	
RISK	Low	
	Medium	
	High	

Scoring Weights

Value between..	..and	Rank
1	1.5	Low
1.5	2.5	Med
2.5	3	High

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		Is Outcome Applicable?	CORRIDOR SCORING		WORTH		RISK	
Standard Outcome Code	Outcome (brief descriptor)	(1=yes, 0=no)	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.								
P1	Increased Frequency of Inundation		3	3	High	3		
P2	Increased Spawning Habitat for Splittial	0				FALSE		
P3	Increased Rearing Habitat for Salmon	0				FALSE		
P4	Increased Local Aquatic Primary and Secondary Production		2	3	Med	2		
P5	Increased Food Export	0				FALSE		
N1	Increased Stranding		2	4			Low	1
N2	Increased Mortality Due to Water Quality Degradation (including water temperature, DO, eutrophication)		2	2			Med	2
N3	Increased Microcystis		2	2			Med	2
N4	Increased Exposure to Selenium		2	2			Med	2
N5	Increased Mercury Methylation		1	3			Low	1
N6	Increased Mobilization or Re-suspension of Toxics (including pesticides)		2	2			Med	2
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.								
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)		4	3	High	3		
P17	Increased Terrestrial Invertebrates					FALSE		
N12	Establishment of Invasive Species (SAV, Clams=not scored)		1	4			Low	1
					0			
					WORTH		RISK	
					High	2.7	Med	2.0

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		SALMONID SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
P3	Increased Rearing Habitat for Salmon	2	2	Med	2		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							

WORTH			RISK		
Med		**2.0**	#N/A		**0.0**

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		SPLITTAIL SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
P2	Increased Spawning Habitat for Splittial	3	3	High	3		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							

SCORING with SLR					
WORTH			**RISK**		
High	●	**3.0**	#N/A	●	**0.0**

Corridor 2B - Modified-DRERIP Evaluation Summary

- Assumptions/Changes to Corridor Description made During Evaluation
  - For purposes of this DRERIP evaluation, Corridors 2A and 2B are being parsed such that: 2A+Fabian Tract=2B. Corridor 2A was evaluated previously and separately from this evaluation. The scores below represent both 2A and 2B together.
  - The evaluation team agreed to parse out two viewpoints expressed by the group and assume "two scenarios":
    - Scenario 1 is the approach as described in the Corridor Document and modeled by the consultants; it includes a considerable area of sub-tidal acreage.
    - Scenario 2 would have the marsh designed such that most acreage is emergent tidal marsh. (This assumes that the portion in the yellow elevation range on the map would become emergent tidal marsh that was created by tule planting). This 2 scenario concept provides a better approach to manage/avoid negative outcomes.
  - Phasing will be ignored for purposes of this evaluation; the assumption is that the tules get planted tomorrow and the marsh is in "full affect".
  - The late-long term condition will be analyzed by the evaluations today for both scenarios.
  - The Evaluation Team evaluated Corridor 2B considering both an Isolated Old River Corridor (IROC) and "no IROC"; details on assumptions are presented in each outcome.

- Summary of Key Outcomes Related to Objectives
  - *Objective: Increase the extent of ecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead*
    - Positive Outcomes
      - New floodplain areas (that transition into marsh habitat) would be available for inundation that would benefit splittail and salmonids
  - *Objective: Increase the spatial extent and connectivity of tidal marsh.*
    - Positive Outcomes
      - New marsh area would be well connected to upstream floodplains, but downstream connection into the Delta links to poor habitat
      - Minimal habitat for smelt; some habitat for splittail spawning and salmonid rearing and white sturgeon rearing.

        - Negative Outcomes
            - Invasive species (clams, SAV) will certainly occur, but adverse effect on fish species is uncertain and likely low magnitude
            - Water quality (especially temperature, potentially DO) may be an issue, but numerical modeling data is lacking
    - *Objective: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes*
        - Positive Outcomes
            - Channel complexity will increase with Fabian tract inundated
        - Negative Outcomes
            - Potential for entrainment is an issue yet to be examined quantitatively/with modeling, but conceptually is a large factor that needs to be addressed.

- <u>Key Uncertainties</u>
    - The hydrodynamics (spatially, and temporally [within each water year and by water year type]) of how flows come in from the San Joaquin River as well as how tidal action works within an opened-Fabian Tract. These dynamics influence water quality, residence time of fishes for spawning and rearing, and the distribution of food and out-migrating fishes.
    - How sub-tidal habitat areas within a restored marsh area are either managed or modified in the restoration designs such that they are eliminated, in order to reduce undesirable habitat areas.
    - Related to the above, are sub-tidal areas located in the South Delta beneficial for native fish?
    - What were the historical ecological functions of the South Delta for smelt? Is it feasible to re-create those processes/habitats within the context of BDCP South Delta restoration?
    - A “landscape-scale processes conceptual model” would be helpful in understanding ecosystem dynamics (physical and ecological) that occur across the transition between habitat types (i.e., the gradation from floodplain to marsh).
    - An understanding of habitat conditions and outmigration success for fishes that may rear in an inundated Fabian Tract. Also, the relationship between successful outmigration downstream of Corridor 2B compared to that of Corridor 4.

- <u>Data Gaps</u>
    - Multi-dimensional hydrodynamic modeling (as related to inundation of Fabian Tract, entrainment, and water quality) is of particular interest as it is a key driver in many of the important processes and outcomes considered.

- Additional information/research on site-specific marsh habitat design options that can improve water quality conditions/mitigate potential adverse conditions that might be generated by creation of tidal marsh habitats in the South Delta. (See also the separate M&I and Agriculture WQ Evaluations in June, 2012)

- <u>Potential corridor re-configurations or combinations to increase the worth /decrease the risk of potential implementation.</u>
    - An Isolated Old River Corridor (IROC) would decrease the risk of entrainment of fish and food. This is a key consideration in configuring habitat in Corridor 2B.
    - Modification of the Fabian Tract (Corridor 2B) footprint to address the sub-tidal marsh areas that would be created if the entire tract were opened via full levee breaches. In other words, steer restoration design toward what evaluators assumed as “Scenario 2” during these evaluations.
    - In conjunction with the recommendation above, consider that Fabian Tract could be adaptively restored with the floodplain at upstream end completed first with the downstream, more-tidal areas restored later when uncertainty is resolved.
    - Salmon and splittail could potentially end up in Fabian Tract (after being routed through a lowered Paradise Cut weir) which would have marsh habitat. The combination of Corridors 2A and 2B should be considered as a coupled pair if in the future this corridor shows promise. Consider how Corridor 2B itself might be adaptively phased in to an overall South Delta solution (i.e., later than other areas) given uncertainty.
    - In terms of lower/ecologically-relevant flows, consider reconfiguration of the channel split at Old River-Grant Line Canal to favor more flow thru Old River. This need not preclude channel and floodway sizing in these areas to be optimized for flood conveyance.

Corridor 2B - Detailed Evaluation Notes

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Scientific Evaluation Worksheet & Notes
Corridor 2B

Evaluation Team:
Facilitator: Bruce DiGennaro
Participants: Eric Ginney, Coach; John Clerici (observer), Ron Melcer, Jeremy Thomas, Ray McDowell, John Cain, Steve Cimperman, Sheng Jun Wu, Christine Joab, Deanna Sereno, Mike Hoover, Michelle Orr, Andrea Thorpe, Cathy Marcinkevage, Ted Sommer, Josh Israel
Note-taker: Kateri Harrison

General opening discussion. Reminder that the approach taken in this worksheet is to assess the magnitude and certainty of the objective statement and its associated outcomes. These are tracked in the accompanying spreadsheet. This represents a slightly different approach from that taken during the 2009 DRERIP Evaluations.

For purposes of this DRERIP evaluation, Corridors 2A and 2B are being parsed such that: 2A+Fabian Tract=2B. Corridor 2A was evaluated previously and separately from this evaluation. A key question is whether there are any ecological benefits that we could realize from removing levees and allowing inundation of Fabian Tract? <u>The scores below represent both Corridors 2A and 2B together.</u> *This is a regional landscape change in the Delta.*

Portions of Fabian Tract would be inundated all the time, other portions would not. The exact configuration is not yet determined and would require modeling to better understand such inundation and tidal dynamics. Breaching levees in a tidally influenced area does create flow/discharge. The likely spatial area of habitat with and without grading was considered. Modelers assumed Fabian Tract could have some grading to extend the intertidal zone. The color codes on the tides are based on existing tides and without grading. So grading (filling) would yield less of the yellow sub-tidal elevation range. BDCP's definition of "tidal marsh" includes both sub-tidal and open water. Evaluators noted that in general, there is a lot of concern about situations similar to Frank's Tract which is open water.

South Delta ROA has been mapped in Appendix E of the Draft BDCP. Appendix E includes effects analysis and it may be useful in this evaluation. The consultant team cautioned that while the ROA is clearly presented in Appendix E, the actual "hypothetical" tidal marsh area within that ROA is <u>**not**</u> the same as Corridor 2B (which is only Fabian Tract). The hypothetical for the effects analysis is different and includes **none** of Fabian Tract. A homework assignment for the consultant team was to determine if there is any similarity between the modeling assumptions made in Appendix E and the modeling that ESA/PWA used for the South Delta. *[Consultant Team Answer: after conferring with ICF, it appears that the situation is as was suggested by ESA PWA during the evaluation: the hypotheticals are very different, and the outcomes for salmon (as stated in the effects analysis) are limited to only temperature and turbidity, as taken from one node in DSM2 on the lower San Joaquin River and extrapolated across the hypothetical]*

The evaluators then noted that the BDCP's effects analysis modeling creates confusion because the ROA's are depicted as large blobs on a map. However, when the actual modeling of the hypotheticals within those blobs is run, the analysts do not share that subset or any related assumptions. There is very little definition of what BDCP is doing in the South Delta and this has resulted in unvetted assumptions.

The potential effects on salinity of larger tidal prism are very difficult to model in this area. Small increases in salinity have a big impact on the quality of drinking water. However, small increases in salinity have minimal effect on fish. This issue was noted to be more important for the M&I and Agriculture Water Quality Evaluations held in June. A condition with low exports and with low San Joaquin River flow sets the stage for a tidal system with sea water and associated higher salinity. Additional modeling of salinity intrusion is recommended. This salinity will affect both M&I uses and X2. By creating a tidal basin (Fabian Tract in Corridor 2B) it will increase the tidal prism and bring more sea water into this area. Changes in tides will change dynamics. For example, at Liberty Island restoration the tidal range (difference between high and low tide) shrunk.

In conclusion, restoration in corridors 2A and 2B will increase the variation in salinity. The restoration of 2A and 2B might influence south Delta exports.

Overall Clarifying Assumption for All Corridor 2B analysis

Based on existing elevations and interpreted tidal range, one option for Fabian Tract is to have a large area that is sub-tidal (as shown on the figures for Corridor 2B). Another option would be to in some manner block off this subtidal area (located in the generally northwest corner of Fabian tract) via a new levee, plant tules, to raise the elevation (via subsidence reversal techniques and potentially carbon farming), and eventually the terrestrial could be converted to create tidal marsh. The marsh could be created via grading or via tule marsh accretion.

The evaluators wanted to understand whether sub-tidal areas located in the South Delta would provide benefits for native fish?

The evaluators expressed a tension between analyzing a project as described by BDCP or re-writing the project description to make it better. It was noted that oftentimes BDCP planning teams remove parts of project descriptions that do not seem feasible, practical, or beneficial. Many evaluators felt that this DRERIP evaluation should objectively score the entire project as modeled/originally-conceived. Several evaluators felt that restoring sub-tidal areas is not a good idea. Negative outcomes are associated with sub-tidal open water. Open sub-tidal can be colonized by Egeria. The previously-discussed option of levees and subsidence reversal allows engineers to 1) partition; 2) grade; and/or 3) plant tules. Such a strategy would create all emergent marsh habitat within Fabian Tract, or floodplain. The sub-tidal would be minimized or eliminated. This would require cross-levees and tule planting and the design objective would be to minimize open water and sub-tidal.

After much discussion, the evaluation team agreed to parse out the two viewpoints expressed by the group and assume “two scenarios”. Scenario 1 is the approach as described in the Corridor Document and modeled by the consultants; it includes lots of sub-tidal acreage. Scenario 2 would be designed such that most acreage is emergent tidal marsh, as per the discussion outlined above. This assumes that the portion in yellow (elevation range) on the map would become emergent tidal marsh that was created by tule planting. Phasing will be ignored for purposes of this evaluation. Assume that tules get planted tomorrow. The late-long term condition will be analyzed by the evaluations today for both scenarios. This 2 scenario concept provides a better approach to manage/avoid negative outcomes. The group noted that this is a good example of two differing professional viewpoints and agreed to move ahead to engage them both.

OBJECTIVE: INCREASE FREQUENCY OF FLOODPLAIN INUNDATION TO SUPPORT REPRODUCTION AND VIABILITY OF SACRAMENTO SPLITTAIL AND CHINOOK SALMON.

Potential Positive Ecological Outcome

Outcome P1: Increased Frequency of Inundation
Clarifying Assumptions: 2,500 acres of sub-tidal would be flooded along with 1,000 acres of floodplain.   Note: Additional modeling is needed. Topography is flat and inundation will be shallow, so the channel will be relatively deep.

Scientific Justification: Compared to 2A, this restoration improves many more acres (1,500 acres of floodplain is proposed). This proposed restoration will double the amount of inundated acres in this entire area.

Magnitude Scenario #1 includes sub-tidal: Medium to High "3-4"

Certainty Scenario #1 incldues sub-tidal: The Frequency of flooding is not known (need more modeling). Uncontrolled environmental variables **Medium "3"**

Magnitude Scenario #2 all emergent: Same as sub-tidal. **Medium to High "3-4"**

Certainty Scenario #2 all emergent: Same as sub-tidal. **Medium "3"**

Note: Magnitude scores rounded down in the spreadsheet to remain conservative.

Outcome P2: Increased Spawning Habitat for Splittail

Scientific Justification: Same as Corridors 1A and 2A. Under existing conditions there are no ecologically significant benefits on Fabian Tract. The consulting team developed a table explaining the floodplain details. 6,095 acres of floodplain is misleading. There was no 2-D modeling. If you peal out the 1500 acres of floodplain and this is similar to 1A and 2A. We assume fish will not use the tidal marsh based on Dutch Slough studies. Tidal marsh does not serve as splittail spawning habitat

Magnitude Scenario #1 sub-tidal: **Medium "3"**

Certainty Scenario #1 sub-tidal: Same as 1A and 2A, **Medium "3".**

Magnitude Scenario #2 all emergent: Not scored by the group

Certainty Scenario #2 all emergent: Not scored by the group

Outcome P3: Increased Rearing Habitat for Salmon

Magnitude Scenario 1 sub-tidal: Higher than Corridor 2A. If 30-50% of the fish that emerge from San Joaquin gravels and travel downstream to the flow split onto Old River. Splits at Grant Line, so breach there, too. At the flow split there will be a lot of cues. Perhaps fish do not move only with the flows but respond to these cues. If only 50% of fish would by Paradise Cut and get swept into this area. Is 50% sig for the population? Probably minor. However regionally, this is likely the largest area. 1500 new acres of floodplain. **Magnitude: Medium "3"**

Certainty Scenario 1 sub-tidal : Medium "3"

Magnitude Scenario 2 all emergent: Not scored by the group

Certainty Scenario 2 all emergent: Not scored by the group

OBJECTIVE: INCREASE THE SPATIAL EXTENT AND CONNECTIVITY OF TIDAL MARSH.

Un-numbered Outcome: Increase the spatial extent and connectivity of tidal marsh (Note: the group chose to take this entire objective and make it an "outcome" as related to corridor function [see corridor tab in spreadsheet]).
Magnitude Scenario 1 sub-tidal: Not scored by the group. **Certainty Scenario 1 sub-tidal:** Not scored by the group. **Magnitude Scenario #2 all emergent:** Connectivity downstream does not follow a natural gradient. Connectivity to other marshes in interior delta (i.e. regional connectivity) is poor. East Delta and West Delta ROA have issues too. Old River is called "West Canal". Natural gradients are important from both an ecological community perspective and a landscape perspective. There is also an internal site habitat gradient from floodplain upstream to marsh downstream, which appears beneficial but is not well-described because there are no "landscape" conceptual models in DRERIP. There is good connection on this Fabian Tract site between floodplain and mash. Currently this site does not support tidal marsh. The proposed restoration will add several thousand acres of tidal marsh. **Medium "3"**
Certainty Scenario 2 all emergent: The tidal range situation is not clear. Changes to the tidal range could reduce the extent of the marsh. This could be mitigated via design. **Low "2".**

Outcome P6: Increased Spawning Habitat for Splittail

Magnitude Scenario #2 all emergent. Splittail will spawn in marsh. The frequency is not as important. Tidal marsh is not as desirable habitat as compared to floodplain) **Low "2"**

Certainty Scenario #2 all emergent**: Low "2"**

Magnitude Scenario 1 sub-tidal: Not scored by the group.

Certainty Scenario 1 sub-tidal: Not scored by the group.

Outcome P7: Increased Rearing Habitat for Salmonids

Clarifying Assumptions:

- Lower weir. For this outcome, the group reiterated the assumption that Corridor 2A was in effect and the weir would be lower.

Magnitude Scenario 2 all emergent
This habitat is available every single year and if 50% of the San Joaquin River salmon travel down here. In the past, this area was a bottle neck for salmon. The restoration will be a big improvement.   **Medium "3".**

Certainty Scenario 2 all emergent: **Low "2".**

Magnitude Scenario 1 sub-tidal: Not scored by the group.

Certainty Scenario 1 sub-tidal: Not scored by the group.

Outcome P8: Increased spawning habitat for Delta smelt

Clarifying Assumptions:

- Currently, the South Delta is a sink for delta smelt. Refer to BDCP effects assessment for additional information on smelt ecology and this phenomenon.

Magnitude Scenario 2 all emergent: **1 minimal**. Ignores sink (this part of the outcomes is captured as a negative outcome, below).

Certainty Scenario 2 all emergent: **1 minimal.**

Magnitude Scenario 1 sub-tidal: Not scored by the group.

Certainty Scenario 1 sub-tidal: Not scored by the group.

Outcome P10: Increased spawning for Longfin smelt

Scientific Justification:

Magnitude Scenario 2 all emergent: Similar to 2009 DRERIP but lower magnitude and certainty. **Minimal "1"**

Certainty Scenario 2 all emergent: Low "2"

Magnitude Scenario 1 sub-tidal: Not scored by the group.

Certainty Scenario 1 sub-tidal: Not scored by the group.

Outcome P12: Increased rearing habitat for Juvenile and Sub-adult White Sturgeon

General Discussion: Sturgeon could be residents year-round. If this is not an isolated (protected) from the facilities, then fish will get entrained.

West Canal is an agricultural canal. Old River is a natural channel of the San Joaquin River, but it has to go past West Canal. West Canal has negative flows right to the facilities. This area has terrible habitat conditions. However, in the future, if we imagine this without entrainment (ie with an IROC), then the quality of the habitat is somewhat better; however, at this time an isolated corridor is not part of the project. If the project changes to incorporate an IROC, then evaluators should return to re-analyze the situation. Hopefully, the project proponents will improve the project description later to alleviate / mitigate the negative effects. There are reports on the IROC, but BDCP has not incorporated it yet. The BDCP proposal in the South Delta appears vague to the evaluators. The hydrodynamics of an IROC were not clearly explained in the description and are generally not well understood. It is important to think of this holistically.

Currently today, the South Delta does not have tidal marsh or riparian habitat. Any habitat that does exist is located within the zone of entrainment. The areas downstream of the South Delta are not particularly good habitat (this is the case for <u>all</u> of the corridors). This is a consistent assumption that applies to all corridors.

Magnitude Scenario 2 all emergent: Even with an isolated facility, still have limited downstream connectivity. Sturgeon are here year round. If water quality conditions were appropriate and if they were outside the zone of entrainment. Overall this restoration represents a small contribution of tidal marsh acreage to the Delta system. Conceptual model is that sturgeon use subtidal, not intertidal **Low "2"**

Certainty Scenario 2 all emergent: Low "2"

Magnitude Scenario 1 sub-tidal: Not scored by the group.

Certainty Scenario 1 sub-tidal: Not scored by the group.

Potential Negative Ecological Outcomes

Outcome N12: Clams & SAV

Scientific Justification:
Note that the evaluators referenced back to the 2009 DRERIP evaluation related to Corbicula establishment that could limit, if not eliminate, the productivity befits of the restoration to native fish. Similarly established of SAV and centrarchid predators could lead to predation rates on the site that eliminate any net benefits at a population level. A worst case scenario is that clams eat every bit of production.

Clam - Magnitude Scenario 1 – sub-tidal, all fish species: The habitat in this region is generally in very poor condition. **Minimal "1"**

SAV Magnitude Scenario 1 – sub-tidal all fish species: **Low "2".**

SAV & Clams Certainty Scenario 1 - sub-tidal: We have high certainty that clams and SAV will invade (4) and low certainty that this will impact the fish species. **Low "2"**

Clams Magnitude Scenario 2- all emergent, all fish species: Clams and SAV will not be in the emergent marsh. However, if food is exported off the marsh, we will see well-fed clams. **Minimal "1"**

SAV Magnitude Scenario 2 all emergent all fish: SAV will grow in adjacent channels, but not grow in marsh. **Low "2"**

SAV & Clams Certainty 2 – all emergent: **Low "2"**

Outcome N3C: Invasive fish / Predators [note that *zero magnitude* meant that this outcome was not included in the spreadsheet]

Magnitude Scenario 2 – all emergent for salmon and splittail: this restoration action (and any tidal habitat) will create more habitat for invasive fish species. Predation is currently high (already at 97%) and this rate will stay the same. More complex habitat will create more places for native fish to hide from predators. Tidal marsh will provide a net benefit, even with predation.

This is a wash “**zero” 0 magnitude** or a small net benefit.

Certainty Scenario 2 – all emergent: Evaluators are fairly certain that increased abundance of invasive predators will occur. However, the effect of this increase in predation on salmon and other native fish populations, given the already high rates, is less certain. **Low “2”**

Outcome N7a: Increased Mortality Due to Water Quality Degradation (including water temperature, DO, eutrophication)

Scientific Justification: This restoration will increase residence time and therefore may increase water temperature. If there were no Isolated Old River Corridor there might be better water quality due to flow thru of San Joaquin River (?). This restoration will be increasing the tidal prism and pulling in more water from the sea. Higher tidal velocity in the river downstream of Fabian Tract. Solar radiation on subtidal areas would increase temperature. If water temperatures increase just a little bit, then predators will eat more due to bioenergetics.

An example is Mildred Island where temperatures did increase in the sub-tidal zone 5 ft. depth. The overall south Delta will have an increased residence time, which will influence temperature.

Magnitude for Scenario 1 sub-tidal: Splittail are resident fish species but moving to western Delta. Smelts are sensitive to temperature and therefore would experience greater impact. It is not a High 4 magnitude because there may be some pools of cooler temperature refugia. Fish may avoid high temperature areas. Sustained minor population effect. **Medium "3".**

Certainty: We do not understand the timing or magnitude of the temperature changes. Habitat Suitability Index (HSI) for temperature flattens for a while and then drops. Spring season is the time of most concern for some species. **Minimal "1"**

Magnitude for Scenario 2 – all emergent all fish: Less solar radiation and temperature increase would be less. Some discrepancy regarding whether the "Chris Enright hypothesis" about cooling via marsh vegetation applies here in the south Delta. It was noted that the tules do have a lot of surface area and evaporative cooling. **Low "2"**

Certainty for Scenario 2 – all emergent all fish: Minimal "1"

Outcome N7b: Low Dissolved Oxygen (note, because this is a sub-part of Outcome N7, and scores in that outcome were higher [more negative], those scores were retained in the spreadsheet for conservatism)

Clarifying Assumptions:
Vegetation will die back. More nutrients released. Frank's Tract dissolved oxygen problems may not have been measured. Big dissolved oxygen problems are Suisun and Stockton DWSC. Longer residence time. SAV and higher temperatures contribute to a lower dissolved oxygen.

Comparatively Frank's Tract is not a good area to compare to because it has better flows. Snodgrass Slough on the east side is better example.

Magnitude Scenarios 1 and 2 all native: Problem during summer and fall. Salmon are present in April. The modeling shows dissolved oxygen is suitable, but this modeling is constrained and may not apply here. The RWQCB has water quality objectives for dissolved oxygen, if the water quality objective and this scenario reduces the water quality objective, then that is a problem. **Low "2"**

Certainty Scenarios 1 and 2 all native: The low dissolved oxygen is a hypothesis. **Minimal "1".**

Outcome N3F: Increased Microcystis (Not applicable to the aquatic species being evaluated; no score in spreadsheet)

Clarifying Assumptions:
Longer resident time and warmer temps will increase occurrence of Microcystis. Microcystis is present in Aug and Sept. Fish are not present at this time. However, this is a key water quality issue for M&I. See June 2012 M&I / Agricultural Water Quality Evaluation.

Scientific Justification:

Magnitude: N/A to fish but see note above regarding M&I

Certainty: N/A.

Outcome N10: Increased Mercury Methylation

Magnitude for scenario 1: sub-tidal and open water will demethylate mercury via photo-demethylation. The site will be a sink for mercury and that is a positive thing. **Minimal to low "1-2".**

Certainty: **High "4"**

Magnitude for scenario 2 all emergent: Most of the emergent marsh will be low marsh. High marsh would be more of a problem. **Minimal to low "1-2.**

Certainty: For fish, certainty is **High"4".**

(Note, for other species, there is less certainty Minimal "1" and this is not directly applicable to today's evaluation)

Outcome N9: Increased Exposure to Selenium

Clarifying Assumptions:

- Higher residence time. Selenium is bio-accumulated by clams. More opportunities for selenium to get into food chain for those fish that eat clams. The fish have plenty of clams to eat.
- There are selenium clean-ups in progress and so the situation could improve

Magnitude for scenario 1 sub-tidal: Higher concentration within San Joaquin River water (as compared to Sacramento River water) so would have a higher concentration of selenium. Residence time is the mechanism. If the clams have a higher selenium concentration, this is not an issue for salmon. Bio-accumulation of selenium in sturgeon may reduce their reproductive capacity. Daily dose level has been exceeded. Sturgeon are already past the selenium threshold, so the additional 3% more is the proverbial drop in the bucket. Score for most native fish is **Low “2**”. However for salmon magnitude is a **Minimal “1”.**

Certainty for scenario 1 sub-tidal: Minimal to Low “1-2”

Magnitude for scenario 2 all emergent: Tules no net change in # of clams. However, will be increased residence time in the tidal marsh. Pumping pattern also increases residence time.
Score for most native fish is **Low “2**”. However, score for salmon magnitude is **Minimal “1”.**

Certainty for scenario 2 all emergent: Minimal to Low “1-2”.

OBJECTIVE: RESTORE HABITATS AND RIVER CONDITIONS (I.E., THE MAGNITUDE AND DIRECTION OF FLOW IN FLUVIAL REGIMES) THAT FAVOR SURVIVAL AND GROWTH OF JUVENILE SALMONIDS, STURGEON, DELTA SMELT, LONGFIN SMELT, AND OTHER NATIVE FISHES

Potential Positive Ecological Outcomes

Outcome P16: Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)

Scientific Rationale: Currently the channel is constrained between two levees and it is a low energy environment and fish biologists often recommend more channel complexity. However, if levees are removed natural channel erosion, deposition, migration and related ecological processes will be rehabilitated. Channel complexity will increase over time due to big flow events moving thru with depositional features. Re-vegetation will occur. Flow goes thru Grant Line. Junction is an issue. There is an expanded Paradise Cut. Flows to the Delta would increase with concurrent higher discharge and increased velocity through Paradise Cut.

Bathymetric evolution; there is a balance. Physical habitat needs to be coupled with hydrodynamic flow regime. Rate of natural channel evolution will be slow in Corridor 2B (in-Delta environment, not the San Joaquin River). It will take a long time to develop this into a complex sediment balance. This will be a low velocity area. Physical complexity has to come with the right flows. Slow flows, so slow geomorphic change. Could allow rafting of large woody debris, which would be valuable.

Magnitude on intermediate outcome – physical only: Low "2"

Certainty for physical only: Fairly well understood condition is a **medium "3"**

Magnitude on native fish: Minimal to Low "1-2"

Certainty for all fish "**minimal "1**"

Outcome NX Entrainment (unnumbered outcome; added at end of spreadsheet and not counted in roll up scores because of lack of data)

Clarifying Assumptions:

- Entrainment will increase a lot if there is habitat in Corridors 2A and 2B that ends up adjacent to the pumps.
- Restoration will increase native fish population abundance so overall, a greater number of fish would get entrained. The Evaluation Team recognizes that rate or % of population entrained is a better metric.

Any fish that goes down this channel will get entrained in the pumps if they are operating. If Paradise Weir is not improved (via this restoration), these fish may have stayed in than San Joaquin River. Depends on operations such as amount of pumping in the south Delta and water year type, and the configuration of the Weir and any operable barriers (at Paradise Weir, in the mainstem San Joaquin River, or elsewhere).

Magnitude without Old River corridor: Caveat: Magnitude depends on the operations. This could have a high adverse effect on salmon, but there is not enough information available to make a specific determination. This negative outcome is a **medium to High "3-4"**

Certainty without Old River corridor: Medium "3"

Magnitude Scenario 2 with isolated Old River corridor. Fewer fish will be entrained. May have significant effects on pelagic fish, but we do not have enough data. The entrainment zone may shift to Middle River; but there have been several hypotheses on this. **Minimal - Low "1-2"**

Certainty Scenario 2 with isolated Old River corridor: Modeling runs should be available for this somewhere. **Minimal "1"**

Notes: This may affect water supply or OCAP BO's RPA.

Data Gaps & Key Uncertainties

Data Needs *(indicate specific models, DLO relationships, or other information indicating the need):*

- Multi-dimensional hydrodynamic modeling of Fabian Tract inundation. This plays into water quality, entrainment of food and individuals of certain species, and also influences habitat itself. This is a key driver.

Key Uncertainties and Research Needs *(describe specific research activities that could be employed to increase understanding):*

- Is sub-tidal areas located in the South Delta beneficial for native fish?
- Does it matter exclusively on entrainment and water quality?
- What were the historical ecological functions of the South Delta for smelt? Is it feasible to re-create those processes/habitats within the context of BDCP South Delta restoration?
- A "landscape-scale processes conceptual model" would be helpful in understanding ecosystem dynamics (physical and ecological) that occur across the transition between habitat types (ie the gradation from floodplain to marsh).
- An understanding of habitat conditions and outmigration success for fishes that may rear in an inundated Fabian Tract. Also, the relationship between successful outmigration downstream of Fabian Tract compared to downstream of Corridor 4.

Scoring Summary

Corridor 2B

Species Name	Scenario 2: WithOUT Sub-Tidal Marsh;				*SCENARIO 1: With Sub-Tidal Marsh; WithOUT*			
	WORTH		RISK		WORTH		RISK	
Corridor Score (Habitat; Physical Process)	Med	2.3	High	3.0	High	3.0	High	3.0
Salmonids	Med	2.0	Med	2.0	--	--	Med	2.0
Splittail	Med	2.0	--	--	--	--	--	--
Green sturgeon	Low	1.0	--	--	--	--	--	--
White surgeon	Med	1.5	--	--	--	--	--	--
Delta smelt	Low	1.0	--	--	--	--	--	--
Longfin smelt	Low	1.0	--	--	--	--	--	--
	Med	1.5	High	**3.0**	High	3.0	High	**3.0**

Scoring Key

WORTH	High	
	Medium	
	Low	
RISK	Low	
	Medium	
	High	

Scoring Weights

Value between..	**..and**	**Rank**
1	1.5	Low
1.5	2.5	Med
2.5	3	High

		Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC		SCENARIO 1: With Sub-Tidal Marsh; WithOUT IORC		CORRIDOR SCORING: Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC				CORRIDOR SCORING: SCENARIO 1: With Sub-Tidal Marsh; WithOUT IORC			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		CORRIDOR SCORING		CORRIDOR SCORING		WORTH		RISK		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	Magnitude	Certainty	Magnitude	Certainty	Grade	Numeric	Grade	Numeric	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.													
P1	Increased Frequency of Inundation	3	3	3	3	High	3			High	3		
OBJECTIVE: Increase the extent and connectivity of tidal marsh.		3	2			Med	2						
N7	Increased Mortality Due to Water Quality Degradation (including water temperature, DO, eutrophication)	2	1	3	1			High	3			High	3
N9	Increased Exposure to Selenium	1	2	2	2			Med	2			Med	2
N10	Increased Mercury Methylation	1	4	1	4			Low	1			Low	1
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.		2	3			Med	2						
N12clam	Establishment of Invasive Species (Clams)	1	2	1	2			Med	2			Med	2
N12SAV	Establishment of Invasive Species (SAV)	2	2	2	2			Med	2			Med	2
XX	**ENTRAINMENT--not included in roll up**	1	1 (???)	3	3								

Scenario 2: WithOUT Sub-Tidal Marsh; WITH						SCENARIO 1: With Sub-Tidal Marsh; WithOUT					
WORTH			RISK			WORTH			RISK		
Med	●	**2.3**	High	●	**3.0**	High	●	**3.0**	High	◆	**3.0**

Standarized Outcomes for South Delta Corridors DRERIP Evaluations		Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC — SALMONID SCORING		SCENARIO 1: With Sub-Tidal Marsh; WithOUT IORC — SALMONID SCORING		Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC — WORTH		Scenario 2 — RISK		SCENARIO 1: With Sub-Tidal Marsh; WithOUT IORC — WORTH		SCENARIO 1 — RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.													
P3	Increased Rearing Habitat for Salmon	3	3			High	3				FALSE		
OBJECTIVE: Increase the extent and connectivity of tidal marsh.													
P7	Increased Rearing Habitat for Salmon	3	2			Med	2				FALSE		
N9	Increased Exposure to Selenium	1	2	1	2			Med	2			Med	2
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.													
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	1	1			Low	1				FALSE		

SCORING with SLR				SCORING without SLR			
WORTH		**RISK**		**WORTH**		**RISK**	
Med	**2.0**	Med	**2.0**	#DIV/0!	**#DIV/0!**	Med	**2.0**

		Corridor variations:	Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC		Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		Is Outcome Applicable?	SPLITTAIL SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	(1=yes, 0=no)	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.								
P2	Increased Spawning Habitat for Splittial		3	3	High	3		
OBJECTIVE: Increase the extent and connectivity of tidal marsh.								
P6	Increased Spawning Habitat for Splittial		2	2	Med	2		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.								
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)		1	1	Low	1		

SCORING with SLR					
WORTH			RISK		
Med		2.0	#N/A		0.0

		Corridor variations:	Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC		Scenario 2: WithOUT Sub-Tidal Marsh; WITH IORC			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		Is Outcome Applicable?	WHITE STURGEON SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	(1=yes, 0=no)	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.								
OBJECTIVE: Increase the extent and connectivity of tidal marsh.								
P12	Increased rearing habitat for white sturgeon		2	2	Med	2		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.								
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)		1	1	Low	1		

SCORING with SLR					
WORTH			RISK		
Med	🟡	1.5	#N/A	🟢	0.0

Corridor 4 - Modified-DRERIP Evaluation Summary

- <u>Assumptions/Changes to Corridor Description made During Evaluation</u>
  - The late-long term condition was analyzed for these evaluations.
  - Fish stranding locations are assumed to be "designed-out" of restoration actions.
  - Sturgeon are assumed to be potential year-round residents of this corridor.
  - Floodplain inundation *was modeled without HORB as the HORB was not a part of the original corridor assumptions*. With HORB, most of the fish move through Corridor 4.

- <u>Summary of Key Outcomes Related to Objectives</u>
  - *Objective: Increase the extent of ecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead*
    - Positive Outcomes
      - New floodplain areas (that transition into marsh habitat) would be available for inundation that would benefit splittail and salmonids—and all outmigrating fish would go through this corridor if the HORB is in place. Low risk of stranding.
  - *Objective: Increase the spatial extent and connectivity of tidal marsh.*
    - Positive Outcomes
      - New marsh area would be well connected to upstream floodplains, but downstream connection into the Delta links to poor habitat—Stockton Deep Water Ship Channel (SDWSC; which negating the pumps is worse than downstream of Fabian)
      - Minimal habitat for smelt; some habitat for splittail spawning and salmonid rearing and white sturgeon rearing.
    - Negative Outcomes
      - Water quality (especially DO and temperature) is likely an issue with the downstream SDWSC , but numerical modeling data is lacking
  - *Objective: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes*
    - Positive Outcomes
      - Channel complexity will increase with the new setback floodplain and an unconstrained, erodible left-bank.
    - Negative Outcomes
      - Risk of invasive species (clams, SAV) similar to other corridors.

- *Objective: Reduce entrainment mortality of juvenile salmonids, smelt, sturgeon, splittail, and other native fishes*
    - While entrainment was conceptually-evaluated and was scored for this corridor, it was not used in the rollups because the other corridors do not have scores for entrainment.

- <u>Key Uncertainties</u>
  - The marsh at the downstream end of the corridor will have longer residence times. Any increase in organic matter loading will contribute more to the problem of already-low levels of DO in the SDWSC, and the proximity of this corridor to the SDWSC is a concern. A potential mitigating effect is greater velocities due to the increase in the tidal prism.
  - A "landscape-scale processes conceptual model" would be helpful in understanding ecosystem dynamics (physical and ecological) that occur across the transition between habitat types (i.e., the gradation from floodplain to marsh).

- <u>Data Gaps</u>
  - Multi-dimensional hydrodynamic modeling (especially as related to water quality) is of particular interest as it is a key driver in many of the important processes and outcomes considered.
  - Examine runoff into Corridor and evaluate potential for water quality impacts.

- <u>Potential corridor re-configurations or combinations to increase the worth /decrease the risk of potential implementation.</u>
  - Analyze the effects of potential HORB operation and integrate into future corridor evaluations. There is a need to examine potential negative effects of HORB outside Corridor 4.

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Scientific Evaluation Worksheet & Notes

Corridor 4

Evaluation Team: Facilitator: Bruce DiGennaro

Participants: John Clerici, Ron Melcer, Eric Ginney, Jeremy Thomas, Ray McDowell, John Cain, Steve Cimperman, Sheng Jun Wu, Christine Joab, Deanna Sereno, Mike Hoover, Michelle Orr, Andrea Thorpe, Cathy Marcinkevage, Ted Sommer, Val Connor, Josh Israel
Note-taker: Kateri Harrison

Date: Thursday, February 2, 2012

For this analysis, the group assumed that:

- Corridors 2A and 2B are not going to be restored.
- The Head of Old River Barrier (HORB) is installed and is operational at low flows (<10,000 cfs), year round.
- Active channel margin enhancement occurs in specified locations.
- All outmigrating fish pass by this location, unless they travel down Old River at a flow higher than 10,000 cfs.

Floodplain inundation was modeled without HORB as the HORB was not a part of the original corridor assumptions. The manifestation of this is that the discharge/area of inundation curves in the corridor document are accurate to how this corridor is being evaluated for flows above 10,000 cfs, which is when there is no HORB [i.e. it is not operational above 10,000 cfs]. For flows less than 10,000 cfs, then the curve in the corridor document is not accurate due to lack of HORB in the model (and would tend to underestimate the floodplain inundation in Corridor 4 because that extra flow would be routed down the mainstem of the San Joaquin River, not Old River). With HORB, most of the fish move through this corridor. We assume some improvements to the right (eastern) bank, and that that the left (western) bank will be allowed to naturally evolve once the levees are set back. Currently the channel is trapezoidal in shape through this reach.

OBJECTIVE: INCREASE THE EXTENT OF ECOLOGICALLY-RELEVANT FLOODPLAIN HABITAT TO SUPPORT REPRODUCTION AND VIABILITY OF SACRAMENTO SPLITTAIL AND CHINOOK SALMON & STEELHEAD

Potential Positive Ecological Outcome(s)

Outcome P1: Increased Frequency of Inundation

Scientific Justification:
Under existing conditions, Corridor 4 is constrained by levees on both banks. Levee setbacks would provide up to 6,000 acres of habitat. It is anticipated that this will have a sustained population effect for target species. This corridor spans a larger topographic gradient than other corridors, allowing a diversity of habitat types from floodplain at the upstream end to tidal marsh at the downstream end. It was noted that the northern edge of the proposed left bank levee setbacks may not be optimally configured according to one evaluators understanding.

The group pondered if there would be incremental improvements to habitat based on the location of the proposed setbacks, and if would there be a landscape level effect. The consensus was: yes. Alternative 1A has a larger footprint; however, Corridor 4 has more potential for tidal marsh habitat restoration. The group was reminded that this outcome is specifically concerned with floodplain habitat.

Based on evaluations, 15,500 cfs is the recommended ecologically-relevant flow for salmon, and 11,600 cfs is the recommended ecologically-relevant flow for splittail. For salmon, these flows occur for a minimum duration of 14 days every 4 years, for splittail these flows occur for a minimum duration of 21 days every 4 years. At these flows, there would be 4,000 acres (at flows of 15,500 cfs), and 3,500 acres (at flows of 11,600 cfs) of floodplain, riparian, and tidal marsh habitat. The group was concerned about the limited temporal effects on fish populations associated with this evaluation. If the hydrology were different then we may see a different (and potentially improved) ecological benefit.

It was also mentioned that the current topography is less than optimal, and that natural channel morphology changes could change the distribution of habitats along the corridor substantially.

Magnitude Physical Only – Intermediate Outcome: Low "2"

Certainty: High "4".

Outcome P2: Increased Spawning Habitat for Splittail

Scientific Justification:
Same as Corridors 1A and 2A: Larger amounts of inundated floodplain, as proposed here, will benefit the species.

Magnitude: Medium "3"

Certainty: Medium "3"

Outcome P3: Increased Rearing Habitat for Salmon

Scientific Justification:
The group thinks the magnitude of benefit in terms of rearing habitat for salmon will be greater than that for Corridor 2A because there will be a greater frequency of inundation (due to lower topography and more accessible floodplain areas).

Magnitude: Medium "3"

Certainty: Medium "3"

Potential Negative Ecological Outcome(s)

Outcome N1: Increased Stranding
Scientific Justification: Stranding not an issue in tidal marsh habitats; however in floodplain habitats this can be an issue that was assumed to be mitigated through design. **Magnitude: Low “2”** **Certainty: High “4”**

OBJECTIVE: INCREASE THE SPATIAL EXTENT AND CONNECTIVITY OF TIDAL MARSH HABITAT

Potential Positive Ecological Outcome(s)

Outcome Px: Increase the spatial extent and connectivity of tidal marsh habitat (Note – evaluators scored the objective as an outcome.)

Magnitude (intermediate outcome – physical only): Acreages are similar to 2B. **Medium "3".**

Certainty: Changes to the tidal range could reduce the extent of the marsh habitat. This could be mitigated through design. **Low "2".**

Outcome P6: Increased Spawning Habitat for Splittail

Scientific Justification:
Splittail will spawn in marsh habitats. The frequency is not as important. Tidal marsh is not as desirable habitat as compared to floodplain, but floodplains exist in Corridor 4.

Magnitude for the tidal marsh portion: Low "2"

Certainty for the tidal marsh: Low "2"

Outcome P7: Increased Rearing Habitat for Salmonids

Scientific Justification:
This habitat will be available every year, with high probability that at least 50% of the SJR salmon travel through this corridor and could potentially utilize this habitat. In the past, this area was a bottle neck for salmon. The restoration will be a big improvement.

Magnitude for tidal marsh portion: Medium “3”.

Certainty: Low “2”.

Outcome P10: Increased spawning habitat for Longfin smelt

Clarifying Assumptions:
See 2009 DRERIP

Scientific Justification:
Similar to 2009 DRERIP but with lower magnitude and certainty. The South Delta could have significant negative outcomes for delta and longfin smelt depending on the actual configuration of flood and ecosystem restoration actions.
Magnitude: Minimal “1”

Certainty: Low “2”

Outcome P12: Increased rearing habitat for White Sturgeon

Clarifying Assumptions:

- Sturgeon could be resident year-round.

Scientific Justification:
Downstream connectivity is a concern. Sturgeon are here in this corridor year-round. If water quality conditions were appropriate and if they were outside the zone of entrainment, then they might benefit. Overall this is a small contribution of tidal marsh to the total quantity of marsh habitat in the Delta. Juvenile and sub-adult sturgeon will rear here. Corridor 4 has tidal exchange.

Magnitude: Low "2"

Certainty: Low "2"

Potential Negative Ecological Outcome(s)

Outcome N7: Increased Mortality Due to Water Quality Degradation (including water temperature, DO, eutrophication)

Scientific Justification:
With the HORB in place, there will be shorter residence time in the channels and floodplains and this should yield fewer water quality impacts. The marsh at the downstream end of the corridor will have longer residence times. There are low levels of DO in the Stockton DWSC and any increase in organic matter loading will be contributing to this problem. The proximity of this corridor to the Stockton DWSC is a concern.

RWQCB would like to see some modeling about the potential impacts for this water quality concern. A mitigating impact is greater velocities due to the increase in the tidal prism. As you progress past the WWTP the channel gets deeper. Dissolved oxygen problems are dependent on flow. Stockton upgraded their WWTP in 2006 and their nutrient loading has declined; however dissolved oxygen problem still remains June to October.

Magnitude: Medium "3"

Certainty: Evaluators are unable to understand the timing or magnitude of the temperature changes because the screening-level modeling does not provide for that type of data. Spring season is the time we are most concerned about for some species. **Minimal "1".**

Recommendations for future study: Analyze the effects of the HORB and integrate into the corridor evaluations. Need to look at potential negative effects of HORB outside corridor 4.

Outcome N8: Increased Microcystis

Clarifying Assumptions:

- Longer resident time and warmer temperatures will increase occurrence of Microcystis. Microcystis is present in August and Sept. Fish are not present at this time. However, this is a key water quality issue for M&I.

- Restoration will slow down water and heat up water temperatures. This might affect timing of microcystis bloom and etc. Microcystis occurs in turning basin and part of the Stockton ship channel. Tidal marsh could worsen the microcystis situation.

Scientific Justification:

Magnitude: N/A to fish but see above re: M&I. Microcystis does occur near Stockton DWSC. **Not scored by group.**

Certainty: Not scored by group.

Outcome N9: Increased Exposure to Selenium

Clarifying Assumptions:

- Higher residence times of water in critical habitats can lead to selenium exposure.
- Selenium is bio-accumulated by clams.
- More opportunities for selenium to get into food chain from those fish that eat clams.

Scientific Justification:
Higher concentrations of San Joaquin River water (as compared to Sacramento River water) would lead to higher concentrations of selenium. Residence time is the mechanism. If the clams have a higher selenium concentration, this is not an issue for salmon. However, bioaccumulation in sturgeon will reduce reproductive capacity. Sturgeon have already past the selenium threshold.

For Corridor 4, delivering selenium to the Bay Area is a concern, so allowing bioaccumulation may prevent distribution downstream. This might be a "sink" for selenium.

Magnitude: For most fish **Low "2"**. However for **salmon** magnitude is a **Minimal "1".**

Certainty: Minimal to Low "1-2".

Outcome N10: Increased Mercury Methylation

Scientific Justification:
Sub-tidal and open water will facilitate photo-demethylation. High marsh would be more of a problem.

Magnitude: Minimal to Low "1".

Certainty: For fish, certainty is **High "4".**

Note, for other species, certainty would be Minimal "1"; however this is not directly applicable to today's evaluation.

Outcome N11: Increased Mobilization or Re-suspension of Toxics (including pesticides)

Clarifying Assumptions:

- Increased residence time creates higher probabilities for re-suspension.
- Corridor is likely a sink for toxics.

Scientific Justification:
Corridor #4 is adjacent to urbanized areas. There is runoff from urban neighborhoods as well as I-5.

Note: Stockton has raw sewage overflow into Mosher Slough, and Stockton DWSC. The northern part of this corridor might experience this issue, but that is speculation; nothing definitive. In general, urban land-use is something to be aware of. Fish kills along dead end sloughs in Stockton might be related to sewage spills. BDCP-related restoration will not change those sorts of issues. There is high population density along the eastern bank. Will these urban uses impact the fish?

Recommendation: In future planning, examine runoff into Corridor 4 and evaluate potential for water quality impacts

Magnitude: Not scored by group.

Certainty: Not scored by group.

OBJECTIVE: RESTORE HABITATS AND RIVER CONDITIONS (I.E., THE MAGNITUDE AND DIRECTION OF FLOW IN FLUVIAL REGIMES) THAT FAVOR SURVIVAL AND GROWTH OF JUVENILE SALMONIDS, STURGEON, DELTA SMELT, LONGFIN SMELT, AND OTHER NATIVE FISHES

Potential Positive Ecological Outcomes

Outcome P16: Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)
Clarifying Assumptions: Compare assumptions stated for Corridor 1A to Corridor 4
Scientific Justification: The right bank protects the adjacent urbanized area. Because of the location of Corridor 4, it is more constrained than Corridor 1A. However, the channel is fairly wide. **Magnitude:** Score is **Medium "3"** **Certainty:** Score is **Medium "3"**

Potential Negative Ecological Outcome(s)

Outcome N12: Establishment of Invasive Species (SAV, Clams, invasive competitors)
Scientific Justification: See 2009 DRERIP **Clam - Magnitude all fish species:** Compared to other sites, Corridor 4 will have more scour. The habitat in this region is generally in very poor condition. **Minimal "1".** **SAV Magnitude all fish species**: **Low "2".** **SAV & Clams Certainty:** We have high certainty that clams and SAV will invade and low certainty that this will impact the fish species. **Low "2".**

OBJECTIVE: REDUCE ENTRAINMENT MORTALITY OF JUVENILE SALMONIDS, SMELT, STURGEON, SPLITTAIL, AND OTHER NATIVE FISHES

Potential Negative Ecological Outcome(s)

Outcome Nx: Entrainment

(Note: entrainment was not scored for any of the other corridors because of a lack of data. While entrainment was conceptually-evaluated and was scored for this corridor, it was not used in the rollups because the other corridors do not have scores for entrainment.)

Clarifying Assumptions:

- For this particular habitat, it is assumed that HORB will be installed. HORB might prevent entrainment?
- During wet years, there will be pumping from the north Delta facilities.
  If the barrier at head of Old River (HORB) is operational year-round, this is different than Scenario 6. Scenario 6 assumed that 50% leaky between June to October. Unintended consequences for smelt?

Scientific Justification:

HORB in place, so San Joaquin River salmon are OK, but other fish may suffer. More modeling is needed to look at the entrainment issue.

Magnitude for corridor 4: **Minimal to Low “1-2”.**

Certainty for corridor 4: It’s been analyzed a lot, **Low “2”.**

DATA GAPS & KEY UNCERTAINTIES

Data Needs:

- M&I water quality impacts from restoration

Key Uncertainties and Research Needs:

- Examine runoff into Corridor and evaluate potential for water quality impacts
- Analyze the effects of the HORB and integrate into the corridor evaluations. Need to look at potential negative effects of HORB outside corridor 4.
- The marsh at the downstream end of the corridor will have longer residence times. There are low levels of DO in the Stockton DWSC and any increase in organic matter loading will be contributing to this problem. The proximity of this corridor to the Stockton DWSC is a concern. RWQCB would like to see some modeling about the potential impacts for this water quality concern. A mitigating effect is greater velocities due to the increase in the tidal prism.
- The South Delta could have significant negative outcomes for delta and longfin smelt depending on the actual configuration of flood and ecosystem restoration actions.

Scoring Summary

Corridor 4

Species Name	With HORB				*WithOUT HORB*			
	WORTH		RISK		WORTH		RISK	
Corridor Score (Habitat; Physical Process)	High	2.7	High	3.0	--	--	--	--
Salmonids	High	2.7	Med	2.0	--	--	Med	2.0
Splittail	Med	2.0	--	--	--	--	--	--
Green sturgeon	Low	1.0	--	--	--	--	--	--
White surgeon	Med	1.5	--	--	--	--	--	--
Delta smelt	Low	1.0	--	--	--	--	--	--
Longfin smelt	Low	1.0	--	--	--	--	--	--
	Med	1.7	High	**3.0**	#DIV/0!	#DIV/0!	Med	**2.0**

Scoring Key

WORTH	High	
	Medium	
	Low	
RISK	Low	
	Medium	
	High	

Scoring Weights

Value between..	..and	Rank
1	1.5	Low
1.5	2.5	Med
2.5	3	High

		Corridor variations:	With HORB		With HORB			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		Is Outcome Applicable?	CORRIDOR SCORING		WORTH		RISK	
Standard Outcome Code	Outcome (brief descriptor)	(1=yes, 0=no)	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.								
P1	Increased Frequency of Inundation		2	4	High	3		
N1	Increased Stranding		2	4			Low	1
OBJECTIVE: Increase the extent and connectivity of tidal marsh.			**3**	**2**	**Med**	**2**		
N7	Increased Mortality Due to Water Quality Degradation (including water temperature, DO, eutrophication)		3	1			High	3
N9	Increased Exposure to Selenium		2	2			Med	2
N10	Increased Mercury Methylation		1	4			Low	1
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.						FALSE		
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)		3	3	High	3		
P17	Increased Terrestrial Invertebrates	0				FALSE		
N12clam	Establishment of Invasive Species (Clams)		1	2			Med	2
N12SAV	Establishment of Invasive Species (SAV)		2	2			Med	2
XX	**ENTRAINMENT**		1	2	With HORB			
					WORTH		RISK	
					High	**2.7**	High	**3.0**

		With HORB		WithOUT HORB		With HORB				WithOUT HORB			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		SALMONID SCORING		SALMONID SCORING		WORTH		RISK		WORTH		RISK	
Standard Outcome Code	Outcome (brief descriptor)	Magnitude	Certainty	Magnitude	Certainty	Grade	Numeric	Grade	Numeric	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.													
P3	Increased Rearing Habitat for Salmon	3	3			High	3				FALSE		
OBJECTIVE: Increase the extent and connectivity of tidal marsh.													
P7	Increased Rearing Habitat for Salmon	3	2			Med	2				FALSE		
N9	Increased Exposure to Selenium	1	2	1	2			Med	2			Med	2
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.													
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	3	3			High	3				FALSE		
P17	Increased Terrestrial Invertebrates						FALSE				FALSE		
N12	Establishment of Invasive Species (SAV, Clams, invasive competitors) (need to separate clams, competition, and SAV)								FALSE				FALSE

SCORING with SLR				SCORING without SLR			
WORTH		RISK		WORTH		RISK	
High	2.7	Med	2.0	#DIV/0!	**#DIV/0!**	Med	2.0

		Corridor variations:	With HORB		With HORB			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		Is Outcome Applicable?	SPLITTAIL SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	(1=yes, 0=no)	Magnitude	Certainty	Grade	Numeric	Grade	Numeric
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.								
P2	Increased Spawning Habitat for Splittial		3	3	High	3		
OBJECTIVE: Increase the extent and connectivity of tidal marsh.								
P6	Increased Spawning Habitat for Splittial		2	2	Med	2		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.								
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)		1	1	Low	1		

SCORING with SLR			
WORTH		RISK	
Med	2.0	#N/A	0.0

		With HORB		With HORB			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		GREEN STURGEON SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
OBJECTIVE: Increase the extent and connectivity of tidal marsh.							
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	1	1	Low	1		

SCORING with SLR					
WORTH			**RISK**		
Low	●	**1.0**	#N/A	●	**0.0**

		With HORB		With HORB			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		WHITE STURGEON SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecological-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
OBJECTIVE: Increase the extent and connectivity of tidal marsh.							
P12	Increased rearing habitat for white sturgeon	2	2	Med	2		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	1	1	Low	1		

SCORING with SLR			
WORTH		**RISK**	
Med	**1.5**	#N/A	**0.0**

		With HORB		With HORB			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		DELTA SMELT SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
OBJECTIVE: Increase the extent and connectivity of tidal marsh.							
P8	Increased spawning habitat for Delta smelt	1	1	Low	1		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	1	1	Low	1		

SCORING with SLR					
WORTH			**RISK**		
Low	🔴	**1.0**	#N/A	🟢	**0.0**

		With HORB		With HORB			
Standarized Outcomes for South Delta Corridors DRERIP Evaluations		LONGFIN SMELT SCORING		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	**Magnitude**	**Certainty**	**Grade**	**Numeric**	**Grade**	**Numeric**
OBJECTIVE: Increase the extent ofecologically-relevant floodplain habitat to support reproduction and viability of Sacramento splittail and Chinook salmon & Steelhead.							
OBJECTIVE: Increase the extent and connectivity of tidal marsh.							
P10	Increased spawning habitat for longfin smelt	1	2	Low	1		
OBJECTIVE: Restore habitats and river conditions (i.e., the magnitude and direction of flow in fluvial regimes) that favor survival and growth of juvenile salmonids, sturgeon, delta smelt, longfin smelt, and other native fishes.							
P16	Increased Channel Complexity (including in-channel and channel margin riparian vegetation, LWD, and emergent vegetation)	1	1	Low	1		

With HORB					
WORTH			**RISK**		
Low	🔴	**1.0**	#N/A	🟢	**0.0**

Is it worthwhile?

		Certanity			
		1	2	3	4
Magnitude	1	***Low***	***Low***	***Med***	***Med***
	2	***Low***	***Med***	***Med***	***High***
	3	***Med***	***Med***	***High***	***High***
	4	***Med***	***High***	***High***	***HIgh***

How Risky is it?

		Certanity			
		1	2	3	4
Magnitude	1	***Med***	***Med***	***Low***	***Low***
	2	***High***	***Med***	***Med***	***Low***
	3	***High***	***High***	***Med***	***Med***
	4	***High***	***High***	***High***	***Med***

Roll-up weights

Value between..	..and	Rank
1	1.5	Low
1.5	2.5	Med
2.5	3	High

Scientific Evaluation Worksheet

Evaluation Team: Betty Andrews (ESA PWA, coach), Mark Tompkins (NewFields River Basin Services), Mike Archer (MBK Engineers), Michael Mierzwa (DWR), Joe Bartlett (DWR), Samson Haile-Selassie (DWR), Ray McDowell (DWR), Scott Woodland (DWR), Steve Cimperman (DWR), Chris Neudeck - Feb 1 only (KSN, Inc.), Bob Scarborough (DWR, Feb 2 only) Minta Schaefer (ESA PWA, note taker), Lucy Croy (NewFields River Basin Services, modeling support, Feb 1 only)

Date: February 1 and 2, 2012

Note: Magnitude and certainty scoring is tracked in an accompanying Excel spreadsheet. Criteria for scoring magnitude and certainty are described within the South Delta Flood Evaluation Instructions, which can be found in Section 7.6, Methods and Materials for Modified-DRERIP, Flood, Terrestrial Species, and Water Quality Evaluations, of the BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description and Assessment Document. The results of the flood evaluations are provided in Section 4.2.2, Summary of Flood Evaluations, of the Corridor Description and Assessment Document.

Assumptions:

- SLR assumption is reasonable for a screening-level analysis
- We are comparing existing to proposed with and without-SLR, rather than looking at the impact of SLR on existing conditions
- The flood objective area (FOA) is defined as the San Joaquin River from Mossdale to Stockton, Old River between the San Joaquin and Middle Rivers and Paradise Cut.

FLOOD OUTCOMES – MODEL RUN A

Outcome P1F: Decreased Stage	Outcome N1F: Increased Stage
Justification for scoring: • Under with- and without-SLR conditions, minimal WSE decreases throughout the FOA of <0.5 feet. • WSE decreases of up to 5.74 feet (per model results in spreadsheet form) in upstream-most 15.5 miles of the San Joaquin River, which is upstream of the FOA. • A magnitude of 1 was chosen because WSE decreases within the FOA were less than 0.5 feet. • A certainty of 4 was chosen because the understanding is high for flood hydraulics. Model results seem to logically predict the attenuation of WSE that would be expected to occur in the upper portion of the San Joaquin River under corridor conditions. The minimal WSE decreases throughout the FOA are also logical based on professional judgment. • Additionally, a certainty of 4 was chosen because the difference between the with-SLR and without-SLR results on the San Joaquin River from Vernalis to Mossdale is negligible. • A scale of large was chosen because decreases in stage described above are observed throughout the FOA and beyond. • The magnitude, certainty, and scale assigned to the without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.	**Justification for scoring:** • Minimal WSE increase of approximately 0.02 feet at Mossdale (per model results in spreadsheet form). • A magnitude of 1 was chosen because WSE increase was less than 0.5 feet. • A certainty of 3 was chosen because while the understanding for flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, the modeling precision does not exist to support a high level of certainty. • A scale of small was assigned because increases in stage occurred within a portion, but not most, of the FOA. • The magnitude, certainty, and scale assigned to the without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.

FLOOD OUTCOMES – MODEL RUN B

Outcome P1F: Decreased Stage	Outcome N1F: Increased Stage
Justification for scoring: • WSE decreases of up to 1.8 feet in the FOA along Paradise Cut (up to 1.5 feet under with-SLR conditions), up to 2.6 feet along the San Joaquin River and Old River of up to 2.25 feet under with and without-SLR conditions. • Comparable WSE decreases extend upstream and downstream of FOA throughout the modeled reaches with the exception of a portion of the San Joaquin River as described under Outcome N1F. • When comparing model runs B and D, they are similar in magnitude through FOA, but there is a far greater reduction upstream of FOA in model run D. • A magnitude score of 3 was chosen because decreases in stage were in between 1.5 and 3 feet in the FOA and exceeded 2.5 feet outside of the FOA. • A certainty of 4 was chosen because the understanding is high for flood hydraulics. Model results seem to logically predict the attenuation of WSE that would be expected to occur under corridor conditions. • A scale of large was chosen because decreases in stage are observed throughout the FOA and beyond. • The magnitude, certainty, and scale assigned to the without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.	**Justification for scoring:** • WSE increases within the FOA of up to approximately 3.2 feet along the downstream-most 22,000 feet of the San Joaquin River. Could be biased by boundary effects. The distance to the maximum impact is approximately 13,000 feet or 2.5 miles from the downstream boundary. Under with-SLR conditions, WSE increases of up to approximately 2.4 feet. • A magnitude score of 4 was chosen because increases in stage are potentially difficult to mitigate due to existing infrastructure (e.g., Hwy 4, railroad, wastewater treatment plant ponds, and urban development). The ship channel and turning basin could provide additional conveyance if flows could be successfully routed through the constricted area just upstream. • A certainty score of 3 was chosen because while the understanding of flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, boundary effects may be influencing the model result. • A scale of small was assigned because increases in stage occurred within a portion, but not most, of the FOA. • The magnitude, certainty, and scale assigned to the without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.

FLOOD OUTCOMES – MODEL RUN C

Outcome P1F: Decreased Stage	Outcome N1F: Increased Stage
Justification for scoring: • WSE decreases within the FOA of up to 1.25 feet along the San Joaquin River, 0.9 along and Old River, and 0.85 feet along Paradise Cut. Under with-SLR conditions, WSE decreases up to 1.25 feet along the San Joaquin River, 0.85 along Old River, and 0.8 feet along Paradise Cut. • Under with and without-SLR conditions, WSE decreases of up to 5.8 feet in upstream-most 16 miles of the San Joaquin River, which is upstream of the FOA. • All other reaches have WSE decreases of less than 0.5 feet. • A magnitude score of 2 was chosen because decreases in stage were in between 0.5 and 1.5 feet. • A certainty score of 4 was chosen because the understanding is high for flood hydraulics. Model results seem to logically predict the attenuation of WSE that would be expected to occur under corridor conditions. • A scale of large was chosen because decreases in stage are observed throughout the FOA and beyond. • The magnitude, certainty, and scale assigned to the without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.	**Justification for scoring:** • Outcome N1F is not applicable to Model Run C.

FLOOD OUTCOMES – MODEL RUN D

Outcome P1F: Decreased Stage	Outcome N1F: Increased Stage
Justification for scoring: • WSE decreases within the FOA are up to 2.6 feet in the San Joaquin River, up to 2.25 feet along Old River, and up to 1.75 feet along the upstream-most 2.7 miles of Paradise Cut. Under with-SLR conditions, WSE decreases of up to 2.5 feet along the San Joaquin River, up to 2.25 feet along Old River, and 1.65 feet along Paradise Cut. • Under with and without-SLR conditions, WSE decreases of up to 5.75 feet in upstream-most 16 miles of the San Joaquin River, which is upstream of the FOA. • WSE decreases along Middle River of up to 1.85 feet. • All other reaches have WSE decreases of less than 0.5 feet. • When comparing model runs B and D, they are similar in magnitude through FOA, but there is a far greater reduction upstream of FOA in model run D. • For without-SLR conditions, a magnitude score of 4 was chosen because stage decreases exceed 3 feet within the FOA. For with-SLR conditions, a magnitude score of 3 was chosen because stage decreases within the FOA are in between 1.5 and 3 feet. • A certainty score of 4 was chosen because the understanding is high for flood hydraulics. Model results seem to logically predict the attenuation of WSE that	**Justification for scoring:** • WSE increases within the FOA of up to approximately 2.4 feet along the downstream-most 27,000 feet of the San Joaquin River. Could be biased by boundary effects. The distance to the maximum impact is approximately 13,050 feet or 2.5 miles from the downstream boundary. This result also applies to the with-SLR condition. • There may be potential for the ship channel and turning basin to accommodate flows. • WSE increases of up to 0.5 feet within the downstream-most 4.5 miles of Paradise Cut. • WSE increases within Grant Line Canal of up to 0.8 feet under without-SLR conditions. • A magnitude score of 4 was chosen because increases in stage are potentially difficult to mitigate due to existing infrastructure (transportation corridors, wastewater treatment plant ponds, and urban development). • A certainty score of 3 was chosen because while the understanding of flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, boundary effects may be influencing the model result. • A scale of small was assigned because increases in stage occurred within a portion, but not most, of the FOA. • The magnitude, certainty, and scale assigned to the

Outcome P1F: Decreased Stage	Outcome N1F: Increased Stage
would be expected to occur under corridor conditions. • A scale of large was chosen because decreases in stage are observed throughout the FOA and beyond. • The certainty and scale assigned to the without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.	without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.

FLOOD OUTCOMES – MODEL RUN E

<table>
<tr><th>Outcome P1F: Decreased Stage</th><th>Outcome N1F: Increased Stage</th></tr>
<tr><td>
Justification for scoring:

WSE decreases within the FOA of up to approximately 1.9 feet along the San Joaquin River, 2 feet along Old River, and 2.5 feet along Paradise Cut. Under with-SLR conditions, WSE decreases within the FOA of up to approximately 1.9 feet along the San Joaquin River, 2.2 feet along Old River, and 2.6 feet along Paradise Cut.
Comparable WSE decreases extend upstream and downstream of FOA throughout the modeled reaches with the exception of a portion within Old River as described under Outcome N1F.
A magnitude score of 3 was chosen because stage decreases are in between 1.5 and 3 feet within the FOA.
A certainty score of 4 was chosen because the understanding is high for flood hydraulics. Model results seem to logically predict the attenuation of WSE that would be expected to occur under corridor conditions.
A scale of large was chosen because decreases in stage are observed throughout the FOA and beyond.
The magnitude, certainty, and scale assigned to the without-SLR condition as well as the basis for those designations also apply to the with-SLR condition.

</td><td>
Justification for scoring:

Up to a 2-foot increase without-SLR and approximately 0.75-foot increase with-SLR along lower Old River.
Could be biased by boundary effects. The distance of the maximum impact is 4,300 feet or 0.8 miles from the boundary.
Mitigation would likely have relatively few constraints in this non-project levee, non-urban setting. Uncertainty exists about such factors as soil types and the scope of infrastructure modifications, etc.
A magnitude score of 2 was chosen for without-SLR conditions because stage increases are expected to be mitigable with moderate investment. A magnitude score of 1 was chosen for with-SLR conditions because stage increases are expected to be mitigable with minor investment.
A certainty score of 3 was chosen for both the with-SLR and without-SLR conditions because, while the understanding of flood hydraulics is high and the model results seem to logically predict hydraulics under corridor conditions, boundary effects may be influencing the model result.
A scale of 0 was chosen because the location was smaller than the definition of small in the scale criteria.

</td></tr>
</table>

FLOOD OUTCOMES – MODEL RUN F

Outcome P1F: Decreased Stage	Outcome N1F: Increased Stage
Justification for scoring: • WSE decreases within the FOA of up to approximately 2.1 feet along the San Joaquin River, 2.4 feet along Old River, and 2.1 feet along Paradise Cut. Under with-SLR conditions, WSE decreases within the FOA of up to approximately 2.0 feet along the San Joaquin River, Old River, and Paradise Cut. • A magnitude score of 3 was chosen because stage decreases are in between 1.5 and 3 feet within the FOA. • A certainty score of 4 was chosen because the understanding is high for flood hydraulics. Model results seem to logically predict the attenuation of WSE that would be expected to occur under corridor conditions. • A scale of large was chosen because decreases in stage described above are observed throughout the FOA and beyond. • The magnitude, certainty, and scale assigned to the without-SLR condition as well as the basis for those designations apply to the with-SLR condition.	**Justification for scoring:** • Large increase at downstream boundary along Middle River of up to approximately 5.25 and 4.0 feet without and with-SLR, respectively. • Could be biased by boundary effects. The distance of the maximum impact is 28,700 feet or 5.4 miles from the downstream boundary. • Uncertainty about levee overtopping potential downstream of Corridor 3. • Mitigation potential, but may require large investment due to the spatial extents of the improvements that may be needed. • A magnitude score of 4 was chosen because stage increases are large and extensive and mitigation may require significant investment. • A certainty score of 3 was chosen for both the with-SLR and without-SLR conditions because it is very likely that boundary effects are influencing the model result. • A scale of 0 was chosen because the location was smaller than the definition of small in the scale criteria.

DATA GAPS, KEY UNCERTAINTIES, NEW IDEAS, AND SUGGESTIONS FOR FUTURE SOUTH DELTA PLANNING

Data Needs *(indicate specific models, DLO relationships, or other information indicating the need):* See Section 5 of the BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description and Assessment Document.
Key Uncertainties and Research Needs *(describe specific research activities that could be employed to increase understanding):* See Section 5 of the BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description and Assessment Document.
Important New Ideas or Understandings *(describe these items here):* See Section 5 of the BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description and Assessment Document.
Potential corridor re-configurations (or corridor combinations) to increase the worth /decrease the risk of potential implementation. Also add comments on any restoration design considerations. *(Describe those new configurations or changes here):* See Section 5 of the BDCP South Delta Habitat and Flood Corridor Planning, Corridor Description and Assessment Document.

Scoring Summary
Flood Evaluations

Model Run	SCORING			
	WORTH		RISK	
A	Med	2.0	Low	1.0
A with SLR	Med	2.0	Low	1.0
B	High	3.0	High	3.0
B with SLR	High	3.0	High	3.0
C	High	3.0	--	--
C with SLR	High	3.0	--	--
D	High	3.0	High	3.0
D with SLR	High	3.0	High	3.0
E	High	3.0	Med	2.0
E with SLR	High	3.0	Low	1.0
F	High	3.0	High	3.0
F with SLR	High	3.0	High	3.0

Scoring Key

WORTH	High	
	Medium	
	Low	
RISK	Low	
	Medium	
	High	

Scoring Weights

Value betw	..and	Rank
1	1.5	Low
1.5	2.5	Med
2.5	3	High

BLUE INDICATES A SCORING CHANGE

		Corridor variations:		Without SLR		With SLR	
Standarized Outcomes for South Delta Corridors Flood Evaluations		Is Outcome Applicable?		CORRIDOR SCORING		CORRIDOR SCORING	
Standard Outcome Code	**Outcome (brief descriptor)**	(1=yes, 0=no)	Scale (S,M,L)[1]	Magnitude	Certainty	Magnitude	Certainty
Model Run A							
P1	Reduced stage in flood objective area	1	L	1	4	1	4
N1	Increased stage in flood objective area	1	S	1	3	1	3
Model Run B							
P1	Reduced stage in flood objective area	1	L	3	4	3	4
N1	Increased stage in flood objective area	1	S	4	3	4	3
Model Run C							
P1	Reduced stage in flood objective area	1	L	2	4	2	4
Model Run D							
P1	Reduced stage in flood objective area	1	L	4	4	3	4
N1	Increased stage in flood objective area	1	S	4	3	4	3
Model Run E							
P1	Reduced stage in flood objective area	1	L	3	4	3	4
N1	Increased stage in flood objective area	1	0	2	3	1	3
Model Run F							
P1	Reduced stage in flood objective area	1	L	3	4	3	4
N1	Increased stage in flood objective area	1	0	4	3	4	3

[1] **When the affected area is smaller than the definition of "small" per the spatial scale criteria described in the flood evaluation instructions, a value of zero is used.**

		CORRIDOR SCORING				CORRIDOR SCORING			
		Without SLR				With SLR			
		WORTH		RISK		WORTH		RISK	
Standard Outcome Code	**Outcome (brief descriptor)**	Grade	Numeric	Grade	Numeric	Grade	Numeric	Grade	Numeric
Model Run A						**Model Run A**			
P1	Reduced stage in flood objective area	Med	2			Med	2		
N1	Increased stage in flood objective area			Low	1			Low	1
Model Run B						**Model Run B**			
P1	Reduced stage in flood objective area	High	3			High	3		
N1	Increased stage in flood objective area			High	3			High	3
Model Run C						**Model Run C**			
P1	Reduced stage in flood objective area	High	3			High	3		
Model Run D						**Model Run D**			
P1	Reduced stage in flood objective area	High	3			High	3		
N1	Increased stage in flood objective area			High	3			High	3
Model Run E						**Model Run E**			
P1	Reduced stage in flood objective area	High	3			High	3		
N1	Increased stage in flood objective area			Med	2			Low	1
Model Run F						**Model Run F**			
P1	Reduced stage in flood objective area	High	3			High	3		
N1	Increased stage in flood objective area			High	3			High	3

South Delta Flood and Habitat Planning

Screening Evaluation Process for Evaluating Terrestrial Habitat

The BDCP covers approximately 60 terrestrial species. The charter for the South Delta Habitat Working Group requests that DRERIP evaluators seek to identify opportunities within the corridors for creating habitat for terrestrial species, including waterfowl, to the extent practicable.

Clearly, changes in the landscape as assumed for the South Delta under "corridor conditions" would have an influence on terrestrial habitat for the BDCP covered terrestrial species. However, evaluation of potential outcomes for terrestrial species in the assumed South Delta corridors is difficult because the site-specific planning for riparian restoration and other revegetation (active or passive) and an assessment of terrestrial landscape evolution in the corridors is not to be completed in this initial screening-level evaluation of the conceptual South Delta corridors. Further, there are no DRERIP conceptual models for the BDCP terrestrial species. For these reasons, scoring outcomes for terrestrial species is not possible in the full DRERIP evaluation process.

To support further thinking and consideration of the potential outcomes for terrestrial species, there is utility in assessing terrestrial *habitat* as surrogates for the many species that use them. The process below identifies issues and concerns associated with four of the assumed corridors in the South Delta, as identified by state and federal fish and wildlife agencies and the BDCP consultant team.

At this stage of screening-level evaluation of the corridors, it is important to gain a better understanding of how terrestrial habitat may change, what sorts of key questions and uncertainties surround these changes, and what are the data gaps. Additionally, gaining input on restoration design criteria and considerations related to habitat configuration in restoring terrestrial habitat in the corridors is also important to gain at this time so that it can be integrated into future planning and design at the corridor- and sub-corridor-level. Such meso- and micro-scale design consideration is important for future planning work, which would focus upon increasing the level of design for a single corridor or a combination of corridors based on the outcomes of this evaluation and the previously-completed DRERIP evaluations for species and flood.

INSTRUCTIONS:

In the following tables, develop responses to the prompts. Support this work with process-based outcomes from Section 4 of the Corridor Documents, as appropriate. All input should be focused upon terrestrial habitat; however, note any instances where there is a potential interaction with aquatic species that is not being covered by the full DRERIP evaluations of those species. In completing the tables, consider that the charter for the South Delta Habitat Working Group specifies an assessment of several additional hypothetical considerations relative to the corridors. These considerations should be integrated into the evaluation of each corridor, in the tables below, in whichever category is appropriate. Not all may be applicable to terrestrial species; if not, mark as N/A.

1. How 55 inches of sea level rise (assumed to occur by the end of the century) influences flooding and ecological outcomes.

2. How the corridors will perform if several islands in the central and west Delta are permanently inundated in the future (note which islands may have a particular influence and/or are being assumed in the evaluation).
3. How the corridors may be consistent with a barrier at the head of Old River, or how it can achieve the same or better benefits without the barrier or with a barrier open more of the time than currently planned.
4. How the corridors might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants.

Also, assess the corridor to determine if its implementation would have the potential to change system dynamics (either within the Delta or as inputs to the Delta) beyond the existing range conditions (i.e. change in inflows to the Delta, modified hydrodynamic conditions, or salinity regimes) such that the current understanding of how the system works may no longer hold. Consider how the changes may affect the ability to evaluate the corridor using the recommended models methods in response #5.

Evaluators Names:

Nat Seavy (PRBO Conservation Science), Tom Griggs (River Partners), Ron Melcer (DWR FESSRO), Laura Cholodenko (CDFG), Ellen Berryman (ICF), Heather Webb (USFWS), Lori Rinek (USFWS), Michael Hoover (USFWS), Rebecca Sloan (ICF), Neil Clipperton (CDFG), Amy Richey (Mosaic Associates), Junko Hoshi (CDFG), Judy Bendix (Mosaic Associates). ***Bruce DiGennaro, Facilitator; Eric Ginney, Coach; Minta Schaefer, note-taker.***

NOTE: Corridors 3 & 4 were not explicitly examined during these evaluations for a variety of reasons. On their own, these corridors (3 and 4) were deemed less-important to key terrestrial species as they would not meet the needs of some specific species. However, in combination with other corridors, Corridors 3 & 4 could meet the needs of specific species. Lack of time also was a factor on the decision to initially focus evaluations on corridors other than 3 & 4. However, many of the 'general' comments and issues related to Corridors 1A/B and 2A/B may be applicable to Corridors 3 and 4.

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Items Common to Corridors 1A/B, 2A, and 2B

Key Potential Issues Applicable to Corridors 1A/B, 2A, and 2B	Habitat Loss and Impacts to Species/Natural Communities a) If levee removal would include loss of riparian vegetation, it could adversely affect woodrat refugia and Swainson's hawk habitat; potentially migratory songbirds, too. However, this would presumably only be a short term negative effect. b) Loss of agriculture could depress conditions for species that use wildlife compatible agriculture. This concern is countered by the fact that many types of habitat restoration considered for the corridors would restore the native habitats that these species originally relied upon prior to Euro-American habitat conversion to agriculture. The nexus with existing HCPs is another, related issue. However, removal of agriculture in some areas could benefit the ecosystem as well and should be considered. Reduction in the amount and allocations of certain agricultural chemicals that find their way into the water would potentially benefit the ecosystem, as well as elimination or reduction in the unscreened pumping of water from South Delta water ways. Based on a rough overlay of the BDCP habitat suitability models and the conservation actions outlined for the South Delta corridors, it appears these listed species could be impacted: riparian brush rabbit, riparian woodrat, San Joaquin kit fox, townsend's big-eared bat, California black rail, California least tern, greater sandhill crane, least bell's vireo, Swainson's hawk, tricolored blackbird, western burrowing owl, western yellow-billed cuckoo, white-tailed kite, yellow-breasted chat, western pond turtle, California red-legged frog, California tiger salamander, western spadefoot toad, valley elderberry longhorn beetle, California linderiella, caper-fruited tropidiocarpum, delta button-celery, Mason's lilaeopsis, Delta mudwort, and slough thistle. There wasn't enough time for each species to be addressed for this review deadline, but eventually each species will need to be analyzed critically through this process. Here are some initial thoughts by species for consideration: • Riparian brush rabbit – Identify the potential of higher use corridors utilized by the

		RBR with Patrick Kelly and others from ESRP; consider that in addition to taking into consideration the potential for future establishment and expansion. San Joaquin kit fox – Are the areas identified as overlap with the species habitat suitability models, areas where they are broken from identified movement corridors? SAIC has mentioned in the past that some of the habitat near Clifton Court Forebay would not be accessible to the kit fox, yet is modeled as suitable habitat in the species models. Best to verify. • Greater sandhill crane – Do any of these corridors fall into the high density/risk areas identified by Gary Ivey? What is the breakdown of ag types being considered in these various corridor options? • Swainson's hawk – Similarly to the crane, what is the breakdown of ag types being impacted? • Valley elderberry beetle – *May need to address how* modification of the existing *flooding* regime (inundation frequency and duration) of the San Joaquin River floodplain may *influence* valley elderberry beetle including its host plant *elderberry shrubs* (*Sambucus spp.*) and associated vegetation. Species/Natural community • Which covered species/natural communities (NCs) and other sensitive species appear on each corridor unit? • For each relevant covered species/NC identified above, which key conservation factors for each species/NC would be strongly influenced by the corridor restoration for each corridor and for each scenario considered in the modeling processes? • What are the expected species/NC responses to the influence identified above? • Which responses identified above are positive, negative, or neutral, and which

	ones are critical? <u>Multiple Species</u> • How will a conclusion on the net benefit of each corridor to the system be determined, which would become a basis to choose preferred corridors and the restoration actions? • All the habitats and their interactions with covered species should be included in a determination of value if a corridor analysis is to be completed. If a corridor is evaluated for terrestrial species effects it also needs to be evaluated for its effects on aquatic species and vice versa. • How will consideration of positive and negative effects on covered species be considered in any decision process related to habitat restoration in the South Delta? <u>Vegetation Management</u> c) In areas where levees and/or riprap will be removed for setbacks and the channel margin habitat is assumed to be generated via "passive restoration," invasive species may colonize the fresh, alluvial soils. d) If disturbance is used to meet the 1,000 acre early successional riparian habitat goal, there is potential for invasive vegetation to colonize disturbed areas. e) What are the likely invasive species to colonize the site? What methods and measures can be taken to reduce seed sources and occurrence of non-target non-species prior to, during, and after construction? Overall, to reduce the likelihood of invasive species colonization on site, active vegetation management (weed control and/or active revegetation) should be considered before, during and after physical modifications (e.g. grading, levee removal). What are the target vegetation associations following restoration? What species are likely to recruit

	on their own? What species will need to be actively revegetated?
<u>**Outstanding Uncertainties Applicable to Corridors 1A/B, 2A, and 2B**</u>	<u>Uncertainties Applicable to Corridors 1A/B, 2A, and 2B</u> <u>Planning and Land Use</u> a) Are there any conflicts between the development of the corridors and the NMFS recovery goals, or USFWS Recovery goals for species and habitats including but not limited to giant garter snake, kit fox, vernal pools? *(Consultant team notes: they were in part considered as input for corridor development).* b) Are there any conflicts between development of corridors and permitting/recovery processes related to habitat restoration/flood management actions in the South Delta, including existing biological opinions, and SWRCB, Corps of Engineers and EPA permits? Are there any conflicts between corridors and the San Joaquin Council of Governments Habitat Conservation Plan (2000)? c) Consider including information from other existing permits, plans and decisions within and adjacent to the South Delta Habitat Restoration area. These include but are not limited to Contra Costa County HCP/NCP, East Alameda County Conservation Strategy, CVPIA, Joint Venture, French Camp Conservation Bank, Pace Preserve, Bushy Creek Conservation Bank, Byron Conservation Bank, Haera Wildlife Conservation Bank, and the San Joaquin Wildlife Refuge Management Plan? Check the plan area to determine if any of these or other local plans apply. d) Are there agriculture and/or other conservation plans within the corridor? If so, they should be reviewed for potential conflicts. e) How do proposed actions relate to Central Valley Joint Venture habitat objectives for the delta?

	<u>Wildlife-Compatible Agriculture</u> f) What types of agricultural lands are currently in this corridor? *(Consultant team notes: see corridor document for these data*). What benefits do they provide birds? What habitat will new flood tolerant agricultural lands provide for birds, if such lands are incorporated into the restoration design at a later phase? <u>Ecohydraulics/Ecohydology and Geomorphology</u> g) What will the river stage be in relation to the restored floodplain, tidal, riparian and channel margin habitats? (*Consultant team notes: such stage/discharge relationships are specific to each and every river cross section or location. Such data is available from the team's modeling; a location must simply be identified to make the query*). Will the frequency and timing of inundation provide meaningful/significant habitat quantity and quality for the covered BDCP species? h) To what extent does the corridor provide water depth and inundation diversity on the floodplain? BDCP covered species require a diversity of terrestrial habitats, which are supported by certain inundation frequencies. Species also require infrequently inundated areas for refuge from flooding. i) To what extent does inundation in each corridor allow for meeting BDCP objectives for habitat protection and restoration in the South Delta and the assumptions for where habitat will be restored? j) Do larger, more-scouring types of flows occur in certain corridors which would facilitate the maintenance of early succession riparian vegetation? Certain flows may have larger potential for sustaining early succession vegetation which may allow BDCP to rely on more passive management. How does the receding hydrograph affect seed dispersal, plant regeneration and rooting period (e.g., if flows recede too quickly)? k) Do we have a good understanding of the expected outcomes of the abiotic components

	including hydrologic/geomorphic responses related to inundation duration, distribution, frequency, intensity, or sediment load composition and distribution patterns, and so on? l) Do we have some understanding for the vegetation responses to these abiotic shifts? If so, what are these? Are we using or are we going to use these assumptions consistently in BDCP analysis? m) Is it possible to get regular disturbance by fluvial process within the various corridors? Note that soil type and elevation analyses were conducted by SAIC that may help to answer this question. <u>Invasive Vegetation and Predation</u> n) Will creation of tidal wetland areas in the South Delta create areas with warmer, shallow water where submerged aquatic vegetation (SAV) will grow and predators will frequent? o) Do larger more scouring types of flows occur in certain corridors which would expose larger amounts of unvegetated soils? Invasive species may colonize. <u>Impacts to Habitat</u> p) Will the corridors adversely affect habitat corridors and connected habitats necessary for species (GGS, riparian endemic avifauna)? q) Will the upstream impacts of habitat restoration early in BDCP make habitats in the South Delta worse before habitat restoration occurs? If so, what are the temporal estimates of effects on covered species from year 1 through 50? r) What are the impacts of additional watershed water uses within the San Joaquin River? This could further reduce the frequency and extent of inundation of any floodplain habitat. s) What are the expected shifts in range of each relevant covered species responding to the

	change in vegetation distribution following restoration and considering climate change? <u>Entrainment</u> t) Will productivity from new South Delta habitat restoration areas actually be more vulnerable to entrainment, and therefore become unavailable to native fishes? u) If in-river and in-Delta suspended-sediment is increased or decreased as a result of this habitat restoration, how might pelagic fishes respond? If they were more drawn into the South Delta would this effect entrainment? When might suspended-sediment be affected—at what flows and during what times of the year given the different restoration possibilities? <u>Contaminant/Water Quality Effects</u> v) Will creation of channel and floodplain habitat create sinks for selenium and other contaminants that could influence terrestrial and aquatic species? w) Will water temperatures in habitat areas in the South Delta become more detrimental to aquatic and terrestrial species (e.g., increased water temperatures could result in increased avian species diseases, reductions in the appropriate food sources, increased detrimental chemical synergies)?” Will potential degrading of instream habitat conditions create more prevalence of low dissolved oxygen and increased *Microcystis*? x) If tidal habitat is increased in the South Delta would salinity levels also increase in the adjacent channels? If so, how might that impact the ecology and agricultural/municipal users? y) Will any increases in nutrients from restoration areas exacerbate dissolved oxygen concerns at the Port of Stockton? z) Will methylmercury effects be fully addressed? aa) Will potential water quality concerns from adjacent urban areas be addressed?

	bb) Will the new floodplain habitat potentially increase or decrease turbidity concentrations downstream?
Hypotheses and Questions to Consider that are Applicable to Corridors 1A/B, 2A, and 2B	Questions Applicable to Corridors 1A/B, 2A, and 2B Levee Setbacks a) Do we need to remove the entire levees? Removing a greater amount of existing levee has increased impacts on existing habitats (e.g. riparian). This may also have species impacts (such as giant garter snake) in that under the present flooding regime, the levees may provide refuge from flood. Planning should consider this benefit. b) Do we understand the geomorphology of the San Joaquin River floodplain in this area enough to be able to determine how the river will react when the levees are setback? As a result of floodplain restoration actions will it be necessary to protect adjacent areas with additional revetment? Will these additional revetment actions be mitigated as are all other similar actions? c) If levees are not setback what would the restoration and the benefits look like (i.e., no action)? Habitat and Species Effects d) What is the residence time of the water after flooding? (Understood to be a site-specific factor addressed in design.) e) Given that the changes proposed in each corridor will likely have ecological winners and losers, are the overall changes such that on average, we are benefitting covered fish, wildlife and migratory birds (the CVJV habitat objectives are one way to measure this.) f) Will the specific effects be estimated for associated riparian endemic species including riparian brush rabbit, Swainson's hawk, white-tailed kite, yellow-breasted chat, yellow-billed cuckoo, and valley elderberry longhorn beetle (CNRA, 2010)?

	g) There is a BDCP objective to create 1,000 acres of early succession habitat. Which corridor would be best to obtain that? In order to make this recommendation, it's essential to understand corridor inundation frequencies, land elevations, soil and water quality, locations of upstream riparian seed sources, and if the action commitment includes any active restoration components. h) What are the target species for restoration within the restoration boundary? What survival and recruitment rates are needed outside and within the restored areas for these to act as corridors or sustain sensitive species populations within the floodplain? i) What are the survival rates and causes of mortality of target species? Do these vary intra-annually? j) Can buffers be added (e.g., predator barriers) to reduce edge effects?
Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions. All are Applicable to Corridors 1A/B, 2A, and 2B	Suggested Analyses Applicable to Corridor 1A/B, 2A, and 2B a) The riparian bird distribution maps developed by PRBO (Jongsomjit et al. 2007, available online here: www.prbo.org/cadc/lip) can provide baseline measurement of habitat quality for many riparian birds. b) 2- or 3-D hydrodynamic modeling, LiDAR elevation information and tidal/flow data, including climate change assumptions. Ad a minimum evaluation should included analysis of existing elevations, tidal/flow data and climate change assumptions. 2 or 3D modeling and LiDAR may be outside the scope of the existing screening assessment work that supported these evaluations. c) Analyze the heterogeneity of the floodplain topography and flood frequency to assess how much high ground there will be and how frequently various areas within the floodplain will be inundated. d) Complete particle tracking analysis for Head of Old River Barrier (HORB) in/out operations and

	habitat restoration impacts. Will habitat restoration effect Old and Middle River (OMR) flow criteria and entrainment? Will HORB operations effect OMR and entrainment? Is a particle tracking analysis the best method? e) It would be ideal to understand future fluvial processes/evolution of the river and floodplain as well as how existing riparian vegetation communities will respond to corridor actions. One way to address this is to develop a landscape-scale conceptual model for how the river, floodplain, and existing vegetation can be expected to evolve during and after the rehabilitation of inundated floodplain habitat. With this information, the value of that habitat for covered species can be evaluated using Suitability Indices (SIs) for representative species. This process would need to include fish and wildlife agency representation. Many if not most of these SIs are already being worked on in the BDCP process.
Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level. All are Applicable to Corridors 1A/B, 2A, and 2B	Suggestions for Restoration Design Applicable to Corridors 1A/B, 2A, and 2B BDCP Biological Goals and Objectives a) It is important for the goals of the Terrestrial Technical Team (TTT) for terrestrial species be considered in floodplain restoration planning in the South Delta. For example, if a corridor meets the total riparian acreage goal, does it also meet the species-specific habitat characteristics contained in the entire set of Goals and Objectives? A combination of large blocks of riparian is needed for certain bird species; certain topographic requirements are needed to protect riparian brush rabbit; spatial heterogeneity in vegetation structure is desired; etc. Which corridor or combination of South Delta corridors most-efficiently meets the BDCP Goals and Objectives, while still achieving the habitat requirements and the species needs? b) While other independent projects may arise, the BDCP BGOs of some covered species must be met within the 10,000 acres of floodplain restoration that occurs under BDCP. c) Consider how to reconcile the issue of immediate short term impacts to some species vs.

	long term benefits (i.e. riparian brush rabbit and woodrat). d) Opportunities that meet many of the BDCP biological goals and objectives identified for the South Delta are limited, so the associated conservation actions should be prioritized within the study area in order for BDCP to meet its obligations under the plan e) Some species, natural communities, and/or ecological processes have conflicting conservation needs. Analysis of the benefits and impacts to the system is needed as a basis to integrate the overall conservation approach. Much of this may be able to be resolved within the site specific designs. Vegetation f) Lateral and vertical heterogeneity are important in vegetation communities and should be incorporated into restoration design. g) If active planting becomes a component of restoration within the corridor, soils maps should be used in the process of determining the appropriate vegetation to plant. Wildlife-Compatible Agriculture h) Don't assume that agricultural lands don't have wildlife habitat value. Consult with Central Valley Joint Venture (CVJV) and others to ensure that conversion of agricultural fields to riparian or tidal marsh will not have unintended consequences on species including migratory birds. Work with CVJV to ensure that remaining "flood tolerant agriculture" in the corridors is also wildlife friendly, and that other goals, principles and objectives mentioned in the CVJV letter dated July 23, 2012 are considered in BDCP habitat restoration planning for the South Delta." Bird Communities i) Consult available literature on riparian restoration designs that provide the greatest

	benefits for the bird community (Gardali et al. 2010, RHJV 2004). Species-Specific Planning j) Technical experts should be involved in the development of restoration plans so that species-specific habitat requirements can be incorporated. Levee Setbacks k) Consider whether floodplain habitat restoration would necessitate more armored levees and their associated mitigations on reaches of the river in other locations, either upstream or downstream. In short, unintended adverse consequences outside the area of restoration. Placement of additional armored levees into any waterway of the Central Valley requires consideration and implementation of actions that would mitigate their impacts. Mitigation includes avoidance and minimization measures in addition to compensatory actions. BDCP quantifies and mitigates for the effects of levee building and armoring associated with restoration; however, requirements by the USACE and others may not be included in BDCP conservation. l) Levees or portions of levees can provide refugia from flooding for terrestrial species and this should be considered in restoration planning. Floodplain Processes m) If the floodplains cannot be inundated frequently enough, neither sediment nor biota would be mobilized accordingly—e.g., additional riparian vegetation will not reseed and serial stages of riparian vegetation would not be maintained for appropriate species and woody debris would not be transferred into the aquatic environment. Build floodplains to be inundated to attain these things. In addition, these inundation and associated habitat evaluations need to fully consider potential changes associated with climate change in the future.

	<u>Habitat Connectivity</u> n) Terrestrial habitats should be designed to link and be complimentary to existing and planned adjacent land uses. In doing so, consider the minimum patch sizes for the riparian brush rabbit and other species. <u>Marsh Habitat</u> o) BDCP covered terrestrial species require a diversity of tidal marsh elevations, not just regularly inundated low marsh (e.g., Black Rail will not likely use large expanses of marsh that are under water twice a day and there are many plant species that can't be inundated twice daily). <u>Ecohydrology</u> p) Consider the dynamics of the local hyporheic zone and the connection between the river and local groundwater as it relates to riparian vegetation. <u>Invasive Vegetation</u> q) Consider nutrient cycling (e.g., Scotch broom,), erosion and sedimentation rates (e.g., giant reed, Brazilian waterweed), and hydrologic regimes (e.g., giant reed, tamarisk). <u>Management After Implementation</u> r) Consider how much management will be necessary under an altered flow regime (i.e., potential changes to the SJRRP flow regime) and with the potential for invasive species colonization. s) How would long- and short-term management differ? <u>Infrastructure</u>

	t) Consider effects on existing infrastructure. <u>Economics</u> u) If existing agricultural lands are to be converted to habitat, the effect on the local tax-base should be considered in the decision making process. <u>Climate Change & Sea level rise</u> v) Consider projected sea level rise and estuarine transgression scenarios. At a minimum use web tools developed by PRBO to understand projected scenarios at project site. http://data.prbo.org/apps/sfbslr/ In addition, consider results of habitat evolution scenarios as developed by ESA-PWA as noted in August 24th, 2012 memo to ICF (ESA-PWA 2012). w) Consider expected impacts beyond sea-level rise, including shifts in precipitation patterns and water temperature on proposed restoration project location and actions. x) The SF Bay Sea-Level Rise Web Tool (Veloz et al. 2011; www.prbo.org/sfbayslr) can be expanded and calibrated to include bird modeling for the entire Bay-Delta for multiple species of concern (Black Rail, Song Sparrow, Common Yellowthroat, and Marsh Wren). Conservation prioritization and restoration recommendations should include information on multiple species and multiple scenarios to increase the probability of success over time (Veloz et al. 2012). Standard monitoring protocols for marsh species (http://www.wrmp.org/protocols.html) and appropriate demographic modeling tools (Nur *et al.* 2012) can be used to evaluate the effects of restoration with spatially-explicit models based on Bay Delta specific demographic data. y) What are the expected shifts in range of each relevant covered species responding to the change in vegetation distribution following restoration and considering climate change? z) Revegetation plant pallets should consider future climate conditions in species selection.

Worksheets Specific to Corridor 1A/B

Date: June 13, 2012

1. Process-based Outcomes	Outcomes Unique to Corridor 1A/B BDCP Goals and Objectives a) Actions within corridor 1 would likely be required to meet the goals and objectives of specific species, e.g. riparian brush rabbit and riparian woodrat. Corridor 1 may present opportunities to meet *early project timeline mitigation needs* because of the existing habitat and proximity to upstream San Joaquin River National Wildlife Refuge (SJRNWR). b) The upstream SJRNWR is a demonstration of restoration being feasible in this portion of the San Joaquin River it is also a good example of the difficulty in acquiring adequate water supply to provide for that habitat and the significance of extensive partnerships to assist in meeting any habitat management goals and objectives. c) Good opportunity to protect known occurrence of riparian brush rabbit, as per the plan's requirements. Riparian Habitat d) 750 acres of riparian habitat within Corridor 1 seems feasible based onthe overall size of the corridor, the existing land elevations that have riparian and the adjacent land areas at these elevations that are in agriculture but would appear viable as potential future riparian habitat. e) Corridor 1A currently has approximately 1,200 acres of riparian and 9,300 acres of agriculture. Under Corridor 1A, this would shift to approximately 8,200 acres of riparian and 3,500 acres of agriculture. These changes will have positive effect on the habitat that is available to fish and wildlife, including migratory birds in this region. f) This might be the only place where you can set the levees back as far as was considered in any

	of the corridors. Levee setbacks of this magnitude could potentially provide wide riparian corridors, which are critically important for meeting certain aquatic and most all of the terrestrial BGOs. <u>Habitat Connectivity</u> g) Potential connectivity to SJRNWR upstream - rare least bell's vireo breeding in SJRNWR and proposed expansion of reserve runs right along the southern boundary of Corridor 1. h) A riparian brush rabbit preserve is located within the riparian area at an oxbow of the SJR near Mossdale. This is a great place to expand 'preservation' and augment later for restoration. <u>Fluvial Processes</u> i) Evaluators had concern about channel avulsion from placement of a weir on the bend on the SJR at Walthall Slough; however, Walthall Slough is perched and risk may be less than perceived. j) There are remnants of natural fluvial morphology and some semblance of process (e.g., see DWR levee repair issues figure in corridor document); this is a positive indicator for the landscape-scale dynamics of this corridor. <u>Outcomes Applicable to Corridors 1A/B (2A and 2B, too)</u> k) Restoration of riparian habitat will improve conditions for riparian songbirds.
2. Key Potential Issues	<u>Issues Unique to Corridor 1A/B</u> <u>Existing Populations</u> a) There is a population of riparian brush rabbits near Stewart Tract. Care should be taken to not impact them with Corridor 1 actions.

	<u>Contaminant/Water Quality Effects</u> b) The creation of the channel and floodplain habitats that dissipate flows in the San Joaquin River could exacerbate water quality problems (e.g., dissolved oxygen) downstream, including at the Port of Stockton. 1. More frequent flooding any off-stream areas upstream of the Stockton ship channel will increase issues with dissolved oxygen. 2. Removal of the head of Old River barrier, in autumn, reduces flow volume and velocity in the San Joaquin River and has been estimated to increase the flushing time of the Stockton Ship Channel from days to weeks, contributing to a depletion of dissolved oxygen (Monsen 2007). This would be the same concern with a lower connection at Paradise Cut; however, the magnitude of flows on the SJR in the autumn would likely not connect with a lowered Paradise Cut weir (i.e., only larger-magnitude flood flows would be routed through a lowered weir)
3. Outstanding Uncertainties	<u>Uncertainties Unique to Corridor 1A/B</u> Nothing specific to just Corridor 1A/B.
4. Hypotheses and Questions to Consider	<u>Questions Unique to Corridor 1A/B</u> Nothing specific to just Corridor 1A/B.
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	<u>Suggested Analyses Specific to Corridor 1A/B</u> a) The Central Valley Joint Venture (CVJV) habitat objectives. The CVJV uses a collaborative, non-regulatory approach to provide wildlife habitat resources in a manner that also provides benefits such as improved water quality, flood control, and recreational opportunities. The 2006 implementation Plan ((http://www.centralvalleyjointventure.org/plans/) establishes conservation objectives (expressed as acres of habitat) for waterfowl, shorebirds, and riparian songbirds. In the Delta Basin, the 2006 Implementation Plan set a 5 year target of adding 1,100

	acres of riparian songbird habitat and enhancing 31,000 acres of rice fields. In the context of these targets, the proposed changes in Corridor 1A could provide a profound contribution to the riparian target, and could also contribute to the rice target if this was one of the flood compatible agricultural crops.
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	Suggestions for Restoration Design Specific to Corridor 1A/B a) It is important to have connectivity between existing habitat upstream within the area to be preserved and the rehabilitated areas within Corridor 1. b) Consider that the morphology of many areas of the San Joaquin River result in infrequent overbank flows with minimal riparian vegetation regeneration in many areas. c) Use the upstream SJRNWR as a case study for restoration in this portion of the San Joaquin River.
7. Data Gaps	a) Riparian Songbird Monitoring. To address the need for monitoring riparian songbird populations, PRBO, The Nature Conservancy, and Audubon California have designed and implemented a new regional monitoring program for riparian songbirds along the Sacramento and San Joaquin Rivers. By collecting information at fixed legacy sites and at randomly selected sites that are reselected each year taking into account changes in the distribution of potential habitat, this program has been designed to make inferences at a regional scale. However, it does not currently include the Delta. Expanding this program to include the Delta could provide a cost-effective means of measuring larger-scale response of riparian songbird populations to the BDCP management actions.

Worksheet Specific to Corridor 2A

Date: June 13, 2012

1. Process-based Outcomes	Outcomes Unique to Corridor 2A Relative to Other Corridors a) Corridor 2A provides less habitat area when compared to Corridor 1. Existing riparian in Corridor 2 is in a very narrow band and includes a lot of invasive vegetation. Refugia from Inundated Floodplains b) A potential negative outcome of Corridor 2A and/or connecting together Corridors 1 and 2A is that Corridor 2A may function in isolation (like a 'sink') for the riparian brash rabbit and other terrestrial species. Therefore, this corridor would need to be managed for the rabbit. Flood-Compatible Agriculture c) There is opportunity for flood compatible agriculture in this corridor (perhaps to a degree greater than in Corridor 1?). Habitat Connectivity d) Corridor 2A provides an east/west connection for flood flows, but would not be connected to riparian habitat downstream *without implementing other corridors*. It would be better for connectivity if upstream and downstream areas were restored as well.
2. Key Potential Issues	Issues Unique to Corridor 2A Refugia from Inundated Floodplains a) Some of the levees may need to be retained to provide refugia from flooding for riparian brush rabbit—homes, agriculture and freeways/railroads are the "habitat" outside the levees.

	<u>Predation</u> b) There may be potential increased predation by dogs and feral cats due to the planned housing encroachment on the northern side of the Paradise Cut. The narrow setback area increases this risk. <u>Contaminant/Water Quality Effects</u> c) If Corridor 2 included flood/wildlife-compatible agriculture, the type of crops and farming practices would need to be considered carefully to avoid pesticide and herbicide pollutant inputs and choosing crops that would reduce the quality of the floodplain habitat when inundated. d) Tidal flows may decrease in the San Joaquin River due to the north Delta Restoration. Phasing needs to be considered. e) Tidal habitat creation in Corridor 2B could additionally dampen tidal amplitude, causing increased temperature effects, increase salinity and probable decreases in oxygen levels. This could result in the need to release additional flows from upstream sources to meet water quality standards. This could also create problems for native aquatic species as a result of temperature increases, reduction in flows resulting in increased predator success rates and increased nonnative competitive species like SAV, largemouth/smallmouth bass, striped bass, etc. f) In addition, consideration should be given to calculation of the more long-term retention of San Joaquin River water on wetlands in the South Delta. Retention and evaporation of this water will increase the detrimental effect of chemical substances currently found in San Joaquin River water, including selenium, mercury, and agricultural, municipal and industrial chemical compounds. There are ample examples of adverse environmental effects of this sort of impact to terrestrial and aquatic resources in the South Delta.

3. Outstanding Uncertainties	<u>Uncertainties Unique to Corridor 2A</u> <u>Aquatic Foodweb</u> a) Will the “backwater” areas of Paradise Cut and the Fabian Tract create invasive predator areas and become a sink for native species? b) Will the “backwater” areas of Paradise Cut and the Fabian Tract create feeding and roosting areas for native covered terrestrial species? <u>Entrainment</u> c) Will increased frequency of Paradise Cut flow divert more downstream-migrating juvenile salmonids, which will then end up closer to the pumps and more readily entrained? The potential for entrainment of fish species (salmon, Delta smelt, longfin smelt, splittail, sturgeon) in the South Delta, even with a new dual conveyance system, may limit or constrain the potential for habitat restoration in the South Delta. <u>Urban Development</u> d) Will there be a development requirement for a buffer zone along the levee? Any recreational opportunity around levee? What will be the degree of access from the housing area to the levee and the floodplain?
4. Hypotheses and Questions to Consider	<u>Questions Specific to Corridor 2A</u> Nothing specific to just Corridor 2A.
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer	<u>Suggested Analyses Specific to Corridor 2A</u> Assess existing water quality information in the South Delta and incorporate into South Delta habitat

questions.	restoration design and decision processes. Especially for 2A and 2B as these areas are currently in cultivation and there are documented existing toxicity problems (Deanovic et. al. 1995).
6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	Suggestions for Restoration Design Specific to Corridor 2A Nothing specific to just Corridor 2A.
a) Data Gaps	a) Local or site-specific suspended sediment and organic accumulation rates. b) Delta-specific habitat relationships for Black Rail and other species. c) Delta-specific demographic data (abundance, survival and reproduction data) for species of interest.

Worksheet Specific to Corridor 2B

Date: June 13, 2012

1. Process-based Outcomes	Outcomes Unique to Corridor 2B BDCP Goals and Objectives a) Corridor 2B could provide a large portion of the 65,000 acre BDCP tidal marsh habitat requirement. However, this area is not currently incorporated into the BDCP marsh strategy. b) The benefits of corridor 2B are largely aquatic. Refugia from Inundated Floodplains c) Corridor 2B would need to be managed for certain terrestrial species to provide refugia from inundation, as appropriate. Bird Species d) By creating tidal marsh, the corridor could increase population sizes of California black rails and other bird species of concern and increase bird species diversity and bird population connectivity. Habitat Connectivity e) Corridor 2B would achieve greater connectivity if portions of Stewart Tract were to be included as a part of restoration actions. f) Migratory birds may benefit from such a connected corridor. Habitat for Specific Species g) Corridor 2B could potentially provide habitat for pond turtle, California black rail, Delta

	mudwort. <u>Factors Influencing Outcomes</u> h) Extent of sea-level and suspended sediment availability will strongly affect outcomes. i) Proximity of urban areas may have a strong influence.
2. Key Potential Issues	<u>Issues Unique to Corridor 2B</u> <u>BDCP Goals and Objectives</u> a) Could this area be a tradeoff with northern areas (e.g., Yolo Bypass) for certain waterfowl habitats? See CVJV for zones; is this a factor? Is the South Delta a place where BDCP can be more flexible because it is not such a high priority for BDCP? b) Will creation of tidal wetland areas in the South Delta create areas of warmer, shallow water where submerged aquatic vegetation (SAV) will grow and predators will frequent? c) Low population sizes <u>may mean</u> that even if quality habitat is created, individuals may not recruit. Sea-level rise and low sediment availability may impede marsh formation (Stralberg et al. 2011). Some concern about the “near-linear shape of the [restoration] areas” maximizing edge effects and access to predators, making the areas a potential predator trap. <u>Contaminant/Water Quality Effects</u> d) Tidal flows may decrease in the San Joaquin River due to the north Delta Restoration. Phasing needs to be considered. e) Tidal habitat creation in Corridor 2B could additionally dampen tidal amplitude, causing increased temperature effects, increase salinity and probable decreases in oxygen levels. This could result in the need to release additional flows from upstream sources to meet water quality standards. This could also create problems for native aquatic species as a result of

	temperature increases, reduction in flows resulting in increased predator success rates and increased nonnative competitive species like SAV, largemouth/smallmouth bass, striped bass, etc.
3. Outstanding Uncertainties	Uncertainties Unique to Corridor 2B Aquatic Foodweb a) Will "backwater" areas of Paradise Cut and the Fabian Tract create predator sink areas? b) Will "backwater" areas of Paradise Cut and the Fabian Tract create feeding and roosting areas for native covered terrestrial species? Urban Development c) Will there be a development requirement for a buffer zone along the levee, recreational opportunity around levee, the degree of access from the housing area to the levee and the flood plain?
4. Hypotheses and Questions to Consider	Questions Specific to Corridor 2B Marsh Habitat a) What levels of suspended sediments and sea-level rise may result in suitable marsh habitat for target species?

5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	Suggested Analyses Specific to Corridor 2B a) Assess agricultural operations and water use/returns relative to terrestrial species usage of this corridor in terms of fertilizers/biocides. b) Consider how expansion of this corridor to include portions of Stewart Tract may increase the functions and values of this corridor.

6. Suggested restoration design criteria and considerations that are important to integrate into future planning and design at the corridor- and sub-corridor-level	Suggestions for Restoration Design Specific to Corridor 2B a) Maximize tidal exchange. b) Augment site elevation with clean dredged material to speed marsh vegetation colonization and improve resilience to sea level rise. c) Promote tall, dense vegetation for cover and nesting. d) Plan for SLR (increased inundation, landward marsh migration) in the tidal marsh/upland ecotone. e) Provide refugia from inundation for terrestrial species, particularly the riparian brush rabbit. f) Consider inclusion of Stewart Tract. g) Using the South Bay Salt Ponds as an example, there may be a tradeoff of shallow open water and restoration to the tidal marsh (good for different species). The tradeoffs need to be examined. Also, Yolo BP example and the waterfowl folks' concern with marsh as related to waterfowl benefits.
7. Data Gaps	a) Local or site-specific suspended sediment and organic accumulation rates. Delta-specific habitat relationships for black rail and other species. Delta-specific demographic data (abundance, survival and reproduction data) for species of interest.

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South Delta Flood and Habitat Planning

Process for Evaluating Water Quality for Municipal, Industrial and Agricultural Uses

Changes in water quality in the assumed South Delta "corridor conditions" have an influence on aquatic species and human uses. The effects on aquatic species are covered by the DRERIP evaluations, with outcomes listed for each of the key species being evaluated. The evaluation of potential changes in water quality and how they may influence the use of water in the South Delta for municipal, industrial and agricultural uses[1] is covered by the modified-DRERIP evaluation process described below.

Evaluation of potential water quality changes that may occur in the assumed South Delta corridors is difficult because multi-dimensional hydrodynamic modeling dedicated to assessing water quality is not to be completed in this initial screening-level evaluation of the conceptual South Delta corridors. Further, there is no DRERIP conceptual model for M&I/Ag water quality. For these reasons, scoring outcomes for water quality are not possible in the formal DRERIP evaluation process. Additionally, the evaluation of water quality is complicated by conflicting benefits and detriments associated with certain changes in anticipated water quality. Therefore, this screening-level evaluation of the corridors seeks to promote a better understanding of: 1) key process-based changes, 2) potential issues, 3) outstanding questions and uncertainties, and 4) data gaps. Systematically developing a greater understanding of these items for each corridor will support development of appropriate technical investigations in any future planning work, which would focus upon a single corridor or a combination of corridors based on the outcomes of this evaluation and the DRERIP evaluations for species and flood.

INSTRUCTIONS FOR REVIEWERS:

In the following tables, develop responses to the prompts. Support this work with process-based outcomes from Section 4 of the Corridor Documents, as appropriate. All input should be focused upon M&I/Ag water quality; however, note any instances where there is a potential interaction with covered species. In completing the tables, consider that the charter for the South Delta Habitat Working Group specifies an assessment of several additional hypothetical considerations relative to the corridors. These considerations should be integrated into the evaluation of each corridor, in the tables below, in whichever category is appropriate. Not all may be applicable to water quality; if not, mark as N/A.

1. How 55 inches of sea level rise (assumed to occur by the end of the century) influences flooding and ecological outcomes.
2. How the corridors will perform if several islands in the central and west Delta are permanently inundated in the future (note which islands may have a particular influence and/or are being assumed in the evaluation).
3. How the corridors may be consistent with a barrier at the head of Old River, or how it can achieve the same or better benefits without the barrier or with a barrier open more of the time than currently planned.

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[1] Hereto, any reference to water quality in this evaluation worksheet is in relation to M&I and Agricultural uses unless otherwise noted.

4. How the corridors might perform under a condition where Old or Middle Rivers are isolated from the influence of the South Delta pumping plants.

Also, assess the corridor to determine if its implementation would have the potential to change system dynamics (either within the Delta or as inputs to the Delta) beyond the existing range conditions (i.e. change in inflows to the Delta, modified hydrodynamic conditions, or salinity regimes) such that the current understanding of how the system works may no longer hold. Consider how the changes may affect the ability to evaluate the corridor using the recommended models methods in response #5.

Evaluators Names:

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Overview

The following is an overview of the June 13th working group discussion with respect to water quality. This overview provides a summary of water quality issues that are relevant to potential restoration action within all corridors, in general. More-detailed consideration for each of the corridors is provided in subsequent sections, using the original worksheet provided for evaluators.

The general overview is broken down into a series of themes relevant to water quality and restoration:

- Theme 1: Changes in the Concentration of Organic Carbon
- Theme 2: Changes in the Concentration of Salts and Elemental Constituents
- Theme 3: Changes in the Occurrence and Concentration of Planktonic Algae and Cyanobacteria
- Theme 4: Changes in Nutrient Concentration
- Theme 5: Other Considerations

THEME 1: CHANGES IN THE CONCENTRATION OF ORGANIC CARBON

Restoration of wetlands is generally considered likely to increase the load of organic carbon (including particulate organic carbon [POC] and dissolved organic carbon [DOC], which is collectively known as total organic carbon [TOC] which includes particulate and dissolved fractions) exported from restored areas, potentially resulting in increased organic carbon concentrations in affected portions of the Delta.

Effects on Beneficial Use

Municipal: DOC and TOC are critical parameters with respect to municipal use. Specific DOC fractions, especially humic acids and other plant or soil derived material, are precursors to drinking water disinfection byproducts (DBPs). Elevated carbon levels can substantially affect the cost of water treatment.

Organic carbon in not generally considered a constituent of concern for industrial service users that utilize water for cooling purposes. Industrial users that utilize water in support of human food production may require cleaner water that has lower salt, nutrient, and organic matter content. However, such industrial users are commonly served via municipal water delivery systems, rather than as direct diverters.

Agriculture: Organic carbon concentration is not a concern for agriculture. However, sediment controls on agricultural practices/discharges have been generally unsuccessful in trapping DOC. Studies have shown that elevated DOC concentrations can increase the mobility of pyrethroid pesticides, and can also increase their desorption, thereby causing increased risk of pesticide exposure for aquatic organisms in the water column.

Habitat: Increasing levels of organic carbon associated with new wetlands is generally regarded as being beneficial with respect to ecosystems, with the assumption being that increased carbon is at least in part “bioavailable”, and thus could support Delta food webs. Stated another way, increases in net primary productivity can drive increases in DOC concentration, which is generally considered to be beneficial to ecosystems.

Restoration Design Considerations

- Plant species and planting density chosen for wetland restoration may have important effects on the export rate of organic carbon, based on the extent to which produced organic carbon is bioavailable, and/or may contribute to the formation of drinking water disinfection by-product (DBPs). Some prior case studies may be important data sources for evaluating these types of effects.

- Note that not all organic carbon forms DBPs. However, the sources of DBP-forming organic carbon are not well known on a fine scale – i.e., it is not known the extent to which specific plant or algal species contribute or do not contribute to DBP-forming organic carbon such that a comprehensive list of species to be used or avoided can be developed.

- Organic carbon quality is an important consideration. Need to consider if good-quality food and habitat are occurring concurrent with any elevated organic carbon levels, and to consider their role in any ecosystem benefits. Significant increases in organic carbon levels that have low bioavailability may not be as helpful as smaller increases in organic carbon levels that have high bioavailability.

- Organic carbon exported from leaching of surface sediments, also wetland and algal production. Thus, organic carbon export rates are affected by soil type/percentage of peat, and duration of inundation; however, it is not clear how long these leaching-type effects would continue following the completion of restoration and the concentrations may decrease with time. This may be a critical consideration for land areas that have not been inundated for a long time. More research here seems warranted.

- Careful wetland design, accounting for organic carbon considerations, is critical; this includes the location of levee breaches on islands planned for inundation.

- Organic carbon export from floodplain restoration areas may be less detrimental than tidal wetlands because floodplain restoration areas would only export significant amounts of carbon during high flow events. During such events, organic carbon is diluted by the high flows.

- Organic carbon modeling may be completed using DSM2. However, more spatially explicit results, such as from a 2D hydrodynamic model, may be warranted.
- See also discussion regarding phytoplankton bloom conditions.
- **Recommended Study: Factors Influencing the Bioavailability and DBP Formation Potential of Organic Carbon Produced by Restored Wetlands**

  Organic carbon is an important source of energy to Delta food webs, but also contributes to the formation of disinfection byproducts during municipal water treatment processes. Organic carbon is not a single constituent or molecule type, but a wide array of different compounds and chemicals, some of which are available to organisms and food webs, some of which are not. Also, Delta research has shown that select fractions of organic carbon contribute to the formation of DBPs, while others do not. Therefore, it is in the best interests of the proposed restoration effort to identify and implement those restoration practices that maximize the production of beneficial organic carbon that can support food webs, and minimize the production of detrimental organic carbon that results in DBP formation. The study should assess the extent to which specific plant or algal species contribute or do not contribute to the production of bioavailable organic carbon and DBP-forming organic carbon. A list of preferred restoration species and species to be avoided would be developed. Additionally, assemblages of individual species or habitat types may be generally more beneficial (less detrimental) in terms of the quality of organic carbon produced. The study should identify opportunities and procedures for the implementation restoration practices that support the production of bioavailable organic carbon and minimize the production of DBP-forming organic carbon. Doing so would help ensure that the proposed restoration is effective in terms of habitat quality and also drinking water quality.

THEME 2: CHANGES IN THE CONCENTRATION OF SALTS AND ELEMENTAL CONSTITUENTS

Restoration and flood management actions considered within the corridors could affect the concentration of salts within affected waters. Changes in salt concentration could occur as a result of changes in hydrodynamics, or as a result of leaching from re-inundated land areas exposed to Delta waters, especially in areas where soil-borne concentrations of salts are already elevated. Changes in flow, especially flow reductions, could lead to elevated salt concentrations. Some areas (discussed in the corridor-specific sections, below) are suspected sources for salt discharge in the South Delta, including dairy related discharges and salty groundwater inflow. Reduction in flow in areas where these already-salty inputs occur would lead to a net increase in the concentration (but not the load) of salts in these areas, which would affect water quality.

Effects on Beneficial Use

Municipal: Salt concentration is a critical parameter with respect to municipal use. Elevated salt levels can only be practicably dealt with via dilution. Total dissolved solids concentrations of less than 500 mg/L are preferred for municipal applications, although the maximum tolerable value is somewhat variable based on the availability of higher quality water for blending/dilution.

Industrial: Salts that include high levels of calcium and magnesium (hard water) may contribute to increased scaling and buildup in certain industrial facilities (especially boilers and heating equipment), requiring the use of anti-scaling additives, blending with other waters, and other measures to mitigate scale formation.

Agriculture: Salt concentration is a critical parameter with respect to agricultural use. Salt tolerance varies depending upon the crop or agricultural use in question, with select crops showing sensitivity to salt concentrations at about 500 mg/L. Above this value, additional crop species may be affected. Lower salt concentrations are preferred overall, because elevated concentrations can have an incremental effect on crop yield. Non-enforceable limits of 500 mg/L have been recommended by CVSALTS, but such limits have not been ratified.

Habitat: Salt concentration has variable effects with respect to habitat value, and has varying effects on different species that occur in the Delta. Concentrations above 1-2 parts per thousand may be detrimental to some freshwater species. Long term or chronic changes in salt concentration have the potential to affect ecological community structure. This is particularly true for harmful algal blooms (HABs). Cyanobacteria typically have a higher tolerance or a wider range of tolerance for salt than other desirable phytoplankton. Increased salt concentrations could thereby result in increased incidence or severity of HAB incidence.

Restoration Design Considerations

- Specifics of restoration activities, including levee removal, are important. The location and manner of levee breaches will inform water quality results, as will changes in flows with respect to salts.
- Marine sediments may or may not leach salts, although leach rate is likely to decrease over time. Map of marine sediments would be useful in support of planning and other analyses with respect to salt.
- Balance between land retirement and salt reduction is of interest, especially with regard to modeling.

THEME 3: CHANGES IN THE OCCURRENCE AND CONCENTRATION OF PLANKTONIC ALGAE AND CYANOBACTERIA

Implementation of the restoration and flood management actions considered within the corridors could result in changes in flow regime and other changes. This could result in changes in the occurrence and concentration of planktonic algae and cyanobacteria within affected areas. Reductions in flow rates, either due to blockage of flows or widening of channels, could result in warmer water surface temperatures, which could in turn support phytoplankton blooms including harmful algal blooms (HABs), such as *Microcystis* blooms.

Effects on Beneficial Use

Municipal: Algal blooms are a critical concern for potable water. HABs can result in odor and taste problems for municipal water supplies. Some forms of HABs can result in the production of toxic chemicals, such as microcystin. In addition, some studies have expressed concern that certain types of treatment (i.e., chlorination) could lyse algal cells, thereby exposing toxins that otherwise may not have been released. Also, when large mats of algae are formed, clogging of equipment can occur, which results in increased operation and maintenance costs for pumps and pumping infrastructure.

Industrial: Planktonic algae and cyanobacteria concentrations are generally not of high concern for most industrial users that maintain direct diversions from Delta waters. However, during significant bloom conditions, clumps of cyanobacteria can clog water intake pumps and pumping equipment, which results in increased operation and maintenance costs.

Agriculture: Algal blooms are generally of low concern for agricultural use. However, under major bloom conditions, toxins (microcystin and others) produced by the blooms can have toxic effects on livestock.

Habitat: Algal productivity is a critical concern with respect to habitat value. Insufficient algal productivity can lead to limited energy entering the Delta food web – phytoplankton production is critical to the Delta food web. Cyanobacteria may have reduced food value in comparison to other phytoplankton. Too much algal production is also a concern. Excessive bloom conditions can lead to low dissolved oxygen concentrations, while blooms of certain types of phytoplankton can result in the production of toxic compounds, which can be directly toxic to fish and wildlife.

Restoration Design Considerations

- Avoid marsh designs that are shallow, wide, and have a long residence time and are slow-draining, especially when only one inlet-outlet is present, or with "dead-end" designs. Such conditions would promote excessive algal blooms.
- Details regarding flow regime/hydrodynamics are important. If a dead-end design is necessary, some potential adverse issues could probably be mitigated via design, if carefully considered. For example, design a marsh area prone to only limited algal blooms by eliminating shallow, hot, and long-residence-time restoration areas. Mildred Island presents an interesting example.

- Especially in dead-end designs, a very high or low tide event could result in the flushing of strongly elevated levels of algae coming out of a restoration area. Daily tidal cycles may support a more reasonable export load when considering water quality modeling results because the results from very high or low tide events (with more-adverse outcomes) are anomalous and water treatment facilities can be managed to avoid diversion at those isolated times.
- Constrained levee breaches may function similar to a dead-end design.
- Careful breach/wetland design is critical.

THEME 4: CHANGES IN NUTRIENT CONCENTRATION

Implementation of the restoration and flood management actions considered within the corridors could result in a net change in the occurrence and availability of select nutrients. Nutrients support primary productivity. Low nutrient levels can have a dampening effect on primary productivity, while excessively-high nutrient levels can lead to a considerable increase in the occurrence of phytoplankton bloom conditions (discussed previously). Nutrients in the Delta that are critical to achieving ideal levels of primary productivity include nitrate, ammonia, organic nitrogen, phosphate, and total phosphorous.

Effects on Beneficial Use

Municipal: Except in extreme cases, nutrients are not a critical concern with respect to municipal water quality, but may be a moderate concern. Elevated nutrient levels support algal bloom or eutrophic conditions, which are generally considered detrimental to water quality. Elevated nutrient levels can also contributed to elevated growth rates for nuisance plants (i.e., Egeria densa), which can clog pumps and associated infrastructure, resulting in increased operation and maintenance costs. At very high concentrations (>10 mg/L as N), nitrate can be harmful to human health. However, levels of nitrate this high are not anticipated to occur as a result of implementing the restoration and flood management actions considered within the corridors.

Industrial: Elevated levels of nutrients are not a key concern for most industrial users.

Agriculture: Elevated levels of nutrients are generally of low concern for agricultural use. However, elevated nutrient levels can contribute to elevated growth rates for nuisance plants (i.e., *Egeria densa*), which can clog agricultural pumps.

Habitat: Elevated nutrient levels are generally of moderate concern for direct effects with respect to habitat. However, elevated nutrient levels can support algal blooms or eutrophication. Excessive algal blooms can be detrimental to habitat value, as discussed previously. Over time, elevated nutrient levels can lead to changes in community structure and the distribution of select species may be affected.

Restoration Design Considerations

- Careful breach/wetland design is critical.
- As applicable, in areas where elevated nutrients may be anticipated, implementation of restoration activities or features that could promote algal blooms should be avoided.

THEME 5: OTHER CONSIDERATIONS

Various other water quality considerations are also relevant to the proposed restoration actions, and should be considered within the framework of ongoing BDCP evaluations. These include the potential for generation of methylmercury, potential reductions of dissolved oxygen, and other key water quality constituents, which were evaluated in the previously completed DRERIP evaluations.

Corridor 1A

1. Process-based Outcomes	This corridor contains primarily floodplain areas and is along a primary migration route for salmonids (Section 4.1.1). Pulses of organic carbon could be discharged during a flood event (typically December-May), but such discharges would be limited in duration and would be subject to dilution because of the relatively-high flow rates (Table 4.1.3a, Section 4.1.1.2). Changes to organic carbon outside of flood periods would be less than for corridors with a large proportion of proposed tidal wetlands.
2. Key Potential Issues	In comparison to corridors with a larger proportion of tidal/submerged wetlands, restoration effects on municipal and industrial and agricultural water quality in this corridor would be comparatively small. Downstream water quality conditions may be an issue because increased production of organic matter (total organic carbon and phytoplankton/primary production) may contribute to low dissolved oxygen conditions in the Stockton DWSC.
3. Outstanding Uncertainties	Land use within the corridor and its influence on export of biocides, fertilizers and fuels during flood events when non-habitat areas may become inundated. Land use changes are occurring upstream along the mainstem of the San Joaquin River, for instance, the 1,600 acre Dos Rios Ranch, which is proposed for flood control and natural riparian areas, and 50 acres proposed as a wetland mitigation bank by the City of Manteca. The potential effects of such land use changes and restoration on downstream water quality remain unknown.
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	Further assessment and evaluation is merited with respect to effects on downstream water quality.
6. Changes in system dynamics that alter current understanding of the system	

7. Data Gaps	Potential management actions in Corridor 1A could have unknown effects on dissolved oxygen concentrations in the Stockton DWSC, due to potential for increased algal production or the production of other oxygen demanding substances. Potential flow changes in the mainstem San Joaquin River as a result of changes in the San Joaquin River Restoration Program and the State Board's San Joaquin River flow objectives, as well as the BDCP Project/proposed pumping, also represent significant data gaps.

Corridor 1B

1. Process-based Outcomes	This corridor contains primarily floodplain areas and is along a primary migration route for salmonids (Section 4.1.1). Pulses of organic carbon could be discharged during a flood event (typically December-May), but such discharges would be limited in duration and would be subject to dilution due to high flow rates. Changes to organic carbon outside of flood periods would be less than for corridors with a large proportion of proposed tidal wetlands.
2. Key Potential Issues	In comparison to corridors with a larger proportion of tidal/submerged wetlands, restoration effects on municipal and industrial and agricultural water quality in this corridor would be comparatively small. Downstream water quality conditions may be an issue because increased production of organic matter (total organic carbon and phytoplankton/primary production) may contribute to low dissolved oxygen conditions in the Stockton DWSC.
3. Outstanding Uncertainties	Land use within the corridor and its influence on export of biocides, fertilizers and fuels during flood events when non-habitat areas may become inundated. Land use changes are occurring upstream along the mainstem of the San Joaquin River, for instance, the 1,600 acre Dos Rios Ranch, which is proposed for flood control and natural riparian areas, and 50 acres proposed as a wetland mitigation bank by the City of Manteca. The potential effects of such land use changes and restoration on downstream water quality remain unknown.

4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	Further assessment and evaluation is merited with respect to effects on downstream water quality.
6. Changes in system dynamics that alter current understanding of the system	
7. Data Gaps	Potential management actions in Corridor 1A could have unknown effects on dissolved oxygen concentrations in the Stockton DWSC, due to potential for increased algal production or the production of other oxygen demanding substances. Potential flow changes in the mainstem San Joaquin River as a result of changes in the San Joaquin River Restoration Program and the State Board's San Joaquin River flow objectives, as well as the BDCP Project/proposed pumping, also represent significant data gaps.

Corridor 2A

1. Process-based Outcomes	Corridor 2A essentially functions as a dead end slough during times when San Joaquin River distributary flows are not spilling through the Paradise Cut Weir. Flood flows occur relatively-rarely, so this dead-end slough configuration is the norm, not the exception. There is considerable salt buildup in the low-water channels of this corridor, also elevated algae bloom conditions and toxicity. Dairy waste on left bank was also mentioned.
2. Key Potential Issues	Key sources of salt buildup include groundwater, dairies, and possibly other industrial uses as applicable (i.e., in and around the Sugar Cut area). There may also be high existing rates of algal growth in Paradise Cut, under existing conditions. This could be exacerbated or potentially mitigated depending on the approach to reconfiguration and management. If BDCP adds low flows through Paradise Cut, this could export an increased load of water quality pollutants to municipal water supply pumps. *(Note: such a low-flow connection has not been discussed previously and is not a likely component of future South Delta corridor planning).*
3. Outstanding Uncertainties	Typical concentration of algae in this corridor; specific sources of salt loading, which may include saline groundwater, dairy wastes, and effluent from a sugar facilities and other industry; agricultural pumping of water from the river and its storage in Paradise Cut as a stilling basin for local irrigation—and this inundation and return flows as a source of water quality degradation through the export of concentrated salts, nutrients, etc. during times of low flow (summer/irrigation season).
4. Hypotheses and Questions to Consider	Because water quality is poor in this area, especially with respect to salt concentrations, are there other opportunities to benefit water quality/mitigate salt concentrations that could be implemented?
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	Further assessment and evaluation is merited, especially with a better understanding of the existing sources of salts and nutrients, and their fate and transport within the South Delta.
6. Changes in system dynamics that alter current understanding of the system	

7. Data Gaps	

Corridor 2B

1. Process-based Outcomes	Breaching of levees could result in a dead-end waterbody condition, which could result in elevated algal blooms, temperature, and organic carbon concentration. How an inundated Fabian Tract would function without levees in terms of hydrodynamic and water quality processes is of particular importance. Increases in intertidal and subtidal habitat could increase the tidal prism and could also increase salinity
2. Key Potential Issues	Design of levee breaches and restoration approach is critical. Flow-through design may be preferred, or depending on hydrodynamics, measures could possibly be implemented that would reduce effects of a dead-end waterbody. If dead-end waterbody effects are not mitigated or avoided, this could be detrimental to municipal water supplies and possibly habitat values. Some dairy lagoons drain directly into Paradise Cut. These are potential sources of organic carbon, salts, and nutrients. However, note that such discharges are prohibited and illicit. Anticipated future enforcement actions are anticipated to reduce nutrient loading associated with dairy lagoons that drain directly into Paradise Cut. Land use in Fabian Tract is primarily agricultural. Opening up this area to Delta flows could result in this area becoming a potential source of sediment bound nutrients and pesticides, which could be detrimental to municipal water suppliers and to aquatic life.
3. Outstanding Uncertainties	The hydrodynamics of an inundated Fabian Tract is a key uncertainty.
4. Hypotheses and Questions to Consider	Sensitivity analysis of breach locations is an important consideration.
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	Further assessment and evaluation is merited, especially with respect to levee breach design and wetland design, and associated effects on water quality.
6. Changes in system dynamics that	Sensitivity analysis of breach locations is an important consideration. Cause and effect “water quality

alter current understanding of the system	outcomes" or "entrainment outcomes" at the pumps may no longer hold true depending on if and how the levees on Fabian Tract were to be breached and the island inundated.
7. Data Gaps	

Corridor 3

1. Process-based Outcomes	Breaching of levees could result in a dead-end waterbody condition (low flow, high residence time), which could result in elevated algal blooms, temperature, and organic carbon concentration. Probably lower potential for dead-end waterbody conditions at Corridor 3 as compared to Corridor 2B. Flow split between Old and Middle Rivers is also a concern. Pushing too much water down Middle River is not a good idea due to flooding (not so much water quality). Also if Middle River is deepened upstream, this could cause/support increased flooding downstream, where Middle River constricts. Fine to push more water through Grant Line Canal with respect to flooding, but not Middle River.
2. Key Potential Issues	Design of levee breaches and restoration approach is critical. Flow-through design may be preferred, or depending on hydrodynamics, measures could possibly be implemented that would reduce effects of a dead-end waterbody. If dead-end waterbody effects are not mitigated or avoided, this could be detrimental to municipal water supplies and possibly habitat values.
3. Outstanding Uncertainties	
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	Further assessment and evaluation may be merited, especially with respect to levee breach design and wetland design, and associated effects on water quality.
6. Changes in system dynamics that alter current understanding of the	

system	
7. Data Gaps	

Corridor 4

1. Process-based Outcomes	Water quality effects in a restored Corridor 4 will likely have a strong nexus with the hydrodynamic influence (and water quality conditions of) the Stockton Deep Water Ship Channel (DWSC). Breaching of levees in Corridor 4 could result in a "dead-end waterbody condition", which could result in elevated algal blooms, temperature and organic carbon concentration, and decreased dissolved oxygen.
2. Key Potential Issues	Nexus with Stockton DWSC. For aquatic uses, dissolved oxygen concentrations may be an issue if organic carbon is transported downstream to the Stockton DWSC. For municipal uses, increased levels of organic carbon could be a potential issue.
3. Outstanding Uncertainties	Land use changes of retiring ag land and restoring it to riparian and wetland habitat are occurring upstream along the mainstem of the San Joaquin River. These include the 1,600 acre Dos Rios Ranch and 50 acres for a proposed wetland mitigation bank for the City of Manteca. Along with these considerations, how would a restored estuary function upstream of an anthropogenic feature like the Stockton DWSC?
4. Hypotheses and Questions to Consider	
5. Suggested assessment/modeling tools, techniques, monitoring, to help resolve uncertainties/answer questions.	Further assessment and evaluation is merited, especially with respect to levee breach design and wetland design, and associated effects on water quality especially downstream in the Stockton DWSC.
6. Changes in system dynamics that alter current understanding of the system	

7. Data Gaps	Potential effects on downstream dissolved oxygen concentration in the Stockton DWSC; potential flow changes in the mainstem of the San Joaquin River that would result from FERC relicensing on SJR tributaries; modification of San Joaquin River Flows due to changes in the San Joaquin River Restoration Program and the State Board's San Joaquin River flow objectives, and also the BDCP project itself and associated pumping operations.

Attachment 5E.B
Review of Restoration in the Delta

Attachment 5E.B
Review of Restoration in the Delta

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Acronyms and Abbreviations

Bay-Delta	San Francisco Bay/Sacramento–San Joaquin River Delta
BDCP	Bay Delta Conservation Plan
cm	centimeters
Delta	Sacramento–San Joaquin River Delta
DWR	California Department of Water Resources
m/s	meters/second
mm	millimeters
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
SAV	submerged aquatic vegetation

Attachment 5E.B
Review of Restoration in the Delta

5E.B.1 Introduction

Most of the historic intertidal, tidal, and freshwater wetland habitats in the Sacramento–San Joaquin River Delta (Delta) have been isolated, removed, or substantially modified by the extensive channelization and levee system. A recent assessment found about a 97% decline in freshwater emergent wetland (both tidal and non-tidal) habitat, compared to historic conditions (Whipple et al. 2012). This lost habitat has included seasonally inundated floodplains, subtidal and intertidal freshwater and brackish wetlands, shallow-water channel margin, and associated riparian habitat.

The historically extensive tidal marshs, floodplains, and channel margins provided a mosaic of habitats for resident and seasonally migratory fish such as delta and longfin smelt, Sacramento splittail, sturgeon, and juvenile Chinook salmon (Whipple et al. 2012). These aquatic environments also provided nutrients and primary and secondary production in a variety of forms, including decaying emergent vegetation, phytoplankton, zooplankton, macroinvertebrates, and insects that formed the historic Delta's trophic food web.

Restoration of elements of the Delta's historic habitat has been identified as an important conservation action that can help restore some of the ecosystem functions that would benefit listed fish species, as well as a large variety of other aquatic species and wildlife (Simenstad et al. 2000; Sommer et al. 2001; Moyle et al. 2008). Consequently, habitat restoration is a major component of the Bay Delta Conservation Plan (BDCP). Specifically, the BDCP calls for restoration of tidal marshs (Conservation Measure 4), wider channel margins (Conservation Measure 5), and reconnection of riverine floodplains (Conservation Measure 6). These measures would increase overall habitat complexity to benefit the aquatic ecosystem. Along with other components of the BDCP, these measures are intended to enhance the ecosystem function of the Delta.

Restoration of these ecosystem functions will require careful planning, study, and adaptation to achieve the benefits desired. The BDCP provides the mechanisms, framework, and funding to do so. The Delta is a highly altered system, and is anticipated to continue to evolve because of climate change, sea level rise, nonnative species, human activity, and other factors. These realities must be acknowledged and integrated into the BDCP restoration planning and designs. While the Delta will never be the ecosystem it once was, thoughtful planning and implementation of tidal marsh restoration in the Delta can provide for the conservation and management of covered fish species in the face of the evolving environment.

This report summarizes the lessons learned from previous restoration activities in the Delta, to provide a starting point for planning and study of restoration concepts: what should we try to replicate or avoid? Previous conversion of lands to tidal marshs has been accomplished both deliberately and unintentionally (e.g., unrepaired levee failures). For clarity, this paper refers to unintentional events that result in rapid and dramatic changes in the environment as *accidental change* and reserves the term *restoration* for deliberate actions (Society for Ecological Restoration 2004). In some cases, accidental changes have resulted in improved conditions for native fish species (e.g., Liberty Island), while in other cases, environmental transformations have unintentionally created habitats that benefit nonnative species to the detriment of native species (e.g., Franks Tract). The BDCP includes only deliberate restoration to benefit native fish and wildlife species. However, accidental change at Liberty Island, which was the result of an unintentional levee failure, is a particularly useful example of the type of successful ecosystem function that the BDCP intends to create. Along with other intentional restoration, experiences to date can inform how specific restoration projects should be designed and what can reasonably be expected from future restoration.

Over the 50-year implementation period of the BDCP, an adaptive management program with a robust science component will be implemented to ensure that restoration actions taken under the BDCP will yield the best possible ecological results. However, it's important to recognize that the success of individual restored areas will vary due to site-specific characteristics, design, and the evolution of the site over time. The complexities of tidal estuarine systems are such that clear directional movement toward goals is not always obvious, and unexpected consequences can occur (Zedler and Callaway 1999). Restoration will produce habitats supplying various services (habitat for desired species, including local feeding and other rearing opportunities) supporting native and nonnative species. Some restoration projects will be successful relative to BDCP goals and some will be less successful because they foster less desirable species and processes (Matern et al. 2002; Nobriga et al. 2005). Other factors such as sea level rise and climate change will also influence the function of each site. In short, there is much to learn about restoration in the Delta, especially in the context of a continually changing abiotic environment and species mix.

This review primarily pertains to BDCP Conservation Measure 4, which provides for restoration of 65,000 acres of tidal natural communities (tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal brackish emergent wetlands) and transitional uplands to accommodate sea level rise. For this discussion, *tidal marsh* refers to fresh water and brackish tidally influenced aquatic areas above mean low-low water. Aquatic areas below this point are referred to as *subtidal*.

This review is divided into two sections. The first section is a generalized synthesis of goals, drivers, and considerations that pertain to BDCP restoration and is informed by the scientific literature and lessons learned from environmental transformations and restoration that have occurred in the Delta to date. The second section is a specific review of environmental transformation and restoration events in the Delta and more specific points that can inform BDCP restoration.

5E.B.2 Synthesis of Delta Transformations and Restoration

5E.B.2.1 Goal of Tidal marsh Restoration

Restoration is the deliberate modification of environmental conditions toward a desired end state that promotes conditions believed to be conducive to management goals (e.g., abundance of desired species) (Society for Ecological Restoration 2004). While examples of restoration are found in the Delta, many of the major environmental changes that have occurred to date and that will inform the initial BDCP restoration efforts have involved accidental changes. In some cases, restoration-related actions such as monitoring have also been initiated after environmental transformations (e.g., Liberty Island) in an attempt to understand processes that move the environmental transformation toward a condition that favors natives species like delta smelt.

The goal of tidal restoration under the BDCP is to create and enhance landscapes that support native fish species by generating the ecological functions that benefit these species (e.g., the production of desirable food, refuge from predation, and habitat conditions with suitable abiotic characteristics) (Teal et al. 2009). In this sense, *functions* refer to processes that create and maintain habitat for fish, plant, and invertebrate species and their interconnected food webs. Functions also include physical-chemical transformations of the landscape (biogeomorphology) that are supportive of native species and their habitats (e.g., tidal marsh plain evolution and maturation). Success requires establishment of functions that support native fish species, enhance connectivity across species life histories, and provide habitat complexity (in time and space) to support a range of species and life stages. In short, restoration should move the present condition of the Delta toward a condition that better supports native fishes and other desired wildlife.

5E.B.2.2 Importance of Tidal Marshes

Tidal marshes link terrestrial and subtidal habitats within an estuary and are among the world's most productive ecosystems (Tiner 1984). They increase overall biological productivity by supplying and receiving substantial amounts of organisms, organic carbon, surface/groundwater, and energy (Ewel et al. 2001). This flux of energy and material enhances aquatic foodwebs and boosts the production of estuarine fish and wildlife species. Tidal marshs can also improve water quality, provide flood abatement, and sequester atmospheric carbon (Rabenhorst 1995; Costanza 1996; Weslawski et al. 2004; Zedler and Kercher 2005).

Historically, the Delta was an immense tidal marsh characterized by vast areas of tule marsh that supported a community of fish species adapted to its variable conditions (Whipple et al. 2012). In its present state, the Delta has lost much of the tule marshes and conditions overall have been greatly altered from the historic condition. The delta continues to support an array of native fish species and, increasingly, numerous nonnative fish and aquatic species. The importance of the Delta marsh ecosystem to many native species has been well documented (Kimmerer 2004; Cloern and Jassby 2012; and many others). This paper focuses on key ecological processes in the tidal marsh that contribute to habitat for native fish species.

5E.B.2.2.1 Habitat for Native Fish Species

Habitat is defined here consistent with Hall et al. (1997) as the resources and conditions that promote occupancy by an organism and provide for and contribute to its survival and reproduction. Habitats are species-specific and include biotic and abiotic features that control survival across a species' life history; such features include food, competitors, predators, and physical attributes such as temperature, cover, or depth. The quantity and quality of occupied habitat is related to the biological carrying capacity and productivity, and therefore abundance, of fish populations (Hayes et al. 1996).

Based on the above definition, two aspects of habitat will be considered with respect to BDCP restoration: (1) direct occupancy of the habitat by life stages of covered fish species, and (2) ecological value of restored habitat, especially in regard to production of food for covered fish species. Restoration is intended to increase the quantity of suitable habitat for native fish species in the delta in regard to one or both of these aspects of habitat.

Direct Occupancy of Habitat

One purpose of restoration of the Delta under CM4 is to provide habitat needed for different life stages of covered fish species. CM4 is intended to substantially increase the amount of tidal and subtidal area in the Delta with the expectation that the increase will provide occupancy benefits for covered fish species. Most species have preferences for specific habitat types for life stage functions such as spawning; life stages move between different habitat types over the course of their life history. Delta smelt, for example, generally move upstream into freshwater areas to spawn, while juveniles and adults move downstream into more brackish water (Sommer et al. 2011). The potential occupancy value of projected habitat restoration under the BDCP has been analyzed using Habitat Suitability analysis (Appendix 5.E, *Habitat Restoration*). The analysis analyzed BDCP restoration at the scale of the geographic subregions and not at the scale of specific restoration projects. This analysis calculated suitability-weighted measures of area for specific types of aquatic habitat, termed *habitat units*. Changes in habitat units between geographic subregions over time and between species were compared to evaluate BDCP effects on suitable habitat Delta-wide. Suitability was based on life stage-specific rating curves for temperature, salinity, and turbidity that were developed in coordination with fish and wildlife agency biologists and that reflect applicable literature and current understanding.

Food Production for Covered Fish Species

BDCP restoration is also intended to enhance food production in the Delta for covered fish species. Primary and secondary production originating from tidal marsh habitat can support local fish communities and, under the right conditions, can be exported to support communities in other areas of the Delta (Cloern 2007). Export of production from shallow production areas to deeper, less productive areas requires physical and hydrologic connectivity (Cloern 2007), which the BDCP is intended to provide. Restored areas in the Delta can be sources or sinks for food production; the result is highly dependent on local features and especially hydrodynamic factors and consumption by clams (Lucas et al. 2002; Lehman et al. 2010). Restoration that results in the net export (source) or *in situ* consumption (sink) of phytoplankton and zooplankton can both be beneficial to covered fish species depending on how they use the restored habitat. Whether a site is ultimately a source or sink of production depends on flow, tidal influence, clam grazing, and topography (Lucas et al. 2002; Cloern 2007; Lehman et al. 2010), all of which are important considerations for restoration design.

Decline in the quantity and quality of pelagic food in the Delta has been implicated in the decline in pelagic fish species, such as delta smelt (Baxter et al. 2010; Cloern and Jassby 2012). The Delta food web is complex, involving planktonic, benthic, epibenthic, insect, and detrital pathways (Durand 2008). Zooplanktonic food resources in the Delta have been significantly altered, to the detriment of native species, as a result of the introduction and proliferation of invasive aquatic species including clam and zooplankton species (Feyrer et al. 2003; Winder and Jassby 2011). Food resources in the Delta for covered fish species are based on primary production, which supports secondary consumers such as zooplankton, which are in turn consumed by covered fish. Primary production enters the Delta food web in two forms: living phytoplankton and detritus derived from decaying phytoplankton and emergent macro-vegetation. Both forms of primary production can be enhanced by restoration of tidal environments (Lehman et al. 2010; Howe and Simenstad 2011). Phytoplankton growth rate is limited by light, and it is therefore produced in the surface photic zone and in shallow-water habitats (Lopez et al. 2006; Cloern 2007; Greene et al. 2011). In principal, expansion of shallow-water environments should enhance phytoplankton production. This aspect of potential food production was evaluated in the BDCP using a simple index of area-weighted phytoplankton production based on depth (Lopez et al. 2006). Invasive clams consume much of the phytoplankton currently produced in the Delta, diminishing the actual amount of accessible primary and early secondary production before it can move into the diatom-copepod-mysid shrimp food chain that historically supported the covered fish species during their Delta residence (Greene et al. 2011; Lucas and Thompson 2012; Miller and Stillman 2013).

Macrophytic emergent vegetation is also associated with shallow tidal environments and can be an important source of primary carbon in estuarine systems (Maier and Simenstad 2009). Emergent vegetation can form substrates for insects and other invertebrates that are consumed by covered fish species. Recent work at Liberty Island has shown that delta smelt, while generally considered pelagic feeders, consumed aquatic insects (Chironomids) associated with emergent vegetation (Whitley and Bollens 2013). Emergent vegetation also produces detritus that is consumed by insects, various crustaceans, and other species that are eaten by covered fish species. Much of the food value of detritus to fishes actually comes from microbes that break down plant cellulose and are then consumed by some zooplankton species. The extent of the usefulness of this detrital food web path for support of native fishes is not known in the Delta.

5E.B.2.3 Delta Restoration Design Considerations

5E.B.2.3.1 Large-Scale Drivers of Restoration Success

Restoration is often driven by the desire to create specific types of habitat (e.g., shallow tidal marsh) with specific habitat characteristics, such as depth, that can be controlled through dike management, grading, or filling. However, the ultimate success of restoration depends on larger-scale drivers of habitat quality, such as salinity, water temperature, freshwater flow regime, and pollutants, which collectively control environmental conditions and species success in a given region. These conditions are not generally controllable at the site scale. Therefore, the location of restoration may be of paramount importance and ultimately determine the biological value or success of the action. For example, the apparent success of the Liberty Island transformation appears to be due in part to the juxtaposition of flow from the Sacramento River (Yolo Bypass) and Cache Slough, tidal flux and wind that result in high turbidity, movement of sediment, and local prey production. Sediment comes primarily from Yolo Bypass and the inward movement of sediment from Suisun Bay during the summer, which, along with strong summer winds, keeps the area turbid during the portions of the year that Yolo Bypass is not flooded. The result appears to be that the island provides on-site habitat and food for delta smelt and other species (Whitley and Bollens 2013) while also exporting some of its production. On the other hand, Lucas et al. (2002) observed that hydrologic conditions and “tidal sloshing” that occurred at Franks Tract resulted in a net sink of primary carbon, whereas Mildred Island was a net producer of primary carbon. To varying degrees, these larger-scale conditions can be controlled (through upstream flow regulation, for example), and restoration investments in the Delta can be enhanced or limited to the extent that favorable larger-scale conditions are provided.

At present in the Delta, some invasive species act as large-scale drivers through their roles as ecological engineers (Jones et al. 1994; Kimmerer et al. 2008), altering habitat and species distribution and the outcome of environmental transformation and restoration. As discussed below, the invasive nonnative aquatic plant Brazilian waterweed (*Egeria densa*) and clams (*Corbicula* and *Potamocorbula*) can reduce diatom (algae), zooplankton, and native fish production at both the local and regional scales (Jassby et al. 2002; Kimmerer 2002; Cloern 2007; Lucas and Thompson 2012).

The overbite clam invasion affected the distribution of some fishes in the estuary (Kimmerer 2006; Sommer et al. 2011). The distribution of fish species and the factors that may control their distribution therefore also substantially influence the potential of restoration to increase beneficial ecological processes consistent with the needs of native fish species.

Time is the ultimate large-scale driver of conditions across physical and biological scales. The entire Delta is geologically relatively young (Atwater et al. 1979) and biogeographically in flux (Cohen and Carlton 1998). Because of its young age, the Delta ecosystem prior to Euro-American settlement had a relatively small number of native fish species; this abruptly changed in the late nineteenth century with the introduction of nonnative species and large-scale reclamation of the Delta's original marsh land. Today, nonnative fish species greatly outnumber native species in the Delta (Cohen and Carlton 1998; Grimaldo 2004; Nobriga et al. 2005). As a result, biological communities are continually changing (Matern et al. 2002; Brown and Michniuk 2007) as species compete to exploit available food and space and, in so doing, rearrange the food web (Winder and Jassby 2011). Many of the Delta restoration sites are also quite young (Simenstad et al. 2000) and are evolving in response to restoration and sea level rise. For example, Liberty Island was flooded in 1998, Franks Tract in 1938, and Mildred Island in 1983. Plowed furrows formerly of agricultural use are still visible at low tide in Liberty Island. These sites continue to develop in response to the broader scale changes described above, and change will be exacerbated by the expected rise in sea level and air/water temperature. Therefore, restoration sites will change in response to species dynamics and hydrogeomorphology.

5E.B.2.3.2 Fine-Scale Drivers of Restoration Success

Fine-scale drivers refer to local factors that determine the structure, quality, and quantity of habitat for fish species as well as the ecological processes that affect fish habitat. Local conditions can be actively shaped by direct restoration actions such as grading, filling, and vegetation plantings, but the final result will also be affected by fine-scale drivers such as topography.

Active restoration involves the manipulation of fine-scale drivers to jump-start natural processes and develop conditions believed to be conducive to desired species and ecological processes. For instance, specific vegetation will only establish at sites when appropriate threshold elevations are met, which could take many decades under a passive restoration scheme that accumulates organic matter over time through vegetation growth and decay. However, this process could be accelerated through the placement of dredged material (such as at Montezuma Wetlands) or other appropriate fill material (Miller et al. 2008). Enhancing the establishment of vegetation could also be achieved at restoration sites by recontouring sites to achieve a target elevation. Recontouring can also increase the diversity of habitats across the site, potentially increasing biodiversity.

At a fine scale as well as at larger scales, invasive species can control conditions and the success of restoration. Lucas et al. (2002) compared environmental transformation at Franks Tract and Mildred Island and observed that Franks Tract has large areas of *Egeria* and provides habitat for *Corbicula*, which limits its *in situ* production of phytoplankton. Mildred Island, in contrast, has markedly different hydraulic conditions, and does not support as much *Egeria* or *Corbicula* production, so it appears to be a net exporter of primary carbon to the Delta food web (Lucas et al. 2002). Water depth, flows, and "tidal sloshing" differ between the sites, as well, and contribute to their net export or consumption of primary productivity (Lucas et al. 2002). *Egeria* and other submerged aquatic vegetation (SAV) can reduce benefits of active restoration projects. Restoration at Decker Island, which involved restoration of a U.S. Army Corps of Engineers dredge spoils site, has been plagued by development of dense *Egeria* beds, especially in shallow channels that were created at the site (Rockriver 2008). Nonnative fish species were more abundant than native species in restored channels with dense vegetation. Rockriver (2008) recommended substrate changes to discourage centrarchid fish species (e.g., bass), and chemical applications to control SAV.

5E.B.2.3.3 Climate Change

Climate change is anticipated to result in appreciable change to Delta environments and will affect the outcome of restoration accidental changes that may take place in the future (Parker et al. 2011). Climate change is expected to result in higher sea level, a "flashier" freshwater flow regime, and higher air/water temperatures (Dettinger 2005; Cloern and Jassby 2012). Cloern et al. (2011) assembled evidence indicating future conditions in the San Francisco Estuary would be characterized by increased air and water temperatures, salinity, and sea level; decreasing precipitation, runoff, and snowmelt contribution to runoff; reduced turbidity; and increasing frequency of extreme environmental conditions beyond historical observations. Sea level rise is anticipated to increase the occurrence of accidental dike breaches and other transformative events that, if the past is a guide, will result in variable benefits to native fish species' habitats. The BDCP can provide the funding and scientific information necessary to manipulate these sites to the benefit of covered fish species.

The rate of accretion of sediment and peat is a significant determinant of the ability of marshes to accommodate sea level rise (Kintisch 2013). Accretion of sediment and organic matter can be enhanced through restoration of marsh vegetation. The presence of natural or artificial berms, dikes, sea walls, or other barriers will exacerbate the effects of sea level rise by impeding natural landward development of marsh environments (Kintisch 2013).

Based on monitoring data from San Francisco Bay marshes, Callaway et al. (2011) predicted that changes in salinity resulting from climate change would have a more immediate impact than sea-level rise on tidal marsh vegetation. However, they also report that sea-level rise poses a potentially greater long-term threat, depending on its rate. Climate change could also enhance conditions for nonnative species, with adverse effects on native fish species. Lehman et al. (2013) report evidence that toxic *Microcystis* blooms will likely increase with climate change due to increased water temperature and reduced flow during droughts. Moyle et al. (2013) predicted that native fish species in the Delta were more vulnerable to climate change than were nonnative fishes because of the generally greater tolerance of nonnative species to the warmer conditions expected with climate change.

Climate change is likely to present special challenges for CM4 restoration by exacerbating many of the current factors adversely affecting restoration success; therefore, the BDCP's proposed restoration of natural environmental conditions and ecological processes in the Delta take on even greater import. Callaway et al. (2011) suggest restoring habitat sooner rather than later, to maximize the flexibility needed to address the uncertainties of climate change. They reason that vegetated wetlands are likely to be more resilient to climate change than unvegetated sites, and mature vegetated sites are likely to be more resilient than newer sites. The BDCP includes an expedited schedule for tidal marsh restoration.

Restoration is also expected to increase the diversity of habitats and ecological processes in the Delta, which should increase the resiliency of the Delta to climate change. Cloern et al. (2011) suggested that climate change will affect both watersheds and oceans, making estuaries like the

Delta especially vulnerable to the predicted effects of climate change. They note that climate change will likely exacerbate the other anthropogenic changes in the Delta such as decreased sediment supply, introduced species and population growth, and urbanization. The result, they predict, will be inevitable changes to biological communities. Therefore, climate change is expected to both increase the value of BDCP restoration and the uncertainty of benefits.

5E.B.2.3.4 Habitat Complexity

The performance of individual species is a reflection of the quantity, quality, and diversity of their habitat (Southwood 1977; Hayes et al. 1996). A diverse array of habitats across the landscape promotes greater life history diversity within fish populations and improved population structure (McElhany et al. 2000). A key goal for a regional restoration program in the Delta is an array of local habitat features that collectively meet the habitat needs of covered fish species during all life stages. Liberty Island is a rare example of accidental change that meets the needs of delta smelt. Liberty Island is part of a regional habitat continuum that includes the Yolo Bypass, Cache, Miner, Barker, and Lindsay sloughs. The island includes wetlands, beaver ponds, vegetated marsh, and very turbid open water habitat, creating areas of net production and consumption of carbon (Lehman et al. 2010) and an array of species habitats (Simenstad et al. 2000). Liberty Island (Nobriga et al. 2005) and the surrounding northern Delta region (Sommer et al. 2004; Brown and Michniuk 2007) are also areas of relatively high native fish use.

Tidal restoration can create habitat with a wide range of specific functions (Callaway et al. 2011). Key goals for increasing physical diversity at restoration sites have been the incorporation of tidal channels to provide connectivity between aquatic and wetland habitats, and the distribution of a variety of vegetation across the sites. Restoration practitioners have acknowledged the lack of complexity in restored tidal marshs and have begun to incorporate additional approaches into the design and implementation of tidal marsh restoration (Callaway et al. 2011).

5E.B.2.3.5 Geomorphic Processes Affecting Restoration

Erosion

Erosion can have a key influence on the success and stability of a tidal marsh restoration project. Typically caused by tidal energy (currents) and wave action, erosion reduces the establishment of vegetation, which is often needed to prevent additional erosion from occurring (Schoelhamer et al. 2007). Wave action can resuspend and redistribute sediment, thereby limiting the ability of plants to take root, or changing the sediment conditions (i.e., grain size) and making the area less suitable for some types of vegetation. On the other hand, turbidity improves habitat quality for many native species such as delta smelt, for which it is believed to increase feeding efficiency and provide cover from predators (Bennett 2005). Wind waves result in sediment resuspension when the critical shear stress of erosion is exceeded such that unconsolidated silt and clay resuspend in shallow areas at relatively lower wind speeds of 4 meters per second (m/s), while larger-sized sediment resuspends at higher wind speeds of 10 m/s or more (Ganju et al. 2006). The potential for wind-driven resuspension of sediment is largely site-specific and depends on the orientation of the site relative to prevailing winds, depths and shape of the underwater terrain, and availability of sediment. These factors appear to have come together at Liberty Island, for example, resulting in generally high turbidity that contributes to its value for native fish (Simenstad et al. 2000).

Accretion

Accretion at restoration sites is the process by which sediment and organic matter deposit locally to provide a substrate for emergent plant growth and the ultimate development and maintenance of marsh elevation (Culberson et al. 2004). Accretion is an important mechanism for tidal marshes to cope with sea level rise (Callaway et al. 2011; Kintisch 2013). Macrophytic vegetation, which traps sediment and contributes to peat formation, is also an important factor in the ability of tidal marshs to accommodate sea-level rise (Morris et al. 2002). These factors presently appear to allow the Delta to keep up with sea level, though the ability to maintain wetlands in the face of the expected increased rate of sea level rise is uncertain (Miller and Fujii 2010). Recent trends in reduced sediment delivery to the Delta (Wright and Schoellhamer 2004) could reduce the ability of the Delta to keep up with sea level rise (Cloern et al. 2011).

Restoration under the BDCP could enhance accretion and the ability of the Delta to accommodate future sea level. Accretion within a site is dependent on a number of factors, including the presence of vascular plants (tules) that trap sediment and contribute to peat formation, as well as the initial depth contours of the site, wave action, and flow patterns. While accretion tends to occur relatively rapidly at first (e.g., immediately following a breach) as a large influx of sediment occurs, the accretion rate frequently slows as site conditions reach a new equilibrium (Simenstad et al. 2000). Sites with a frequent or continual source of sediment material (turbid water inflow), limited currents or wave action, and with development of macrophytic vegetation have a greater potential to maximize accretion rates (Morgan-King and Schoelhamer 2012). Accretion rates at sites without these conditions could take decades to reverse the effects of previous subsidence (Miller et al. 2008). For example, Sherman Island was breached in the 1920s but still remains below mean high-high-water (Simenstad et al. 2000). However, even sites with conditions like Sherman Island can show limited changes in elevation over time, as a result of factors such as erosion and compaction rates. Despite turbid overlying water and sediment influx, accretion at Liberty Island has been limited to areas with emergent vegetation that traps sediment (Simenstad et al. 2000).

Rapid accretion of sediment, in the range of 10 millimeters (mm) per year at Browns Island, 30 mm per year at Donlon Island, and even higher local rates of deposition, have been observed in the Delta (Reed 2002). High rates of sediment accumulation have been observed in Mildred Island (47 to 51 mm/year) and Rhode Island (44 mm/year), primarily because those deeply subsided areas are too deep for wind wave-driven sediment resuspension to effectively trap sediment or develop areas of tules and other vascular plants. Similarly, high rates of sediment accumulation have been observed in upstream portions of the Yolo Bypass and other flood bypasses due to the combination of high sediment load and deep water (Singer et al. 2008). In contrast, some areas such as Sherman Lake, Big Break, and possibly Franks Tract appear to have very slow accretion rates, although wind waves appear to be the primary cause of low accretion rates in Franks Tract (Simenstad et al. 2000). The rate of accretion across the Delta is a significant problem in the face of sea level rise (Orr et al. 2003; Miller et al. 2008; Bates and Lund 2013) and declining sediment availability (Wright and Schoellhamer 2004). However, restoration processes can facilitate accretion and help accommodate sea level rise by providing opportunities for tidal marshes to keep pace with rising sea level and/or migrate into adjacent uplands when higher sea levels inundate these areas (Miller et al. 2008).

Compaction and Subsidence

Much of the underlying substrate in the Delta is peat that formed from the expansive historical Delta marshes (Whipple et al. 2012). As agriculture and levee development began in the late nineteenth century, almost immediately it was observed that the soil behind the levees would compact, resulting in the failure of the levee or the need to continually raise levees as the protected land compacted (Thompson 2006). Loss of elevation due to compaction and subsidence continues to be a major problem in the Delta that may affect restoration efforts because of subsidence of former wetland soils from oxidation (Bates and Lund 2013) and consolidation (Deverel and Rojstaczer 1996). Of particular concern for raising the elevations of subsided island back toward sea level (subsidence reversal) is that levees protecting the projects can fail after the internal islands have had their elevations raised (Sanderstom et al. 2010; Bates and Lund 2013). The stability of Delta levees is threatened by continued subsidence of Delta peat islands and the potential for large floods and rarer earthquakes (Mount and Twiss 2005). Up to 6 meters of land-surface elevation has been lost in the 150 years since Delta marshes were leveed and drained, primarily from oxidation of peat soils (Miller et al. 2008). Flooding subsided peat islands halts peat oxidation by creating anoxic soils, but restored wetlands will often require net accumulation of new material over many decades to recover land-surface elevations. Lands subsided more than 4 to 6 meters below sea level will hinder establishment of vegetation due to inadequate light penetration—but at these depths, they may also have limited potential for growing phytoplankton. For land less than 1.5 meters below sea level, tules can establish and presumably outcompete invasive water weeds (Sanderstom et al. 2010).

The impacts of subsidence, accretion, and erosion in the Delta will be greatly magnified by expected sea level rise, especially in a seismically active region (Mount and Twiss 2005). Levee failures are expected to increase along with island flooding. Mount and Twiss (2005) estimate a two-in-three chance of catastrophic flooding or earthquakes in the Delta by 2050, which would increase island flooding and greatly alter hydrodynamics in the Delta. Accidental changes in the future will likely result in *post hoc* restoration similar to that which has occurred in the past (Moyle et al. 2008), such as Liberty island. Catastrophic events such as those discussed by Mount and Twiss (2005) would greatly alter the political, social, and ecological landscape of the Delta and the goals for and direction of its restoration.

5E.B.2.3.6 Possible Negative Aspects of Restoration

Environmental transformation and restoration that have occurred to date have had mixed results in part because of the highly dynamic nature of the Delta and the complexities of nonnative species, hydrodynamics, and pollution (Brown 2003). Some sites have become lakes (e.g., Franks Tract) that favor invasive plants, invertebrates, and fish, while others provide more natural Delta conditions with benefits to native species (Nobriga et al. 2005). While a newly flooded island might benefit invasive species, under different circumstances, a flooded island could instead provide important habitat or food sources for desirable species (Moyle and Bennett 2008). Managing these flooded islands as habitat for desirable species can be challenging, due to the depth of subsidence prior to inundation, colonization by invasive aquatic plants, hydrodynamics and water quality, the effects on adjacent islands, and the influence of flooded islands on food webs both within the islands and in adjacent channels (Sanderstom et al. 2010). For example, Franks Tract has developed into a highly popular fishing spot for black bass. Habitat varies significantly across the Delta, and the occupation of habitat by native fishes depends on the location within the Delta, depth, proximity to the Sacramento and San Joaquin rivers, size, strength of tidal and riverine currents, and a host of other factors (Meng et al. 1994; Lucas et al. 2002; Matern et al. 2002; Moyle et al. 2010).

Many of the negative outcomes of restoration to date involve dominance by nonnative species; however, this is an ecosystem-scale issue and not always a reflection of habitat restoration. Species of invasive clams and SAV have become dominant ecological engineers in the Delta and exert a profound influence on ecological conditions and species composition (Lopez et al. 2006; Baxter et al. 2010; Santos et al. 2011). While pervasive, the distribution of these species is not uniform across the Delta. SAV, for example, is a greater problem in the southern Delta than in the northern and western Delta (Santos et al. 2011). Clams appear to be concentrated in some areas and less common in other areas (Durand 2008), but their grazing influence can transcend their immediate distribution. To the extent that the present observed distribution of SAV and clams is stable, this distribution suggests a basis for prioritization of restoration to maximize potential success.

Habitat for Nonnative Fish Species

Nonnative species dominate the biomass of fish everywhere in the BDCP Plan Area. Centrarchid species, such as bass, thrive in shallow vegetated environments and will likely benefit from increases in water temperature expected with climate change (Moyle et al. 2013). For these reasons, transformed and restored habitats are dominated by nonnative fish species, many of which can prey on native fishes (Brown 2003; Nobriga and Feyrer 2007). This does not mean that restoration should be viewed pessimistically, but it does suggest that habitat restoration should not be conceptualized as the creation of "oases" of native fish habitat. Rather, habitat restoration should be viewed as a tool to enhance general fish habitat attributes in regions where native fishes can persist. Native fish species will be part of a broader assemblage of native and nonnative species benefiting from improved habitat attributes, including local prey production and water quality improvements (Moyle et al. 2010). As discussed below, this especially pertains to introduced aquatic vegetation, such as *Egeria*, that forms habitat for a particular group of nonnative centrarchid fish species. Nobriga et al. (2005) found high fish biomass in areas dominated by *Egeria*, but mainly of nonnative species; native fish, such as delta smelt, Chinook salmon, and splittail were more common in lower productivity, turbid open water. Franks Tract has developed extensive beds of *Egeria* and large numbers of black bass. California Department of Fish and Wildlife surveys showed that nonnative centrarchids, including largemouth bass, bluegill, and redear sunfish, along with other nonnative fishes, dominate vegetated habitats including emergent, submerged, and mixed vegetation and shoreline with riparian vegetation (Meng et al. 1994; Chotkowski 1999; Grimaldo et al. 2012; Chotkowski 1999). McGowan and Marchi (1998) found only these and other nonnative species in dense *Egeria* beds in the Delta. Chotkowski (1999) found that juvenile Chinook salmon, inland silverside, lamprey, and threadfin shad were more abundant in unvegetated habitats than in vegetated ones, although half of the 24 species captured in these areas were nonnative species; nonnative species are even more dominant when abundance is considered (Meng et al. 1994).

Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) has been introduced in the delta and has altered the environment to the detriment of native fishes (Nobriga et al. 2005; Brown and Michniuk 2007). The reasons for the proliferation of SAV species are not fully established, but a reasonable hypothesis is the suppression of diatoms due to grazing by the clam *Potamocorbula*, allowing nutrients to shift to species such as macrophytes, which are not grazed by clams. Since the *Potamocorbula* invasion, nitrogen inputs have increased (Jassby 2008) while phosphorus inputs have decreased, changing the nitrogen to phosphorus ratios in the estuary, which also has consequences for aquatic plant growth (Glibert 2010).

Brazilian waterweed, *Egeria densa*, is an introduced aquatic plant that forms dense beds that trap sediment and provide habitat for nonnative fishes such as largemouth bass (Brown 2003). *Egeria* covers substantial portions of the Delta and is a major determinant of Delta conditions in some areas

(Santos et al. 2011). Shallow aquatic areas that are often created by restoration projects can be readily colonized by *Egeria* (Simenstad et al. 2000). SAV beds tend to slow local water velocities, resulting in loss of suspended sediment and increased water transparency. For delta smelt, which require turbid water, this impedes their ability to feed while making them more vulnerable as prey (Baskerville-Bridges et al. 2004; Feyrer et al. 2007).While small numbers of some native fishes, like prickly sculpin and Chinook salmon, have been found in *Egeria* habitat (Grimaldo 2004), such habitat does not appear to be utilized extensively by the species of greatest concern, including anadromous salmonids, splittail, and delta smelt, but is used by several nonnative predatory fish species (Brown 2003). The distribution of *Egeria* varies spatially and temporally between years due to a variety of factors (Santos et al. 2011). Restoration sites such as Liberty Island do not yet have an *Egeria* problem, whereas in others, such as Franks Tract, it is a dominant ecological factor. The distribution of *Egeria* and other submerged macrophytes in the Delta is likely due to salinity regime, presence of suitable rooting substrate, water velocities, turbulence, and light regime, as influenced by shading and turbidity (Brown 2003). In addition to *Egeria*, other invasive species have been shown to substantially affect native vegetation species and wetland ecosystem functions (Callaway et al. 2011). These include water hyacinth (*Eichhornia crassipes*), which can form dense floating mats of rooted vegetation and is particularly found in the southern Delta (Santos et al. 2011).

Clams

Restoration of shallow tidal environments in the Delta also has the potential to increase the abundance of nonnative clams (*Corbicula* and *Potamocorbula*) that compete with other species for phytoplankton in the Delta (Lucas et al. 2002; Baxter et al. 2010; Winder and Jassby 2011; Lucas and Thompson 2012). Invasive species of clams have greatly altered the Delta and the associated food web through their ability to filter the water column and consume phytoplankton (especially diatoms and ciliates) that otherwise could have supported zooplankton that, in turn, would have supported covered fish species (Baxter et al. 2010; Winder and Jassby 2011). Clams also graze early instars of zooplankton, thereby cropping secondary production before covered fish species can attain it (Durand 2008).These clams have compromised the ability of the Delta ecosystem to deliver carbon to higher trophic levels including fish, resulting in a cascade of changes that are still not wholly understood (Durand 2008; Baxter et al. 2010).

Pollutants

Restoration has some potential to increase mercury methylation in the Delta and to locally increase its mobility when grading or other ground disturbance occurs (Alpers 2008). Mercury occurs in several forms, but methylmercury is the most toxic form. It is formed by bacteria under anaerobic conditions; such conditions are often associated with wetlands, and thus restoration might increase accumulation of mercury in the food web, resulting in increased ecological risks (Alpers 2008). Highly vegetated, flooded wetland sediments in the Delta have been found to be net producers and exporters of methylmercury (Slotten et al. 2002). Mercury accumulation in the food web is affected by the interactions between a number of complex and variable factors, including mercury concentration, water chemistry, microbial population dynamics, and food web structure (Brown 2003; Davis et al. 2008). Conversion of land from agriculture to flooded wetlands will also almost certainly result in increased methylation of mercury in the Delta (Brown 2003). However, whether wetland-generated methylmercury will enter Delta food webs is unclear (Slotten et al. 2002). Based on available information, it is expected that methylmercury concentrations in restored tidal marshs will remain stable once restoration is complete; however, there is uncertainty associated with the available data regarding the balance of sediment accretion, sea-level rise, and sediment erosion. There is also uncertainty regarding the cumulative effect of many tidal restoration projects on sediment supply (Brown 2003).

5E.B.3 Review of Delta Restoration Projects

The environment of the Delta has been radically transformed over the last century and a half due to human actions, accidents, and natural processes (Whipple et al. 2012). In most cases, these changes have been made to support some specific human need such as shipping, agriculture, or urban development and, overall, have created an environment that is less supportive of native species or natural ecological processes. Accidents that have occurred such as breaching of levees have, in some cases, produced environments that resemble what was there historically, yet other accidents have produced new environments, such as lakes that primarily support nonnative species. In this paper we have referred to these accidents as *accidental changes*. More recently, agencies have undertaken deliberate action to change the environment through restoration to benefit native species.

Environmental transformations and restoration that has occurred to date can inform BDCP restoration, recognizing that much remains to be learned about large-scale restoration in the Delta, especially in light of expected changes in regional climate. What follows is a discussion of transformation and restoration actions that have occurred to date, with a summary of specific lessons that emerge from these actions.

5E.B.3.1 Accidental Changes

Contemporary restoration efforts breach and/or remove the levees surrounding Delta islands with the goal of regaining wetland habitat. However, experience so far with levee breaches, both planned and unplanned, has shown that the transition from shallow open water to tule marshes occurs slowly, if at all (Reed 2002). Sedimentation rates in tidal marshes are an important control on this transition that can be enhanced by sediment trapping by emergent vegetation (CALFED Bay-Delta Program 2001). The Delta currently includes several flooded islands where levee breaching has clearly not resulted in the restoration of former marsh habitats (e.g., Mildred Island, Franks Tract), and some areas where recovery of vegetated marsh has been almost complete (e.g., Lower Mandeville Tip, western Sherman Lake).

Liberty Island, Franks Tract, and Mildred Island are sites of accidental changes that have been particularly studied and provide useful insights for future restoration.

5E.B.3.1.1 Liberty Island

Liberty Island, encompassing 5,209 acres, was breached in 1998 (Lehman et al. 2010) and later acquired for conservation. This site is perhaps the best example of the potential for restoration to provide habitat and food for native fish species. Liberty Island is part of a large complex of planned restoration areas and naturally restoring areas, including Cache Slough, Little Holland, and Prospect Island, and it is also hydrologically connected to the Sacramento River and is downstream of Yolo Bypass. The complexity of habitats and processes and the hydrologic connection to Yolo Bypass appear to contribute to the restoration of natural habitats and processes. While the site is still relatively young, natural processes are restoring various habitats, including tidal perennial aquatic at the southern end and freshwater emergent wetland, sloughs, and riparian habitat at the northern end. Ongoing analysis as part of the CALFED Bay-Delta Program's BREACH studies are providing considerable information on species composition, habitat use, feeding, and physical processes such as flow/tides, sediment movement, and habitat formation. Lehman et al. (2010) have shown how the site produces and accumulates organic production within Liberty Island while also exporting production downstream. Whitely and Bollens (2013) found that Liberty Island supported a robust community of native fish species (along with nonnative species) and that native species such as delta smelt appeared to be feeding actively on insects and zooplankton produced within the site. Sommer et al. (2011) report that some delta smelt appear to be resident in the Cache Slough area and do not undertake the downstream migration to the Central delta that is generally believed to be typical of delta smelt.

Nearly 800 acres of fresh and saline tidal emergent wetlands have naturally developed since 1997 (Hickson and Keeler-Wolf 2007). Native fish species include Chinook salmon, splittail, longfin and delta smelt, tule perch, Sacramento pikeminnow, and starry flounder. Chinook salmon smolts are highly robust with large condition factors (California Department of Fish and Game 2008). In some areas, native species account for up to 21% of the samples, which is fairly high for the contemporary Delta. Diets of native fishes include planktonic and insect prey, and fish show a relatively high degree of stomach fullness (Whitley and Bollens 2013).

An important feature of the Liberty Island site it that it is hydrologically complex; these hydrodynamics shape environmental conditions and the resulting biological response. The site is at the downstream end of the Yolo Bypass and is heavily influenced by freshwater flow from the Sacramento River. It is also subject to significant tidal fluctuations that push water upstream and then pull water back downstream. The result is high turbidity and flow conditions that appear to have limited the growth of SAV.

Although largely passive, the restoration of Liberty Island is considered a prototype for habitat restoration in the San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) because it contains relatively high numbers of delta smelt in residence and appears to support a natural food web and ecological processes (Lehman et al. 2010). The area has been the focus of intense monitoring and research for several years as part of the BREACH III studies and more *ad hoc* precursors. Many of the results have yet to be published; as a result, some of this discussion will rely on presentations by and discussions with the primary investigators.

Two primary drivers of delta smelt abundance at Liberty Island are postulated, but ultimately the necessary biotic and abiotic habitat attributes both have to be present in order for fish to successfully colonize any potential habitat: (1) there is abundant food for delta smelt life stages within Liberty Island and the surrounding sloughs and channels that make up the Cache Complex, and (2) the water in this area retains turbidity even during drier portions of the year (Morgan-King and Schoelhamer 2012). Delta smelt are often associated with highly turbid conditions, which may aid in feeding and avoidance of predators (Baskerville-Bridges et al. 2004). Lehman et al. (2010) studied the import and export of organic material and found that although the inorganic and organic materials were exported on an annual basis, the magnitude and the direction varied on a seasonal basis. Mesozooplankton carbon was dominated by calanoid copepods, which are a primary prey item of delta smelt, and exported most of the year, except during the summer. High hourly and daily variation in chlorophyll, salt, and total suspended solids were found to be the product of high frequency changes in concentration and tidal flow. Tidal flow rather than river discharge was responsible for 90% or more of the material flux into and out of Liberty Island. Recent studies by Lehman (unpublished data) show that two small ponds at the northern end of Liberty Island are net exporters of phytoplankton to the larger open water portion of the island. Thus, these ponds may subsidize the local planktonic food web within Liberty Island.

In a study on sediment characteristics of waters surrounding Liberty Island, Morgan-King and Schoellhamer (2012) found that, on an annual average basis, the area was a net exporter of sediment, although sediment accumulates from landward transport during the dry season. Sediment in the area is continually suspended by both wind waves and tidal currents. During the winter when river flows increase, there is a net export of sediment downstream that dominates the annual sediment flux. The hydrodynamics of the region, including low freshwater flow during the dry season, dominance of flood tides, and limited tidal excursion, all favor the retention of sediment in the surrounding area, including Liberty Island. Key findings in the BREACH III studies by ESA PWA concluded that marsh expansion was limited by lateral vegetation expansion, increase in mudflat area is limited by wave erosion, vegetation enables sediment deposition in vegetated areas equal to sea level rise as projected, and vegetation and rates of sediment deposition can be managed to some extent by planting vegetation. Overall, it would seem that proper hydraulic connection to breached islands and their sediment sources are of paramount importance for properly functioning habitats that will sustain native biota. The landward transport of sediment, surrounding backwater sloughs with high residence time, and complex morphology—along with large open areas where sediment is resuspended by wind and tidal currents—are all physical drivers that allow Liberty Island to have habitat suitability that favors native species like delta smelt.

5E.B.3.1.2 Franks Tract

Franks Tract is a flooded island lake created by breaching of a ring dike in 1938. In contrast to the more complex hydrodynamics of Liberty Island, the lake is primarily influenced by tidal flow. Despite the relatively long period since breaching, the site appears to have limited long-term potential to naturally reach elevations appropriate to grow tules and cattails. There is no evidence that sediment has built up relative to sea level rise since the breach (California Department of Fish and Game 2008). Similar to the Liberty Island site, the long fetches at Franks Tract result in wave action that resuspends sediments and limits settling. But unlike Liberty Island, the remnant levees around Franks Tract are armored, which limits the natural development of shallow peripheral environments with tules. Instead, the shallow depths occurring in Franks Tract, along with its armored levees, allowed the island to be extensively invaded by *Egeria* (Santos et al. 2011), and *Corbicula* clams (Lucas et al. 2002).

Investigations at Franks Tract have indicated that it is generally a net sink for organic production (Lucas et al. 2002), meaning that more production is consumed within the lake, largely by benthic clams, than is produced. This is due to patterns of tidal flux and consumption by clams.

The California Department of Water Resources (DWR) and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) are evaluating installing operable gates to control the flow of water at key locations (Threemile Slough and/or West False River) to limit the entry of higher salinity water into Franks Tract. In addition to improving drinking/agricultural water quality, a potential ancillary benefit of this tidal pumping proposal is that operation of the gates may encourage movement of fish species of concern away from the central and southern Delta, where their survival rates are reduced, and to areas that provide more favorable habitat conditions.

5E.B.3.1.3 Mildred Island

Mildred Island, now a large, tidally influenced lake within the central Delta, was formed during flooding in 1983 (Lucas et al. 2002; Nobriga et al. 2005). Much of the original levee still surrounds the island, with terrestrial (giant reed [*Arundo donax*]), emergent aquatic (tule), SAV (mostly *Egeria*), and floating aquatic vegetation occurring within a relatively narrow (5-meter-wide) band around the site (Grimaldo 2004). While the rim edge consists of wadeable depths, the interior habitat is relatively deep (about 4 meters). This deeper water is believed to limit the invasion of *Egeria* and Asian clams (Lopez et al. 2006). Water clarity within the island is substantially higher than at other sites, with Secchi disk depths (used to measure water transparency) always exceeding 50 centimeters (cm) (Nobriga et al. 2005). In contrast to the nearby Franks Tract, Mildred Island is a net producer of phytoplankton—an important food source for the Delta (Lucas et al. 2002; Lopez et al. 2006); however, the local fish fauna in the central and southern Delta near Mildred Island is greatly dominated by nonnative fishes (Grimaldo 2004; Nobriga et al. 2005), so it is unlikely that many native fishes acquire a noteworthy benefit from this particular source of phytoplankton production.

The Mildred Island site has accumulated of about 2 feet of sediments since the initial flooding (about 47 to 51 mm per year). However, the deeply subsided condition prior to inundation (nearly 15 feet) would take a century or more for natural accretion to restore tidal elevations (CALFED Bay-Delta Program 2001). Currently, the deep water at Mildred Island appears to prevent *Egeria* and clams while allowing phytoplankton production (Lucas et al. 2002).

5E.B.3.1.4 Tidal Lakes and Flooded Islands Lessons Learned

Franks Tract and Mildred Island have been breached for extended periods of time and are presumed to have reached some kind of steady state (Lucas et al. 2002). They have been comparatively intensively studied and offer some lessons for restoration. Breaching of Franks Tract resulted in massive *Egeria* beds, a large population of nonnative predatory fish, and relatively little phytoplankton production. Breaching of Mildred Island, on the other hand, resulted in relatively little *Egeria* and net production of phytoplankton to the Delta, though it also harbors large populations of nonnative predatory fish (Nobriga et al. 2005). Tidal transport between Mildred Island and Franks Tract (the lakes) and their adjacent sloughs and channels shapes the spatial structure of phytoplankton biomass within and near the two lakes. For example, when the lakes receive water from adjacent channels during flood tides, much of the water may return to the channel on the ebb tide. Since phytoplankton cells mostly move passively with water movement and their growth rates are dependent on local light and nutrient conditions, they are influenced by the conditions of the water that they travel in over the tidal cycle, not just what is within the lake (Cloern 2007).

The interaction of tidal transport with the morphology of channels, levees, levee breaches, channel bends, and channel junctions creates the transport asymmetries that can quickly disperse plankton patches within the lakes or from the lakes into surrounding channels. The water characteristics within tidal lakes are not static (Lucas et al. 2002; Monsen et al. 2007). The geometry of the basin and the hydrodynamic forces create circulation patterns that vary from high to low exchanges, where phytoplankton mass can be dispersed or accumulate. For example, in Mildred Island, tidal mixing and flushing decrease from north to south with a hydrodynamic “dead zone” occurring in the southeast. This phenomenon where water and phytoplankton recirculate *in situ* creates a zone of high phytoplankton biomass. When benthic grazing and respiration exceed phytoplankton production, the habitat becomes a net negative producer of (pelagic) primary productivity. This is the case in Franks Tract, while Mildred Island is a net producer of phytoplankton biomass (Lucas et al. 2002). This is consistent with findings from other studies, where shallow water habitats can be either sources or sinks of primary net productivity (Jassby 2008).

Mixing processes within the lakes and between the lakes and their adjacent channels highly influenced the ability of these habitats to turn primary productivity into zooplankton. Mildred Island shows localized regions of high primary productivity, which translated into high zooplankton biomass in those regions. In Franks Tract, a net sink of primary productivity was still able to sustain zooplankton production by transport of phytoplankton via tidal exchange from outside channels into the lake (Lucas et al. 2002). Therefore, these systems are open, and the food-supply function is available by tidally driven imports in conjunction with internal production.

The comparison of these two lakes shows that seemingly similar habitats can function at completely opposite ends of the spectrum when it comes to food production. Some of these processes can be controlled through physical design of the habitats, such as water depth and the hydraulic consequences of levee break size and position to control residence time and circulation pathways. Some biotic processes are not controllable (e.g., the extent of *Corbicula* colonization), and therefore limit the ability to predict outcomes of specific projects.

5E.B.3.2 Other Transformation Sites

5E.B.3.2.1 Blacklock

In 2006, a breach was constructed in the levee along Little Honker Bay at the Blacklock Restoration site. With this breach, 70 acres of tidal marshs were created in the Suisun Marsh. The overall approach has been a passive restoration strategy in which natural sedimentation and plant detritus accumulation are anticipated to restore the site to intertidal elevation; natural colonization would establish the plant and wildlife communities.

5E.B.3.2.2 Big Break

Big Break is presently a flooded island similar to Franks Tract. Pilot-scale restoration projects within it will: (1) restore tidal marsh, floodplain, and Antioch dune habitat on the Delta of Marsh Creek to restore target fish and dune species, (2) restore bio-filtration floodplains along urbanizing reaches of Marsh Creek to protect and improve water quality entering the Delta, (3) monitor aquatic species in Big Break and water quality along Marsh Creek, (4) develop a volunteer-driven native plant nursery to generate plants for restoration, and (5) continue a public outreach, education, and citizen planning program in the watershed to monitor the project over time.

5E.B.3.2.3 Donlan Island

Donlan Island was breached in 1937 (Simenstad et al. 2000). Subsequently, nine dredged material islands were created in 1985 as part of a beneficial re-use effort. As demonstrated at other sites in the Delta (Lower Mandeville Tip and Venice Cut islands), tule marsh vegetation establishes quickly at intertidal elevations (Simenstad et al. 2000). However, initial colonization of bare soil occurred rapidly but then slowed, presumably because prime areas had been occupied and new areas with favorable conditions for vegetation have not developed.

5E.B.3.2.4 Mandeville Tip

The lower Mandeville Tip site was breached in about 1933, forming relatively shallow (typically about 2 meters deep) flooded habitat. Simenstad et al. 2000 reported that tule marsh vegetation established quickly at the intertidal elevations, based on a 1937 photograph showing nearly complete revegetation in the four years following the breach, although subsequent expansion of tule beds was substantially slower. Extensive SAV beds still occur at the site, extending as far as 25 meters from the shoreline during the summer; the dominant species are nonnative Brazilian waterweed (*Egeria densa*) and Eurasian milfoil (*Myriophyllum spicatum*) (Grimaldo 2004). Where wave energy is high, marsh erosion may be increased further, as is evident over time at lower Mandeville Tip (Simenstad et al. 2000).

5E.B.3.2.5 Sherman Lake

Sherman Lake was formed in 1869 when floodwaters inundated Sherman Island, as the westernmost portion of the island was never reclaimed (Nobriga et al. 2001). Sherman Lake is a turbid flooded island at the confluence of the Sacramento and San Joaquin rivers, with relatively deep channels separating small islands, which are the remnants of the former northern levee. Tules and giant reed dominate the shoreline vegetation, while SAV is sparse except within the dendritic tidal marsh channel system at the western edge of the lake. The water is usually turbid, with Secchi disk depths rarely exceeding 50 cm (Nobriga et al. 2001). Nobriga et al. (2005) reported the highest relative abundance of native fishes at the northeastern edge of this site (compared to Liberty Island, Decker Island, Mildred Island, and the San Joaquin River channel at Medford Island). Newer studies by the Interagency Ecological Program and University of California, Davis are reporting similar initial results.

5E.B.3.2.6 Venice Cut

The Venice Cut Island levees, built in 1906, were breached during the construction of the Stockton Ship Canal, in approximately 1933. Dredged material islands were subsequently created in 1986. There are relatively high energy conditions at Venice Cut because it is immediately adjacent to the Stockton Ship Channel and, as such, affected by hull displacement waves from large ships. The interior portions of the site are generally shallow (about 2 meters), with a relatively large breach area exposed to the main river channel.

5E.B.3.2.7 Prospect Island

Prospect Island has flooded seven times since 1981, and likely has little value for agriculture (Sanderstom et al. 2010). Therefore, the intentional breaching and re-flooding of Prospect Island could create beneficial habitat for Delta and migratory fish species (Sanderstom et al. 2010).

5E.B.3.3 Deliberate Restoration

5E.B.3.3.1 Hill Slough Tidal Marsh Restoration

The largest intact undiked wetlands remaining in Suisun Marsh are associated with Cutoff Slough and Hill Slough in north-central Suisun Marsh. The Hill Slough project will restore approximately 950 acres of diked seasonal wetland to tidal habitat. The project will reintroduce tidal action to the site, restoring a full habitat spectrum transitioning from perennial aquatic habitat in the deepest areas, to high and low intertidal marsh, to lowland alluvial habitat at higher elevations. The outcome will be a self-sustaining marsh ecosystem created through restoration of natural hydrologic and sedimentation processes and reliance on natural abiotic and biological succession processes (CALFED Bay-Delta Program 2010).

5E.B.3.3.2 Calhoun Cut Ecological Reserve Enhancement

This project would complete planning and restoration design for the Calhoun Cut restoration project to reestablish tidal circulation in the marshes along Lindsey Slough in the Cache Slough complex. Acquisition of the Peterson Ranch will add 1,600 acres to the Calhoun Cut Ecological Reserve to protect vernal pool habitat, provide habitat connectivity, and allow floodplain migration expected from climate change (CALFED Bay-Delta Program 2010).

5E.B.3.3.3 Meins Landing Tidal Marsh Restoration

DWR purchased the 666-acre Meins Landing property in 2005, in partnership with the Suisun Marsh Preservation Agreement agencies and the State Coastal Conservancy. The property is a mosaic of managed wetlands and upland habitats comprising freshwater marsh, seasonally flooded habitat, annual grassland, and pickleweed (California Department of Water Resources 2009). While the restoration project design is still in development, the project provides an opportunity to restore habitats as part of a broad collaborative effort of regional wetland management in the Delta. The restoration approach is to provide levee improvements on Van Sickle Island and meet wetland restoration goals in several closely aligned State programs.

5E.B.3.3.4 Mayberry Farm Subsidence Reversal Project

The Mayberry Farms Subsidence Reversal Project was designed to restore approximately 274 acres of palustrine emergent wetlands on a nearly 308-acre property on Sherman Island owned by DWR and previously managed as winter-flooded emergent wetlands and for grazing. Project construction occurred in 2010 and involved improving the perimeter ditches, interior berms, interior water conveyance channels, intake siphons, and water control structures. In addition, a buttress berm and seasonally flooded loafing islands for waterfowl were constructed using no imported fill material. Evaluations of annual subsidence, flow, mercury, and methylmercury concentrations inside the wetlands and monitoring of greenhouse gas emissions are some of the topics of research currently underway at the site (California Department of Water Resources 2013).

5E.B.3.3.5 Northern Liberty Island Fish Conservation Bank Restoration Project

This 808-acre mitigation bank project is located in Cache Slough and was constructed and breached in late 2010 to restore, enhance, and create habitat for native Delta fish species. The project site provides a mosaic of open water, riparian, marsh, and upland floodplain habitat.

5E.B.3.3.6 Dutch Slough

The Dutch Slough Tidal Marsh Restoration Project would restore up to 483 acres of emergent wetland (a portion of which would be tidal) in the Delta. The restoration actions include filling and grading marsh areas, excavating channels, managing or planting vegetation to favor native plant establishment (revegetation), and breaching levees (Phillip Williams & Associates 2006).

Restoration actions and physical and vegetative processes create and interact with the following habitat structures: vegetated marshplain, tidal channels, subtidal open water, floodplain, riparian, upland and transition, soil profile and chemistry, and water chemistry (Phillip Williams & Associates 2006).

The Dutch Slough project also has a research component to generate important information regarding the best methods to restore tidal marsh habitats in the Delta, although many more large-scale projects will likely be needed to fill the overall information gap regarding how freshwater tidal marsh restoration can contribute toward an overall goal of native fish restoration in the Delta. The 1,200-acre pasture site has the potential for restoring over 6 miles of shoreline and a mosaic of tidal, riparian, and upland habitats, to provide enhanced fish and wildlife habitat in the western Delta. The unique, relatively unsubsided site topography would allow restoration of intertidal dendritic channels. The habitat restoration in the upland sites will allow for the development of riparian forest and shaded riverine habitats (California Department of Fish and Game 2008). The project also incorporates subsidence reversal/carbon sequestration on 120 acres.

5E.B.3.3.7 McCormack-Williamson Tract

The McCormack-Williamson Tract is a 1,654-acre island located immediately downstream of the confluence of the Cosumnes and Mokelumne Rivers, owned by The Nature Conservancy. The island offers opportunities for restoration of critical tidal freshwater marsh and floodplain habitat (Grosholz and Gallo 2006; Moyle et al. 2007) and may also moderate flood flows in the northern Delta, and is particularly suitable for expanding shallow water and tidal marsh habitat in the Delta. The restoration project is currently undergoing design and permitting processes, and is expected to be implemented in 2014 (California Department of Water Resources 2009).

5E.B.3.3.8 Grizzly Slough

The goal of the Grizzly Slough project was to evaluate the potential to restore stream and floodplain habitat through the breaching/modification of levees and to create habitat for native terrestrial and aquatic species on a 489-acre parcel of the Cosumnes River Nature Preserve owned by DWR. The project is intended to restore connectivity between the Cosumnes River and its floodplain and to increase seasonal floodplain inundation to transport nutrients, biota, water, and sediment from adjacent waterways onto the Grizzly Slough property. Restoration of this connection between the river and its floodplain will foster the accretion and erosion of sediment for the development of splays and channels that help establish diverse habitat types. The project will promote a self-sustaining and dynamic system that will lead to habitat, community, and species diversity and complexity. A 35-acre mitigation site for the Thornton-New Hope Project has been developed by the Delta Levees Program into a diverse assemblage of habitats while maintaining conventional agricultural activities on the remaining land.

5E.B.3.3.9 Sherman Island

Sherman Island lies at the confluence of the Sacramento and San Joaquin rivers. Since the mid-nineteenth century, the island has had a long history of dikes being breached by storms (Hanson 2009). The interior of the island deeply subsided following diking and agricultural development, increasing vulnerability to levee failure (Hanson 2009). Various restoration projects are underway on the island. DWR is conducting a subsidence reversal project at Mayberry Farms involving excavation of channels and water level control to restore about 274 acres of emergent wetlands.

Reclamation District 341, with funding from DWR, constructed four sections of setback levee to increase levee stability along Mayberry Slough on Sherman Island in 2004 and 2005 (California Department of Water Resources 2009). The setback levee totaled approximately 4,500 linear feet and cost $1.7 M, and represents an opportunity to reverse some of the ecological damage resulting from levee construction and maintenance by implementing a habitat development project that will augment the existing riparian vegetation and enhance habitat for locally occurring and migratory native species. The goal of the project is to create 3.7 acres of functioning intertidal channel margin habitat with an intertidal bench to provide habitat and food benefits to native aquatic species by lowering the elevations on the waterside of the existing levee (California Department of Water Resources 2013).

5E.B.3.3.10 Decker Island

Decker Island was created from dredged material from the Sacramento Deep Water Ship Canal (Nobriga et al. 2001). The site includes a 470-acre restoration tract, surrounded by the Sacramento River to the northwest and Horseshoe Bend, a former meander of the Sacramento River, along its eastern, southern, and western shorelines. The Decker Island Habitat Development/Levee Improvement Project is intended to restore marsh habitat by lowering land surface elevations and excavating waterways and channels and using that material to strengthen existing levees (Rockriver 2008).

Decker Island is approximately 20 feet above sea level, because it was built from dredge spoils deposited on the original marshland when the Sacramento River was dredged and straightened at Horseshoe Bend between 1917 and 1937. Exotic weeds and grasses developed on the dry, upland site, providing little habitat value for native species. The project's two phases developed 26 acres of fish and wildlife habitat at the northern tip of Decker Island. Phase I was completed in December 2000 and created approximately 13.5 acres of habitat. Phase II was completed in 2004 and created 12 additional acres of similar habitat (California Department of Water Resources 2013).

To encourage the development of diverse vegetation communities, the site was planted with wetland rushes, shrubs, and trees. Along drier slopes, grasses were seeded to control erosion and provide upland habitat. Large rootwads were aligned along the riverbank to protect the young plantings, minimize erosion, and enhance fish habitat. While success criteria are being developed and will consist of percent cover of the desired species, plant mortality and overlapping habitat types are natural parts of ecological succession and will not be discouraged. Collectively, these efforts should lead to the long-term sustainability of a complex wetland ecosystem with considerable wildlife, water quality, and aesthetic benefits (California Department of Water Resources 2013).

5E.B.3.3.11 Twitchell Island

One goal of the 1997 Twitchell Island demonstration project was to examine the effects of a permanently flooded, freshwater wetland on peat soil subsidence and trapping atmospheric carbon dioxide (Meadows 2009). Flooding subsided peat islands halts peat oxidation by creating anoxic soils, but net accumulation of new material in restored wetlands is required to recover land-surface elevations (Miller et al. 2008). By flooding soils on subsided islands to a depth of approximately 1 foot, decomposition of peat soil was stopped, and ideal conditions for establishing emergent marsh vegetation were created (Fujii 2007). The demonstration project initially resulted in some accretion of biomass, but accretion rates accelerated and land-surface elevation began increasing much more rapidly in 2003 to 2005, reaching about 10 inches of accumulation by 2005 (Meadows 2009). Fujii (2007) estimated that land surface elevations would continue to increase at a rate of about 3.9 inches per year, with the accretion of more biomass over time. In contrast, the surrounding areas used for agricultural purposes have lost elevation due to subsidence (California Department of Water Resources 2013). Research at the Twitchell site has shown that appropriate land management practices can not only eliminate but also reverse subsidence.

5E.B.3.3.12 Twitchell Island Farm Scale Rice Pilot Project

A 300-acre parcel on Twitchell Island is the site of a demonstration project to evaluate whether growing rice is an effective and sustainable way to reduce subsidence and facilitate carbon sequestration, while maintaining a farm economy in the Delta. This pilot project will provide an opportunity to evaluate this technique while considering water quality, farming, and best management practice issues that must be evaluated and resolved. The data analyzed during this project will allow DWR and others to develop recommendations on how this method may be applied to reduce subsidence and sequester carbon. Data will also provide a road map for best management practices that can be used for larger-scale rice growing in the Delta.

5E.B.4 Synthesis and Conclusion

The Delta is a greatly altered, highly varied, and rapidly changing ecosystem (Matern et al. 2002; Lund et al. 2007; Cloern and Jassby 2012). The future Delta ecosystem will be markedly different from the historic system, with new species and processes (Moyle and Bennett 2008; Lund et al. 2010; Cloern and Jassby 2012). The past, while informative, is not necessarily the best template for the future Delta. Conditions in the Delta will change regardless of the BDCP, due to climate change and urbanization and the evolving balance between native and nonnative species. The BDCP provides an opportunity to shape future conditions through habitat restoration. The backdrop of ever-evolving physical and ecological conditions will increase the challenges and heighten the uncertainties of restoration. Nonetheless, the experience of environmental transformation and restoration in the Delta has shown that conditions and processes that support native species can be restored. Characteristics of location, scale, and hydrologic connections appear to be key to the success of transformations that have occurred to date. Restoration under the BDCP will be an ongoing process of learning from experience and incorporating research, monitoring, and synthesis of information. At the same time, examples abound of accidental changes and restoration that have resulted in conditions favoring nonnative species.

The BDCP provides a strategic and coordinated approach that emphasizes the need to improve restoration methods and learn from experience. An overall experimental design that identifies questions, prioritizes restoration projects, initiates investigations, and synthesizes results will be needed to translate past experience into useful knowledge and to achieve the goals of the BDCP. The precarious condition of many Delta fish species that is linked to changes in environmental conditions (Baxter et al. 2010) indicates that restoration of Delta environments is essential to their conservation and to management of native fishes in the Delta. The importance of restoration increases in the context of regional climate change and resulting increased temperatures and sea level (Callaway et al. 2007). The BDCP provides an unprecedented and essential opportunity for large-scale restoration in the Delta aimed at restoring and enhancing delta fish, invertebrate, wildlife, and plant communities.

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