FLOODED ISLANDS

FEASIBILITY STUDY
BASELINE REPORT

PREPARED FOR:

CALIFORNIA DEPARTMENT OF WATER RESOURCES

FOR SUBMITTAL TO:

CALIFORNIA BAY-DELTA AUTHORITY

FEBRUARY 2005

PREPARED BY:

EDAW

SWANSON HYDROLOGY + GEOMORPHOLOGY

HANSON ENVIRONMENTAL, INC.

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1 EXECUTIVE SUMMARY

The purpose of the Feasibility Study of Ecosystem and Water Quality Benefits Associated with Franks Tract, Lower Sherman Lake, and Big Break (Flooded Islands Feasibility Study) is to evaluate the potential to create ecosystem, water quality, recreational, and other benefits at Franks Tract, Lower Sherman Lake, and Big Break (Flooded Islands). The Baseline Report, one of many documents that will be created as part of the study, is a collection of information regarding issues to be considered in evaluating potential restoration alternatives. This document provides information regarding the physical, ecological, and social conditions at the Flooded Islands.

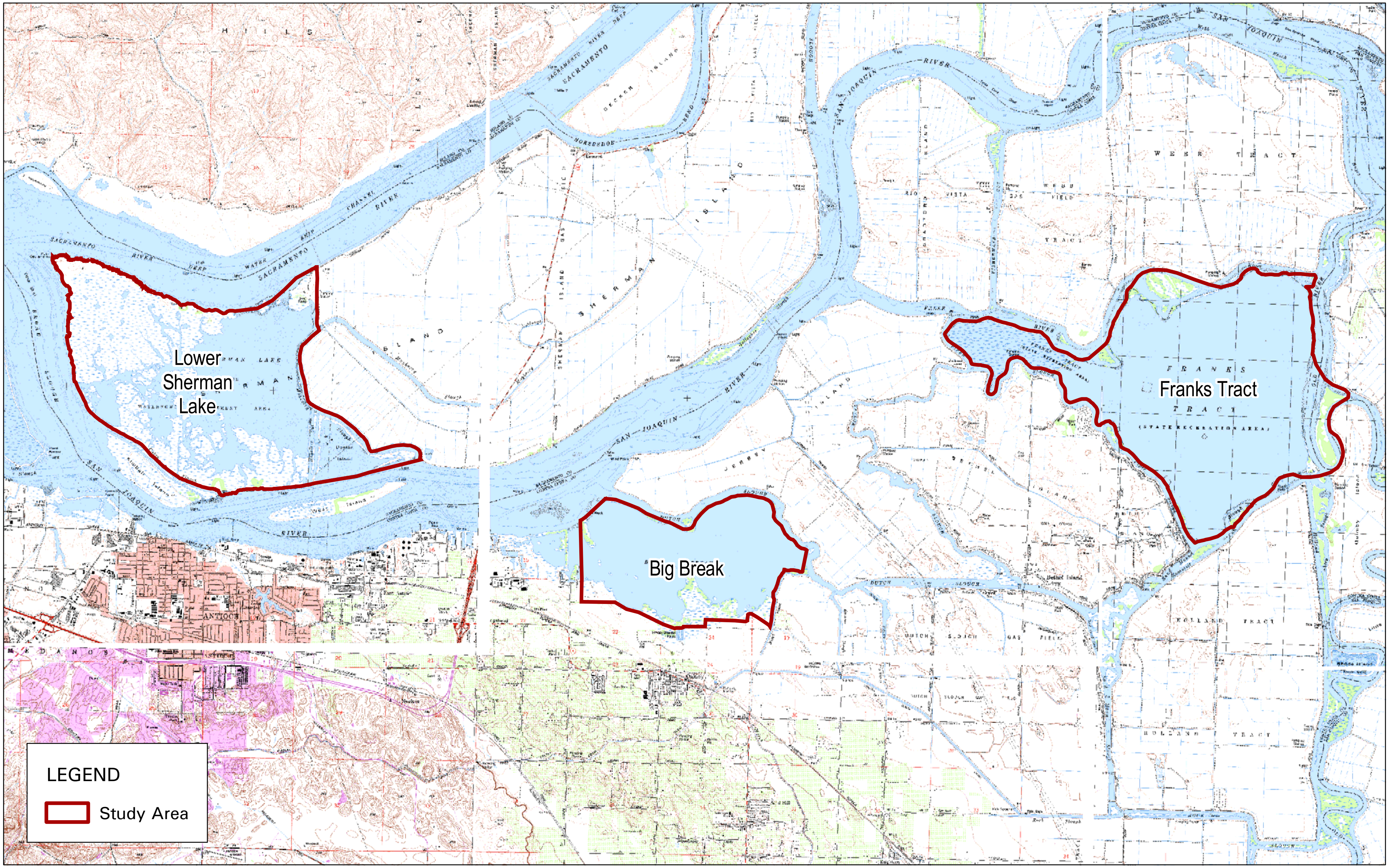
The Flooded Islands are located in the Sacramento–San Joaquin River Delta, a major water supply, recreation, and ecological resource in the state. The Delta, at the confluence of the Sacramento and San Joaquin Rivers, is the largest estuary system on the West Coast. The estuary system functions as the hub of an extensive network of waterways that flow through the north and central regions of California. This aquatic system is the conduit through which runoff from over 40%of the State's land area flows into the San Francisco Bay and ultimately to the Pacific Ocean. Although the Delta is essentially a freshwater system, water levels and flow velocities are subject to tidal influence and fluctuating salinity concentrations because of its relatively low elevation.

In general, the Delta consists of a network of several hundred islands interconnected by 700 miles of waterways and encompasses approximately 738,000 acres. Of those 738,000 acres, there are approximately 60,000 acres of waterways with about 57,238 of those acres navigable. The water surface area provides approximately 635 miles of linear channels. The Delta supplies drinking water for two-thirds of the California population and irrigation water for over 7,000,000 acres of agriculture.

The three study areas (Exhibit 1-1) historically were islands created by constructed levees in the western and central Delta that became flooded and submerged when their levees were breached.

The largest of the three study areas is Franks Tract (Exhibit 1-2). Franks Tract encompasses the Franks Tract State Recreation Area, which is owned and managed by the Department of Parks and Recreation (State Parks). Franks Tract is bound by False River and Webb Tract on the north, Old River and Mandeville Island on the east, Sand Slough and Holland Tract on the south, and Piper Slough and Bethel Island on the west. Franks Tract consists of two submerged areas. The western portion of Franks Tract, known as Little Franks Tract, is a 330-acre area projecting from the larger 3,300-acre main submerged area known as Big Franks Tract.

The Lower Sherman Lake project site (Exhibit 1-3) consists of three main parts: the main submerged area known as Lower Sherman Lake, a submerged island named Donlon Island, and Lower Sherman Island. Lower Sherman Lake is the largest flooded area of Sherman



Sources: USGS Quads (Antioch North 1978, Antioch South 1980, Bouldin Island 1993, Brentwood 1978, Jersey Island 1978, Woodward Island 1978)

Study Area

EXHIBIT 1-1

Flooded Islands Feasibility Study Baseline Report

X 04110052.01 2/05

0 8000 16000 FEET

NORTH

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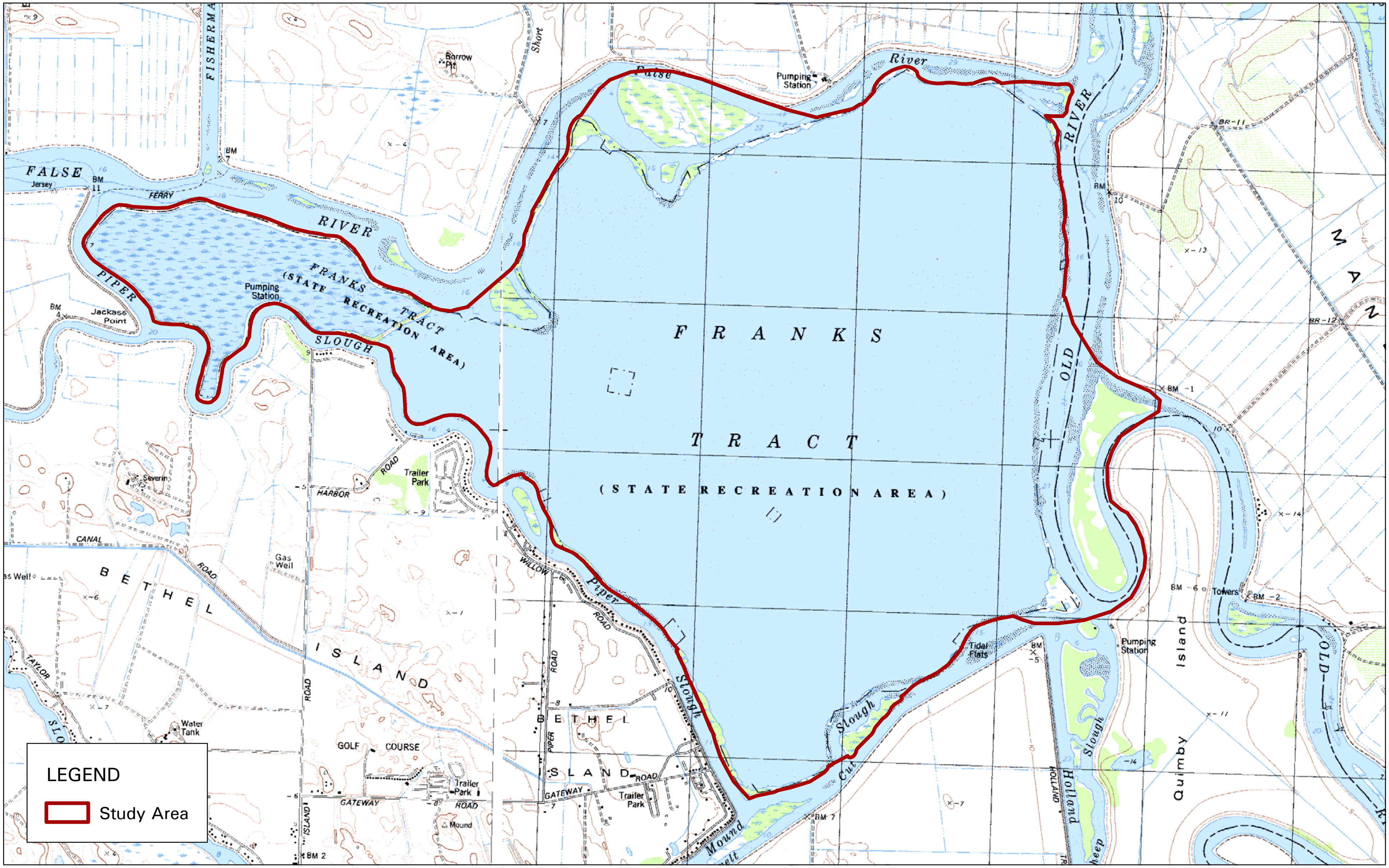

Sources: USGS Quads (Bouldin Island 1993, Jersey Island 1978)

Franks Tract

EXHIBIT 1-2

Flooded Islands Feasibility Study Baseline Report

X 04110052.01 2/05

0 3000 6000 FEET

NORTH

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Source: Antioch North Quad 1978

Lower Sherman Lake

EXHIBIT 1-3

Flooded Islands Feasibility Study Baseline Report

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Island. Lower Sherman Island, located to the west of Lower Sherman Lake, is an upland area penetrated by numerous sloughs. Lower Sherman Lake and Lower Sherman Island collectively form the Lower Sherman Wildlife Area, which is owned by the Department of Fish and Game (DFG). Donlon Island is located between Sherman Island and Lower Sherman Island and is to the south of Lower Sherman Lake.

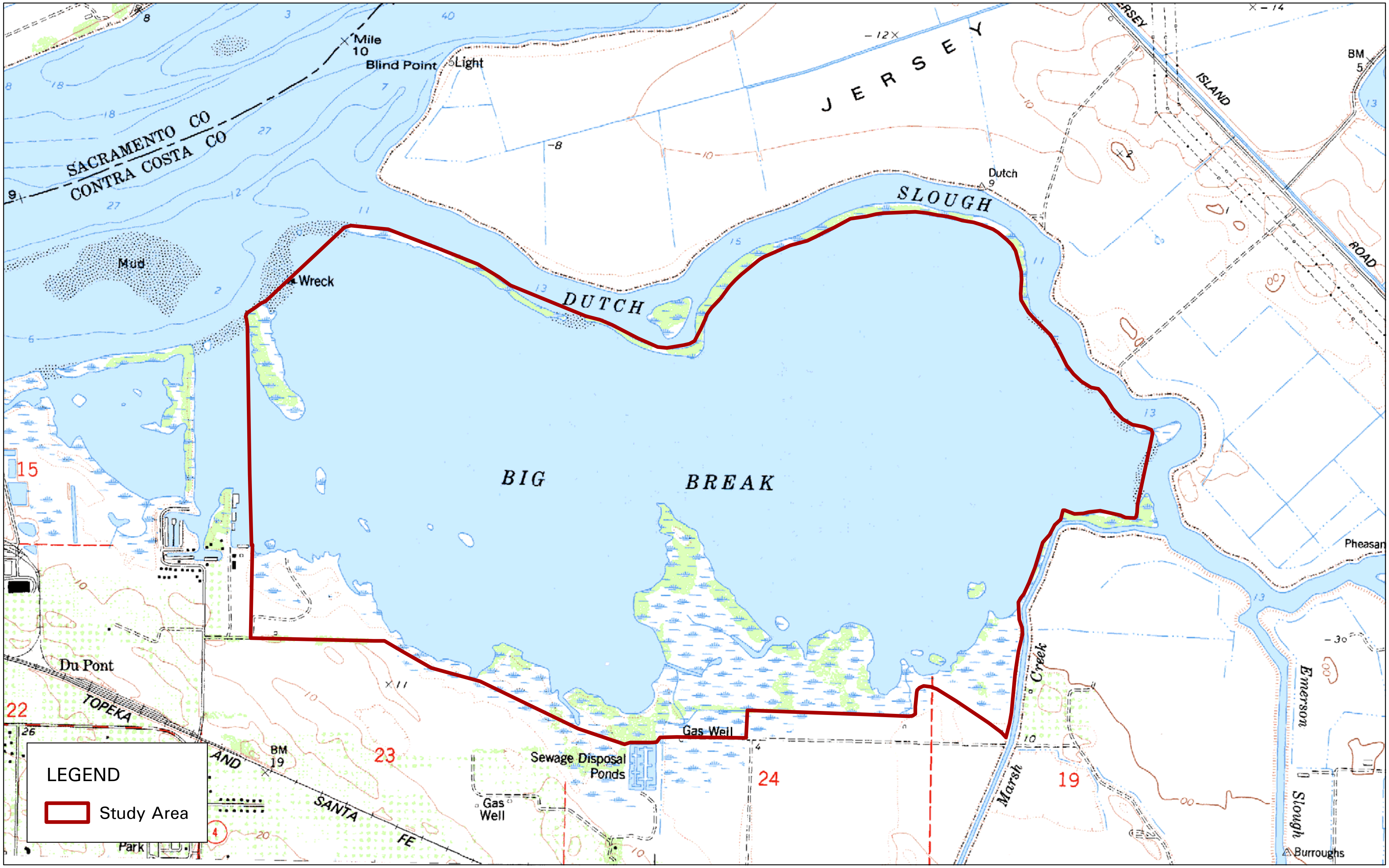
The Big Break project site (Exhibit 1-4) consists mostly of the East Bay Regional Park District's (EBRPD) Big Break Regional Shoreline. Big Break Regional Shoreline includes the flooded portion of Big Break Tract, starting just south of the former levees, plus 40 acres of upland areas along the south shore of Big Break. Most of this upland area is referred to as the Lauritzen Site. The Lauritzen Site contains old barges and pilings that have been grown over by aquatic plants, forming a wetland area interspersed with islands and scrap. The Big Break project site also includes some areas outside the Big Break Regional Shoreline; these portions are in the Vintage Marsh and Ironhouse Sanitary District property.

BATHYMETRY, TOPOGRAPHY, AND SEDIMENTATION

The Delta collects all of the freshwater runoff from the Central Valley, which is subject to constant interaction with ocean tidal forces and saltwater, and then discharges it toward San Francisco Bay and the Pacific Ocean. The complexity of the Delta is primarily the result of its geologic evolution and a long history of basin subsidence, sediment deposition, biotic activity, interactions with sea-level changes over the past several million years, and in recent history, human activities and modifications, and reclamation actions. Today, the topography of the Delta ranges from elevations 6 to 30 feet above sea level at the tops of levees to -15 to -45 feet below sea level in the deepest channels. The elevation of islands varies from 10 to 20 feet above sea level to less than 20 feet below sea level at deeply subsided islands.

The hydrologic function of the Delta involves the interaction of streamflow runoff from the major rivers (Sacramento River from the north and San Joaquin River from the south) and tidal inflow of salt water from the Pacific Ocean. The runoff of the Sacramento River is greater, accounting for 80% of the freshwater runoff by volume. The water in the San Joaquin River and its tributaries has been highly diverted for agricultural use, and much of the runoff is diverted upstream of the Delta. At their junction, runoff from the Sacramento River channel near Sherman Island flows southward to create a freshwater barrier across the mouth of the San Joaquin; without this barrier, it is postulated that saltwater inflow to the south-central Delta would increase significantly. The hydrology of the Delta is also greatly affected by diversion pumps situated in the south Delta area to serve the federal and state water projects. These further affect ecological function and at times reverse outflows away from San Francisco Bay.

Ecologically, the most significant change has been the loss of intertidal landforms, wetlands, and shallow shoals that support diverse plant communities and wildlife habitats. The reclamation of the large islands to agriculture through construction of dredger cuts left only remnants of the original shoreline, and many of these Delta islands were destroyed by erosion from wind-generated waves, flood currents, tidal currents, and boat wakes. Subsidence of



Source: USGS Jersey Island Quad 1978

Big Break

EXHIBIT 1-4

Flooded Islands Feasibility Study Baseline Report

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NORTH

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islands has also resulted in lower land surfaces and reduced intertidal area. Data documenting sedimentation in all three sites in the study area are generally scarce, and analyses to date are inconclusive. Water levels in the study area are influenced by tides, wind, surface runoff, and river flows.

GEOLOGY, SOILS, AND SEISMOLOGY

The Great (Central) Valley Geomorphic Province is a valley trough that extends over 400 miles from north to south and consists of the Sacramento and the San Joaquin Valleys. The Central Valley Geomorphic Province is a long, low trough underlain by Quaternary sedimentary rock, lesser amounts of Tertiary sedimentary rock, and Cretaceous shales. This geologic base is overlain with alluvium and fill deposits, including peat and detrital sediments that are interbedded with glacial sands and gravel washed down from the Sierra Nevada. Occupying the lowest part of the western Sacramento Basin is the Delta. Originally, the Delta was part of the inland sea of Tertiary and post-Tertiary times, but during the post-Pleistocene, the Delta became filled with many islands formed by waters moving through this region. During flooding, sediments were deposited along the islands' shores, forming natural levees. Each island's interior subsided, and seasonal ponds provided an ideal environment for tule (*Scirpus* spp.). These tule marshes have formed significant peat deposits throughout the Delta.

Valley land and valley basin land soils occupy most of the Central Valley floor. Valley land soils consist of deep alluvial and Aeolian soils that make up some of the best agricultural land in the state. Valley basin lands consist of organic soils of the Sacramento–San Joaquin Delta, poorly drained soils, and saline and alkali soils in the valley trough.

By 1920, it was recognized that the drained Delta lands were subsiding. Subsidence, as it relates to Delta islands, refers generally to the falling level of the land surface that results primarily from the process of peat soil oxidation. Subsidence occurs throughout the Delta, and is due to varying causes: oxidation, shrinkage, wind erosion, tectonic movement, compaction, consolidation (gas withdrawal), burning, and export of peat (Center for Design Research, UCD 1988). Subsidence of the peat soils has caused the tidally influenced islands to become holes in which the land surfaces are now 10–25 feet below sea level.

The Delta is subject to seismic risk because of its proximity to the San Andreas Fault system. This fault system includes the San Andreas, Hayward, Calaveras, Rogers Creek, Antioch, Green Valley–Concord, and Greenville faults. All of these faults have been active historically. The likelihood of a significant seismic event in the next 50 years is high (about the same probability as a 100-year flood event). CALFED's Seismic Vulnerability Sub-Team of the Levees and Channels Technical Team predicted that an earthquake with a magnitude of 6.0 (Richter Magnitude) has a 25% chance of occurring in the next 50 years. The most severe effect from earthquakes in the Delta would be damage to the levee system. Many levees in the Delta are water saturated, lack cohesion, and are constructed on extremely unstable soils that could amplify earthquake waves passing from bedrock to unconsolidated soil layers.

WATER QUALITY

Delta waters serve several beneficial uses, each of which has water quality requirements and concerns associated with it. The Delta is a major habitat area for important species of fish and aquatic organisms, as well as a source of water for municipal, agricultural, recreational, and industrial uses. The primary water quality variables of the Delta related to the Flooded Islands Feasibility Study may be generally placed in the primary categories of salinity, organic carbon, and mercury.

Salinity

Water quality at all three project sites is influenced by location in the central and western Delta, and thus the surrounding Delta channels are exposed to a range of salinity conditions from freshwater to brackish levels. The location, geometry, and presence of specific breach locations on Franks Tract result in saline water being trapped within the island that is then subject to hydrodynamic forces that cause salt transport further into the southern Delta where it may contribute to source water degradation for Delta water users. Flow from the Sacramento River through Lower Sherman Lake into the San Joaquin River occurs via the existing breaches. The flow may contribute to substantially reduce salinity levels in the southern Delta than would otherwise occur without the breaches.

Organic Carbon

Delta inflows, island drainage discharges, miscellaneous waste discharges, and in-channel processes all contribute to organic carbon cycling and associated ecosystem effects and contaminant potential of Delta source waters used for drinking water. The relative importance of each at any given time depends on many variables, including location, sources and loads, channel flows, tides, and biological processes. River sources of organic carbon appear to dominate in the winter, whereas biological processes (phytoplankton growth) in the Delta appear to dominate in spring and summer. Dissolved organic carbon (DOC) varies considerably in quality. It is a complex heterogenous mixture of organic molecules with different molecular weights, solubilities, polarities, reactivities, and bioavailability potential. DOC quality varies considerably among sources and in Delta channels is not a simple mixture of DOC from the rivers and DOC in the agricultural drains. The quality of the DOC is as important as the quantity in affecting primary (planktonic) productivity in the food web and trihalomethane (THM) formation potential in drinking water exports. In-channel phytoplankton productivity is now considered to be the most important food source of zooplankton. The importance of peat soils highlights the potential significance of wetland restoration to water quality issues. Flooding islands with peat soils for restoration purposes inundates remaining peat soils and reestablishes the same tidal wetland processes that led to the formation of such soils over time.

Mercury

Mercury concentrations result from natural and anthropogenic sources in the environment and continually cycles in the aquatic environments of the Sacramento and San Joaquin River Basins and Delta. In-Delta methyl mercury formation processes may be as important a factor to ecosystem exposure and uptake in the food chain as the much larger overall riverine inputs of mineralized forms. Total mercury concentrations in coastal mountain streams have been measured at levels two orders of magnitude higher than levels in Sierra mountain streams, and the methyl mercury concentration patterns were equivalent. Methylation of mercury is the key step in the entrance of mercury into food chains. Nearly 100% of the mercury that bioaccumulates in fish tissue is methylated. The rates of methylation in the Delta are influenced by the bioavailability of inorganic mercury to methylating bacteria, the concentration and form of inorganic mercury, and the distribution and activity of methylating bacteria. The highest methyl mercury sediment concentrations have been found in the central Delta. The central Delta also has been documented to have the greatest mercury methylation potential when compared to the surrounding tributaries. Solid-phase methyl mercury concentrations vary seasonally; the highest concentrations occur during late spring and summer. Interiors of wetlands consistently have been documented to have higher solid-phase methyl mercury concentrations and methyl mercury to total mercury ratios than fringes of wetlands or open water habitats. Findings suggest that dense wetlands may export methyl mercury to surrounding channels; however, biological findings indicate no distinct localized increase in net methyl mercury bioaccumulation in flooded wetland tracts versus adjacent aquatic habitats within Delta subregions. Some of the most well developed, highly vegetated wetland tracts have exhibited reduced levels of localized net mercury bioaccumulation. These results suggest that wetland restoration projects may result in localized mercury bioaccumulation at levels similar to, but not necessarily greater than, levels within their surrounding Delta subregion.

AQUATIC, WETLAND, AND TERRESTRIAL VEGETATION AND HABITATS

The Delta is a mosaic of vegetation and habitat types distributed along hydrological, salinity, and geomorphological gradients. Before land reclamation and flood control activities around the turn of the 20th century, the Delta supported a complex network of rivers and sloughs with in-channel islands and vast expanses of tidal marsh. Following the construction of levees, in-channel islands were isolated from tidal flooding, causing significant subsidence of the interior islands. Marsh habitat is currently being eroded by high flow velocities in the Delta's confined and deepened channels and waves generated by wind and watercrafts. The dominant vegetation types growing in the study area include emergent tidal marsh, riparian scrub/woodland, and submerged and floating aquatic vegetation. However, the three subsided islands in the study area are currently characterized by vast expanses of open water habitat, although they have been flooded for a number of years. These flooded islands have not accumulated enough sediment to support the reestablishment and expansion of tidal marsh vegetation. However, the existing vegetation and habitat types support potential habitat for 14 special-status plant species, and several of these species are known to inhabit or have been observed in the study area.

FOOD WEB

Along the salinity gradient extending from the Golden Gate upstream into the western and central Delta and tributaries, the species composition of the aquatic community changes dramatically, although the basic functional relationships among organisms (e.g., predator–prey, etc.) remain similar throughout the system. The primary energy input to the system is solar radiation, which is used, along with nutrients, by the primary producers (phytoplankton, vascular plants, and macroalgae) to convert inorganic carbon and nutrients to organic matter through photosynthesis. Zooplankton (e.g., copepods, cladocerans, mysid shrimp), prey on the phytoplankton. The vascular plants and macroalgae are grazed on and also produce detritus, which is decomposed by microbes and consumed by detritivores (e.g., polychaete worms, amphipods, cladocerans, and a diverse group of other fish and macroinvertebrates). The primary consumers are in turn preyed upon by secondary consumers, consisting mainly of invertebrates (polychaete worms, snails, copepods, mysid shrimp, shrimp, and crabs) and fish (delta smelt, threadfin and American shad, gobies, sculpin, juvenile chinook salmon, and a variety of other resident and migratory fish species). These in turn are preyed on by top consumers, such as fish (striped bass, catfish, sturgeon, largemouth bass, and Sacramento pikeminnow), marine mammals, birds, and humans. The role of a species in the food web may be different at different lifestages, or it may utilize various levels of the food web simultaneously.

FISH AND WILDLIFE

Fisheries

The biological environment of the Bay–Delta estuary is a complex community of plants and animals inhabiting the saltwater, estuarine (brackish-water), freshwater aquatic, and terrestrial habitats. The Bay–Delta is a complex estuarine ecosystem, a transition zone between inland sources of fresh water and saltwater from the ocean. Suisun Bay and the western and central Delta, including the flooded islands, contain several aquatic habitats, including sloughs and cuts, shallow channel and shoal areas, the main river channels, and open-water aquatic habitats. Together, these habitats support a large and diverse aquatic community, which includes several native, nonnative, special-status, and recreationally important species of fish.

The primarily open-water habitat in Franks Tract, Lower Sherman Lake, and Big Break is relatively shallow (most of the open-water habitat within the flooded islands is less than 10 feet deep), with a relatively uniform bottom composed of silt, sand, peat, and other organic matter whereas the surrounding channels in the western and central Delta vary in size and hydraulic complexity. Tules and other emergent and submerged aquatic vegetation grow in open water areas and along the shoreline margins of the Flooded Islands and provide habitat for spawning, juvenile rearing, and adult holding and foraging.

Results of fishery sampling in the Bay–Delta estuary show that 55 fish species inhabit the estuary, and approximately one-half of those are introduced species. Many nonnative fish species inhabiting the estuary, such as striped bass and American shad, were purposefully introduced to provide recreational and commercial fishing opportunities. Others have been introduced accidentally into the estuary through movement through connecting waterways (e.g., threadfin shad and inland silversides). Many fish and macroinvertebrate species have been accidentally introduced into the estuary, primarily from Asia, through ballast water discharges resulting from commercial cargo transport (e.g., yellowfin and chameleon gobies). The purposeful and unintentional introductions of nonnative fish and macroinvertebrates have contributed to a substantial change in the species composition, trophic dynamics, and competitive interactions affecting the population dynamics of native species. Many of these introduced fish and macroinvertebrates have colonized and inhabit the Flooded Islands. Several native resident and migratory fish species have been listed for protection under the State and/or Federal Endangered Species Act, including Delta smelt, winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead. Suisun Bay and the western and central Delta have been designated as critical habitat for Delta smelt and winter-run Chinook salmon and as Essential Fish Habitat for managed species, including Pacific salmon.

Avian Species

The Delta is in a prime location within the Pacific flyway, the major pathway for migratory bird species on the West Coast. At least 230 species of birds are found in the Delta. Many of these species inhabit the Delta only or primarily during fall and winter, when the Delta becomes home to an abundance of migratory and wintering wildlife. The most conspicuous groups of wintering birds include waterfowl, shorebirds, wading birds, and raptors. In addition, many species of Neotropical migratory birds migrate through or breed in the Delta.

Very little ornithological information is available that is specific to the project sites, although a few observations of note have been made at each site. In particular, some general descriptions of the birds at Franks Tract SRA have been published.

Areas in and adjacent to the project sites are currently, or have great potential to be, of significance for 11 special-status bird species: least bittern, Swainson's hawk, California black rail, California clapper rail, greater sandhill crane, burrowing owl, bank swallow, California yellow warbler, saltmarsh common yellowthroat, Suisun song sparrow, and tricolored blackbird. Several of these species are largely confined to or reach their greatest population density in the Delta, and consequently could be given significant consideration in the current and future management of the project sites.

Other Wildlife Species

The upland grassland and ruderal areas around these islands have the potential to support several common mammal species, such as black-tailed jack rabbit (*Lepus californicus*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), California ground squirrel (*Spermophilus* *beecheyi*), California vole (*Microtus californicus*), western harvest mouse (*Reithrodontomys megalotis*), house mouse (*Mus musculus*), Botta's pocket gopher (*Thomomys bottae*), Virginia opossum (*Dedelphis virginiana*), feral cats (*Felis domesticus*), Norway rat (*Rattus norvegicus*), and possibly coyote (*Canis latrans*) and red or gray foxes (*Vulpes vulpes, Urocyon cinereoargenteus*). The aquatic areas of the islands provide foraging habitat for several common and special-status species of bats, and upland areas around the islands may provide suitable roosting habitat. The wetland margins of the islands likely support muskrat (*Ondatra zibethicus*), and may support American beaver (*Castor canadensis*), northern river otter (*Lutra canadensis*), or American mink (*Mustela vision*). Common reptile and amphibian species most likely found in and around the three islands include western fence lizard (*Sceloporus occidentalis*), common garter snake (*Thamnophis sirtalis*), western rattlesnake (*Crotalis viridis*), gopher snake (*Pituophis melanoleucus*), Pacific tree frog (*Hyla regilla*), western toad (*Bufo boreas*), bullfrog (*Rana catesbeiana*), and possibly red-eared slider turtles (*Chrysemys scripta*).

Special-status species of particular concern that could inhabit the area of the flooded islands include valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*), salt marsh harvest mouse (*Reithrodontomys raviventris*), giant garter snake (*Thamnophis Gigas*), western pond turtle [*Emys (=Clemmys) marmorata*], California tiger salamander (*Ambystoma tigrinum*), and silvery legless lizard (*Anniella pulchra pulchra*). Several other special-status species have been recorded in the area, or have the potential to exist in the area; however, these species are not likely to be found in habitats provided by the three flooded islands, or they are presumed extirpated from the area.

One of the most difficult impacts on the Delta's natural resources to assess and treat is the introduction of nonnative species, which compete with native species for food and shelter, and which prey directly on native species. Such predators can have a major impact on the ability of natural areas to support wildlife, including threatened native species.

INVASIVE SPECIES OF CONCERN

<u>Egeria densa</u>

The open water habitat within the study area supports extensive infestations of the invasive, nonnative species Egeria (*Egeria densa*), which is more commonly known as Brazilian waterweed. This freshwater aquatic plant species was introduced to the Delta approximately 30 year ago and since has spread extensively throughout its waterways. Dense infestations of Egeria have created problems for navigation, recreation, agriculture, and processes supporting the Delta's aquatic ecosystem. Egeria forms dense monotypic infestations that outcompete and eventually replace native aquatic plants. The reduction and/or elimination of native aquatic vegetation and the addition of these nonnative infestations disturb the Delta's food web and many biogeochemical cycles supporting its ecosystem function. Studies of these infestations in the Delta reveal that the growth and proliferation of Egeria are primarily regulated by substrate elevation and stability and water velocity. The percent cover (areal extent of infestations in open water habitat) of Egeria infestations in the Delta has been tracked since 1999, and the surveys in 2000 show that Egeria provided approximately 61% cover in open water areas at Franks Tract, approximately 30% cover at Lower Sherman Lake, and approximately 52% cover at Big Break.

Corbicula fluminea

Corbicula fluminea is the most widespread and abundant freshwater clam in California. It is the dominant mollusk and the third most abundant benthic organism in the Delta, and is one of the most commonly identified benthic organisms in fish stomachs. Densities of 2,000 young clams per square meter are common, and populations may range up to 20,000 clams per square meter.

Corbicula appears to do better in artificial or disturbed situations than in areas unchanged by human activity. The clam is a shallow burrower, sheltering in mud, sand, gravel, organic debris, or under rocks. *Corbicula* lives in still as well as moving waters. Depth does not seem to be restrictive; the clam is found from intertidal areas to depths of over 12 meters (39.4 ft) in lakes and reservoirs. In the latter situation, temperature and chemical limitations may control distribution. Although it is considered a freshwater mollusk, the clam's physiology enables it to withstand brackish water with salinities up to 17% (sea water is about 34%). *Corbicula* survival rates vary in saline waters, depending on the degree of acclimation provided. At 4.5% salinity, the clam attains 50% sodium saturation in the tissues, a value considerably higher than that reported for most freshwater organisms. It does well in the intertidal areas of river deltas, where it is exposed to daily and seasonal changes in water depth and salinity. Research on *Corbicula* distribution in the Delta is currently being compiled, and results are anticipated in spring 2005.

Biofouling and competition with native species are two negative effects of this introduced species. In addition, because grazing by *Corbicula* significantly reduces phytoplankton biomass in some flooded islands (such as Franks Tract), and because phytoplankton biomass in flooded islands with large populations of *Corbicula* is within the range known to be food limiting for some zooplankton, "over-grazing" by *Corbicula* has the potential to limit the viability of some habitats as sources of high-quality food for zooplankton, and ultimately for fish and species in higher trophic levels. *Corbicula* has become a serious pest in North America; few natural predators or disease organisms control its numbers, a typical situation when exotic animals are introduced in an area where no close relatives are present. Efforts to control the clam have had mixed results.

LAND USE

For regulatory purposes, the region in which the flooded islands are located is the Legal Delta, as defined in Section 12220 of the California Water Code. Various city and county, and three state and local agencies are responsible for land use planning in the Delta.

The State Lands Commission has jurisdiction over submerged lands of the state and protects the public trust values, including easements for water-borne commerce, navigation, fisheries, recreation, and open space. The passage of the Delta Protection Act of 1992 (California Water

Code Section 12220) established the Delta Protection Commission. The Delta Protection Commission has land use planning jurisdiction over the Primary Zone, which generally consists of the central portion of the Delta. The Delta Protection Commission is charged with preparation of a regional plan for the Primary Zone. The purpose of this regional plan is to address land uses and resource management for the Legal Delta, with particular emphasis on agriculture, wildlife habitat, and recreation.

Most of Franks Tract is owned and managed by State Parks as a State Recreation Area (SRA). According to Public Resources Code Section 5019.56, the SRA classification denotes an area selected, developed, and operated to provide outdoor recreation opportunities to meet other than purely local needs. Lower Sherman Island and Lake are owned and operated by DFG. DFG currently does not have a Land Management Plan developed for Lower Sherman Lake, but expects to complete one in 2006. Currently, Lower Sherman Island Wildlife Area is unimproved. Management of this unit is conducted based on compliance with the Public Resource Code, but is without unit-specific goals, policies, and objectives. Most of Big Break is owned by EBRPD, a local agency without land use planning jurisdiction. Most of the project site is classified by EBRPD as Big Break Regional Shoreline. The Big Break Regional Shoreline Land Use Plan was completed in 2001. The Shoreline Land Use Plan designates two recreational areas on the Lauritzen site that would contain developed facilities, such as picnic tables, piers, parking areas, and boat ramps.

The Lower Sherman Lake study area is located in Sacramento County. The Sacramento County General Plan was most recently adopted in 1993. The Sacramento County General Plan Land Use Diagram identifies Sherman Island and Lower Sherman Lake with the Recreation designation and Lower Sherman Island with the Natural Preserve designation. The majority of Franks Tract and all of the Big Break study areas are located in Contra Costa County. The Contra Costa County General Plan was adopted in July 1996.

WATER USE

The Delta is the primary source of the State's freshwater, whereas most of the population of the State resides elsewhere. Approximately 75%of the State's fresh water originates north of the City of Sacramento, while 75%of the water needs are generated south of Sacramento. Although water diversions from the Delta vary on a year-to-year basis, on average, 18.4% of the fresh water in the Delta is directly diverted at the Contra Costa, Banks, and Tracy Pumping Plants. Approximately 75.5% of the water flows out from the Delta to the Bay. The remaining 6.1% of the water is directly used in the Delta (i.e., direct diversion by 1,800 intakes into irrigation channels for 520,000 acres of agricultural lands in the Delta and lost via evapotranspiration) and lost in the channels.

The 2 main water diversion programs are the State Water Project (SWP) and Central Valley Project (CVP). Local agencies, such as the City of Vallejo, also operate their own diversion programs, using Contra Costa Canal, North Bay Aqueduct, and other local diversion infrastructure. Direct diversion by private entities, such as Western Delta Industry and 1,800-plus agricultural users, also occurs in the Delta.

The federal CVP, administered by the United States Bureau of Reclamation (Reclamation), stores and transports water from the Sacramento and San Joaquin Rivers for irrigation uses in the Central Valley, as well as municipal uses in Contra Costa Water District's (CCWD) service area and elsewhere. CVP supplies water to more than 250 long-term water contractors for a maximum annual delivery of approximately 9,300,000 AF.

The SWP, administered by California Department of Water Resources (DWR), captures, stores, and conveys water to 29 water agencies throughout the state. Approximately two-thirds of the people in the state received at least a part of their drinking water from the SWP. Long-term contracts for a combined maximum of 4.12 million acre feet were signed with public water agencies, known as the SWP contractors. Water deliveries have ranged from 1.4 million acre-feet in dry years to almost 4.0 million acre-feet in wet years. Five contractors use SWP water primarily for agricultural purposes (mainly southern San Joaquin Valley); the remaining 24 use SWP water primarily for municipal purposes.

Water derived in the Delta is used for a variety of purposes, including irrigation, domestic consumption, industrial use (i.e., power plant cooling), and environmental protection (i.e., habitat maintenance, water quality improvement, Wild and Scenic Rivers requirements). Water use and the volume of water available for use are in part dedicated by compliance with water quality standards for water bodies in California, enforced by State Water Resource Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCB), and based on the beneficial uses designated in region-specific water quality control plans (basin plans).

RECREATION

The Delta is a major recreational resource for northern California, and recreation is an important economic activity for the communities in and around the Delta. Water-based recreation activities in the Delta include cruising, water-skiing, fishing and hunting from a boat, sailing, wind sports, and boat camping. The two most popular activities are boating and fishing.

Owing to its central location and the expanse of open water, Franks Tract is considered the hub for the Delta's recreational boating and is also well known for its popular striped bass fishery. There is a long history of hunting in the Delta in association with privately owned agricultural lands and on a few publicly owned properties in the Delta. All three Flooded Islands are popular for hunting from boats. The far western side of the Delta, along the Sacramento River, has become renowned throughout the western United States as one of the premier wind sports (windsurfing and kite boarding) locations in the country. Camping and recreational vehicle use is also available at several locations in the Delta, primarily at larger parks, resorts, and marinas.

Studies conducted in the Delta during the past 10 years have identified several key recreation issues. Perceptions of poor water quality are common among many Delta users, along with related concerns about improper disposal of boat wastes. The CALFED Bay–Delta program has proposed 12 actions that are primarily aimed at improving ecological conditions and modifying the flow and diversion of water in the Delta. Most of these have potential negative impacts to recreation, such as displacement of existing facilities and restrictions on boat travel. Potential benefits would primarily be due to improved water quality, a key recreation issue in the Delta, and habitat restoration that would enhance nature-related pursuits, such as non-motorized boating, wildlife viewing, and fishing. Some actions may also provide opportunities for development of new facilities to serve both boaters and land-based recreationists.

MATERIALS FOR RESTORATION

When planning a restoration project in the Delta, it is important to address the type and quality of fill and observe the regulatory framework for dredging and fill materials. Reusing dredge spoil materials is a promising approach for simultaneously addressing a portion of the Delta subsidence problem and the dredge spoil disposal issue. Dredge spoils can be used to strengthen existing levees, build new cross levees, and raise small areas to near sea level for tidal marsh restoration. Aside from using dredge spoils as fill materials, there are other fill materials and methods for restoring levees and constructing islands. The issues that are relevant to the Flooded Islands project sites include the use of rice-straw bales, island capture of bed load and suspended sediment moving through the Delta, and importation of soil from upland sites.

2 INTRODUCTION

This chapter describes the purpose of the feasibility study of ecosystem and water quality benefits associated with Franks Tract, Lower Sherman Lake, and Big Break (Flooded Islands Feasibility Study) and the Baseline Report and the locations of the study areas. The Baseline Report includes background information on the three study areas in Chapter 3, descriptions of environmental conditions relevant to the discussion and design for the feasibility study in Chapter 4, and identification of available information and data gaps in Chapter 5. Because knowledge on the Sacramento-San Joaquin River Delta continues to expand rapidly over time, this document represents a snapshot of the knowledge available at the time of the preparation of the Baseline Report.

2.1 STUDY PURPOSE

The purpose of the Flooded Islands Feasibility Study (study) is to evaluate the potential to create ecosystem, water quality, recreational, and other benefits at Franks Tract, Lower Sherman Lake, and Big Break (study areas). A number of documents will be created as a part of the study, including:

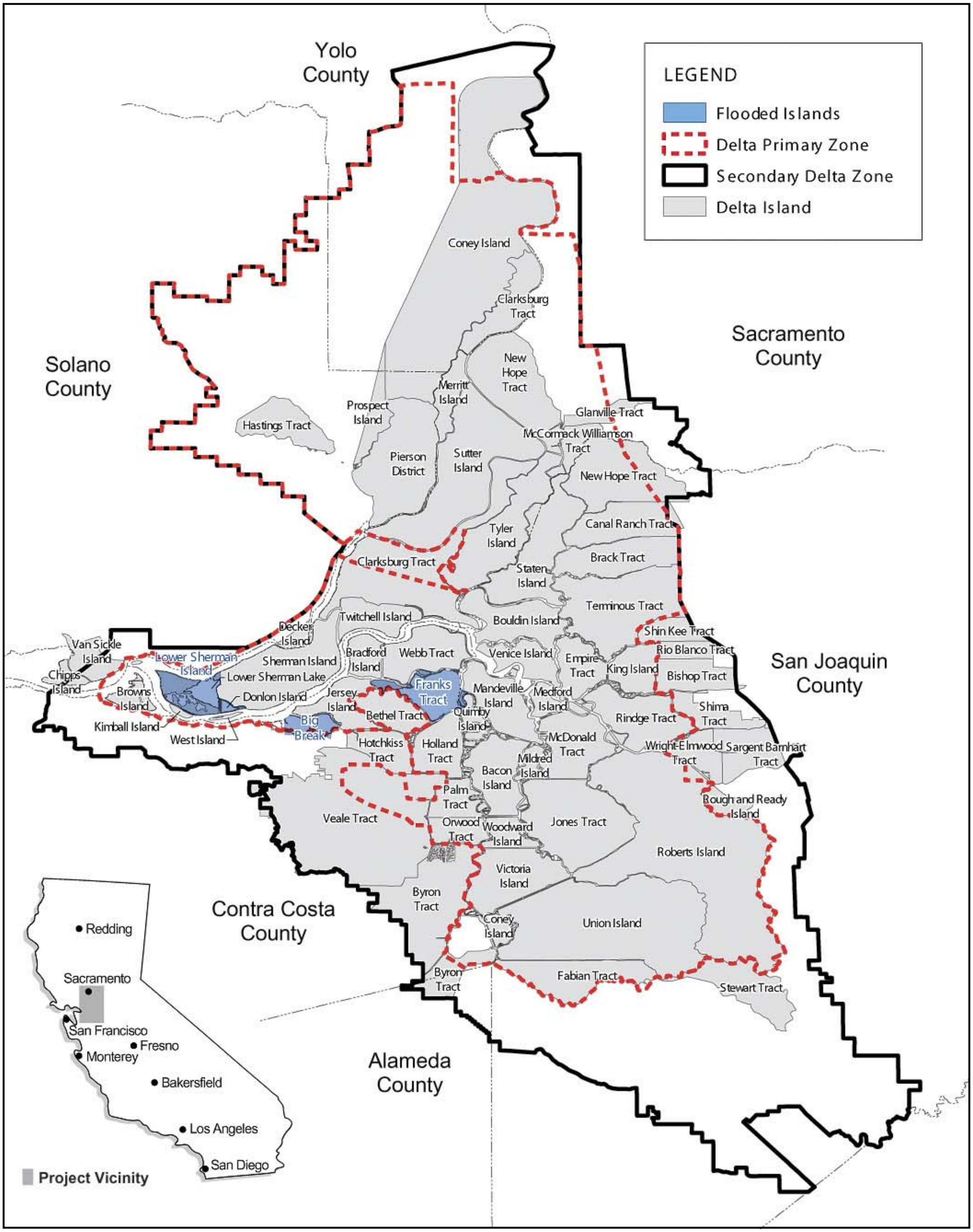
- Baseline Report
- Goals and Objectives Statement
- Hydrological Modeling Study
- Feasibility Report

2.2 PURPOSE OF BASELINE REPORT

The Baseline Report is a collection of information regarding issues to be considered in evaluating potential restoration alternatives. This document also provides a description of the physical environmental conditions at the study areas and in the Sacramento–San Joaquin River Delta. The existing physical environment constitutes the baseline condition, with which a lead agency would compare any physical changes implemented pursuant to the Feasibility Study when determining the environmental impacts in subsequent environmental review documents.

2.3 REGIONAL SETTING

The study areas, described below, are located in the Sacramento-San Joaquin River Delta (the Delta), a major water supply, recreation, and ecological resource in the state (see Exhibit 2-1). The Delta, at the confluence of the Sacramento and San Joaquin Rivers, is the largest estuary system on the West Coast (see Exhibit 2-1). The estuary system functions as the hub of an extensive network of waterways that flow through the north and central regions of California. This aquatic system is the conduit through which runoff from over 40 percent of the State's land area flows into the San Francisco Bay and ultimately to the Pacific Ocean. Major tributaries that converge in the Delta include the Calaveras, Cosumnes, Mokelumne,



Source: DWR 2003

Regional Map

EXHIBIT 2-1

Sacramento, and San Joaquin Rivers. Other rivers that add to the Delta drainage include the American, Yuba, Rubicon, Tuolumne, Merced, Feather, Pitt, and Shasta Rivers. Although the Delta is essentially a freshwater system, water levels and flow velocities are subject to tidal influence and fluctuating salinity because of its relatively low elevation.

The legal boundaries of the Delta were formally defined in 1959 with the passage of the Delta Protection Act (Section 12220 of the California Water Code). For the purposes of land use and planning, the region within which the flooded islands are located is the "Legal Delta" as defined in Section 12220 of the Water Code. The Legal Delta covers approximately 738,239 acres. For the purposes of the Baseline report, the Legal Delta is synonymous with "the Delta." In general, the Delta, which consists of a network of several hundred islands interconnected by 700 miles of waterways (see Exhibit 2-2), is bound by Interstate 5 (I-5) on the east, the City of Sacramento to the north, the Yolo Bypass and the City of Pittsburg on the west, and Interstate 205 on the south. The Delta encompasses approximately 738,000 acres, which is equivalent to 295,200 hectares or 1,150 square miles. Of those 738,000 acres, there are approximately 60,000 acres of waterways with about 57,238 of those acres actually navigable. That water surface area provides approximately 635 miles of linear channels. The Delta supplies drinking water for two-thirds of the California population and irrigation water for over 7,000,000 acres of agriculture.

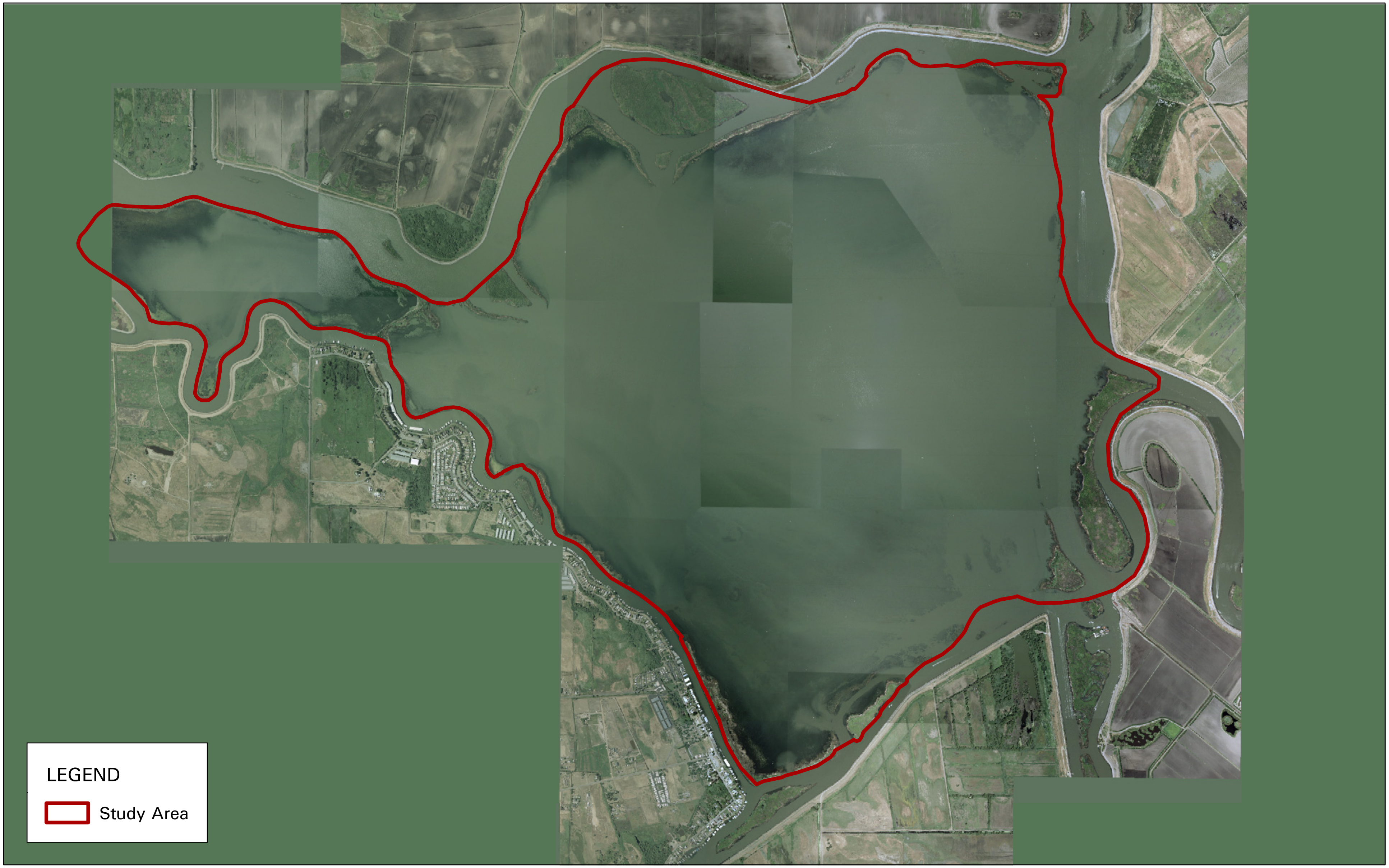
Generally, the Delta is rural with a feeling of remoteness, although it is situated within a relatively short driving distance from San Francisco Bay Area and Central Valley cities and communities.

2.4 STUDY AREAS

The three study areas historically were islands created by constructed levees in the western and central Delta that became flooded and submerged when their levees were breached (see Section 3.2). Each of the study areas is described below.

2.4.1 FRANKS TRACT

The largest of the three study areas is Franks Tract, as shown in Exhibit 2-2. Franks Tract encompasses the Franks Tract State Recreation Area, which is owned and managed by the Department of Parks and Recreation (State Parks). Franks Tract is bound by False River and Webb Tract on the north, Old River and Mandeville Island on the east, Sand Slough and Holland Tract on the south, and Piper Slough and Bethel Island on the west. Franks Tract consists of two submerged areas. The western portion of Franks Tract, known as Little Franks Tract, is a 330-acre area projecting from the larger 3,300-acre main submerged area known as Big Franks Tract.



Source: DWR 2004

Study Area 1 of 3: Franks Tract

EXHIBIT 2-2

Flooded Islands Feasibility Study Baseline Report
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2.4.2 Lower Sherman Lake

The Lower Sherman Lake project site consists of three main parts: the main submerged area known as Lower Sherman Lake, another submerged island named Donlon Island, and Lower Sherman Island, as shown in Exhibit 2-3. Lower Sherman Lake is the largest flooded area of Sherman Island. Lower Sherman Island, located to the west of Lower Sherman Lake, is an upland area penetrated by numerous sloughs. Lower Sherman Lake and Lower Sherman Island collectively form the Lower Sherman Wildlife Area, which is owned by the Department of Fish and Game (DFG). Donlon Island is mostly submerged. Donlon Island is located between Sherman Island and Lower Sherman Island and is to the south of Lower Sherman Lake.

2.4.3 Big Break

The Big Break project site consists mostly of the East Bay Regional Park District's (EBRPD's) Big Break Regional Shoreline. Big Break Regional Shoreline includes the flooded portion of Big Break Tract, starting just south of the former levees, plus 40 acres of upland areas along the south shore of Big Break near Big Break Road, as shown in Exhibit 2-4. Most of this upland area is referred to as the Lauritzen Site. The Lauritzen Site contains old barges and pilings that have been grown over by aquatic plants, forming a wetland area interspersed with islands and scrap. The Big Break project site also includes some areas outside the Big Break Regional Shoreline; these portions are in the Vintage Marsh and Ironhouse Sanitary District property.

Sources: DWR 2004, Sacramento County 2002

Study Area 2 of 3: Lower Sherman Lake

EXHIBIT 2-3

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Sources: DWR 2004, Sacramento County 2002

Study Area 3 of 3: Big Break

EXHIBIT 2-4

Flooded Islands Feasibility Study Baseline Report

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3 STUDY AREA HISTORY

This chapter describes the major events that resulted in the existing conditions at each of the three flooded islands.

3.1 DELTA RECLAMATION AND FLOODING

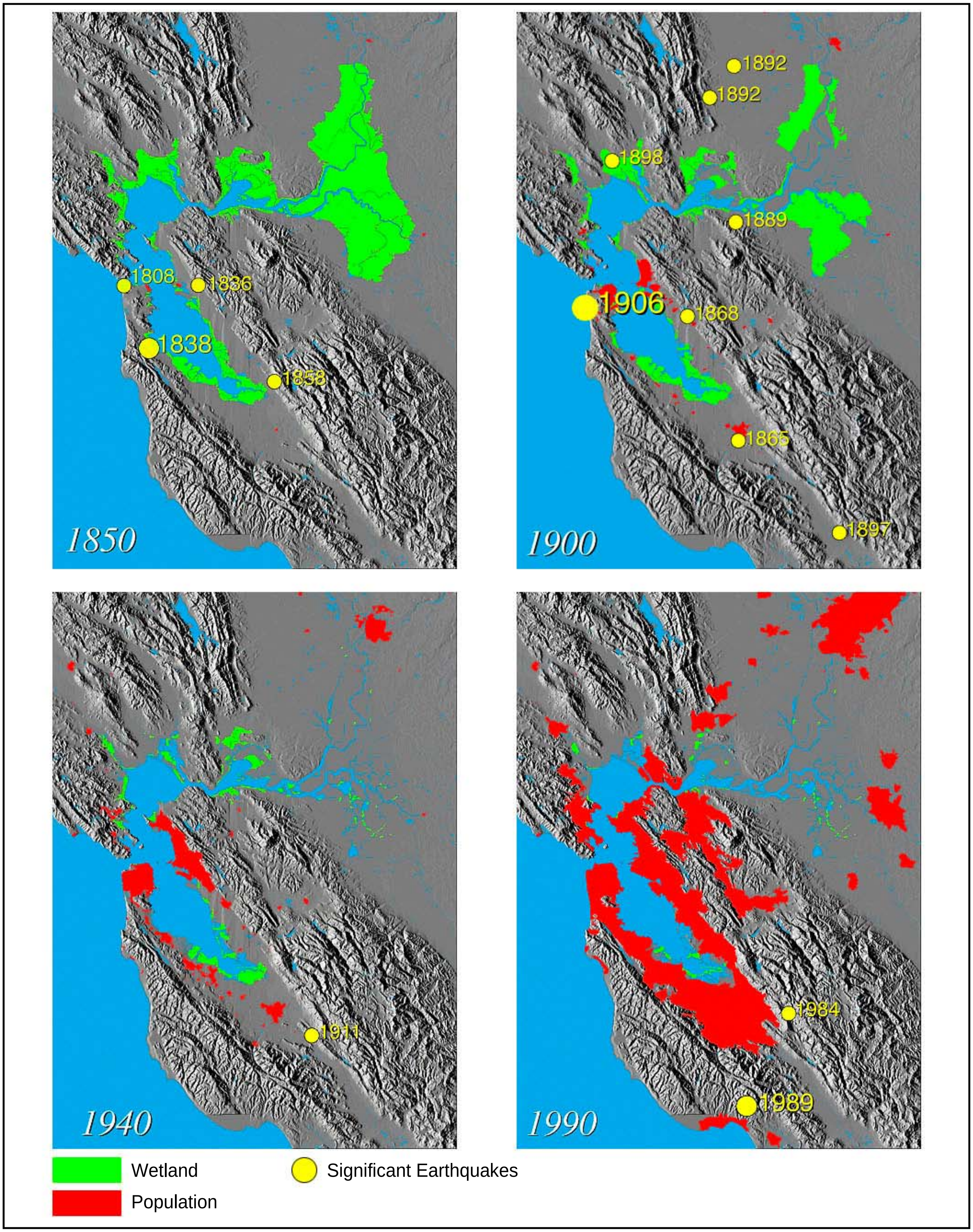
3.1.1 DELTA LAND RECLAMATION

Reclamation and development of the Delta began in late 1850 when the Swamp and Overflow Land Act conveyed ownership of all swamp and overflow land, including Delta marshes, from the federal government to the State of California. Proceeds from the sale of swampland by the State were to go toward reclaiming the swamplands. In 1855, California passed the Reclamation District Act providing for sale of swamp and overflow lands at $1 per acre with payments over 5 years, and a 320-acre limit. In 1861, the State Legislature created the Board of Swamp and Overflowed Land Commissioners to manage reclamation projects. In 1866, the Board's authority was transferred to county boards of supervisors. In 1868, the Legislature removed acreage ownership limitations and by 1871 most of California's swampland was in private ownership (DWR 1995a). Exhibit 3-1 shows the loss of wetland between 1850 and 1990.

Today, these lands in the Delta are ringed with levees and have their own districts for maintaining the levees. Some islands belong to more than one district. A more populated island, Bethel, formed an organization with broader responsibilities, the Bethel Island Municipal Improvement District.

Nineteenth-century developers at first thought levees 4 feet high and 12 feet at the base would protect Delta lands from tides and river overflow, but that proved inadequate mostly owing to peat soils. By 1869, substantial levees had been constructed on Sherman Island and Twitchell Island by Chinese laborers, and in 1870 and 1871 the owners reaped harvests of grain and row crops. Small-scale reclamation projects were started on Rough and Ready Island and Roberts Island in the 1870s, but the peat soils showed their weakness as levees. The peat soils would sink, blow away when dry, and develop deep cracks and fissures throughout the levee system. Sherman and Twitchell Islands flooded annually in the early 1870s (DWR 1995a).

In the late 1870s, the developers had begun to realize that hand- and horse-powered labor could not maintain the reclaimed Delta islands. Steam-powered dredges began to be used to move the large volume of alluvial soils from the river channels to construct the large levees. These dredges were capable of moving material at about half the cost of hand labor. The peak of Delta land reclamation was reached with the clamshell-type dredge, still commonly used. Advantages of this machine over its predecessors were versatility, ease of operation, and modest capital and operating costs. After World War I, the number of operating dredges decreased greatly, as nearly all Delta marshland had been reclaimed. By this time, the Delta had been transformed from a large tidal marsh to a series of improved channels and leveed islands (DWR 1995a).



Source: USGS 2000

Wetland Elimination and Population Growth

EXHIBIT 3-1

In 1880, the State Engineer designed a flood control plan for the Sacramento Valley. This plan included a system of levees and bypasses for transporting floodwaters away from protected areas. In 1917 Congress authorized the Sacramento Flood Control Project, which was completed by the U.S. Army Corps of Engineers in 1960. Storage reservoirs and similar protective measures were constructed on the Sacramento–San Joaquin rivers and major tributaries. These systems, denoted "project levees" to distinguish them from other levees, provide effective flood control for a portion of the Delta.

As a result of the serious flooding problems in 1986, the State Legislature passed the Delta Flood Protection Act of 1988 (SB 34). A portion of the Act provides flood control improvement projects for eight islands (Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb) of the west Delta. These islands were identified as being critical to protecting Delta water quality because they are adjacent to major Delta channels in the area where fresh and salt waters mix. The Act also significantly increased monetary assistance to districts charged with the maintenance of local Delta levees via the Delta Levees Maintenance Subvention Program. In 1991, Senate Bill 1065 went into effect to assure that these flood protection activities result in no net loss of fish or wildlife habitat and to provide $3 million to mitigate past impacts (DWR 1995a).

Most of the Delta lowlands are protected by nonproject levees. "Nonproject" distinguishes these levees from those that are part of federal flood control projects. Improvement and maintenance of nonproject levees is challenging because of poor foundations and regulations to protect levee wildlife habitat. Local districts responsible for maintaining these levees are reimbursed for a portion of the costs under the Delta Levees Subvention Program established in 1973. The Delta Flood Protection Act of 1988 (SB 34), Assembly Bill 360, significantly increased reimbursement opportunities but also added a major environmental mandate to ensure no net long-term loss of habitat (DWR 1995a, 2005).

3.1.2 FLOODING HISTORY

Today the Delta covers 738,000 acres that are imperfectly protected from flooding by more than 1,100 miles of levees (DWR 1995a and USGS 2000). Levee failures have been common in the Sacramento–San Joaquin Delta since reclamation began in the 1850s. Each island and tract in the Delta has flooded at least once, and several have flooded repeatedly (Table 3-1). About 100 levees have failed since the early 1890s (Table 3-2). The most recent flood in the Delta occurred in June 2004 at Upper Jones Tract.

Initially, most of the failures were caused by overtopping during spring flooding. Although construction of upstream reservoirs since the 1940s has reduced the threat of overtopping, it has not reduced the incidence of levee failure. Other causes of flooding include subsidence, groundwater effects, and decomposition of soil used to construct the levees. Seismic activities are also thought to exacerbate the effects of these causes. These factors that increase flooding risk are further discussed in Section 4.2.

Table 3-1
Delta Islands Flooding History From 1900 to 2004

Island / Tract	Acres Flooded	Year(s) Flooded
Andrus	7,200	1902, 1907, 1909, 1972
Bacon	5,546	1938
Bethel	3,400	1907, 1908, 1909, 1911
Big Break	2,200	1927, 1928
Bishop	2,100	1904
Bouldin	5,600	1904, 1907, 1908, 1909
Brack	2,500	1904
Bradford	2,000	1950, 1983
Brannan	7,500	1902, 1904, 1907, 1909, 1972
Byron	6,100	1907
Canal	ND	1958
Clifton Court	3,100	1901, 1907
Coney	900	1907
Deadhorse	200	1950, 1955, 1958, 1980, 1986, 1997
Donlon	3,000	1937
Edgerly	150	1983
Empire	3,500	1950, 1955
Fabian	6,200	1901, 1906
Fay	100	1983
Franks	3,300	1907, 1936, 1938
Glanville	ND	1986, 1997
Grand	ND	1955
Grizzly	8,000	1983, 1998
Holland	4,100	1980
Ida	100	1950, 1955
Jersey	3,400	1900, 1904, 1907, 1909
Little Franks	350	1981, 1982, 1983
Little Mandeville	200	1980, 1994
Lower Jones	5,700	1907, 1980
Lower Roberts	10,300	1906
Mandeville	5,000	1938
McCormack-Williamson	1,500	1938, 1950, 1955, 1958, 1964, 1986, 1997
McDonald	5,800	1982
McMullin Ranch	ND	1997
Medford	1,100	1936, 1983
Middle Roberts	500	1938
Mildred	900	1965, 1969, 1983
New Hope	2,000–9,000	1900, 1904, 1907, 1928, 1950, 1955, 1986
Palm	2,300	1907
Paradise	ND	1997
Pescadero	3,000	1938, 1950, 1997
Prospect	1,100	1980, 1981, 1982, 1983, 1986, 1995, 1997
Quimby	700	1936, 1938, 1950, 1955

Table 3-1 Delta Islands Flooding History From 1900 to 2004		
Island / Tract	Acres Flooded	Year(s) Flooded
RD 17	4,500–5,800	1901, 1911, 1950
RD 1007	3,000	1925
Rhode	100	1938
River	ND	1997
Ryer	11,600	1904, 1907
Sargent Barnhart	1,100	1904, 1907
Sherman	10,000	1904, 1906, 1909, 1937, 1969
Shima	2,394	1983
Shin Kee	700	1938, 1958, 1965, 1986
Staten	8,700	1904, 1907
Stewert	3,900	1938, 1950, 1997
Terminous	5,000–10,000	1907, 1958
Twitchell	3,400	1906, 1907, 1908
Tyler	8,700	1904, 1907, 1986
Union	24,000	1906
Upper Jones	6,200-5,700	1906, 1980, 2004
Upper Roberts	500	1938
Van	ND	1983, 1998
Venice	3,000	1904, 1906, 1907, 1909, 1932, 1938, 1950, 1982
Victoria	7,000	1901, 1907
Walthall	ND	1997
Webb	5,200	1950, 1980
Wetherbee	ND	1997
ND = No data Source: DWR 1982, 1993, 2002a, and USACE 1979		

Table 3-2 Historic Flooding by Decades		
Decade	Number of Island/Tracts	Total Number of Levees Breached
1990–1910	27	54
1911–1920	2	2
1921–1930	3	3
1931–1940	15	18
1941–1950	12	15
1951–1960	9	11
1961–1970	4	5
1971–1980	9	9
1981–1990	15	22
1991–2000	12	13
Source: DWR 2002a		

FRANKS TRACT

In winter 1937, the Franks Tract levee on False River crumbled and the 3,500-acre island was flooded. The reclamation district assessed itself $100,000 to repair the levee and pump the island dry. Just after completion of the levee repair in late 1938, the levee broke again. Reclamation efforts ceased on Big Franks Tract, and Big Franks Tract has remained a vast lake, now owned by the California Department of Parks and Recreation (State Parks). Little Franks Tract was last flooded in 1983; since then, Little Franks Tract has remained submerged, forming a contiguous open-water area with Big Franks Tract. State Parks purchased Franks Tract from 13 separate landowners, beginning in 1959 and completing the purchase in 1975. State Parks has not made an effort to reclaim Franks Tract.

LOWER SHERMAN LAKE

Sherman Lake was formed in 1869 when floodwaters inundated Sherman Island (Nobriga et al. 2001). Later that year, most of Sherman Island was reclaimed for agriculture by levee construction; the westernmost portion of the island that includes Lower Sherman Lake remained flooded. The island suffered significant levee breaches in 1871, 1872, and 1873. The reclamation and preservation of Sherman Island had cost $500,000 by early 1874, and in 1875 the lower 4,500-acre portion of the island was abandoned. Much of the remainder of the island was given a levee 12 feet high and 120 feet wide at the base. The island flooded again in 1925 when the levees were breached by storm surges, and it has remained flooded because of high repair costs (Thompson and Dutra 1983).

BIG BREAK

Between the late 1800s and 1910 the Big Break estuary was transformed by construction of levees along Dutch Slough and the edge of the San Joaquin River and by dewatering of the marshland. In 1927 a portion of the levee protecting Big Break failed and flooded approximately 2,200 acres. In 1928, a large expanse of the levee was broken, resulting in the inundation of approximately 2.5 square miles. By the time financing was available to repair the levee, the area had been declared a part of the state's waterway system and remains so today (East Bay Regional Park District 2001).

3.2 PREVIOUS LAND USES

This section summarizes best uses of the three sites. A description of existing uses is provided in Section 4.9.

3.2.1 GENERAL DESCRIPTION

The first inhabitants of the Delta were Miwok Indians, whose traditional use of land ceased shortly after European settlers arrived. Beginning around 1776 with the establishment of Mission Dolores, the Spanish began subdividing the land into ranchos. Other ethnic groups arrived to take advantage of the abundant natural resources. French fur trappers arrived in 1832. Anglo mountaineers also began to settle in the area, as well as Chinese farmers following the end of their involvement in laying of the first railroad through the Sierra Nevada. With the ease of transport via seagoing ships navigating through the Delta to trade supplies and fur and the mass immigration drawn by the California Gold Rush in 1848, settlement and transformation of the Delta accelerated. Many former miners erected hand-built levees and drained the nutrient-rich soil to put the Delta into agricultural production. They converted tidelands, submerged lands, swamps, and overflowed lands, and burned off the tules. In the 1870s, steam-powered clamshell dredges allowed for the construction of more stable levees. By 1930s, there were 57 constructed islands, encompassing 550,000 acres in the Delta. This pattern of primarily agricultural land use remains dominant in the Delta; dry grains and other specialty crops such as asparagus are most commonly grown today (EBRPD 2001).

Water infrastructure is another major land use in the Delta. Starting in the 1950s, a network of pumps, reservoirs, dams, and canals was constructed to divert water and provide flood control for the Delta.

More recently, urban development in the Delta is accelerating. Primarily along the fringes of the Delta, new residential, commercial, and other urban land uses have been planned, proposed, and, in some instances, constructed.

Despite human-made alterations to the Delta, a broad variety of plants, wildlife, and aquatic life remains. Public, nonprofit, and private entities have purchased lands and development rights to maintain open-space land use and protect natural resources. These abundant natural resources continue to provide opportunities for hunting, fishing, wildlife observation, and other resource-based recreational activities. For this reason, and because of the vast expanses of natural and created open water, recreation remains another major land use in the Delta.

FRANKS TRACT

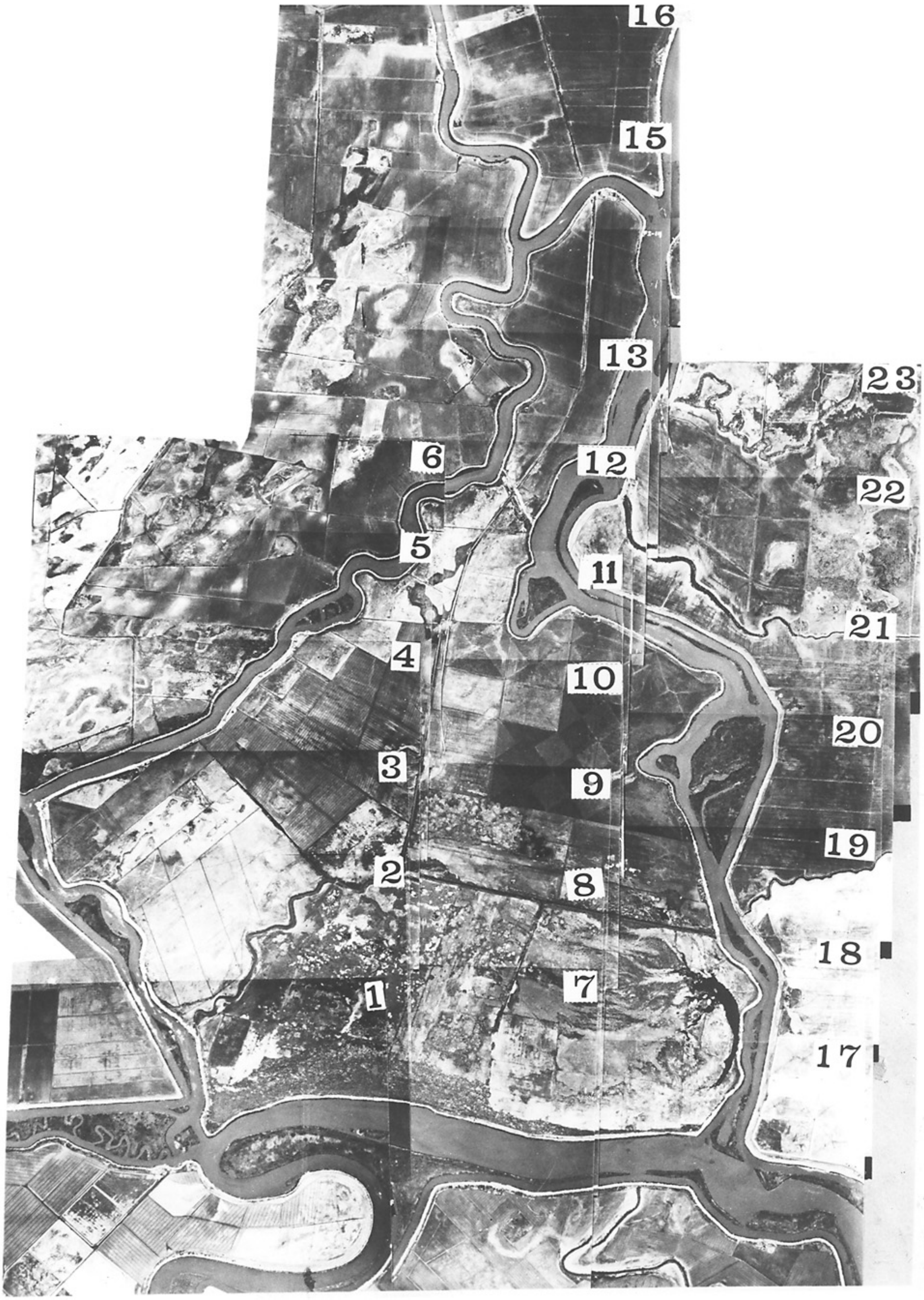
Before the flooding of Big Franks Tract, this island supported agricultural uses, as shown in Exhibit 3-2. Since then, Franks Tract has remained an open-water area with levees deteriorating over time. Because of the submergence of Franks Tract, uses are water- and resource-related recreation and wildlife habitat.

LOWER SHERMAN LAKE

Sherman Island was reclaimed by 1869, and agricultural land uses, principally grain and row crop production, began in 1870. However, flooding was an impediment to agricultural use from the beginning and because of high revolving costs resulting from levee repairs, reclamation efforts were abandoned and the island has been allowed to flood since 1925 (see Section 3.2.2 Flooding History above).

BIG BREAK

A 1850s maps shows that Big Break was originally a relatively straight shoreline of sand dune and marshy lands bordered by oak woodlands, with Dutch Slough penetrating into the interior of the mainland. Between the 1850s and 1910, the shoreline of the Big Break estuary was radically transformed by the erection of dikes along Dutch Slough and the river's edge and the dewatering



Source: Unknown

Franks Tract (1937) Before Final Inundation

EXHIBIT 3-2

of the marshland. Asparagus was farmed until 1928, when, during a heavy storm, a big expanse of the levee was broken (see Section 3.2.2 Flooding History above). Since it became flooded, uses of Big Break have been recreational, such as boating, fishing, and hunting.

The Lauritzen site and the western half of the Big Break estuary were acquired by Howard F. Lauritzen in the 1950s when he traded property with Pittsburg Steel Company and started a marine construction company along Big Break Road. The Lauritzen family used the site to store equipment and as a weekend retreat. The cabin and water tower he constructed remain. Lauritzen also developed a marine salvage business; he contracted with the U.S. Army Corps of Engineers and disposed of abandoned World War II military barges in the shallow waters. Silt accumulated around the abandoned barges, and vegetation, both native and exotic, gained a foothold, forming artificial islands that provide wildlife habitat. Marine construction activities continued on the site until it was rented out for residential use.

In 1995, EBRPD purchased Porter Ranch, which consists of 980 acres of the eastern half of the Big Break estuary. The western half, including the 668-acre Lauritzen parcel, was purchased in 2000. EBRPD also has some regulatory rights in the water, as does the State. The sources of funding for these purchases include Measure AA, sponsored by EBRPD in 1988, grants from the Habitat Conservation Fund, and a U.S. Bureau of Reclamation mitigation grant (EBRPD 2001).

3.3 PROPERTY OWNERSHIP

3.3.1 GENERAL DESCRIPTION

Most Delta properties are in private ownership, as shown in Exhibit 3-3. Many federal, state, and local agencies own property, rights, and easements in the Delta. The largest swath of government-owned land is Sherman Island, which was purchased by the Department of Water Resources. Non-governmental conservation-oriented organizations also own large areas in the Delta.

FRANKS TRACT

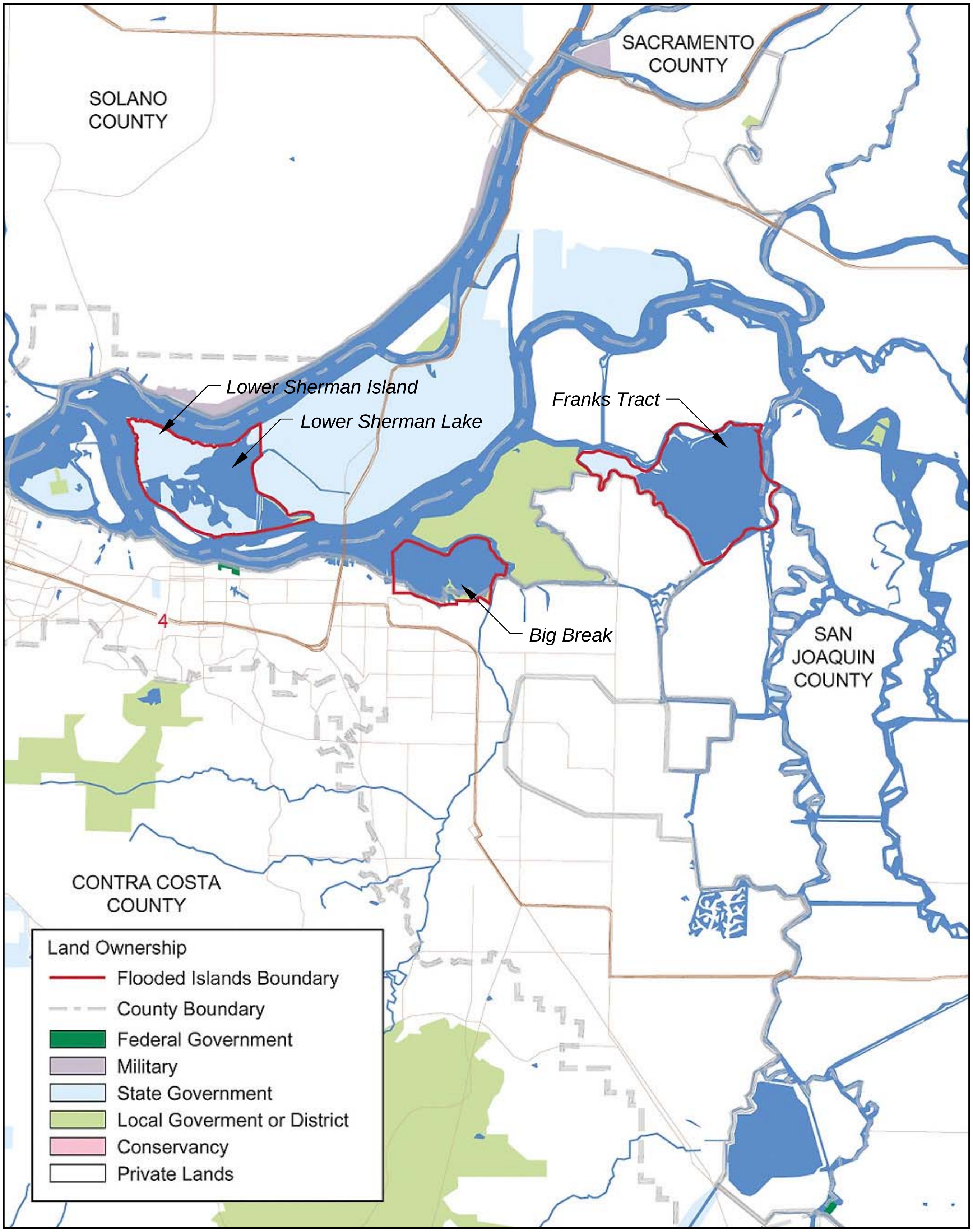
Most of Franks Tract is owned by State Parks. The navigation rights of some of the waterways are owned by the State Lands Commission. Some mineral rights on Franks Tract are owned by private entities.

LOWER SHERMAN LAKE

Lower Sherman Island and Lower Sherman Lake are owned by the Department of Fish and Game (DFG). DFG manages its property as the Lower Sherman Island Wildlife Area. Donlon Island is owned by the Department of Water Resources.

BIG BREAK

Most of Big Break is owned by East Bay Regional Park District. A portion of the study site is owned by Ironhouse Sanitary District, and another portion is Vintage Marsh.



Source: State of California Teale Data Center – GIS 1999 and Delta Protection Commission 1995

Land Ownership

EXHIBIT 3-3

Flooded Islands Feasibility Study Baseline Report
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4 EXISTING CONDITIONS

This chapter presents discussions of the existing conditions in the regional context of the Delta and at each of the three study areas, whenever specific information is available. The subjects presented are those pertinent to the Feasibility Study. Hydrology is not discussed as a separate topic in this document, however; instead, it will be described in detail in a follow-up document for the Feasibility Study. The discussions below are based on available information from academic articles; books, agency documents, websites, and databases; interviews conducted for the proposed project; CALFED conference materials; and other sources (see Chapter 7, References). Chapter 5 identifies the subjects for which existing data are lacking. The discussions below for each general subject are divided in separate sections.

4.1 BATHYMETRY, TOPOGRAPHY, AND SEDIMENTATION

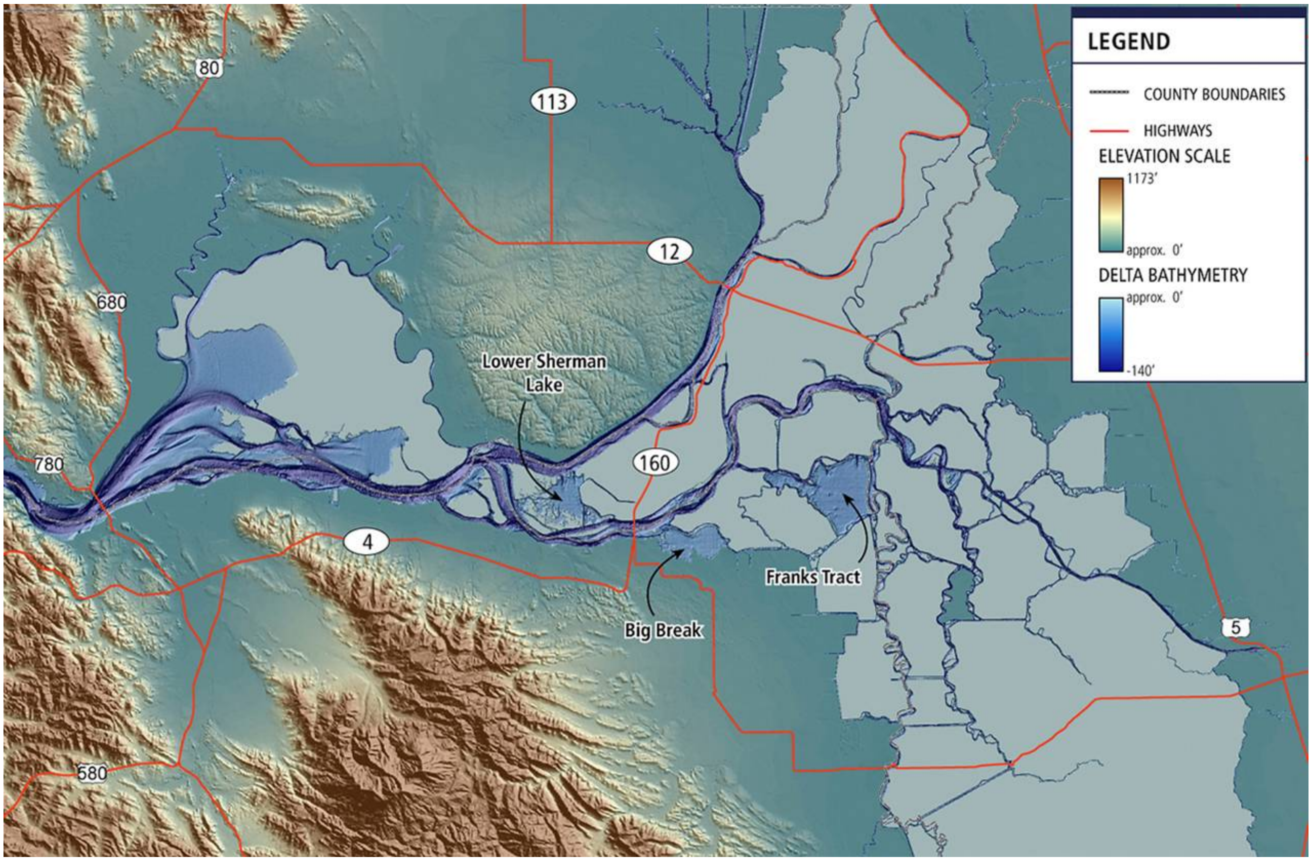
This section provides baseline information on several aspects of the geomorphology of the three study areas. The purposes of this discussion are to describe the erosional forces and sedimentation issues at the study areas and to identify potential engineering approaches for designing new islands in the study areas that can withstand the forces present and benefit ecosystem functions. Creating new intertidal habitat, as well as facilitating growth and evolution of desired vegetation communities in the Delta, have been promoted as key actions in the effort to restore wildlife populations. These actions are balanced with another set of issues that includes increases in maintenance costs and creation of navigation hazards.

The objectives of this section are to present the available data for each site and to describe the geomorphic issues that should be addressed during a feasibility assessment. Data on geomorphology that would provide some predictive capability useful in the design for the Feasibility Study but that are not currently available are also identified (also see Chapter 5).

4.1.1 GENERAL DESCRIPTION ON BATHYMETRY, TOPOGRAPHY, AND SEDIMENTATION

The three study areas are located within the Delta, a hydrologically complex region of channels and approximately 60 islands (Exhibit 4.1-1). The Delta collects all of the freshwater runoff from the Central Valley, which is subject to constant interaction with ocean tidal forces and saltwater, and then discharges it toward San Francisco Bay and the Pacific Ocean. The complexity of the Delta is primarily the result of its geologic evolution and a long history of basin subsidence, sediment deposition, biotic activity, and interactions with sea-level changes over the past several million years. At times, the Delta was predominately a freshwater body receiving abundant sediment generated from active glaciations and outwash from the Sierra Nevada; during other periods, mineral sedimentation was limited, and land- and soil-forming processes were dominated by profuse marsh vegetation growth and development of peat soils.

The natural site complexity was further complicated and affected by human modifications and reclamation activities that occurred in the early 1900s and by development of the federal and state water projects in the mid 1900s (see Sections 3.1 and 4.10). Hydraulic gold mining in the late 1800s delivered massive volumes of mineral sediments to the Delta that reportedly buried many areas of peat soil. Large-scale dredging and levee construction was fueled by an intense period of agricultural development and flood-control project construction. All major Delta islands were permanently affected by reclamation of islands from marshlands to agricultural use. Channels were dredged for large ship navigation. These activities greatly modified the natural hydrologic function of the islands and in turn their ecological function. Damming of nearly all rivers flowing into the Central Valley from the Sierra Nevada and those in the Upper Sacramento River Basin not only lessened sediment supplies but also reduced the volume and modified the timing of fresh water reaching the Delta. The reclaimed islands subsided owing to oxidation of peat soils, and efforts to stabilize the surrounding levee led to installation of riprap slopes and uniform shorelines.



Source: Swanson Hydrology + Geomorphology 2004

Bathymetric Location Map of Study Areas

EXHIBIT 4.1-1

Today, the topography of the Delta ranges from elevations 6 to 30 feet above sea level at the tops of levees to -15 to -45 feet below sea level in the deepest channels. The elevation of islands varies from 10–20 feet above sea level to less than 20 feet below sea level at deeply subsided islands.

The hydrology of the Delta is greatly affected by diversion pumps situated in the south Delta area to serve the federal and state water projects. These further affect ecological function, and at times reverse outflows away from San Francisco Bay. In the late 1980s, federal resource agencies found significant impacts to winter run chinook salmon in the Sacramento River, and this led to changes in the operations of reservoirs and the diversion of water from the Delta.

The hydrologic function of the Delta involves the interaction of streamflow runoff from the major rivers and tidal inflow of salt water from the Pacific Ocean. Two major rivers supply the majority of the freshwater: the Sacramento River from the north and the San Joaquin River from the south. The runoff of the Sacramento River is greater, accounting for 80% of the freshwater runoff by volume. The water in the San Joaquin River and its tributaries has been highly diverted for agricultural use, and much of the runoff is diverted upstream of the Delta. At their junction, runoff from the Sacramento River channel near Sherman Island flows southward to create a freshwater barrier across the mouth of the San Joaquin; without this barrier, it is postulated that saltwater inflow to the south-central Delta would increase significantly.

Ecologically, the most significant change has been the loss of intertidal landforms, wetlands, and shallow shoals that support diverse plant communities and wildlife habitats. The reclamation of the large islands to agriculture through construction of dredger cuts left only remnants of the original shoreline, and many of these Delta islands were destroyed by erosion from wind-generated waves, flood currents, tidal currents, and boat wakes (Swanson Hydrology 1999; 2003). Subsidence of islands has also resulted in lower land surfaces and reduced intertidal area. Significant research is being conducted to analyze the evolution of flooded islands where levees have been naturally or artificially breached, particularly in terms of their habitat restoration potential. These studies include the Integrated Regional Wetlands Monitoring Pilot Project (IRWM 2004) and the Sacramento/San Joaquin Delta Breached Levee Wetland Study (University of Washington Wetland Ecosystem Team 2002).

The following are descriptions of the existing conditions of the study areas, the available data, and an assessment of data gaps and analytical needs for future project phases.

4.1.2 BATHYMETRY, TOPOGRAPHY, AND SEDIMENTATION AT FRANKS TRACT

Franks Tract encompasses a 3,300-acre area of flooded island that was last reclaimed in 1938, after repeated levee breaks made maintenance as farmland uneconomical. The central submerged island area is generally -8.0 feet below MSL and is underlain by a mix of peat soils and sand dune deposits (Exhibit 4.1-2). The surrounding areas are dredger cut channels and remnant levee segments (both subaerial and submerged). Franks Tract is bound by the

Source: Swanson Hydrology + Geomorphology 2004

Bathymetric Location Map of Franks Tract

EXHIBIT 4.1-2

following waterways: False River and Washington Cut to the north, Old River to the east, Piper Slough to the west, and Sand Mound Slough to the south.

The Franks Tract State Recreation Area has been extensively studied for island/intertidal creation since the late 1980s (State Parks 1987; Moffatt and Nichol Engineers 1991a, 1991b, 2002; DWR 2000a). State Parks owns and operates Franks Tract for boating and fishing recreation. The 1987 General Plan for Franks Tract called for construction of islands to improve recreation and create habitat. Moffatt and Nichol Engineers (2002) developed an island-creation demonstration project that involved creation of four islands with a range of subtidal and supratidal elevations to support a variety of habitats. The engineering of the demonstration island projects was developed during the feasibility study (Moffat and Nichol Engineers 1990, 1991), based on technical data and results from bathymetry, hydrographic, topographic, and geophysical surveys, as well as analysis of wind conditions and wind–wave interaction, tidal hydraulics, and sediment transport. The demonstration projects were carried through the environmental review phase (JSA 2002) but have not been funded and constructed at the time of this writing.

Bathymetric data have been compiled by USGS (2004) for Franks Tract and the entire Delta area using a number of bathymetric and topographic surveys. The data was combined and corrected from various datums to the NGVD 1929 datum, then interpolated into a 10-meter grid database. Horizontal control was attained through interpolation of shoreline and cross-section surveys. The bathymetric data have been used to conduct modeling studies for various projects within the Delta, including the DSM1 and DSM2 salinity and tidal/water surface modeling conducted by Resource Management Associates (RMA) for the Feasibility Study. The bathymetric data appear sufficiently detailed to support future modeling scenarios on a large scale; more site-specific surveys may be needed for detailed assessments of certain study areas.

Topographic data of areas above water and shorelines 4.0 feet NGVD are available from a variety of sources, including surveys used by the California State Reclamation Board and the U.S. Army Corps of Engineers for Sacramento–San Joaquin Special Studies (USACE 2002).

Data documenting sedimentation in the Franks Tract area are generally scarce, and analyses to date are inconclusive. Local residents and recreational users report substantial aggradation in Franks Tract and loss of depth; however, the period of perceived aggradation coincides with an increase in the growth of the invasive, non-native aquatic plant, Brazilian waterweed (see Section 4.8), which could have the same effect on boating as sedimentation. Moffatt and Nichol Engineers attempted to compare bathymetric surveys taken in 1992 and 1998 and found little change in bathymetry; however the latter survey was deemed to contain significantly less detail than the former and, thus, the comparison may not be valid. As a result, the degree of sedimentation and potential rates of sedimentation are not known.

Estimates of sedimentation within historically breached islands made as part of the BREACH Study (University of Washington 2002) found aggradation rates on some islands in the range of 47–51 millimeters per year. These rates should only be applied to smaller islands; they represent a maximum rate, given that the original breach event would have increased sediment concentrations near breached levees and areas surrounding the hydraulic surges beyond normal levels. If these higher-than-normal rates of sedimentation were applied to larger breached islands, such as Franks Tract, the resulting estimates would show more sedimentation than has been recorded. Thus, larger islands, such as the three study areas, with their greater fetch and wind wave generation, may have reached their equilibrium between sediment supply, deposition, and rescouring. Installing islands and intertidal landforms may change this equilibrium locally and throughout their vicinity.

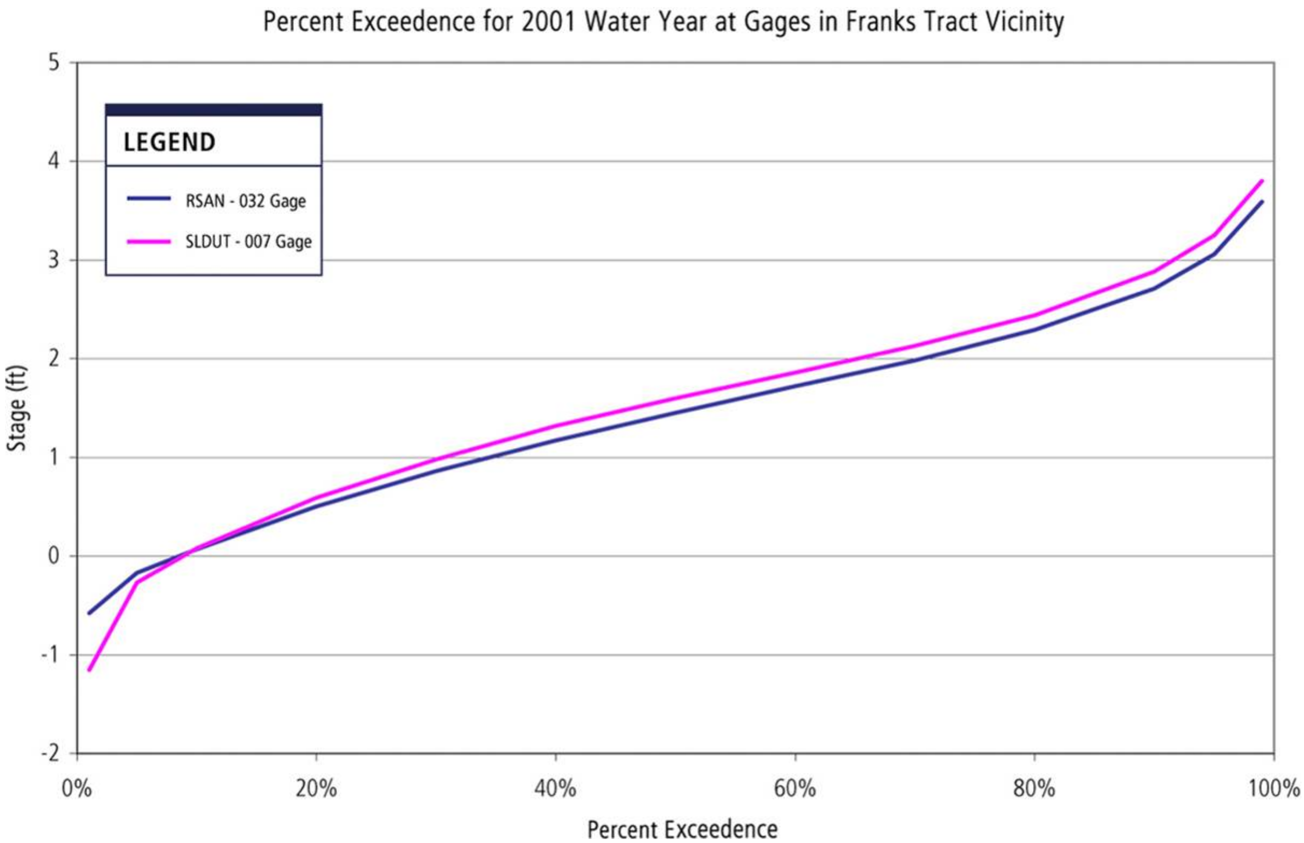
Water levels in Franks Tract are influenced by tides, wind, surface runoff, and river flows. In Franks Tract, tides exert the strongest influence on water level (M&N 2002). Table 4.1-1 below shows Tidal Datum information for Jersey Island, False River Gage.

Table 4.1-1
Tidal Characteristics Near Franks Tract

Tidal Plane	Feet above Mean Lower Low Water	Elevation (NGVD)
Estimated Highest Water Level	+6.5	+6.9
Mean Higher High Water	+3.4	+3.8
Mean High Water	+2.9	+3.3
Mean Tide Level	+1.7	+2.1
Mean Low Water	+0.5	+0.9
Mean Lower Low Water	+0.0	+0.4
Estimated Lowest Water Level	-2.0	-1.6
Source: Moffat & Nichol Engineers, 1991b		

Stage and flow data have been collected at nearby gauging stations operated by DWR and USGS (IEP 2004). Exhibit 4.1-3 shows two tidal stage duration curves generated by gages located at San Andres Landing on the San Joaquin River (RSAN–032), and Jersey Island in Dutch Slough (SLDUT-007), both in the vicinity of Franks Tract. RMA (pers. comm. 2004) has developed the model RMA-2 for Franks Tract and the Delta to assess the effect of various projects on water quality; the RMA-2 model also simulates flow velocities and vectors, as well as stage. The model was originally developed for simulation of tidal hydrodynamics, but it was adapted for use with flood hydraulic models to simulate large-scale flood events in the Delta (USACE 2002).

Moffat and Nichol (2002) analyzed sediment transport on the western side of Franks Tract as part of the Franks Tract Restoration Demonstration Project. They estimated littoral transport and the effect of island placement and orientation affecting erosion by wind-generated waves. In general, the predominate wind direction at Franks Tract is from the west, and shoreline areas subject to wind–wave erosion face predominate wind directions and long fetch distances; the east side of Franks Tract is particularly vulnerable to wind–wave erosion. The available wind and wave data appear adequate for consideration of other sites for island and intertidal landform creation.



Gage locations shown on Exhibit 4.2-2. Data source: Interagency Ecological Program HEC-DSS Website

Source: Swanson Hydrology + Geomorphology 2004

Tide Stage Duration Curve for 2001 Water Year for Gages Near Franks Tract

EXHIBIT 4.1-3

The data and analysis developed by Moffat and Nichol (1990; 1991; 2002) in studies of Franks Tract appear to be sufficiently detailed for assessing the feasibility of new island construction. The least understood factor is the potential for sedimentation. It would be useful to assess present trends by replicating the detail of the 1992 bathymetric survey, and by assessing suspended load supply in the upper water column.

4.1.3 LOWER SHERMAN LAKE

Lower Sherman Lake (Exhibit 4.1-4) is located at the western edge of the Delta between the Sacramento and San Joaquin Rivers just east of their confluence. It covers over 3,000 acres and has depths between 3 and 12 feet below Mean Sea Level. The western side of Sherman Lake is shallow (most of the area is less than 3 feet deep during low tide) whereas the eastern third of this project site is deeper (up to 12 feet). Lower Sherman Lake is bounded by Lower Sherman Island to the west, Lower Sherman Island and the Sacramento River to the north, Sherman Island to the east, and Mayberry Slough, Mayberry Cut, and Donlon Island to the south.

Bathymetric data have been compiled by USGS under the same program described under the Franks Tract section above (USGS 2004). In addition, RMA (pers. comm. 2004) has developed the RMA-2 model for Lower Sherman Lake that simulates stage and flow velocity and vectors under low-flow tidal conditions.

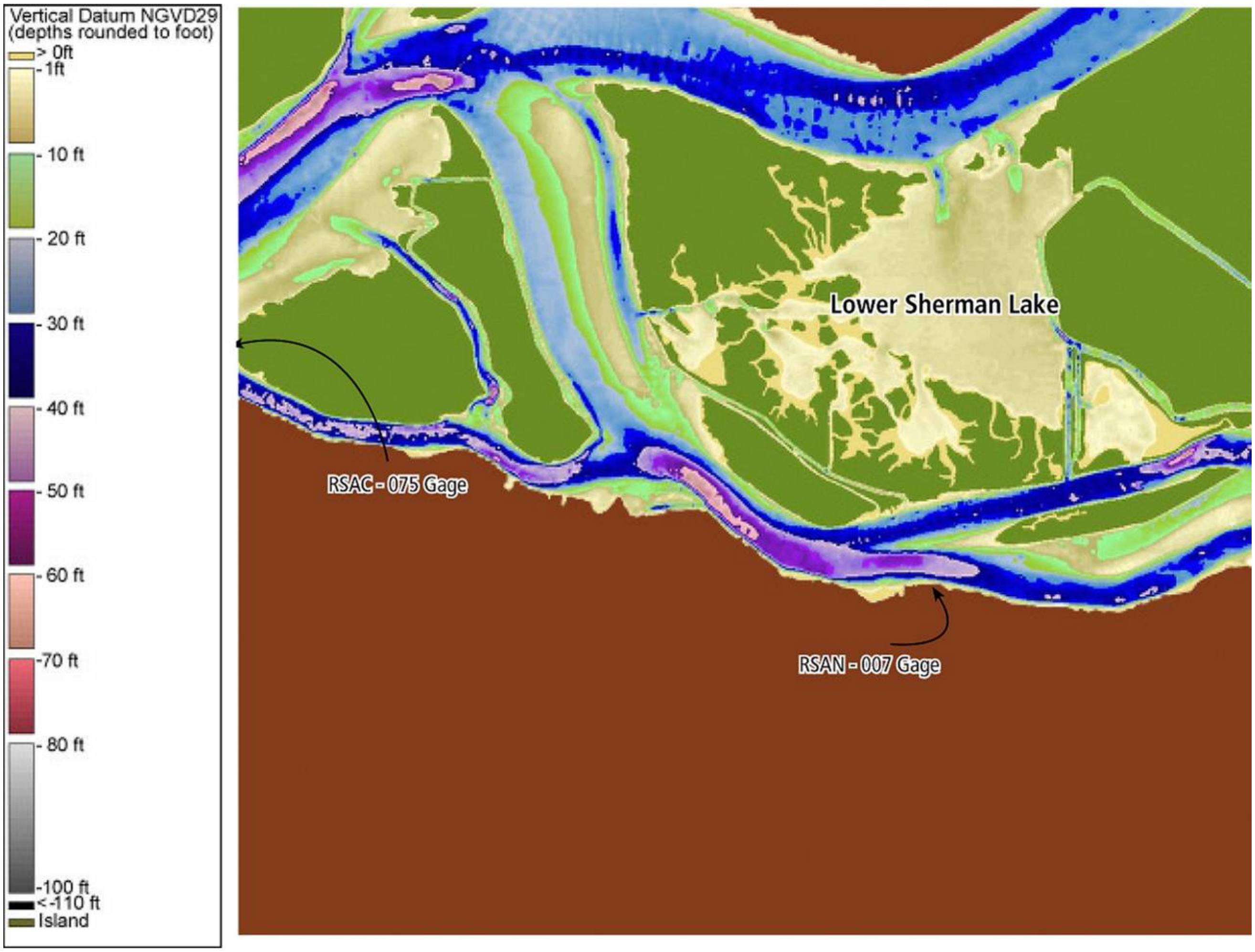
Topographic data for areas above shoreline elevation (about +4.0 feet NGVD) surrounding Lower Sherman Lake are available from USGS (2002).

Stage data in the Lower Sherman Lake area is available from the IEP (2004). Exhibit 4.1-5 shows two stage duration curves for the 2001 water year generated from two gages located at Antioch on the San Joaquin River (RSAN-007), and Pittsburg on the Sacramento River (RSAC-075). Table 4.1-2 shows tidal characteristics near Lower Sherman Lake. New detailed data are being collected as part of the Integrated Regional Wetlands Monitoring Pilot Project (IRWM 2004), which is examining the geomorphic and biotic changes in flooded island ("restored") settings versus natural intertidal marsh islands.

Table 4.1-2
Tidal Characteristics Near Lower Sherman Lake and Big Break

Tidal Plane	Feet Above Mean Lower Low Water	Elevation (NGVD)
Mean Higher High Water	+3.84	+2.85
Mean High Water	+3.35	+2.39
Mean Tide Level	+1.97	+0.98
Mean Low Water	+0.59	-0.39
Mean Lower Low Water	+0.0	-0.98

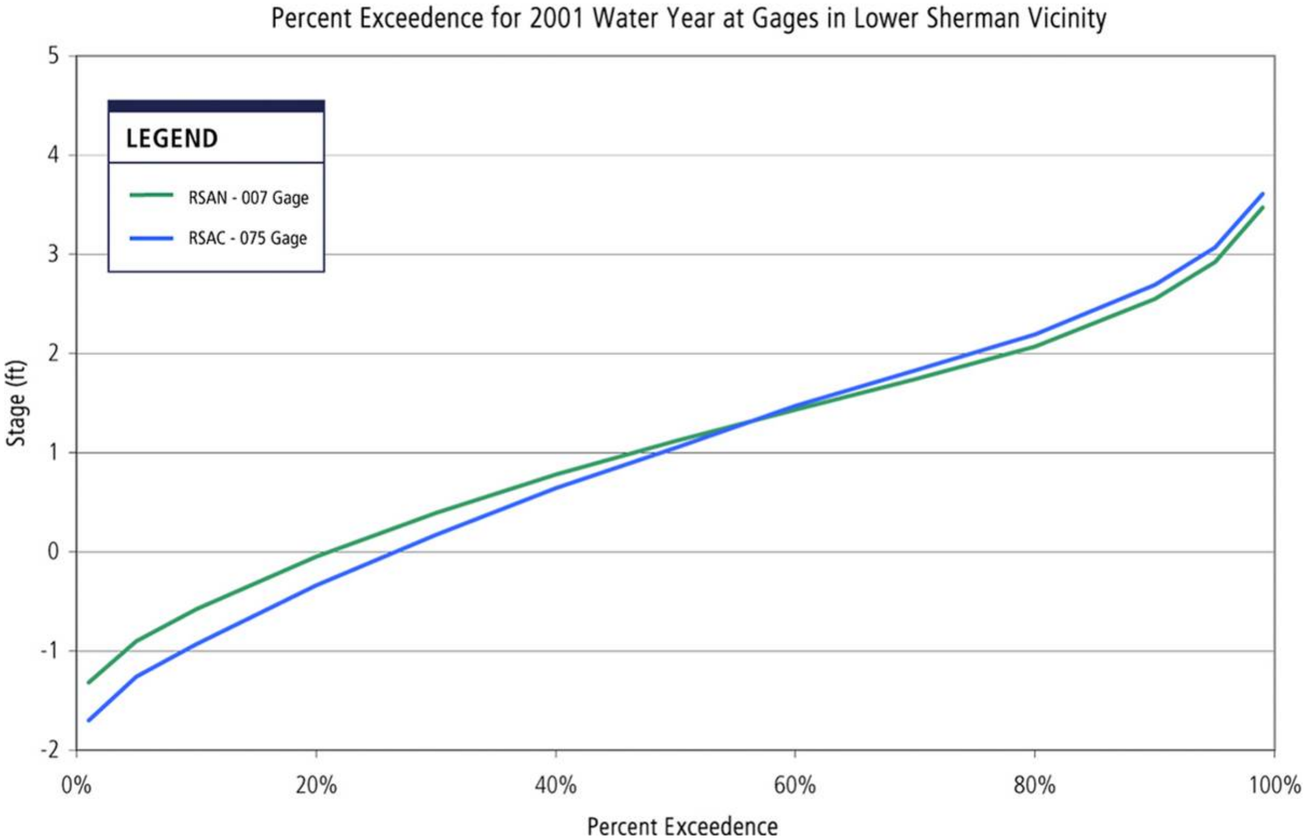
Source: University of Washington Wetland Ecosystem Team 2002



Source: Swanson Hydrology + Geomorphology 2004

Bathymetric Map of Lower Sherman Lake

EXHIBIT 4.1-4



Gage locations shown on Exhibit 4.2-4. Data source: Interagency Ecological Program HEC-DSS Website

Source: Swanson Hydrology + Geomorphology 2004

Tide Stage Duration Curve for 2001 Water Year for Gages Near Lower Sherman Lake

EXHIBIT 4.1-5

There are no specific data on sedimentation in Lower Sherman Lake; however, the BREACH project (University of Washington 2002) provides sedimentation rates for breached island sites (as discussed above in the Franks Tract section) that may be applicable. An investigation of breached island evolution found that large open water areas such as Lower Sherman Lake, Big Breach, and Franks Tract may have reached equilibrium because sedimentation may be limited by long fetches and high wind–wave action. It might be instructive to apply some of the recent assessments of sedimentation rates and data compiled for the IRWA and BREACH projects for restored intertidal areas as a means to predict potential sedimentation rates in created islands and intertidal areas.

There appear to be sufficient wind data available to develop an assessment of wind–wave energy within Lower Sherman Lake. It would also be instructive to assess historical erosion rates at shorelines in and around the area as a means to assess potential erosion.

4.1.4 BIG BREAK

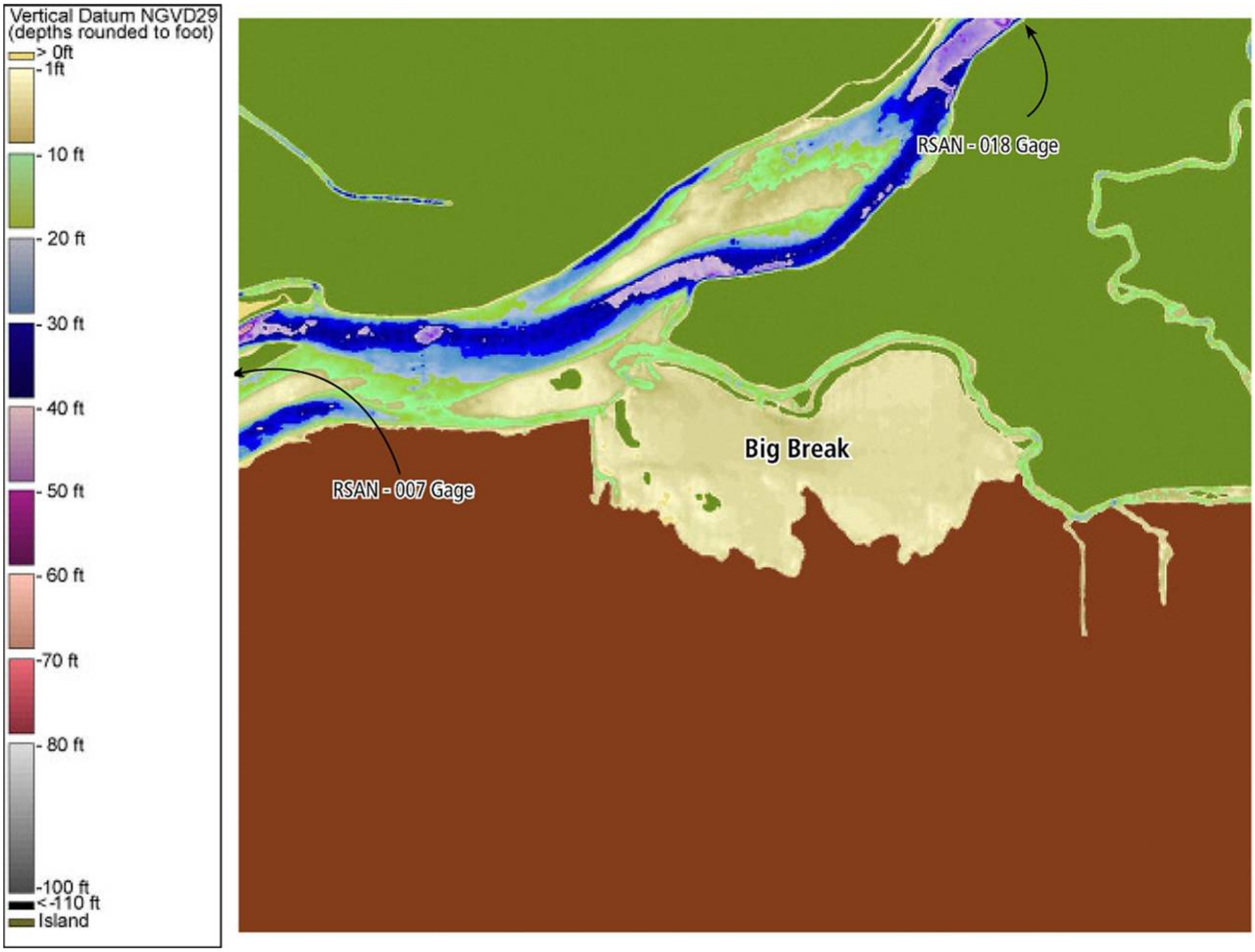
Big Break encompasses about 1,600 acres of flooded island area and is located along the southern bank of the San Joaquin River, just east of the town of Antioch (Exhibit 4.1-6). It is bounded by the City of Oakley to the south, Dutch Slough and Jersey Island to the north and east, and the San Joaquin River to the west. Big Break is owned by the East Bay Regional Park District and is operated for recreation, wildlife habitat, and open space.

Big Break was a reclaimed island under agricultural use and surrounded by levees until the levees failed about 80 years ago. Water depths range between 3 and 7 feet below sea level in the main flooded island area; Dutch Slough, the channel that bounds the northern side of Big Break, has depths between 10 and 20 feet below sea level.

Bathymetric data for Big Break are available from USGS, which developed a grid of data from multiple sources and surveys (USGS 2004) (Exhibit 4.1-6). Topographic data of surrounding areas above shoreline elevations and the limits of USGS bathymetry data are available from the U.S. Army Corps of Engineers (USACOE 2002) as part of their Sacramento/San Joaquin River River Comprehensive Study.

Water stage data is available from several surrounding gauging stations; Exhibit 4.1-7 is a stage duration plot for the Big Break area from two gages on the San Joaquin River located at Antioch (RSAN-007), and Jersey Point (RSAN-018). Table 4.1-2 shows tidal characteristics data for the Antioch NOS Gage, located just west of Big Break. RMA has developed the RMA-2 model for Big Break and the Delta; the model simulates tidal hydrodynamics, stage, flow velocity magnitude, and direction.

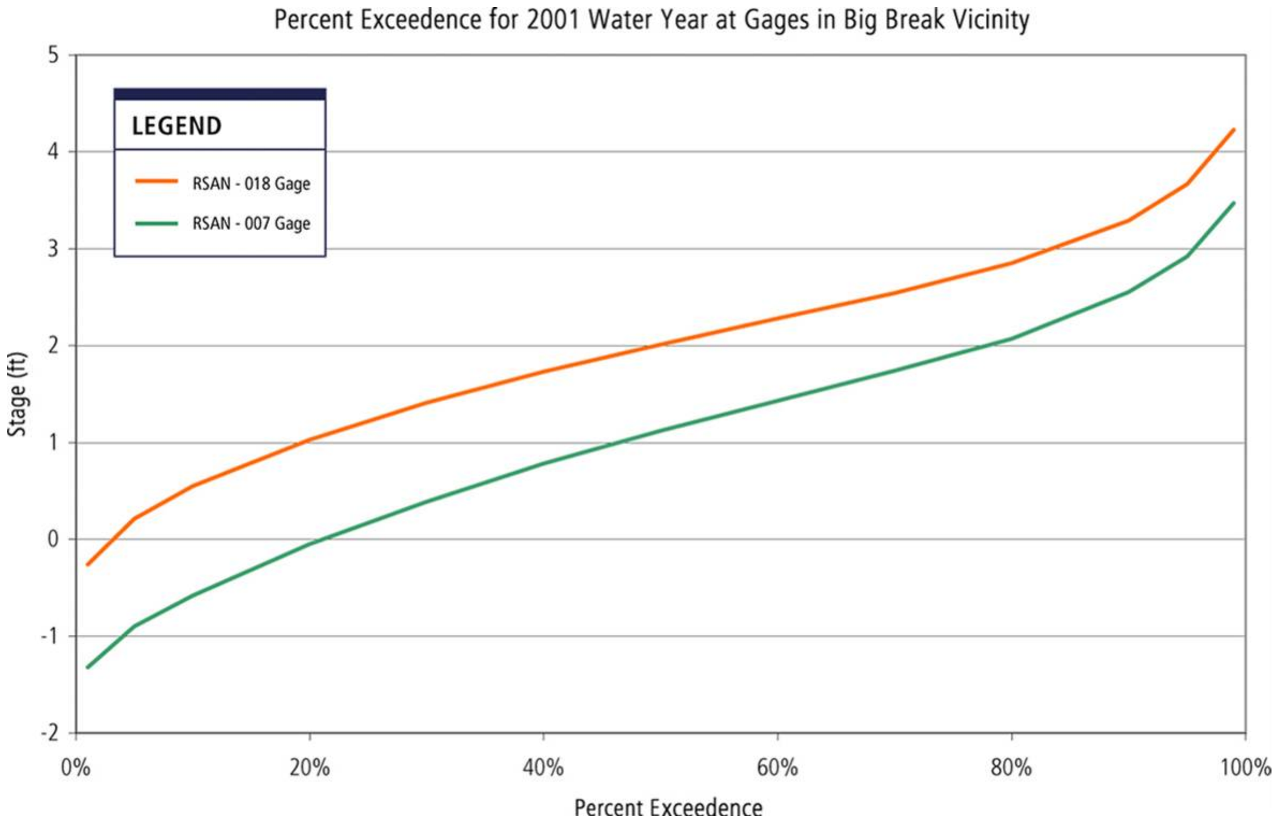
No specific data on sedimentation is available for Big Break other than perhaps comparisons of past bathymetric surveys that, to date, have not been completed. Investigations of sedimentation rates under the BREACH I study (University of Washington 2002) postulate that large flooded islands ceased subsiding after flooding and then reached an equilibrium depth as wind-generated waves balanced out sediment inputs.



Source: Swanson Hydrology + Geomorphology 2004

Bathymetric Map of Big Break

EXHIBIT 4.1-6



Gage locations shown on Exhibit 4.2-6. Data source: Interagency Ecological Program HEC-DSS Website

Source: Swanson Hydrology + Geomorphology 2004

Tide Stage Duration Curve for 2001 Water Year for Gages Near Big Break

EXHIBIT 4.1-7

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4.2 GEOLOGY, SOILS, AND SEISMICITY

This section begins with a general description of the geology and soils in the Delta, followed by soil types at each project site. The section also includes discussions on land subsidence, seismic risk, and levee stability.

4.2.1 DELTA GEOLOGY AND SOILS

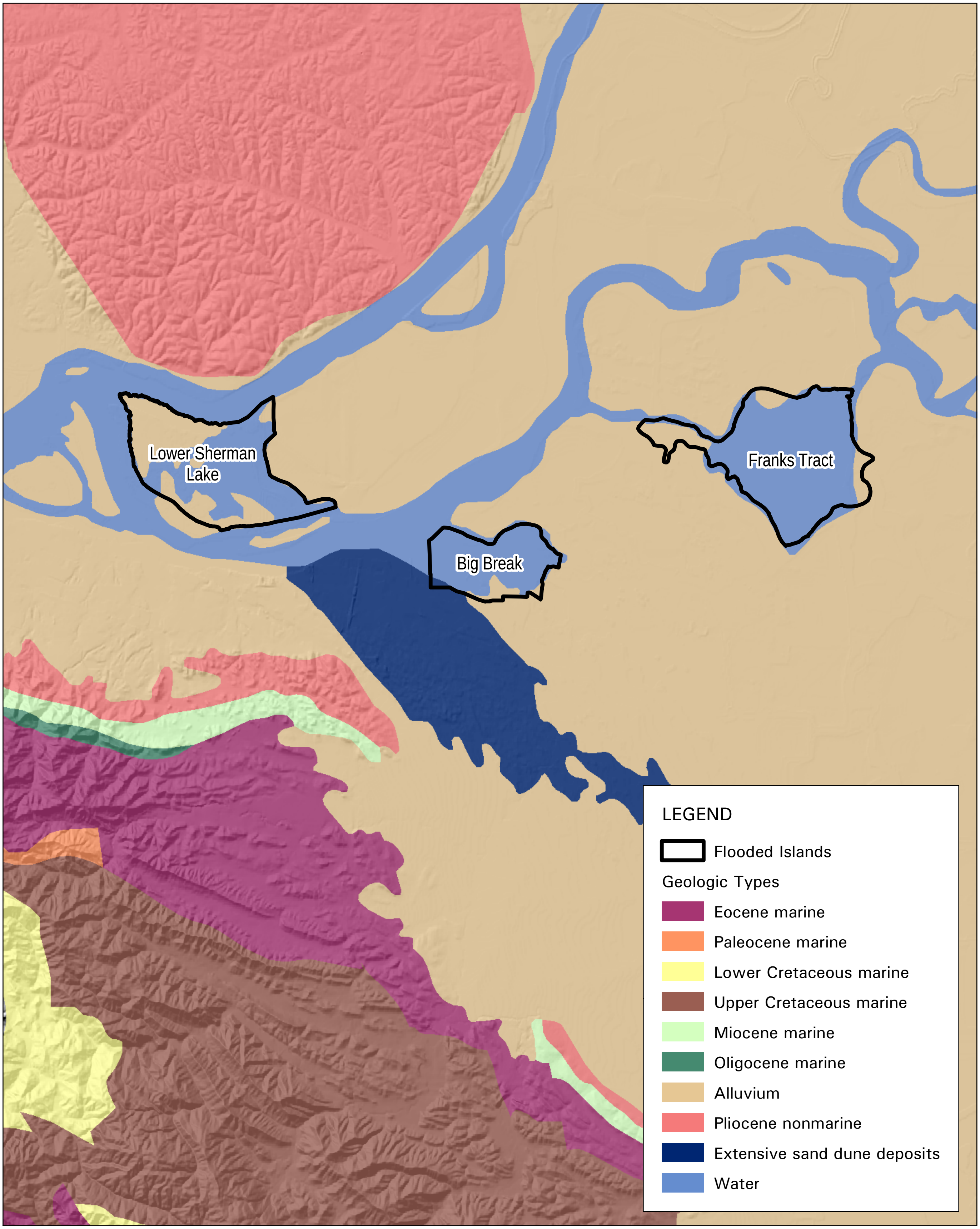
GENERAL DESCRIPTION

The Great (Central) Valley Geomorphic Province is a valley trough that extends over 400 miles from north to south and consists of the Sacramento and the San Joaquin valleys. It is divided into two subbasins, the Sacramento and the San Joaquin. The San Joaquin Valley is composed of the San Joaquin River basin, drained by the San Joaquin River from the south, and the Tulare basin, a hydrologically closed basin that is drained only during extremely wet periods. The Sacramento Valley is drained by the Sacramento River from the north. The confluence of these two major river systems and lesser streams and systems forms the inland Delta, which is drained through Suisun Bay and the narrow Carquinez Strait to San Pablo and San Francisco bays and eventually into the Pacific Ocean (CALFED 2000).

The Central Valley Geomorphic Province is a long, low trough underlain by Quaternary sedimentary rock, lesser amounts of Tertiary sedimentary rock, and Cretaceous shales (Exhibit 4.2-1). This geologic base is overlain with alluvium and fill deposits including peat and detrital sediments that are interbedded with glacial sands and gravel washed down from the Sierra Nevada. Occupying the lowest part of the western Sacramento Basin is the Delta. Originally, the Delta was part of the inland sea of Tertiary and post-Tertiary times, but during the Post-Pleistocene, the Delta became filled with many islands formed by waters moving through this region. During flooding, sediments were deposited along the islands' shores, forming natural levees. Each island's interior subsided, and seasonal ponds provided an ideal environment for tule (*Scirpus* spp.). These tule marshes have formed significant peat deposits throughout the Delta (Center for Design Research, UCD 1988).

The upper and lower watersheds of the area contain four primary physiographic land types, each with characteristic soil conditions: valley land, valley basin land, terrace land, and upland. Valley land and valley basin land soils occupy most of the Central Valley floor. Valley land soils consist of deep alluvial and Aeolian soils that make up some of the best agricultural land in the state. Valley basin lands consist of organic soils of the Sacramento–San Joaquin Delta, poorly drained soils, and saline and alkali soils in the valley trough (CALFED 2000).

The soils of the Delta region vary primarily as a result of differences in geomorphological processes, climate, parent material, biologic activity, topography, and time (CALFED 2000). Much of the Delta area is underlain by sedimentary bedrock overlain by thick deposits of alluvial sediments. The deepest portion of these surficial deposits consists of a complex mixture of coarse sand and gravel bed-load deposits, sand- and silt-sized overbank deposits, and silt- and clay-sized backwater deposits. The most recent deposits are generally dark-



Source: California Department of Conservation Division of Mines and Geology 2000

Geologic Types

EXHIBIT 4.2-1

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colored, often highly organic, and of mixed lithologic composition and origin. The recent sediments along the eastern margin of the Delta are derived mostly from metamorphic sources in the Sierra Nevada foothills, whereas the sediments along the western edge of the Delta are derived from the uplifted Tertiary sedimentary rocks of the Coast Range (JSA 1997).

Soils in the Feasibillity Study area reflect its original land cover, which consisted mostly of tule marsh vegetation and riparian forest vegetation. Soil types include loams, clays, clay loams, silty clay loams, fluvaquents, and mucks. Mineral soils cover most of the upland portions of the Delta, whereas the lowlands are dominated by peat soils. These soils are generally deep (up to 60 feet) and very poorly to poorly drained (JSA 1997).

The Delta region contains primarily soils with the required physical and chemical soil characteristics, growing season, drainage, and moisture supply necessary to qualify as prime farmland. This includes 80–90% of the area of organic and highly organic mineral soils, Sacramento River and San Joaquin River deltaic soils, and basin and basin rim soils. Most remaining soils of the Delta qualify as farmland of statewide importance (CALFED 2000).

Differences in granular texture of the submember units of individual formations become important in understanding soil distributions and wetland development opportunities. For example, certain shale members of sedimentary rock may be more likely to support more clay-dominant soils that offer greater water impoundment through reduced porosity/permeability (compared to sandier soils with better drainage) (JSA 2004).

Two environmental concerns associated with Delta soil are salinity and wind erosion. Increasing soil salinity has been recognized as a problem in the San Joaquin Valley since the late 1800s, when a rapid increase in irrigated acreage coincided with increasingly poor drainage (because of elevated shallow groundwater table levels) and elevated soil salinity levels in the western and southern portions of the San Joaquin Valley (CALFED 2000).

Dissolved salts in irrigation water can lead to high soil salinity, an unfavorable condition for agricultural crop production. High soil salinity is an issue in several portions of the Delta, including the south Delta area, the west Delta area (primarily Sherman and Twitchell Islands), and Suisun Marsh. North and east Delta areas receive relatively low-salinity water from the Sacramento River and east side tributaries, and do not experience salinity problems. The concentration of salinity in shallow groundwater and the salt mass contained in Delta soils are direct consequences of the quality of the irrigation water drawn from Delta channels (CALFED 2000).

Another concern is wind erosion. The Delta organic soils and highly organic mineral soils have wind erodibility ratings of 2-4 on a scale where 1 is most erodible, and 8 is least erodible. The high wind erodibility of Delta soils is due to their organic matter content. The rate of wind erosion is estimated at 0.1 inch per year (CALFED 2000).

FRANKS TRACT

Known soils in Franks Tract consist of fluvaquents; fluvaquents 0–2% slopes, frequently flooded; Rindge muck, partially drained, 0–2% slopes; and Ryde silt loam; as depicted in Exhibit 4.2-2. Franks Tract is located in Soil Region IV, Sacramento Valley. Soils in this region vary depending on the parent material, drainage, and age developed from alluvial deposition. The soil types found in the area of Franks Tract are mixed alluvium and sedimentary alluvium. The three underlying soils of Franks Tract, grouped as a Rindge–Kingile Association, are nearly level, poorly drained mucks, with depths exceeding 60 inches. The fluvaquents, found in the sloughs and channels, are very poorly drained, loamy mineral soils consisting of stratified, fine sandy loam, loam, silt loam, and silty clay loam (Center for Design Research, UCD 1988).

The Rindge Series are very poorly drained organic soils that have formed in marshes through the accumulation of remains of tules, reeds, and other aquatic plants. Highly organic (50%–80%), a typical profile shows several layers of very strongly acid muck of progressively darker color. Permeability is rapid; soils are level or nearly so, with slow run-off. If the soil is tilled and exposed, soil blow-out is a moderate hazard. If allowed to dry, it shrinks irreversibly. During summer, it is subject to peat fires (Center for Design Research, UCD 1988).

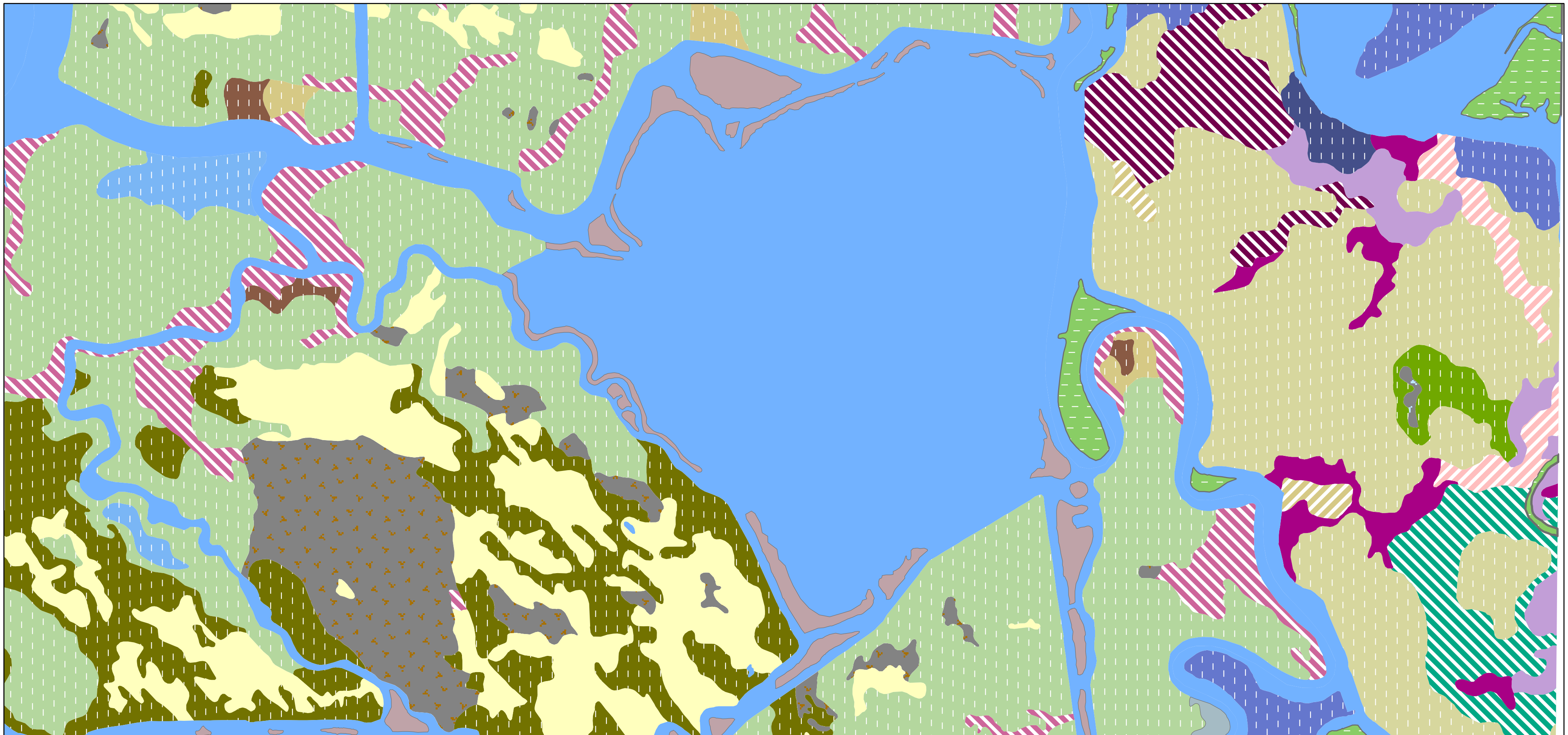
The Ryde Series are very poorly drained soils formed by the slow accumulation of reed and sedge remains stratified with fine-textured mineral sediments. A typical profile shows a stratified range of medium acid silt loam, medium acid heavy silt loam, and light clay loam stratified with thin layers of sandy loam and organic material. These soils are level or nearly so, with very slow runoff and no hazard of erosion where silts have been tilled and exposed (Center for Design Research, UCD 1988). Subsidence occurrence at Franks Tract is due to peat export, but water levels preclude a determination of the rate or amount of export (Center for Design Research, UCD 1988).

LOWER SHERMAN ISLAND

Known soils in Lower Sherman Island consist of fluvaquents 0–2% slopes, frequently flooded; medisaprists, 0–2% slopes, frequently flooded, and xeropsamments, 1–15% slopes, as depicted in Exhibit 4.2-3. Medisaprists consist of very deep, very poorly drained, organic soils in tidal marshes. These soils formed in hydrophytic plant remains stratified with alluvium derived from mixed rock sources. They are regularly inundated by tidal water. Xeropsamments consist of very deep, moderately well drained to excessively drained soils in areas of dredge piles that have been deposited on flood plains and natural levees. These soils formed in recently dredged material removed from the bottom of channels (NCSS 1987).

BIG BREAK

Brentwood dune sands, deposited in the Pleistocene and Holocene, underlie the drainages in the area of Big Break. This deposit type extends through the northern portion of the region. These sands are being buried by Basin Deposits found in the surrounding areas of this region.



LEGEND

- Franks Tract
- Egbert Mucky Clay Loam
- Fluvaquents
- Fluvaquents, 0-2% Slopes, Frequently Flooded
- Itano Silty Clay Loam, Partially Drained, 0-2% Slopes
- Kingile Muck
- Peltier Mucky Clay Loam, Partially Drained, 0-2% Slopes
- Piper Fine Sandy Loam
- Piper Loamy Sand
- Piper Sandy Loam, Partially Drained, 0-2% Slopes
- Rindge Muck
- Rindge Muck, Partially Drained, 0-2% Slopes
- Rindge Mucky Silt Loam, Partially Drained, 0-2% Slopes
- Rindge Mucky Silt Loam, Partially Drained, 0-2% Slopes OVE
- Ryde Clay Loam, Partially Drained, 0-2% Slopes
- Ryde Silt Loam
- Ryde Silty Clam Loam, Organic Substratum, Partially Drained, 0-2% Slopes
- Ryde-Peltier Complex, Partially Drained, 0-2% Slopes
- Shima Muck
- Shima Muck, Partially Drained, 0-2% Slopes
- Venice Muck
- Venice Muck, Partially Drained, 0-2% Slopes
- Venice Mucky Silt Loam, Partially Drained, 0-2% Slopes, Ove
- Water
- Webile Muck

Source: SSURGO 1998

Soils - Franks Tract

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LEGEND

- Lower Sherman Lake
- Brentwood Clay Loam
- Capay Clay, 0-2% Slopes
- Capay Clay, 2-9% Slopes
- Clear Lake Clay
- Delhi Sand, 2-9% Slopes
- Fluvaquents
- Fluvaquents, 0-2% Slopes, Frequently Flooded
- Gazwell Mucky Clay, Partially Drained, 0-2% Slopes
- Joice Muck
- Marcuse Clay
- Medisaprists, 0-2% Slopes, Frequently Flooded
- Piper Loamy Sand
- Rincon Clay Loam, 0-2% Slopes
- Rincn Clay Loam, 2-9% Slopes
- Rincon Clay Loam, 9-15% Slopes
- Rindge Muck
- Rindge Muck, Partially Drained, 0-2% Slopes
- Rindge Mucky Clay Loam, 0-2% Slopes
- Rindge Mucky Silt Loam, Partially Drained, 0-2% Slopes
- Rindge Mucky Silt Loam, Partially Drained, 0-2% Slopes, Ove
- Sailboat Silt Loam, Partially Drained, 0-2% Slopes
- Sailboat Variant Silty Clay Loam, Partially Drained, 0-2% Slopes
- Scribner Clay Loam, Partially Drained, 0-2% Slopes
- Shima Muck
- Sycamore Silty Clay Loam
- Sycamore Silty Clay Loam, Clay Substratum
- Suisin Peaty Muck
- Tamba Mucky Clay
- Tidal Marsh
- Urban Land
- Valdez Silt Loam, Drained
- Valdez Silty Clay Loam, Wet
- Water
- Xeropsamments, 1-15% Slopes
- Zamora Silty Clay Loam, 2-5% Slopes

Source: SSURGO 1998

Soils - Lower Sherman Lake

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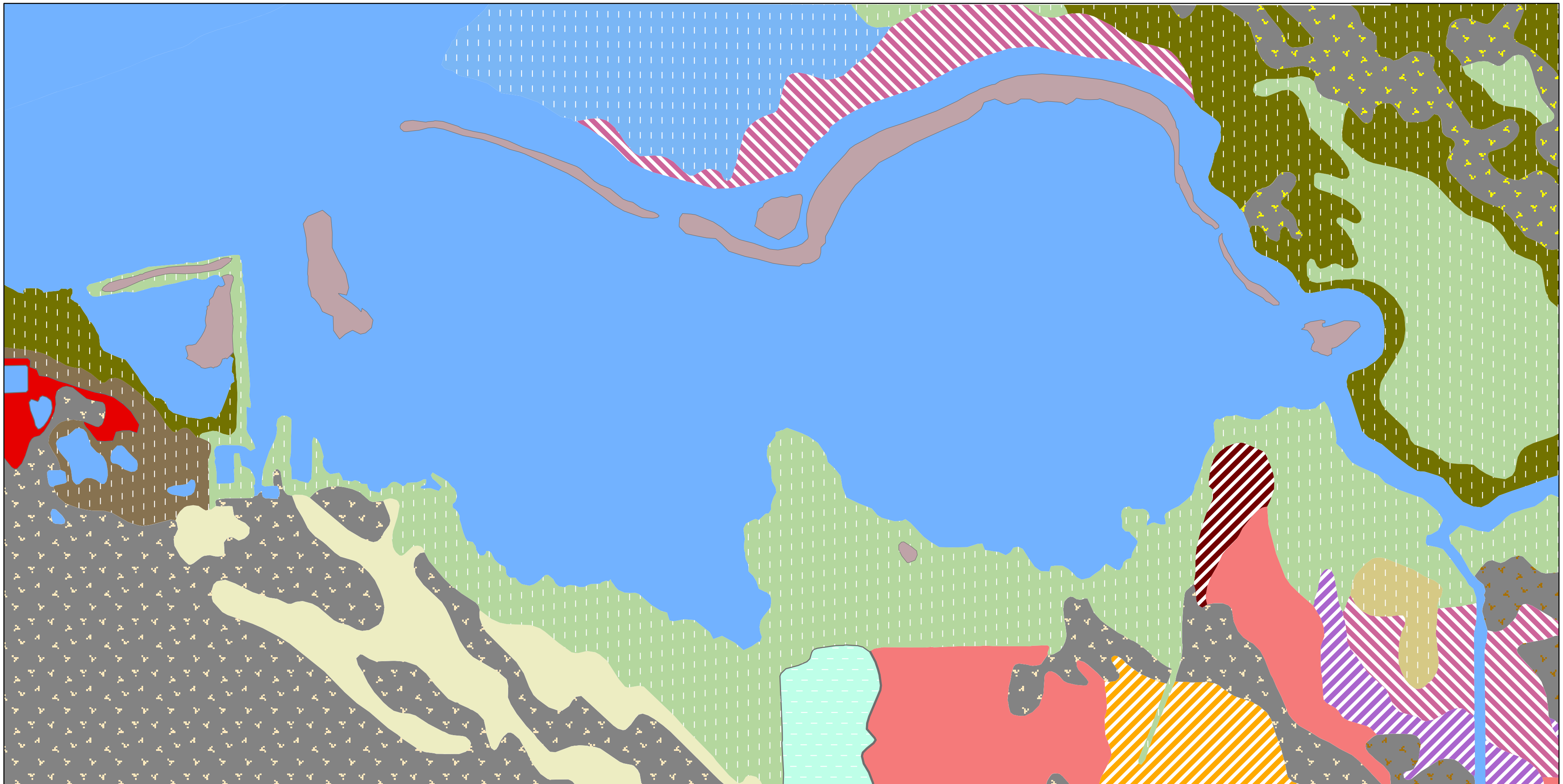
The Basin Deposits are very fine silty clay and clay deposits at alluvial fan edges and adjacent to bay mud (JSA 2004).

The Big Break area is very flat, with estuary and marshes lying at sea level. The 40-acre Lauritzen Site provides the only land area along the water's edge, of which only about 6 acres are above the 100 year flood level (EBRPD 2001).

The Big Break area lies in the flood plain of the San Joaquin River, and surficial deposits include sand, silts, and clays deposited by the river. The bedrock geology dips into a basinal low formed by two opposing normal tensional faults in the subsurface, the down-to-the west Midland Fault on the east side, and the down-to-the east Sherman Island Fault on the west side. Neither fault is regarded as active. A potential for liquefaction of the surficial deposits and subsequent damage to structures exists in the area if a strong earthquake occurs. Strong ground motion was recorded to the north in the Winters–Vacaville area in 1892 (magnitude 6.4), in the Antioch area in 1889 (magnitude 6.0), and minor earthquakes have been recorded in the Montezuma Hills and Antioch areas (EBRPD 2001).

Known soils in Big Break consist of fluvaquents; Rindge muck, partially drained, 0–2% slopes; marcuse clay, strongly alkali; and delhi sand, 2–9% slopes, as depicted in Exhibit 4.2-4. The soils of Big Break are those of the Delta Plain, which was once a freshwater marsh. These soils formed in the accumulated remains of tules, reeds, and other aquatic plants with thin layers of silty mineral matter. The organic content increases with depth. The surface of these soils lies at or below sea level to about 15 feet above sea level. Most wetland soils at Big Break are classified as "Rd," Rindge Muck. Rindge soils are deep, black, organic material and have been primarily used for irrigated pasture, field corn, and asparagus. The levees and larger islands are classified as "Fc," Cluvaquents, very poorly drained, loamy, mineral soils in sloughs and river channels. The tidal slough and low areas of the Lauritzen Site are "Pd," Piper sand. These soils formed in windblown material that had encroached into the northwestern part of the Delta. They are very poorly drained and are saturated within 20 to 40 inches all year and within 20 inches for as much as 4 months per year. These soils are used primarily for dryland or irrigated pasture. In the early 1900s, before the levee failed, asparagus was farmed at Big Break.

The higher elevations of the Lauritzen Site are classified as "DaC," Delhi sand. There areas are very deep sands, formed in wind-modified stream deposits of mixed origins. They have rapid permeability and slow runoff. There are only "slight" degrees and kinds of limitations indicated for Delhi sands for roads and dwellings (without basements). The American Association of State Highway and Transportation Officials (AASHTO) classification is A-3. Topsoil is sandy and poor. Embankments for water retention have medium shear strength, low compressibility, high permeability of compacted soil, medium-to-high susceptibility to piping, and good compaction characteristics. Bedrock is greater than 5 feet deep and the shrink–swell potential is low (EBRPD 2001).



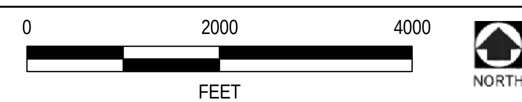
LEGEND

- Big Break
- Capay Clay, Wet, 0-2% Slopes
- Delhi Sand, 2-9% Slopes
- Fluvaquents
- Joice Muck
- Kingile Muck
- Marcuse Clay
- Marcuse Clay, Strongly Alkali
- Piper Fine Sandy Loam
- Piper Loamy Sand
- Piper Sand
- Rindge Muck
- Ryde Silt Loam
- Sacramento Clay
- Shima Muck
- Sycamore Silty Clay Loam
- Sycamore Silty Clay Loam, Clay Substratum
- Urban Land
- Venice Muck
- Water

Source: SSURGO 1998

Soils - Big Break

EXHIBIT 4.2-4



EDAW

Evidence of former saltwater intrusion remains in the upland soils of the Lauritzen property, and these soils contain residual salts. The entire Lauritzen site is underlain by a permanent near-surface water table that may elevate 1 or 2 feet from an approximate 8-foot depth during sustained high tides or high flood flows (EBRPD 2001).

4.2.2 SOIL SUBSIDENCE

Soil subsidence is a major problem in the Delta, primarily because it increases the risk and extent of flooding. The following discussion describes the causes of soil subsidence, as well as methods for reversing subsidence.

CAUSES OF SUBSIDENCE

Reclamation and Soil Decomposition

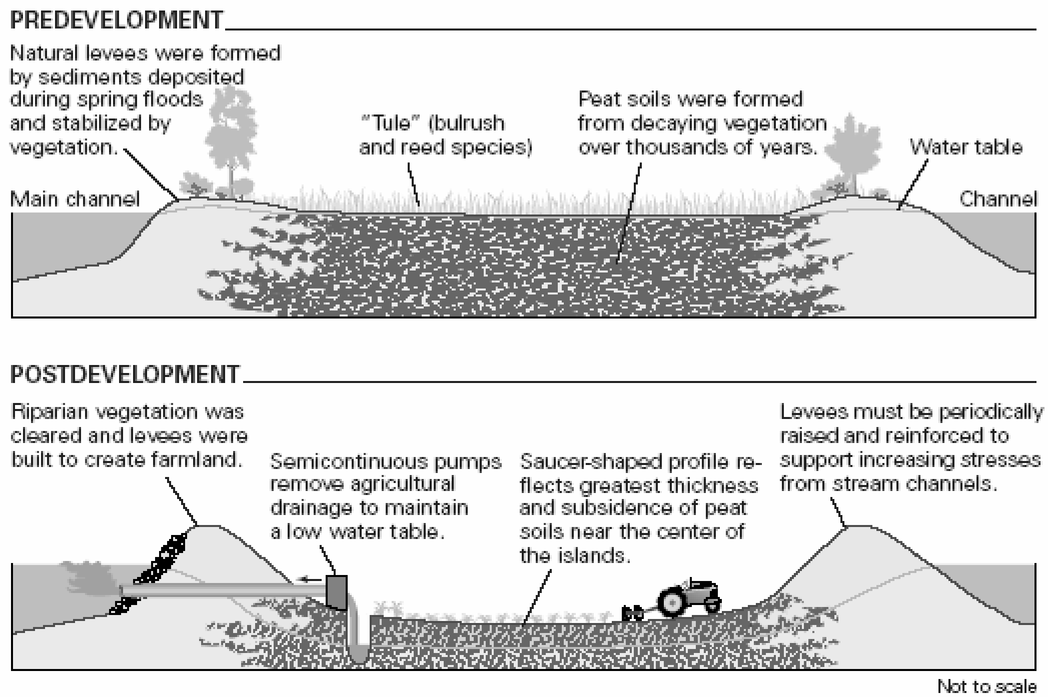
Reclamation

The Delta islands have been reclaimed for agricultural use because of their fertile soils. Conversion of the Delta wetlands to farmlands began in 1850 when the federal government transferred ownership of "swamp and overflow" lands to the states. Substantial reclamation was accomplished between 1880 and 1920 (CALFED 2000). Drainage of the Delta islands for agricultural production was essentially completed by the1930s, when it assumed its present configuration of about 65 islands surrounded by over 1,100 miles of artificial levees and over 700 miles of waterways (DWR 2002).

By 1920, it was recognized that the drained Delta lands were subsiding (CALFED 2000). Subsidence, as it relates to Delta islands, refers generally to the falling level of the land surface that results primarily from the process of peat soil oxidation (CALFED 2000). Subsidence occurs throughout the Delta, and is due to varying causes: oxidation, shrinkage, wind erosion, tectonic movement, compaction, consolidation (gas withdrawal), burning, and export of peat (Center for Design Research, UCD 1988).

For the past 7,000 years in the Delta there has been a close balance between the generation of space for accumulation of sediment, known as accommodation space, and the filling of this space by allochthonous and autochthonous sediment. Over the past 150 years, the construction of levees and the subsidence of island elevation led to the creation of more than 3 billion cubic yards of new accommodation space, all subaerial and below mean sea level (Mount 2004). Subsidence of the peat soils has caused the tidally influenced islands to become holes in which the land surfaces are now 10–25 feet below sea level (USGS 2000) (See Exhibit 4.2-4).

When most of the existing levees were constructed, the difference between the water level in the channel and the island surfaces was less than 5 feet. Because of the decreasing island-surface elevations, the levees are now required to hold back substantially more water than when they were originally constructed. This resulted in an increase in hydraulic pressures on levees that were constructed on foundations of sand, peat, and organic sediments, and has caused about 35 levee failures since the 1930s (DWR 2002). Preliminary simulations of island subsidence and sea-level rise over the next 50 years indicate that levee instability in the Delta will increase by 33% to as much as 66%.



Source: USGS 2000

There is increasing pressure to prevent Delta islands from flooding for protection of water quality, recreational use, agriculture, wildlife habitat, and property. As the islands continue to subside, levee repair and maintenance will become more critical and expensive. A critical factor in preventing further losses resulting from levee failure is stopping and reversing subsidence of the peat soils (DWR 2002).

Soil Decomposition

The dominant cause of land subsidence in the Delta is decomposition of organic carbon in the peat soils. Before agricultural development, the soil was waterlogged and anaerobic (oxygen-poor). Organic carbon accumulated faster than it could decompose. Drainage for agriculture led to aerobic (oxygen-rich) conditions that favor rapid microbial oxidation of the carbon in the peat soil. Most of the carbon loss is emitted as carbon dioxide gas to the atmosphere (Deverel and Rojstaczer 1996, cited in USGS 2000). Studies by the USGS and the Department of Water Resources (DWR) indicate that as much as 50 pounds of carbon dioxide are released per acre per day from Delta peat soils. The amount of carbon dioxide released is directly proportional to the amount of subsidence. Soil moisture and temperature influence the amount of carbon dioxide loss. Carbon dioxide losses are greatest during the spring and summer and lowest during the winter. Wetter and colder conditions result in lower carbon dioxide losses (DWR 2002).

The deposition of the Delta peat soils began about 10 thousand years ago as marsh plants died, decayed, and accumulated under oxygen-deficient conditions. Rising sea levels during the last 10 thousand years caused oxygen-deficient conditions to be maintained as decaying plants accumulated. The reclamation and drainage of these soils created oxygen-rich conditions in which the peat soils were consumed by microorganisms, such as bacteria and fungi (DWR 2002).

Elevation measurements made from 1922 to 1981 indicate that land-use practices on peat soils (organic or highly organic mineral soils) tended to cause from 1 to 3 inches of subsidence per year (CALFED 2000). DWR estimates that peat soils of the Sacramento–San Joaquin Delta have subsided at rates of 0.4–0.6 inches per year (DWR 2002). The warm California temperatures are the primary reason that the Delta soils subside at relatively rapid rates. Also, an extensive network of drainage ditches prevents islands from flooding internally and maintains groundwater levels deep enough for agricultural crops to grow, resulting in soil that is exposed to oxygen, thus promoting greater decomposition by microorganisms (USGS 2000). The accumulated agricultural drainage is pumped through or over the levees into stream channels. Without this drainage, the islands would become flooded. Levee settlement may be partially caused by peat oxidation if land adjacent to levees is not protected from subsidence (CALFED 2000).

Subsidence has been highest on the central Delta islands, where soil organic matter contents are the highest. Also, the Delta islands are often bowl shaped because more subsidence occurred in the relatively high-organic-matter peats in the center of the islands. The water table is usually deeper toward the center of the island, where canals collect the island's drainage water, which also contributes to higher oxidation rates (DWR 2002).

METHODS FOR REVERSAL OF SUBSIDENCE

Subsidence management techniques arrest or reduce future subsidence: subsidence reversal techniques entail importing or growing fill material to physically rebuild subsided islands to sea level. Possible techniques for subsidence reversal including the following:

- Cultivation of nontidal tule ponds to gradually accrete island surface elevations;
- Use of rice-straw bales;
- Beneficial use of current and historical dredge spoils for levee construction and upgrades;
- Island capture of bed load and suspended sediment currently moving through the Delta;
- Importation of soil from upland sites (NHI 2002).

See Section 4.12 for a discussion of subsidence reversal techniques with "reuse materials."

Recent studies have been conducted on the potential for subsidence control through wetland restoration in the Delta. A study performed on Twitchell Island involved flooding the island and planting tules and cattails to show how wetlands affect the carbon process. Wetland areas were flooded at two different depths, 25cm and 55cm in the West and East Ponds, respectively (Drexler et al 2004).

Results showed a significant drop in carbon with flooding. From 1998 through 2001, mean accretion rates of mineral and organic matter in the West and East Ponds were 2.57 cm per year and 2.21 cm per year, respectively. Carbon (C) content of accreted material was approximately 16% in both wetlands. The accretion rate in terms of carbon was approximately 15,350 kg C per year in the West Pond (0.56 kg C per square meter per year), and 7,117 kg C per year in the East Pond (0.27 kg C per square meter per year). The difference in carbon storage between the wetlands is due to higher bulk density in the West Pond, which indicates that the shallower-water treatment may provide significantly greater carbon storage than the deeper-water treatment (Drexler et al. 2004). There was no noted difference in productivity between water depths, because deeper water resulted in taller but less-dense plants; however, depth slowed colonization (Knittweis 2000).

Another study related to the Twitchell wetlands used modeling to simulate accretion in the wetlands from 1997 to 2004. For these wetlands, the model estimated 64 cm of accretion in 50 years. Model results for increased levels of sediment application show greater accretion. For example, the model simulated 215 cm of accretion in 50 years for inorganic sediment inputs of about 1.25 g/cm2 per year (Deverel).

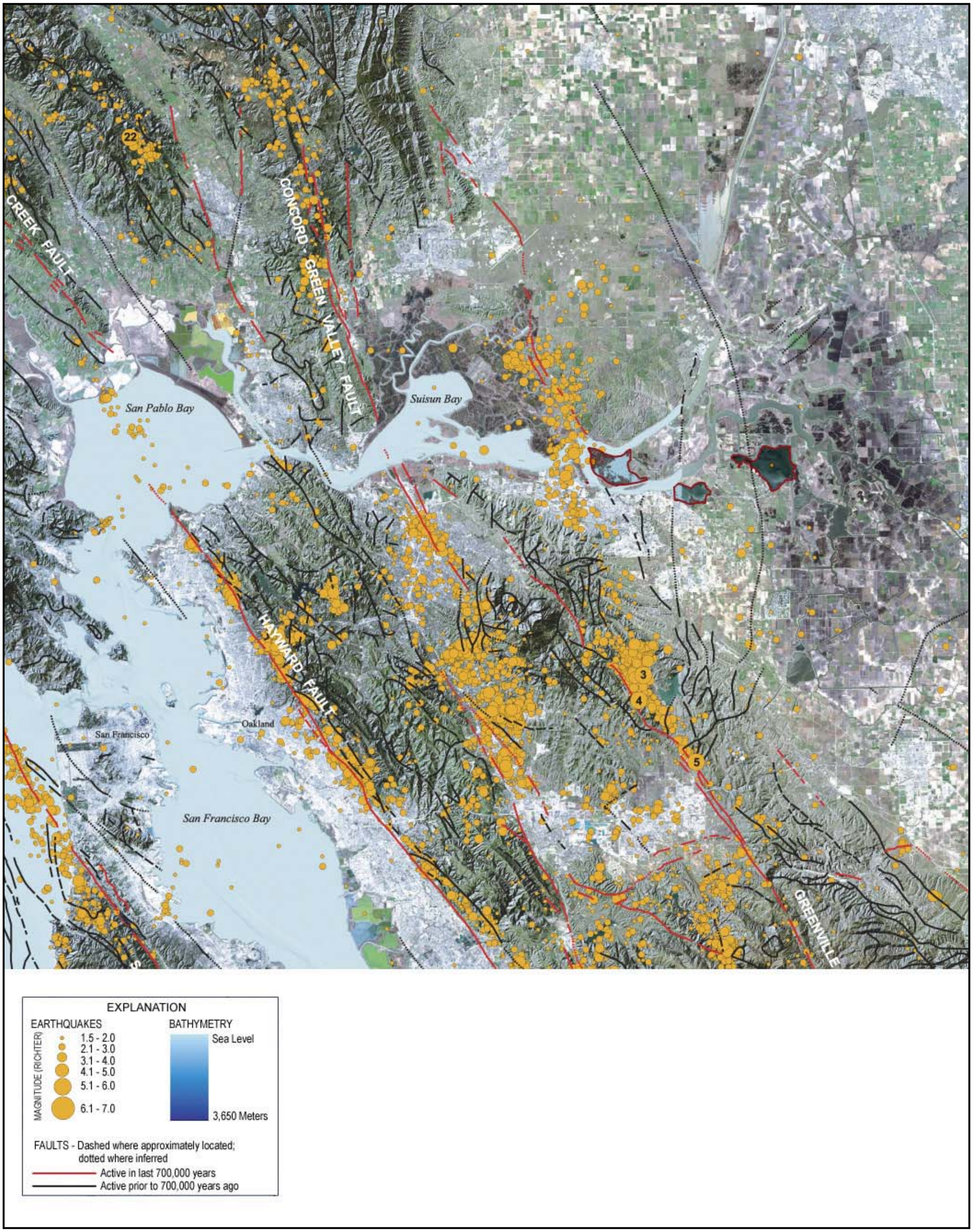
4.2.3 DELTA SEISMICITY

This subsection describes the seismicity of the Delta. Seismic information is generalized for the region; no study-area-specific information is provided.

SEISMIC RISK

The Delta is subject to seismic risk because of its proximity to the San Andreas Fault system. This fault system includes the San Andreas, Hayward, Calaveras, Rogers Creek, Antioch, Green Valley–Concord, and Greenville faults. All of these faults have been active historically (JSA 1997) (Exhibit 4.2-5).

A study assessing the probability of earthquakes in the San Francisco Bay Area was released in 2003 by Working Group 2002. Led by USGS, the working group consists of scientists from USGS, California Geological Survey, major universities, and private companies. The recently released study accounts for changes in the understanding of earthquake science as well as new ideas about modeling. The results indicate the Bay Area is highly likely to experience a damaging earthquake – a 62% probability for one or more events of M6.7 or higher from 2003 to 2032. The Hayward–Rodgers Creek system is estimated to have a probability of 27% – the highest probability of the Bay Area faults (Exhibit 4.2-6) (BSL 2004).



Source: USGS 2004

Earthquakes and Faults of the San Francisco Bay-Delta

EXHIBIT 4.2-5

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MILES
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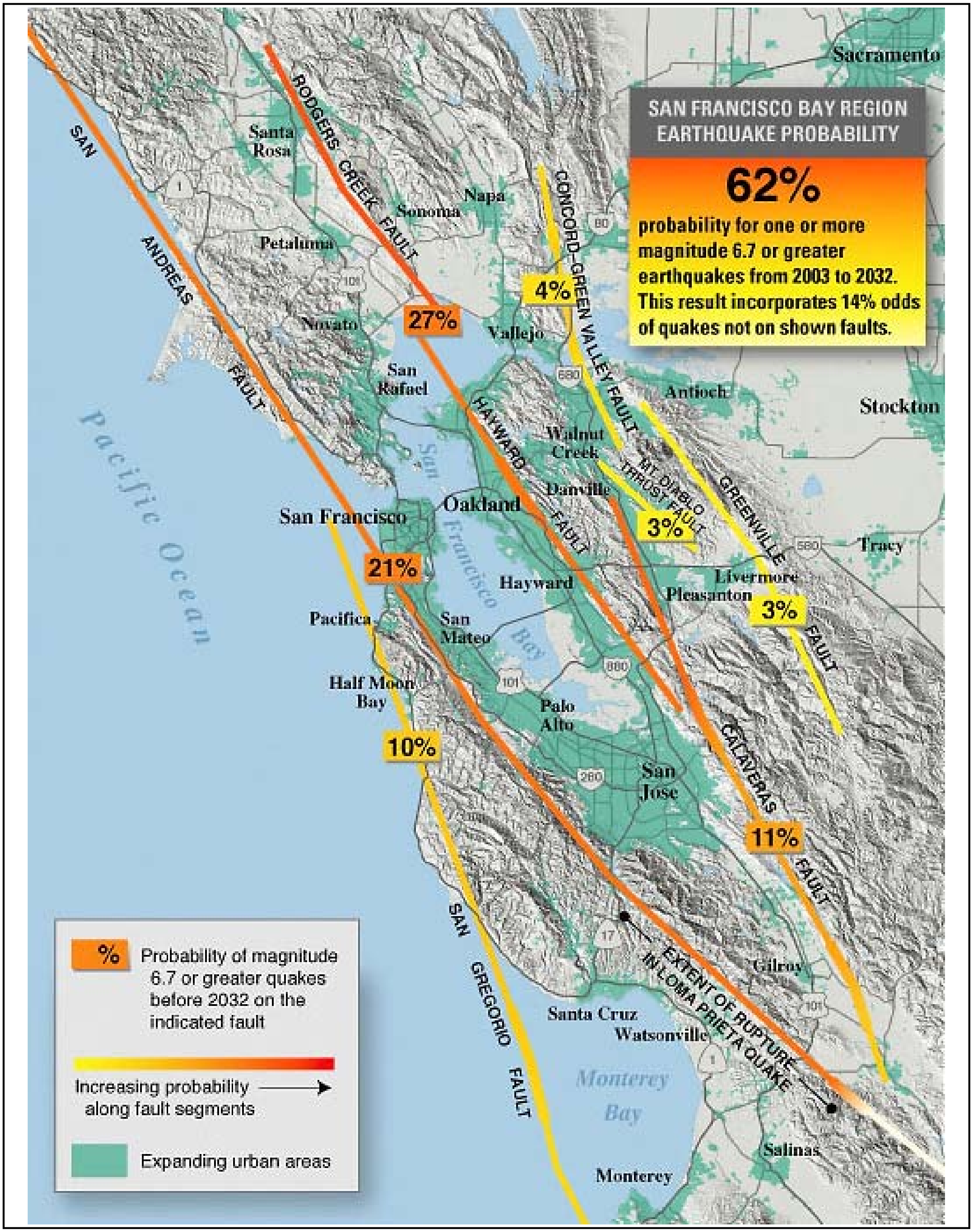


Source: Berkeley Seismological Lab 2002

San Francisco Bay Region Earthquake Probability

EXHIBIT 4.2-6

0 10 20
MILES
NORTH

The Delta levees are in a region of relatively low seismic activity compared to the San Francisco Bay Area. The major strike-slip faults in the Bay Area (San Andres, Hayward, and Calaveras Faults) are located more than 16 miles from the Delta region. The less active Green Valley and Marsh Creek–Clayton Faults are more than 9 miles from the Delta region. Small but significant local faults are situated in the Delta region (CALFED 2000). Many geologists theorize that a "hidden" major blind-thrust fault runs through the western Delta (CRVC fault) (Abrahamson et al. 2000).

Three active faults lie in the area of the three flooded islands, and are capable of producing strong seismic shocks. Buried under recent alluvium, the northwest-trending Midland Fault zone is a major subsurface feature. Drill holes from gas fields indicate that the latest movement in this zone occurred in Eocence times. The California Division of Mines and Geology considers the possibility that the Vacaville earthquake of 1892 originated along this fault. The Antioch fault, running north/south through the city of Antioch, is very active, and has produced nine earthquakes between 1962 and 1971, ranging from 2.5 to 5.0 on the Richter scale. There has been no historical activity on the Tracy–Stockton fault to the southwest; however, the possibility of seismic activity here is not discounted. The Greenville fault near the City of Livermore produced significant seismic activity in 1980, registering quakes of 5.5 and 5.8 on the Richter scale (Center for Design Research, UCD 1988). No historical earthquake damage has ever been recorded in the Delta. The highest recorded shaking is up to 0.08g in the West Delta, and 0.05g in the East Delta (Knittweis 2000). Appendix 4.2 of this document, "The In-Delta Storage Program Seismic Analysis Draft Report, Appendix A, Seismic Sources", prepared for DWR, includes a complete and detailed description of the faults and fault systems relevant to the three flooded islands.

The likelihood of a significant seismic event in the next 50 years is high (about the same probability as a 100-year flood event) (Mount 2004). CALFED's Seismic Vulnerability Sub-Team of the Levees and Channels Technical Team predicted that an earthquake with a magnitude of 6.0 (Richter Magnitude) has a 25% chance of occurring in the next 50 years.

Seismic vulnerability is highest at the western edge of the Delta because of poor levee embankment and foundation soils, and a higher exposure to seismic shaking in the San Andreas fault system (CALFED 2000). Odds that multiple levees could fail in a single seismic event in 50 years are greater than 60% (Leavenworth 2004).

SEISMIC THREAT TO LEVEE SYSTEM

Seismic activity is a potential threat to levee stability in the Delta. The most severe effect from earthquakes in the Delta would be damage to the levee system. Many levees in the Delta are water saturated, lack cohesion, and are constructed on extremely unstable soils that could amplify earthquake waves passing from bedrock to unconsolidated soil layers. The following effects could result from seismic shock:

- Liquefaction of levees or foundation soils, especially where depth to groundwater is shallow

- Compaction and settlement of levees or foundation soils
- Lateral spreading of levees or foundation soils
- Slumping, lurching, or ground cracking of levees
- Erosion or topping of levees by seiches (Center for Design Research, UCD 1988)

Historical information indicates that little damage to Delta levees has been caused by historical earthquakes. No report could be found to indicate that an island or tract had been flooded owing to an earthquake-induced levee failure. Furthermore, no report could be found to indicate that significant damage had ever been induced by earthquake shaking. The minor damage that has been reported has not significantly jeopardized the stability of the Delta levee system (CALFED 2000).

This lack of severe earthquake-induced levee damage corresponds to the fact that no significant earthquake motion has apparently ever been sustained in the Delta area since the construction of the levee system approximately a century ago. The 1906 San Francisco earthquake occurred 50 miles to the west, on the San Andreas Fault, and produced only minor levels of shaking in the Delta. As the levees were no yet very tall in 1906, these shaking levels posed little threat. Continued settlement and subsidence over the past 90 years and the increasing height of levees needed for flood protection have, however, substantially changed this situation. Consequently, the lack of historical damage should not lead, necessarily, to a conclusion that the levee system is not vulnerable to moderate-to-strong earthquake shaking. The current levee system simply has never been significantly tested (CALFED 2000).

The 2000 CALFED Seismic Vulnerability Report evaluated levee fragility and seismic vulnerability of the existing levee system. More than 600 miles of levees were considered in the assessment. Two models were considered; one model including a "hidden" major blind-thrust fault through the western Delta (CRVC fault) that geologists theorize exists, and another that theorizes no CRCV fault (Knittweis 2000). Based on earthquake modeling and levee conditions, the Sub-Team found that an earthquake with a magnitude of 6.0 (Richter Magnitude) will cause 8 to 26 levee failures in the Delta (CALFED 2000). Factors of failure included soil liquefaction and inertial/dynamic deformation (Knittweis 2000). The Sub-Team predicted that such an earthquake has a 25% chance of occurring within the next 50 years (CALFED 2000). They also predict that an earthquake with a 100-year return period is likely to cause three to ten levee failures on one or more islands. A stronger earthquake with a return period of 300 years might result in up to 40 levee failures (Abrahamson et al. 2000)

The probability of levee failure is increased during periods of high water, when stress is greatest. With failure of large levees, substantial flooding would inundate those Delta islands with substandard or particularly fragile levees. According to DWR, most of the levee system would fail during a severe earthquake (Center for Design Research, UCD 1988). The levee upgrades underway in the Delta focus on defense against static pressures, such as flood flows in a river. Existing upgrades would do almost nothing to prevent soil liquefaction (NHI 2002).

4.3 METEOROLOGY AND CLIMATOLOGY

This section provides general baseline information on the meteorology and climatology of the Bay–Delta region, as well as their effect on hydrology in the Delta. Because the study areas experience the same climatic conditions as the region, no additional project site-specific information is included in this section. This section relies primarily on a report produced by Bay Area Air Quality Management District (2004). Trends in global warming related to the hydroclimate of the Central Valley and Bay–Delta are also discussed.

4.3.1 BAY–DELTA CLIMATE AND LARGE-SCALE INFLUENCES

The summer climate of the West Coast is dominated by a semipermanent high pressure cell centered over the northeastern Pacific Ocean. Because this high pressure cell is quite persistent, storms rarely affect the California coast during the summer. Thus the conditions that persist along the coast of California during summer are a northwest air flow and negligible precipitation. A thermal low pressure area from the Sonoran–Mojave Desert also causes air to flow onshore over the San Francisco Bay Area much of the summer.

The steady northwesterly flow around the eastern edge of the Pacific high pressure cell exerts a stress on the ocean surface along the West Coast. This induces upwelling of cold water from below. Upwelling produces a band of cold water that is approximately 80 miles wide off San Francisco. During July the surface waters off San Francisco are 30°F cooler than those off Vancouver, more than 700 miles farther north.

Air approaching the California coast, already cool and moisture laden from its long trajectory over the Pacific, is further cooled as it flows across this cold bank of water near the coast, thus accentuating the temperature contrast across the coastline. This cooling is often sufficient to produce condensation, and a high incidence of fog and stratus clouds along the Northern California coast in summer.

In winter, the Pacific high pressure cell weakens and shifts southward, upwelling ceases, and winter storms become frequent. Almost all Bay Area annual precipitation takes place from November through April. During the winter rainy periods, inversions are weak or nonexistent, winds are often moderate, and air pollution potential is very low. When the Pacific high pressure cell becomes dominant in winter, inversions become strong and often are surface based; winds are light and pollution potential is high. These periods are characterized by winds that flow out of the Central Valley into the Bay Area and often include "tule fog."

TOPOGRAPHIC INFLUENCES ON CLIMATE

The San Francisco Bay Area is characterized by complex terrain consisting of coastal mountain ranges, inland valleys, and bays. Elevations of 1,500 feet are common in the higher terrain of this area. Normal wind flow over the area can be radically distorted in the lowest levels. This is particularly true when the air mass is stable and the wind velocity is not strong. With stronger winds and unstable air masses moving over the area this distortion is reduced. The distortion is greatest when low-level inversions are present with the surface air, beneath the inversion, flowing independently of the air above the inversion. This latter condition is common in the summer, the surface air mass being the sea breeze.

The only major sea-level pass through California's Coast Range is found in the Bay Area. Here the Coast Range splits into western and eastern ranges. Between the two ranges lies the San Francisco Bay. The gap in the western Coast Range is known as the Golden Gate, and the gap in the eastern Coast Range is the Carquinez Strait. These gaps were originally cut by rivers that are part of the drainage system from the Sierra Nevada mountains runoff. Besides allowing water to flow to the ocean, these gaps allow air to pass into and out of the Central Valley.

The eastern gap, the Carquinez Strait, extends from Davis Point in Rodeo to Martinez, ending at Suisun Bay. The term "Carquinez Strait" is often loosely used to include the region east to Antioch. At sea level, the strait is 1-2 kilometers wide, with terrain immediately north and south reaching 500-600 feet.

WINDS

In summer, the northwest winds to the west of the Pacific coastline are drawn into the interior through the Golden Gate and over the lower portions of the San Francisco Peninsula. Immediately to the south of Mount Tamalpais, the northwesterly winds accelerate considerably and come more nearly from the west as they stream through the Golden Gate. This channeling of the flow through the Golden Gate produces a jet that sweeps eastward but widens downstream, producing southwest winds at Berkeley and northwest winds at San Jose; a branch curves eastward through the Carquinez Straits, the study areas and their vicinity, and into the Central Valley. Wind speeds may be locally strong in regions where air is channeled through a narrow opening such as the Carquinez Strait, the Golden Gate, or San Bruno Gap. For example, the average wind speed at San Francisco International Airport from 3 p.m. to 4 p.m. in July is about 17 knots, compared with only about 7 knots at San Jose and less than 6 knots at the Farallon Islands.

The sea breeze in the study areas between the coast and the Central Valley commences near the surface along the coast in late morning or early afternoon; it may be first observed only through the Golden Gate. Later in the day the layer deepens and intensifies while spreading inland. As the breeze intensifies and deepens it flows over the lower hills farther south along the Peninsula. This process frequently can be observed as a bank of stratus "rolling over" the coastal hills on the west side of the Bay. The depth of the sea breeze depends in large part on the height and strength of the inversion. The generally low elevation of this stable layer of air prevents marine air from flowing over the coastal hills. It is unusual for the summer sea breeze to flow over terrain exceeding 2,000 feet in elevation.

In winter, the Bay Area experiences frequent storms and moderate-to-strong winds and periods of stagnation with very light winds. Winter stagnation is characterized by outflow from the Central Valley, nighttime drainage flows in coastal valleys, weak onshore flows in the afternoon, and otherwise light and variable winds.

Prevailing winds in the Delta are from the west in the Carquinez Straits, particularly during the summer. During summer and fall months, high pressure offshore, coupled with thermal low pressure in the Central Valley, caused by high inland temperatures, sets up a pressure pattern that draws marine air eastward through the Carquinez Straits almost every day. The wind is strongest in the afternoon because that is when the pressure gradient between the East Pacific high and the thermal low is greatest. Afternoon wind speeds of 15 to 20 mph are common throughout the Straits region, accelerated by the venturi effect setup by the surrounding hills. Annual average wind speeds are 8.2 mph in Martinez, and 9.5-10 mph farther east.

Sometimes the pressure gradient reverses and flow from the east occurs. Typically, for this to occur high pressure is centered over the Great Basin or the Pacific Northwest, setting up an east-to-west or northeast-to-southwest pressure gradient. These high pressure periods have low wind speeds and shallow mixing depths, thereby allowing the localized emissions to build up. The air mass from the east is warmer, thereby increasing photochemical activity, and contains more pollutants than the usual cool, clean marine air from the west. During winter, easterly flow through the Carquinez Strait is more common. Between storms, with the high pressure system no longer offshore, high pressure over inland areas causes easterly flow into the Bay Area through the Carquinez Strait.

TEMPERATURE

In summer, the distribution of temperature near the surface over the Bay Area is determined in large part by the effect of differential heating between land and water surfaces. This process produces a large-scale gradient near the Delta between the coast and the Central Valley, as well as small-scale local gradients along the shorelines of the ocean and bays. The temperature contrast between coastal ocean water and land surfaces 15-20 miles inland reaches 35°F or more on many summer afternoons. At night this contrast usually decreases to less than 100.

The winter mean temperature maximums and minimums reverse the summer relationship in that daytime variations are small, whereas mean minimum (nighttime) temperatures show large differences and strong gradients. The moderating effect of the ocean influences warmer minimums along the coast and penetrating the Bay. Coldest temperatures are in the sheltered valleys, implying strong radiation inversions and limited vertical diffusion.

Air temperatures near the Carquinez Strait do not appear to be noticeably affected by its proximity to water nor to the passage of oceanic air flows. Martinez and Antioch average daily maximum temperatures range from the mid to high 50s in the winter and high 80s in the summer, similar to Concord's temperatures. Average minimum temperatures range from the high 30s to low 40s in winter and mid-50s in summer.

INVERSIONS

A primary factor in air quality is the mixing depth or the vertical dimension available for dilution of contaminant sources near the ground. Over the Bay Area the frequent occurrence of temperature inversions limits this mixing depth and consequently limits the availability of air for dilution. A temperature inversion may be described as a layer or layers of warmer air over cooler air.

Several types of temperature inversion are important. The strong inversions typical of summer are formed by subsidence, the heating of downward-moving air in the high pressure anticyclone over the western Pacific. The surface inversions typical of winter are formed by radiation as air is cooled in contact with the earth's cold surface at night. Although there is a prevalent type of temperature inversion related to season, both inversion mechanisms may operate at any time of the year. At times, surface inversions formed by radiational cooling may reinforce the subsidence inversion aloft, particularly in fall and winter. The thick, strong inversion resulting in this case is especially effective in trapping pollutants.

In the morning the seasonal variations are most dramatic. From June through September there are only 2 days per year, on average, with no inversion below 5,000 feet. March and April have fewer morning inversions. The occurrence of surface inversions is highest from October through January, when the characteristic radiation inversion predominates. A wide cluster of cases between 500–2,500 feet dominates from May through September, when the summer subsidence inversion over the marine layer dominates. There is substantial day-to-day variability in the depth of the marine layer.

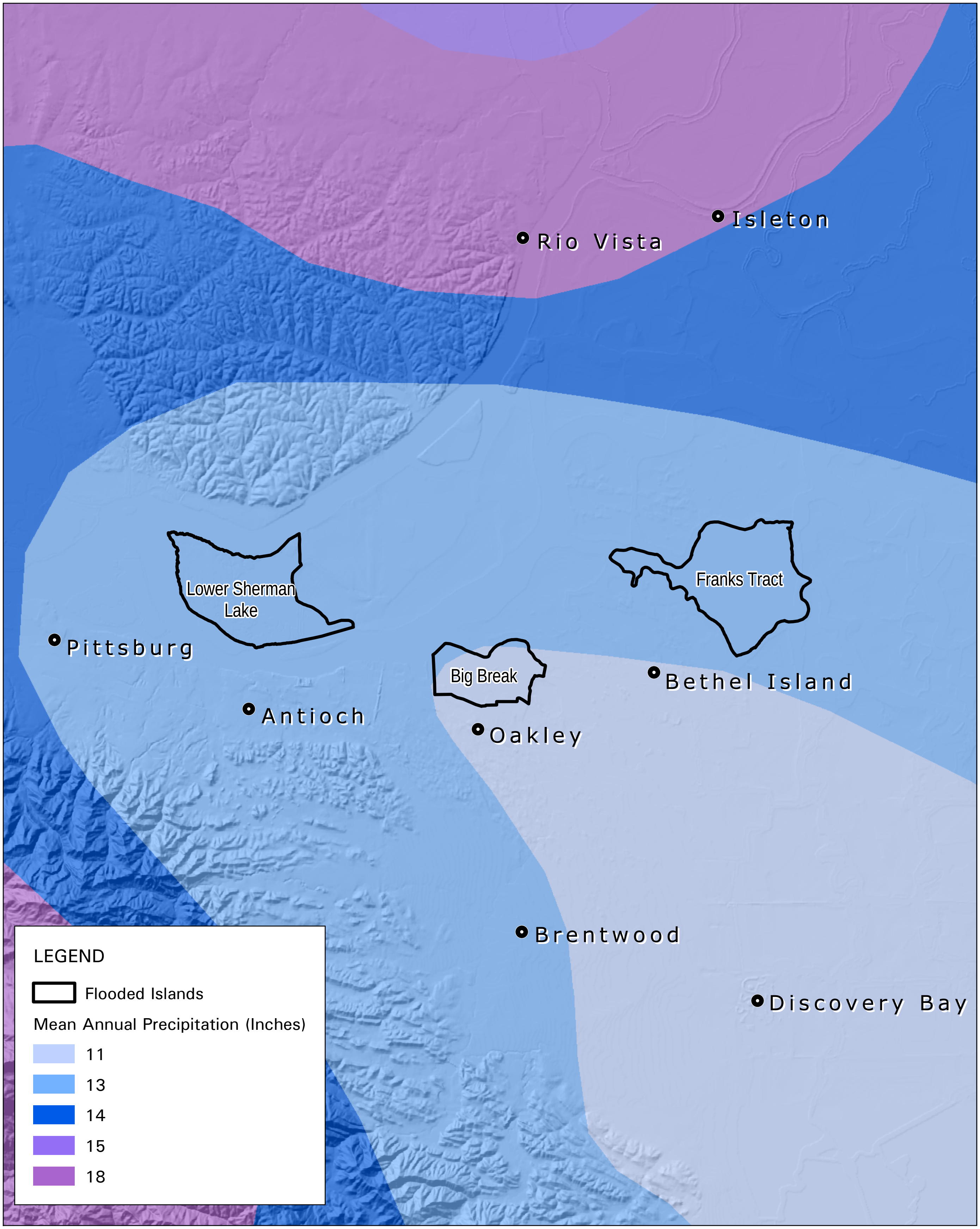
PRECIPITATION

The Bay-Delta area climate is characterized by moderately wet winters and dry summers. Winter rains (December through March) account for about 75% of the average annual rainfall; about 90% of the annual total rainfall is received from November through April; from June 15 to September 22 normal rainfall is typically less than 1/10 inch (see Exhibit 4.3-1).

Annual precipitation amounts show great differences in short distances. Annual totals exceed 40 inches in the mountains and are less than 15 inches in the sheltered or “shadowed” valleys. The frequency of winter rain is more uniform, however, with 10 days per month (December through March) being typical.

During rainy periods, ventilation and vertical mixing are usually high, and consequently pollution levels are low. However, there are frequent winter dry periods lasting more than a week. It is during these dry periods that pollution can develop.

Rainfall amounts in this region are variable, depending upon proximity to terrain. In flat, open areas, such as Fairfield, the annual rainfall is 22 inches. In areas where moderate-sized terrain to the west and south create a rain shadow, as in Martinez, the rainfall is 18.5 inches



Source: Precipitation data gathered from 1900-1960, compiled by USGS 1994

Average Annual Precipitation

EXHIBIT 4.3-1

Flooded Islands Feasibility Study Baseline Report

X 04110052.01 12/04

0 3 6 MILES

NORTH

EDAW

per year. Farther east in Antioch, the annual rainfall is only 13 inches. This low amount is due to the rain shadow effects of Mt Diablo and the surrounding high terrain southwest of Antioch.

4.3.2 Effects of Meteorology on Delta Hydrodynamics

Variations in atmospheric pressure and wind can significantly affect water-surface elevations and flows in the Delta (Oltmann 1998, cited in Burau et al. 1999). An increase in atmospheric pressure results in a lowering of water levels and a "draining" of the Delta; a decrease in atmospheric pressure results in raising water levels and a "filling" of the Delta. Changes in atmospheric pressure are often accompanied by increased wind speeds that also can alter water levels and flows in Delta channels (Burau et al. 1999). Although wind-driven currents are generally weaker than tidal currents, wind-generated waves probably play an important role in sediment resuspension and vertical mixing. Wind-driven waves and flows are especially important in weakly tidal areas such as Franks Tract, where wind-induced circulation may provide the majority of the flushing influence to the "lake." Moreover, from the standpoint of hydrodynamic modeling, wind waves are known to significantly enhance the effective bottom roughness felt by tidal flows.

An example of atmospheric pressure and wind influence on Delta hydrodynamics was documented on December 12, 1995, where a drop in atmospheric pressure and sustained westerly winds resulted in the elimination of the daily low high tide and the associated ebb flow throughout the Delta (Burau et al. 1999).

4.3.3 Global Warming Trends

Anthropogenic warming of the Earth's oceans and atmosphere (National Research Council 2001) and regional warming of the Bay–Delta estuary and its watershed have the potential to greatly affect the current state and function of flooded islands in the Delta. The Central Valley's heavy dependence on reservoirs and snowpack for flood prevention and freshwater storage makes it especially vulnerable to projected hydrologic changes (Knowles and Cayan 2002).

Globally, temperatures have risen an average of nearly 1°C over the past century, and substantial further increases are projected in just a few decades. Conservative estimates of a 2°C increase in California temperatures and a 50 cm rise in sea level are projected in the next 100 years. Such changes would profoundly alter the State's hydrology, affecting the Central Valley watershed, Bay–Delta estuary, and ecological function of Delta islands. From December through March, the Bay–Delta watershed receives an average of 24–32 million acre-feet of fresh water as rain and snow. California depends on artificial storage (reservoirs) and natural storage (snowpack) to make this supply last throughout the year. Snowpack alone delays an average of 40% of the annual supply until after April 1 (Roos 1989, cited in Knowles and Cayan 2002). Highly variable winter and spring runoff is managed as a flood hazard, meaning it is released from reservoirs as quickly as necessary to maintain sufficient flood control storage space. After April, the management goal is reservoir recharge, accumulating the steady stream of snowmelt runoff for distribution later in the year. The combination of natural variability and management actions determines streamflow patterns throughout the watershed and salinity variability in the Bay–Delta estuary (Knowles and Cayan 2002).

Warmer temperatures reduce the volume of the snowpack, contributing to higher flood peaks during the rainy season and reduced warm-season flows after April. Signs of a warming trend include a long-term decrease in the fraction of Bay inflows arriving in the spring (Roos 1991; Aguado et al. 1992; Wahl 1992; Dettinger and Cayan 1995, cited in Knowles and Cayan 2002), earlier onset of spring plant blooms and of the initial spring snowmelt runoff pulse (Peterson et al. 2000; Cayan et al. 2001, cited in Knowles and Cayan 2002), and increased spring salinity in the estuary (Peterson et al. 1995; Knowles 2000, cited in Knowles and Cayan 2002). A sustained warming trend would alter hydrologic conditions throughout the watershed, consequently changing the annual salinity cycle of the estuary. The amount of snowpack reduction would determine the level of impact on the economies and ecosystems that depend on this freshwater supply. Preliminary estimates by Knowles and Cayan (2002) suggest that a projected warming of 1.6ºC by 2060 would cause the loss of over 1/3 of the watershed's total April 1 snowpack, whereas a 2.1ºC warming by 2090 would reduce April snowpack by 50%. These changes would significantly change streamflow patterns throughout the watershed and affect estuarine salinity.

Additional information is needed regarding global warming and its potential effects on restoration efforts and overall management of the Delta. Changes in sea level, precipitation, snowpack, and/or seasonal runoff have the potential to greatly alter the Delta from its current state.

4.4 WATER QUALITY

This section analyzes current water quality conditions in the vicinity of the flooded islands project area and in the greater Sacramento-San Joaquin River drainages and Bay-Delta. Delta waters serve several beneficial uses, each of which has water quality requirements and concerns associated with it. The Delta is a major habitat area for important species of fish and aquatic organisms, as well as a source of water for municipal, agricultural, recreational, and industrial uses. The primary water quality variables of the Delta related to the Flooded Islands Feasibility Study may be generally placed in the primary categories of salinity, organic carbon, and mercury. Each of these categories is discussed in detail below. Additional water quality parameters important to the Bay-Delta are also discussed.

4.4.1 SALINITY

Salinity concentrations in Delta waters affect agricultural, industrial, and municipal water supply beneficial uses, as well as habitat quality for aquatic life in the Delta. This section provides detailed baseline information on salinity issues in the Delta, salinity investigations and monitoring, processes and hydrodynamics, and ecological and water quality considerations. Specific information on Franks Tract, Lower Sherman Lake, and Big Break are provided when available. This baseline report primarily relies on existing information from previously completed studies and documents that address salinity in the Delta. The results of these reports are summarized in this section.

GENERAL DESCRIPTION

The salinity of surface waters is measured by several different parameters. Salinity is a measure of the mass fraction of salts (routinely reported with either of the equivalent terms parts per thousand [ppt] or practical salinity units [PSUs]), whereas TDS is a measure of the concentration of salts (measured in mg/L). Ocean water generally averages about 35 PSUs; brackish estuarine conditions are typically defined by salinities in the range of 5 to 10 PSUs. Because of the high mineral salt content of ocean water, it is more dense than fresh water. In estuaries, tidal action will force highly saline water in along the bottom of the channel and freshwater can “float” on top of the more dense saline water. Electrical conductivity (EC) is a measurement of the ionic activity of water and is relied upon as a simple analytical measurement that is closely correlated with salinity and total dissolved solids (TDS) concentrations in water in most naturally-occurring waters. For Delta waters, 1 EC unit is considered equivalent to a TDS of 0.64 mg/L. Two equivalent units are routinely used to report EC values, micromhos per centimeter (μmhos/cm) and microSiemens per centimeter (μS/cm). EC represents the ability of water to carry an electrical current and varies according to the number and type of ions in the water (the higher the ions and corresponding salts, the higher the EC).

Along with EC and TDS, the specific anions chloride and bromide are of concern in the Delta due to their importance in drinking water quality. Bromide is a specific anion that primarily enters the Delta from ocean water and tidal exchange and is a particular concern because it is a factor in trihalomathane (THM) and bromate formation caused by specific drinking water disinfection processes. Bromide is present in seawater at a relatively constant fraction of 0.003 to 0.004 on a weight basis. Chloride is a specific ion subject to regulation for its potential to adversely impair aesthetic taste and odor in drinking water supplies, and agricultural water uses. The concentration of bromide and chloride are not necessarily perfectly correlated (i.e., linear relationship) to EC or TDS concentrations. For example, water sources that have been influenced by seawater intrusion to a greater degree may have a relatively greater proportion of bromide content than water influenced by the Sacramento River having very low bromide content.

State and Federal Water Supply Operations and Delta Salinity Controls

The adverse effects of salinity in the Delta have been studied since 1916 starting with the State Water Commission that found saline water conditions were affected by dry summer month and high tide conditions. Agricultural water diversions and subsequent agricultural drainage in the valley added to salinity problems. These problems were also influenced by attempts to allow faster drainage of winter outflows by clearing river channels of hydraulic mining sediments and altering them for flood control projects. These attempts instead allowed saline water to further intrude upstream.

In 1920 a critically dry year combined with increased upstream agricultural diversions resulted in salinity intrusion up the Delta. In response, a committee was formed, the Riverlands Association, to begin an extensive salinity investigation, coordinated with the State, at 28 Delta stations. The conditions precipitated a lawsuit to prevent upstream users to take any water that would reduce Sacramento River flows to less than 3,500 cfs past Sacramento. In the end, the lawsuit was overruled by the State Supreme Court and litigation continued. In 1921, salinity investigations were assigned to the Division of Water Rights, now the State Water Resources Control Board (SWRCB). Presently, the SWRCB is a regulatory agency that has authority over water quality standards in the Delta and water rights permits for the State Water Project (SWP) and Central Valley Project (CVP) to protect the beneficial uses of the Delta.

1995 Delta Water Quality Control Plan

The State Water Resources Control Board adopted the Bay-Delta Water Quality Control Plan (WQCP) in 1995 that established the current comprehensive set of specific numerical water quality objectives for the Delta (SWRCB 1995). The 1995 WQCP contains the specific EC and chloride objectives at a variety of locations with variable limits that depend on the water year type. The numerical limits in the 1995 WQCP are designed to protect three broad categories of beneficial uses: fish and wildlife, agriculture, and municipal and industrial water supply. The 1995 WQCP also established requirements for Delta outflow, export pumping rates, and operating protocols for the Delta Cross Channel (DCC) and Suisun Marsh salinity control gates. The 1995 WQCP limits are key factors in the water supply operational decisions made for the SWP and CVP reservoirs, and pumping plants in the southern Delta. In general, a focused set of objectives contained in the 1995 WQCP are the controlling, or most restrictive, conditions that govern DWR and USBR operating decisions at any one time. Real-time water quality conditions are monitored closely by DWR and USBR and water supply operators make decisions based on the monitoring data to maintain Delta water quality standards.

The WQCP objectives for municipal and industrial water supply beneficial use protection includes a maximum salinity of 250 mg/L in chloride concentration limit for the major Delta water supply diversion locations (i.e., Banks, Tracy, Rock Slough, Old River Contra Costa Water District [CCWD] water supply intake for Los Vaqueros Reservoir, and North Bay Aqueduct). In addition, the WQCP includes a schedule of days that chloride must be less than 150 mg/L in Rock Slough that serves CCWD's pumping plant. The 150 mg/L chloride objective for Rock Slough is applicable for between 155 and 240 days every year, depending on the water year type.

To protect agricultural beneficial uses, the 1995 WQCP includes eight compliance locations for in-Delta agricultural use protection and two for export uses at Banks and Tracy pumping plants. EC objectives vary considerably with the particular location in the Delta, seasonally, and with hydrological year type, ranging between 450 μS/cm in the spring in wet years at Emmaton, Jersey Point, and interior Delta, to 2,780 μS/cm at Emmaton in critically dry years. In addition, EC objectives in south Delta are effective year-round while those at Emmaton, Jersey Point, and interior Delta apply only between April and August.

SWP and CVP Water Rights Operating Agreements

SWP and CVP operations are adjusted to meet Delta water quality standards by increasing releases of stored water in project reservoirs to reduce repel the encroachment of tidal salinity and provide freshwater into the southern Delta channels, or altering specific facility operations such as export pumping or gate positions. Water rights Decision-1641 and Order WR 2001-05 contain the current water right requirements for the U.S. Bureau of Reclamation (USBR) and the Department of Water Resources (DWR) to implement the WQCP flow and water quality objectives. D-1641 includes both long-term and temporary requirements. Order WR 2001-05 requires partial implementation that will remain in effect up to 35 years. In D-1641 and in Order WR 2001-05, the SWRCB assigned responsibilities, for specified periods, to water users (including the USBR and DWR in D-1641, and DWR in Order WR 2001-05) in the watersheds of the San Joaquin River upstream of Vernalis, the Mokelumne River, Putah Creek, Cache Creek, within the boundaries of the North Delta Water Agency, and within the Bear River watershed. These responsibilities require that the water users in these watersheds will contribute specified amounts of water to protect water quality, and that DWR and/or USBR will ensure that the objectives are met in the Delta (California Bay-Delta Authority 2003).

Regulatory Salinity Monitoring Programs

DWR and USBR operate extensive networks of water quality monitoring stations in the Delta to track and predict salinity conditions in the Delta and implement advance operational decisions to ensure compliance with D-1641 and associated 1995 WQCP terms and conditions.

Some of these stations have continuous EC monitors; others are sampled routinely for chemical and biological measurements.

EC monitors at Jersey Point and Emmaton are especially important for managing the linkage between upstream reservoir releases and export pumping limits needed to satisfy Delta water quality objectives. The CVP and SWP operations staffs have access to telemetered data from these and several other EC monitors. The DWR Delta Operations Water Quality Section prepares and distributes a daily report of data on flows and EC to assist in decision making on Delta water project operations.

General Delta Salinity Conditions

Salinity concentrations within the Delta are primarily a function of the location of high-salt content ocean water with daily tidal action, freshwater inflow to the Delta, and the hydrodynamic processes in the Delta channels that govern channel flow conditions and mixing of water sources with variable salt content. During winter and early spring, freshwater inflows to the Delta are usually above the minimum required to control salinity. However, at least for a few months in summer and fall of most years when freshwater inflows to the Delta have declined, Delta salinity conditions must be carefully monitored and controlled. Broad-scale salinity control actions are taken in the Delta because its channels are at or below sea level and unless repelled by continuous seaward flow of fresh water, seawater can advance into the western Delta and adversely affect compliance with water quality objectives and beneficial uses provided by Delta water resources.

Additional influential factors of problematic Delta salinity conditions include the San Joaquin River inflow, in-Delta agricultural drainage, other miscellaneous inputs (e.g., municipal wastewater, urban runoff, connate groundwater), and evapotranspiration. San Joaquin River inflows are particularly influential to salinity conditions in the southern Delta after winter rainfall and runoff from the Sierra Mountains have ceased and the river is influenced primarily by drainage return flows from the San Joaquin Valley floor. High concentrations of salts are carried by the San Joaquin River into the Delta and much of the salt load represents recirculation and increased salt content of water diverted to the San Joaquin valley via the CVP Delta Mendota Canal. Salinity problems in the western Delta result primarily from the incursion of saline water from the San Francisco Bay when freshwater inflow from the Delta to the bay is low. However, it should be noted that compared to historical conditions, Delta salinity during low-flow periods is much lower since the construction of the major dams on Delta tributaries in the Sierra Mountains and foothills, which allow storage and fresh-water releases during the summer to repel tidal seawater intrusion.

Table 4.4-1 shows a comparison of the average concentrations measured over several years for key salinity indicator parameters at selected locations in the Delta. The data illustrate that overall TDS and EC concentrations are highest in the south Delta channels which are affected by the San Joaquin River input of dissolved mineral salts. Concentrations of chloride and bromide are elevated at Rock Slough in the western Delta due to the strong influence of the ionic composition of seawater influx. For the Sacramento River in the north Delta at Greene's

Landing, which is not substantially affected by sea-water intrusion due to the large flow of the Sacramento River, concentrations of all salinity parameters are uniformly much lower than other Delta locations. Regulatory EC objectives are routinely exceeded in the San Joaquin River at Vernalis, whereas desired standards are typically met at the other monitoring locations in the Delta. The lowest routine concentrations of chloride typically occur in spring and early summer (March through July) and periods of elevated chloride concentrations do not exceed the secondary MCL for chloride of 250 mg/L at any location.

Table 4.4-1
Comparison of Average Ion Concentrations at Delta locations

Location	TDS (mg/L)	EC (μS/cm)	Bromide (mg/L)	Chloride (mg/L)
Sacramento River at Greene's Landing	100	160	0.018	6.8
North Bay Aqueduct	192	332	0.015	26
SWP Clifton Court Forebay	286	476	0.269	77
CVP Banks Pumping Plant	258	482	0.269	81
CCWD intake at Rock Slough	305	553	0.455	109
San Joaquin River at Vernalis	459	749	0.313	102

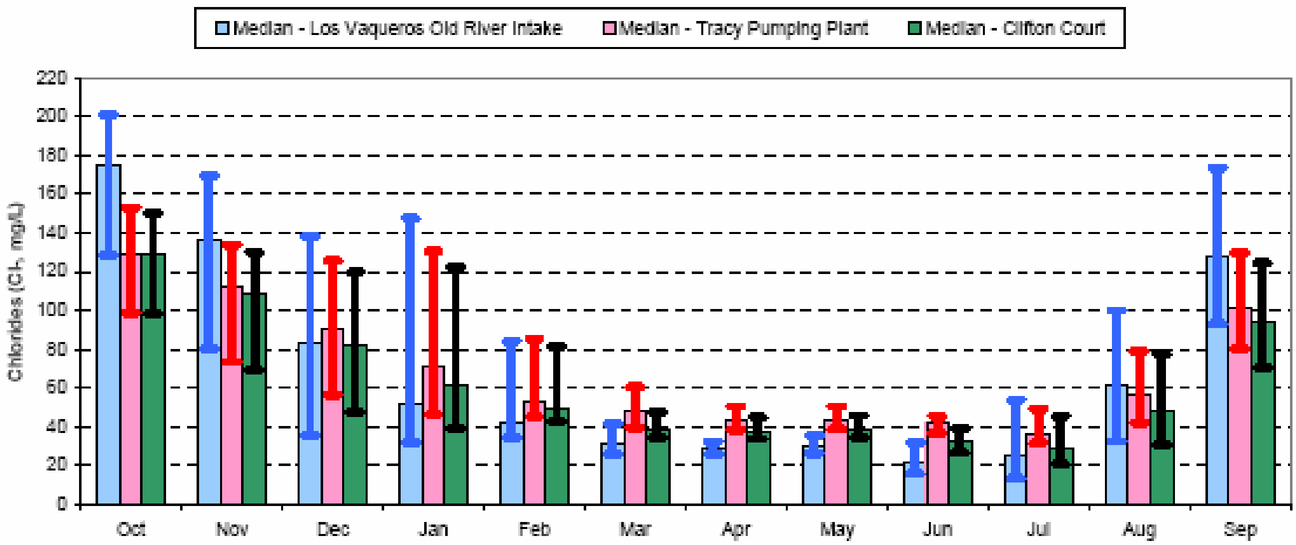
Source: Adapted from California Bay-Delta Authority 2003 – summary data collected generally monthly for the period of 1990 to 1998.

Delta salinity conditions exhibit pronounced seasonal trends in response to freshwater inflows during the winter and low-flow summer and fall conditions when freshwater inflows have declined. Exhibit 4.4-1 shows the seasonal median chloride concentrations based on long-term monitoring data at the three principal water supply diversion locations in the southern Delta. The range bars indicate the statistical range of concentrations from the 25th percentile value to the 75th percentile value. The lowest routine concentrations of chloride typically occur in spring and early summer (March through July) and periods of elevated chloride concentrations do not exceed the secondary MCL for chloride of 250 mg/L at any location.

Elevated salinity conditions within Delta channels occur mainly during years of below-normal runoff (California Bay-Delta Authority 2003). As demonstrated in Exhibit 4.4-2, EC and bromide concentrations are greater during critical (dry) water years than wet/above-normal water years. Additionally, EC levels generally are higher during low Delta outflows as compared to medium or high Delta outflows.

Hydrodynamic Processes and Salinity Effects

Delta hydrodynamic processes consist of the physical effects of freshwater inflows, tidal action, and movement of water in Delta channels. Because tidal inflows are approximately equivalent to tidal outflows during each daily tidal cycle, tributary inflows and export pumping are the principal variables that define the range of hydrodynamic conditions in the Delta. The Sacramento River contributes about 77 percent of the freshwater flows, the San Joaquin River contributes roughly 15 percent, and east side streams provide the remainder. On average, 10



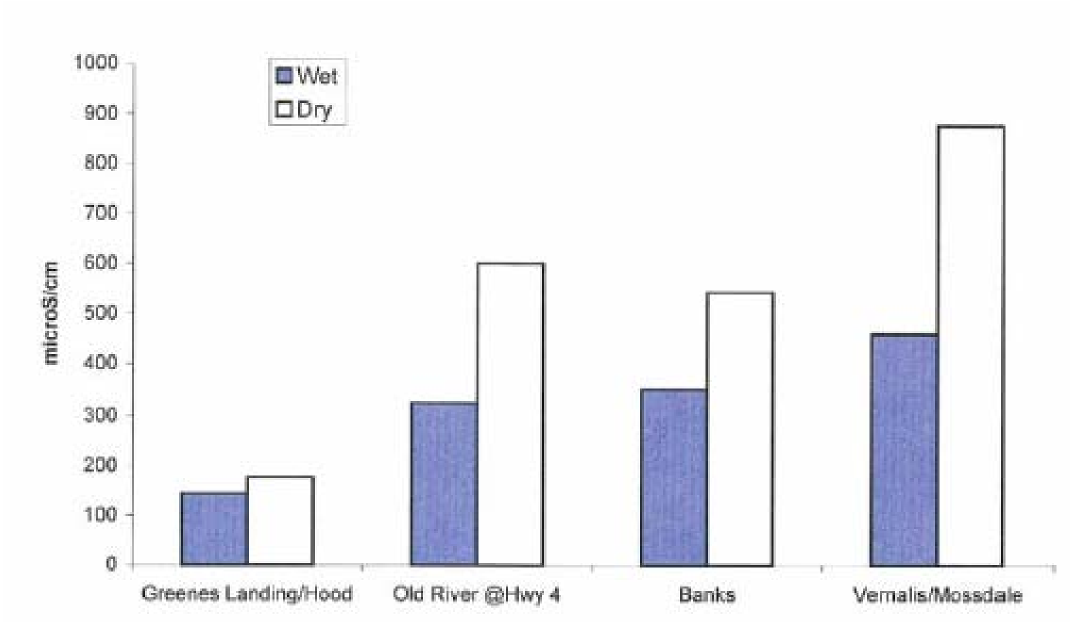
Note: Plots reflect data collected generally monthly for the period of 1990 to 1998

Source: California Bay-Delta Authority 2003

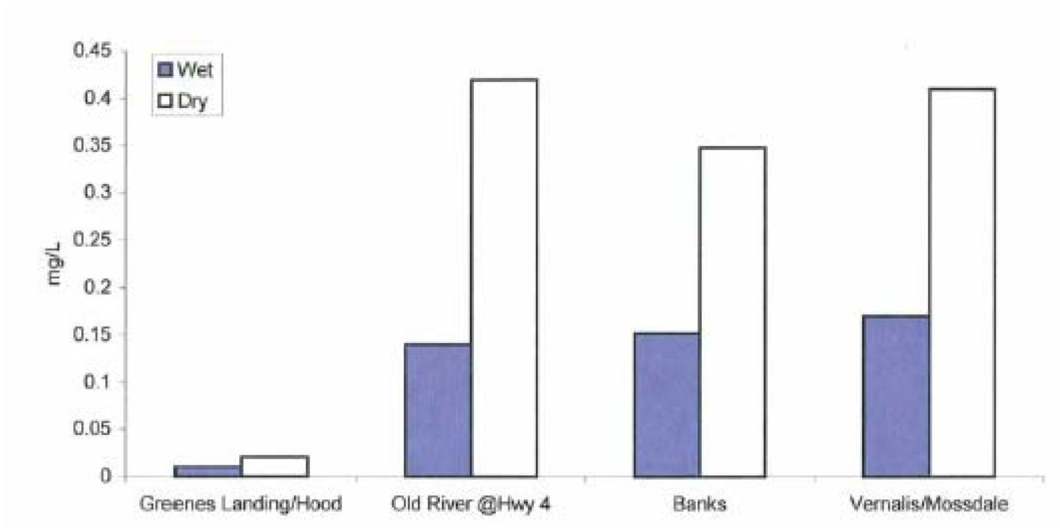
Long-term monthly median concentrations of chloride at Banks Pumping Plant (Clifton Court), Tracy Pumping Plant, and the Los Vaqueros Old River Intake

EXHIBIT 4.4-1

Average Electrical Conductivity Concentration



Average Bromide Concentration



Note: Plots represent data collected generally monthly for the period of 1990 to 1998. Wet years reflect data from wet and above normal water year types; dry years reflect data from dry and critical water year types.

Source: Adapted from California Bay-Delta Authority 2003

Average Chloride and Bromide Concentrations for Wet and Dry Year Types at Locations in the Delta

EXHIBIT 4.4-2

EDAW

percent of the Delta inflow is withdrawn for local use, 30 percent is withdrawn for export by the CVP and SWP, 20 percent is required for salinity control, and the remaining 40 percent provides outflow to the San Francisco Bay ecosystem in excess of minimum identified requirements (CALFED 2000a).

Tidal changes strongly influence Delta channel conditions twice daily by changing water surface elevation, current velocity, and flow direction. The effects of ocean tides on Delta hydrodynamic conditions are modified by freshwater inflow and diversion rates. The extent of tidal influence depends on the tidal prism volume relative to river discharge at a particular Delta location. Delta channels are generally less than 30 feet deep unless dredged and vary in width from less than 100 feet to over 1 mile. Some channels are edged with aquatic and riparian vegetation, but most are bordered by steep banks of mud or riprapped levees (DeHaven and Weinrich 1988). Vegetation is generally removed from channel margins to improve flow and facilitate levee maintenance. Cross-sectional areas and lengths of channels determine divisions of flow when tidal flows can move into more than one channel. Volume determines the change in stage corresponding to a tidal inflow or outflow at a channel location. Tidal flushing at a location can be estimated as the tidal flow divided by the volume.

Water levels, or stage, vary greatly during each tidal cycle, from less than 1 foot on the San Joaquin River near Interstate 5 to more than 5 feet near Pittsburg. Tidal effects are more intense in the western Delta, but even in the central Delta, water surface elevation can vary by more than 5 feet during one tidal cycle. Over the long-term period, the highest minimum stage in Middle River typically occurs in February and is about 0.1 foot below mean sea level (msl). However, during dry and critical years, the highest minimum stage typically occurs in April and is considerably lower than wet year types as about 0.6 foot below msl. The long-term seasonally lowest minimum stages typically occur in August-September at about 0.8 foot below msl. Tidally influenced channel velocities throughout the Delta during the non-winter stormflow seasons can range from -2 feet per second (fps) to more than +3 fps (with negative figures indicating upstream flood tide flow). Tidal effects are not uniform from day to day. There is a distinct pattern of tidal variations within a lunar month. The tidal range is greatest during "spring" tides and smallest during "neap" tides. The mean tide elevation may also change slightly during the spring-neap lunar cycle. This adds a net "tidal outflow" component to daily Delta outflow estimates.

Delta export pumping occurs at several locations: the CVP Tracy Pumping Plant and the SWP Banks Pumping Plant in the southern Delta account for the large majority of Delta exports (i.e., about 5 million acre-feet annually). Comparably much smaller volumes of water are diverted by CCWD at its Rock Slough intake and the Old River intake facility in the southern Delta, and the North Bay Aqueduct pumps at Barker Slough. Agricultural diversions occur across the Delta via hundreds of small diversion pumps. The water diversions affect the distribution of flow in delta channels and reduce the freshwater flow that would enter San Francisco Bay.

Flow that enters the Delta via the Sacramento River flows by various routes to the export pumps in the southern Delta. Some of this flow is drawn to the SWP and CVP pumps through interior Delta channels, facilitated by the CVP's DCC facility. Water that does not travel into the Central Delta continues towards the San Francisco Bay. Under certain conditions, additional Sacramento River waters flow into the Central and South Delta. The Sacramento River waters flow through Threemile Slough, around the western end of Sherman Island and up the San Joaquin River towards the export pumps. When freshwater outflow is relatively low, water with a higher salt concentration enters the Central and South Delta as tidal inflow from the San Francisco Bay. Diversions and export pumping can also increase channel velocities. When SWP and CVP exports cause flow from the Sacramento River to move toward the pumps, then "reverse flow" occurs in the lower San Joaquin River. Prolonged reverse flow has the potential to adversely affect water quality in the Delta and at the export pumps by increasing salinity.

The DCC also has a great influence on the flow of water in Delta channels. The DCC allows freshwater flow to pass from the higher elevation flows of the Sacramento River into Georgiana Slough and then into the Mokelumne River. Flows through the DCC are referred to as cross-Delta flows and allow for the conveyance of Sacramento River water directly from the north Delta to the central and south Delta, and thereby generally lower salinity conditions in the central and south Delta. Higher cross-Delta flows generally allow for more positive flow in the lower San Joaquin River and reduced likelihood of reverse flows. However, operation of the DCC is regulated by the 1995 WQCP and the CVPIA to provide fishery protections.

The flow of water in Old River at Bacon Island is often used as an indicator of hydraulic conditions in the south Delta. As reported in the CALFED Program EIR (CALFED 2000a), average monthly flow is generally negative over the long-term period because flows are generally drawn south by the influence of the SWP and CVP pumps in the south Delta. Flows average about -3,500 cfs in an upstream direction during August, and range from -1,100 to -100 cfs in April. Average monthly flow is always negative in dry and critical years. The net flow in the San Joaquin River at Antioch is a measure of tidal interactions between the west Delta and the interior Delta. Average monthly flow is generally positive over the long-term period, ranging from about -1,200 cfs in October to a range of 10,800 to 12,900 cfs in February. Net channel flows are reduced considerably in dry and critical years with average monthly flow ranging from -2,400 to -2,100 cfs in December, and from 2,200 to 3,600 cfs in April.

QWEST is a measure of net flow in the lower San Joaquin River and other smaller Delta channels. In this evaluation, QWEST is estimated as a function of cross-Delta flow, San Joaquin River and eastside tributary inflow to the Delta, in-Delta diversions, and exports from the Delta. Over the long-term period under existing conditions, the greatest average monthly positive QWEST flow typically occurs in February and is about 7,300 cfs. The greatest average monthly negative (reverse) QWEST flow typically occurs in October and is about (-3,600) cfs. Reverse flow is due to a combination of tidal effects, reduced reservoir releases, and Delta exports. During dry and critical years under existing conditions, the greatest average monthly positive QWEST flow typically occurs in April and is about 1,300 cfs. The greatest average monthly reverse flow typically occurs in December and is about (-5,000) cfs.

Localized salinity changes and subsequent problems may occur when local diversions in shallow, low-capacity channels exceed flows through the channel. When this happens, water stops flowing out of the channel or begins to flow into the channel from both ends. At the same time, drainage return flows continue to be discharged to the channels. These discharges do not move downstream and out of the area but instead become trapped in "null zones" of zero net flow. The lack of circulation prevents better quality water otherwise available from the main channels from freshening the increasingly saline water in the shallow channel, even in wet years. Null zones in the Delta exist predominantly in three areas: in the San Joaquin River between the head of Old River and the City of Stockton, in Old River between Sugar Cut and the CVP intake, and in Middle River between Old River and Victoria Canal (SWRCB 1999). In the south Delta, lowering water levels associated with CVP and SWP pumping are of concern for local agricultural diverters.

Delta Modeling and Assessment Tools

A number of numerical mathematical models have been developed to estimate hydrodynamic and water quality conditions in the Delta under different hydrological conditions. These models attempt to simulate the complex physical processes and factors governing the hydrodynamic conditions (e.g., inter-channel flow conditions, river input flows, tidal action) and transport of water quality constituents (e.g., salt, organic carbon, sediment) to different level of details. Comparisons of model results to field data typically show varying degree of agreement over different historical periods. The uncertainties of the physical processes, coupled with the approximations used in the models to describe the complex physical processes affecting salinity transport in the Delta, lead to a considerable margin of error in modeling results.

The DWR-maintained numerical model, DSM2, is a deterministic 1-dimensional hydrodynamic and salt transport model. DSM2 is routinely used in conjunction with DWR's CALSIM II model that simulates SWP and CVP operations and hydrologic variables on an average monthly basis. CALSIMII and DSM2 are the current models typically used for general applications to water management analyses and planning purposes in the Delta. Flow patterns, velocities, water levels and transport processes within the Delta can be evaluated reflecting the differences in input hydrology and Delta configurations. DSM2 was first developed to use "19-year mean tide" as tidal forcing in planning simulations. Salinity at the downstream boundary was generated using an artificial neural network (ANN) approach to estimate mean daily salinity at four compliance locations (Sacramento River at Collinsville and Emmaton, San Joaquin River at Jersey Point, and Rock Slough) from a time series of Delta outflow. The ANN approach is an empirical approach to provide greater accuracy to salinity modeling of interior Delta channels that relies on daily Delta inflows in the Sacramento River and the San Joaquin River, total Delta exports, and Delta Cross Channel gate operations. A set of coefficients are used to simulate hourly variations from this mean salinity. DSM2 has been updated to use adjusted astronomical tide that accounts for spring-neap variations. The DSM2 simulation output captures the effects of an average tide on Delta flows and water quality and also tracks the pattern of water migration from preselected points throughout the Delta (often referred to as "particle" or "mass fate" tracking). Particle tracking can be used to distinguish the hydrodynamic mass transport of particles in the Delta under different hydrologic conditions. Mass tracking provides insight into relationships between Delta circulation patterns and the fate, movement, and residence time of particles such as fish eggs and larvae. DSM2 can be modified to represent different Delta geometries and facilities.

A number of multi-dimensional models have been developed to simulate hydrodynamic and water quality in all or portion of the Delta in the past ten years. However, multi-dimensional models are designed to simulate more complex geometric and time series phenomenon than DSM2 and inherently require greater complexity and effort to develop. Their applications have primarily been limited to studies aimed at improving understanding of physical processes at various Delta locations. The use of the available model versions for general applications to water management analyses and planning of Delta projects is not currently performed. Some examples of the available multi-dimensional models that have been used include:

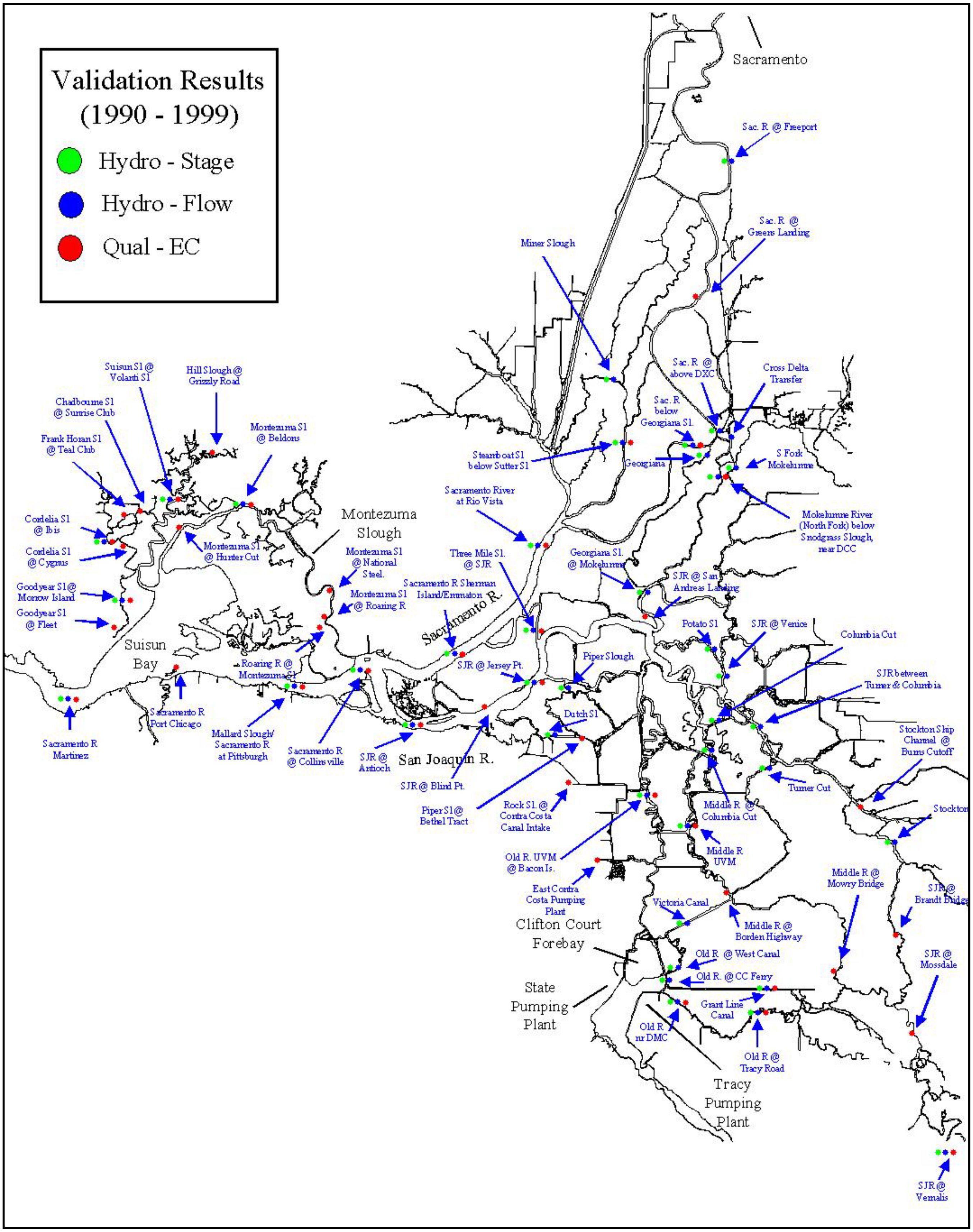
Trim-3D/UnTrim Model: applied to studies of the San Francisco Bay and the Delta by the U.S. Geological Survey and Stanford University. This model has been used for initial simulations of Franks Tract.

RMA-2/RMA-10: Resource Management Associates (RMA) has developed multi-multidimensional models for estuarine hydrodynamics and salt transport that have been used for a variety of Delta applications and a 2-dimensional model is currently being updated for the Flooded Islands project.

Semi-Implicit-3D Model (SI-3D): developed at U.S. Geological Survey to model the San Francisco Bay and portions of the Delta (e.g., geometry at the DCC and operations effects)

Project Area Hydrodynamic and Salinity Conditions

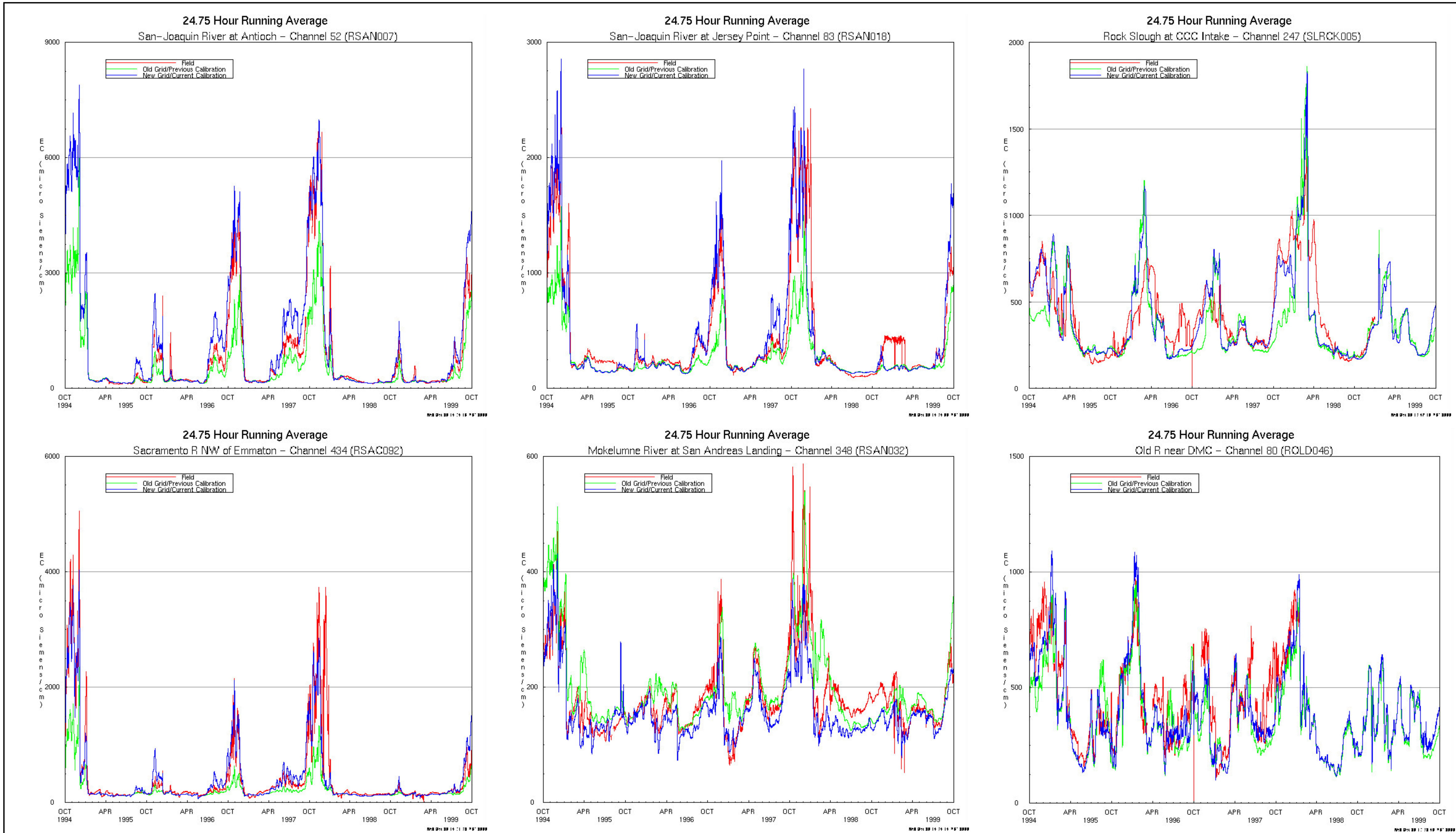
Delta monitoring stations and DMS2 model output illustrate the wide range of salinity conditions and differences at various locations within the project area. Exhibit 4.4-3 shows key stations of DSM2 modeling output and Exhibit 4.4-4 shows simulated and measured EC concentrations for a 5-year period (1994-1999) at several key stations within the project area. The simulated and measured data demonstrate the large variability in EC conditions in the San Joaquin River at Antioch (located south of the west Sherman Island area) that can range from low-EC reflective of freshwater flows during winter Delta inflow periods, up to 8,500 μS/cm during dry periods. The higher inflows in the Sacramento River result in EC values at Emmaton that is lower than on the San Joaquin River ranging up to about 4,000 μS/cm during dry periods. The EC conditions along the San Joaquin River at Jersey Point are very similar to the conditions at Emmaton. The plot showing EC in the Mokelumne River at San Andreas Landing is indicative of freshwater flows across the Delta derived from DCC operations. The



Source: Interagency Ecological Program 2004

DSM2 Model Output Locations

EXHIBIT 4.4-3



Source: Interagency Ecological Program 2004

DSM2-Simulated and Measured EC Conditions at Study Area Locations for 1994-1999

EXHIBIT 4.4-4

plots for Rock Slough and Old River at the DMC show the considerably lower values observed in the southern Delta.

Exhibit 4.4-5 shows DSM2-simulated and measured 24-hour average EC values for similar locations focused within the Flooded Islands project area during October 1992 to reflect typical low-flow seasonal conditions in the fall. The plot for the San Joaquin River at Antioch demonstrates the large daily variation primarily influenced by the salt content of the tidal mixing. The San Joaquin River at Blind Point station is located west of Big Break and demonstrates slightly reduced EC conditions relative to the conditions further west at Antioch. The Jersey Point data show considerable reduction in EC concentrations relative to the Blind Point location. The plot for Piper Slough adjacent to Bethel Tract represents an interior channel location affected by the mixture of both central Delta salinity conditions and high-salt influences of Big Break and Jersey Point. The lower EC conditions in Piper Slough indicate relative isolation of this channel from the San Joaquin River influence. The plots for Rock Slough and Old River near the DMC, similar to Exhibit 4.4-4, indicate the reduced EC levels in the southern Delta. The hourly plots of Exhibit 4.5-4 also demonstrate the time-lag that occurs in the Delta between changes observed in salinity conditions of the central and western Delta locations and the south Delta locations when SWP and CVP pumps are operating. As observed in the plots of Rock Slough and Old River at the DMC, the increase in salinity in the western Delta location that begins about October 24 is not observed in Rock Slough until about a day later and the relative magnitude of change is smaller in the daily fluctuations.

Ecological Considerations

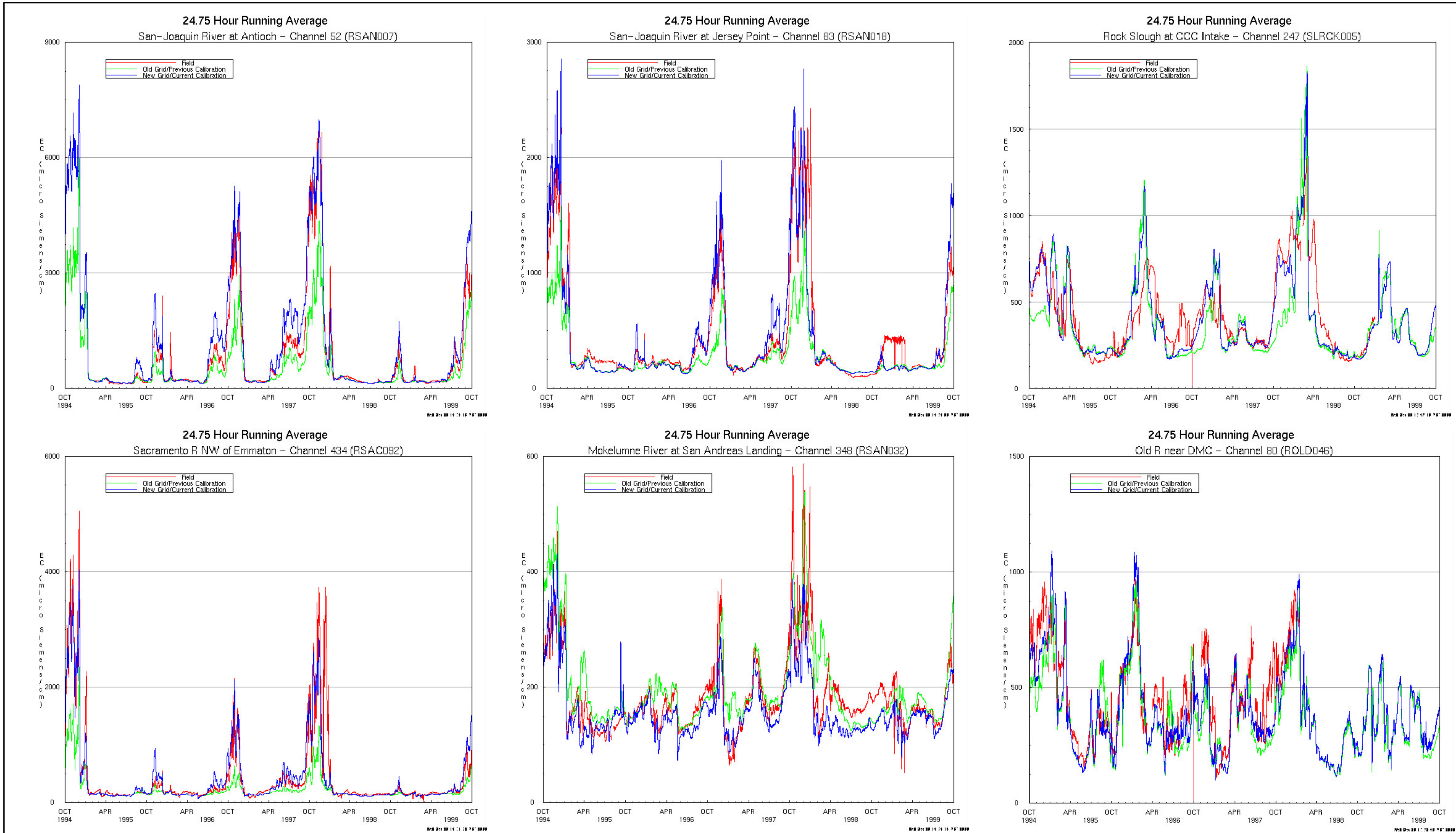
The 1995 WQCP includes a number of water quality objectives for fish and wildlife beneficial uses. Salinity standards and flow control objectives addressed in the WQCP cover a large geographic area in the Delta, extending from the western edge of Suisun Marsh, to the Sacramento River at Collinsville, and to the San Joaquin River at Prisoners Point. Each objective varies seasonally and in some cases with the hydrological year type. In addition, the WQCP contains dissolved oxygen standards for the San Joaquin River near Stockton.

A major regulatory control included in the 1995 WQCP is the constraint on the location of the “entrapment zone” within the Delta. The estuarine “entrapment zone”, or null zone, is an important aquatic habitat region associated with high levels of biological productivity. The upstream boundary of the entrapment zone is recognized by the variable “X2” which represents the 2 ppt salinity isohaline condition as measured 1 meter off the bottom of the Sacramento River channel. The location of the entrapment zone is determined by the magnitude and duration of Delta outflow. D-1641 terms and conditions create specific SWP-CVP operating rules for influencing the X2 location. The zone moves seaward rapidly in response to increased freshwater discharge. With decreased discharge, the zone gradually moves upstream into the Delta. The entrapment zone is the zone of transition between gravitational circulation and riverlike net seaward flow. Gravitational circulation is the flow pattern caused by salinity (density) gradients in which mean bottom flow is landward and mean surface flow is seaward. Gravitationally induced currents are usually small fractions of tidal currents and are weakened by enhanced vertical mixing associated with increased tidal flows (Smith 1987). In general, gravitational currents are highest in the region of the steepest salinity gradient (i.e., greatest change in salinity with distance). High outflows move the salinity gradient seaward, decreasing the influence of gravitational circulation on the Delta.

Water Quality Considerations

A high quality source water for drinking water uses has been advocated by many, in particular the EPA, California Urban Water Agencies (CUWA), and CBDA. CUWA recommends more restrictive salinity standards than the 1995 WCCP for municipal supplies that are exported from the Delta. Even at salinity considerably below the SWRCB D-1641 standard (at 250 mg/L chloride concentration) and the federal secondary MCL (500 mg/L TDS) for municipal and industrial uses, it is expected that increased salinity in Delta source water could adversely affect conjunctive use and groundwater management, water reclamation and reuse, and industrial uses due to increased corrosion. Based in part on the Salinity Management Plan of the Metropolitan Water District of Southern California, CUWA recommended that the CALFED program adopt a target of 150 mg/L TDS for Delta exports destined for southern California, and 220 mg/L TDS for exports to the Bay Area users (CUWA 1998). CUWA also recommended the targets of 50 μg/L bromide and 3.0 mg/L total organic carbon for southern and central Delta drinking water intakes. The SWP's stated salinity goal is 220 mg/L TDS as a long-term average and 440 mg/L TDS as a maximum monthly average. CCWD has an established delivered water quality goal of 65 mg/L chloride concentration. The 100,000 acre-feet Los Vaqueros Reservoir and a Delta intake on Old River at Byron Tract were constructed to store higher quality water from the Delta for blending with lower quality water diverted from Rock Slough during times of low Delta water quality.

The Drinking Water Subcommittee of the Bay-Delta Public Advisory Committee for the CBDA Drinking Water Quality program have adopted targets for achieving drinking water quality in a cost-effective way to implement a multiple barriers approach to protect public health (California Bay-Delta Authority 2004a). The CBDA Drinking Water Quality program adopted targets are for Delta water supplies used for municipal water supply to either: (a) average concentrations at Clifton Court Forebay and other southern and central Delta drinking water intakes of 50 μg/L bromide and 3.0 mg/L total organic carbon, or (b) an equivalent level of public health protection using a cost-effective combination of alternative source waters, source control, and treatment technologies. These objectives were based on estimates of the source water needs to meet increasingly stringent federal drinking water quality standards. Stage 1 of the Disinfectant / Disinfection Byproducts (D/DBP) Rule of the federal Safe Drinking Water Act contains a 10μg /L primary drinking water MCL for bromate, a suspected carcinogen, in treated municipal water supplies. A 50 μg /L bromide concentration in Delta water corresponds to a chloride concentration of around 20 mg/L, which is well below the salinity at Delta intakes at most times. CBDA's equivalent level of public health protection (ELPHP) approach accounts for improvements in treatment technology, increased understanding of the chronic and acute public health risks associated with microbials and disinfection by-products, and development of state and federal drinking water regulations.



Source: Interagency Ecological Program 2004

DSM2-Simulated and Measured EC Conditions at Study Area Locations for 1994-1999

EXHIBIT 4.4-4

Many analyses have shown that such a high water quality of source water recommended in the CALFED Drinking Water Program can not be achieved in Delta water. Consequently, storage for blending is a critical element towards meeting this goal. A number of key actions in the CALFED program, such as the Bay Area Water Supply Reliability and Water Quality Program (formerly the Bay-Area Blending/Exchange Program), expanded Los Vaqueros Project, and Friant Exchange Program, are still in development and are anticipated to be instrumental for improving source water quality towards the CALFED goal for Delta water users.

Future Projects, Water Supply Operations, and Potential Delta Salinity Effects

Several major projects for the California Bay-Delta Authority (i.e., CALFED program), DWR, and USBR are ongoing under the auspices of the CBDA-authorized actions and actions mandated by the Central Valley Project Improvement Act (CVPIA) that will alter Delta water quality patterns. Key projects and programs recently undergoing review or currently underway include the Operations Coordination Action Plan (OCAP), South Delta Improvements Program (SDIP), and Environmental Water Account (EWA).

The Environmental Water Account (EWA) program (California Bay-Delta Authority 2003) was developed as a key element of the CALFED Program Water Management Strategy to manage flows to the Delta at certain times of the year for fish and wildlife enhancement. Under the EWA, Delta exports would generally be reduced in the winter and spring months. The reduced flows available for Delta water supply operations would be later recovered by increased exports when capacity exists and sufficient water is available. The result would be increased CVP and/or SWP pumping during the July through September period. The EWA has set a goal of acquiring at least 190,000 acre-feet of water each year through purchases. EWA expects to obtain another 190,000 acre-feet of water on average each year through additional pumping at times safe for fish. With the EWA, operational decisions are designed to be made in response to real-time movements of fish to provide more effective and efficient use of environmental water releases and curtailed Delta exports. EWA operations have the potential to affect Delta water quality in years when CVP/SWP pumping is reduced below levels that would have been pumped in the absence of EWA actions, and in years when the Delta exports are increased during the summer months to gain back foregone supplies resulting from the earlier EWA actions.

Several programs are ongoing that will alter SWP and CVP Delta export operations at the Banks and Tracy pumping plants. The SDIP program, currently in the development and environmental review stage, is a program identified in the CALFED program. The SDIP would include several actions in the southern Delta including increasing the allowable export pumping rate from the SWP Banks Pumping Plant from the current limit during March 15 to December 15 to 8,600 cfs and modify existing pumping criteria from December 15 to March 15 to allow greater use of SWP export capacity. The project would also include construction of a permanent, operable fish barrier at the head of Old River, and up to three operable barriers in south Delta channels to optimize tidal circulation and water level controls to improve local agricultural water supply diversion conditions. Also, channel dredging and extension of some agricultural diversion pipes would be implemented. An ultimate goal identified in the CALFED Program was to construct physical improvements and develop approved management systems to allow increased pumping capacity at Banks to the installed capacity of 10,300 cfs. The USBR's Operations Criteria and Plan (OCAP) is a water management strategy to optimize the SWP and CVP operating rules under D-1641 and more effectively utilize south Delta pumping plant operations jointly for efficient use of available pumping capacity when sufficient water is available for export (USBR 2003). Modeling for SDIP is ongoing and the effects of the project on Delta salinity conditions are expected to be incremental to existing conditions because the additional pumping capacity would generally be utilized primarily when there are surplus freshwater inflows present in the Delta.

Under the CALFED Program, two conveyance facility improvement studies identified include: (1) evaluating revised DCC operations protocols to address fishery and water quality concerns; and (2) evaluating a screened Through-Delta facility to convey up to 4,000 cfs of Sacramento River water to the Banks and Tracy pumping plants in the south Delta. The USBR is leading studies of the DCC operations improvements and DWR will lead the Through-Delta facility studies (DWR 2004a). The diversion facility on the Sacramento River is an action to be considered only after three separate assessments are satisfactorily completed including: (1) a thorough assessment of DCC operational strategies and confirmation of continued concern over water quality impacts from DCC operations; (2) a thorough evaluation of the technical viability of the Through-Delta facility; and (3) a satisfactory resolution of the fisheries concerns about a Through-Delta Facility. Both projects, if implemented, could dramatically alter salinity conditions through changes in the quantity and timing of freshwater flows entering the Delta.

FRANKS TRACT

The three study areas are all located in the central and western Delta and are routinely exposed to a wide range of salinity concentrations as demonstrated in the EC plots shown in Exhibits 4.5-4 and 4.5-5. Fundamentally, all three of the existing flooded islands comprise a portion of the overall available open water volume within the western Delta subject to tidal exchange. Consequently, the flooded islands contribute incrementally to the distance that high-salt content seawater can enter into adjacent Delta channels. In particular for Frank's Tract, a variety of research has been ongoing to investigate the hydrodynamic and salinity regime within the island perimeter, and associated relationships with hydrodynamic and salinity conditions in adjacent Delta channels. Special field measurement studies have been conducted and preliminary modeling with 2-dimensional modeling has been conducted to evaluate the hydrodynamic connectivity of Franks Tract with surrounding Delta channels. Frank's Tract is being intensively investigated because field and modeling data indicate that hydrodynamic conditions of the island may result in dramatic effects on overall salinity conditions in the central Delta (California Bay-Delta Authority 2004b).

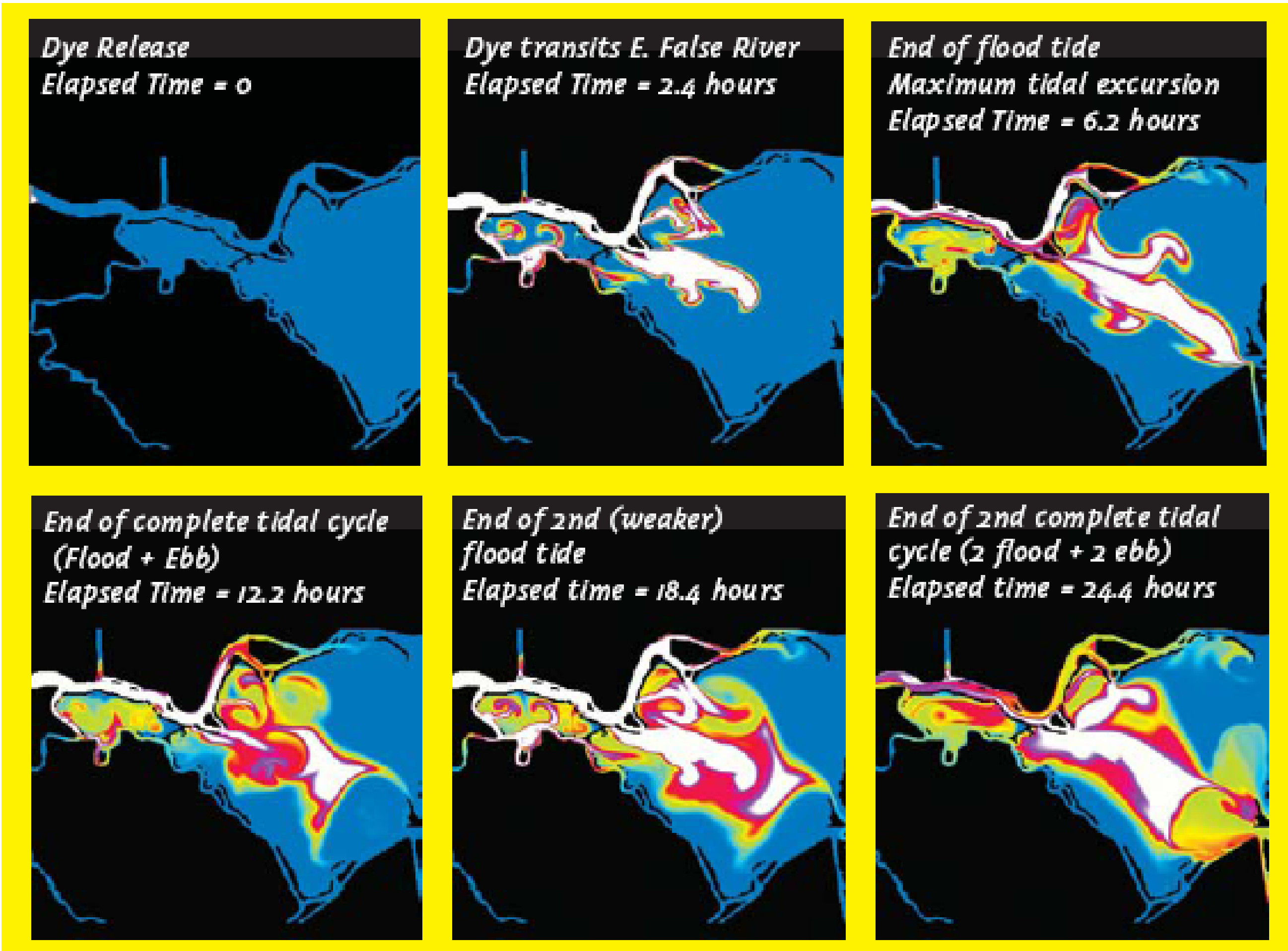
Frank's Tract is connected tidally to the San Joaquin River via the False River channel that forms the northern edge of the island. During a four-month experiment in 2002, tracking of tidal flows with drifters and salinity measurements detected that high-salt content water entered Frank's Tract during the flood tides. However, the data indicated that saline water was retained in Frank's Tract and less dense freshwater near the water surface flowed back into False River during the ebb tide flow. The data also indicated that saline water entering Frank's Tract through the largest existing levee breaches near the west side then mixed within the island and was withdrawn into Old River through levee breaches along the east side of the island. This process is considered an important factor in the hydrodynamic forces that may alter salinity conditions in adjacent Delta channels and the central Delta overall. The data suggests that net reverse flows in Old River draw water from Frank's Tract and can thereby result in higher salinity conditions in flows moving into the southern Delta than would otherwise occur if Frank's Tract did not trap the saline water.

A suite of complex physical phenomenon is involved with the salinity intrusion and mixing occurring at Frank's Tract. Geometry and location of levee breaches play a role in that the breaches located along the western side of the island are within the distance that routing tidal salinity intrusion can occur. Tidal action itself, in terms of the tidal wave propagation that varies over time and by location, also is an important factor in mixing force dynamics. The geometry and size of the levee breaches create a high velocity nozzle effect that facilitates transport and mixing of saline water with freshwater within the island. Bathymetry (i.e., shape, depth, length) of the open water segment, hydraulic residence time of water within the island, and presence of dense vegetation growth may also be an important factor in the mixing characteristics of saline and freshwater sources. Multi-dimensional numerical modeling being conducted for this feasibility study is specifically being developed to increase the resolution of the modeling code to better represent these physical and chemical properties that influence the transport and mixing within the island.

Exhibit 4.4-6 shows an initial modeling scenario that demonstrates the complex salinity mixing phenomenon within Frank's Tract that was conducted by the U.S. Geological Survey and presented in the CALFED Bay-Delta Science Program newsletter (California Bay-Delta Authority 2004b). The simulation was developed to represent the distribution of hypothetical "dye" released within the False River near the western levee breach over a complete 24-hour period of tidal action. The simulation demonstrates that the "dye", that can represent higher salinity water, enters the island and disperses widely, however, also remains relatively confined along an axis between the western levee breaches and the breaches adjacent to Old River.

LOWER SHERMAN LAKE

Lower Sherman Lake lies between the Sacramento River to the north and the San Joaquin River along its southern boundary. It is therefore influenced by salinity profiles and patterns of both rivers. Consequently, the range of salinity conditions in Lower Sherman Lake can generally be represented by the salinity profiles in Exhibit 4.5-4 and Exhibit 4.5-5 for the San Joaquin River at Antioch. The plot for Antioch shows that salinity ranges from freshwater in the winter high Delta inflow periods to brackish with EC ranging up to about 8,000 to 10,000 μS/cm. However, during wet years such as 1995 and 1998, summer low flow conditions can



Time sequence of color plots representing dye concentrations over two tidal cycles based on numerical TRIM2D model simulations. Dye (white), which can be thought of as representing salty San Joaquin River water, is released in False River at the beginning of a flood tide. Prior to the release, the whole area is initialized in the computer model as blue. Thus variations between white and blue indicate dilution of the dye through dispersive mixing processes. In the sequence above, the dye enters Franks Tract, mixes into the fresher ambient water and stays there. This is almost completely a tidal process and thus has virtually nothing to do with the river flows and Delta export rates.

Source: Adapted from California Bay-Delta Authority 2004

Simulated Salinity Mixing Conditions Within Franks Tract

EXHIBIT 4.4-6

EDAW

still have relatively low EC concentrations considered to be representative of a freshwater ecosystem. Initial field sampling indicates that there is about a 1-hour difference between the times that the tidal wave front propagates in the Sacramento River channel and the San Joaquin River channel (Bay-Delta Authority 2001). The difference occurs as a result of the larger tidal prism volume occupied by the Sacramento River channel and the fact that the distance up the channels to Lower Sherman Lake is greater in the San Joaquin River than the Sacramento River. Consequently, stage levels at any point in time are different between the north side of the island and the south side of the island. Field measurements of drift and velocity profiles within Lower Sherman Lake identified that there was considerable flow of water between from the Sacramento River to the San Joaquin River through the east side of the lake. Flow was not as great through the west side of the lake that is more enclosed by remnant levees.

BIG BREAK

Big Break is a shallow flooded area situated along the San Joaquin River slightly west of the Jersey Point monitoring location that is used for Delta WQCP standards compliance evaluations. The flooded area is located between Lower Sherman Lake and Frank's Tract and is thus exposed to salinity conditions that are generally between those of the other islands. Salinity concentrations are low in the winter in a similar pattern with the western Delta. During seasonally low-flow conditions (or year-types with less Delta inflow), Big Break is exposed to salinity conditions that can be closely by the EC time-series plots for the San Joaquin River at Blind Point (refer to Exhibit 4.5-4) that indicated EC values ranging up to about 7,000 μS/cm relative to the higher values (up to 11,000 μS/cm) recorded at Antioch. On a long-term basis, the range of low flow salinity conditions would be expected to lie between the values observed in plots for Antioch and Jersey Point shown in Exhibit 4.5-5, and also likely similar to the range of values observed at Emmaton on the San Joaquin River. Consequently, during low flow periods, the island is likely brackish during most years and may retain relatively low freshwater EC concentrations all year long during above normal and wet years.

4.4.2 ORGANIC CARBON

GENERAL DESCRIPTION

Organic carbon in the Delta originates from several sources. It is a complex mixture of compounds with different potential forms, and, although organic carbon is considered a "contaminant" for drinking water supplies, it is a vital nutrient for the Bay-Delta ecosystem (CALFED 1999). This subsection provides detailed baseline information on the primary sources of organic carbon, transport and spatial distribution, processes and cycling, bioavailability (quality characteristics of the carbon forms), and ecological and water quality considerations. Specific information on Franks Tract, Lower Sherman Lake, and Big Break are provided when available. This baseline report primarily relies on existing information from previously completed studies and documents that address organic carbon in the Delta. The results of these reports are summarized in this section.

Sources and Transport of Organic Carbon

Organic carbon in the Sacramento-San Joaquin Delta originates from a number of sources including tributary inflows (i.e., Sacramento River, San Joaquin River, Yolo Bypass, and eastside streams), in-Delta primary production, and Delta island drainage return flows. Organic carbon-containing compounds are generally represented in complex mixtures of aromatic and aliphatic hydrocarbon structures with attached amide, carboxyl, hydroxyl, ketone, and other functional groups. Dissolved organic carbon (DOC) is defined as that which can pass through a 0.45-μm filter; particulate organic carbon (POC) is retained by the filter. The combination of DOC and POC are referred to as total organic carbon (TOC).

Jassby (1992) and Jassby *et al.* (1993) provided the first estimates of an organic carbon budget for the Bay-Delta. They identified a variety of sources of organic carbon to the Estuary including both production within the Estuary (autochthonous), production transported into the Estuary from rivers, land, and atmosphere (allochthonous), and exchange with the ocean (transport sources) (Table 4.4-2). Jassby *et al.* (1993) synthesized available information on sources and sinks of organic carbon in the Bay and considered spatial and temporal variability to the extent possible with the available data (Brown 2003). In a separate study using a long historical data set to construct a Delta-wide organic matter mass balance, Jassby and Cloern (2000) found that on an annual basis, external river inputs accounted for 69% of the organic matter supply to the Delta, whereas primary producers within the system accounted for 15%.

Table 4.4-2
Sources of Organic Carbon to the Sacramento-San Joaquin Delta

Source		
Unidirectional Sources		
	Autochthonous Sources	
		Phytoplankton
		Benthic microalgae
		Seagrasses
		Microalgae
		Photosynthetic bacteria
	Allochthonous Sources	
		Delta discharge
		Tidal marsh export
		Point source discharges
		Surface runoff
		Atmospheric deposition
		Oil Spills
		Groundwater
Exchange Processes		
		Circulation and mixing
		Dredging activity
		Biotic transport

Source: Jassby 1992

External river inputs of organic carbon to the Delta are dominated by the Sacramento River, which provides 84% of the Delta's freshwater (Jassby and Cloern 2000). A similar analysis of DOC and TOC data for major tributaries of the Sacramento River basin, Yolo Bypass, and San Joaquin basin from 1980-2000 further confirmed the prominence of Sacramento River and Yolo Bypass inputs to the Delta (U.S. Geological Survey 2003). When the Yolo Bypass is flowing, the organic carbon load transported to the Delta can be larger than the Sacramento River input. This latter study also identified a statistically significant trend of overall decreasing DOC mass loading to the Delta measured at the Sacramento River at Freeport and San Joaquin River at Vernalis. However, the majority of site-specific tributaries showed no significant trends (increasing or decreasing), and several showed significant increased loading over the monitoring time period. The large value generally given for riverine input is, however, somewhat misleading because it includes forms of organic carbon not readily available as food to higher organisms (e.g., recalcitrant detritus and dissolved organic carbon). Approximately one-tenth of the actual riverine input has been considered biologically available (Brown 2003). Much of the biologically available organic carbon in Delta discharge has been attributed to be phytoplankton and the breakdown products from dead phytoplankton. Jassby *et al.* (1993) also noted that interannual variability was high in areas with primarily riverine inputs because of annual differences in precipitation and spring runoff.

Schemel *et al.* (1996 cited in Sobczak *et al.* 2002) indicated that the estimate of the allochthonous sources of organic carbon to the Delta in Jassby *et al.* (1993) was too low. Further, organic carbon (and suspended sediment) transport into and through the Delta to downstream areas was determined to be highly episodic with most transport occurring in large, short-term pulses related to flooding events when the Yolo Bypass transported significant quantities of Sacramento River flow (Schemel *et al.* 1996 cited in cited in Sobczak *et al.* 2002). However, the importance of allochthonous sources to the organic carbon budget of the Delta and the estuary as a whole has been based on estimates from literature values of the bioavailability of allochthonous carbon, which may include large portions of recalcitrant detritus. Jassby *et al.* (1996 cited in Brown 2003) re-estimated the carbon budget for the estuary and found little effect of higher estimates of riverine input because of decreased transit time during high flows. Jassby and Cloern (2000) have also concluded that primary production within the Yolo Bypass, while important to organisms within the bypass, does not provide a significant additional source of primary production to downstream areas in the Delta because of dilution (Brown 2003).

Within the Delta, in-channel phytoplankton production, agricultural drainage from the peat soils of the levee-protected islands, marsh export, municipal wastewater treatment effluent discharges, benthic microalgae, and urban stormwater runoff have been documented as the dominant Delta origin sources of organic carbon. The Delta's natural history resulted in the creation of carbon-rich peat soils. The organically rich peat soils of the Delta were created through the natural cycle of tule growth and decay. Of approximately 738,000 acres of islands and channels making up the Delta today, about 250,000 acres confined to the Delta basin are rich in organic matter. In some cases, decayed vegetation formed peat soils over 30-feet deep. Depending on soil type, mineral soils have less than 10% organic matter while peaty organic soils range between 50% and 80% organic matter. The organic-rich soils of the Delta islands result in irrigated agricultural drainage that can exhibit very high DOC concentrations (DWR 1994 cited in DWR 2003a and 2003b). In combination to the peat oxidation process, organic matter is then carried off the islands as water passes through the peat soils from irrigation, rainfall, flooding, seepage, and leaching (DWR 2003a and 2003b). On an annual average basis, Delta drainage is estimated to be similar or slightly less than loading associated with phytoplankton production (Jassby *et al.* 2003).

Allochthonous organic carbon production associated with primary production of phytoplankton within Delta channels is estimated to be considerably larger compared to exports from marsh macrophytes, benthic algae, and the allochthonous sources of wastewater and urban runoff (Jassby *et al.* 2003). However, the quantity of phytoplankton production in the Delta is small compared with other estuaries (Cloern 2001) and internal production has declined about 43% since 1975 (Jassby and Cloern 2000). Overall, organic carbon associated with phytoplankton production is comparable or slightly less than riverine sources during the summer, and can exceed the riverine input during spring and summer seasons of dry year-types (Jassby *et al.* 2003).

Ecological Considerations

DOC influences, if not governs, many aspects of the biology and chemistry of aquatic ecosystems (Thurman 1985). Frequently, DOC regulates biotic processes such as bacterial productivity which in turn influences dissolved oxygen concentrations, food-web structure, and microbially mediated biogeochemical transformations (Wetzel 2001).

Recent studies in the Delta indicate that phytoplankton production is the dominant food supply to the planktonic food web (Jassby and Cloern 2000; Müller-Solger *et al.* 2002; Sobczak *et al.* 2002). It appears that the dissolved and detrital particulate organic carbon delivered to the Delta does not enter the planktonic food web to a significant degree (Sobczak *et al.* 2002). Laboratory growth assays showed that the growth of the cladoceran, *Daphnia magna*, was dependent on phytoplankton biomass and unrelated to the amount of detrital organic matter (Müller-Solger *et al.* 2002). These results were unexpected because phytoplankton production is usually a minor portion of total organic carbon production in the Delta, and phytoplankton standing crop usually represents only a small portion of the total amount of organic carbon present in the Delta at any time (Jassby and Cloern 2000). The combination of metabolic losses, recalcitrance of detrital POC, and short residence time combine to minimize the importance of riverine sources of particulate and dissolved organic carbon to Delta consumers (Jassby and Cloern 2000). These results suggest that incidental export of phytoplankton associated with water export from the Delta may be more important than originally thought.

In the Delta, significant amounts of primary production are exported at the state and federal pumping facilities (Arthur *et al.* 1996; Jassby and Powell 1994; Jassby *et al.* 1993, 1996; Jassby and Cloern 2000 cited in Brown 2003). Jassby and Powell (1994 cited in Brown 2003) calculated that the median chlorophyll exports to water projects exceeded chlorophyll outflow to the Bay by 60% from 1975 to 1989. The importance of phytoplankton production in the

Delta was unexpected because the common conceptual model for estuaries is that organic detritus is the most important form of organic carbon. The increasing understanding of the relative importance of phytoplankton primary production in the carbon budget of the Delta may be particularly important in guiding new research and in evaluating the benefits of various management actions (e.g., Jassby *et al.* 2003, Jassby and Cloern 2000; Lucas *et al.* 2002).

Bioavailability

Sobczak *et al.* (2002) found that a small fraction of the total pool of organic matter in the Delta was bioavailable, suggesting that only a small fraction of the Delta's chemical energy can support secondary productivity. The concentration of DOC was routinely greater than POC, but the bioavailable DOC and bioavailable POC concentrations were more comparable. This discrepancy results from a larger percentage of the particulate organic matter being bioavailable. This finding is ecologically important because POC enters the metazoan food web at a much greater efficiency than DOC. POC is frequently ingested directly, whereas DOC must be routed through the microbial loop, resulting in a large respiratory loss of carbon (Ducklow *et al.* 1986 cited in Sobczak *et al.* 2002). Thus zooplankton secondary production is likely to be more strongly linked to bioavailable POC as opposed to bioavailable DOC (Sobczak *et al.* 2002).

Sobczak *et al.* 2002 also found the phytoplankton-derived organic matter constituted a small fraction of the total and particulate organic matter found among habitats. For example, phytoplankton biomass typically represented only 5% of the total organic matter (i.e., DOC /POC) and 28% of the POC in the deep-river channel habitat. However, phytoplankton biomass was a large and important component of the bioavailable POC. Phytoplankton biomass routinely equaled or exceeded other forms of bioavailable POC in all habitats. Further, phytoplankton biomass and bioavailable POC strongly correlated in all habitats. These findings were surprising because of the small contribution of algal biomass to the Delta's organic matter mass balance (Jassby and Cloern 2000 cited in Sobczak *et al.* 2002). Conversely, detrital-derived POC constituted the majority of the total POC in most habitats (overall median ratio 0.72), but represented a much smaller component of the bioavailable POC. This finding was surprising because detrital organic matter is the energetic basis of many stream and river ecosystems (Vannote *et al.* 1980, Webstrer and Meyer 1997, and Wallace *et al.* 1997 cited in Sobczak *et al.* 2002). This finding contributes to an emergent general pattern of carbon cycling in large rivers and estuaries. Riverine organic matter may be much older and recalcitrant than previously thought (Raymond and Bauer 2001 cited in Sobczak *et al.* 2002). The findings provide strong evidence that the Delta's planktonic food web may be highly reliant on phytoplankton production although this organic-matter source represents a small amount of the ecosystem's potential energy to higher trophic levels (Sobczak *et al.* 2002).

Water Quality Considerations

The Delta supplies all or part of the drinking water for over 22 million Californians; thus, the importance of water quality in the Delta cannot be overstated. Treating Delta water to meet drinking water standards requires, among other things, simultaneous disinfection for pathogens and minimization of disinfection byproducts (DBPs), many of which are suspected carcinogens. Disinfection byproducts result when chlorine or ozone react with some forms of DOC, under some circumstances particulate organic carbon (POC), and bromide, all of which are present in significant concentrations in Delta waters. Although existing treatment plants are able to meet or exceed U.S. Environmental Protection Agency (EPA) standards for DBPs using Delta source water, EPA's regulatory process is likely to lead to more stringent standards for DBPs that are currently regulated, standards for DBPs that are not currently regulated, and more stringent pathogen removal and inactivation requirements. Unless levels of pathogens, organic carbon, and bromide can be reduced in Delta withdrawals, meeting anticipated future drinking water standards will require substantial investments in treatment facilities, new treatment technologies, or high quality water sources to blend with Delta supplies (CALFED 1999).

DBPs are of concern for reasons ranging from objectionable odors to human health risks (CALFED 2000b) posed by some classes of DBPs including trihalomethanes (THMs), haloacetic acids, and bromates. These three classes of DBPs are regulated by the EPA (USEPA 1998). Formation of THMs has been a particular concern in Delta waters (DWR 1994). Thus, export of organic carbon from restored tidal wetlands in the Delta might have negative effects on water quality for those people using the Delta as a source of drinking water. The situation is made even more complex by the fact that agricultural lands on peat soils and managed nontidal wetlands, already provide significant inputs of various forms of organic carbon to Delta waters (Amy *et al.* 1990 cited in Brown 2003).

At present, Delta waters sometimes contain sufficient DOC and bromide to exceed the EPA maximum contaminant level for THMs when water is chlorinated for drinking water purposes (Amy *et al.* 1990 cited in Brown 2003; DWR 1994). Precursors to THM formation include natural organic matter (organic carbon) derived from plant detritus, peat soils, algae, and other sources. The main sources of precursors under present conditions in the Delta have been identified as salt-water intrusion (see Section 4.4.1 above), DOC in drainage water from Delta islands with peat soils, and various other sources of DOC (DWR 1994). The bromide anion in particular is derived primarily from seawater, although it is present in soils of the Central Valley (DWR 2003a and 2003b).

Trihalomethane formation potential and organic carbon concentrations have been monitored in the Delta since the 1980s (DWR 1994). Drainage water from Delta islands, which is pumped over levees into Delta channels, is estimated to contribute from 20% to 50% of the DOC contributing to the formation of THMs in water exported from the Delta by the State Water Project. DWR estimates that based on the ranges of alkalinity of most Delta source waters, the removal of up to approximately 25% to 35% of TOC from Delta water supplies before disinfectants are added may be required to comply with the USEPA Disinfectants/Disinfection Byproducts Rule for source water treatment (DWR 2003a and 2003b).

While the chemical reactions forming THMs generally involve DOC (such as organic acids); under some circumstances POC may also be involved. Dissolved organic carbon is actually a complex mix of substances (Fujii *et al.* 1998). This heterogeneous mixture may include types of organic carbon that vary widely in a number of characteristics including molecular weight, solubility, polarity, chemical reactivity, and availability to organisms. The generally accepted model for THM formation assumes that aromatic forms of carbon (such as resorcinol) are primary precursors to THMs. Natural environments with reducing conditions, such as peat bogs and water-logged soils, tend to produce greater amounts of aromatic DOC compared to well-oxygenated environments. Soil redox conditions also are influenced by water-management practices, irrigation and intentional flooding of fields and drainage ditch depths that help control ground-water levels (Fugii *et al.* 1998).

Detailed studies of organic carbon in the Delta suggest that there is considerable variability in reactivity of organic carbon from different sources (Fram *et al.* 1999 cited in Brown 2003). Different attributes relating to THM formation potential varied widely among different sources of water in the Delta ranging from open channels to agricultural drainage water. In further work, DOC was isolated from Delta waters and analyzed for specific contents including aromatic carbon. Analysis of the data revealed considerable variability in the relationships between different environmental factors. Bergamaschi *et al.* (2000 cited in Brown 2003) also observed wide variability in the quality of organic carbon in Delta waters and noted that the organic carbon at the export pumps did not seem to be a simple mixture of organic carbon from the rivers and from Delta agricultural drains. The results suggest the importance of other Delta sources of organic carbon (upland drainage, wetlands, and algae) that may differ in chemical characteristics and in the physical and chemical processes within the Delta (microbial degradation, flocculation, photolysis) that can change the character of the organic carbon and its likelihood of forming DBPs (Brown 2003).

Tidal Wetland Processes and Flooded Islands

Sources of organic carbon and processes that modify organic carbon within tidal wetlands and flooded islands are especially complex and dynamic. Jassby and Cloern (2000) noted the possibility that tidal wetland export may result from processes that occur only at the margin areas. If this is the case, then the interior areas of large patches of tidal marsh may contribute little organic carbon to Delta waterways, and edge-to-area relationships may be extremely important in predicting the flux of organic carbon from existing and restored tidal wetlands.

Lucas *et al.* 2002 found that superficially similar, geographically proximate flooded island habitats can function very differently and this functional variability is likely amplified because the habitats are "open," and more subject to the direct influence (riverine and tidal) of adjacent channels.

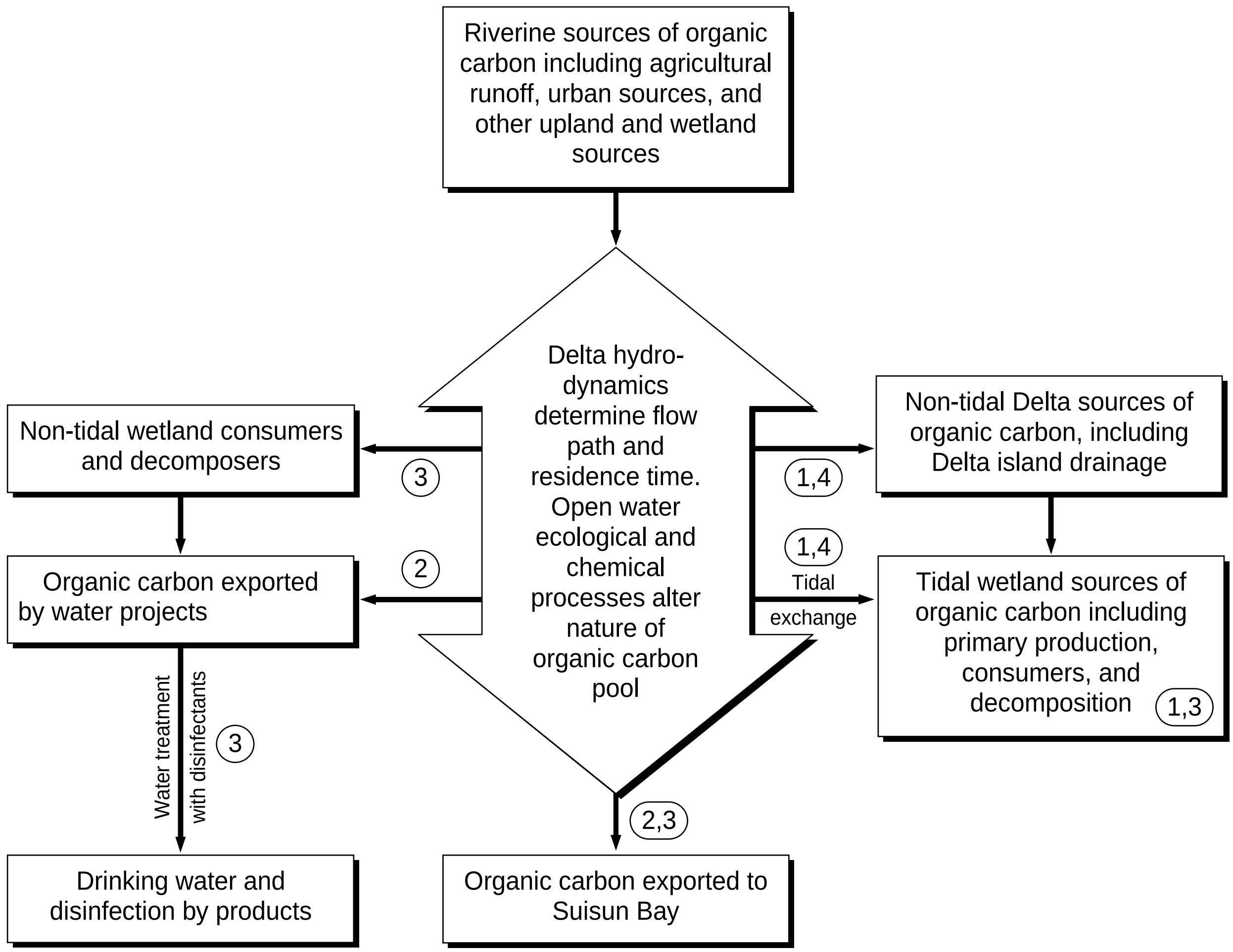
Brown (2003) developed a simple conceptual model of the processes that determined the quality and quantity of organic carbon exported to Suisun Bay or out of the Sacramento-San Joaquin Delta by the major water projects (Exhibit 4.4-7). The model illustrates POC and DOC entering and exiting the tidal wetland during water exchanges related to the tidal cycle; however, the conceptual model does not necessarily reflect temporal variability within the Delta. This imported organic carbon, and organic carbon generated internally through photosynthesis by vascular plants and algae, then enters the food web or various chemical cycles within the wetland environment. Internal processes may further change the chemical or biological nature of the organic carbon and organic carbon may be exported from the wetlands to adjacent river channels in a variety of forms ranging from passively transported DOC to higher trophic level biomass tissues (Brown 2003).

Export of organic carbon from tidal wetlands to channels does not necessarily determine the quality and quantity of organic carbon in exported waters. Organic carbon from other sources (e.g., agricultural drainage water) mixes with the exported tidal wetland organic carbon. Also, additional ecological and chemical processes occur in the channels, possibly changing the chemical composition and quantity of the exported organic carbon. Tidal water exchange will result in some portion of the organic carbon cycling between channels and tidal wetlands more than once. Flooded islands can also result in different mixing regimes that complicate the processes further. These processes will likely result in organic carbon in different regions of the Delta having somewhat different chemical characteristics because of the relative importance of different sources, including tidal wetlands (Brown 2003).

DBPs are only an issue for Delta source waters that are subsequently disinfected for use as drinking water. Delta and specific flooded island hydrodynamics determine both the residence time of water in the Delta and net flow paths through the system. Any contribution of tidal wetland organic carbon to THM formation will depend not only on the character of the organic carbon produced, but also on the location of the tidal wetlands and hydrodynamic conditions. As discussed earlier, the quality and quantity of organic carbon entering and exiting the Delta, changes considerably depending on flow conditions (Brown 2003).

FRANKS TRACT

Unique and complex hydrodynamics, combined with relatively rapid benthic grazing rates, greatly influence carbon processes in Franks Tract. Lucas *et al.* (2002) performed various experiments and modeling in a study to compare ecological function in two open, shallow water habitats, Franks Tract and Mildred Island. They found that tidal hydrodynamics significantly influence particle and, thus, carbon transport into, within, and out of these two flooded islands. Transport modeling in Franks Tract demonstrated that particles tidally sloshed between the lake interior and adjacent channels with a long-term net import of river-borne particles to the lake, as well as substantial dispersion within the lake.



Numbers correspond to the major uncertainties identified in the text: (1) sources of organic carbon, (2) transport processes, (3) quality of organic carbon, (4) management actions. The location of the numbers indicates where a major uncertainty is particularly important in the conceptual model. Addressing these uncertainties is key to understanding and managing the system.

Source: Brown 2003

Conceptual Model of Organic Carbon Process in the Sacramento-San Joaquin Delta

EXHIBIT 4.4-7

EDAW

In addition to hydrodynamic transport, the importance of benthic grazing in limiting phytoplankton biomass accumulation and, thus, carbon, was also demonstrated for Franks Tract (Lucas *et al.* 2002) and has been inferred for the Delta as a whole (Kimmerer 2004). Lucas *et al.* (2002) studied benthic grazing rates associated with *Corbicula* clams in Franks Tract and Mildred Island and determined that Franks Tract acts as a carbon sink. The study compared the range of estimated phytoplankton consumed by the *Corbicula* clams with the range of estimated carbon required for maintenance respiration and moderate rates of growth and reproduction. The study results demonstrated that benthic grazing in Franks Tract results in a net consumption of 2,300 kg of carbon per day. Respiration and benthic grazing losses offset and exceed import and photosynthesis (Lucas *et al.* 2002) (also see Section 4.8).

The study demonstrated that dispersive transport coupled with spatially variable biological processes likely has important general implications. Given the vigorous tidal interaction between Franks Tract and adjacent channels, the influence of this local carbon sink probably extends beyond its boundaries. Riverine and Delta forms of DOC and POC that are the least bioavailable, yet potentially important precursors to THM formation, may slosh into Franks Tract and ultimately dispersed out to drinking water intake pumps. Phytoplankton cells (the most important form of organic carbon to primary production in the food web) may be permanently removed from the water column by *Corbicula* in the lake and prevented from out-sloshing into river channels where they could be utilized by higher trophic-level species and benefit the aquatic community.

LOWER SHERMAN LAKE AND BIG BREAK

Specific information on the carbon processes in Lower Sherman Lake and Big Break is lacking. As discussed above, superficially similar, geographically proximate flooded island habitats can function very differently and this functional variability is likely amplified because the habitats are "open," and more subject to the direct influence (riverine and tidal) of adjacent channels (Lucas *et al.* 2002). Therefore, it is difficult and would be overly speculative to characterize carbon processes in Lower Sherman Lake and Big Break with existing information.

Modeling and experiments similar to those performed by Lucas *et al.* (2002) could be applied to these sites to provide a better understanding of site-specific hydrodynamic transport and biological processes that greatly affect carbon dynamics.

4.4.3 MERCURY

GENERAL DESCRIPTION

Mercury is a highly toxic element that is found both naturally and as an introduced contaminant in the environment. The ecological and water quality implications are determined by the likelihood of exposure, the form of mercury present (some forms are more toxic than others), and the geochemical and ecological factors that influence how mercury moves and changes form in the environment.

This section provides detailed baseline information on the primary sources of mercury, transport and spatial distribution, processes and cycling, bioavailability, and ecological considerations (Exhibit 4.4-8). Specific information on Franks Tract, Lower Sherman Lake, and Big Break are provided where available. This section relies primarily on existing information from previously completed studies and documents that address mercury in the Delta. The results of these reports are summarized in this section.

Sources

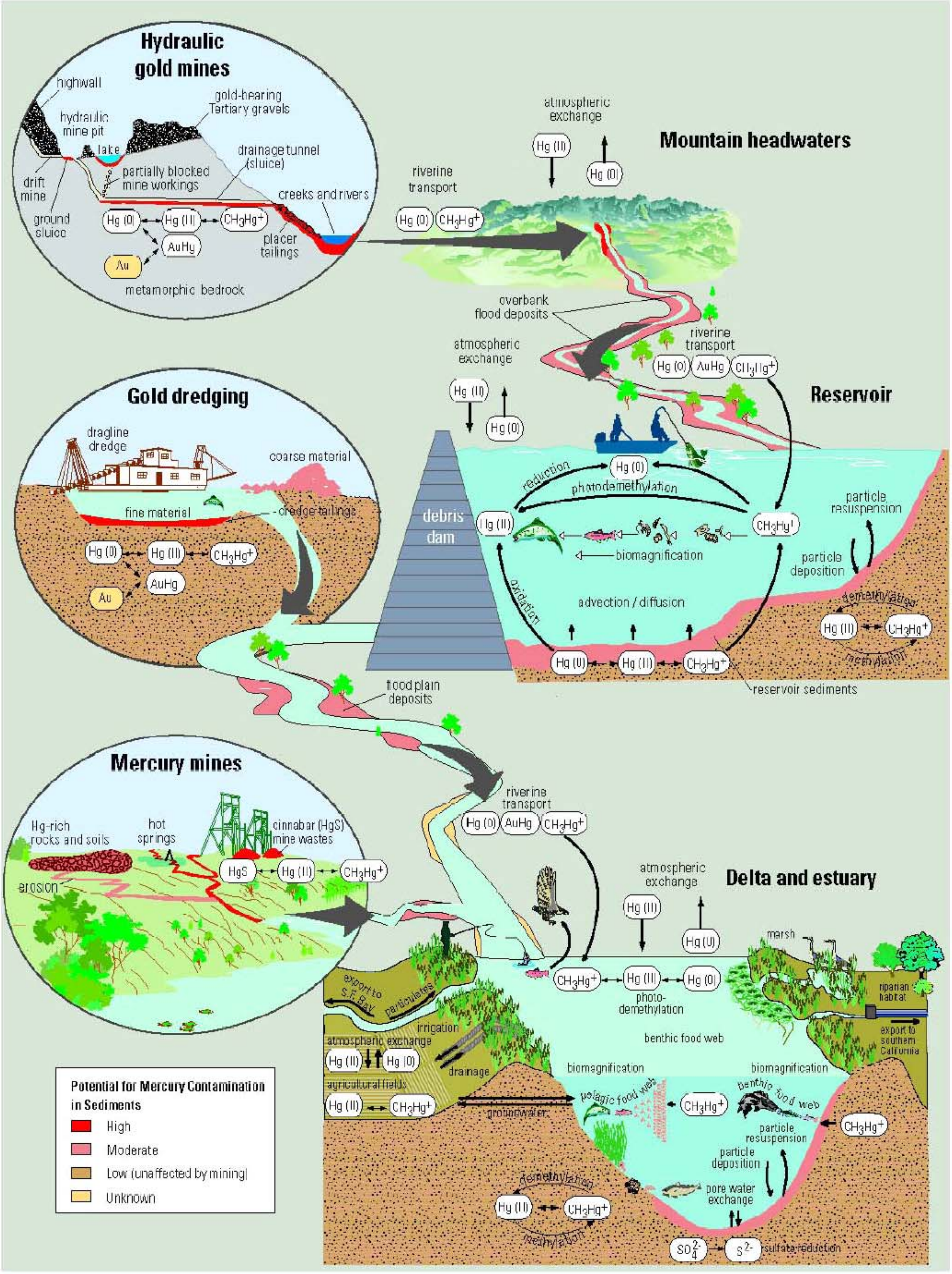
Mercury occurs as a result of both natural and anthropogenic sources in the environment and continually cycles in the aquatic environments of the Sacramento and San Joaquin River basins and Delta. The cycle involves different chemical forms and/or species of mercury as a result of both chemical and biological reactions in aerobic and anoxic microenvironments. On a world wide scale, mining sources are geographically localized but, in California's Central Valley, they are of great importance. Most additional mercury sources are part of a widespread, global cycle (Jones and Slotten 1996).

Natural Sources

Mercury occurs naturally in the environment and, thus, has a background concentration independent of man's releases (see Table 4.4-3). As with any site on the globe, there is natural mercury contamination in the Delta and the San Francisco Bay. Forest fires in Northern California undoubtedly contribute some mercury to the environment. There is an ongoing load of some magnitude associated with the general export of mercury from natural cinnabar deposits, in addition to mining-related point sources. It is difficult to determine what proportion of mercury in the Delta is from natural sources because what is natural varies greatly from one part of the world to the next. Because of airborne mercury pathways, there is no part of the globe today untouched by the world-wide increase in both use and release of mercury by man in this century. The importance, in this region, of localized bulk contamination mercury sources, over and above general deposition from the global cycle, is apparent in elevated mercury levels in tributaries to the Delta. Concentrations in inflowing rivers typically greatly exceed those seen in comparable rivers in regions without local mercury sources (Jones and Slotten 1996).

Anthropogenic Sources

Mercury is used in a broad array of more than 2,000 manufacturing industries and products (Kurita 1987 cited in Jones and Slotten 1996). These include barometers, thermometers, hydrometers, pyrometers, mercury arc lamps, switches, fluorescent lamps, mercury boilers, mercury salts, mirrors, catalysts for the oxidation of organic compounds, gold and silver extraction from ores, rectifiers, cathodes in electrolysis/electroanalysis, and in the generation of chlorine and caustic paper processing, batteries, dental amalgams, as a laboratory reagent, lubricants, caulks and coatings, in pharmaceuticals as a slimicide, in dyes, wood preservatives, floor wax, furniture polish, fabric softeners, and chlorine bleach (see Table 4.4-3) (Volland 1991 cited in Jones and Slotten 1996).



Source: Heim et al. 2003

Conceptual Model of Mercury Processes in the Sacramento-San Joaquin Delta

EXHIBIT 4.4-8

Table 4.4-3 Sources of Mercury in the Environment	
Source	Description
Natural	
Volcanic Activity	Present in the earth's crust at a concentration of 0.5 ppm. Typically in the form of mercury sulfide (HgS) because of the prevalence of sulfides in volcanic gases. Found naturally in deposits as the red sulfide ore, cinnabar. It is commercially mined as this form. Volcanic sources emit an estimated global total of 60,000 kg of mercury per year.
Forest Fires	Biomass, particularly trees and brush, accumulate and harbor a substantial fraction of the biosphere's mercury. When forest fires heat these fuels to temperatures well above the boiling point of mercury (357°C), the mercury may be released to the atmosphere. Forest fires and rain are responsible for the transport and deposition of mercury over much of the world's surface, regardless of its original source.
Ocean Releases	Mercury is a component of seawater and is released naturally through the evaporation of elemental mercury from the ocean's surface. Both elemental and ionic mercury are soluble in water, although elemental mercury to a much smaller degree. As less soluble elemental mercury evaporates, the equilibrium reaction is pulled towards more elemental mercury, which then releases more elemental mercury from the ocean's surface.
Anthropogenic	
Mining	Primary source of mercury to the Delta. Extracted from cinnabar mines in the Coast Range and used in gold mines in the Sierra Nevada. See detailed description below.
Coal Fired Power Plants	Coal is known to contain mercury with concentrations varying from as low as 70 ng/g up to 22,800 ng/g (ppb). During the burning of coal, mercury is initially decomposed to elemental mercury and then, as the flue gas cools and exits the plant, the majority of the mercury is quickly oxidized, probably catalytically due to the presence of other metals in the gas, to its water-soluble, ionic form.
Petroleum Combustion	Crude petroleum is known to contain small but measurable amounts of mercury. Approximately 16 to 18 million barrels (672 to 756 million gallons) of crude oil are consumed daily in the United States. At an average concentration of 0.41 ppm mercury and an average density for crude oil of 6.9 lbs per gallon, the minimum total amount of mercury vaporized daily is therefore 1,901 lbs with an annual discharge of 347 tons nationwide (assuming that all of the oil is combusted).
Smelting	The smelting of ores to yield pure metals is thought to release some mercury into the atmosphere. Most metal ores are thought to have higher concentrations of mercury than coal, although the volumes of ore that are smelted each year are small in comparison with the volume of coal burned for power generation.
Chlor-Alkali Plants	Elemental mercury is employed as the electrode in the electrochemical production of chlorine gas and caustic soda (sodium hydroxide). Near most paper and pulp facilities which employ this technology to bleach the paper product white, the sediment is contaminated with high concentrations of mercury.

Table 4.4-3 Sources of Mercury in the Environment	
Source	**Description**
Mildew Suppression, Laundry Facilities	An infrequent and historical point source of mercury contamination has been the use of mercury compounds for mildew suppression by laundry facilities, which have a chronic problem with moisture and bacterial growth (Sills 1992 cited in Jones and Slotten 1996). This contamination source type should no longer be a problem. The use of mercury as a fungicide in interior latex paints has been similarly banned by the US EPA.
Sewage Treatment	The secondary treatment of sewage involves dewatering, which necessarily concentrates the solids and all non-volatile contaminants, but does little to treat or remove inorganic dissolved contaminants. Mercury is commonly found in urban sewage through point source discharges from dental offices and industrial manufacturing processes such as battery fabrication. As the sewage is dewatered and the solids concentrated, mercury can be either sequestered by the organic humus of sludge or, if the sludge is caked and dried, can be released to the atmosphere in the drying process. If the sludge has been dried, the fate of the sludge itself then dictates the extent of mercury contamination. Commonly, the dried product is incinerated or spread upon tree farms as a fertilizer and organic material. Sewage sludge incineration probably accounts for no more than 3,000 kg/yr in mercury emissions (EPA 1990 cited in Jones and Slotten 1996). The distribution of sludge in this fashion also spreads concentrated mercury over a large area where it is either taken up in the biomass or contributes to surface water runoff and consequently downstream contamination.
Mercury Dumping from Naval Vessels	The US Navy uses mercury as ballast in its subsurface vessel fleet. During inter-ship ballast transfer operations, elemental mercury is occasionally spilled into marine waters, resulting in contamination of both sediment and water. This could be a significant point source of mercury directly within the San Francisco Bay.
Source: Jones and Slotten 1996	

Mining

Historic gold-mining practices created the primary source of mercury in northern California rivers and the Delta. The mountain ranges that surround California's Central Valley and drain into the Sacramento and San Joaquin watersheds contain extensive mineral deposits. Discovery of gold deposits in the Sierra Nevada stimulated the California Gold Rush in 1848, and an abundance of mercury from hundreds of mercury mines in the Coast Ranges facilitated the rapid historic proliferation of gold-mining operations that used the mercury-amalgamation process to extract gold (Alpers and Hunerlach 2000). Hundreds of hydraulic gold-placer mines operated on the east side of the Central Valley. About 100,000 metric tons of mercury was produced by mercury-mining operations in the Coast Ranges, and about 12,000 metric tons of this were used in gold mining in California, with annual losses at mine sites ranging from about 10 to 30 percent of the mercury used (Alpers and Hunerlach 2000). The majority of Coast Range mercury mines that supplied this practice has since been abandoned and remains unreclaimed. As a result of these two activities, bulk mercury contamination exists today on both sides of the Central Valley (Jones and Slotten 1996).

In the past 50 years the amount of additional sedimentation attributable to the Gold Rush has declined substantially, and further declines are predicted (Jaffe *et al.* 1998a cited in Wiener *et al.* 2003). All of the major rivers in the Sacramento River basin (Sacramento, Feather, American, and Yuba) are impounded. The impoundments have decreased sediment export from the basin, and the suspended sediment load of the Sacramento River has declined since 1960 (Krone 1996 cited in Wiener *et al.* 2003). Given that about 90 percent of the total mercury load to the Delta ecosystem from the Sacramento River is sediment borne (Foe 2002), it can be reasonably inferred that mercury loads have correspondingly declined and that future activities affecting sediment budgets could substantially affect mercury loadings (Wiener *et al.* 2003).

Source Transport and Distribution

Historically contaminated sediments are sources of residual mercury from historic mining operations. The present distribution of contaminated sediments extends from small streams below mine sites, to extensive alluvial areas in floodplains where gold was dredged, down gradient through the Delta and into the San Francisco Bay. Recent surveys have provided significant new information on the abundances and distribution of mercury and methyl mercury in sediments in the Delta (Cappiella *et al.* 1999, Heim *et al.* 2003, Slotton *et al.* 2003).

Gill *et al.* (2002) found large temporal and spatial variations in estimated sediment-water exchanges of total mercury and methyl mercury in the Delta. During low-flow conditions, sediment-water exchange of total mercury and methyl mercury rivaled external riverine sources, whereas external sources dominated during high flow.

In another study (Larry Walker and Associates 1997), mercury concentrations and loads were measured at index stations on the Sacramento, Feather and Yuba rivers. A particular focus was placed on the Yuba River, upstream and downstream of Englebright Reservoir, to investigate the effects of foothill reservoirs on downstream mercury transport. The water quality data indicate that a significant amount of Gold Rush era mercury still exists in sediment in the upper Yuba watershed and that this is being transported into Englebright reservoir, where it is largely trapped. Bioavailability studies (Slotten *et al.* 1995) confirm that the reservoir acts as an interceptor of not only inorganic, sediment-based mercury, but of bioavailable methyl mercury as well. Despite the fact that elevated levels of mercury are found in the heavily mined upstream tributaries and, particularly, within Englebright Reservoir itself, the aquatic biota below the impoundment consistently demonstrate significantly reduced tissue concentrations of mercury, as compared to above the reservoir. The bioindicator organisms used in this work represent time-integrated measures of in-stream mercury bioavailability and indicate that the reservoir acts to consistently intercept bioavailable mercury that would otherwise be available for downstream transport, ultimately to the Delta system. The assumption is that mercury cycling in other Sierra watersheds is similar to that observed in the Yuba. Therefore, much, but clearly not all, of the mercury remaining in the Sierras from historic gold mining may be unavailable for downstream transport and biomagnification in the Delta. In the few high mercury rivers without dams, particularly the Consumnes, direct transport of historic gold mining mercury into the Delta remains unimpeded (Jones and Slotten 1996).

The work by Larry Walker and Associates (1997) suggests that the Coast Range, rather than the Sierra Nevada, may be a dominant source of new mercury to Central Valley rivers and the Delta. The Sacramento River mercury mass balance work indicated that the export of mercury from Sierra Nevada rivers was considerably less than that contributed by drainages in the north and central Sierran streams, and northwestern Coast Range portions of the state, possibly largely due to trapping of mercury behind the major Sierra Nevada foothill reservoirs. At the confluence of the Feather and Sacramento rivers at Verona, the upstream Sacramento River was found to contribute 75-80% of the total mercury load at that river mile.

Another mercury mass load export study was undertaken by the Central Valley Regional Water Quality Control Board (CVRWQCB) in the southwestern part of the Sacramento River watershed during 1995. The spring of 1995 was wet, and water from the Sacramento Valley entered the Delta through both the Sacramento River and Yolo Bypass. Highly elevated concentrations of mercury were repeatedly observed in the Bypass. The source of a significant portion of the mercury was traced to Cache Creek, which drains Clear Lake and that is estimated to have exported about a thousand kilograms of mercury to the Delta in 1995. The upper Clear Creek and Cache Creek watershed is known to be enriched in mercury and has several large abandoned mercury mines.

Processes (Methylation and Bioavailability)

Mercury can occur naturally in a variety of forms such as elemental mercury (Hg), dissolved in rainwater (Hg^{+2}), or as the ore cinnabar (HgS), and as an organometal such as methyl mercury (CH_3Hg and (CH_3) 2Hg). Elemental mercury is a liquid under normal conditions that is relatively insoluble in water; however, it can vaporize and thereby is important with respect to atmospheric deposition. Moreover, through natural processes such as chemical and biological reactions, mercury changes form among these species, becoming alternately more or less soluble in water, more or less toxic, and more or less biologically available (Jones and Slotten 1996).

Methylation Rates

The rates of methylation in the Delta are influenced by the bioavailability of inorganic mercury to methylating bacteria, the concentration and form of inorganic mercury, and the distribution and activity of methylating bacteria. Several studies suggest that the bioavailability of inorganic mercury in the Bay-Delta ecosystem varies with the source and that the rate of methylation varies in time and space. There is a significant relation between the abundances of total mercury and methyl mercury across ecosystems, but the concentration of inorganic mercury accounts for little of the variation in methyl mercury production when data for multiple ecosystems are combined (Benoit *et al.* 2003 cited in Wiener *et al.* 2003).

Methylation Potential in Different Source Forms

As discussed above, mercury mined from the coastal range was in the form of cinnabar while the Sierra Range was contaminated exclusively with refined mercury (elemental). These forms of mercury have very different behaviors in terms of reactivity and solubility. The forms of mercury eroding from mining sites in the Coast Range are mainly cinnabar and have low solubility under oxic conditions but can dissolve and become available for methylation in anoxic, sulfidic sediments (Benoit *et al.* 2001, Bloom 2003 cited in Wiener *et al.* 2003). Organic matter can also solubilize cinnabar (Ravichandran *et al.* 1998, Haitzer *et al.* 2002 cited in Wiener *et al.* 2003), although the effect of this dissolution on methylation has not been determined. The release of mercury from gold mines in the Sierra, and the form of mercury in those mines has been less well studied (relative to cinnabar mercury mines), although initial observations indicate that it may be more readily methylated (Heim *et al.* 2003, Gill *et al.* 2002, and Wiener *et al.* 2003).

However, studies that included the sampling of sediment, clams, and fish collected at the mouths of the tributaries coming from both ranges have shown equivalent total and methyl mercury concentrations (Davis *et al.*, 2003; Slotten *et al.* 2003; Foe *et al.* 2003 cited in Heim *et al.* 2003). This research suggests that both source forms contribute significantly to methyl mercury mass loading into the Delta.

Environmental Conditions Affecting Methylation

Several factors are related to methylation, as described below.

Oxidation Reduction Reactions
The transformation of mercury from one state or one species to another takes place in specific microenvironmental conditions. At the aerobic/anaerobic boundary in sediment, which is the limiting depth for oxygen penetration into the sediment, there is a redox potential discontinuity. In the oxygen-rich environment of the upper sediment, the electrochemical potential is oxidizing, thus favoring oxygen metabolism and the ionized (soluble) states of metals. Conversely, the oxygen-poor lower sediments exhibit a reducing electrochemical potential that favors sulfur metabolism by sulfur reducing bacteria.

Sulfate Reducing Bacteria
Methyl mercury is produced primarily by sulfate-reducing bacteria under anoxic and reducing conditions (Gilmour *et al.* 1992 cited in Heim *et al.* 2003). Therefore, factors that increase sulfate reduction rates, such as high water temperature, and high availability of organic carbon are likely to increase the production of methyl mercury (Compeau and Bartha 1985, Gilmour *et al.* 1992 cited in Heim *et al.* 2003). In sulfate-rich estuaries, increased availability of sulfate ions can suppress methylation. In freshwater, increased sulfate levels can cause increased methylation.

Water temperature in the Delta fluctuates annually following a sinusoidal curve with maximum summer water temperatures of approximately 20ºC and winter minimum temperatures of approximately 10ºC. Methyl mercury sediment concentrations in the Bay-Delta have been found to be elevated during periods of warm water temperatures (Heim *et al.* 2003).

Stimulation of microbial activity and any resultant production of methyl mercury is dependent in part on the availability of organic carbon. Numerous field-based studies have suggested that methyl mercury is positively correlated with organic carbon in sediments (Choi and Bartha 1994, Hurley *et al.* 1998, Krabbenhoft *et al.* 1999 cited in Heim *et al.* 2003). In addition, lab based studies have shown that methyl mercury production is positively correlated to organic carbon (Olson and Cooper 1976, Furutani and Rudd 1980, Wright and Hamilton 1982, Lee and Hultberg 1990 cited in Heim *et al.* 2003).

In freshwater systems, it is clear that an increase in sulfur concentration increases sediment sulfate-reduction rates (Rudd *et al.*, 1986 cited in Jones and Slotten 1996). However, there appears to be a window of sulfate concentration that promotes the highest mercury methylation rate. Optimum mercury methylation by sulfate reducing bacteria in sediments is at 200-500 mM (millimoles per liter). Above this range, the formation of insoluble sulfide compounds appears to inhibit methylation. This range is below the concentration of sulfate in marine waters that are also highly buffered compared to freshwaters. In marine environments, there is still a question as to whether sediment mercury is the source of methyl mercury that can be bioaccumulated, in part because it is probable that the reactions controlling the methylation of mercury in sediment and water are different (Gilmour and Henry, 1991). In marine waters, vigorous sulfide formation probably inhibits the methylation of mercury (Jones and Slotten 1996).

pH

The pH of inland surface waters has been found to dramatically affect the amount of mercury taken up by biota (Gilmour and Henry 1991 cited in Jones and Slotten 1996). Specifically, mercury in fish tissue is present predominantly as methyl mercury, so changes in the biogeochemistry of this compound of mercury may account for any increase in bioaccumulation. It has been determined that inorganic mercury binds to organic matter more strongly as the pH declines (Schindler *et al.* 1980 cited in Jones and Slotten 1996), thus decreasing mercury's solubility. Conversely, in sediments a lower pH may increase the solubility of HgS (Ramal *et al.* 1995 cited in Jones and Slotten 1996). Alkalinity and pH affect the biogeochemistry of mercury in numerous ways, including the binding capacity of the various species, the rate of methyl mercury production, and even the uptake efficiency of methyl mercury by aquatic organisms (Cope *et al.* 1990; Slotton 1991 cited in Jones and Slotten 1996). The most important result of these combined effects is that methyl mercury is produced, transported, and accumulated by aquatic organisms significantly more efficiently at low alkalinity and pH; i.e., conditions to the acidic side of neutrality ($<$ pH 7) (Winfrey and Rudd 1990 cited in Jones and Slotten 1996). In California, the naturally moderate to high alkalinity of surface waters maintains the pH at levels typically well above acidic conditions. This is very fortunate, in light of the bulk mercury contamination that supplements global loads in many parts of the Bay-Delta watershed. Under prevailing conditions of high alkalinity and above neutral pH, even grossly contaminated water bodies such as Clear Lake frequently do not demonstrate edible fish mercury levels dramatically higher than those from relatively unpolluted, but acidic, waters. With hypothetical lower levels of alkalinity and pH, surface waters with bulk mercury contamination (i.e., much of the San Francisco Bay-Delta watershed) could be expected to develop fish mercury accumulations far above those seen today (Jones and Slotten 1996).

Percent Fines
In aquatic sediments, mercury and other heavy metal contamination is most strongly correlated with the proportion of fine particles. This is particularly the case when the heavy metal load entering the system is largely in a very diffuse, molecular form, such as in atmospheric deposition, mine leakage of dissolved metals, and direct introduction to the environment of liquid or vaporized elemental mercury. Fine sediment particles contain a disproportionate amount of surface area and adsorption sites and, thus, tend to accumulate far greater concentrations of diffuse heavy metals than do larger sediment particles such as sand and gravel. In local research at a Sierra Nevada foothill reservoir, bottom sediment concentrations of mercury, as well as copper, zinc, and cadmium, were found to increase exponentially at average sediment grain sizes of less than 24 micrometers (Slotton *et al.* 1994; Slotton and Reuter 1995 cited in Jones and Slotten 1996). In addition to largely determining the concentration of mercury in the sediments, sediment particle size also affects the diffusion of oxygen, minerals, and ions which therefore affects bacterial activity and the production of methyl mercury (Jones and Slotten 1996).

Methylation Trends by Habitat Type

The most important sites of microbial methylation in the Bay-Delta ecosystem are expected to be at oxic-anoxic interfaces in sediments, wetlands, and seasonally inundated, vegetated habitats that provide the necessary conditions for sulfate reducing bacteria (St. Louis *et al.* 1994, Hurley *et al.* 1995, Kelly *et al.* 1997, Gilmour *et al.* 1998 cited in Wiener *et al.* 2003).

Within the Delta, marshes seem to be more significant sites of methyl mercury production than open-water sediments. Slotten *et al.* (2003) found that sediment methyl mercury concentrations and methyl mercury to total mercury ratios were significantly greater in highly vegetated marsh habitats as compared to adjacent Delta channel and mudflat environments. Methylation potential experiments showed that flooded wetland sediments exhibited 2-30 times greater potential to produce methyl mercury than aquatic sediments of adjacent channels and flats.

In addition to marshes, Heim *et al.* (2003) identified farmed wetlands as an important source of methyl mercury as the percent coverage of this habitat type was large with respect to the total area of the delta and the methyl mercury concentrations were measured to be relatively high compared to other habitat types (see Table 4.4-4).

Other studies have shown that newly flooded wetlands and reservoirs experience an increase in methyl mercury production (Bodaly *et al.* 1993, Kelly *et al.* 1995, Kelly *et al.* 1997 cited in Heim *et al.* 2003). Kelly *et al.* (1997 cited in Heim *et al.* 2003) concluded that the large increases in methyl mercury concentrations were a result of increased net production of methyl mercury, rather than release of methyl mercury that was in the wetland prior to flooding. The increase in methyl mercury at these newly flooded areas was determined to be likely linked to increased microbial activity in response to a change in environmental conditions. Three changes in environmental conditions known to stimulate methylation of mercury are: 1) sudden death of vegetation supplying a large amount of organic carbon to become available for decomposition, 2) high decomposition leading to an increase in anaerobic habitat, and 3) mercury methylation stimulated by increased temperature.

Table 4.4-4
Methyl Mercury Concentrations by Habitat Type in the Bay-Delta

Habitat Type	Area (sq. km.)	Methyl mercury (ng/g^{-1})
Upland	3,751	0.19 ± 0.03
Riparian Woodland	41	0.24 ± 0.08
Mudflats	3	0.50 ± 0.32
Open Water	238	0.54 ± 0.06
Seasonal Wetlands	167	0.55 ± 0.06
Framed Wetlands	1,447	0.71 ± 0.20
Lakes and Ponds	35	1.26 ± 0.43
Marsh	51	1.46 ± 0.35
Total	5,733	

Source: Heim *et al.* 2003

Heim *et al.*'s (2003) investigation of wetlands to determine if methylation potentials were higher in the interior than adjacent waterways demonstrated clear patterns in both methyl mercury concentrations and the methyl mercury to total mercury ratios. Methyl mercury concentrations at the interior of all marsh areas studied were higher than concentrations at the exterior of the marshes. In addition, the methyl mercury to total mercury ratios were highest at the interior of the wetlands studied.

Mercury Cycling

The internal cycling of mercury and methyl mercury within the ecosystem is only beginning to be understood. The dominant loss terms for mercury in the Bay-Delta ecosystem, based on the present state of knowledge, are processes of microbial and photo demethylation, burial in deposited sediment, emigration or harvest of contaminated biota, loss to agricultural fields, export to the ocean, export to southern California, and evasion to the atmosphere; the relative magnitude of these fluxes is poorly understood. In areas of the Delta where sediments from hydraulic mining are now being eroded (Jaffe *et al.* 1998b, Cappiella *et al.* 1999 cited in Wiener *et al.* 2003), sedimentation and burial of mercury are presumably negligible. Across the estuarine salinity gradient, there are apparent sources of total mercury and sinks of methyl mercury within the Delta (Foe 2002, Choe and Gill 2003, Choe *et al.* 2003 cited in Wiener *et al.*

2003). Roughly half of the waterborne methyl mercury in the estuary is associated with particles (Choe and Gill 2003 cited in Wiener *et al.* 2003). Waterborne total mercury and methyl mercury seem to be strongly associated with organic matter in the estuary (Choe and Gill 2003, Choe *et al.* 2003 cited in Wiener *et al.* 2003).

Gill *et al.* (2002) found that sediments appear to be a net source of methyl mercury to the water column. Stephenson *et al.* (2002), who employed a mass balance approach, suggests that the Delta is a sink for methyl mercury, due to photodemethylation or storage via bioaccumulation. Slotton *et al.* (2003) suggests that inorganic mercury newly delivered from upstream sources is more readily methylated and bioaccumulated than inorganic mercury stored in the Delta.

Both the proportions of total and dissolved mercury concentrations in the water and their absolute values can change due to shifts in the electrochemical potential of the sediment and/or water. Hydrological impacts such as the deposition of abnormally high volumes of silt, scouring, growth of algae or other oxygen-scavenging flora can dramatically alter mercury biogeochemistry and, consequently, the production, transformation, and concentration of the different mercury species (Jones and Slotten 1996).

Ecological Considerations

Bioaccumulation

Methylation of mercury is the key step in the entrance of mercury into food chains. Nearly 100% of the mercury that bioaccumulates in fish tissue is methylated. Mercury accumulates in an organism when the rate of uptake exceeds the rate of elimination. Although all forms of mercury can accumulate to some degree, methyl mercury accumulates to a greater extent than other forms of mercury. Inorganic mercury can also be absorbed but is generally taken up at a slower rate and with lower efficiency than is methyl mercury. Elimination of methyl mercury takes place very slowly resulting in tissue half-lives (i.e., the time in which half of the mercury in the tissue is eliminated) ranging from months to years. Elimination of methyl mercury from fish is so slow that long-term reductions of mercury concentrations in fish are often due mainly to growth of the fish. By comparison, other mercury compounds are eliminated relatively quickly resulting in reduced levels of accumulation (EPA 1997). Inorganic mercury, in contrast to methyl mercury, is not readily transferred through successive trophic levels and does not biomagnify in food webs.

Methyl mercury production and accumulation in the freshwater ecosystem is an efficient process for accumulating mercury which can then be ingested by fish-eating (piscivores) birds, animals and people. In addition, methyl mercury generally comprises a relatively greater percentage of the total mercury content at higher trophic levels. Accordingly, mercury exposure and accumulation is of particular concern for animals at the highest trophic levels in aquatic food webs and for animals and humans that feed on these organisms (EPA 1997).

Methyl mercury readily crosses biological membranes and accumulates to concentrations in aquatic organisms that vastly exceed concentrations in ambient surface waters; for example, concentrations in fish commonly exceed those in the water in which they reside by a factor of 106 to 107. Concentrations of methyl mercury in fish increase with increasing age or size, because of the very slow rate of elimination relative to the rate of uptake (Wiener *et al.* 2003).

Biomagnification of methyl mercury in aquatic food webs has been widely documented, and patterns of biomagnification are similar even in aquatic systems that are different in ecosystem characteristics, mercury source, and intensity of pollution (Wiener *et al.* 2003). The concentration of methyl mercury increases up the food web from water and lower trophic levels to fish and piscivores, and the fraction of mercury present as methyl mercury also increases with increasing trophic level through fish. The fraction of mercury present as methyl mercury can vary greatly in organisms, such as aquatic macroinvertebrates, in trophic levels below fish. The abundance of methyl mercury in the lower trophic levels is strongly correlated with the supply of methyl mercury. In fish within a given trophic level, spatial variation in mercury levels is also strongly influenced by variation in the net production of methyl mercury and its entry into the base of the food web. Concentrations of methyl mercury in fish increase with increasing trophic position, and variation in trophic position accounts for much of the local variation in mercury tissue concentrations, both within and among species within a given water body. Thus, ecological factors, such as feeding relations and food-chain length, can strongly affect methyl mercury exposure in biota atop aquatic food webs (Wiener *et al.* 2003).

The food chain pathway of methyl mercury through larger, piscivorous fish is of primary importance in consumption-related toxicity to higher order consumers, including humans (Jones and Slotten 1996). Concentrations of methyl mercury (quantified as total mercury) in several species of fish recently sampled from the Bay-Delta and tributary streams exceed 0.3 mg/kg (parts per million) wet weight (Slotton *et al.* 2002a, 2002b, Davis *et al.* 2003 cited in Wiener *et al.* 2003), a fish-tissue criterion established by the EPA for the protection of humans who eat noncommercial fish. Within a given species of fish or aquatic macroinvertebrate, there is substantial spatial variation in concentrations of methyl mercury in the Delta (Slotton *et al.* 2002a, 2002b, Davis *et al.* 2003 cited in Wiener *et al.* 2003), reflecting the influence of mercury sources, methylating environments, and other, unidentified processes or factors. The U.S. Fish and Wildlife Service recently completed an assessment on the 0.3 mg/kg methyl mercury criterion for tissue concentrations proposed by EPA in 2001 that indicated the criterion may not be adequately protective for wildlife from bioaccumulation and biomagnification up the food chain (USFWS 2003).

Human Health Concerns

The concern for human health stems primarily from mercury exposure through consumption of contaminated sport fish. Mercury is a neurotoxicant, and in humans is particularly hazardous for fetuses and children as their nervous systems develop. Mercury can cause many types of problems in children, including mental impairment, impaired coordination, and other developmental abnormalities. In adults, mercury has neurotoxic effects that include decrements in motor skills and sensory ability at comparatively low doses, to tremors, inability to walk, convulsions, and death at extremely high exposures (OEHHA 1994a). The U.S. Food and Drug Administration (FDA) action level, by which the California Office of Health Hazard Assessment (OEHHA) establishes fish consumption advisories, is 1.0 mg/kg as methyl mercury. OEHHA uses EPA's national recommended water quality criterion of 0.3 mg/kg methyl mercury as a screening value.

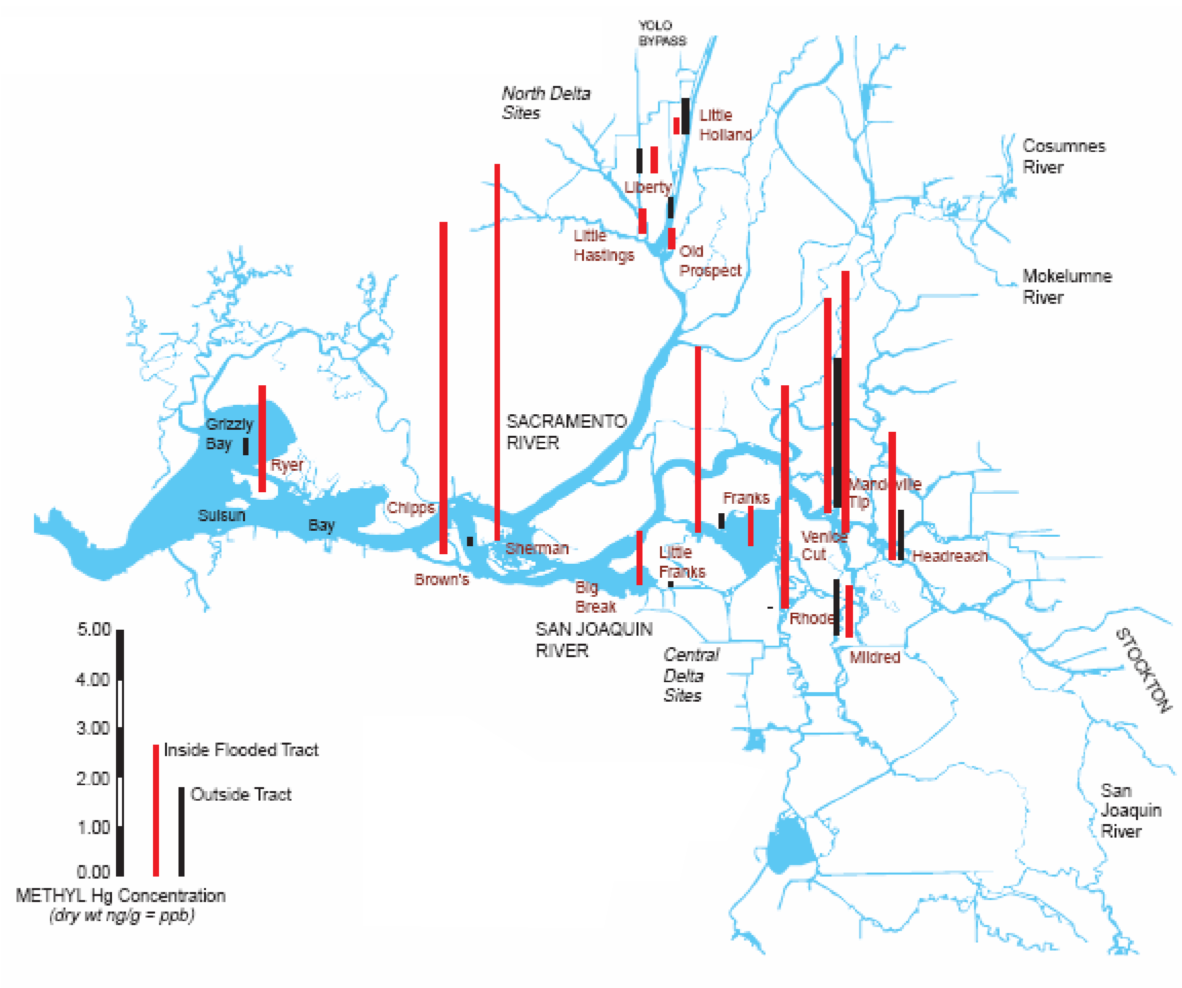
In 1970, a human health advisory was issued for the Delta advising pregnant women and children not to consume striped bass. The advisory was revised in 1993 upon review of more mercury data for striped bass. The revised advisory included size specific consumption advice for adults, children under 15 years, and pregnant women. Recent studies in the Bay-Delta watershed have continued to find mercury concentrations of potential human health concern in several popular sport fish species. Extensive sampling was conducted in San Francisco Bay in 1994 and 1997 (SFBRWQCB 1995 cited in Davis *et al.* 2003). In response to the 1994 results, an interim fish consumption advisory was issued for the Delta, largely due to concern over human exposure to methyl mercury (OEHHA 1994b).

Studies of mercury contamination in sport fish have also been conducted in freshwater portions of the Delta and its watershed. Sport fish sampling was conducted throughout much of the Delta (the "Delta Study") in the summer of 1998 (Davis *et al.* 2000 cited in Davis *et al.* 2003). This sampling focused on largemouth bass and white catfish, which had average mercury concentrations in composite samples from the Delta of 0.29 mg/kg wet weight and 0.27 mg/kg wet weight, respectively. Sport fish were also sampled in the Sacramento River under the Sacramento River Watershed Program (Larry Walker Associates 1999 cited in Davis *et al.* 2003) and in the San Joaquin River as part of the Delta Study. Average mercury concentrations in Sacramento River largemouth bass (0.65 mg/kg wet weight) and white catfish (0.43 mg/kg wet) were higher than the concentrations in these species in the Delta. The average concentration in San Joaquin River largemouth bass (0.49 mg/kg wet weight) was also elevated relative to the Delta. Overall, the freshwater sampling has detected concentrations that are frequently above the mercury screening value and generally similar to those for which consumption advice has been issued for the Delta (Davis *et al.* 2003).

SITE SPECIFIC TRENDS

Spatial trends in site specific mercury concentrations (total and methyl) and mercury bioaccumulation were identified in a study by Slotten *et al.* (2003). Seasonal trends in methyl mercury concentrations were identified by Heim *et al.* (2003). The results of the studies are summarized below.

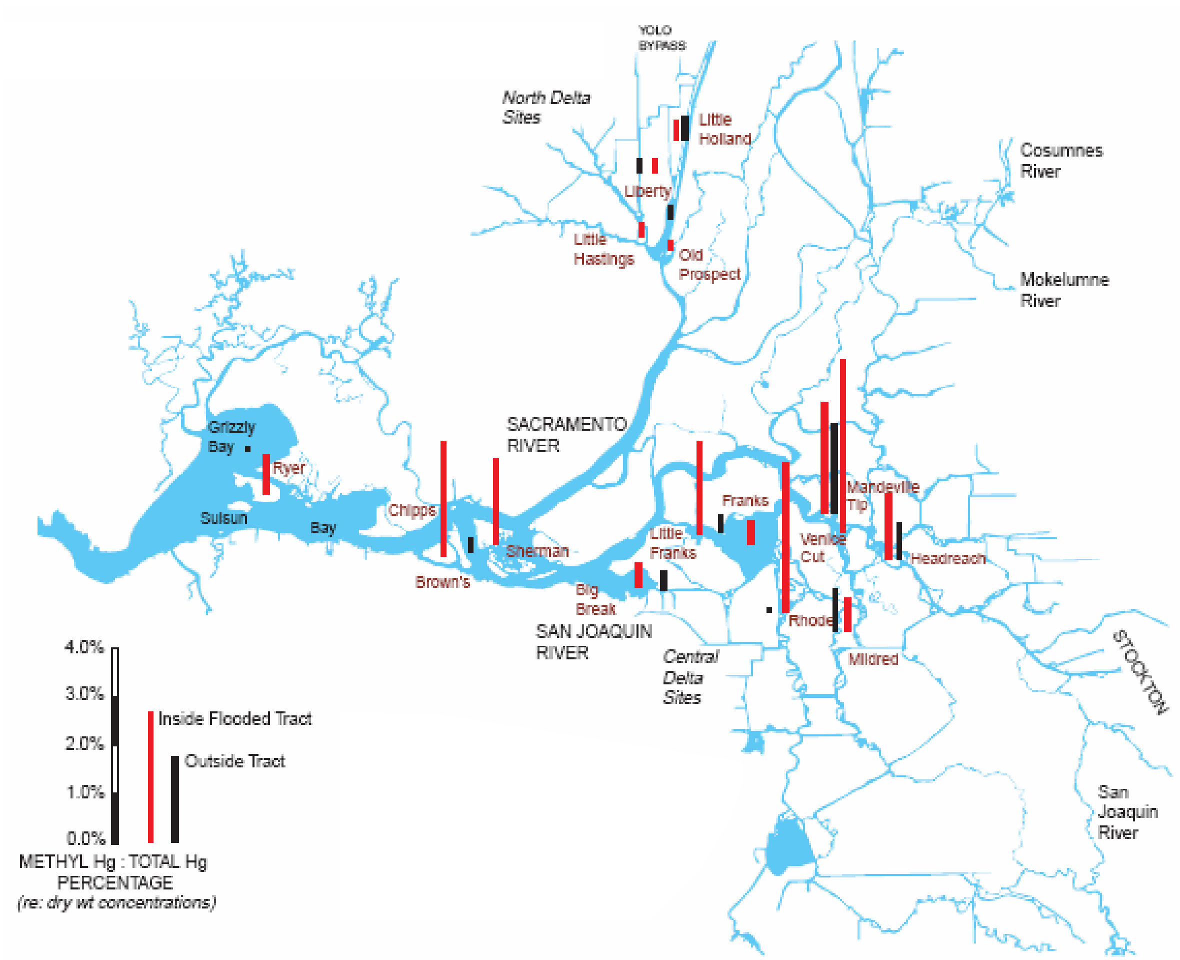
Sediment methyl mercury concentrations (Exhibit 4.4-9) and methyl mercury to total mercury ratios (Exhibit 4.4-10) were significantly greater in highly vegetated marsh habitats as compared to adjacent Delta channel and mudflat environments. Methylation potential experiments showed that flooded wetland sediments exhibited 2-30 times greater potential to produce methyl mercury than aquatic sediments of adjacent channels and flats (Exhibit 4.4-11) (Slotten *et al.* 2003).



Source: Slotten et al. 2001

Sediment Methyl Mercury in Paired Inside/Outside Delta Flooded Tracts

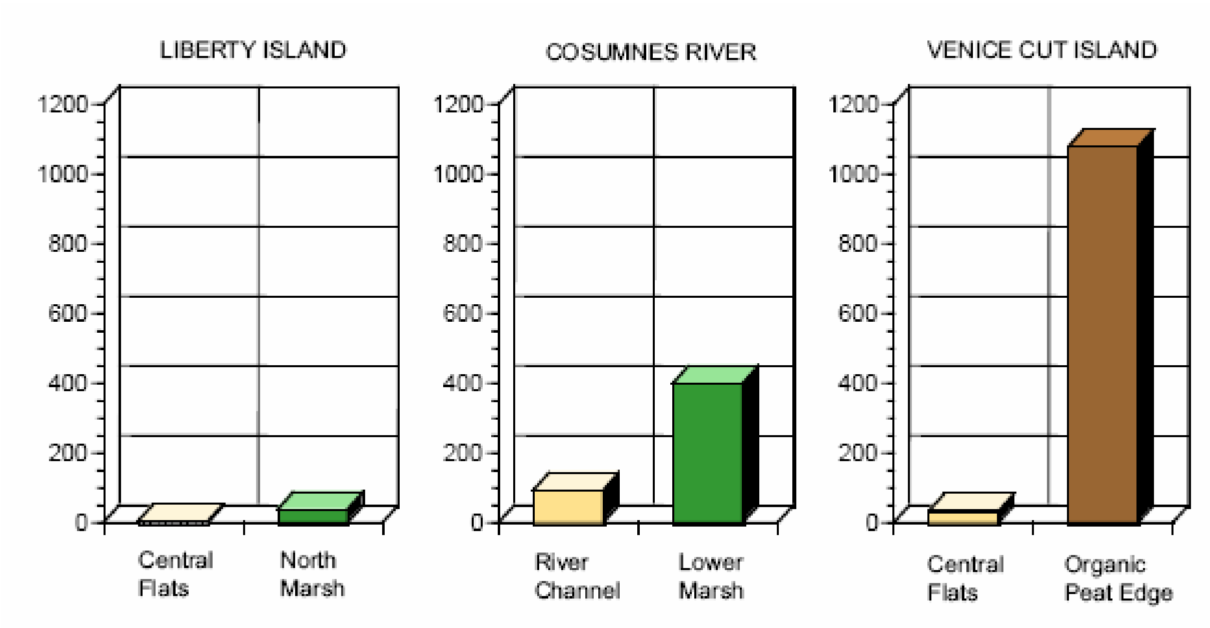
EXHIBIT 4.4-9



Source: Slotten et al. 2001

Sediment Methyl Mercury: Total Mercury Percentage in Paired Inside/Outside Delta Flooded Tracts

EXHIBIT 4.4-10



Source: Slotten et al. 2001

Relative Mercury Methylation Potential of Representative Delta Marsh Habitats vs. Adjacent Aquatic Habitat

EXHIBIT 4.4-11

However, biological findings (Exhibits 4.4-12 and 4.4-13) indicate no distinct localized increase in net methyl mercury bioaccumulation in flooded wetland tracts vs. adjacent aquatic habitats within Delta sub-regions. Some of the most well developed, highly vegetated wetland tracts exhibited reduced levels of localized net mercury bioaccumulation. These results suggest that wetland restoration projects may result in localized mercury bioaccumulation at levels similar to, but not necessarily greater than, levels within their surrounding Delta sub-region (Slotten *et al.* 2003).

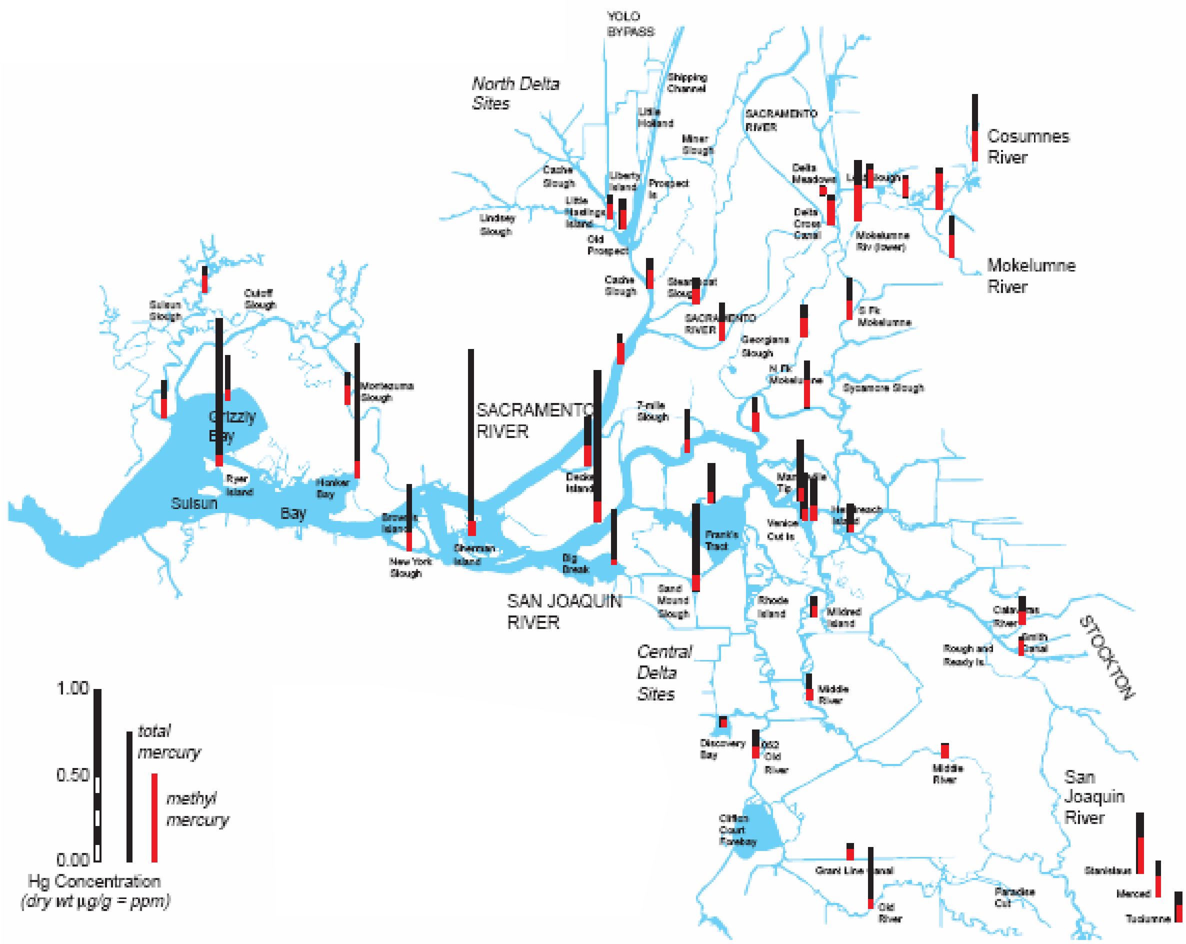
On a larger spatial scale, though, significant differences in bioaccumulation were identified across the Delta (Exhibits 4.4-12 and 4.4-13). Delta locales with elevated biotic mercury concentrations included areas fed by inflows from the Cosumnes River, Yolo Bypass and, to a lesser extent, Sacramento River. The central and south Delta were noticeably lower, despite high signals in some southern tributaries to the San Joaquin River and the presence of numerous flooded tracts in the central Delta including Franks Tract. An additional zone of elevated mercury bioaccumulation was identified in the west Delta between the Sacramento-San Joaquin confluence and Carquinez Strait (just downstream from Lower Sherman Lake and Big Break), potentially resulting from historic mining depositional patterns and/or coincidence with the estuarine entrapment zone. Potential mechanisms for this apparent west Delta elevation in mercury bioaccumulation include elevated sulfate and organic material, supporting methylating microbes, and chemistry of the neutral form of inorganic mercury potentially being more readily transported across microbial membranes. Apart from the west Delta zone of elevated mercury bioaccumulation, the primary regions of elevated biotic mercury that were identified in this work can all be characterized as being dominated by ongoing new inflows of mercury from upstream San Francisco Bay-Delta tributaries. Inputs of elemental mercury from historic gold mining in the Sierra Nevada and abandoned mercury mine cinnabar in the Coast Range appear to be of importance (Slotten et al. 2003).

Franks Tract

Water quality and mercury (total and methyl) concentrations at Franks Tract are influenced by two primary sources, Delta inflow via the San Joaquin and Old rivers and tidal mixing.

Total mercury and methyl mercury concentrations and methyl mercury potential (ratio of methyl mercury to total mercury) in Franks Tract are illustrated in Exhibits 4.4-9 and 4.4-10 (Slotten *et al.* 2003). The large open water area of the study area has lower concentrations and lower methylation potential than many of the surrounding sites. However, the Little Franks Tract portion (west portion of the Franks Tract site) of the site has noticeably higher sediment concentrations and methyl mercury potential.

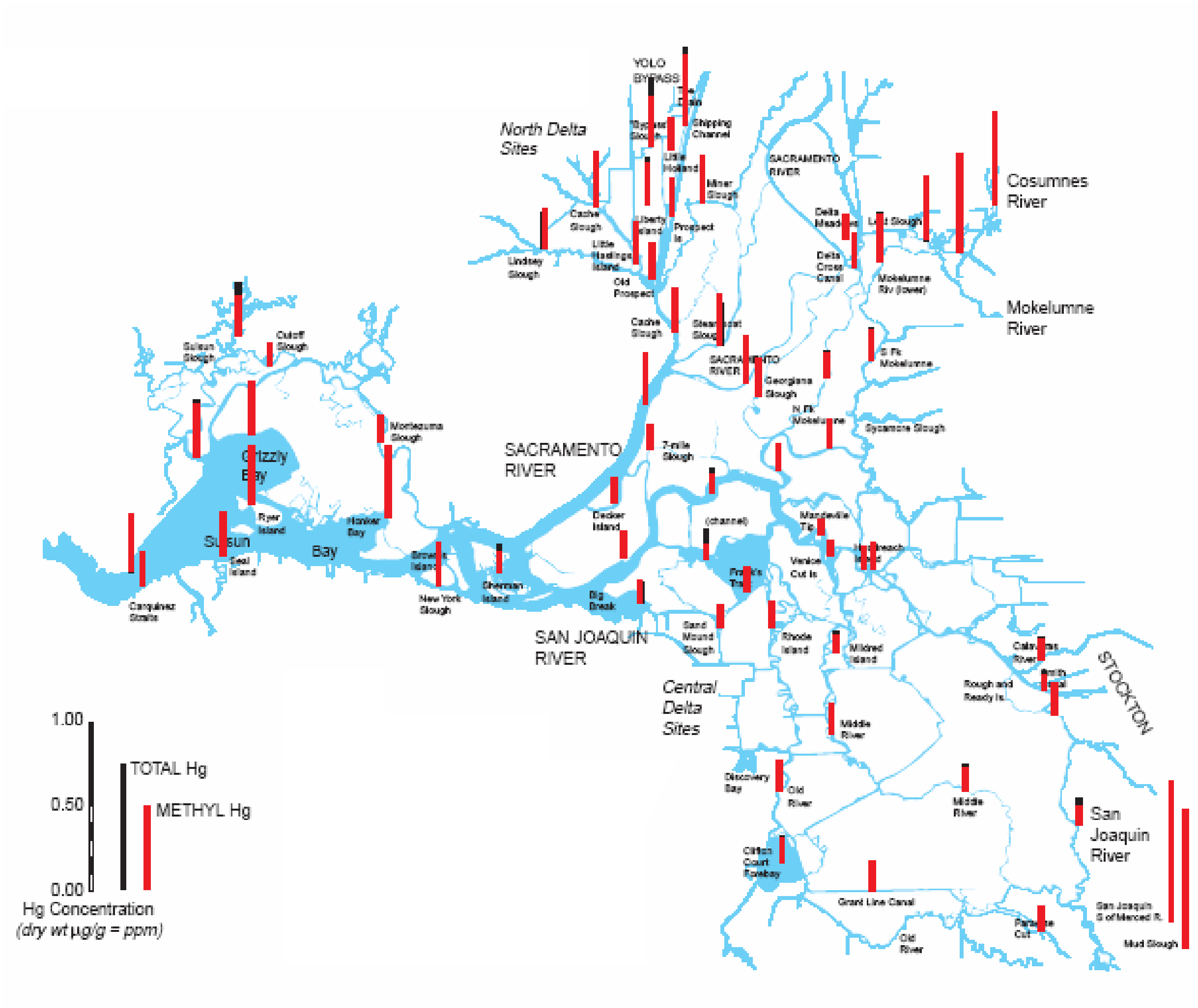
Bioaccumulated concentrations of mercury in *corbicula* clams and inland silversides (fish) in Franks Tract are comparable or lower compared to several surrounding sites in the central Delta (Exhibits 4.4-12 and 4.4-13).



Source: Slotten et al. 2001

Corbicula (Asiatic Clam) Methyl and Total Mercury

EXHIBIT 4.4-12



Source: Slotten et al. 2001

Inland Silversides Total and Methyl Mercury

EXHIBIT 4.4-13

Aqueous methyl mercury concentrations (normalized to suspended particulates) in paired inflowing and outflowing tidal water indicates that the larger open water portion Franks Tract has approximately double the concentration in outflowing than inflowing tidal water. Samples of outflowing water from Little Franks Tract had considerably higher concentrations compared to Franks Tract proper. Both measurements illustrate that Franks Tract is a net source for aqueous methyl mercury to surrounding waterways (Exhibit 4.4-14).

Seasonal Trends

Solid-phase methyl mercury showed distinct seasonal patterns at locations within the central Delta. Methyl mercury concentrations at Franks Tract are elevated twice per year. The largest peak occurred during summer and the smaller peak occurred over winter. The winter peak, although lesser in magnitude (approx. 2 μg/L), was generally a longer lasting feature (3-4 months), while the summer peak reached a maximum (approx. 6 μg/L) and decreased within 1-2 months (Heim *et al.* 2003).

No summer peak was found at Franks Tract during the summer of 2000, perhaps as a result of the sampling frequency. The sampling frequency was once per month at Franks Tract during the summer of 2000, and it is probable that this interval allowed the summer peaks to go undetected. The 2001 summer peak at Franks Tract occurred very rapidly, and sampling twice per month was necessary to capture the event (Heim *et al.* 2003).

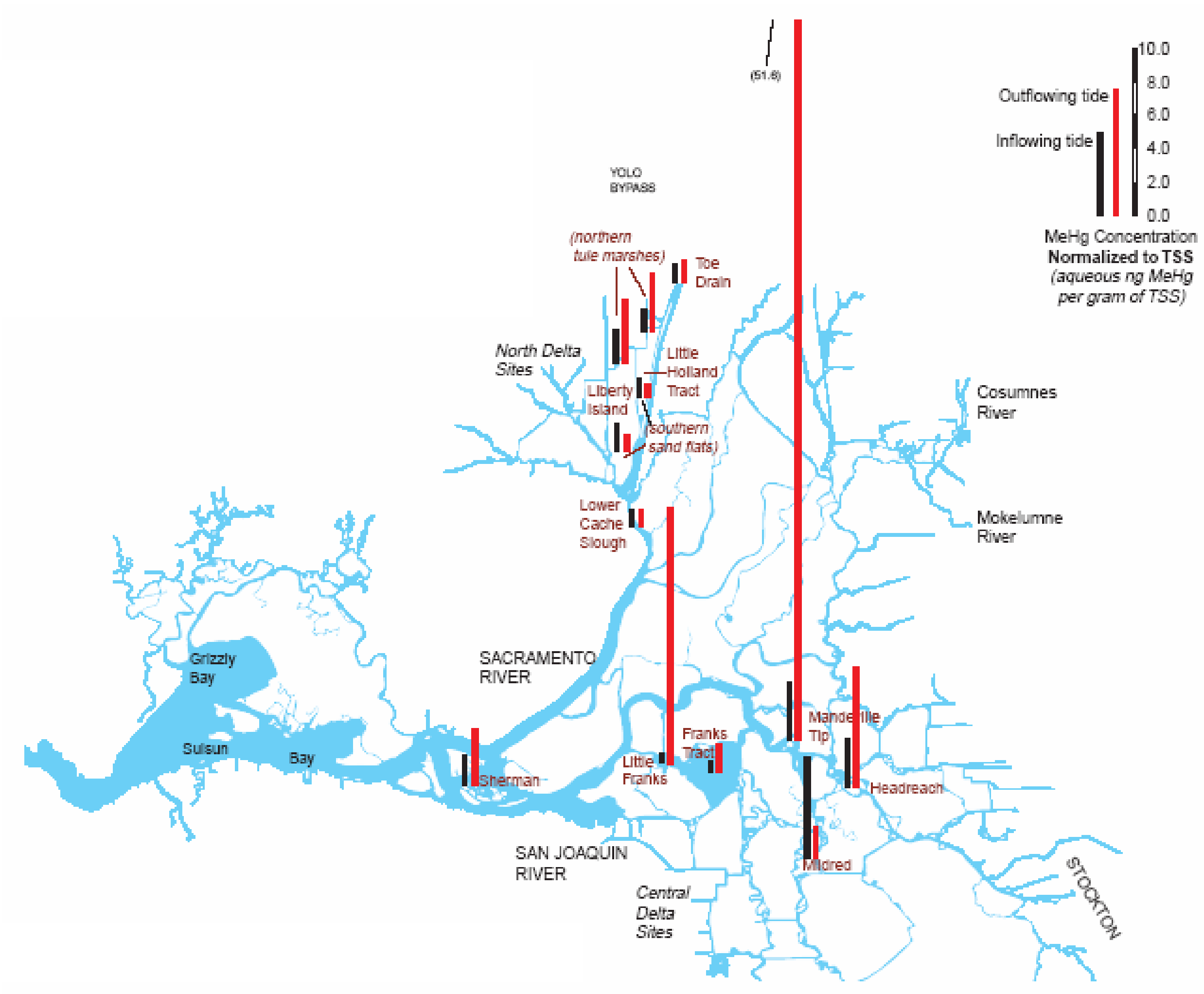
Lower Sherman Lake

Overall water quality and mercury concentrations at Lower Sherman Lake are influenced by two primary sources, Delta inflow via the Sacramento and San Joaquin rivers and tidal influence.

In the general Sherman Island area (at the convergence of the Sacramento and San Joaquin rivers) methyl mercury concentrations have been measured to be as high as many of the central Delta sites (see Exhibit 4.4-9) (Heim *et al.* 2003). Methyl mercury potential also has been measured to be high relative to other sites in the western Delta.

Bioaccumulated concentrations of mercury in *Corbicula* clams at Sherman Island are relatively high compared to sites throughout the entire Delta and comparable to other sites in the western Delta (Exhibit 4.4-12). Bioaccumulated concentrations in inland silversides are comparable or lower compared to many of the surrounding sites in the western Delta (Exhibit 4.4-13).

Aqueous methyl mercury concentrations in paired inflowing and outflowing tidal water indicate that Sherman Island is also a net source for aqueous methyl mercury to surrounding waterways, although not nearly at the levels that were measured at Franks Tract (Exhibit 4.4-14).



Source: Slotten et al. 2001

Aqueous Methyl Mercury in Paired Inflowing vs. Outflowing Tidal Water in Delta Flooded Tracts

EXHIBIT 4.4-14

Seasonal Trends

Sherman Island had an extended period of elevated methyl mercury concentration summer and fall of 2000, followed by a decrease in concentration throughout the remainder of the study (Heim *et al.* 2003).

At Sherman Island, total mercury concentrations were found to be higher during the first half of the study and generally decreased throughout the second half of the study; a similar trend was found for methyl mercury. Total mercury concentrations were also more variable compared with the central Delta. The variable concentrations at Sherman Island may be the result of mean grain size among samples due to the high water flow and scoured bottom conditions that characterize this location (Heim *et al.* 2003).

Big Break

Water quality at Big Break is influenced by three primary sources, Delta inflow via the San Joaquin River, Marsh Creek inflow via Dutch Slough, and tidal forces.

Marsh Creek inflow is affected by natural mercury deposits and associated mining activity near Mt Diablo in the upper watershed. In 1995, a mercury study was undertaken in the Marsh Creek watershed (Jones and Slotten 1996). The research was conducted to identify and quantify mercury sources and local aquatic bioavailability. All significant tributaries were sampled. The small drainage was found to export 10-20 grams of mercury per day, with greater amounts during actual storm events. Mass balance calculations indicated that about 95% of the entire watershed's mercury load originated from the Mount Diablo mining area; about 93% of this was from a relatively small patch of exposed mine tailings. Most of the mercury exported from the mine was found to have initially left the site in dissolved form, highly mobile, and potentially more easily methylated by bacteria than cinnabar particles. Bioaccumulation studies indicated that aquatic organisms immediately below the mine tailings had the highest tissue concentrations in the watershed. Small invertebrates contained up to approximately 100 times the 0.3 mg/kg health guideline concentration of mercury for edible fish. Body burdens fell with increasing distance from the mining area, but were significantly elevated above upstream, control levels for the 10 miles downstream to Marsh Creek Reservoir, where they were also significantly elevated (Jones and Slotten 1996). Below Marsh Creek Reservoir, mercury levels were found to be significantly decreased. The reservoir appears to trap sediments and act as a sink for the mercury.

At the Big Break site, methyl mercury concentrations were noticeably lower than most of the surrounding central and western Delta sites (see Exhibit 4.4-9) (Heim *et al.* 2003). Methyl mercury potential was also low relative to other sites in the central and western Delta (Exhibit 4.4-10).

Bioaccumulated concentrations of mercury in *Corbicula* clams at Big Break were relatively low compared to sites throughout the western Delta (Exhibit 4.4-12). Bioaccumulated concentrations in inland silversides were equivalent to sites in the western Delta and generally lower than many of the sites measures in the central Delta (Exhibit 4.4-13).

Aqueous methyl mercury concentrations in paired inflowing and outflowing tidal water were not measured at the Big Break site (Exhibit 4.4-14).

Seasonal Trends

No specific seasonal data was available for the Big Break site; therefore, trends were not identified.

4.4.4 OTHER WATER QUALITY ISSUES

In addition to the water quality issues discussed above, the lower Sacramento and San Joaquin river drainages and Delta are affected by several other elements, compounds, and general issues. The existing water quality problems of the Delta may be generally placed in the categories of toxic materials, suspended sediments and turbidity, eutrophication and associated dissolved oxygen fluctuations, and bacteria. Each of these broad categories is discussed briefly below.

TOXIC CHEMICALS

Toxic chemicals have impaired water quality in many Delta waterways. High concentrations of some metals from point and nonpoint sources appear to be ubiquitous in the Delta. In addition to mercury (discussed above), high levels of other metals (i.e., copper, cadmium, and lead) in Delta waters are also of concern. Additionally, in localized areas of the Delta (e.g., near Big Break and Lower Sherman Lake, and in Mormon Slough), fish tissues contain elevated levels of dioxin as a result of industrial discharges (SWRCB 1999).

Pesticides are found throughout the waters and bottom sediments of the Delta. High levels of chlordane, toxaphene, and DDT from agricultural discharges impair aquatic life throughout the Delta, while diazinon can be found in elevated concentrations at various locations. The more persistent chlorinated hydrocarbon pesticides are consistently found throughout the system at higher levels than the less persistent organophosphate compounds. The sediments having the highest pesticide content are found in the western Delta (Lower Sherman Lake and Big Break). Pesticides have concentrated in aquatic life in the Delta, and the long-term effects are unknown. The effects of intermittent exposure of toxic pesticide levels in water and of long-term exposure to these compounds and combinations of them are likewise unknown (SWRCB 1999).

SUSPENDED SEDIMENTS

Suspended sediments (silts, clays, and organic matter) are abundant in the Delta and cause turbidity throughout the region. Most of these sediments enter the tidal system with the flow of the major tributary rivers. Some enriched areas are turbid as a result of planktonic algal populations, but inorganic turbidity tends to suppress algal populations in much of the Delta. Continuous dredging operations to maintain deep channels for shipping have contributed to turbidity problems and are a factor in the temporary destruction of bottom organisms through displacement and suffocation (SWRCB 1999).

EUTROPHICATION AND DISSOLVED OXYGEN

The most serious enrichment problems in the Delta (which can lead to eutrophication and low dissolved oxygen) are found upstream of the study areas along the lower San Joaquin River near Stockton and in certain localized areas receiving waste discharges but having little or no net freshwater flow. Low dissolved oxygen levels result in these areas mainly in late summer and coincide with low river flows and high temperatures. Dissolved oxygen problems can be further aggravated by channel deepening for navigational purposes. The resulting depressed dissolved oxygen levels have not been sufficient to support fish life and, therefore, prevent fish from moving through the area. In autumn, these conditions, together with reversal of natural flow patterns by CVP/SWP export pumping, have created environmental conditions unsuitable for the passage of anadromous fish (chinook salmon) from the Delta to spawning areas in the San Joaquin Valley. Flow augmentation in the San Joaquin River in the vicinity of Stockton would occur if South Delta channel barriers are constructed by DWR as part of the Interim South Delta Program (SWRCB 1999).

Warm, shallow, dead-end sloughs of the eastern Delta support populations of planktonic blue-green algae during summer months. Floating and semi-attached aquatic plants, such as water primrose and water hyacinths, frequently clog waterways in the lower San Joaquin River system during the summer. Extensive growths of these plants have also been observed in other Delta waterways. These plants interfere with the passage of small boat traffic and contribute to the total organic load (including carbon) in the Bay/Delta system (SWRCB 1999).

BACTERIA

The bacteriological quality of Delta waters, as measured by the presence of coliform bacteria, varies depending upon proximity of waste discharges and significant land runoff. The highest concentrations of coliform organisms are generally found in the western Delta. However, in other areas, high concentrations often can be found in the vicinity of major municipal waste discharges.

4.4.5 SUMMARY OF MAJOR POINTS

SALINITY

- All three project sites are located in the central and western Delta, and thus the surrounding Delta channels are exposed to a range of salinity conditions from freshwater to brackish levels.

- The location, geometry, and presence of breach locations on Franks Tract result in saline water being trapped within the island that is then subject to hydrodynamic forces that cause salt transport further into the southern Delta where it may contribute to source water degradation for Delta water users.

< Flow from the Sacramento River through Lower Sherman Lake into the San Joaquin River occurs via the existing breaches. The flow may contribute to substantially reduce salinity levels in the southern Delta than would otherwise occur without the breaches.

ORGANIC CARBON

< Delta inflows, island drainage discharges, miscellaneous waste discharges, and in-channel processes all contribute to organic carbon cycling and associated ecosystem effects and contaminant potential of Delta source waters used for drinking water. The relative importance of each at any given time depends on many variables including location, sources loads, channel flows, tides, and biological processes. River sources of organic carbon appear to dominate in the winter. Biological processes (phytoplankton growth) in the Delta appear to dominate in the spring and summer.

< DOC varies considerably in quality. It is a complex heterogenous mixture of organic molecules with different molecular weights, solubilities, polarities, reactivities, and bioavailability potential.

< DOC quality varies considerably among sources and in Delta channels is not a simple mixture of DOC from the rivers and DOC in the agricultural drains.

< The quality of the DOC is as important as the quantity in affecting primary (planktonic) productivity in the food web and THM formation potential in exports. In-channel phytoplankton productivity is now considered to be the most important food source of zooplankton.

< The importance of peat soils highlights the potential significance of wetland restoration to water quality issues. Flooding islands with peat soils for restoration purposes inundates remaining peat soils and reestablishes the same tidal wetland processes that led to the formation of such soils over time.

MERCURY

< In-Delta methyl mercury formation processes may be as important of a factor to ecosystem exposure and uptake in the food chain as the much larger overall riverine inputs of mineralized forms.

< Coastal mountain streams have been found to have two orders of magnitude higher total mercury concentrations than Sierra mountain streams and the methyl mercury concentration patterns were equivalent.

< The highest methyl mercury sediment concentrations have been found in the central Delta. The central Delta had the greatest mercury methylation potential when compared to the surrounding tributaries.

< Solid phase methyl mercury concentrations vary seasonally with highest concentrations occurring during late spring/summer.

< Interiors of wetlands consistently have had higher solid phase methyl mercury concentrations and methyl mercury to total mercury ratios than fringes of wetlands or open water habitats.

< Findings suggest that dense wetlands may export methyl mercury to surrounding channels.

< Distribution of fish and clams with similar methyl mercury tissue concentrations suggests that hydrodynamic action is spreading methyl mercury concentrations through the Delta.

4.5 AQUATIC, WETLAND, AND TERRESTRIAL VEGETATION AND HABITATS

This section describes the marsh formation processes in the Delta that are applicable to all three study areas. The section continues with descriptions of the various habitat types in the Delta that may be found on the project site given changes in hydrological and other processes, as well as existing habitat types found at each project site. The final topic in this section concerns special-status species found in the Delta and those reported at each of the study areas.

4.5.1 PROCESSES AFFECTING VEGETATION ESTABLISHMENT AND MARSH FORMATION IN THE DELTA

Historic tidal marshes in the Delta became established during a warming period approximately 7,000 to 10,000 years ago, when rising seawaters from melting glaciers reached the western Delta. As the rate of sea level rise decreased, equilibrium was reached between advancing waters and the rates of sedimentation and peat formation, which sustained the establishment and vertical growth of marsh vegetation (Atwater and Hedel 1976). Over time, the Delta developed into a complex network of rivers and sloughs with in-channel islands that supported a diverse assemblage of tidal marsh vegetation. The brackish and freshwater marshes common to the Delta were primarily vegetated by bulrush (*Scirpus* sp.), cattails (*Typha* sp.), and common reed (*Phragmites* spp.), which were often referred to by early botanists as "tule" marshes (Simensted et al. 2000).

Around the turn of the century (late 1800s to early 1900s), in-channel islands in the Delta were leveed for land reclamation and flood control. These levees disconnected the islands from tidal flooding, and agricultural crops replaced marsh vegetation. Subsequently, the peat soils created over thousands of years began to oxidize, resulting in significant subsidence of the interior islands (USGS 2000). Marshes not leveed for agriculture were affected by the state's large water projects that dammed rivers and regulated flows. The regulated flows of fresh water from the Sacramento and San Joaquin Rivers into the Delta reduced saltwater intrusion, thereby disrupting processes that supported brackish marsh (Atwater and Hedel 1976). Today, marsh habitat continues to erode owing to high flow velocities in the Delta's confined and deepened channels and waves generated by wind and watercrafts.

The formation and composition of tidal marsh communities are primarily regulated by two ecological factors. Elevation with respect to tidal fluctuation governs the initial establishment and lateral expansion of tidal marsh vegetation, and salinity levels influence the distribution and composition of species within the marsh (Atwater and Hedel 1976). Waters in the Delta generally have minimal salt concentrations, but brackish water may be present in the lower Delta in areas close to the Suisun Bay. Salinity levels in the soil are primarily driven by the interaction between the salinity concentration of tidal waters, local weather conditions, and the marsh vegetation itself (Atwater and Hedel 1976). Some marsh species increase soil salinity levels as salt stored within the plant is released to the soil following senescence and decomposition. The presence of a certain plant species within different marsh vegetation types is the result of individual physiological tolerances and interspecific competition (Josselyn 1983). In general, larger monocots inhabit the lowest marsh surfaces, which are inundated by most high tides, and surfaces at or above high-tide levels are dominated by broadleaf species and a few species of small monocots. Marshes flooded by fresh or brackish water support a more diverse assemblage of species that generally tolerate low-to-moderate salinity concentrations (Atwater and Hedel 1976).

An interdisciplinary team headed by the University of Washington's (UW) School of Fisheries is studying the effects of breached levees in the Delta. The BREACH team consists of university researchers from UW and the University of New Orleans, consultants, and ecologists from the California Department of Water Resources (DWR). This research focuses in part on natural rates of wetland restoration within these flooded areas to provide a conceptual model of the development of freshwater tidal wetland on subsided islands with breached levees (Simensted et al. 2000). Natural sediment accumulation rates were measured for islands that had subsided from approximately 3.5 to 7.5 feet. Results indicate that accumulation rates vary considerably. In some areas of the Delta, sedimentation rates were relatively high (e.g., 47–51mm/yr at Mildred Island and 44 mm/yr at Rhode Island), but in large, open water areas it appears that sediment accumulation may be hindered by forces causing erosion, such as high-velocity waves. At Lower Sherman Lake, Big Break, and Franks Tract, the large open-water habitat has persisted for over 60 years, and these areas may have reached a sort of open-water equilibrium where accumulation and erosion rates have become equal at an elevation significantly below the water's surface (see Section 4.1). Researchers also looked at what elevations, with respect to tide levels, were necessary for marsh vegetation to initially colonize and laterally expand. In general, researchers found that colonization of marsh vegetation requires higher elevations more so than lateral expansion. The median value for colonization was approximately +3.3 feet (ft) mean lower low water (MLLW), and lateral expansion averaged approximately –1 foot MLLW. The lowest value observed at the study sites for pioneer colonization was +1.3 feet MLLW, and lateral expansion occurred as low as –2 feet MLLW. However, these values were generated by data with significant levels of uncertainty, and additional research and monitoring are necessary to verify these results.

To assess lateral expansion rates, researchers performed a time series analysis of historical photographs. An assessment of Lower Sherman Lake indicated that during a 57-year period lateral marsh expansion advanced only in the most sheltered areas, and the highest expansion rates were approximately 5–10 feet/year. Researchers estimate that if this rate of expansion were to continue, it would take several hundred to 1,000 years for the open water area to become completely vegetated. Although vegetation reduces the potential for erosion and facilitates additional accumulation, these rates of lateral expansion are very slow. Marsh elevations at the breached study sites are significantly lower than those at reference sites, even though they have been vegetated for decades (Simenstad et al. 2000).

The flooded islands in the study area have deeply subsided soils, and it appears that they have reached some sort of open-water equilibrium and are not accumulating significant amounts of sediment. Evaluating the processes driving marsh formation is particularly important during restoration planning efforts, especially if particular species are targeted for restoration. The quality of habitat for a particular species can be strongly influenced by the presence of various plant species; therefore it is important that the factors responsible for different types of marsh formation and zonation patterns be incorporated into the restoration design process (Atwater and Hedel 1976).

4.5.2 Aquatic, Wetland, and Terrestrial Vegetation/Habitat Types

General Description

The Delta is a mosaic of vegetation and habitat types distributed along hydrological, salinity, and geomorphological gradients. Submerged and floating aquatic vegetation occurs within the open waters of rivers, sloughs, and lakes. Freshwater and brackish marshes develop where soils are shallow and frequently or permanently inundated, and riparian vegetation develops on higher elevations, such as levees and the banks of sloughs. The dominant vegetation types occurring in the study area include emergent tidal marsh, riparian scrub/woodland, and submerged and floating aquatic vegetation. Submerged and floating aquatic vegetation grows within open water habitat. Additionally, disturbed/developed areas are located on portions of Lower Sherman Lake and Big Break. Less apparent developed/disturbed areas may exist on Franks Tract as well. Current detailed information on vegetation and habitat types present in the study area is lacking. Field reconnaissance surveys should be conducted to adequately delimit and describe existing vegetation and habitat conditions.

Vegetation types described below are based on broad community descriptions, except where detailed information was available. Vegetation type names and descriptions are based on a compilation of Californian and wetland vegetation classifications (Cowardin et al. 1979, Sawyer and Keeler-Wolf 1995, Mayer and Laudenslayer 1988, and Holland 1986), but have been refined to reflect vegetation types documented in the Delta. To map vegetation and habitat boundaries, an aerial base map was scaled at 1 inch = 400 feet for each flooded island. Boundaries were hand-drawn onto these base maps and later digitized for entry into a Geographic Information System (GIS) database. Vegetation and habitat maps are presented for each flooded island in Exhibits 4.5-1 (Franks Tract), 4.5-2 (Big Break), and 4.5-3 (Lower Sherman Lake), but these have been scaled down for inclusion in this report. These vegetation and habitat boundaries are based solely on aerial interpretations and are conceptual. Field reconnaissance surveys will be necessary to ground-truth boundaries and locations of these vegetation and habitat types.

Emergent Tidal Marsh/Tidal Mudflat

Marsh habitat in the study area is dominated by emergent perennial vegetation growing in soils that are tidally submerged on a permanent to intermittent basis. The flooded islands in the study area support both tidally influenced brackish and freshwater marsh, but salt marsh may also be present. Vascular plants are the dominant plant life forms in tidal marshes and the location of these plants is commonly used to define marsh boundaries (Josselyn 1983). Elevation with respect to tidal inundation and salinity primarily regulates the distribution of freshwater, brackish, and salt marshes (Atwater and Hedel 1976). Cowardin et al. (1973) categorized tidally influenced areas as subtidal (permanently flooded), irregularly exposed (surface exposed on a less than daily basis), regularly flooded (alternately flooded and exposed at least once daily), and irregularly flooded (flooded less often than daily). On the Pacific Coast there are usually two unequal high and low tides each day, or a mixed semidiurnal tide pattern. In California, the boundary between regularly inundated and irregularly inundated hydrological regimes likely occurs at the lowest level of the higher high tide (Cowardin et al. 1979). Differences in salinity levels are reflected in the species composition of plants. The term brackish is generally applied to inland waters of intermediate salinity (Cowardin et al. 1979).

Most tidal brackish and freshwater marsh habitats in the Delta occur as narrow bands along island levees and small-to-large swaths on in-channel islands and along shorelines (CALFED 2000c). Five distinct plant associations are commonly found in tidal brackish marshes of the Delta: pickleweed series, saltgrass series, bulrush series, cattail series, and common reed series (CALFED 2000c). The bulrush, cattail, and common reed series are also characteristic of freshwater marsh. The following plant associations are based on vegetation classification units defined in *A Manual of California Vegetation* (Sawyer and Keeler-Wolf 1995).

The pickleweed series is dominated by the low-growing perennial herb pickleweed (*Salicornia* spp.), but also includes other halophytes such as alkali heath (*Frankenia salina*), arrow grasses (*Triglochin* spp.), dense-flowered cordgrass (*Spartina densiflora*), fat-hen (*Atriplex patula*), and saltgrass (*Distichlis spicata*). This association is generally less than 5 feet tall, and cover ranges from continuous to intermittent.

The saltgrass series is dominated by mostly homogenous stands of the perennial species saltgrass, but associates include alkali muhly (*Muhlenbergia asperifolia*), alkali sacaton (*Sporobolus airoides*), Baltic rush (*Juncus balticus*), common pickleweed (*Salicornia virginica*), and slender arrow-grass (*Triglochin concinna*). This plant association is fairly low-growing and the plant species typically do not grow higher than 3.5 feet. Cover can range from continuous to intermittent.

The bulrush series is dominated by a suite of bulrush species including California bulrush (*Scirpus californicus*), tule (*S. acutus*), common three-square (*S robustus*), broadleaf cattail (*Typha latifolia*), narrowleaf cattail (*T. angustifolia*), Nevada bulrush (*S. nevadensis*), river bulrush (*S. fluviatilis*), saltgrass, saltmarsh bulrush (*S. maritimus*), slenderbeaked sedge (*Carex athrostachya*), southern cattail (*T. domingensis*), and umbrella flatsedge (*Cyperus eragrostis*). This predominantly herbaceous plant association has species that reach heights up to 12 feet. Cover is generally dense, but can be variable.

The cattail series is dominated by three cattails: broadleaf cattail, narrowleaf cattail, and southern cattail. Associated species include those listed above for the bulrush series. The plants in this series are generally less than 13 feet tall. Cover is generally dense, but can be variable.

The common reed series is dominated by common reed (*Phragmites australis*), but emergent shrubs and trees may be present. This plant association may reach heights of 13 feet, and cover is typically continuous.

Sources: DWR 2002, EDAW 2004

Franks Tract Vegetation and Habitats

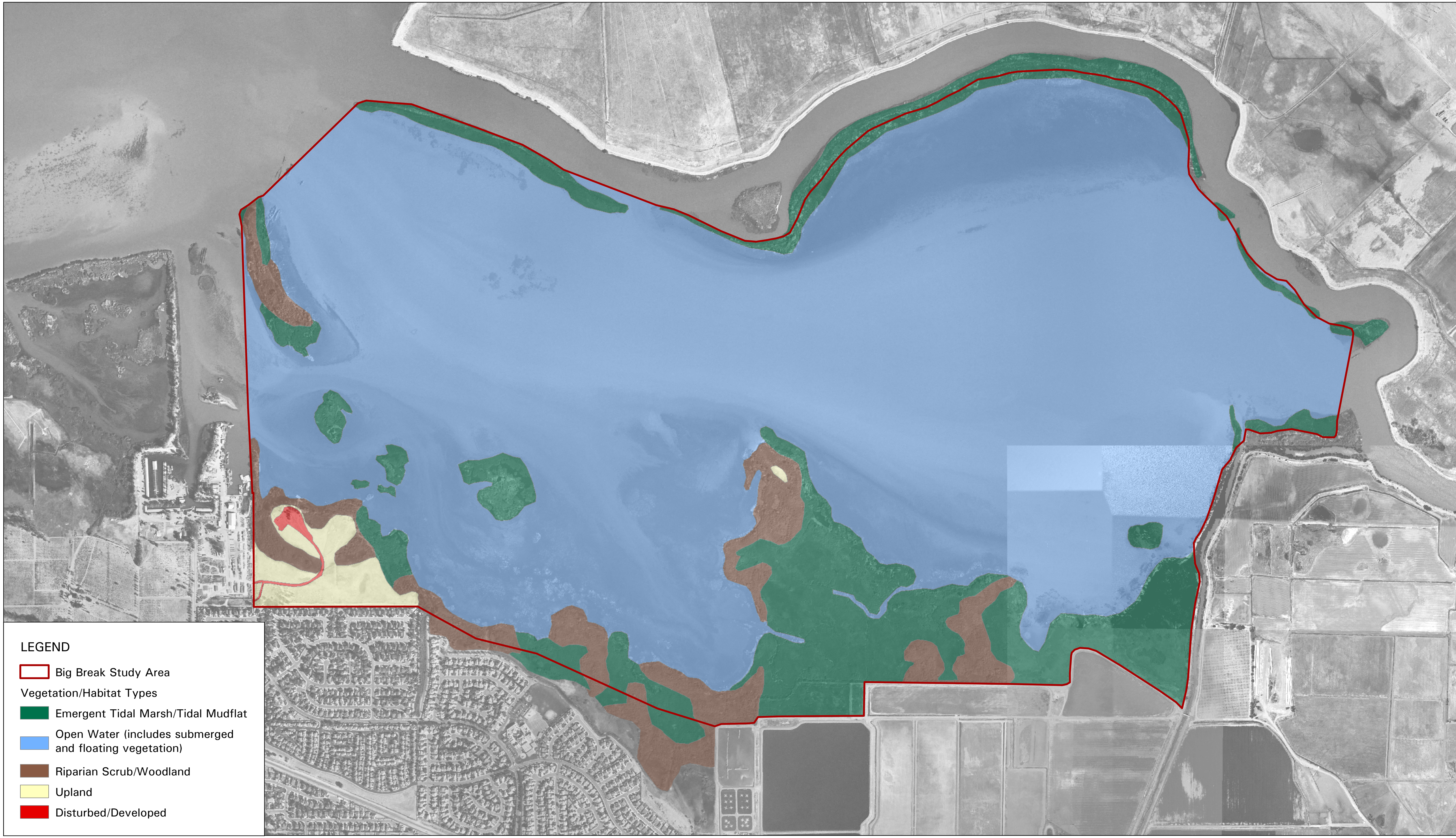
EXHIBIT 4.5-1

Flooded Islands Feasibility Study Baseline Report

X 04110052.01 12/04

0 2,000 4,000 FEET NORTH

EDAW



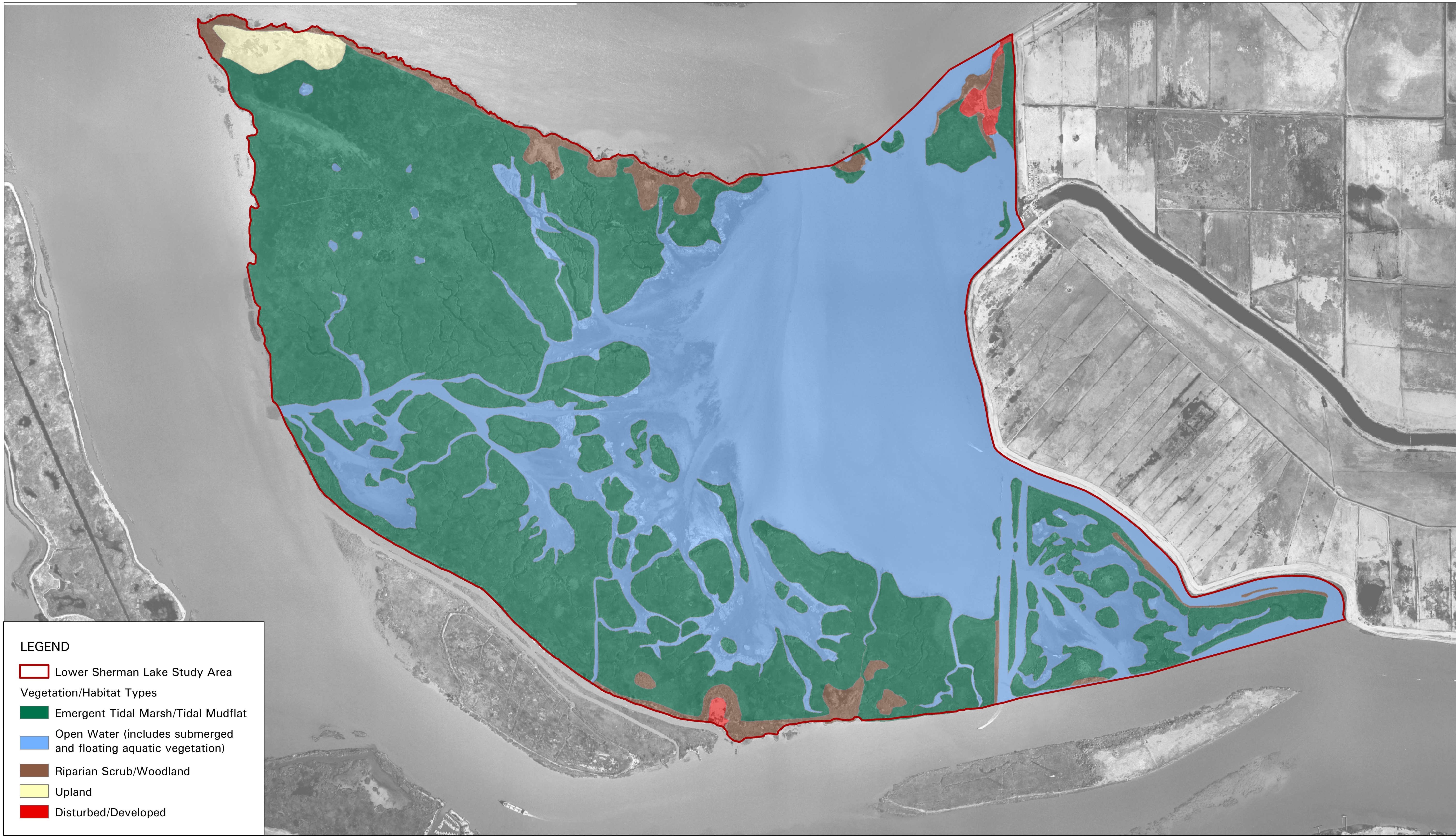
Sources: Sacramento County 2002, DWR 2002, EDAW 2004

Big Break Vegetation and Habitats

EXHIBIT 4.5-2

Flooded Islands Feasibility Study Baseline Report

X 04110052.01 12/04



Sources: Sacramento County 2002, DWR 2002, EDAW 2004

Lower Sherman Lake Vegetation and Habitats

EXHIBIT 4.5-3

Flooded Islands Feasibility Study Baseline Report

X 04110052.01 12/04

EDAW

Within the San Francisco Estuary and lower Delta, there are three major zones of brackish marsh: low marsh, middle marsh, and high marsh (Josselyn 1983). These zones are based on differences in elevation with respect to tide levels. The composition and distribution of species in these zones depends on the period of inundation, sediment salinity levels, and interspecific competition (Josselyn 1983). Low marsh is generally dominated by California bulrush (*Scirpus californicus*), the middle marsh supports cattails and bulrushes (*S. americanus* and *S. robustus*), and the high marsh supports halophytes such as saltgrass and Baltic rush. A number of species typical of freshwater and saline marshes may grow in these high marsh areas. Areas with higher soil salinities support pickleweed, saltgrass, fat-hen, and gumplant (*Grindelia humilus*). If salinity levels are lower in the high marsh areas, brass buttons (*Cotula coronopifolia*) and Baltic rush are more prevalent (Josselyn 1983).

Salt marsh is commonly dominated by low-growing perennials such as saltmarsh cordgrass (*Spartina foliosa*), pickleweed (*Salicornia virginica*), sea blite (*Sueda californica*), and arrow grass (*Triglochin maritimum*), but the composition of this vegetation type is variable depending on elevation and salinity concentrations. In brackish areas, salt marsh may support monocots such as cattails (*Typha* spp.), bulrushes (*Scirpus* spp.), sedges, and common reed, and broad-leaved perennials such as smartweeds (*Polygonum* spp.) and brass buttons (CALFED 2000c).

Tidal mudflats are intertidal habitats generally supporting a low diversity but high productivity of perennial freshwater marsh species. These areas provide habitat for several of the Delta's special-status species such as the Delta mudwort (*Limosella subulata*), Suisun Marsh aster (Aster lentus), and Mason's lilaeopsis (*Lilaeopsis masonii*). Common species include pennywort (*Hydrocotyle spp*.), California loosestrife (*Lythrum californicum*), and water-pimpernel (*Samolus parviflorus*). Areas mapped as Emergent Tidal Marsh/Tidal Mudflat are predominantly emergent tidal marsh, but pockets and swaths of tidal mudflats are included.

Riparian Scrub/Woodland

This vegetation type is typically characterized by narrow linear strips of trees and shrubs, in single-to multiple-story canopies. Riparian scrub/woodland grows in areas subject to intermittent inundation by fresh water and/or areas with sustained high water tables. Factors such as substrate type, hydrology, and water and soil salinity levels determine the composition of this vegetation type (CALFED 2000c). Tree canopies are often continuous and can attain heights of 30 feet. The understory is generally sparsely vegetated with grasses, sedges, and rushes. Some areas may be characterized as scrub, consisting primarily of shrubs and short trees such as sandbar willow (*Salix exigua),* arroyo willow (*S. lasiolepis*), and red alder (*Alnus rubra*), whereas other areas are characterized by multiple canopy stands of shrubs and trees. Much of this vegetation type is infested with the invasive nonnative, Himalayan blackberry (*Rubus discolor*), which commonly creates dense, impenetrable thickets along levee surfaces.

Riparian scrub/woodland is generally found along the higher elevations of remnant levees and areas above the elevations that support tidal marsh. Freshwater marsh and riparian scrub/woodland vegetation types often intergrade with one another. Native woody plant species occurring in this vegetation type include Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), arroyo willow, shining willow (*S. lucida*), sandbar willow, red alder, buttonbush (*Cephalanthus occidentalis*), and California rose (*Rosa californica*). Invasive non-native species, such as black locust (*Robinia pseudoacacia*), Himalayan blackberry, castor bean (*Ricinus communis*), eucalyptus (*Eucalyptus* sp.), and tamarisk (*Tamarix* spp.) are also found in this vegetation type.

Open Water

Most of the area within the three flooded islands is open water. This habitat type is generally unvegetated, but it does support submerged and floating aquatic vegetation. Aquatic plant habitat generally is present in permanently to intermittently inundated shallow water areas, but deeper waters can also support aquatic plants. Aquatic vegetation is commonly differentiated into two categories: submerged vegetation that grows below the water surface and is rooted to the substrate, and floating vegetation that floats freely and does not attach to a substrate (Cowardin et al. 1979). The boundaries for vegetated areas within the open water habitat are difficult to delimit because of seasonal variations in extent and presence, and it is difficult to distinguish aquatic habitat signatures on aerial photographs without the aid of spectral analysis. Therefore, areas mapped as open-water habitat for this report include submerged and floating aquatic vegetation (Exhibits 4.5-1- 4.5-3).

Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) is characterized by rooted vascular plants that occur within shallow to deepwater habitats of slow-moving or still waters. SAV consists of species with floating leaves as well as those that remain submerged. The primary factor determining the presence, composition, and amount of all SAV is the intensity of light available for plant growth. Variations in salinity levels, water depth, nutrient availability, and substrate material determine the species composition of a particular habitat (Cowardin et al. 1979). Native aquatic plant habitat is predominantly vegetated by pondweeds (*Potamogeton* spp.) with floating and submerged leaves (CALFED 2000c). However, SAV within the open water habitat in the study area is dominated by the nonnative species egeria (*Egeria densa*). This introduced species is prevalent in the Delta, and it is currently targeted for abatement by the California Department of Boating and Waterways (DBW). For more information on this species and its effects on aquatic ecosystems, please see Section 4.8.1, "*Egeria densa*."

Floating Aquatic Vegetation

Floating aquatic vegetation grows in freshwater lakes, rivers, and ponds, as well as estuaries with low salinity levels. These freely floating beds of vegetation are located within the water column or on its surface. Wind and water currents circulate and redistribute these floating beds of vegetation (Cowardin et al. 1979). Native floating aquatic species include duckweed (*Lemna* spp.), water-meal (*Wolffia* spp.), and algae. However, large expanses of the open-water habitat within the study area are dominated by the invasive nonnative species water hyacinth (*Eichhornia crassipes*). This plant readily forms dense, interconnected mats that drift along the water's surface. Its thick, waxy leaves are held upright above the water surface on bulbous, air-filled stalks (Bossard et al. 2000). This species can tolerate a wide range of water levels and flow velocities, and extremes in nutrient concentration, pH, and temperature (Batcher 2000). Water hyacinth is a popular nursery item that is commonly sold for home water gardens and ponds because of its ornamental qualities and ability to take up excess nutrients. It is also commonly used to treat effluent at wastewater treatment facilities (Bossard et al. 2000). Water hyacinth is considered one of the most productive plants on earth. In early spring, these plants vegetatively produce daughter plants by runners that grow horizontally along the water surface. Each daughter plant can produce new plants every 6 to 18 days (Western Aquatic Plant Management Society 2002). The densely vegetated free-floating mats generated by this species present safety hazards for boaters, obstruct navigation channels and marinas, and clog irrigation systems. These mats also degrade open-water habitat for aquatic organisms because they decrease the availability of dissolved oxygen (DBW 2004).

Upland

Upland habitat within the study area is primarily dominated by nonnative grasses and forbs. These ruderal upland areas often include large patches of invasive weeds, including Himalayan blackberry, milk thistle (*Silybum marianum*), artichoke thistle (*Cynara cardunculus*), tamarisk (*Tamarix* spp.), fennel (*Foeniculum vulgare*), and perennial pepperweed (*Lepidium latifolium*). Some ornamental tree and shrub species may also occur in upland habitat.

Developed/Disturbed

This habitat type is created by the removal of native vegetation through disturbances such as discing, grading, dredge material placement, and/or the replacement of native habitat with constructed features such as buildings and roads. Vegetation associated with these areas is dominated by ruderal, nonnative grasses and forbs such as wild oats (*Avena fatua*), prickly lettuce (*Lactuca serriola*), Bermuda grass (*Cynodon dactylon*), and common knotweed (*Polygonum arenastrum*), and ornamental trees. These areas also commonly support invasive nonnative species such as yellow starthistle (*Centaurea solstitialis*) and perennial pepperweed.

FRANKS TRACT

The following vegetation and habitat description is primarily based on a General Plan prepared by State Parks for Franks Tract in 1988 (Center for Design Research et al. 1988). The two dominant vegetation types occurring at Franks Tract are emergent marsh and riparian scrub. Tule (*Scirpus acutus*) and broadleaved cattail (*Typha latifolia*) are the dominant species in the emergent marsh, which occurs on the lower portions of remnant levees and in-channel islands. Associated species in this vegetation type include sedges (*Cyperus* spp.), rushes (*Juncus* spp.), smartweeds (*Polygonum* spp.), and Delta mudwort. Riparian scrub is predominantly found along the higher elevations of remnant levees and in-channel islands. The dominant shrub/tree species in this vegetation type include willow (*Salix* spp.) and red alder, but scattered Fremont cottonwood may be present. The understory is extensively infested with Himalayan blackberry and nonnative thistles (*Carduus pycnocephalus*, *Cirsium vulgare*, and *Cynara cardunculus*) that create impenetrable thickets along the remnant levees. Native herbaceous wetland species in the understory include water horehound (*Lycopus americanus*), Suisun Marsh aster, Delta tule pea (*Lathyrus jepsonii* ssp. *jepsonii*), and California loosestrife. Although there was no description in the general plan, a small upland area was evident on the aerial photograph in the southern portion of the study area. The majority of this flooded island is open water, which supports infestations of egeria and water hyacinth.

LOWER SHERMAN LAKE

Very little information is available regarding the vegetation at Lower Sherman Lake. The California Department of Fish and Game (DFG) manages this flooded island as the Lower Sherman Island Wildlife Area. DFG is currently developing their biological resources inventory, and the current types of habitats listed for this wildlife management area include estuarine, lacustrine, and riverine, which are based on the Wildlife Habitat Relationship (WHR) system. These habitat types typically support emergent freshwater marsh, brackish marsh, salt marsh, and riparian scrub. This flooded island is closest to Suisun Bay and, therefore, is likely to be flooded on a regular basis by tidal waters with higher salinity levels than the other two islands. Therefore, there may be large areas of brackish/salt marsh dominated by halophytes such as pickleweed. Areas of Lower Sherman Lake have been disturbed and/or developed. Blinds have been constructed in the northeast corner (adjacent to the boat launch) and along the southern edge of this area for duck hunting. A large portion of the northwest corner of this island appears to support upland vegetation. This upland area was probably formed by the placement of dredged material from the adjacent channel. No description was available for the vegetation in this upland habitat, but the area is likely to be dominated by nonnative annual grasses and forbs such as ripgut brome (*Bromus diandrus*), yellow starthistle, wild oats, Bermuda grass, and nonnative thistles. Open water areas have extensive infestations of egeria and water hyacinth.

BIG BREAK

An extensive survey was conducted at Big Break during summer 2000 for the Big Break Marsh Project (project). The following information is based on the project's vegetation, wetland, and botanical studies report (Vollmar 2000). Big Break is subject to daily tidal fluctuations and is at a sufficient distance from the Bay that the tidal waters inundating this area have minimal salinity levels. A remnant levee runs along the southern border of the open-water area. Riparian scrub vegetation dominated by arroyo willow and Himalayan blackberry grows along the upper portions of this levee, but the lower elevations of the levee support a low cover of tidal marsh vegetation. Extensive stands of perennial emergent marsh are present within the open water habitat. Different elevations have created a mosaic of emergent species in this perennial freshwater marsh with common three-square in shallowly inundated areas, cattail and tule in deeper waters, and California bulrush in the deepest waters. Several sunken barges within the open water area support islands of riparian scrub banded by freshwater marsh at lower elevations. Flats along the shore support large stands of arroyo willow scrub. Riparian habitats also support small stands of tree species such as Fremont cottonwood, Goodding's willow, northern California black walnut (*Juglans californica* var. *hindsii*), coast live oak (*Quercus agrifolia*), prunus (*Prunus* sp.), and red alder. A portion of the Big Break study area supports upland habitat. This upland area is located in the southwestern corner of the study area and primarily supports alkali grassland. Alkali grassland is dominated by perennial grasses including saltgrass and creeping wildrye (*Leymus triticoides*). Associated species are predominantly nonnative annual grasses and forbs such as perennial pepperweed, wild oats, ripgut brome, telegraph weed (*Heterotheca* sp.), and spring vetch (*Vicia sativa*). Other upland habitats present at this location include nonnative tree stands and disturbed/developed areas. The scattered stands of nonnative trees are dominated by black locust (*Robinia pseudoacacia*), tree of heaven (*Ailanthus altissima*), and white poplar (*Populus alba*). Isolated individual trees are predominantly nonnative species such as eucalyptus (*Eucalyptus* sp.), tamarisk (*Tamarix* sp.), and prunus. Disturbed/developed areas are dominated by nonnative and invasive plant species or support buildings and/or paved roads. Infestations of egeria and water hyacinth are present within the extensive open water habitat of Big Break.

4.5.3 SPECIAL-STATUS PLANT SPECIES

GENERAL DESCRIPTION

The Delta is home to several special-status species, many of which are endemic. A special-status species list was developed for the study area by conducting a records search of the California Natural Diversity Data Base (CNDDB) (CNDDB 2004) and the California Native Plant Society's (CNPS) on-line Inventory of Rare and Endangered Plants (CNPS 2004) within the Antioch North, Jersey Island, and Bouldin Island U.S. Geological Survey 7.5-minute quadrangles. Table 4.5-1 presents information on special-status plant species that are either known to occur or have potential to occur within the project site.

FRANKS TRACT

The 1988 General Plan reported the presence of the following special-status species: Suisun Marsh aster, rose-mallow (*Hibiscus lasiocarpus*), Delta tule pea, and Delta mudwort (Center for Design Research et al. 1988). The records search of CNDDB (2004) reports occurrences of the Suisun Marsh aster, rose-mallow, Delta tule pea, and Mason's lilaeopsis at Franks Tract.

LOWER SHERMAN LAKE

The following special-status species were included on the plant list for the Lower Sherman Wildlife Area: Suisun Marsh aster, Delta tule pea, and Mason's lilaeopsis (DFG 2004). The records search of CNDDB (2004) reports that Suisun Marsh aster, Mason's lilaeopsis, and Delta mudwort grow at Lower Sherman Lake.

BIG BREAK

The field surveys conducted for the Big Break Marsh Restoration Project located two special-status plant species within tidal marsh vegetation, the Suisun Marsh aster (one population) and Mason's lilaeopsis (two populations) (Vollmar Consulting 2000). The records search of CNDDB (2004) reports populations of the Suisun Marsh aster, Mason's lilaeopsis, Delta mudwort, and Antioch Dunes evening-primrose (*Oenothera deltoides* ssp. *howellii*) at or in the vicinity of Big Break.

Table 4.5-1
Special-Status Plant Species With Potential to Occur at Franks Tract, Big Break, and Lower Sherman Lake

Species	Legal Status[1]	Habitat[2]	Blooming Period[3]	Potential to Occur4
Aster lentus Suisun Marsh aster	CNPS 1B	Endemic to San Joaquin Delta, generally occurs in marshes and swamps, often along sloughs, from 0 to 3 meters in elevation	May – Nov.	Known to occur at Franks Tract, Big Break, and Sherman Island from CNDDB records
Atriplex cordulata heartscale	CNPS 1B	Chenopod scrub, meadows and seeps, valley and foothill grassland, from 1 to 375 meters in elevation	Apr. – Oct.	May occur
Atriplex joaquiniana San Joaquin spearscale	CNPS 1B	Alkali meadow, chenopod scrub, valley and foothill grassland, often in seasonal alkali wetlands or alkali sink scrub, from 1 to 320 meters in elevation	Apr. – Oct.	May occur
Carex comosa bristly sedge	CNPS 2	Coastal prairie, marshes and swamps, valley and foothill grassland, on lake margins and wet places, from 0 to 625 meters in elevation	May – Sept.	May occur, CNDDB lists occurrence in Webb Tract ponds in non-tidal marsh
Cordylanthus mollis ssp. *mollis* soft bird's beak	FE SR CNPS 1B	Coastal salt marsh, from 0 to 3 meters in elevation	July - Nov	May occur
Erysimum capitatum ssp. *angustatum* Contra Costa wallflower	FE CE CNPS 1B	Inland dunes, stabilized dunes of sand and clay near Antioch along the San Joaquin River, from 0 to 20 meters	Mar – July	May occur
Hibiscus lasiocarpus rose-mallow	CNPS 2	Freshwater marshes and swamps, generally found on wetted river banks and low peat islands in sloughs, known from the Sacramento, San Joaquin Delta watershed, from 0 to120 meters in elevation.	Jun – Sept.	Likely to occur, CNDDB records lists occurrences on and in the vicinity of Franks Tract

Table 4.5-1
Special-Status Plant Species With Potential to Occur at Franks Tract, Big Break, and Lower Sherman Lake

Species	Legal Status[1]	Habitat[2]	Blooming Period[3]	Potential to Occur4
Laythrus jepsonii var. *jepsonii* Delta tule pea	CNPS 1B	Freshwater and brackish marshes, generally restricted to the Sacramento–San Joaquin Delta	May – (Sept.)	Known to occur at Franks Tract from CNDDB records
Lilaeopsis masonii Mason's lilaeopsis	SR CNPS 1B	Freshwater and brackish marshes, riparian scrub, generally found in tidal zones, on depositional soils, from 0 to 10 meters in elevation	Apr. – Nov.	Known to occur at Franks Tract, Big Break, and Sherman Island from CNDDB records, locally common in the Suisun Bay
Limosella subulata Delta mudwort	CNPS 2	Riparian scrub, freshwater marsh, brackish marsh, generally on mud banks of the delta in marshy or scrubby riparian associations, from 0 to 3 meters in elevation	May – Aug.	Known to occur at Big Break and Sherman Island from CNDDB records
Oenothera deltoides ssp. *howellii* Antioch Dunes evening-primrose	FE CE CNPS 1B	Inland dunes, remnant river bluffs and sand dunes east of Antioch, occurs along river bluffs and in loose sand, known only from Contra Costa and Sacramento Counties, from 0 to 30 meters in elevation	Mar – Sept.	May occur, CNDDB lists occurrence adjacent to Big Break (East Bay Regional Park) land
Potomogeton zosteriformis eel-grass pondweed	CNPS 2	Marshes and swamps, from 0 to1,860 meters in elevation	Jun – July	May occur, CNDDB lists occurrence in the vicinity of Webb Tract
Scutellaria galericulata marsh skullcap	CNPS 2	Lower montane coniferous forest, meadows and seeps, marshes and swamps, wet places, from 0 to 2,100 meters in elevation	Jun – Sept.	Likely to occur, CNDDB lists occurrence for Old River between Quinby Island and Franks Tract
Scutellaria lateriflora blue skullcap	CNPS 2	Marshes and swamps, meadows and seeps, from 3 to 500 meters in elevation	July – Sept.	May occur

Table 4.5-1
Special-Status Plant Species With Potential to Occur at Franks Tract, Big Break, and Lower Sherman Lake

Species	Legal Status[1]	Habitat[2]	Blooming Period[3]	Potential to Occur4

[1] Legal Status Definitions
U.S. Fish and Wildlife Service (USFWS) Federal Listing Categories
FE: Federally listed as endangered
California Department of Fish and Game (DFG) State Listing Categories
CE: State listed as endangered
CR: State listed as rare
California Native Plant Society (CNPS) Categories
1B: Plant species considered rare or endangered in California and elsewhere
2: Plants rare, threatened, or endangered in California but more common elsewhere

[2] Habitat descriptions are based on CNPS (2004), CNDDB (2004), and Hickman (1993)

[3] Blooming periods are based on CNPS (2004)

[4] Potential for Occurrence based on CNDDB (2004) records, Vollmar Consulting (2000), and Center for Design Research (1988).

4.6 AQUATIC COMMUNITIES AND FOOD WEB

4.6.1 GENERAL DESCRIPTION

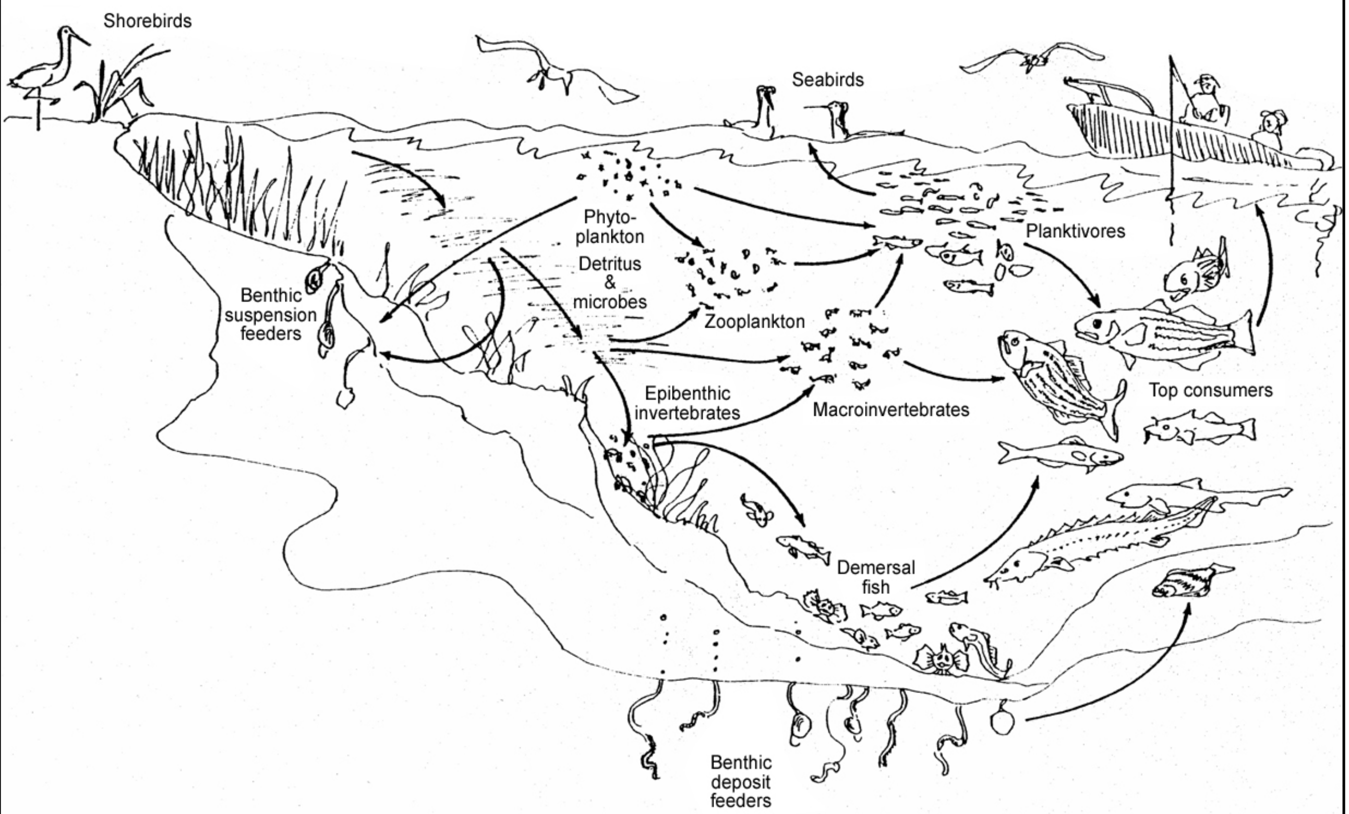
The Bay-Delta is a complex estuarine ecosystem; it is an area of transition between inland sources of freshwater and saltwater from the ocean. Along the salinity gradient extending from the Golden Gate upstream into the western and central Delta and tributaries, the species composition of the aquatic community changes dramatically, although the basic functional relationships among organisms (e.g., predator-prey, etc.) remain similar throughout the system. The Bay-Delta's aquatic communities are conceptually portrayed in Exhibit 4.6-1, which emphasizes the basic feeding relationships among community components and identifies some of more important species of the Bay-Delta ecosystem.

The primary energy input to the system is solar radiation, which is used along with nutrients, by the primary producers (phytoplankton, vascular plants, and macroalgae) to convert inorganic carbon and nutrients to organic matter through photosynthesis. Zooplankton (e.g., copepods, cladocerans, mysid shrimp), prey on the phytoplankton. The vascular plants and macroalgae are grazed on and also produce detritus, which is decomposed by microbes and consumed by detritivores (e.g., polychaete worms, amphipods, cladocerans, and a diverse group of other fish and macroinvertebrates). The primary consumers are in turn preyed upon by secondary consumers, consisting mainly of a variety of invertebrates (polychaete worms, snails, copepods, mysid shrimp, bay shrimp, and crabs) and fish (delta smelt, threadfin and American shad, gobies, sculpin, juvenile chinook salmon, and a variety of other resident and migratory fish species). These in turn are preyed on by top consumers, such as fish (striped bass, catfish, sturgeon, largemouth bass, and Sacramento pikeminnow), marine mammals, birds, and humans. The role of a species in the food web may be different at different lifestages, or it may utilize various levels of the food web simultaneously.

This section briefly discusses the major components of the Bay-Delta aquatic community, including phytoplankton, zooplankton, benthic macroinvertebrates, fish, shrimp, and crabs. Information on aquatic vegetation within the western and central Delta, which represents an important feature of the aquatic habitat is discussed in Section 4.7. The discussion in this section is generalized for the Delta, and no study-area specific data is provided.

PHYTOPLANKTON

Phytoplankton are small photosynthetic plants that form the base of the estuarine food web. They are usually microscopic in size and consist of single cells or chains of cells. Major groups of phytoplankton in the estuary include diatoms, dinoflagellates, and cryptomonads (Herbold *et al.* 1992). Phytoplankton are of prime importance to the ecology of the Bay-Delta estuary because of their position at the base of the food web. The seasonal abundance (standing crop) of copepods, cladocerans, and other pelagic herbivores closely follows the seasonal cycle of phytoplankton abundance in the estuary. Juvenile survival and growth of many fish species such as striped bass and threadfin shad, within the western and central Delta and elsewhere



Source: CDFG 1964; PG&E 1982

The Bay-Delta Aquatic Community and Primary Food Web

EXHIBIT 4.6-1

within the estuary, largely depends on the quality and quantity of phytoplankton and/or associated zooplankton available as a direct or indirect food resource.

In the western and central Delta, interannual variability of phytoplankton is difficult to characterize because of the lack of long-term chlorophyll or productivity data, but the processes are similar to Suisun Bay, where transport of chlorophyll is strongly related to flow. Suisun Bay variability in phytoplankton is largely reflected in the corresponding variability in Delta outflow. Phytoplankton productivity in Suisun Bay is overwhelmingly dominated by shallow-water shoal productivity, and interannual variability therefore reflects fluctuations in shoal, rather than channel productivity (Herbold et al. 1992). Net water column productivity in the deeper open water areas and channels is usually negative because of the small portion of the water column in the photic zone, so biomass must be imported from the shallow-water areas. Advective transport, particularly on ebb tide, is an important mechanism for transporting chlorophyll downstream in estuaries, and Delta outflow therefore is a major factor in controlling variability of phytoplankton productivity. Another major process appears to be consumption by benthic grazing herbivores (Lucas et al. 2002) including the recently introduced Asian clam (Potamocorbula amurensis) and the freshwater clam (Corbicula fluminea), especially during low-flow periods where benthic invertebrates can become established in high enough densities to filter large quantities of water, affecting phytoplankton biomass.

In the low-salinity and freshwater areas of the estuary, including the western and central Delta, diatoms are the dominant phytoplankton. Green algae are abundant during winter and spring and may constitute as much as 60-70 % of the phytoplankton populations of the western and central Delta and Suisun Bay. Green algae are generally less abundant in the more saline regions of the estuary, but may be common in the fresh, slowly flowing waters of the interior Delta. The highest abundance of phytoplankton within the estuary typically occurs within the Suisun Bay freshwater and saltwater mixing zone. Abundance of phytoplankton is typically low during the winter, increasing substantially during the spring and summer months, followed by a reduction in abundance during the fall. Factors affecting the geographic and seasonal distribution of phytoplankton within the estuary include seasonal patterns of solar radiation, seasonal water temperatures, availability of nutrients, current patterns and residence time, and salinity gradients. Turbidity, suspended sediments, and water depth also affect availability of sunlight and the abundance of phytoplankton within different areas of the estuary including the shallow open waters of Franks Tract, and to a lesser degree Big Break and Sherman Lake, where sediment resuspension rates are high.

Lehman (1998) discusses the importance of high concentrations of large diatoms (e.g., *Skeletonema costatum*, *Coscinodiscus* spp. and *Cyclotella* spp.), which during the spring in the 1970's accumulated in the Low Salinity Zone (LSZ), where salinity ranges between 0.6 and 4 ppt in Suisun Bay in the vicinity of Sherman Lake, and decreasing salinities further upstream in the vicinity of Big Break and Franks Tract. This accumulation was considered a primary factor in controlling interannual variation in fish populations within the estuary because it supported zooplankton production. However, since the early 1980s, chlorophyll concentrations and shifts in species composition have occurred throughout the estuary. A 10-fold decrease in chlorophyll concentrations in Suisun Bay has occurred since 1986. This decrease is associated with, and may be the result of, the introduction of the Asian clam. These recent trends have raised questions about the ability of phytoplankton production in the Bay-Delta estuary to support zooplankton production.

ZOOPLANKTON

Zooplankton are microscopic and macroscopic animals that are planktonic (free-floating) or weak swimming fish and invertebrates. Some are permanent members of the plankton and are known as holoplankton. Others, such as eggs, larvae, and juveniles of benthic invertebrates and fish, are members of the plankton only during early lifestages and are known as meroplankton. A number of zooplankton species have been introduced into the estuary (Kimmerer 1998) through ballast water discharges from commercial shipping and have impacted native species inhabiting the estuary.

Zooplankton, the primary consumers within the estuary, are at the center of the estuarine food web and therefore are not only important to lower trophic levels upon which they feed (phytoplankton, detritus), but also to the higher trophic levels for which they serve as prey (fish and macroinvertebrates). Zooplankton include herbivores, which forage mainly on phytoplankton, and detritivores that feed on detritus and microbes. Zooplankton are primarily suspension feeders. Zooplankton include small macroinvertebrates such as calanoid copepods and cladocerans but also include fish and macroinvertebrate eggs and larvae, including delta smelt larvae, threadfin shad, and striped bass eggs and larvae, crabs, and bay shrimp. The abundance and distribution of zooplankton varies substantially within the estuary in response to seasonal cycles and environmental factors such as salinity gradients and river flow and tidal currents. In the high-salinity portions of central Bay, the primary zooplankton includes calanoid copepods (*Acartia clausi, A. tonsa*, and *Paracalanus parvus*). In the low-salinity regions of Suisun Bay and the western Delta the primary zooplankton are calanoid copepods (*Eurytemora affinis* and *A. clausi*) and the opossum shrimp (*Neomysis mercedis*). The cladocerans (*Daphnia pulex* and *D. parvula*), and calanoid copepods (*Diaptomus* spp. and *Limnocalanus macrurus*) are the primary, zooplankton species occurring within the freshwater portions of the central Delta.

Salinity is one of the major factors affecting the distribution and abundance of zooplankton within the estuary as evidenced by the changes in species composition that occur within various regions of the estuary. The distribution and abundance of zooplankton is also related to the availability of food. Physical and chemical conditions that promote phytoplankton productivity (warm temperatures, high solar radiation, high nutrients, slow-moving water, low turbidity and suspended sediment concentrations, shallow waters, etc.) indirectly promote the productivity of zooplankton. Water body configuration and bathymetry also affect phytoplankton productivity and therefore, zooplankton productivity. The shallow areas of Suisun Bay are highly productive, as are many of the shallow slow-moving open and backwater areas further upstream within the central Delta. The location of the saltwater and freshwater mixing zone during the spring also influences the abundance of both phytoplankton and zooplankton in the estuary. When the mixing zone is located in the shallow portions of Suisun Bay the abundance of both phytoplankton and zooplankton increases. When the mixing zone is upstream in the deeper channels of the lower Sacramento and lower San Joaquin Rivers and central Delta in response to reduced freshwater inflow that occurs during drought conditions, productivity and abundance of both phytoplankton and zooplankton is reduced.

Seasonal variations in zooplankton abundance are determined by temperature or photoperiod, coastal hydrography, seasonal cycles of phytoplankton, and Delta inflow and outflow (Kimmerer 2002a, 2002b). Zooplankton biomass tends to be highest in the Bay-Delta estuary during spring and early summer. The abundance of several important zooplankton species inhabiting the Delta has decreased substantially over the past several decades. The most dramatic change occurred with the introduction of the Asian clam (*Potamocorbula amurensis*) in 1986 (Kimmerer and Orsi 1996). The Asian clam plays a significant role in grazing of zooplankton, consuming not only diatoms but also nauplii of the copepod (*Eurytemora affinis*), which is a dominant species in the estuary, and other holoplanktonic and meroplanktonic invertebrates (Carlton *et al.* 1990). At the time of the invasion, the copepod (*Pseudodiaptomus forbesi*), the mysid (*Acanthomysis* spp.) and amphipods became abundant in the regions formerly occupied by *E. affinis* (Kimmerer and Orsi 1996; Kimmerer *et al.* 1999). The introduction of nonnative fish and invertebrates such as the Asian clam has been identified as a major factor affecting the abundance and species composition of zooplankton, and the fish and macroinvertebrate community in general, within the Bay-Delta estuary.

BENTHIC AND EPIBENTHIC MACROINVERTEBRATES

Within the estuary, benthic macroinvertebrates typically live within the top 12 inches of sediment on the Bay-Delta floor. Epibenthic macroinvertebrates typically live on the sediment surface. The benthic and epibenthic communities of the marine inshore waters of central Bay include a diverse group of marine macroinvertebrates. These include gastropods (snails), echinoderms (sea urchins and starfish), polychaetes (sea worms), bivalves (mussels and clams), and crustaceans (barnacles, isopods, amphipods, crabs, and shrimp). Within Suisun Bay and the western Delta, benthic and epibenthic species include bay shrimp, opossum shrimp, amphipods, polychaetes, oligochaetes, and clams. The Asian clam has rapidly expanded its geographic distribution and abundance within Suisun Bay and the central Delta (Thompson and Peterson 1998) and has achieved sufficiently high population abundance that feeding (clams are filter feeders) has significantly altered the abundance of phytoplankton and zooplankton within the estuary.

Characteristics of the benthic and epibenthic macroinvertebrate community are influenced by a variety of physical and water quality conditions that occur within the estuary, the most important being flow velocities, substrate characteristics, and salinity gradients (Thompson *et al.* 2000). As stated in Herbold et al. (1992), the factors most affecting the abundance, composition, and health of the benthic community from year to year are outflow from the Delta, local runoff, and pollution (Nichols and Pamatmat 1988). Lower outflows are associated with lower phytoplankton biomass and hence lower productivity during periods of low flow.

High outflows lead to lower salinities, which particularly control the species abundance and composition in shallow areas where animals are exposed to less saline surface water.

Benthic communities in the Bay-Delta estuary have also been influenced by disturbances such as dredging and filling activities. Sediment grain-size distributions show that sandy sediments persist in areas of high current velocities such as the channel areas (Rubin and McCulloch 1979), while finer sediments settle in areas of lower current velocity such as in the shoals and small channels (Krone 1979) and in the shallow open water habitat in flooded islands such as Franks Tract, Big Break, and Sherman Lake (see Sections 4.1 for additional information on Topography and Bathymetry). Benthic and epibenthic invertebrate populations are generally most abundant in areas having reduced water velocities, fine-grained sediments, and relatively stable benthic environments (little sediment resuspension, movement or disturbance, slow rates of accretion or depletion of sediments). In deeper water channel, and high velocity areas characterized by sand and coarse substrate with substantial daily, seasonal or interannual substrate movement and accretions and depletions, benthic and epibenthic macroinvertebrate communities characteristically have reduced species diversity and abundance.

Many of the more common benthic species that inhabit the estuary are not native to the region but have been transported and introduced into the estuary through the discharge of ballast water from commercial ships, or on the shells of oysters brought from the East Coast for commercial farming in the late 19th century (Carlton 1979). Today, over 40% of the individuals comprising the benthic community in a given area of the estuary can be nonindigenous species (Carlton 1979; Cohen 2000). Many of these introduced species may serve ecological functions similar to native species that they may have displaced; however, some species may be detrimental to the aquatic ecosystem of the estuary.

All but two of the benthic mollusks (i.e., oysters, clams) are introduced. Within the vicinity of Franks Tract, and to a lesser degree further downstream in the vicinity of Big Break and Sherman Lake, one of the dominant mollusks, the Asiatic clam (*Corbicula fluminea*), is intolerant of saline waters (see Section 4.8 for additional information).

Unlike the mollusks, the epibenthic crustaceans (e.g., crabs and shrimp) inhabiting the Suisun Bay and the Delta are still made up of many native species, particularly Bay shrimp (*Crangon* spp.). The smaller epibenthic fauna in the estuary are dominated by four species of shrimp commonly called bay shrimp: California bay shrimp (*Crangon franciscoru)*, blacktail bay shrimp (*C. nigricauda*), blackspotted bay shrimp (*C. nigromaculata*), and *Palaemon macrodactylus*. The California bay shrimp are most abundant in lower salinities, blacktail bay shrimp prefer salinities of 25 ppt or more, and blackspotted bay shrimp are seldom found at salinities below 30 ppt (Baxter *et al.* 1999). *P. macrodactylus*, which was introduced from Korea, is found only in the upper estuary, particularly Suisun Bay. All three *Crangon* shrimps show responses to flow patterns, where the mechanism appears to be greater transport of post-larval shrimp into the estuary by bottom currents in years of high freshwater outflow (Baxter *et al.* 1997). Crabs inhabiting the central Delta in the vicinity of Franks Tract are dominated by the introduced

Chinese mitten crab (DFG unpublished data). Chinese mitten crab are also present further downstream in the vicinity of both Big Break and Sherman Lake (Heib, pers. comm.).

Processes that regulate the abundance and distribution of benthic communities also affect the colonization of the bottom after disturbances, such as modifying or removing habitat by dredging, sediment disposal, levee breaching, or creation of new subtidal and intertidal aquatic habitat (Hanson *et al.* 2004). Patterns of reproduction and the availability of colonists can also have a profound effect on benthic community recovery. Polychaete worms, bivalve mollusks, crabs and shrimp recruit by small larval stages that can be planktonic and capable of dispersal over large geographic areas, or by larger crawl-away larvae that remain near the bottom and the adult habitat (Hanson *et al.* 2004). Amphipods and other similar crustaceans brood their young until they are small juveniles that disperse much like crawl-away larvae. In some species, the adults are the dispersal stage and the first colonists after disturbance. Benthic macroinvertebrates typically have high fecundity and dispersal mechanisms that facilitate colonization of habitat within the estuarine environment.

PREDATION BY FISH COMMUNITIES

Fish species may utilize the Bay-Delta estuary for any or all of their life history stages. They may have planktonic, epibenthic (demersal), and pelagic (open water) life histories. The majority of fish species (e.g., delta smelt, threadfin shad, striped bass, gobies, etc.) inhabiting the estuary have planktonic larval stages; as plankton they feed on zooplankton and in some cases phytoplankton (Moyle 2002). Many of these species forage on plankton during the larval and early juvenile lifestages, and then as juveniles and adults become predators, that are more selective and feed on large invertebrates and fish. Demersal fish such as sturgeon, gobies, sculpin, and striped bass, are planktivorous as larvae but begin to feed on epibenthic invertebrates and fish as juveniles (Moyle 2002, Baker *et al.* 1999). Many smaller fish including delta smelt and threadfin shad are planktivorous throughout their lives (Moyle 2002).

Some estuarine fish do not rely on plankton as a major food source at any lifestage. The live-bearing tule perch, for example, predominantly feed on epibenthic invertebrates, such as mollusks, crustaceans, and polychaetes throughout their life (Moyle 2002). Sturgeon feed on benthic and epibenthic invertebrates by shoveling through the substrate, and feed on fish and large invertebrates in the water column. Many freshwater fish such as juvenile Chinook salmon prey primarily on benthic and drifting insect larvae and crustaceans (Moyle 2002), because zooplankton abundance is low in the swifter flowing freshwater sloughs and rivers.

4.7 FISH AND WILDLIFE

This section provides detailed baseline information on fisheries, avian, and other wildlife resources, including special-status species, that are known to inhabit the Delta and in the wider estuarine system. Specific information pertaining to Franks Tract, Lower Sherman Lake, and Big Break are provided where available.

4.7.1 FISHERIES

San Francisco Bay, Suisun Bay, and the western and central Delta (Bay–Delta estuary) are habitat to a diverse assemblage of freshwater, marine, and estuarine organisms. The biological environment is a complex community of plants and animals inhabiting the saltwater, estuarine (brackish-water), and freshwater habitats within the Bay–Delta estuary. This section provides a summary of information available on the common fish populations inhabiting the Bay–Delta estuary, with emphasis on flooded island shallow-water habitat within Suisun Bay and the central and western Delta. The primary flooded island habitats within the Delta include Franks Tract, Big Break, and Sherman Lake (Exhibits 1-2, 1-3, and 1-4).

GENERAL DESCRIPTION

Aquatic Habitats

Suisun Bay is characteristic of the upstream estuarine transition zone that separates the upstream freshwater Delta from the downstream saltwater bays. Suisun Bay and the western and central Delta, including the flooded islands, contain several aquatic habitats, including sloughs and cuts, shallow channel and shoal areas, the main river channels, and open-water aquatic habitats. Together, these habitats support a large and diverse aquatic community (Table 4.7-1), which includes several recreationally important species of fish. The following sections briefly describe these major habitats within Suisun Bay and the Delta in the vicinity of Franks Tract, Big Break, and Sherman Lake.

Table 4.7-1
Fish Species Collected in Suisun Bay and Central Delta Fishery Sampling

Common Name	Scientific Name	Common Name	Scientific Name
American Shad	*Alosa sapidissima*	Pacific Staghorn Sculpin	*Leptocottus armatus*
Arrow Goby	*Clevelandia ios*	Pacific Tomcod	*Microgadus proximus*
Arrow/Cheekspot Goby	n/a	Plainfin Midshipman	*Porichthys notatus*
Bay Goby	*Lepidogobius lepidus*	Prickly Sculpin	*Cottus asper*
Bay Pipefish	*Syngnathus Zeptorhynchus*	Redear Sunfish	*Lepomis microlophus*
Bearded Goby	*Barbulifer ceuthoecus*	River Lamprey	*Lampetra ayersii*

Table 4.7-1
Fish Species Collected in Suisun Bay and Central Delta Fishery Sampling

Bigscale Logperch	*Percina macrolepida*	Sacramento Pikeminnow	*Ptychocheilus grandis*
Black Bullhead	*Ameiurus melas*	Sacramento Sucker	*Catostomus occidentalis*
Black Crappie	*Pomoxis negromaculatus*	Shimofuri Goby	*Tridentiger bifasciatus*
Bluegill	*Lepomis macrochirus*	Shiner Perch	*Cymatogaster aggregata*
Brown Bullhead	*Ameiurus nebulosus*	Speckled Sanddab	*Citharichthys stigmaeus*
California Halibut	*Paralichthys californicus*	Splittail	*Pogonichthys macrolepidotus*
Chameleon Goby	*Tridentiger trigonocephalus*	Starry Flounder	*Platichthys stellatus*
Channel Catfish	*Ictalurus punctatus*	Steelhead Trout	*Oncorhynchus mykiss*
Cheekspot Goby	*Ilypnus gilberti*	Striped Bass	*Morone saxatilis*
Chinook Salmon	*Oncorhynchus tshawytscha*	Surf Smelt	*Hypomesus pretiosus*
Common Carp	*Cyprinus carpio*	Threadfin Shad	*Dorosoma petenense*
Delta Smelt	*Hypomesus transpacificus*	Threespine Stickleback	*Gasterosteus aculeatus*
English Sole	*Pleuronectes vetulus*	Tule Perch	*Hysterocarpus traski*
Goby Type II	n/a	Unidentified Fish	n/a
Golden Shiner	*Notemigonus crysoleucas*	Unidentified Goby	n/a
Goldfish	*Carassius auratus*	Unidentified Minnow	n/a
Green Sturgeon	*Acipenser medirostris*	Unidentified Smelt	n/a
Inland Silverside	*Menidia beryllina*	Unidentified Sunfish	n/a
Jacksmelt	*Atherinopsis californiensis*	Wakasagi	*Hypomesus nipponensis*
Largemouth Bass	*Micropterus salmoides*	Western Mosquitofish	*Gambusia afinis*
Longfin Smelt	*Spirinchus thaleichthys*	White Catfish	*Ameiurus catus*
Longjaw Mudsucker	*Gillichthys mirabilis*	White Crappie	*Pomoxis annularis*
Northern Anchovy	*Engraulis mordax*	White Croaker	*Genyonemus lineatus*
Pacific Herring	*Clupea pallasi*	White Sturgeon	*Acipenser transmontanus*
Pacific Lamprey	*Lampetra tridentata*	Yellowfin Goby	*Acanthogobiusflavimanus*

Source: DFG unpublished data

Sloughs and Cuts

There are many sloughs and cuts within the Suisun Bay and the Delta. The major slough within Suisun Bay, New York Slough, is part of the shipping channel connecting Suisun Bay and the San Joaquin River. Numerous human-made inlets have been excavated as harbors and marinas for recreational boat moorages within the Delta in the immediate vicinity of Franks Tract. A dredged channel also provides access to the marina located within Big Break. Sherman Lake has a public boat ramp and small marina. In addition, there are many naturally occurring sloughs and cuts within Sherman Lake, and to a lesser extent within Big Break and Franks Tract. Siltation and reduced water depth in many of these areas have adversely affected navigation and require periodic maintenance dredging. Stands of emergent vegetation, particularly cattails (*Typha* spp.) and tules (*Scirpus* spp.), border many of these cuts and sloughs.

Common invertebrates that inhabit Delta sloughs and cuts include amphipods, shrimp, polychaetes (e.g., marine worms), and small bivalves (e.g., clams). Fish commonly found in the area include threadfin shad (*Dorosoma petenense*), striped bass (*Morone saxatilis*), Sacramento splittail (*Pogonichthys macrolepidotus*), Delta smelt (*Hypomesus transpacificus*), tule perch (*Hysterocarpus traski*), Sacramento pikeminnow (*Ptychocheilus grandis*), white catfish (*Ameiurus catus*), yellowfin goby (*Acanthogobius flavimanus*), carp (*Cyprinus carpio*), and largemouth bass (*Micropterus salmoides*). In addition, the calm waters and shelter afforded by many of the cuts and sloughs attract early life stages of many fish species.

Shallow Channel and Shoal Areas

The area between the shore and deepwater ship channels is characterized by water depth less than 10 feet, a mud and silt or mud–sand bottom, and reduced tidal and river currents. The smaller channels within the Suisun Bay and the Delta are characterized by water depths less than 6 feet with a silt and mud substrate. Areas within the interior open waters of Franks Tract, Big Break, and Sherman Lake are characterized as shallow shoal-type habitat. Many areas adjacent to the shoals and channels are bordered by tules.

Large numbers of small crustaceans, particularly mysid shrimp (*Mysis* spp), bay shrimp (*Palaemon macrodactylus* and *Cragon* spp.), and amphipods inhabit the shallow-water area in and adjacent to the flooded islands. These invertebrates serve as an important food supply for young-of-the-year striped bass, juvenile Chinook salmon (*Oncorhynchus tshawytscha*), and other young fish. The shallow shoal areas serve as a foraging and rearing area for juvenile striped bass and Chinook salmon, in addition to a variety of other resident and migratory species. Other fish found inhabiting shallow channel and shoal areas include threespine stickleback (*Gasterosteus aculeatus*), tule perch, Sacramento pikeminnow, gobies, inland silversides (*Menidia beryllina*), starry flounder (*Platichthys stellatus*), Sacramento splittail, Delta smelt, carp, white catfish, and largemouth bass.

Deep River Channels/Levee Breaches

The river channels are characterized by depths of more than 10 feet and strong tidal and river currents, typically 30–40 cm/sec (1.1-1.5 ft/sec) or more. Areas immediately adjacent to levee breaches within Franks Tract are characteristic of deep river channel-type fishery habitat. The lower San Joaquin River near Big Break is a deep-water maintained navigational shipping channel with water depths typically ranging from 40 to 50 feet within the channel. The lower Sacramento and San Joaquin rivers adjacent to Sherman Lake are also deep-water maintained navigational shipping channels with water depths typically ranging from 40 to 60 feet within the channel. The river bottom in areas where water velocities are high, is generally composed of sand. This is typical of the scour that occurs as a result of high tidal current velocities within the deeper levee breaches and within the navigational shipping channels. Finer silt and other sediments occur in areas adjacent to the main channel or levee breaches in areas where water velocities are reduced. Invertebrates, which inhabit these channels, include bottom-dwelling polychaetes, amphipods, bivalves, and shrimp. These higher velocity areas also serve as habitat for larger predatory fish, such as striped bass, that prey on smaller fish as they pass in and out of levee breaches and higher-velocity river channels.

Open Water

The open waters of Suisun Bay and the Delta serve as migratory routes for several species of anadromous fish whose adults swim upstream to the freshwater reaches of the tributary rivers to spawn and whose juveniles return downstream to the ocean. These fish include steelhead (*Oncorhynchus mykiss*), Chinook salmon, white (*Acipenser transmontanus*) and green sturgeon (*Acipenser medirostris*), striped bass, and American shad (*Alosa sapidissima*). In addition, the open water habitat within Suisun Bay, Franks Tract, Big Break, and Sherman Lake supports populations of resident species including largemouth bass, Sacramento pikeminnow, white catfish, and threadfin shad.

Aquatic Habitat Function and Use

Fish, shrimp, and crabs use habitats within Suisun Bay and the Delta for a number of functions including, but not limited to:

- Adult and juvenile foraging;
- Spawning;
- Egg incubation and larval development;
- Juvenile nursery areas; and
- Migratory corridors.

Species use of aquatic habitats for any of these functions may vary in response to a suite of factors, and many of these factors may vary daily, seasonally, and annually.

The Bay–Delta aquatic environment is dynamic, varying in response to factors such as the magnitude of freshwater inflow from the Sacramento and San Joaquin river systems and other tributaries and resultant changes in salinity gradients, wind and tidally driven current patterns, seasonal variation in water temperatures, and a variety of other physical and biological processes. The habitat use and functions of areas within the estuary vary in response to these physical factors as well as to differences in life history characteristics and habitat requirements for the wide variety of fish and macroinvertebrates inhabiting the estuary. It may, therefore, be possible to predict whether a species is likely to utilize a site, and to predict what that use might be under a given set of circumstances. However, in an ecosystem where conditions such as salinity and freshwater flow may change rapidly and somewhat unpredictably, it may be difficult to predict the distribution and abundance of aquatic species with precision. The DFG fishery studies provide general insight into how many aquatic species may respond to some of the varying conditions in flooded islands and adjacent aquatic habitat within Suisun Bay and the Delta.

Baxter *et al*. (1999) described the geographic distribution of various fish, shrimp, and crabs inhabiting the estuary and their response to seasonal and geographic variation in salinity gradients and water temperature. The geographic distribution of many of these species is determined, in large part, by salinity tolerance and preference. Within the Bay–Delta estuary, salinities range from freshwater in the river systems to marine, as influenced by tidal exchange with nearshore coastal waters. Within the Bay–Delta estuary, fresh water and salt water mix, forming a dynamic and productive estuarine habitat characterized by a wide range of salinities, both geographically and seasonally. The geographic distribution and habitat usage patterns for the fish, shrimp, and crabs, which may vary by different life stages of the species, reflect in large part the response to these salinity conditions and other physical habitat conditions, including water depths, substrate, availability of suitable cover, and other factors.

Baxter *et al*. (1999) categorized the fish, shrimp, and crabs inhabiting the Bay–Delta estuary based on three life history strategies, including:

< Species that reside in the estuary year-round;

< Species that seasonally inhabit the estuary, typically as foraging, spawning, or juvenile nursery habitat; and

< Anadromous or migratory species that move through the estuary during passage to or from freshwater and coastal marine habitats. The vast majority of anadromous fish species, including Chinook salmon, steelhead, striped bass, American shad, and sturgeon, migrate through the Delta and the Sacramento and San Joaquin rivers during their upstream and downstream migrations through the estuary.

Among the seasonal inhabitants, many species use the Bay–Delta estuary as a spawning area and/or juvenile nursery habitat on either an obligatory or nonobligatory basis (Baxter *et al*. 1999). For obligate species, reproduction and rearing of juveniles occurs almost exclusively within a bay or estuarine environment. Baxter *et al*. (1999) identifies Pacific herring (*Clupea pallasi*), jacksmelt (*Atherinopsis californiensis*), and many surfperch as examples of obligate species that migrate into the estuary to reproduce. Other estuarine obligate species such as starry flounder and bay shrimp reproduce in coastal marine waters, with larvae and/or early juvenile life stages migrating into the estuary to rear.

Nonobligate species may inhabit the estuary during any given year. The presence of nonobligate species varies substantially from one year to the next within the Bay–Delta estuary. Nonobligate species include Dungeness crab (*Cancer magister*), brown rockfish (*Sebastes auriculatus*), and English sole (*Pleuronectes vetulus*), which reproduce in the ocean and enter the estuary as small juveniles for rearing (Baxter *et al.* 1999). These species are typically found in the more marine areas of the estuary and are generally not abundant upstream in Suisun Bay or the Delta.

Opportunistic species use the Bay–Delta estuary as an extension of their habitat based on the suitability of environmental conditions. Baxter *et al.* (1999) notes that several freshwater or low-saline species, such as white catfish and threadfin shad, may opportunistically use habitats within the western Delta and Suisun Bay, San Pablo Bay, or central Bay during periods of high freshwater outflow from the river systems that result in lower salinity and more suitable habitat conditions for these species further downstream in the system.

Anadromous species, such as Chinook salmon and steelhead, spawn within freshwater portions of rivers and creeks tributary to the Bay–Delta estuary. Juvenile rearing habitat for these species is also primarily within the freshwater or low-saline portions of the system. Juvenile Chinook salmon and steelhead emigrate from freshwater habitat and move downstream through the estuary, which is used primarily as a migratory corridor and short-term foraging habitat, as they move into coastal waters for rearing. Franks Tract, Big Break, and Sherman Island and adjacent regions in Suisun Bay and the Delta serve as foraging habitat for salmon fry during rearing in the Delta and as smolts migrate downstream from the tributary river systems. Adult Chinook salmon and steelhead subsequently migrate back upstream to spawn, again using the Bay–Delta estuary as a migratory corridor. Other anadromous species, such as striped bass, have high salinity tolerance and inhabit freshwater, estuarine, and marine waters for an extended time as both juveniles and adults. Juvenile and adult striped bass reside year-round within Suisun Bay and the Delta, including Franks Tract, Big Break, and Sherman Lake.

Habitat use by various species of fish, shrimp, and crabs in the estuary has been categorized by Baxter *et al.* (1999). Because the Bay–Delta estuary serves as a critical element of the habitat for resident species and species that use the system as an obligate nursery, changes in habitat quality or availability may have a great effect on these species populations. Year-class strength for these species is dependent, in part, on habitat conditions within the Bay–Delta estuary. Species that use the Bay–Delta estuary as a nonobligate nursery area or on an opportunistic basis would be expected to have year-class strength affected to a lesser degree by variation in habitat quality and availability within the Bay–Delta that might be affected by changes in habitat conditions and/or habitat enhancement projects with the Delta flooded islands. Changes in habitat quality and availability within the Bay–Delta estuary may affect all of these species in various ways, and the significance of potential habitat alterations as a result of aquatic habitat enhancement projects needs to be assessed, in part, based on the life-history strategies and habitat usage patterns and functions associated with the Bay–Delta estuary.

A wide range of life-history strategies and habitat requirements characterize fish, shrimp, and crabs inhabiting the Bay–Delta estuary (Moyle 2002, Baxter *et al.* 1999). As noted above, habitat requirements of the various species and their life-history stages are determined by a variety of factors including:

< Salinity gradients;

< Seasonal variation in water temperature conditions;

< Variation in water depth;

< Substrate;

< Variation in water velocity and current patterns; and

< Availability of foraging and cover habitat and physical structures such as pilings and emergent vegetation, high velocity areas adjacent to levee breaches and deep-water channel habitat, and riprap, which provide foraging areas and shelter and cover.

Species functional habitat use in Suisun Bay and the Delta, including flooded islands, varies in response to these physical habitat features and the life history of the species (Baxter *et al.* 1999, DFG unpublished data, Hanson unpublished data). Species such as Chinook salmon and steelhead use the estuary as a temporary foraging and migratory corridor during juvenile emigration from freshwater rearing areas to coastal marine waters and again as adults migrate from coastal marine waters upstream to freshwater spawning habitat (Moyle 2002).

The abundance (density) of various species within an area provides important information on the values, uses, and functions of various habitats for different life stages of a species. For example, high abundance of a species or life stage within a specific area suggests that physical and chemical habitat characteristics (e.g., water depth, substrate, salinity, temperature, availability of prey, and availability of cover and shelter) are being met for that species during the time they occupy that habitat. Information on seasonal abundance patterns within an area can be used, in combination with information on the life-history characteristics of the species, to help identify the functional use of different habitats for activities such as adult foraging, spawning and egg incubation, larval dispersal, juvenile nursery and rearing, seasonal migration patterns, and other habitat functions (Hanson *et al.* 2004). Available data were examined from the DFG fishery sampling program, and other fishery studies, to provide information on habitat use by various species and life stages in Suisun Bay and the Delta in the vicinity of the three flooded islands.

In addition to fishery sampling conducted by DFG, information is available on habitat use and function for various fish species within San Francisco Bay, the Bay–Delta estuary, and nearshore coastal waters. Information on fish spawning and the occurrence of larval fish (ichthyoplankton) in the estuary has been compiled by several investigators, including Wang (1986). Information is also available from fishery surveys conducted in Suisun Bay and the Delta by USFWS, California Department of Water Resources (DWR), US Bureau of Reclamation (USBR), and others.

Recreational anglers and commercial party boats that fish in Suisun Bay and the Delta, including Franks Tract, Big Break, and Sherman Lake, provide anecdotal information on habitat function for species such as adult striped bass, white sturgeon, largemouth bass, and other species. Catch data provides information useful in evaluating habitat use and function in the area for adult and subadult life stages of various fish, which are not effectively sampled using conventional fishery collection techniques (e.g., otter trawl and midwater trawl sampling). Information from these various sources can then be used collectively as part of the scientific foundation for determining potential effects of aquatic habitat enhancement projects in the Delta flooded islands on habitat use and function and species occurrence within the area.

The Bay–Delta estuary is characterized by a diverse assemblage of physical habitats that function in a variety of ways that meet the life-history requirements of various aquatic species. Information and knowledge regarding the habitat requirements (e.g., preferred substrate, preferred water depths, salinity ranges, temperature ranges, etc.) and life history strategies and habitat usage patterns provide an important foundation for understanding the habitat functions of the estuary. Information on habitat function and use for these various species and life stages provides a useful framework for evaluating the potential beneficial effects resulting from proposed habitat enhancement projects being identified and evaluated for potential construction within the Delta flooded islands.

Essential Fish Habitats

The San Francisco Bay, Suisun Bay, and the western and central Delta, including Franks Tract, Big Break, and Sherman Lake, have been designated as Essential Fish Habitat (EFH) by the Pacific Fisheries Management Council (PFMC) to protect and enhance habitat for coastal marine fish and macroinvertebrate species that support commercial fisheries (http://swr.nmfs.noaa.gov). The amended Magnuson–Stevens Fishery Conservation and Management Act, also known as the Sustainable Fisheries Act (Public Law 104-297), requires all federal agencies to consult with the Secretary of Commerce on activities or proposed activities authorized, funded, or undertaken that may adversely affect EFH of commercially managed marine and anadromous fish species (Office of Habitat Conservation 1999). The EFH provisions of the Sustainable Fisheries Act are designed to protect fishery habitat from being lost as a result of disturbance and degradation. The act requires that EFH must be identified for all species federally managed under PFMC. PFMC is responsible for managing commercial fisheries resources along the coasts of Washington, Oregon, and California. Managed species are covered under three fisheries management plans:

- Pacific Groundfish Fishery Management Plan;
- Coastal Pelagic Fishery Management Plan; and
- Pacific Salmon Fishery Management Plan.

The *Groundfish Fishery Management Plan* defines the aquatic habitat necessary to allow for groundfish production to support long-term sustainable fisheries for groundfish and for groundfish contributions to a healthy ecosystem. The groundfish fishery EFH includes all waters from the mean higher high water line, and the upriver extent of saltwater intrusion in river mouths, along the coasts of Washington, Oregon, and California seaward to the boundary of the U.S. exclusive economic zone. The Coastal Pelagic Fishery Management Plan east-west boundary of EFH is defined to be all marine and estuarine waters from the shoreline along the coast of California, Oregon, and Washington offshore to the limits of the exclusive economic zone and above the thermocline where sea surface temperatures range between 10 and 26°C (44 to 79°F). (http://swr.nmfs.noaa.gov/hcd/cpsefh.pdf). Under the *Pacific Coast Salmon Fishery Management Plan,* the entire San Francisco Bay–Delta estuary (including the flooded islands) has been designated as EFH for spring-, fall-, late fall- and winter-run Central Valley Chinook salmon (Pacific salmon). These areas serve as a migratory corridor, holding area, and rearing habitat for adult and juvenile salmon.

Critical Habitat

The Sacramento and San Joaquin Rivers and the Bay–Delta estuary serve as a migration corridor for anadromous salmonids, which have been listed for protection under the California and/or federal Endangered Species Acts. Listed salmonids that occur seasonally in the Delta in the vicinity of the flooded islands include winter-run Chinook salmon, spring-run Chinook salmon, and steelhead trout. The Sacramento River and Bay–Delta estuary are designated as critical habitat by NOAA Fisheries for winter-run Chinook salmon. These areas of the estuary were designated as critical habitat for spring-run Chinook salmon and steelhead; however, the designation has been suspended pending further review. The Bay–Delta estuary, including the flooded islands, has been designated as critical habitat by USFWS for Delta smelt.

Special-Status Fish Species

The Bay–Delta estuary, including the Delta flooded islands, serves as habitat for a variety of special status fish species, several of which have been listed for protection under the federal and/or California Endangered Species Acts. Data from the DFG fishery surveys were analyzed to assess the occurrence (e.g., presence or absence) and relative abundance of selected species within the Delta. Data were also reviewed from salvage operations at the SWP and CVP export facilities for the occurrence of protected fish species. Analysis of the DFG survey data and SWP and CVP salvage records showed that there were no Coho salmon collected from any Suisun Bay or Delta stations. Central Valley steelhead trout are present seasonally within the Delta. Green sturgeon inhabit Suisun Bay and the Delta. Delta smelt and juvenile Chinook salmon identified as winter-run and spring-run Chinook salmon have been collected within Suisun Bay and the Delta, including the flooded islands. Longfin smelt Sacramento splittail, and green sturgeon, which have been identified as State Candidate Species of Special Concern, also inhabit Suisun Bay and the Delta.

Data on the occurrence of special status species in the DFG surveys and SWP and CVP salvage provide a technical basis for assessing occurrence of protected and special-status fish within the Delta. However, each sampling method has limitations; each samples for a particular suite of fish and none of the methods appear to effectively sample for large fish, such as adult white and green sturgeon, although otter trawls captured some individuals (juveniles) of these species.

Chinook salmon, (winter-run, federally- and state-listed as endangered; Central Valley fall/late-fall-run, a federal candidate species and California Species of Special Concern; and spring-run, federally- and state-listed as threatened) and steelhead, (Central Valley ESU, federally-listed as threatened) use the Delta in the vicinity of Franks Tract, Big Break, and Sherman Lake as a migratory corridor. In addition, Delta smelt, (federally- and state-listed as threatened) and Sacramento splittail, (California Species of Special Concern and formerly a federally threatened species1) have been documented within the waters of Suisun Bay and the Delta, including the flooded islands. Suisun Bay and the Delta, including Franks Tract, Big Break, and Sherman Lake, are in the area designated as EFH for managed species, including Pacific salmon.

Suisun Bay and the Delta in the vicinity of the flooded islands provide habitat for a variety of resident and migratory fish species (Table 4.7-1). Sampling results from fishery monitoring programs conducted by the DFG, USFWS, DWR, USBR, and others provide information on species composition, seasonal patterns in abundance, and geographic distribution of fish in the estuary. Results of fishery monitoring in the estuary have documented the occurrence of Delta smelt, winter-run Chinook salmon, spring-run Chinook salmon, and steelhead seasonally within the area. In addition, fishery studies have shown that fall-run/late-fall-run Chinook salmon also inhabit the area seasonally. The following is a brief discussion of the status, life history, and other factors affecting population abundance and status of the protected fish species that seasonally inhabit Suisun Bay and the central Delta in the vicinity of Franks Tract, Big Break, and Sherman Lake. Although fall-run/late-fall-run Chinook salmon have not been listed for protection under either the California or federal Endangered Species Acts, they are included as part of this discussion of the Delta fishery community because of their inclusion in Essential Fish Habitat (EFH) for Pacific salmon.

Delta Smelt

Delta smelt are listed as a threatened species under both the California and federal Endangered Species Acts. Delta smelt are endemic to the Sacramento–San Joaquin Delta estuary. Delta smelt inhabit the freshwater portions of the Delta and Sacramento and San Joaquin rivers and the low-salinity portions of Suisun Bay. Delta smelt typically have a 1-year

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[1] U.S. Fish and Wildlife Service. 2003. Notice of Remanded Determination of Status for the Sacramento Splittail (*Pogonichthys macrolepidotus*); Final Rule. 50 CFR Part 17. September 22.

lifecycle, although a small percentage of the adults may live to year two. Adult Delta smelt migrate upstream into channels and sloughs of the eastern Delta during fall and winter in preparation for spawning. Delta smelt live their entire life cycle in the Sacramento–San Joaquin Delta. USFWS has prepared a recovery plan for Delta smelt (USFWS 1996) that identifies criteria for evaluating the status of the Delta smelt population. These criteria include annual indices of abundance and geographic distribution in the estuary as determined through DFG fall mid-water trawl surveys. Indices of abundance and geographic distribution of Delta smelt have improved in recent years. USFWS continues to evaluate the available scientific information regarding the status of Delta smelt and the performance of various management actions designed to improve protection, reduce mortality, and enhance habitat quality and availability for Delta smelt within the estuary.

Life History

Delta smelt is a short-lived estuarine species endemic to the Sacramento–San Joaquin estuary. Adult Delta smelt typically range in length from approximately 60 to 70 mm (standard length), although some individuals have been reported to be as large as 100–120 mm (Moyle 2002). Juvenile and adult Delta smelt typically inhabit open waters of the western and central Delta and Suisun Bay, including the vicinity of the flooded islands. Delta smelt inhabit shallow-water areas (typically less than 3 m (9 ft) deep at lower low water); however juvenile and adult Delta smelt also occur in the deeper channel areas (Hanson, unpublished data). Juvenile and adult Delta smelt are generally found to the lower reaches of the Sacramento River downstream of Rio Vista, the San Joaquin River downstream of Mossdale, and in Suisun Bay, where salinity typically ranges from approximately 2 to 7 ppt.

During fall and winter, adult Delta smelt migrate upstream into the freshwater channels and sloughs of the central Delta and lower reaches of the Sacramento and San Joaquin Rivers in preparation for spawning. Spawning occurs between January and July; peak spawning occurs during April through mid-May (Moyle 2002). Spawning occurs in shallow edge waters in Delta channels and sloughs, such as Cash, Lindsay, and Barker Sloughs, and the lower reaches of the Sacramento River. Delta smelt have adhesive eggs that are broadcast over the bottom and other hard substrates, including rocks, woody material, and aquatic vegetation (Wang 1986; Wang, pers. comm.,). Eggs remain attached to the substrate during incubation. After hatching, the larval (planktonic) Delta smelt drift downstream with river and tidal currents. Larval Delta smelt feed on zooplankton during spring and early summer. As the larval and early juvenile Delta smelt grow, they are distributed further downstream in low-salinity habitats of the central Delta and Suisun Bay, where they continue to develop through summer and fall.

Factors Affecting Abundance

A variety of environmental and biological factors affect the abundance of Delta smelt within the estuary (USFWS 1996; Moyle 2002). These factors include changes in the seasonal timing and magnitude of freshwater inflow to the Delta, entrainment of larval, juvenile, and adult Delta smelt into numerous unscreened water diversions located throughout the Delta, in addition to entrainment and salvage mortality at the State Water Project (SWP) and Central Valley Project (CVP) water export facilities (USFWS 1996). Changes in the species composition and abundance of zooplankton, thought to be in response to competition with introduced zooplankton species, affect food availability for Delta smelt (Moyle 2002). Predation by striped bass, largemouth bass, and a number of other fish species inhabiting the estuary is also a source of mortality for Delta smelt (USFWS 1996). In response to seasonal and interannual variability in hydrologic conditions in the estuary, toxic substances, interbreeding with introduced Wagasaki smelt (*Hypomesus nipponensis*), and variation in the quality and availability of low-salinity habitat in the Delta and Suisun Bay may also affect the population abundance of Delta smelt (USFWS 1996).

<u>Status in Suisun Bay and the Central Delta</u>

Juvenile and adult Delta smelt are most abundant in the central Delta in the vicinity of Franks Tract during the fall, winter, and spring (DFG unpublished data). Larval, juvenile, and adult Delta smelt are most abundant in the western Delta and Suisun Bay in the vicinity of Big Break and Sherman Lake during spring, summer, and fall (DFG unpublished data). Juvenile and adult Delta smelt do not typically inhabit the central Delta during summer, when water temperatures exceed approximately 25°C (77°F) (Bennett, pers. comm.). Adult Delta smelt potentially spawn in the central Delta, lower rivers, and Suisun Bay (e.g., Suisun Marsh) during late winter and spring (spawning by Delta smelt has not been documented within the Delta or tributaries) (Wang, pers. comm.). Delta smelt larvae occur within Suisun Bay and the Delta during spring (DFG unpublished data). As a result of their life history and geographic distribution, Delta smelt may occur seasonally within Franks Tract, Big Break, and Sherman Lake as eggs, larvae, juveniles, and adults. Delta smelt seasonally inhabiting the open waters within flooded islands would be vulnerable to an increased risk of predation mortality from striped bass, largemouth bass, and other predatory fish

Restoration efforts that increase habitat complexity and provide additional refuge and shelter habitat could increase spawning habitat and significantly reduce predation rates in flooded islands habitats. Restoration that results in changes to local hydrodynamics could also decrease entrainment losses suffered at Delta export facilities.

Winter-run Chinook Salmon

Winter-run Chinook salmon are listed as an endangered species under both the California and federal Endangered Species Acts. NOAA Fisheries has recently proposed downgrading the listing status of winter-run Chinook salmon from endangered to threatened under the federal Endangered Species Act (http://swr.nmfs.noaa.gov).

Winter-run Chinook salmon historically migrated into the upper tributaries of the Sacramento River for spawning and juvenile rearing (Moyle 2002). With the construction of Shasta and Keswick dams, winter-run salmon no longer had access to historic spawning habitat within the upper watersheds (NMFS 1997). As a result of migration blockage, spawning and juvenile rearing habitat for winter-run Chinook is limited to the main-stem Sacramento River downstream of Keswick Dam. During the mid-1960s, adult winter-run Chinook salmon returns to the Sacramento River were relatively high (up to approximately 80,000 returning adults; NMFS 1997). However, the population declined substantially during the 1970s and 1980s. The population decline continued until 1991, when the adult winter-run Chinook salmon population returning to the Sacramento River was estimated to be less than 200 fish (NMFS 1997). As a result of the substantial decline in abundance, the species was listed as endangered under both the California and federal Endangered Species Acts. During the mid- and late 1990s, the numbers of adult winter-run Chinook salmon returning to the Sacramento River gradually increased and the trend of increasing abundance continues (USFWS unpublished data). Approximately 8,200 adult winter-run Chinook salmon returned to the river to spawn in 2001, 7,400 adults in 2002, and 8,200 adults in 2003 (DFG unpublished data). As with other Chinook salmon stocks, NOAA Fisheries continues to evaluate the status of the winter-run Chinook salmon population and the effectiveness of various management actions implemented in the Sacramento River, Delta, and ocean to provide improved protection and reduced mortality for winter-run Chinook salmon, in addition to providing enhanced habitat quality and availability for spawning and juvenile rearing (NMFS 2003). NOAA Fisheries has prepared a draft recovery plan for winter-run Chinook salmon (NMFS 1997).

Life History

Winter-run Chinook salmon are an anadromous species spending 1–3 years in the ocean before migrating upstream to the Sacramento River to spawn (Moyle 2002). The majority of adult winter-run Chinook salmon returning to spawn are 3-year-olds; however, the adult population also includes 2-year-old and 4-year-old Chinook salmon (NMFS 1997). Adult winter-run salmon migrate upstream through San Francisco Bay, Suisun Bay, and the Delta during winter and early spring, with peak migration occurring during March (Moyle 2002). Adult winter-run Chinook salmon migrate upstream in the Sacramento River; the majority of adults spawn in the reach upstream of Red Bluff. Winter-run Chinook salmon spawn within the main stem of the Sacramento River in areas where gravel substrate, water temperatures, and water velocities are suitable.

Spawning occurs during the spring and summer (mid-April through August; Moyle 2002). Egg incubation continues through fall. Juvenile winter-run Chinook salmon rear within the Sacramento River throughout the year, feeding primarily on aquatic insects. Juvenile winter-run salmon (smolts) migrate downstream through the lower reaches of the Sacramento River, Delta, Suisun Bay, and San Francisco Bay during winter and early spring (December through May) as they migrate from the freshwater spawning and juvenile rearing areas into the coastal marine waters of the Pacific Ocean. The Sacramento River mainstem is the primary upstream and downstream migration corridor for winter-run Chinook salmon. Juvenile winter-run Chinook salmon may migrate from the Sacramento River into the central Delta, passing into the Delta through the Delta Cross-channel, Georgiana Slough, or Three Mile Slough, during their downstream migration. The migration timing of juvenile winter-run Chinook salmon varies in and among years in response to a variety of factors, including increases in river flow and turbidity resulting from winter storms.

Factors Affecting Abundance

A variety of environmental and biological factors have been identified that affect the abundance, mortality, and population dynamics of winter-run Chinook salmon. One primary factor that has affected population abundance of winter-run Chinook salmon is loss of access to historic spawning and juvenile rearing habitat in the upper reaches of the Sacramento River and its tributaries as a result of the migration barrier caused by Shasta and Keswick dams. Operation of the Red Bluff Diversion Dam, which impedes adult upstream migration and increases vulnerability of juvenile winter-run Chinook salmon to predation mortality, has been identified as a factor affecting mortality within the river. In recent years, changes to Red Bluff Diversion Dam gate operations have been made to provide improved access for upstream and downstream migrating winter-run Chinook salmon. Water temperature within the mainstem Sacramento River is also a factor affecting incubating eggs, holding adults, and growth and survival of juvenile winter-run Chinook salmon rearing in the upper Sacramento River. Modifications to Shasta Reservoir storage and operations and water temperature management have been implemented in recent years to improve water temperature conditions in the upper reaches of the Sacramento River. Juvenile winter-run Chinook salmon are also vulnerable to entrainment at many unscreened water diversions along the Sacramento River and in the Delta, in addition to entrainment and salvage mortality at the SWP and CVP export facilities.

Changes in habitat quality and availability for spawning and juvenile rearing, exposure to contaminants and acid mine drainage, predation mortality by Sacramento pikeminnow, striped bass, largemouth bass, and other predators, and competition and interactions with hatchery-produced Chinook salmon are all factors affecting winter-run Chinook salmon abundance. In addition, subadult and adult winter-run Chinook salmon are vulnerable to recreational and commercial fishing, ocean survival is affected by climatic and oceanographic conditions, and adults are vulnerable to predation mortality by marine mammals.

A number of changes have been made to improve the survival and habitat conditions for winter-run Chinook salmon. Modifications have been made to reservoir operations for instream flow and temperature management and to operation of the Red Bluff diversion gate, and several large previously unscreened water diversions have been equipped with positive-barrier fish screens. Changes to ocean salmon fishing regulations and modifications to SWP and CVP export operations have also improved the survival of both adult and juvenile winter-run Chinook salmon. These changes in management, in combination with favorable hydrologic and oceanographic conditions in recent years, are thought to have contributed to the trend of increasing abundance of adult winter-run Chinook salmon returning to the upper Sacramento River to spawn since the mid-1990s.

Status in Suisun Bay and the Central Delta

Adult and juvenile winter-run Chinook salmon primarily migrate upstream and downstream within the main-stem Sacramento River. Juvenile winter-run Chinook salmon may migrate from the Sacramento River to the central Delta during their downstream migration and may also inhabit flooded islands as a temporary foraging area and migration pathway during the winter and early spring migration period. The occurrence of juvenile winter-run Chinook salmon in Suisun Bay and the Delta would be expected to occur during late fall through early spring when Delta water temperatures would be suitable for juvenile winter-run Chinook salmon migration.

Although the majority of adult winter-run Chinook salmon migrate upstream in the main-stem Sacramento River, there is a probability, although low, that adults may migrate into the central Delta. The majority of adult winter-run Chinook salmon migrate upstream in the Sacramento River past Sherman Lake. The occurrence of adult winter-run Chinook salmon in the central Delta, including Big Break and Franks Tract, although expected to be very low, would be limited to winter and early spring adult upstream migration.

Because winter-run Chinook salmon do not spawn within Suisun Bay or the Delta, there is no probability that habitat enhancement projects in the Delta flooded islands would adversely or beneficially affect winter-run Chinook salmon spawning or egg incubation.

Central Valley Spring-run Chinook Salmon

Spring-run Chinook salmon are listed as a threatened species under both the California and federal Endangered Species Acts.

Spring-run Chinook salmon were historically widely distributed and abundant within the Sacramento and San Joaquin river systems (Yoshiyama *et al*. 1998). Spring-run Chinook salmon historically migrated upstream into the upper reaches of the main-stem rivers and tributaries for spawning and juvenile rearing (Moyle 2002). Construction of major dams and reservoirs on these river systems eliminated access to the upper reaches for spawning and juvenile rearing, and completely eliminated the spring-run Chinook salmon population from the San Joaquin River system (Moyle 2002). Spring-run Chinook salmon abundance has declined substantially (NMFS 2003), and the geographic distribution of the species in the Central Valley has also declined substantially. Spring-run spawning and juvenile rearing currently occur consistently in only a small fraction of their previous geographic distribution, including populations inhabiting Deer, Mill, and Butte creeks, the main-stem Sacramento River, several other local tributaries on an intermittent basis, and the lower Feather River (Moyle 2002). Recent genetic studies show that spring-run Chinook salmon returning to the lower Feather River are genetically similar to fall-run Chinook salmon. Hybridization between spring-run and fall-run Chinook salmon, particularly on the Feather River where both stocks are produced within the Feather River hatchery, is a factor affecting the status of the spring-run Chinook salmon population (DWR 2004b). NOAA Fisheries is in the process of developing a recovery plan for Central Valley spring-run Chinook salmon.

Life History

Spring-run Chinook salmon are an anadromous species, spawning in freshwater and spending a portion of their life cycle in the Pacific Ocean. Adult spring-run Chinook salmon migrate upstream into the Sacramento River system during the spring months, but are sexually immature (Moyle 2002). Adult spring-run Chinook salmon hold in deep cold pools in rivers and tributaries over the summer months before spawning (Moyle 2002). Spawning occurs during late summer and early fall (late August through October) in areas characterized by suitable spawning gravels, water temperatures, and water velocities (Bjorn and Reiser 1991). Eggs incubate in the gravel nests (redds), emerging as fry during late fall and winter. A portion of the fry appear to migrate downstream soon after emerging, where they rear in the lower river channels, and potentially within Suisun Bay and the central Delta, during winter and spring. After emergence, a portion of the spring-run Chinook salmon fry remain resident in the creeks and rear for approximately 1 year (Hill, pers. comm.). The juvenile spring-run Chinook salmon that remain in the creeks migrate downstream as yearlings primarily during the late fall, winter and early spring with peak yearling migration occurring in November (Hill and Weber 1999). The downstream migration of both spring-run Chinook salmon fry and yearlings during late fall and winter typically coincides with increased flow and turbidity associated with winter stormwater runoff (Ward, pers. comm.).

Factors Affecting Abundance

A variety of environmental and biological factors have been identified that affect the abundance, mortality, and population dynamics of spring-run Chinook salmon. A primary factor that has affected population abundance of spring-run Chinook salmon has been the loss of access to historic spawning and juvenile rearing habitat in the upper Sacramento River and its tributaries and the San Joaquin River as a result of migration barriers caused by construction of major dams and reservoirs (Yoshiyama *et al.* 1998, Moyle 2002). Operation of the Red Bluff Diversion Dam, which impedes adult upstream migration and increases vulnerability of juvenile spring-run Chinook salmon to predation mortality, is a factor affecting mortality within the river (Vogel, pers. comm.). Water temperature within the rivers and creeks is also a factor affecting incubating eggs, holding adults, and growth and survival of juvenile spring-run Chinook salmon (Ward, pers. comm.). Juvenile spring-run Chinook salmon are also vulnerable to entrainment at many unscreened water diversions along the Sacramento River and in the Delta, in addition to entrainment and salvage mortality at the SWP and CVP export facilities. Changes in habitat quality and availability for spawning and juvenile rearing, exposure to contaminants, predation mortality by Sacramento pikeminnow, striped bass, largemouth bass, and other predators, and competition and interactions with hatchery-produced Chinook salmon are all factors affecting spring-run Chinook salmon abundance. In addition, subadult and adult spring-run Chinook salmon are vulnerable to recreational and commercial fishing, ocean survival is affected by climatic and oceanographic conditions, and adults are vulnerable to predation mortality by marine mammals.

A number of changes have been made to improve the survival and habitat conditions for spring-run Chinook salmon. Several large previously unscreened water diversions have been equipped with positive-barrier fish screens. Changes to ocean salmon fishing regulations, and modifications to SWP and CVP export operations have also been made to improve the survival of adult and juvenile spring-run Chinook salmon. Improvements in fish-passage facilities have also improved migration and access to Butte Creek. These changes and management actions, in combination with favorable hydrologic and oceanographic conditions in recent years, are thought to have contributed to the trend of increasing abundance of adult spring-run Chinook salmon returning to spawn in Butte Creek and other habitats in the upper Sacramento River system in recent years.

Status in Suisun Bay and the Central Delta

Adult and juvenile spring-run Chinook salmon primarily migrate upstream and downstream in the main-stem Sacramento River. Juvenile spring-run Chinook salmon may migrate from the Sacramento River to the central Delta during their downstream migration and may also use Suisun Bay and the Delta as temporary foraging areas and migration pathways during winter and early spring migration. Juvenile spring-run Chinook salmon occur in Suisun Bay and the Delta during late fall through early spring, when water temperatures in the Delta would be suitable for juvenile spring-run Chinook salmon migration.

Although the majority of adult spring-run Chinook salmon migrate upstream in the main-stem Sacramento River passing Sherman Lake, there is a probability, although low, that adults may migrate into the central Delta. The occurrence of adult spring-run Chinook salmon in the western and central Delta in the vicinity of Big Break and Franks Tract, although expected to be very low, would be limited to the late winter and spring adult upstream migration.

Because spring-run Chinook salmon do not spawn in Suisun Bay or the Delta, there is no probability that habitat enhancement projects in the Delta flooded islands would adversely or beneficially affect spring-run Chinook salmon spawning or egg incubation.

Central Valley Steelhead

Central Valley steelhead have been listed as a threatened species under the Federal Endangered Species Act. Steelhead are not listed for protection under the California Endangered Species Act, but are identified as a Species of Concern.

Central Valley steelhead historically migrated upstream to the high gradient upper reaches of Central Valley streams and rivers for spawning and juvenile rearing. Construction of dams and impoundments on most Central Valley rivers has created impassable barriers to upstream migration and substantially reduced the geographic distribution of steelhead. Although quantitative estimates of the number of adult steelhead returning to Central Valley streams to spawn are not available, anecdotal information and observations indicate that population abundance is low. Steelhead distribution is currently restricted to the main-stem Sacramento River downstream of Keswick Dam, the Feather River downstream of Oroville Dam, the

American River downstream of Nimbus Dam, the Mokelumne River downstream of Comanche Dam, and a number of smaller tributaries to the Sacramento River system, Delta, and San Francisco Bay. The Central Valley steelhead population is composed of both naturally spawning steelhead and steelhead produced in hatcheries. NOAA Fisheries continues to evaluate the status of steelhead and to develop a recovery plan for the species.

Life History

Central Valley steelhead, like Chinook salmon, are anadromous. Adult steelhead spawn in fresh water, and the juveniles migrate to the Pacific Ocean where they reside for a period of years before returning to the river system to spawn. Steelhead that do not migrate to the ocean, but spend their entire life in fresh water, are known as resident rainbow trout.

Adult steelhead migrate upstream during fall and winter (September through approximately February) with steelhead migration into the upper Sacramento River typically occurring during fall, and adults migrate into lower tributaries typically during the fall and winter. Steelhead spawn in areas characterized by clean spawning gravels, cold-water temperatures, and moderately high velocity. Spawning typically occurs during winter and spring (December–April); the majority of spawning activity occurs during January through March. Unlike Chinook salmon that die after spawning, adult steelhead may migrate downstream after spawning and return to spawn in subsequent years.

Steelhead spawn by creating a depression in the spawning gravels where eggs are deposited and fertilized (redd). The eggs incubate within the redd for a variable period, which is dependent on water temperature. After hatching, the young steelhead emerge from the gravel redd as fry. The young steelhead rear in the stream system, foraging on insects for 1–2 or more years before migrating to the ocean. After rearing within the stream, the juvenile steelhead undergo a physiological transformation (smolting) that allows the juvenile steelhead to migrate from the freshwater rearing areas downstream to coastal marine waters. Downstream migration of steelhead smolts typically occurs during late winter and early spring (January–May). The seasonal timing of downstream migration of steelhead smolts may vary in response to a variety of environmental and physiological factors, including changes in water temperature, changes in stream flow, and increased turbidity resulting from stormwater runoff. The juvenile steelhead rear in the coastal marine waters for approximately 2–3 years before returning to their natal stream as spawning adults.

The steelhead life cycle is characterized by a high degree of flexibility (plasticity) in the duration of both their freshwater and marine rearing phases. The steelhead life cycle is adapted to respond to environmental variability in stream hydrology and other environmental conditions.

Factors Affecting Abundance

Factors affecting steelhead abundance are similar to those described for winter-run and spring-run Chinook salmon. A primary factor affecting population abundance of steelhead has been the loss of access to historic spawning and juvenile rearing habitat in the upper reaches of the Sacramento River and its tributaries and the San Joaquin River as a result of the migration barriers caused by construction of major dams and reservoirs. Water temperature in the rivers and creeks, particularly during summer and early fall, is also a factor affecting growth and survival of juvenile steelhead. Juvenile steelhead are vulnerable to entrainment at many unscreened water diversions along the Sacramento River and in the Delta, in addition to entrainment and salvage mortality at the SWP and CVP export facilities. Changes in habitat quality and availability for spawning and juvenile rearing, exposure to contaminants, predation mortality, passage barriers and impediments to migration, changes in land-use practices, and competition and interactions with hatchery-produced steelhead are all factors affecting steelhead abundance. Unlike Chinook salmon, steelhead are not vulnerable to recreational and commercial ocean fishing, although steelhead support a small inland recreational fishery for hatchery-produced fish. Ocean survival is affected by climatic and oceanographic conditions, and adults are vulnerable to predation mortality by marine mammals.

A number of changes have improved the survival and habitat conditions for steelhead. Several large previously unscreened water diversions have been equipped with positive-barrier fish screens. Improvements to fish-passage facilities have also improved migration and access to spawning and juvenile rearing habitat.

Status in Suisun Bay and the Central Delta

Adult and juvenile steelhead primarily migrate upstream and downstream in the main-stem Sacramento River, passing Sherman Lake. Juvenile steelhead migrate from the Sacramento River and its tributaries through the central Delta, Suisun Bay, and San Francisco Bay during the winter and early spring migration. Steelhead do not spawn in Suisun Bay or the Delta; however juvenile steelhead may temporarily forage in Suisun Bay and the Delta during emigration, and hence they would potentially be present in the vicinity of the Delta flooded islands during the seasonal migration period. Juvenile steelhead occur in Suisun Bay and the Delta during the winter and early spring migration, when water temperatures in the Delta would be suitable for juvenile steelhead migration.

Although the majority of adult steelhead migrate upstream in the main-stem Sacramento River, there is a probability that adults migrate through the central Delta and would be present seasonally in the vicinity of Franks Tract, Big Break, and Sherman Lake. The occurrence of adult steelhead within the Delta, and potentially within Delta flooded islands, would be limited to the winter and early spring adult upstream migration.

Because steelhead do not spawn in Suisun Bay or the Delta, there is no probability that habitat-enhancement projects in Delta flooded islands would adversely or beneficially affect steelhead spawning or egg incubation.

Fall-run Chinook Salmon

Fall-run Chinook salmon are the most abundant species of Pacific Salmon inhabiting the Sacramento and San Joaquin river systems. Fall-run Chinook salmon are not listed for protection under the California or federal Endangered Species Acts. In addition to fall-run Chinook salmon, the group of Pacific Salmon comprises late-fall-run Chinook salmon (which are not listed under either the California or federal Endangered Species Act), and spring-run Chinook salmon and winter-run Chinook salmon, which are discussed above. Although fall-run and late-fall-run Chinook salmon are not listed for protection under the Endangered Species Act, they are included in this analysis because they occur seasonally in Suisun Bay and the central Delta in the vicinity of the flooded islands, which are located in the area identified as EFH for Pacific salmon.

NOAA Fisheries proposed in 1998 that Central Valley fall-run and late-fall-run Chinook salmon be listed under the Federal Endangered Species Act as a threatened species. Based on further analysis and public comment, NOAA Fisheries decided that fall-run and late-fall-run Chinook salmon did not warrant listing; they remain as a candidate species for further analysis and evaluation.

Although fall-run and late-fall-run Chinook salmon inhabit a number of watersheds in the Central Valley for spawning and juvenile rearing, the largest populations occur within the main-stem Sacramento River, Feather River, Yuba River, American River, Mokelumne River, Merced River, Tuolumne River, and Stanislaus River. Fall-run Chinook salmon, in addition to spawning in these river systems, are also produced in fish hatcheries on the Sacramento River, Feather River, American River, Mokelumne River, and Merced River. Hatchery operations are intended to mitigate for the loss of access to upstream spawning and juvenile rearing habitat resulting from construction of dams and reservoirs in the Central Valley in addition to producing fall-run Chinook salmon as part of the ocean salmon enhancement program to support commercial and recreational ocean salmon fisheries. Fall-run Chinook salmon also support an inland recreational fishery.

<u>Life History</u>

Fall-run Chinook salmon are anadromous with spawning and juvenile rearing occurring within freshwater rivers and streams and juvenile and adult rearing occurring within coastal marine waters. Adult fall-run Chinook salmon migrate from the coastal marine waters upstream through San Francisco Bay, Suisun Bay, and the central Delta during late summer and early fall (approximately late July through early December). Adult fall-run Chinook salmon migrate upstream to areas characterized by suitable spawning conditions, which include the availability of clean spawning gravels, cold water (considered be less than 56°F) and relatively high water velocities. Fall-run Chinook salmon spawning is similar to that described for other Chinook salmon, with the creation of redds where eggs are deposited and incubate. Fall-run Chinook salmon spawning occurs from October through December with the greatest spawning activity occurring typically in November and early December.

The success of fall-run Chinook salmon spawning is dependent, in part, on seasonal water temperatures. After incubating and hatching, the young salmon emerge from the gravel redd as fry. A portion of the fry population migrates downstream soon after emergence, where they rear in the lower river channels, western and central Delta including areas adjacent to Franks Tract and Big Break, and Suisun Bay adjacent to Sherman Lake during spring. The remaining juvenile salmon continue to rear in the upstream stream systems through spring, until they are physiologically adapted to migration into saltwater (smolting), which typically takes place from April through early June. A small proportion of the fall-run Chinook salmon juveniles may, in some systems, rear through summer and fall migrating downstream during fall, winter, or early spring as yearlings.

The juvenile and adult Chinook salmon rear within coastal marine waters, foraging on fish and macroinvertebrates (e.g., northern anchovy, Pacific herring, squid, krill, etc.), until they reach maturation. Adult Chinook salmon spawn at ages ranging from approximately 2 to 5 years; the majority of adult fall-run Chinook salmon returning at age 3. Chinook salmon, unlike steelhead, die after spawning.

Late-fall-run Chinook salmon have a similar life history, as described for other Pacific salmon.

Factors Affecting Abundance

A variety of environmental and biological factors affect reproductive success, mortality, and population dynamics of fall-run and late-fall-run Chinook salmon. The loss of access to historic spawning and juvenile rearing areas as a result of the construction of dams and reservoirs on many of the Central Valley river systems is a factor affecting population abundance. In addition, exposure to seasonal water temperatures during both the upstream migration of adults and downstream migration of juveniles, changes in instream flows resulting from reservoir operations, degradation of the quality and availability of suitable spawning habitat and juvenile rearing areas, and the effects of hatchery operations on Chinook salmon have been identified as important factors affecting abundance. Juvenile Chinook salmon are also susceptible to entrainment at unscreened water diversions, losses resulting from salvage and handling at the SWP and CVP export facilities, predation mortality by native and nonnative fish species, interannual variability in hydrologic conditions in streams and rivers, and variability in ocean rearing conditions have also been identified. Concern has also been expressed regarding the effects of contaminant exposure, and impediments and barriers to upstream and downstream migration. Ocean commercial and recreational angler harvest, and inland recreational harvest, are also factors affecting population abundance.

Management practices have been altered to regulate commercial and recreational angler harvest, improve instream flow conditions, improve water temperature management downstream of reservoirs, improve quality and availability of spawning and juvenile rearing habitat, and improve fish passage facilities at a number of existing migration impediments and barriers. Management changes also address concerns regarding contaminant exposure, the success of fish handling and salvage at the SWP and CVP export facilities, and a number of water diversions on the Sacramento and San Joaquin river systems have been equipped with positive barrier fish screens designed to reduce or eliminate juvenile salmon entrainment mortality. These management changes, in combination with recent favorable hydrology and ocean rearing conditions contribute to an increasing trend in adult fall-run Chinook salmon abundance in the ocean and Central Valley river systems.

Status in Suisun Bay and the Central Delta

Adult and juvenile Chinook salmon primarily migrate upstream and downstream within the mainstem Sacramento and San Joaquin Rivers although both adult and juvenile Chinook salmon also migrate through central Delta channels. Juvenile Chinook salmon, particularly in the fry stage (generally 1.5 to 3 inches) may rear in Suisun Bay and the western and central Delta, including at Franks Tract, Big Break, and Sherman Lake, and they forage along channel and shoreline margins and lower velocity backwater habitats. Juvenile fall-run Chinook salmon in the Delta occur during late winter (fry) through early spring (smolts) when water temperatures in the Delta would be suitable for juvenile Chinook salmon migration.

Although the majority of adult fall-run Chinook salmon migrate upstream the mainstem Sacramento and San Joaquin Rivers, adults also migrate into the central Delta. Adult fall-run Chinook salmon within the western and central Delta in the vicinity of the flooded islands would be limited to the fall (October through December) during upstream migration.

Because fall-run and late-fall-run Chinook salmon do not spawn in Suisun Bay or the central Delta, there is no probability that habitat enhancement projects within Delta flooded islands would adversely or beneficially affect Chinook salmon spawning or egg incubation. Habitat enhancement projects in Delta flooded islands could, however, greatly affect habitat quality for rearing juveniles. Restoration efforts could increase overall food supply, reduce predation through additional predator refuge and shelter habitat, and reduce fish entrainment at Delta export facilities through improved hydrodynamics.

Recreational Fish Species

Suisun Bay and the Delta, including Franks Tract, Big Break, and Sherman Lake, support recreational fisheries that include a variety of resident and migratory fish. Recreationally important fish species include striped bass, Chinook salmon, largemouth bass, catfish, and sturgeon. See Section 4.11 for additional discussion on fish-related recreation.

FISHERIES IN THE STUDY AREAS

Fisheries in the three study areas are first discussed together, based on Delta-wide studies. Fisheries specific to Franks Tract are described next. Because Big Break and Lower Sherman Lake are sufficiently close to each other and contain similar types of habitats, their species composition would be similar and are discussed together.

Habitat

Franks Tract, located in the central region of the Sacramento–San Joaquin Delta (central Delta), provides approximately 3,000 acres of shallow open-water habitat for a variety of resident and migratory fish and macroinvertebrates. Lower Sherman Lake and Big Break are located in the western Delta adjacent to Antioch. Lower Sherman Lake is near the confluence of the lower Sacramento and San Joaquin Rivers and provides approximately 3,300 acres of shallow open-water habitat. Big Break is adjacent to the lower San Joaquin River and provides approximately 2,200 acres of shallow open water habitat.

The primarily open-water habitat in Franks Tract, Sherman Lake, and Big Break is relatively shallow (most of the open-water habitat within the flooded islands is less than 10 feet deep), with a relatively uniform bottom composed of silt, sand, peat, and other organic matter. Tules and other emergent and submerged aquatic vegetation grow in open water areas and along the shoreline margins of Franks Tract, Big Break, and Lower Sherman Lake and provide habitat for spawning, juvenile rearing, and adult holding and foraging.

Franks Tract, Big Break, and Lower Sherman Lake are located in the area of the estuary influenced by freshwater inflow from the Sacramento and San Joaquin River systems and tidal effects from coastal marine waters of San Francisco, San Pablo, and Suisun Bays. The flooded islands, as well as the surrounding waters in the western and central Delta, are characterized by low salinity levels under most environmental conditions; however, salinity intrusion upstream into the Delta does occur under critical drought conditions, in response to catastrophic levee breaching, and the dynamic balance between freshwater inflow and marine water intrusion into the estuary. Although the flooded islands primarily provide shallow open-water aquatic habitat, the surrounding channels in the western and central Delta vary in size and hydraulic complexity.

Channels surrounding the flooded islands range from the dredged navigational shipping channels in the lower Sacramento and San Joaquin rivers to small dead-end sloughs hundreds of feet wide, with depths up to approximately 50 to 60 feet, typically ranging from approximately 20 to 30 feet in width with water depths typically less than 6 feet deep. The main river channels are typically protected from erosion by managed levees stabilized by riprap and other structures. Small dead-end sloughs are typically lined by emergent aquatic vegetation, including both tules and reeds (*Phragmites communis*).

Levees surrounding reclaimed islands and channels in the western and central Delta are typically vegetated by native and nonnative grasses and shrubs with intermittent stands of tules, reeds, and cattails. Mature riparian trees are not abundant along western and central Delta levees. Substrate in the flooded islands and the surrounding sloughs and channels is primarily sand, soft silt, clay, and mud, in addition to deposits of organic material such as peat and decaying tules and reeds.

Levee breaches at Franks Tract, which occurred in 1938 (see Section 3.2) and have remained open since that time, provide a hydraulic connection between the open waters in Franks Tract and the larger channels in the central Delta, which frequently range from approximately 300 to 500 wide and approximately 6 to 12 feet deep. Big Break levee breaches provide hydraulic connection between open waters and the lower San Joaquin River, which is 300 to 500 feet wide in the managed navigational shipping channel more than 40 feet deep. Lower Sherman Lake is hydraulically connected with the lower Sacramento and San Joaquin Rivers where water depths are typically 50 feet or greater in the maintained navigational shipping channel. Tidal fluctuations in the estuary result in tidal currents entering and exiting Franks Tract, Big Break, and Lower Sherman Lake that provide opportunities for fish and macroinvertebrate movement from the western and central Delta channels in and out of the flooded islands.

Water quality and hydrodynamic conditions affecting fishery habitat in the flooded islands are influenced by a variety of factors, including the magnitude of seasonal freshwater inflow to the Bay–Delta estuary from the Sacramento and San Joaquin rivers, tidal circulation patterns in the western and central Delta, salinity, and seasonal variation in water temperatures. Turbidity and suspended sediment concentrations in Franks Tract, Big Break, and Lower Sherman Lake are influenced by wind- and wave-induced turbulence, resuspension of sediments in the shallow open waters and the resulting fetch associated with the relatively large surface area of these flooded islands.

Results of fishery sampling in the Bay–Delta estuary show that 55 fish species inhabit the estuary (Baxter *et al.* 1999), of which approximately one-half are nonnative introduced species. Many fish species inhabiting the estuary, such as striped bass and American shad, were purposefully introduced to provide recreational and commercial fishing opportunities. Many fish species have been introduced accidentally into the estuary through movement among connecting waterways (e.g., threadfin shad and inland silversides). A number of fish and macroinvertebrate species have been accidentally introduced into the estuary, primarily from Asia, through ballast water discharges resulting from commercial cargo transport (e.g., yellowfin and chameleon gobies). An estimated 100 macroinvertebrate species have also been introduced, primarily through ballast water discharge, into the estuary (Carlton 1979). The purposeful and unintentional introductions of nonnative fish and macroinvertebrates have contributed to a substantial change in the species composition, trophic dynamics, and competitive interactions affecting the population dynamics of native species. Many introduced fish and macroinvertebrates have colonized and inhabit Franks Tract, Big Break, and Lower Sherman Lake.

The estuary and Delta provide habitat for a variety of resident and migratory fish species and other freshwater and estuarine organisms (Table 4.7-1), several of which have been listed for protection under the State and/or Federal Endangered Species Act (ESA), including Delta smelt, winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead. Suisun Bay and the western and central Delta have been designated as critical habitat for Delta smelt and winter-run Chinook salmon and as Essential Fish Habitat (EFH) for managed species, including Pacific salmon. As a result of the sensitivity and importance of aquatic habitat within Suisun Bay and the western and central Delta, including Franks Tract, Big Break, and Lower Sherman Lake, this section provides additional information specifically focusing on these sensitive and protected species and their habitat. This section provides a summary of information available on the aquatic resources inhabiting the Bay–Delta estuary, and specifically the western and central Delta adjacent to the flooded islands, including phytoplankton, zooplankton, benthic macroinvertebrates, and common fish populations.

Species Composition and Distribution

The fishery survey programs designed and implemented by DFG (Baxter *et al.* 1999) are long-term studies that began in 1980 and continue; data is collected monthly using multiple gear types to sample juvenile and adult fish and macroinvertebrates, in addition to sampling for fish eggs and larvae. The fishery data has been analyzed based on the density of each species collected, using various sampling methods. The density of a species collected using the otter trawl, which samples on and near the bottom (benthic and epibenthic zone), is reported as the number of individuals per hectare. The density of ichthyoplankton collected in the plankton net is reported as the number of individuals per 10,000 cubic meters of water sampled. The density of a species collected using the midwater trawl, which samples in the water column (pelagic zone), is reported as the number of individuals per 10,000 cubic meters of water sampled. Information on the calculation of densities for each DFG sampling method is presented by Baxter *et al.* (1999). The Delta smelt 20 mm surveys, conducted throughout spring in the Delta since the early 1990s provide additional information on the seasonal and geographic distribution of Delta smelt larvae in various regions of the Delta.

The following sections summarize and analyze information from DFG surveys to characterize:

< Species composition in Suisun Bay and the western and central Delta in the vicinity of Franks Tract, Big Break, and Sherman Lake;

< Differences in species composition by location/habitat;

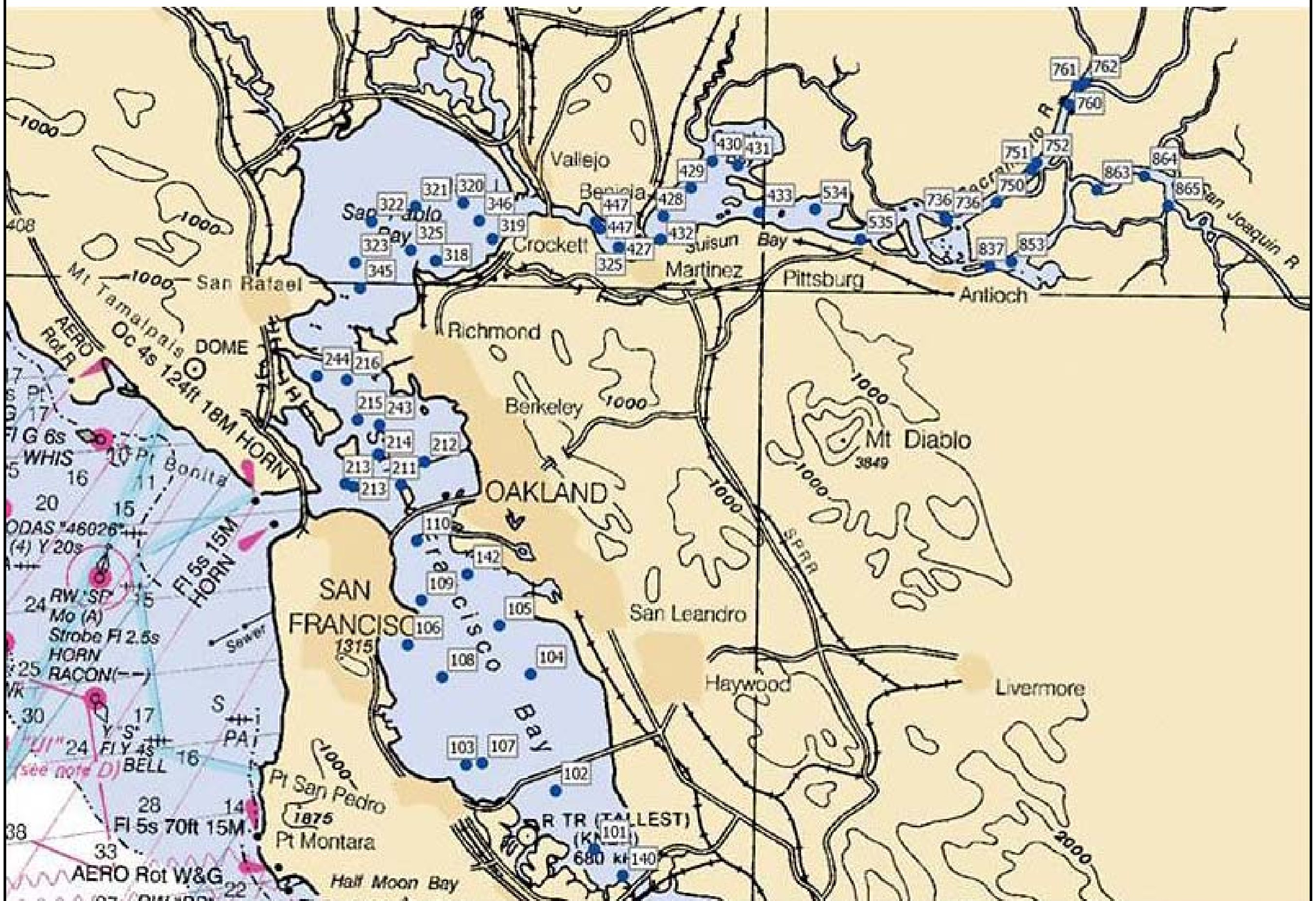
< Occurrence of threatened and endangered species; and

< Interannual variation in species abundance and distribution.

The information generated through these analyses has been documented in the following sections.

DFG *Fishery Surveys*

DFG sampled approximately monthly using midwater trawls and otter trawls, from 35 stations from the South Bay upstream into the Sacramento River, to Sherman Island and the San Joaquin River at Antioch (Baxter *et al.* 1999). An additional 17 sampling stations were added between 1988 and 1994. Based on the types of trawls and data available, DFG sampling stations (837, 857, 863, 864, and 865) were chosen for analysis to reflect the fishery community inhabiting central Delta in the vicinity of Franks Tract (Exhibit 4.7-1). Fishery sampling data from Stations 535, 736, 758, and 837 were selected to represent the fish community in Suisun



Source: Baxter et al. 1999

CDFG Open Water Sampling Stations

EXHIBIT 4.7-1

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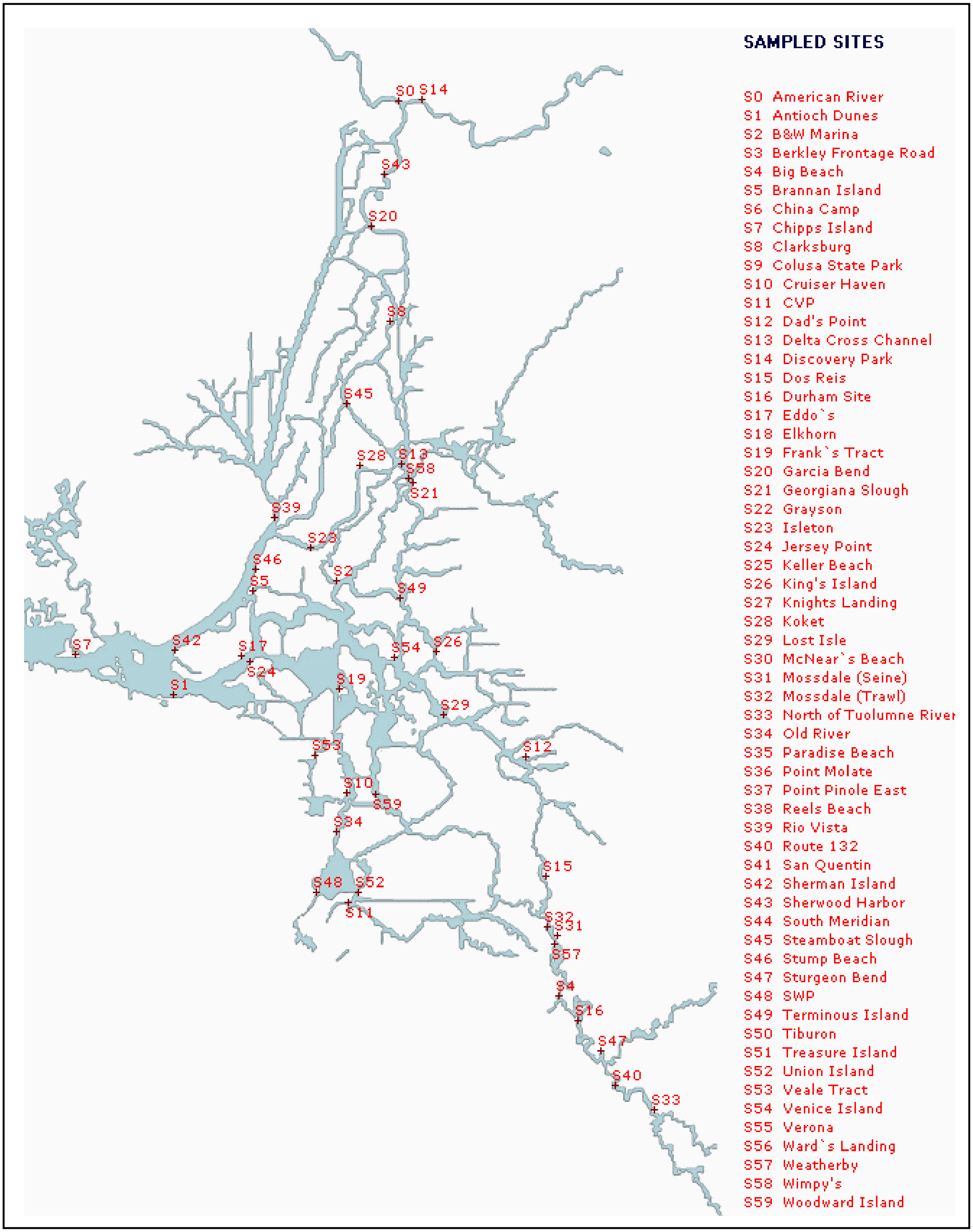
Bay and the western Delta near Lower Sherman Lake and Big Break. Information on the fishery community in Suisun Bay and the Delta is also available from the DFG real-time monitoring program (Exhibit 4.7-2). Data on the seasonal densities and geographic distribution of larval Delta smelt were from the 20 mm Delta smelt surveys at Station 901 in Franks Tract, Station 802 in the lower San Joaquin River near Big Break, and Station 703 in Lower Sherman Lake (Exhibit 4.7-3). Fishery data available from the DFG summer townet and fall midwater trawl surveys (Exhibit 4.7-4). Many of these fishery survey programs target specific species during limited times of the year (20 mm Delta smelt survey, summer townet survey, fall midwater trawl survey, etc.). The Bay–Delta fishery survey program, however, has sampled year round over an extended period represents a variety of hydrological and environmental conditions in the Bay–Delta estuary. Hence the survey provides important information on the seasonal distribution of the fishery community and is the primary source of data used to characterize the Delta fishery community in the following section.

DFG Bay–Delta open water stations that began operating in 1980 (Exhibit 4.7-1) sample monthly using otter trawls and midwater trawls. The otter trawl is towed on the bottom against the current for 5 minutes and then retrieved. The midwater trawl is towed with the current for 12 minutes and retrieved obliquely. The plankton net (505-μm mesh) mounted on a steel sled is towed on the bottom for 5 minutes and retrieved obliquely. Inshore fishery sampling has been conducted using a beach seine. This DFG fishery survey program has sampled in the Suisun Bay and Delta channels, but not specifically within Franks Tract, Big Break, or Lower Sherman Lake (Exhibit 4.7-1), however, results of these extensive fishery surveys in the area are expected to be representative of the fishery community inhabiting the flooded islands.

The variation in sampling methods expectedly yields different results. The otter trawl samples more effectively from the near substrate area (epibenthic), the midwater trawl samples more effectively in the open-water column, and the plankton net samples the smaller components of the aquatic community. The beach seine samples the inshore fishery community inhabiting shallow water areas immediately adjacent to the shoreline. It is necessary to review the results of all four methods to gain an understanding of the overall aquatic community inhabiting Suisun Bay and the Delta in the vicinity of the flooded islands. Because many of the fish inhabiting the area, particularly as adults, are not effectively sampled by these conventional survey methods additional information from limited electrofishing surveys and reports from recreational anglers fishing in the flooded islands and surrounding waters has also been used.

The DFG survey data has been used to determine species composition in the aquatic community as the total numbers of a species collected at each survey station or for each group of surveyed stations. Species composition is therefore a measure of the number of individuals of each species caught, not a measure of the biomass represented by the species.

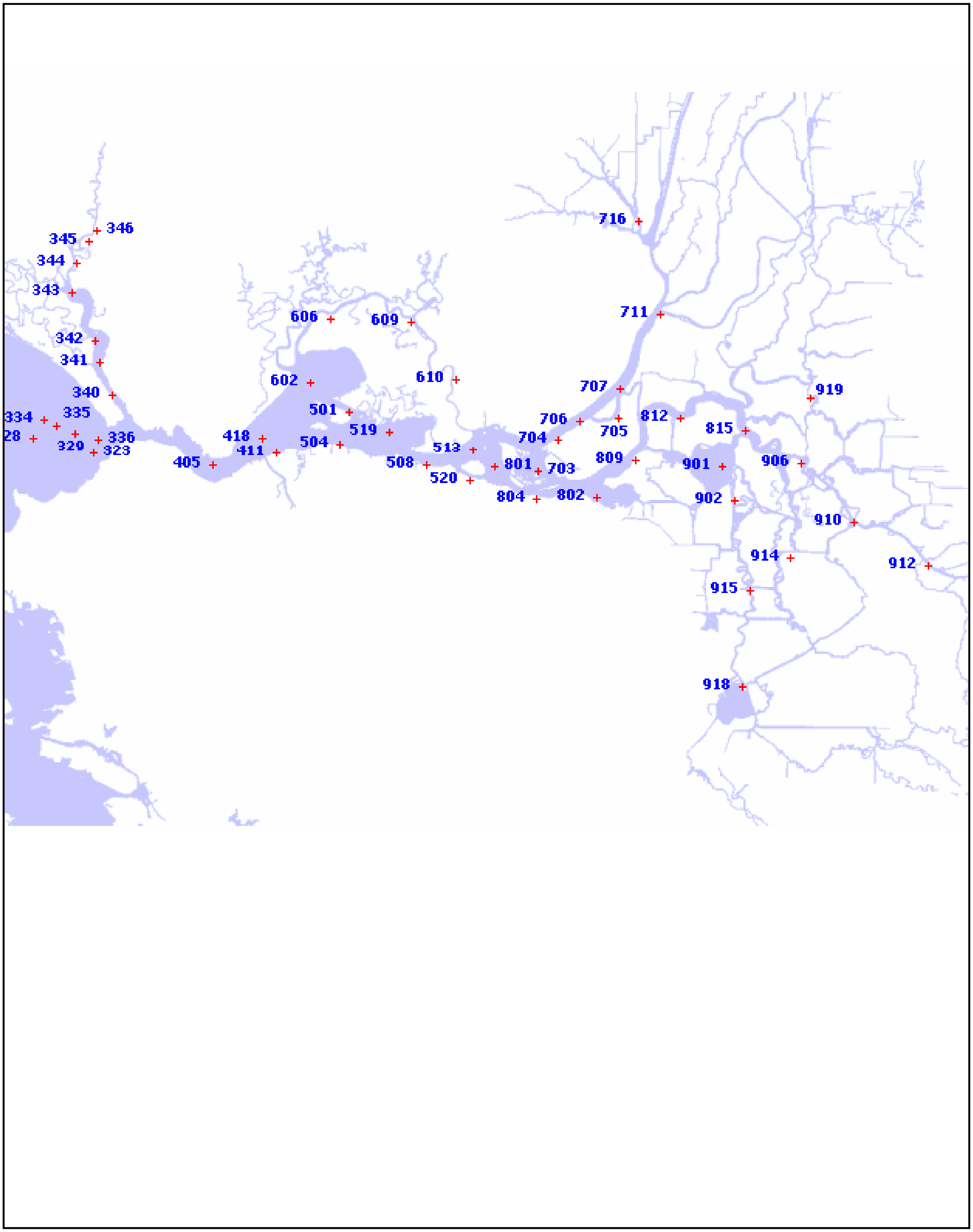
Results of the DFG fishery survey program provide valuable insight into the species composition, geographic distribution, and seasonal periods of occurrence for various fish species inhabiting the central Delta, lower San Joaquin River near Big Break, and the



Source: CDFG 2004

2004 Real-time Fishery Monitoring Locations (CDFG)

EXHIBIT 4.7-2



Source: CDFG 2004

20mm Delta Smelt Survey Locations (CDFG)

EXHIBIT 4.7-3

Flooded Islands Feasibility Study Baseline Report
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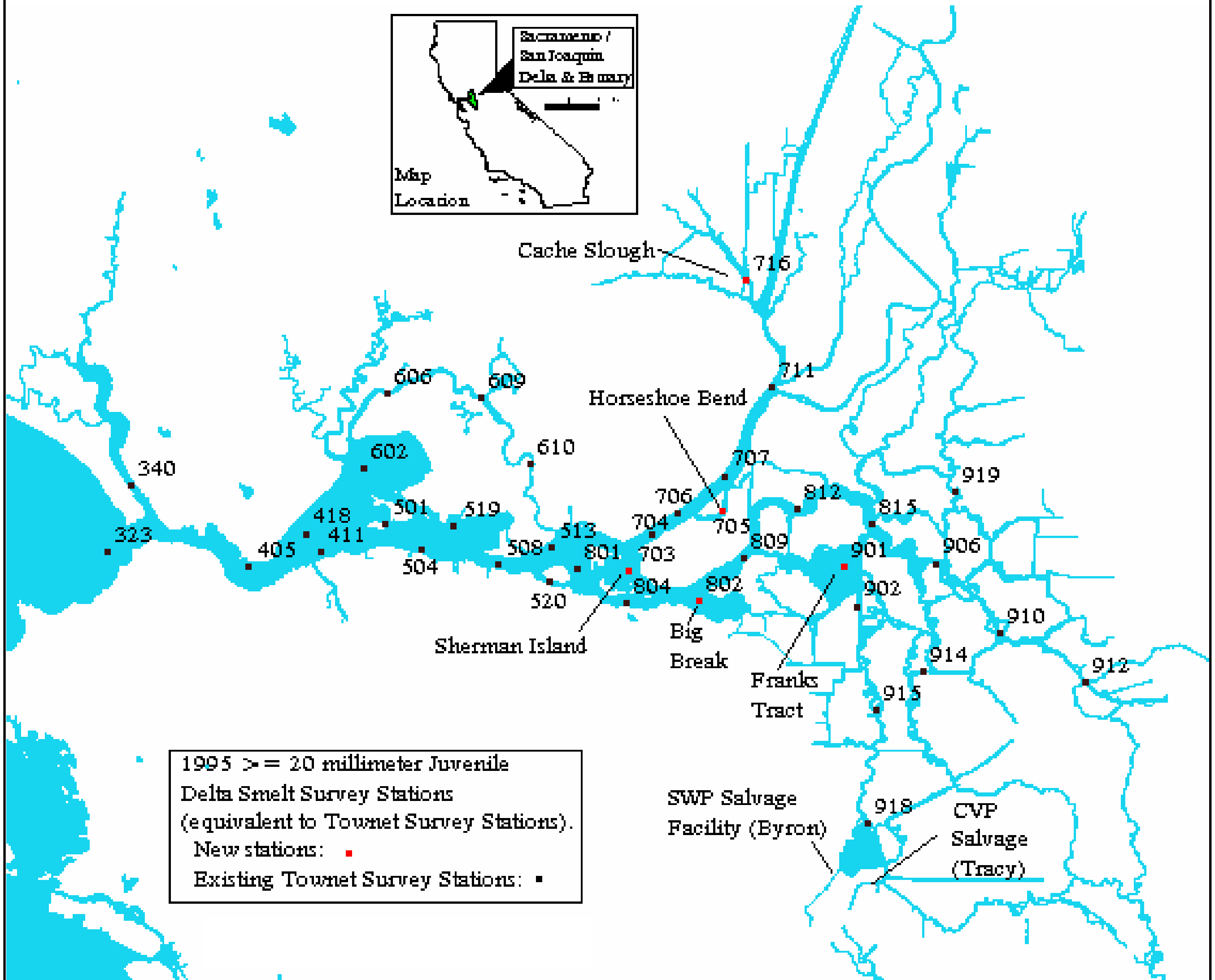

Source: CDFG 2004

Summer Townet Survey Locations (CDFG)

EXHIBIT 4.7-4

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confluence of the Sacramento and San Joaquin Rivers near Lower Sherman Lake. Results of the surveys should, however, be interpreted with caution. Fishery sampling using plankton nets, otter trawls, beach seines, and midwater trawls, primarily collect the early life stages of fish species. Larger sub-adult and adult fish are able to avoid capture by these sampling methods and therefore are either absent or may be underrepresented as members of fish community. For example, juvenile steelhead emigrating through the Delta effectively avoid capture and therefore, although present in the Delta during their migration period, may not be detected using these conventional fishery sampling techniques. A number of fish species that inhabit areas associated with pilings and docks or other structures such as largemouth bass may also be underrepresented in the sampling effort. Species that inhabit shallow water areas or intertidal habitat are also underrepresented in results of DFG open water fishery surveys conducted in deeper subtidal habitats. Larger individuals, such as adult striped bass and sturgeon, although present within Suisun Bay and the Delta, are not represented in collections using these sampling techniques. Analysis and interpretation of the DFG fishery data, although a useful and powerful source of information available to describe the Bay–Delta estuary fish and macroinvertebrate community, needs to be interpreted in combination with information from other surveys, and general information on habitat conditions within an area of estuary, when establishing a foundation for characterizing fish and macroinvertebrate communities within the flooded islands and other regions of the estuary.

Central Delta near Franks Tract:

Sampling in the central Delta using otter trawls and midwater trawls at Stations 863, 864, and 865 show that the most abundant fish species inhabiting the area include striped bass, American shad, threadfin shad, white catfish, yellowfin goby, and Chinook salmon (Table 4.7-2). In total, 31 fish species have been collected from these central Delta sampling stations using the otter trawl and midwater trawl. Delta smelt were the eleventh most abundant fish species collected.

Data on the occurrence and abundance of crab and shrimp were summarized from the DFG otter trawl surveys. As would be expected, the crab community inhabiting the central Delta is dominated by the recently introduced Chinese mitten crab. Bay shrimp were the most common shrimp species in the central Delta in the general vicinity of Franks Tract.

Results of inshore beach seine surveys in the central Delta (Station 857) showed that inland silversides dominate the near-shore fishery community (Table 4.7-3). Other fish species included striped bass, threadfin shad, splittail, Sacramento pikeminnow, Chinook salmon, tule perch, yellowfin goby, threespine stickleback, Delta smelt, and nine other species.

Striped bass, longfin smelt, unidentified smelt, threadfin shad, and prickly sculpin eggs and larvae were the most common ichthyoplankton collected in the central Delta (Station 837; Table 4.7-4). In total 22 taxa of fish and larvae were collected in central Delta plankton sampling.

Table 4.7-2 **Species Composition and Relative Abundance of Fish Collected from the Central Delta near Franks Tract by Otter Trawl and Midwater Trawl**	
Fish Species	Number Collected
Striped Bass	3937
American Shad	3690
Threadfin Shad	1955
White Catfish	688
Channel Catfish	323
Yellowfin Goby	116
Chinook Salmon	107
Splittail	95
Starry Flounder	93
Tule Perch	63
Delta Smelt	58
Redear Sunfish	53
Bigscale Logperch	44
Shimofuri Goby	14
Longfin Smelt	6
Prickly Sculpin	6
Bluegill	5
Pacific Staghorn Sculpin	5
White Sturgeon	5
Largemouth Bass	4
River Lamprey	3
Bearded Goby	2
Common Carp	2
Pacific Lamprey	2
Steelhead Trout	2
Wakasagi	2
Black Crappie	1
Blue Catfish	1
Green Sturgeon	1
Inland Silverside	1
Threespine Stickleback	1
Stations 863, 864, 865 Source: DFG unpublished data	

Table 4.7-3 **Species Composition and Relative Abundance of Fish Collected from the Central Delta Near Franks Tract by Beach Seine**	
Fish Species	Number Collected
Inland Silverside	1104
Striped Bass	199
Threadfin Shad	92
Splittail	44
Sacramento Pikeminnow	39
Chinook Salmon	19
Tule Perch	18
Yellowfin Goby	13
Threespine Stickleback	12
Delta Smelt	8
American Shad	5
Northern Anchovy	2
Pacific Staghorn Sculpin	2
Surf Smelt	2
White Catfish	2
Channel Catfish	1
Common Carp	1
Jacksmelt	1
Largemouth Bass	1

Station 857
Source: DFG unpublished data

Table 4.7-4 **Species Composition and Relative Abundance of Fish Eggs and Larvae (ichthyoplankton) Collected in the Central Delta Near Franks Tract**	
Fish Species	Number Collected
Striped Bass	4071
Longfin Smelt	2563
Unidentified Smelt	1452
Threadfin Shad	886
Prickly Sculpin	807
Chameleon Goby	290
Pacific Herring	234
Unidentified Minnow	105
Unidentified Sunfish	56
Yellowfin Goby	48
Common Carp	30
Northern Anchovy	28
Delta Smelt	24
Bigscale Logperch	10

Table 4.7-4 Species Composition and Relative Abundance of Fish Eggs and Larvae (ichthyoplankton) Collected in the Central Delta Near Franks Tract	
Inland Silverside	4
Arrow/cheekspot Goby	2
Splittail	2
Bay Goby	1
Bluegill	1
Chinook Salmon	1
Longjaw Mudsucker	1
Sacramento Sucker	1
Station 837 Source: DFG unpublished data).	

Results of DFG 20 mm Delta smelt surveys at Station 901, located within Franks Tract, between 1995 and 2002 showed that the proportion of larval Delta smelt within the flooded island varied from 0% (1995) to 3.5% (1999) of the smelt collected at all sampling stations. Larval Delta smelt densities within Franks Tract were typically less than 1% of the larval population. Larval Delta smelt densities within Franks Tract were generally greatest in May and early June.

In addition, results of discussions with recreational anglers indicate that adult striped bass, largemouth bass, white catfish, and sturgeon support recreational fisheries within Franks Tract and the surrounding channels and sloughs.

Lower San Joaquin River and Suisun Bay Near Lower Sherman Lake and Big Break:

Sampling in the lower Sacramento and San Joaquin Rivers near Sherman Lake and Big Break and using otter trawls and midwater trawls at Stations 535, 736, and 837 (Exhibit 4.7-1) show that the most abundant fish species inhabiting the area include striped bass, longfin smelt, American shad, yellowfin goby, threadfin shad, white catfish, Delta smelt, and Chinook salmon (Table 4.7-5). In total, 46 fish species have been collected from these sampling stations using the otter trawl and midwater trawl. Delta smelt were the seventh most abundant fish species collected.

Data on the occurrence and abundance of crab and shrimp were summarized from the DFG otter trawl surveys. As would be expected, the crab community inhabiting Suisun Bay and the western Delta near Big Break and Lower Sherman Lake is dominated by the recently introduced Chinese mitten crab. Bay shrimp were the most common shrimp species in Suisun Bay and the western Delta in the general vicinity of Big Break and Lower Sherman Lake.

Table 4.7-5 Species Composition and Relative Abundance of Fish Collected from Suisun Bay and the Western Delta near Big Break and Sherman Lake by Otter Trawl and Midwater Trawl	
Fish Species	Number Collected
Striped Bass	10161
Longfin Smelt	3429
American Shad	2997
Yellowfin Goby	1725
Threadfin Shad	1277
White Catfish	748
Delta Smelt	630
Chinook Salmon	455
Channel Catfish	443
Northern Anchovy	357
White Sturgeon	203
Starry Flounder	195
Pacific Staghorn Sculpin	149
Splittail	141
Tule Perch	128
Bigscale Logperch	92
Pacific Herring	81
Bearded Goby	72
Chameleon Goby	58
River Lamprey	35
Shimofuri Goby	29
Pacific Lamprey	27
Threespine Stickleback	16
Prickly Sculpin	15
Common Carp	12
Plainfin Midshipman	11
Bay Goby	8
Green Sturgeon	5
White Croaker	5
Brown Bullhead	4
Sacramento Pikeminnow	4
Steelhead Trout	4
English Sole	3
Inland Silverside	3
Redear Sunfish	3

Table 4.7-5 Species Composition and Relative Abundance of Fish Collected from Suisun Bay and the Western Delta near Big Break and Sherman Lake by Otter Trawl and Midwater Trawl	
Bluegill	2
California Halibut	2
Goldfish	2
Speckled Sanddab	2
Wakasagi	2
Black Bullhead	1
Black Crappie	1
Largemouth Bass	1
Pacific Tomcod	1
Shiner Perch	1
Western Mosquitofish	1
Stations 535, 736, and 837 Source: DFG unpublished data	

Results of inshore beach seine surveys in Suisun Bay and the western Delta (Stations 758 and 837) showed that inland silversides dominate the near-shore fishery community (Table 4.7-6). Other fish species included striped bass, threadfin shad, Chinook salmon, splittail, Sacramento pikeminnow, American shad, tule perch, and Delta smelt, and 17 other species.

Striped bass, longfin smelt, unidentified smelt, Pacific herring, prickly sculpin, threadfin shad, and northern anchovy eggs and larvae were the most common ichthyoplankton collected in the Suisun Bay and western Delta (Stations 535, 736, and 837; Table 4.7-7). In total 36 taxa of fish and larvae were collected in Suisun Bay and western Delta plankton sampling near Big Break and Lower Sherman Lake.

Results of DFG 20 mm Delta smelt surveys at Station 703, located in Lower Sherman Lake, between 1995 and 2002 showed that the larval Delta smelt densities were highly variable. The proportion of the larval Delta smelt collected in Sherman Lake varied from less than 1 % (1995) to 22% (2000). Approximately 15% of the larval Delta smelt collected in 1997 were from Lower Sherman Lake, with approximately 5% of the larval Delta smelt collected in 1999 and 2002 were from Lower Sherman Lake. Larval Delta smelt densities were typically greatest in Lower Sherman Lake in June.

Results of DFG 20 mm Delta smelt surveys at Station 802, located in the lower San Joaquin River near Big Break, between 1995 and 2002 showed that the larval Delta smelt were only collected in one year (1996) representing approximately 1% of the smelt collected at all sampling stations. No larval Delta smelt in other years surveyed. Larval Delta smelt densities were greatest in early May in 1996.

Table 4.7-6
Species Composition and Relative Abundance of Fish Collected from the Suisun Bay and the Western Delta near Big Break and Sherman Lake by Beach Seine

Fish Species	Number Collected
Inland Silverside	4451
Striped Bass	1244
Threadfin Shad	560
Chinook Salmon	78
Splittail	64
Sacramento Pikeminnow	56
American Shad	52
Tule Perch	47
Delta Smelt	32
Threespine Stickleback	17
Yellowfin Goby	16
Pacific Staghorn Sculpin	5
Western Mosquitofish	4
Longfin Smelt	2
Northern Anchovy	2
Steelhead Trout	2
Surf Smelt	2
White Catfish	2
Bigscale Logperch	1
Channel Catfish	1
Common Carp	1
Golden Shiner	1
Jacksmelt	1
Largemouth Bass	1
Prickly Sculpin	1
White Crappie	1

Stations 758 and 837
Source: DFG unpublished data

Table 4.7-7
Species Composition and Relative Abundance of Fish Eggs and Larvae (ichthyoplankton) Collected in Suisun Bay and the Western Delta near Sherman Lake and Big Break

Fish Species	Number Collected
Striped Bass	14417
Longfin Smelt	12063
Unidentified Smelt	6855
Pacific Herring	2469
Prickly Sculpin	2087
Threadfin Shad	1334
Northern Anchovy	1216
Chameleon Goby	942
Yellowfin Goby	714
Delta Smelt	333
Arrow/cheekspot Goby	179
Common Carp	133
Unidentified Minnow	119
Unidentified Sunfish	76
Bigscale Logperch	33
American Shad	19
Inland Silverside	7
Splittail	6
Threespine Stickleback	6
Bay Goby	4
Bluegill	4
Goby Type II	4
Sacramento Sucker	3
White Sturgeon	3
Arrow Goby	2
Cheekspot Goby	2
Jacksmelt	2
Starry Flounder	2
Unidentified Goby	2
Bay Pipefish	1
Chinook Salmon	1
Longjaw Mudsucker	1
Pacific Staghorn Sculpin	1
Unidentified Fish	1
Western Mosquitofish	1
White Croaker	1

Stations 535, 736, and 837
Source: DFG unpublished data

In addition, results of discussions with recreational anglers indicate that adult striped bass, white catfish, and sturgeon support recreational fisheries in the main river channels surrounding Lower Sherman Lake. Habitat in Lower Sherman Lake supports active recreational fisheries for largemouth bass, striped bass, and catfish. The lower San Joaquin River near Big Break supports recreational fisheries for adult striped bass, largemouth bass, white catfish, and sturgeon. Big Break is a popular recreational fishing area for largemouth bass.

4.7.2 AVIAN SPECIES

GENERAL DESCRIPTION

The Delta is in a prime location within the Pacific flyway, the major pathway for migratory bird species on the West Coast. At least 230 species of birds are found in the Delta. Many of these species inhabit the Delta only, or primarily, during the fall and winter months, when the Delta becomes home to an abundance of migratory and wintering wildlife. The most conspicuous groups of wintering birds include waterfowl, shorebirds, wading birds, and raptors.

Currently the project sites are largely inundated, and consequently they are of significance primarily for the abundance of wintering waterfowl that migrate down the Pacific flyway each year. Delta waterfowl populations are a highly valued and diversified biological resource and are found in all regions. Large numbers of ducks, geese, and swans winter in the Central Valley after migrating from northern breeding areas. Abundant species include northern pintail (*Anas acuta*), northern shoveler (*Anas clypeata*), mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), American wigeon (*Anas americana*), green-winged teal (*Anas crecca*), lesser scaup (*Aythya affinis*), ring-necked duck (*Aythya collaris*), and white-fronted goose (*Anser albifrons*). Some species, such as mallard, gadwall, and Canada goose (*Branta canadensis*), are also yearlong residents and breed locally in wetlands and nearby uplands. Waterfowl are a significant component of the ecosystem, and are of high interest to recreational hunters and bird watchers. Historical waterfowl wintering habitat areas have declined by approximately 95% and, as a result of substantial losses of wetland and grassland habitats, waterfowl breeding populations have declined from historical levels.

Two other major avian guilds, shorebirds and wading birds, and Neotropical migratory birds, are also of significance in the habitats found on the project sites.

Hundreds of thousands of shorebirds and wading birds annually migrate through, winter, or breed in the Delta. Because of the levels of inundation, habitat for most shorebird species is limited at Big Break and Franks Tract, but several species are common as migrants in the intertidal areas of Lower Sherman Island. Some shorebird and wading bird species are winter migrants, limited to shallow water areas and shorelines. Others are statewide, year-round residents. Shorebirds and wading birds are dependent on many different habitats, although each species may be dependent on only one or a few habitats. These habitats include perennial aquatic, tidal slough, seasonal and emergent wetland, midchannel island and shoal, riparian, and agricultural. Representative species of the shorebird and wading bird guild include great blue heron (*Ardea herodias*), great egret (*Ardea alba*), western sandpiper (*Calidris mauri*), and long-billed dowitcher (*Limnodromus scolopaceus*). These species are a significant component of the ecosystem and are of high interest to recreational bird watchers. There have been substantial losses of historic habitat used by these species, and available information suggests that population levels of many of these species are declining.

Herons and egrets are common year-round residents that breed and winter throughout the study area. Many nesting heron rookeries have been identified by researchers in the Suisun Bay and areas of the Delta adjacent to the project sites. Most of these rookeries include mixed species, mainly great blue heron, great egret, and black-crowned night-heron (*Nycticorax nycticorax*). Conversion has eliminated 95% of historic wetland habitat, resulting in smaller, detached patches of suitable habitat for nesting and foraging. Riparian habitats suitable for use by colonial-nesting species, such as egrets, have been lost or fragmented and are subject to increased disturbance during the nesting season. Protecting existing and restoring additional suitable perennial aquatic, tidal slough, seasonal and emergent wetland, midchannel island and shoal, and riparian habitats, and reducing the effect of factors that can suppress breeding success will be critical to maintaining healthy shorebird and wading bird populations in the Delta.

Many species of Neotropical migratory birds migrate through or breed in the Delta. The neotropical migratory bird guild comprises bird species that breed in North America and winter in Central and South America. Representative species of the neotropical migratory bird guild are the western kingbird (*Tyrannus verticalis*), western wood-pewee (*Contopus sordidulus*), tree swallow (*Tachycineta bicolor*), cliff swallow (*Petrochelidon pyrrhonota*), Bullock's oriole (*Icterus bullockii*), Wilson's warbler (*Wilsonia pusilla*), and yellow-breasted chat (*Icteria virens*). Individual accounts are given for some neotropical migrants, such as the Swainson's hawk (*Buteo swainsoni*) and California yellow warbler (*Dendroica petechia brewsteri*). The project sites contain limited patches of riparian habitat for neotropical migrant birds, primarily on isolated levees and in-channel islands.

There have been substantial losses of historic habitat used by Neotropical migratory species, and available information suggests that population levels for many of these species are declining. Protecting existing and restoring additional suitable wetland, riparian, and grassland habitats will be critical to maintaining healthy Neotropical migrant bird populations in the project sites. Restoration of nesting habitat will help reduce nest parasitism and predation by creating habitat conditions that render Neotropical birds less susceptible to these stressors.

Very little ornithological information is available that is specific to the project sites, although a few observations of note have been made at each site. Some general descriptions of the birds at Franks Tract SRA have been published. The limited information specific to each site is given at the end of this section.

In addition to information presented in the general description above, areas in and adjacent to the project sites are currently, or have great potential to be, of significance for 11 special-status bird species. Several of these species are largely confined to or reach their greatest population density in the Delta, and consequently could be considered in the current and future management of the project sites.

SPECIAL-STATUS BIRD SPECIES

Special-status species include those that are legally protected or are otherwise considered sensitive by federal, state, or local resource conservation agencies and organizations. The project sites are, or could potentially be, important for many of these species. Although few have been recorded using the project sites in recent years, their presence cannot be discounted. Consequently there is significant potential for future management and restoration work to encourage or generate suitable habitat for these species.

Eleven key special-status species fitting these parameters are discussed here in taxonomic order: least bittern (*Ixobrychus exilis*), Swainson's hawk, California black rail (*Laterallus jamaicensis coturniculus*), California clapper rail (*Rallus longirostris obsoletus*), greater sandhill crane (*Grus canadensis tabida*), burrowing owl (*Athene cunicularia*), bank swallow (*Riparia riparia*), California yellow warbler, saltmarsh common yellowthroat (*Geothlypis trichas sinuosa*), Suisun song sparrow (*Melospiza melodia maxillaris*), and tricolored blackbird *(Agelaius tricolor)*.

The Delta is home to an abundance of additional special-status bird species in winter, including peregrine falcon (*Falco pergrinus*), ferruginous hawk (*Buteo regalis*), Cooper's hawk (*Accipiter cooperi*), sharp-shinned hawk (*Accipiter striatus*), northern harrier (*Circus cyaneus*), white-tailed kite (*Elanus caeruleus*), long-billed curlew (*Numenius americanus*), short-eared owl (*Asio flammeus*), and loggerhead shrike (*Lanius ludovicianus*). These species are not discussed in detail here because their special status is specific to the breeding season and these species occur in or adjacent to the project sites during nonbreeding seasons.

Some other special-status bird species no longer occur in the Delta, and their recovery as part of this project is unlikely. These include two riparian forest species, western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) and little willow flycatcher (*Empidonax traillii brewsteri*).

Least bittern

This species is the smallest member of the heron family. The least bittern uses freshwater tidal and nontidal marshes and wetlands for foraging and nesting habitat. The population and distribution of this species have declined substantially, primarily as a result of reclamation of its wetland habitats. The least bittern is listed as a Species of Special Concern by DFG, is on Audubon's Blue List, and is a U.S. Fish and Wildlife Service "Migratory Nongame Bird of Management Concern."

The least bittern inhabits stands of emergent vegetation within freshwater marshes and wetlands. Shallow water, emergent cover, and substrate with high invertebrate abundance are the most important features of least bittern habitat. The bittern also feeds on amphibians, fish, crayfish, and small mammals. Much of the western least bittern's wetland habitats have been destroyed or modified since the mid-1800s. This decline in wetlands has reduced population densities of the bitterns throughout their range. Habitat loss is largely a result of reclamation for agricultural, industrial, and urban uses and water management projects. The total area of those remaining habitats represents only a small percentage of their historic level. These habitats continue to be threatened by sedimentation, water diversions, recreational activities, water quality, and land use practices. Insufficient quantity and quality of wetland habitat is the primary factor limiting recovery of the species' population in the estuary. Other factors that can adversely affect the least bittern include disturbance during its breeding period, contaminants, and excessive predation by nonnative species. Restoring suitable tidal and nontidal freshwater wetlands in the Delta is critical to the recovery of the species in the estuary. These restored habitats would provide nesting and foraging habitat for the least bittern.

Swainson's hawk

Swainson's hawk is state listed as a threatened species. Swainson's hawks breed close to Franks Tract at Bouldin Island (CNDDB). Historically, it nested throughout lowland California. However, the current Swainson's hawk nesting distribution is limited to the Mojave Desert, northeastern California, the Central Valley, and a few isolated locations in the Owens Valley. Swainson's hawk typically occurs in California only during the breeding season (March through September) and winters in Mexico and Central and South America. The species was once thought to winter exclusively in Argentina; however, recent telemetry studies (satellite radio) have shown the species to winter in Mexico, with additional detections in Central America and South America. The Central Valley population migrates only as far south as Central Mexico (Estep 2001). Additionally, thirty (30) individual hawks have been wintering in the Delta for several years (Estep 2001), and there are records of small numbers of Swainson's hawks wintering in southern Florida and Texas.

Historically, as many as 17,000 Swainson's hawk pairs may have nested in California. Currently, an estimated 700 to 1,000 Swainson's hawk pairs nest in the state. This appears to represent a decline of more than 94% in California's historical nesting population (Bloom 1980). There are 882 known extant nesting sites in California (Estep 2001). The Central Valley supports an estimated 600 to 900 of the remaining breeding pairs. The overall Swainson's hawk population is considered to be declining. To a large degree, the decline of the Swainson's hawk can be attributed to the long-term, cumulative effects of riparian and wetland habitat conversion and degradation.

Swainson's hawks begin to arrive in the Delta from wintering grounds in Mexico, Central America and South America in March to breed and raise their young. The species typically roosts and migrates in groups. Territories are usually established by April, and incubation and brooding continue through June. The young begin to fledge in July and remain with the parents for approximately 1 month following fledging or until the southern migration in early fall. Telemetry studies have shown that some fledglings leave the nesting area and their parents to join a juvenile group or remain alone before the fall migration (Estep 2001). Swainson's hawks are opportunistic foragers, flushing prey (rodents, insects, and some birds) from fields, pastures, and grasslands adjacent to their nests. In the Central Valley, their primary diet consists of small rodents, including *Microtus californicus*, or meadow mice. During summer, the hawks consume large quantities of insects. Males feed females while they incubate the eggs. Both parents feed the young.

Swainson's hawks prefer large nesting trees with a panoramic view of their foraging grounds. Foraging habitats, open fields and grasslands, need to be in flying distance of (maximum observed is 18 miles) and adequate to support the high densities of microtine rodent populations and birds upon which they feed. During the breeding season, Swainson's hawks require suitable foraging habitat in association with suitable nesting habitat. Swainson's hawk nesting preference is for large valley oaks (*Quercus lobata),* cottonwoods (*Populus fremontii*), or willow (*Salix goodingii*). In the interior of the Delta, the species will often nest in smaller trees owing to the lack of large trees (Estep 2001). The area required for foraging depends on the season and crop cycle, as the species' foraging ranges depend on the dynamics of the agricultural system and how it affects prey abundance and availability. Swainson's hawks' highly active foraging behavior may result in birds traveling as far as 18 miles from a nesting site (Estep 1989). Swainson's hawks have been observed foraging behind farm machinery (moving harvester blade or disc) and capturing rodents exposed by ground disturbance. Swainson's hawk foraging ranges during the breeding season have been estimated to be 1,000 acres to almost 7,000 acres (Estep 1989).

Suitable cover types for foraging habitats include, in order of suitability: (1) native grassland; (2) agriculture soon after discing; (3) alfalfa and other hay crops; (4) fallow fields; (5) lightly grazed pasture; (6) combinations of hay, grain, and row crops; (7) rice fields prior to flooding and after draining; and (8) heavily grazed pasture. Unsuitable cover types for foraging habitat include vineyards, mature orchards, cotton, thistle in fallow fields and any crop in which prey are unavailable because of high vegetation height and density, as well as flooded rice fields. Observations indicate that rice farming lands are used by Swainson's hawks for foraging, particularly where there is vegetation at the perimeter of the fields. Although generally considered less than suitable habitat for Swainson's hawk, rice fields do provide invertebrate populations, water and refuge (levees) for upland species, and forage before and after flooding.

California black rail

The California black rail is a rarely seen, year-round resident of saline, brackish, and fresh emergent wetlands. Aside from recently discovered populations in the Central Valley, viable populations of the species are found only in the Suisun Marsh, San Francisco Bay, and the Delta. The California black rail is associated with tidal and nontidal emergent wetlands. The population and distribution of this species have declined substantially, primarily as a result of reclamation of its wetland habitats. Habitat loss and declining population have warranted its listing as threatened under the California Endangered Species Act. Historical and current loss or degradation of salt, brackish, and freshwater marshes are the major factors that limit this species in the Delta (CALFED 2000e).

Historically, the black rail was a resident of coastal wetlands from Santa Barbara County to San Diego County. Much of the California black rail's marshland habitat in California has been destroyed or modified since the mid-1800s. This decline in marshland has reduced population densities of black rail throughout its range. Important habitats for the species include tidal perennial and nontidal perennial aquatic, dead-end and open-ended sloughs, seasonal wetland and aquatic, saline and fresh emergent wetland, and midchannel islands and shoals. Many tidal habitats, including those that support pickleweed, bulrushes, and saltgrass, are critical types for this species that need to be protected, and only a small percentage of their historical extent remains. Upper wetland or upland areas adjacent to these habitat areas provide nesting and escape cover during high tides and floods. Black rails are especially abundant in undiked tidal marshes of Suisun Marsh. They are most often associated with dense stands of American bulrush (*Scirpus americanus*) immediately adjacent to high marsh meadows supporting pickleweed–saltgrass associations. They are often associated with soft bird's-beak, an endangered plant of the high tidal marsh (Grinnell and Miller 1944).

Black rail habitat is directly influenced by sediment supply from the upstream portion of the Delta and tidal influences from the Bay. As sediment is deposited in a tidal marsh, the elevation of the marsh changes. Eventually, the marsh may no longer be affected by tidal action or support tidal marsh plants that depend on the interaction of compatible tides and sediment supply regimes. Water quality in habitat areas must be sufficiently high to support the invertebrates and vegetation that sustain black rails. Currently, the condition most hazardous to the black rail's existence in salt marshes is the elevated water level associated with the highest tides and high outflow conditions. High water destroys nests and forces rails to leave the marsh temporarily in search of sufficient cover in uplands. Black rails use corridors between wetland and upland habitats to seek cover during high tides. However, these corridors have been fragmented by the extensive system of Delta levees, which are often devoid of vegetation. This lack of sufficient cover subjects black rails to predation, frequently by nonnative species. These habitats continue to be threatened by sedimentation, water diversions, recreational activities, and land-use practices. Insufficient quantity and quality of emergent wetland habitat is the primary factor limiting recovery of the species' population in the estuary. Other factors that can adversely affect the black rail include disturbance during its breeding period, contaminants, and excessive predation by nonnative species. Restoring suitable fresh, brackish, and saline emergent wetlands and tidal sloughs in the Delta and adjacent higher elevation habitats is critical to the recovery of the species in the estuary.

California clapper rail

The clapper rail is a year-long resident in coastal wetlands and brackish areas around San Francisco Bay and adjacent parts of the Delta. The California clapper rail is associated with saline emergent wetlands. The population and distribution of this species have declined substantially, primarily as a result of reclamation of its tidal saltmarsh habitats. Loss of habitat and declining population have warranted its listing as endangered under the State and federal Endangered Species Acts.

This species characteristically inhabits the more saline marshes of the Delta. Highest population densities are associated with large tidal marsh areas with well-developed channel systems. Habitat loss is largely a result of reclamation for agricultural, industrial, and urban uses and water management projects. Populations have also been limited because of loss or degradation of tidal salt marshes for waterfowl hunting and management. The total area of these remaining habitats represents only a small percentage of their historic level.

The California clapper rail breeds from February through August. The preferred habitat is saline tidal marshes, but California clapper rails also use brackish marsh areas with alkali bulrush. They build platform nests concealed by a canopy of cordgrasses and pickleweed. They may also use cattails and bulrushes in fresh emergent wetland habitats, although these areas are not considered suitable foraging and breeding habitat. Adjacent upper wetland habitat is also important because it provides nesting and escape cover during high tides and floodwaters (Grinnell and Miller 1944).

Significant loss of saline and brackish emergent wetland habitat and associated upland habitats and high marshes is the primary factor for the decline in this species' populations. These habitat losses have reduced populations sufficiently that predation by nonnative species, such as the Norway rat, red fox, and feral cats; swamping of nests by boat wakes; and contaminants, such as selenium, are now also substantial factors affecting the ability of the species to recover. Protecting existing and restoring additional suitable saline and brackish emergent wetlands and adjacent higher elevation habitats and reducing the effect of other factors that can suppress breeding success will be critical to the recovery of the California clapper rail. The Suisun Marsh and San Francisco Bay areas once comprised a mosaic of large contiguous blocks of tidal saline emergent wetland in association with adjacent upland habitats. Restoration of saline and brackish emergent wetland and associated upland habitats in the Suisun Marsh/North San Francisco Bay Region will help the recovery of this species by increasing habitat area (CALFED 2000e).

Clapper rail habitat utilization in Suisun Marsh and the Napa Marshes suggests that a natural network of small tidal creeks that begin high in the marsh and grade down into large tidal sloughs and bays are essential habitat components for successful breeding populations. Improved habitat would also include water-quality levels and other components necessary to support isopods, arthropods, mollusks, and insects on which clapper rails feed. These components could be provided by developing and implementing a program to reduce the level of toxins that adversely affect clapper rail populations in the Delta.

Clapper rail breeding success could be improved by reducing the adverse effects of boat wakes on nests during the February–August breeding period. Restoring high-quality clapper rail habitat would also reduce the adverse effects of predation by nonnative species by creating habitat conditions that are more favorable for rails and less favorable for predators.

Greater sandhill crane

This subspecies of the sandhill crane primarily winters in the Delta and forages and roosts in agricultural fields and pastures. Because the winter range of the greater sandhill crane overlaps with the winter range of other sandhill crane subspecies, all subspecies are considered important resources. The greater sandhill crane population has declined primarily as a result of loss of suitable wetland nesting habitats. The loss of habitat and declining population have warranted its listing as threatened under the California Endangered Species Act. Major factors that limit this species in the Delta are related to adverse effects of conversion of grassland and wetland habitats for agricultural, industrial, and urban uses.

The greater sandhill crane is important to the biological integrity and health of the Delta and Sacramento–San Joaquin Valley ecosystems. The greater sandhill crane is found throughout most of the Central Valley in winter and nests in northeastern California and Oregon.

Habitats used by the sandhill crane include seasonal and freshwater emergent wetlands, grasslands, and agricultural lands. Large wintering populations of greater and lesser sandhill cranes congregate in the Sacramento and San Joaquin Valleys. Generally, crane wintering habitat consists of shallowly flooded grasslands that are used as loafing and roosting sites, and nearby agricultural areas that provide food sources that include rice, sorghum, barley, and corn. In the Delta, in adequate roost sites that are relatively free from disturbance and quality and quantity of forage, potential limiting factors on the wintering population remain.

The state-listed greater sandhill crane is a fully protected species because the small remaining population depends on habitat that is threatened with loss or degradation. The conversion of grasslands, wetlands, and agricultural land to urban development is an ongoing process that is not likely to be reversed. The sandhill crane now depends primarily on artificially created areas where natural wetland and grassland habitats have been eliminated. Disturbance associated with human activities, illegal harvest, and predation have also affected the overall health of the crane population, although less severely than the loss and degradation of its habitats.

Greater sandhill crane populations will benefit from restoration of shallowly flooded wetlands. Implementing existing crane recovery and waterfowl management plans will also help achieve restoration goals. Such strategies could be implemented through collaborative work with organizations to maintain and improve existing preserves, cooperative agreements with land management agencies, or conservation easements or purchase from willing sellers. Restoration of ecosystem processes and habitats in other regions will also allow seasonal and fresh emergent wetlands and grasslands to develop that will provide habitat for wintering sandhill cranes elsewhere in the Central Valley.

Western burrowing owl

The western burrowing owl is a California Species of Special Concern. Burrowing owls are also protected under Section 3503.5 of the California Fish and Game Code, which prohibits take of raptors, including eggs and young.

Burrowing owls typically inhabit open, dry, sparsely vegetated habitats, such as annual and perennial grasslands and agricultural areas. They can also use habitats in urban areas, such as vacant lots, airports, athletic fields, golf courses, and railroad corridors. Burrow availability is a critical feature of suitable habitat. Burrowing owls are capable of digging their own burrows in areas with soft soil, but they generally prefer to adopt those excavated by other animals, typically ground squirrels. In areas where burrows are scarce, they may use pipes, culverts, debris piles, and other artificial features.

Burrowing owls in California historically ranged throughout the Central Valley, were found in suitable habitat in coastal areas from Marin County south to the Mexican border, and sparsely inhabited desert areas in the northeastern and southeastern portions of the state. Though once a widely distributed and common grassland bird, the burrowing owl has declined for at least the last half century. Based on a survey of the majority of the owl's range in California, an estimated 9,450 nesting pairs of owls remained statewide in the mid-1990s, exclusive of the deserts and the Great Basin areas. The number of breeding owl colonies located in the survey area declined nearly 60% from the 1880s to the 1990s, and the statewide number of owls is currently thought to be declining at about 8% per year (Center for Biological Diversity et al. 2003).

Burrowing owls are primarily threatened by direct habitat loss to urban conversion and reduction of habitat suitability because of ground disturbance and ground squirrel control. In April 2003, a petition was submitted to the Fish and Game Commission proposing that burrowing owl be listed as threatened or endangered under CESA. The petition cited evidence of significant declines in local and statewide burrowing owl populations, with the rate of decline accelerating greatly in the past 20 years (Center for Biological Diversity et al. 2003). However, in December 2003, the Fish and Game Commission approved the DFG recommendation to reject the petition, concluding that although some populations are declining significantly, there is insufficient evidence that the species is threatened over a significant portion of its range.

Bank swallow

The bank swallow is associated with riparian and riverine habitats and nests in vertical cliff and bank faces eroded by rivers. The population and range of this species have declined primarily as a result of the loss or degradation of suitable nesting habitat along streams and rivers. The loss of habitat and declining population have warranted its listing as threatened under the California Endangered Species Act. The major factor that limits this species contribution to the health of the Delta is related to the adverse effects of levees and bank-protection structures on river and stream channel migration. These structures inhibit or prevent the channels' ability to erode its banks and form the nesting cliffs and banks required by the species (CALFED 2000e).

Once an abundant lowland species in California, the bank swallow is now limited to breeding in a small part of its former range. The bank swallow is found in only a small number of ecological units in the Central Valley that are adjacent to major rivers and their tributaries. The species was observed nesting at Brannon Island SRA in June 2000 (CNDDB), an observation that is close to the project sites.

Colonies nest along the Sacramento River from mile 143 to mile 243; 40–60 colonies remain along the upper Sacramento River and approximately l0–20 colonies on the Feather River. Five to 10 colonies are located above and below mile 143 on the Sacramento River. Other small colonies are found along other waterways, including the American River, Thomes Creek, Cache Creek, and the Cosumnes River (Grinnell and Miller 1944).

Bank swallows breed in vertical banks or cliffs that are created when streams and rivers erode their banks. Friable soils are an important habitat requirement. Their population is estimated to have been reduced by 50% since 1900. Only a few colonies remain within the State as a result of stream channelization, bank protection, and flood control projects. As much as 75% of the current breeding population in California concentrates along the banks of Central Valley's streams; 70–80% of remaining breeding habitat is found along a small stretch of the Sacramento River.

The decline of the bank swallow can be attributed primarily to human activities that have changed the ecosystem processes that create and sustain its bank and bluff nesting habitat. Stream meander migration is necessary to maintain, enhance, and create the fine textured or sandy-type vertical banks or cliffs in which bank swallows dig their nesting holes. Levees and riprapped banks along streams and rivers have impeded the creation of nesting cliffs by preventing channels from following the natural process of erosion, deposition, and meandering. Proposed projects for confining channels within the species' nesting range represent the largest threat to maintaining bank swallow colonies. The general deterioration, including loss of adjacent floodplain habitats (e.g., shaded riverine aquatic, riparian corridors and forests, and open grasslands) has also, although to a lesser degree, contributed to the species' decline.

California yellow warbler

As a Neotropical migrant, the California yellow warbler inhabits California from April to October. During these months, the California yellow warbler primarily uses underbrush of open deciduous riparian woodlands for home territories, foraging areas, and nesting sites. Recently, breeding populations in valley areas have been declining as a result of destruction of riparian habitats as well as nest parasitism by brown-headed cowbird (*Moluthrus ater*). Because of a consistent, gradual decline of breeding populations in California, the California yellow warbler has been listed as a California Species of Special Concern.

California yellow warblers summer throughout northern California and in the coastal regions of southern California. In recent decades, there has been a marked decline in the breeding population of California yellow warblers in the San Joaquin and Sacramento valleys (Grinnell and Miller 1944). Once common in these areas, the California yellow warbler has been displaced owing to loss of riparian habitat caused by agricultural and urban development. Another cause of breeding population decline is brood parasitism by brown-headed cowbirds. Brood parasitism by cowbirds has been documented to lower the reproductive success of warblers. In areas where cowbird populations are high, the population numbers of California yellow warblers are very low, despite the quality of habitat; therefore, decline of warbler populations resulting from parasitism may be partly attributable to loss of the birds' common habitat. As habitat decreases, both species use the remaining habitat for foraging and territory, creating a situation where California yellow warblers are more accessible and therefore more easily parasitized by brown-headed cowbirds (CALFED 2000e).

Greater areas of riparian habitat and lowering population densities of yellow warblers and cowbirds may allow for higher population numbers of passerine species that cowbirds can also parasitize. With more habitat and greater numbers of those species that cowbirds can parasitize, the rate at which California yellow warblers are being parasitized may decrease. Furthermore, by creating more riparian habitat and improving the quality of existing habitat, a more diverse and sustainable riparian community will be created.

Saltmarsh common yellowthroat

The saltmarsh common yellowthroat is designated as a DFG Species of Special Concern. The historical distribution of the saltmarsh common yellowthroat included the San Francisco Bay Area from Tomales Bay and Napa Sloughs south to San Jose during the breeding season, and San Francisco Bay south along the coast to San Diego County during winter (Grinnell and Miller 1944). Although the range for the yellowthroat has remained relatively stable, the total population of the subspecies has decreased. The saltmarsh common yellowthroat occurs throughout the year in Suisun Marsh.

During the breeding season, from April to July, saltmarsh common yellowthroats build nests among dense vegetation in fresh- or brackish-water marshes. Associated plant species include cattails, tules and other sedges, young willow trees, and blackberry vines. The species is found near saltwater marshes more often during fall and winter (Grinnell and Miller 1944). Loss of suitable habitat around the Delta, San Francisco Bay, and along the coast is the main reason for the decline of the species. Brood parasitism by brown-headed cowbirds has also negatively affected numbers in some localities.

A major focus of efforts to maintain saltmarsh common yellowthroat will be to assure that marsh restoration programs in the Delta consider and integrate habitat needed for the species.

Suisun Song Sparrow

Suisun song sparrows live only in and around the Suisun Marsh and Bay. The Suisun song sparrow is associated with saline emergent wetlands (Grinnell and Miller 1944). The population and distribution of this species have declined substantially, primarily as a result of reclamation of tidal saltmarshes. The loss of habitat and declining condition of this species' population have warranted its inclusion as a Species of Special Concern. Major factors that limit this species in the Delta are related to adverse effects of historical and current degradation of tidal saltmarshes for agricultural, industrial, and urban uses, and excessive predation on nests and individuals by nonnative predators.

Historically, much of the Suisun Marsh was a brackish tidal marsh. The Suisun song sparrow inhabited areas with suitable brackish marsh vegetation. The total area of historical tidal marsh habitat is estimated to have been about 66,600–73,700 acres. Between 70,000 and 77,000 pairs of Suisun song sparrows are estimated to have used the available marsh habitat annually. Recent estimates indicate that fewer than 6,000 pairs remain in 13 isolated populations, representing 8% of the species' former abundance. The remaining 13 populations number from about 1,300 pairs to about 20 pairs. Because artificial levees were constructed beginning in the late 1800s, the managed marsh areas on the nontidal side of the levees are flooded seasonally and then 'drained or allowed to dry. These areas are consistently avoided by Suisun song sparrows. The birds require appropriate vegetation for nesting sites, song perches, and foraging cover. The vegetation must also produce seeds or harbor invertebrates that the birds pick up from the surface of mudflats. Each sparrow's territory must contain permanent water or moisture in the form of tidal ebb and flow. Typically, each territory contains at least one patch of tall, hard-stemmed bulrush that stands above the surrounding vegetation and is used as a singing perch. The birds apparently need these high song perches to establish territory, and the absence of song perches may be a limiting factor in the distribution of pairs (CALFED 2000e).

The Suisun song sparrow is physiologically and behaviorally adapted to this area's naturally occurring brackish tidal conditions. It can drink brackish water and breeds earlier than upland subspecies. Early breeding avoids nest flooding during the highest spring tides (Grinnell and Miller 1944).

The primary threat to the continued existence of the Suisun song sparrow is the continuing loss of habitat and severe fragmentation of brackish tidal marsh habitat in and around Suisun Marsh. The once-vast marsh has been reduced to small areas that are separated by barriers or connected only by narrow strips of vegetation along the banks of tidal sloughs. Interbreeding between populations in these areas is rare.

Egg and nestling mortality is about 50% in the first 3 weeks after eggs are laid. The primary causes of this mortality are predation on eggs and nestlings by the introduced Norway rat, predation on nestlings by feral house cats, and flooding of nests during high tides. Maintenance of levees, dikes, and other structures during the breeding period may also create sufficient disturbance to cause nesting failure. Levees constructed in the sparrow's habitat are high enough above the surrounding marsh to allow the growth of upland plants that require fresh water. Although Suisun song sparrow territories may include these areas, the species avoids centering its territory in this type of vegetation.

Long-term changes in the salinity gradient of the Delta may also have an effect on the species' distribution and abundance. The normal brackish condition of Suisun Marsh is directly attributable to the amount of freshwater outflow it receives from the Delta. This fresh water mixes with saltwater transported on incoming tides through the Carquinez Strait. The amount of freshwater outflow has been reduced since historical times during water-years that are now considered normal. Suisun song sparrows can withstand short-term alterations in brackish conditions because they can subsist on pure saltwater for several days. The vegetation they occupy in the brackish marsh is similarly adapted. If the water regime changes drastically or for long periods, however, a large-scale change in habitat could result. If salinity decreases, the Suisun song sparrow could face lowered reproductive rates, increased competition, and loss of genetic integrity as a result of breeding with invading upland subspecies that consume fresh water. If the water becomes too salty, saltwater marsh vegetation could displace brackish vegetation; saltwater marsh is not suitable habitat for the species, which is not adapted to consume saltwater for extended periods (CALFED 2000e).

Restoration of tidal emergent wetlands in the Delta will help to recover this species by increasing its habitat area. Restoring associated higher elevation uplands would provide escape cover during high tides and flooding. Restoring these habitats would allow the population to increase at existing protected habitat areas and would ensure long-term survival. The restoration of high-quality sparrow habitat would also reduce the adverse effects of predation by nonnative species by creating habitat conditions that are more favorable for sparrows and less favorable for predators. The potential adverse effects of disturbance on breeding success could be reduced by encouraging agencies, organizations, and private landowners, through cooperative agreements and incentive programs, to conduct infrastructure maintenance activities in occupied habitat areas so that tidal brackish marsh vegetation is disturbed as little as possible and adults are not disturbed during the breeding season. The possibility of managing breeding of the species to increase its reproductive success should be investigated (e.g., transferring eggs and/or young between nearby isolated populations to increase genetic interchange between populations). If the species responds favorably to such manipulations, the period for its recovery would be reduced.

Tricolored Blackbird

The tricolored blackbird is considered a Species of Concern by USFWS and is a state Species of Special Concern. Tricolored blackbird is a medium-sized blackbird that is distinguished from other blackbirds by its distinctive white-tipped red shoulder patches on mature males. This species is commonly found in large flocks, foraging in marshes, rice fields, and wet meadows. Females show varying amounts of red on the shoulders, and their plumage is sooty brown and streaked overall. The species nests in large colonies in marshes, silage and grain fields, and blackberries.

The species is largely endemic to California, with smaller populations in Baja California, Nevada, Oregon, and Washington. During the breeding season, tricolored blackbirds inhabit the Central Valley, the low foothills of the Sierra Nevada and Coast Range from Shasta County south to Kern County, the coast from Sonoma County south to the Mexican border (Grinnell and Miller 1944, Beedy and Hayworth 1991). Band recoveries from this species indicate that some wintering individuals travel nomadically along the entire length of the Central Valley, into the San Francisco Bay and Sacramento–San Joaquin Delta area, up to the northern and eastern plateau region of California, and into southern Oregon. Tricolored blackbirds continue to breed throughout their historic range, although populations have declined within this range.

The tricolored blackbird is generally considered a marsh species, nesting primarily in bulrush (*Scirpus* spp.) and cattail (*Typha* spp.) marsh habitats. High quality nesting substrates tend to occur in conjunction with one of three Delta managed wetland types: permanent, semipermanent, or seasonal wetland (DeHaven 2000). With the reduction of wetland habitats in California, an increasing number of tricolored blackbirds have recently been found nesting in nonmarsh habitats, such as blackberry (*Rubus* spp.) brambles, thistle (*Cirsium* spp.) stands, and nettle (*Urtica* spp.) stands (Beedy and Hayworth 1991). Proximity to suitable foraging habitat, such as flooded fields, grassy fields, and pond margins, is an important factor in nest site selection (Grinnell and Miller 1944). In the Central Valley and Delta, the cattail marshes have had a universally low reproductive success, due to the large predator populations of black-crowned night herons. Such cattail marshes include refuges and those associated with rice fields. In general, vineyards and orchards provide low habitat value for tricolored blackbird, due to the lack of adequate nesting substrate and limited foraging area (DeHaven 2000).

Tricolored blackbirds nest in small-to-large colonies (up to 50,000 individuals). They often return to the same nesting areas in subsequent years, but will occasionally relocate their breeding colonies if suitable habitat is available elsewhere. The tricolored blackbird breeds in large colonies near fresh water, preferably in emergent wetland with tall, dense cattails or tules, but also in thickets of willow, blackberry, and wild rose. Nesting colonies of tricolored blackbird are highly susceptible to disturbance. Ideal breeding habitat for tricolored blackbird includes two elements: (1) dense nesting substrate (i.e., blackberry or aquatic emergent vegetation), which provides protection from predators, and (2) a large supply of insects within proximity to nests and occurring at the time of fledging (DeHaven 2000).

Tricolored blackbirds forage in large flocks and may travel up to 4 miles (6.4 km) from nest or roost sites to forage. Tricolored blackbirds forage on the ground in croplands, grassy fields, flooded land, and along edges of ponds (Zeiner et al. 1990). In the Delta and Central Valley, foraging habitat consists primarily of pastures and certain types of agricultural fields. Tricolored blackbirds eat mostly insects, and selection of colony sites is primarily a function of proximity to concentrated insect food supplies (e.g., grasshoppers [*Orthoptera*], beetles and weevils [*Coleoptera*]) (Beedy and Hayworth 1991). In winter, tricolored blackbirds often leave the immediate vicinity of their nesting colonies and concentrate in huge roosts in marsh habitat (Grinnell and Miller 1944).

FRANKS TRACT

Of the three study areas, bird use of Franks Tract is most well understood. A wide variety of birds favor freshwater and riparian scrub-shrub habitat that occurs on the levees and channel islands within and around Franks Tract SRA. Large flooded areas provide habitat for numerous species of birds, while backwater areas around many of the channel islands provide important breeding and feeding areas. During fall and winter, a large variety of waterfowl inhabit the open-water habitat. Year-round residents are gulls, great blue herons, terns, swallows, crows, blackbirds, cormorants, and kingfishers. Franks Tract SRA is used primarily as a loafing place for waterfowl, as its water depth of more than 2 meters exceeds the foraging depth of most bird species. It is also generally believed that both hunting pressure and boat traffic limit the waterfowl use of the SRA.

Before the 1981 levee failure, Little Franks Tract held more than 100 bird species (Center for Design Research 1988). The unique combination of minimal human traffic and continuous marsh and riparian habitat created an important roosting, feeding, nesting, and loafing refuge. Yellow-headed blackbirds, a species irregular elsewhere in the Delta, were common here. The riparian woodland along the southern margin of the tract held a black-crowned night-heron colony. Species scarce elsewhere in the Delta, such as American redstart (*Setophaga ruficilla*), golden eagle (*Aquila chrysaetos)*, and yellow-breasted chat, were apparently commonly reported (Center for Design Research 1988). There have been no known sightings of rare, threatened, or endangered species of birds within the borders of the SRA (Center for Design Research 1988), although the potential habitats exist for many species.

LOWER SHERMAN LAKE

A draft bird list exists for Lower Sherman Lake Wildlife Area (State of California 2004). However, rather than a list of known occurrences based on field observations, this list has been generated from the California Wildlife Habitat Relationships system (CWHR), a predictive model based on habitat type. Consequently, it is of limited value for determining existing conditions at the site.

Comments under General Description and Franks Tract are broadly applicable to Lower Sherman Lake. The only confirmed report of a special status bird species in the area concerns multiple reports of burrowing owls in various locations immediately north of Lower Sherman Lake, around Collinsville and Toland Landing (CNDDB).

BIG BREAK

In addition to broadly applicable comments under the General Description and Franks Tract sections, there is one significant ornithological observation specific to Big Break. Three California black rails were reported calling in May 1978 on the south side of Big Break 1km west-northwest of Oakley Wastewater Treatment Plant (Manolis 1978). The same area was resurveyed in November 1981, and two adults were found to be in the same area (CNDDB). This was an area of habitat typical for the species in the Delta, reported as undeveloped brackish *Salicornia* marsh with little tidal influence.

4.7.3 OTHER WILDLIFE SPECIES

This subsection pertains to wildlife other than fish and avian species, which are discussed above.

GENERAL DESCRIPTION

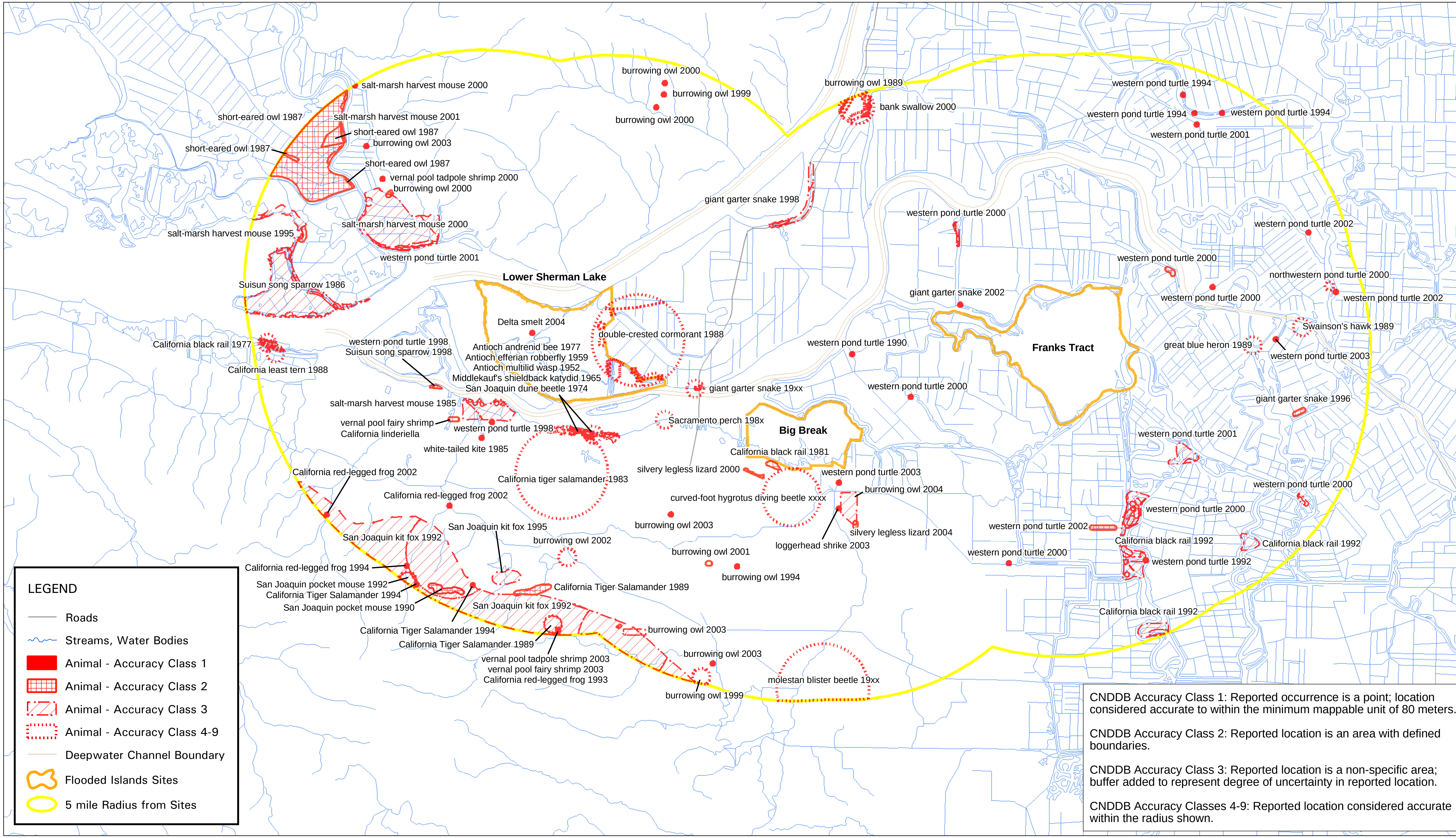
Common Species

The upland grassland and ruderal areas around these islands have the potential to support several common mammal species, such as black-tailed jack rabbit (*Lepus californicus*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), California ground squirrel (*Spermophilus beecheyi*), California vole (*Microtus californicus*), western harvest mouse (*Reithrodontomys megalotis*), house mouse (M*us musculus*), Botta's pocket gopher (*Thomomys bottae*), Virginia opossum (*Dedelphis virginiana*), feral cats (*Felis domesticus*), Norway rat (*Rattus norvegicus*), and possibly coyote (*Canis latrans*) and red or gray foxes (*Vulpes vulpes, Urocyon cinereoargenteus*). The aquatic areas of the islands provide foraging habitat for several common and special-status species of bats, and upland areas around the islands may provide suitable roosting habitat. The wetland margins of the islands likely support muskrat (*Ondatra zibethicus*), and may support American beaver (*Castor canadensis*), northern river otter (*Lutra canadensis*), or American mink (*Mustela vision*). Common reptile and amphibian species most likely found in and around the three islands include western fence lizard (*Sceloporus occidentalis*), common garter snake (*Thamnophis sirtalis*), western rattlesnake (*Crotalis viridis*), gopher snake (*Pituophis melanoleucus*), Pacific tree frog (*Hyla regilla*), western toad (*Bufo boreas*), bullfrog (*Rana catesbeiana*), and possibly red-eared slider turtles (*Chrysemys scripta*).

Special-Status Species

The Sacramento–San Joaquin Delta is considered one of the most modified and intensely managed estuaries in North America, leading to a decline in several plant and animal species(CALFED 2000c) In-channel islands, the last remnants of the original Delta tidal marshes, support high habitat values for many special-status species. The Delta In-Channel Island Work Group has developed a strategy to protect the islands (Nelson et al. 2004). Many of the biotechnical treatments used for the In-Channel Island Demonstration Project may be useful for restoration design of similar habitats in the three flooded islands to enhance or create habitats for several special-status wildlife species.

One special-status species of particular concern that could occur in the area of the flooded islands following restoration activities is the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) (Table 4.7-8). One special-status mammal species, the salt marsh harvest mouse (*Reithrodontomys raviventris*) has been recorded several times within 5 miles of the islands (Exhibit 4.7-5). Four special-status reptile or amphibian species, the giant garter snake (*Thamnophis Gigas*), the western



Source: CNDDB 2004, DWR 2002, Teale 2001

CNDDB Occurrences

EXHIBIT 4.7-5

Flooded Islands Feasibility Study Baseline Report

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Miles

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pond turtle [*Emys (=Clemmys) marmorata*], the California tiger salamander (*Ambystoma tigrinum)* and the silvery legless lizard (*Anniella pulchra pulchra*), have been recorded within 5 miles of the islands (CNDDB 2004). Several other special-status species have been recorded in the area, or have the potential to exist in the area including the California red-legged frog (*Rana aurora draytonii*), western spadefoot toad (*Scaphiopus hammondi hammondi*), San Joaquin whipsnake (*Masticophis flagellum ruddocki*), California horned lizard (*Phrynosoma coronatum frontale*), the California tiger salamander (*Ambystoma californiense*),Townsend's big-eared bat (*Plecotus townsendii townsendii*), pallid bat (*Antrozous pallidus*), greater western mastiff bat (*Eumops perotis*), fringed myotis (*Myotis thysanodes*), long-legged myotis (*Myotis volans*), and the San Joaquin kit fox (*Vulpes macrotis mutica*). However, these species are not likely to be found in habitats provided by the three flooded islands, or they are presumed extirpated from the area. Therefore, they are not discussed further.

Table 4.7-8
Special-Status Wildlife Species of Importance at the Flooded Islands

Species	Status
Amphibians	
California Tiger Salamander (*Ambystoma tigrinum*)	FT
Reptiles	
Silvery legless lizard (*Anniella pulchra pulchra*)	FSC, SSC
Western pond turtle [*Emys (+Clemmys) marmorata*]	SSC
Northwestern pond turtle [*Emys (=Clemmys) marmorata marmorata*]	FSC, SSC
Giant garter snake (*Thamnophis gigas*)	FT, CT
Mammals	
Salt-marsh harvest mouse (*Reithrodontomys raviventris*)	FE, SE
Invertebrates	
Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)	FT

U.S. Fish and Wildlife Service
FE = Federal Endangered
FT = Federal Threatened
FSC = Federal Species of Concern
California State and Department of Fish and Game
CE = State Endangered
CT = State Threatened
SSC = State Species of Special Concern
CP = Protected Species

Sources: CNDDB, Lauritzen Wildlife report, Dutch Slough report, Coco DHCP and App D

The CALFED Multi-Species Conservation Strategy (2000) identified one amphibian species, one reptile species, and one mammal species that have been listed as threatened or endangered under the federal Endangered Species Act (ESA). Several other species are listed under the State of California's ESA, or are being proposed or considered for listing under both federal and State ESAs. In response, initiatives have been enacted to protect and restore the Delta's natural resources and species including the CALFED Bay–Delta Authority Ecosystem Restoration Program, the Delta Regional Ecosystem Restoration Implementation Plan and the CALFED Multi-Species Conservation Strategy (CALFED 2000c).

The CALFED Strategic Plan for Ecosystem Restoration presents six goals to guide the implementation of restoration actions. The first Strategic Goal focuses on at-risk species, which includes all species designated for recovery (CALFED 2000c).

CALFED Recovery-Designated Species

For species designated for Recovery, or "R," CALFED has established a goal to recover the species within the CALFED ERP Ecological Management Zones. A goal of "recovery" was assigned to those species whose recovery is dependent on restoration of the Delta and Suisun Bay/Marsh ecosystems and for which CALFED could reasonably be expected to undertake all or most of the actions necessary to recover the species. Recovery is achieved when the decline of a species is arrested or reversed, threats to the species are neutralized, and thus, the species' long-term survival in nature is assured (CALFED 2000c). The "recovery" species that could inhabit the study area is the valley elderberry longhorn beetle.

Valley Elderberry Longhorn Beetle

The valley elderberry longhorn beetle (VELB) is a federally listed threatened species associated with riparian habitats. The distribution and populations of this species have declined substantially, primarily as a result of the loss or degradation of habitat in its range. The loss of habitat and declining condition of this species' populations have warranted its listing as threatened or endangered under the federal ESA. Major factors that have contributed to the decline of VELB include adverse effects of conversion of native habitats for agricultural, industrial, and urban uses, and land and water management practices that degrade habitats used by this species (CALFED 2000c).

VELB has been found only in association with its host plant, elderberry (Sambucus spp.). Elderberry is a component of the remaining riparian forests and adjacent grasslands of the Central Valley. Entomologists estimate that the range of this beetle extends from Redding at the northern end of the Central Valley to the Bakersfield area in the south. Important stressors on VELB are fragmentation of riparian habitat; grazing; and excessive collection of the species for commercial, recreational, scientific, or educational purposes. Local populations can also be severely damaged by pesticides inadvertently drifting from nearby agricultural lands into occupied habitat areas (CALFED 2000c).

Protecting existing and restoring additional suitable riparian habitats and establishing new populations will be critical to recovery of the VELB in the Bay–Delta. Restoration of riparian habitats in the Sacramento–San Joaquin Delta Ecological Management Zone will help maintain healthy populations by increasing the quality and quantity of habitats used by these species. The period required to achieve recovery of the VELB could be reduced by introducing the species into unoccupied or restored habitat areas. Such a strategy could be implemented through cooperative agreements with land management agencies or cooperative agreements with willing landowners. The VELB would also benefit from development and implementation of alternative designs for and maintenance of flood control, bank protection, and other structures that reduce their potential adverse effects on existing riparian habitats. Restoration of ecosystem processes and habitats in other ecological management zones will also allow riparian vegetation to develop that will provide habitat for these species elsewhere in the Central Valley. The benefit of these restorations for recovery of the VELB would be increased by implementing restoration of riparian habitats in a manner that links isolated areas supporting existing VELB populations (CALFED 2000c).

Contribute-To-Recovery-Designated Species

This section addresses those species designated as "Contribute to Recovery" ("r") in the ERP. For species designated "r," CALFED will make specific contributions toward the recovery of the species. The goal "contribute to recovery" was assigned to species for which CALFED Program actions affect only a limited portion of the species range and/or CALFED Program actions have limited effects on the species. To achieve the goal of contributing to a species' recovery, CALFED is expected to undertake some of the actions under its control and within its scope that are necessary to recover the species. When a species has a recovery plan, CALFED may implement some of the measures identified in the plan that are within the CALFED Problem Area, and some measures that are outside the Problem Area. For species without a recovery plan, CALFED would need to implement specific measures that would benefit the species. The "contribute to recovery" species that could inhabit the study area are the salt marsh harvest mouse and the giant garter snake (CALFED 2000c).

Salt Marsh Harvest Mouse

The loss of habitat and declining condition of this species' population have warranted its listing as endangered under the State and Federal Endangered Species Acts. Degradation of habitat resulting from agricultural practices, diking, and human disturbance has limited greatly what habitat is available. Other factors or "stressors" that have contributed to the decline or potentially could inhibit the recovery of the species include human activities that disturb the species and predation by nonnative species. Grazing, water management practices, land use practices, contaminants, and human-made structures, such as dikes and levees, continue to degrade the quality remaining habitat areas (CALFED 2000c).

The salt marsh harvest mouse occurs only in saline emergent wetlands associated with San Francisco Bay and its tributaries. Historically, these areas supported extensive tidal wetlands, which sustained dense stands of pickleweed (*Salicornia* spp.). These plants, in turn, supported the salt marsh harvest mouse. Barriers, such as a road or path no more than 10 feet across, isolate the mouse in fragmented habitats because it will not use or travel across areas lacking vegetation. Upland areas consisting of grasslands or salt-tolerant plants adjacent to saline emergent wetlands offer refuge during extreme high tides and high outflow periods. Restoration of adjacent upland habitat will help to recover this species by increasing habitat area. Introducing mice into unoccupied habitat areas within their historic range would speed the recovery of the species by establishing new populations before the species would be expected naturally to expand into these or restored habitat areas. Restoration of salt marsh harvest mouse is integrally linked with restoration of saline emergent wetlands and adjacent grasslands adjacent to San Pablo and Suisun bays (CALFED 2000c).

General restoration actions recommended by CALFED include:

< Restore wetland and perennial grassland habitats adjacent to occupied nesting habitats to create a buffer of natural habitat to protect nesting pairs from adverse affects that could be associated with future changes in land use on nearby lands and to provide suitable foraging habitat and nesting habitat area suitable for the natural expansion of populations.

< To the extent practicable, design dikes constructed in enhanced and restored saline emergent wetlands to provide optimal wetland-to-upland transition habitat.

< To the extent practicable, salt marsh enhancement efforts should be directed toward degraded marshes that are of sufficient size and configuration to develop fourth-order tidal channels (marshes would likely need to measure at least 1,000 acres).

< To the extent practicable, salt marsh enhancements and restorations should be designed to provide low-angle upland slopes at the upper edge of marshes to provide for the establishment of suitable and sufficient wetland-to-upland transition habitat. Transition habitat zones should be at least 0.25 mile wide.

The assessment of restored pickleweed habitat traditionally calls for measurements of percent cover. Recent surveys have shown no strong correlation with percent cover and salt marsh harvest mouse abundance (R2 = 0.0019). Preliminary results show a slight linear correlation with pickleweed density (R2 = 0.4308) but not pickleweed height (R2 = 0.0002) (Bias et al.2003).

Habitat maps of historic tidal marshland conditions have been used to generate guidelines for sizing, shaping, and locating restoration and mitigation projects in the context of regional tidal marsh conservation planning (Collins et al. 2004).

<u>Giant Garter Snake</u>

Loss of habitat and declining populations have warranted the listing of the giant garter snake as threatened under the State and federal Endangered Species Acts. The giant garter snake lives in the Central Valley of California. It inhabits sloughs, low-gradient streams, marshes, ponds, small lakes, agricultural wetlands, and other waterways, where it feeds on small fish and frogs during the active season. The distribution and population of these prey species have declined substantially, primarily as a result of the loss or degradation of wetlands and nearby uplands (CALFED 2000c).

Major factors that have contributed to the decline of the giant garter snake include the adverse effects of conversion of aquatic, wetland, riparian, and adjacent upland habitats to other land uses and land-use practices that degrade the value of otherwise suitable habitat areas. Historic habitat areas used by these species have been substantially reduced as a result of converting land for agriculture, urban, or industrial uses or degraded as a result of ongoing land-use practices. Remaining habitat areas, such as ponds, rivers, streams, lakes, marshes, and irrigation ditches, are largely fragmented. Associated uplands, used for reproduction and hibernation, are largely unavailable. Upland habitats adjacent to aquatic habitats are now mostly isolated in small riparian bands along the tributaries that supply water to the Sacramento and San Joaquin rivers and along canals with small levees (CALFED 2000c).

Because much of the original habitat used by the giant garter snake has been lost, irrigation canals and ditches (especially canals with nearby vegetation) now provide important replacement habitat for these species. Rice farming makes up a significant portion of the agricultural activity in the Sacramento Valley, and drainage ditches associated with rice farming provide much of this surrogate habitat. Adjacent breeding and hibernating cover, however, is often limiting for the giant garter snake (CALFED 2000c).

Although the giant garter snake may have historically inhabited the once-extensive marshes of the Delta, suitable habitat is now extremely limited. Most major Delta waterways are either lined with rock or densely covered by woodlands that provide no basking sites. In addition, many of the Delta waters support populations of introduced game fish that prey on juvenile giant garter snakes. Only the off-shore islands, sloughs, and agricultural canals of the Delta still provide suitable habitat for the giant garter snake (IES 2000).

General restoration actions recommended by CALFED include:

< Create canals, side channels, and backflow pools containing emergent vegetation to provide forage habitat and escape cover, and create dispersal corridors by linking habitat areas.

< Restore suitable adjacent upland habitat or modify land-use practices to render existing uplands as suitable habitat and reestablish connectivity between wetland and upland habitat areas, provide nest and hibernation sites, and provide refuge habitat during floods.

< Create buffer zones where none currently exist to improve habitat value.

This section addresses those species designated as "Maintain" in the ERP.

Maintain-Designated Species

For species designated "maintain," or "m," the CALFED Program will undertake actions to maintain the species. This category is less rigorous than "contribute to recovery." For this category, CALFED will avoid, minimize, and compensate for any adverse effects to the species commensurate with the level of effect on the species. Actions may not actually contribute to the recovery of the species; however, at a minimum, they will be expected to not contribute to the need to list an unlisted species or degrade the status of an already listed species. CALFED will also, to the extent practicable, improve habitat conditions for these species.

The maintain species addressed in this section are the California tiger salamander and the western pond turtle.

California Tiger Salamander

California tiger salamander occur throughout much of the Central Valley, San Francisco Bay, and coast ranges and foothills below 3,000 feet, as well as along the coast in the southern portion of the State. Declining populations have warranted their designation as species of special concern and species of concern by the California Department of Fish and Game (DFG) and U.S. Fish and Wildlife Service, respectively. Major factors that limit these resources' contribution to the health of the Delta are related to adverse effects of conversion of seasonal wetlands and adjacent uplands to other land uses and excessive mortality resulting from introduction of nonnative predators and some land use practices.

Tiger salamanders typically inhabit scattered ponds, intermittent streams, or vernal pools that are associated with grassland-oak woodland habitat below Elevation 1500. Vernal pools covering more than 250 square feet, with fairly turbid water, provide optimal habitats. Most surface movements of the western spadefoot and California tiger salamander, including breeding activity, are associated with the onset of fall and spring rains that fill traditional breeding ponds. Warm days followed by rains or high humidity levels at night trigger reproductive and foraging activities and adults of these species sometimes appear in large numbers. They require fish-free breeding ponds next to upland habitat containing rodent burrows in which they can over-summer. Patches of suitable habitats are naturally somewhat isolated from one another, promoting genetic diversity within the species which presumably reflects adaptations to local conditions.

California tiger salamander populations have declined primarily as a result of habitat loss or degradation and competition or predation from nonnative species. The abundance from population to population is unknown but is influenced by the size and quality of individual habitat patches within the fragmented pockets that the species are known to inhabit. The greatest threat to the continued existence of the tiger salamander is habitat loss and competition by nonnative species. Habitat loss is a result of increased urbanization and conversion of native grasslands to agriculture. The spadefoot and salamander may be found in high densities in isolated areas but adjacent breeding habitat is increasingly being converted for other uses.

Introduction of predatory fish and bullfrogs in known breeding ponds is also an important factor attributed to the decline of these species. Juvenile and adult bullfrogs can prey on larvae and terrestrial forms of these native species. Other important stressors that affect the spadefoot and salamander are rodent control activities, which reduce the availability of summer estivation (burrowing) sites. The use of rodent burrows may be more important for the California tiger salamander than for western spadefoot. Research on the extent and necessity of burrow use by both species would be valuable. In addition to rodent control activities, development of roads between breeding ponds and terrestrial habitats, resulting in deaths from automobiles during the species' migrations, has also contributed to the decline.

Implementing guidelines developed by DFG for vegetation, grazing, traffic, and pest management would increase these species' reproductive success and reduce the level of mortality from unnatural sources. These guidelines could be implemented through cooperative agreements with land management agencies and organizations and development and implementation of incentive programs to encourage land use practices that improve habitat conditions for and reduce mortality on these species.

Long-term survival of these diverse populations depends on numerous protected areas containing both breeding ponds and upland habitats (CALFED 2000c).

General restoration actions recommended by CALFED include:

< Reduce the use of herbicides that adversely affect California tiger salamander and its habitats.

< Reduce mowing, to the extent feasible, to control vegetation and livestock grazing near occupied seasonal wetlands from October to March.

< Reduce traffic, where feasible, on roads crossed by these species during migration periods.

< Develop alternative control measures to replace the use fumigants to control rodents.

< Draining waterways used by the spadefoot and salamander during the periods when these species are dormant could be beneficial by reducing populations of nonnative predatory fish and bullfrogs.

Western Pond Turtle

The western pond turtle is the only turtle native to the Central Valley region and to much of the western United States. The loss of habitat and declining conditions have warranted the listing of the western pond turtle as a Species of Concern by U.S. Fish and Wildlife Service (USFWS) and a Species of Special Concern by DFG. The decline of the western pond turtle mostly can be attributed to adverse effects of conversion of aquatic, wetland, riparian, and adjacent upland habitats to other land uses and land-use practices that degrade the value of otherwise suitable habitat areas (CALFED 2000c).

The western pond turtle inhabits ponds, rivers, streams, lakes, marshes, and irrigation ditches with rocky or muddy bottoms. Dense cover and exposed basking sites are important components of these wetland habitat types. Western pond turtle inhabits every region of California except drainages on the eastern slope of the Sierra Nevada. Population densities vary, however, and are highly influenced by the quality of isolated habitats. A disproportionately large percentage of western pond turtle populations only include adults, indicating poor reproductive success (CALFED 2000c).

Historic habitat areas used by these species have been substantially reduced as a result of converting land for agriculture, urban, or industrial uses or degraded as a result of ongoing land-use practices. Remaining habitat areas, such as ponds, rivers, streams, lakes, marshes, and irrigation ditches, are largely fragmented. Associated uplands, used for reproduction and hibernation, are largely unavailable. Upland habitats adjacent to aquatic habitats are now mostly isolated in small riparian bands along the tributaries that supply water to the Sacramento and San Joaquin rivers and along canals with small levees (CALFED 2000c).

Because much of the original habitat used by the western pond turtle has been lost, irrigation canals and ditches (especially canals with nearby vegetation) now provide important replacement habitat for these species. Rice farming makes up a significant portion of the agricultural activity in the Sacramento Valley, and drainage ditches associated with rice farming provide much of this surrogate habitat. Adjacent breeding and hibernating cover, however, is often limiting for this species. Other factors that limit these populations include some agricultural practices (e.g., discing, mowing, burning, and applying herbicides and rodenticides) that degrade habitat or cause mortality; introduced large predatory fish that prey on juveniles and injure adults; and mortality caused by flooding of hibernation sites during heavy rains, floods, or for waterfowl (CALFED 2000c).

Although considered to be just one widely distributed species, it is likely that the pond turtle is a complex of closely related subspecies, each adapted for a different region. The western pond turtle is still common enough in the Bay–Delta watershed so that it is not difficult to find them in habitats ranging from sloughs of the Delta and Suisun Marsh to pools in small streams. The problem is that most individuals seen are large, old individuals; hatchlings and small turtles are increasingly rare. The causes of the poor reproductive success are not well understood, but factors that need to be considered include elimination of suitable breeding sites, predation on hatchlings by nonnative predators (e.g., largemouth bass, bullfrogs), predation on eggs by nonnative wild pigs, diseases introduced by nonnative turtles, and shortage of safe upland over-wintering refuges. If present trends continue, the western pond turtle will deserve listing as a threatened species (it may already) (CALFED 2000c).

General restoration actions recommended by CALFED include:

< Create canals, side channels, and backflow pools containing emergent vegetation within the South, East, and North Delta Ecological Management Units of the Sacramento–San Joaquin Delta Ecological Management Zone to provide forage and cover habitat, and create dispersal corridors by linking habitat areas.

< Restore suitable adjacent upland habitat or modify land-use practices to render existing uplands as suitable habitat and reestablish connectivity between wetland and upland habitat areas, provide nest and hibernation sites, and provide refuge habitat during floods.

< Create buffer zones where none currently exist to improve habitat value.

Non-CALFED Designated Special-Status Species

Silvery Legless Lizard

The silvery legless lizard is not designated by CALFED for special protections, but it is a species of importance in the area of the Flooded Islands project. It is nearly endemic to California. It ranges from Antioch in Contra Costa County south through the Coast, Transverse, and Peninsular Ranges, along the western edge of the Sierra Nevada Mountains and parts of the San Joaquin Valley and Mojave Desert to El Consuelo in Baja California. Its elevation range extends from near sea level on the Monterey Peninsula to approximately 1,800 meters above sea level in the Sierra Nevada foothills (JSA 2002).

The East Bay Regional Park District Legless Lizard Preserve is located east of the intersection of Highway 4 and Big Break Road north of Oakely. This is the only California Natural Diversity Database record for this species in the inventory area, but other occurrences are likely to exist within the area because of the presence of suitable habitat (JSA 2002).

Silvery legless lizards occur primarily in areas with sandy or loose loamy soils, such as under sparse vegetation of beaches, chaparral, or pine-oak woodland; or near sycamores, cottonwoods, or oaks that grow on stream terraces. The sandy loam soils of stabilized dunes seem to be especially favorable habitat. The species is often found under or in close vicinity to logs, rocks, old boards, and the compacted debris of woodrat nests. Rocky soils or areas disturbed by agriculture, sand mining, or other human uses are not suitable for legless lizards. Soil moisture is essential for legless lizards to conserve energy at high temperatures; soil moisture also allows shedding to occur. Adult and juvenile lizards are insectivorous and subsist largely on larval insects (especially moths and beetles), adult beetles, termites, and spiders (JSA 2002).

Silvery legless lizards bear live young and are believed to breed from early spring through July. Oviductal eggs are observed in females from July through October and litters of one to four (normally two) young are born in September, October, and November. Gestation lasts about 4 months. Young lizards typically reach sexual maturity in 2 to 3 years (for males and females, respectively). Longevity of silvery legless lizards in the wild is unknown. However, sexually mature adults have lived for almost 6 years under laboratory conditions (JSA 2002).

Legless lizards are fossorial animals that construct burrows in loose sandy soil. They appear to be active mostly during the morning and evening, when they rest just beneath the surface of sunlight-warmed substrate. They may also be active on the surface at night when substrate temperatures remain warm for extended intervals. Known predators of legless lizards include ringneck snakes (*Diadophis punctatus*), common king snakes (*Lampropeltis getulus*), deer mice (*Peromyscus maniculatus*), long-tailed weasels (*Mustela frenata*), domestic cats (*Felis sylvestris*), California thrashers (*Toxostomea redivivum*), American robins (*Turdus migratorius*), and loggerhead shrikes (*Lanius ludovicianus*) (JSA 2002).

The legless lizard's specialization for a fossorial existence in substrates with a high sand fraction makes it vulnerable to many types of habitat loss and disturbance. Legless lizards cannot survive in urbanized, agricultural, or other areas where a loose substrate in which to burrow has been removed or altered (e.g., disturbed by blowing or bulldozing). Other factors can alter the substrate such that the species cannot survive in the area. These factors include livestock grazing, off-road vehicle activities, sand mining, beach erosion, excessive recreational use of coastal dunes, and the introduction of exotic plant species, such as ice plants (*Carpobrotus edulis* and *Mesembryanthemum crystallinum*), Marram grass (*Ammophila arenaria*), veldt grass (*Ehrharata calycina*), and eucalyptus trees (*Eucalyptus* spp.). These factors decrease soil moisture or alter the conformation of the substrate, which may act to limit the food base or make the substrate physically unsuitable for legless lizards. Pesticides may also threaten legless lizards because of the species' insectivorous diet. Increasing numbers of feral cats associated with residential areas also threaten extant populations of this species (JSA 2002).

Detailed studies of legless lizard habitat requirements need to be conducted to determine the precise distribution and ecological needs of this species.

Invasive Wildlife Species

The introduction of nonnative species has made the San Francisco Bay–Delta estuary the most invaded estuary in the world (CALFED 2000e). A review of sampling data and species lists revealed that exotic species dominate many of the Bay–Delta ecosystem's biotic associations, including infaunal and epifaunal soft-bottom benthos (organisms living in or on the bottom sediments), fouling communities, brackish-water zooplankton, and freshwater fish. In these communities, exotic organisms typically account for 40 to 100% of the common species, up to 97% of the total number of organisms, and up to 99% of the biomass. About half of all invasions in the 145-year record were reported in the last 35 years. On the basis of the raw data, the rate of invasions has increased from an average of one new species established every 55 weeks from 1851 to 1960, to an average of one new species every 14 weeks from 1961 to 1995 (Cohen and Carlton 1998).

Nonnative aquatic invertebrates of the Bay–Delta include a wide variety of sponges, coelenterates, worms, mollusks, and crustaceans. Most are bottom-dwelling organisms as adults, but some planktonic forms have also become well established, especially in the last few years. Most were introduced accidentally from the hulls of ships passing through or abandoned or sunk in the Bay–Delta, from the release of ship ballast water, and from oysters (which usually contain dozens of nestling, symbiotic, and parasitic invertebrates) brought in from Japan and the Atlantic coast for aquacultural purposes. The first recorded introduced species, the Atlantic barnacle (*Balanus improvisus*) was observed in 1853. Since then, many species of nonnative fish and invertebrates have been introduced into the estuary (CALFED 2000e).

The success of these introduced species is due in part to the comparatively small number of native species thought to have been present during aboriginal times and in part to environmental modifications to which nonnative species were often preadapted. The relatively low native-species diversity is thought to be a result of the relatively young age of the Bay–

Delta estuary and its isolation from other Pacific Coast estuarine systems. Important environmental changes that most likely decreased native species' ability to compete with nonnative species include changes in Bay–Delta morphometry, vegetation, hydraulics, and the amount and timing of Delta outflow (CALFED 2000e).

The introduction of these organisms has greatly increased the species diversity of the Bay–Delta aquatic community. Most nonnative fish and invertebrates perform a vital role in the Bay–Delta food web. Nonnative species now figure prominently in the diets of fish species, shorebirds and invertebrate-eating waterfowl, and other wildlife species. However, this increase in diversity has occurred at the expense of native species, some of which have declined precipitously or even become extinct because of predation and competition from nonnatives. Certain species have become so abundant in some areas or have been shown to exert a negative effect on ecosystem health or economics in other areas that their mere presence in the Bay–Delta is a source of considerable concern. A new invader can effectively destroy the value of a restoration project (CALFED 2000e). Three species of considerable concern that may be found in the area of the three flooded islands are the Chinese mitten crab (*Eriocheir sinensis*), and two Asian clams, *Potamocorbula amurensis* and *Corbicula fluminea*. *Corbicula fluminea* is addressed in Chapter 4.8.

Mitten Crab *(Eriocheir sinensis)* spends most of its life in fresh water and migrates downstream to spawn in salt water. Mitten crabs were first captured in south-Bay shrimp trawls in 1993. Their distribution and abundance have increased every year since then. Although these crabs may have an adverse effect on the red swamp crayfish (another nonnative species), its greatest potential negative impact on the Bay–Delta may be its effect on levees. Mitten crabs dig burrows in clay-rich soils where banks are steep and lined with vegetation. These burrows accelerate bank erosion and slumping and, over time, may pose a serious threat to Delta levee integrity (CALFED 2000e).

The Asian clam, *Potamocorbula amurensis*, was first observed in 1986 and has since become extremely abundant in the Bay and western Delta. This species is well adapted to the Bay–Delta saltwater conditions and exerts a heavy grazing loss on phytoplankton and zooplankton in the Bay (CALFED 2000e). Introduced clams can filter the entire volume of the South San Francisco Bay and Suisun Bay at least once a day (Cohen and Carlton 1995). Precisely how the Asian clam is affecting other benthic invertebrates, the zooplankton abundance and composition, or larval and young fish health is not well understood, but is thought to be generally detrimental. *Potamocorbula* has been a major control on phytoplankton in the northern Bay (Canuel and Thompson 2003). On the positive side, Asian clams may contribute to the food web as an important food source for white sturgeon (CALFED 2000e). Because *Potamocorbula amurensis* is a saltwater clam, it is of less importance in the area of the Flooded Islands, which are less saline than Bay waters. Its freshwater counterpart, however, *Corbicula fluminea*, can have a dramatic impact in the brackish and freshwater areas of the Delta. The effects of *Corbicula* are less studied than those of *Potamocorbula amurensis*. The effects of *Potamocorbula* may serve as an example for the potential widespread effects of *Corbicula*.

Invasive terrestrial species can have similarly detrimental effects. These impacts are among the most difficult to assess and treat. Nonnative terrestrial species can compete with native species for food and shelter, and can prey directly on native species. Such predators can have a major impact on the ability of natural areas to support wildlife, including threatened native species, such as salt marsh harvest mice (CALFED 2000c).

The bullfrog is not native west of the Rockies but has been successfully introduced throughout most of California, from Oregon to Mexico. Bullfrogs can establish and thrive in most permanent aquatic habitats that support emergent vegetation. Population levels in semipermanent aquatic habitats vary from year to year. Bullfrogs are particularly notorious for their voracious appetites. Bullfrogs feed on most vertebrates and invertebrates that can be seized and swallowed (CALFED 2000c). This single species has is a major factor in the decline of numerous native Delta species, including the California red-legged frog, western pond turtle, and California tiger salamander (Robins and Cain 2002).

The Norway rat was introduced unintentionally and was established in many areas by the mid-1800s. Increases in urban development, landfills, and riprap areas have resulted in large populations of these rats living along the bay shores. They are a threat to ground-nesting wildlife (CALFED 2000c).

Housecats, both tame and feral, are major predators to bird and mammal populations in the wetland areas of the Bay–Delta Estuary and wildlife areas elsewhere (CALFED 2000c). Domestic dogs (*Canis domesticus*) let loose in natural areas cause many of the same impacts as housecats.

The red-eared slider is a turtle native to the southeastern United States and sold in pet stores throughout the west. The species has become established in the wild in some locations through release by pet owners. The range and status of sliders in the Delta are unknown, but it is possible that this species is successfully reproducing. If so, it could compete with native aquatic species in and dependent on the Delta (CALFED 2000c).

Red fox was introduced in the Central Valley, and the species has spread to marshes throughout the Bay–Delta system. It threatens many native endangered wildlife species, such as the clapper rail and several other San Joaquin Valley animals (CALFED 2000c).

The general goal for nonnative wildlife control is to develop and implement control programs to reduce population abundance and to reestablish larger blocks of connected habitats to provide more extensive habitat and protection for native wildlife. Economical but lethal means of control (poisons, traps) are often controversial for many of these species and may also affect native species. There is thus a need to focus on prevention (e.g., containment and neutering of pets), nonlethal means of removal (e.g., live-trapping) where feasible, and on developing support and methods for lethal control where necessary (CALFED 2000c).

General control actions recommended by CALFED include:

- Reduce Norway rat populations using a combination of activities, including the removal of garbage and rubbish; the breaking down of stubble in field crops, such as corn, to expose the rodents to predation during winter; the use of biological controls and rodenticides (CALFED 2000c).

- Periodically drain aquatic habitats to reduce populations of bullfrogs. Bullfrog larvae have an extended growing season, sometimes even overwintering, compared to native amphibians such as the California red-legged frog (CALFED 2000c).

- Reduce red fox populations in critical habitat areas suitable for salt marsh harvest mouse, San Joaquin kit fox, California clapper rail, and California black rail (CALFED 2000c).

FRANKS TRACT

Before the levee failure in 1981, Little Franks Tract was a noted wildlife area; muskrat, raccoon, beaver, and river otter were all sighted. Today's levee remnants support otter, rabbit, and skunk, and rodents and rabbits use the riparian habitat. Lizards, gopher snakes, and racers are representative of the reptiles at Franks Tract, but no pond turtles have been identified, despite prime riparian and marshy habitat at Franks Tract State Recreation Area (SRA). The marsh and riparian habitats likely support amphibian species such as the Pacific treefrog. There have been no known sightings of rare, threatened, or endangered species of mammals or birds within the borders of the SRA, although potential habitat exists for many species (CDR & EDAW 1988).

A giant garter snake was found on Webb Tract (adjacent to Franks Tract to the North) during April, 2002 near the ferry dock. A western pond turtle was observed in two locations on Holland Tract, and river otters were observed on both Webb Tract and Bouldin Island (CBDA 2004).

A 2002 habitat evaluation found that suitable roosting bat habitat is present on four nearby Delta islands (Bacon Island, Holland Tract, Bouldin Island, and Webb Tract) in crevices, cavities and foliage found on trees and structures. Accessible structures were visually inspected and no roost sites were found. Foraging habitat is present on each island and acoustic surveys at selected sites detected bat activity near water features, riparian vegetation, and open pasture on Bacon Island and Holland Tract (CBDA 2004).

BIG BREAK

Several common species or their traces have been observed in the Big Break area, including coyotes, red and gray foxes, raccoons, striped skunks, river otter, California ground squirrels, California voles, Western harvest mice, opossum, beaver, domestic (feral) cats, Norway rat, bullfrogs, and western fence lizards (IES 2000). Beavers, muskrats, and river otters that forage in the area may potentially den at Big Break. Big Break is strewn with old structures that provide potential roosting or hibernaculum habitat for several bat species, including the pallid bat (EBRPD 2001).

If appropriate restoration measures were undertaken, several special status wildlife species would have the potential to occur at the Lauritzen property on the southwestern corner of Big Break. Currently, the Lauritzen property has been determined to be unsuitable for salt-marsh harvest mouse, San Pablo vole, Suisun shrew, California red-legged frog, and giant garter snake. No occurrence records for red-legged frogs have been recorded in or adjacent to the Delta in many years (IES 2000). The San Pablo vole and the Suisun shrew are restricted to San Pablo Bay and Suisun Marsh, respectively (CALFED 2000c).

Surveys were conducted for silvery legless lizards on the Lauritzen property. No evidence was found of legless lizards, but because of their fossorial nature, they could have been missed during visual surveys. The nearest known locations of populations are from an EBRPD legless lizard preserve about ¼ mile south of the Lauritzen site. There is potential habitat along the berm and around the barn at the Lauritzen site. However, this site does not appear to provide high-quality habitat (IES 2000).

Surveys were conducted for basking western pond turtles on the Lauritzen property. No turtles were observed during surveys, but they have been observed along the shoreline at the Lauritzen site (IES 2000) and a large population is known to occur in the lower Marsh Creek. (PWA et. al. 2004) The tidal sloughs and fresh water marshes of Big Break provide habitat for Western pond turtles which have been observed basking on rocks, logs, and exposed banks. The Big Break area has suitable breeding habitat for turtles, and females can lay their eggs in the sandy banks and well-drained upland soils

Surveys were conducted for bat roosting habitat on the Lauritzen property. No sign of pallid bats was found during surveys, but they could forage throughout the Big Break area and roost in tree hollows or in an old barn on the Lauritzen site (IES 2000).

Surveys were conducted for several species in the area of Dutch Slough, located to the north and east of Big Break. Species that were not seen but potential habitat was found for include Lang's Metalmark Butterfly, salt-marsh harvest mouse, western pond turtle, and giant garter snake. Eric Hansen, a consulting herpetologist, considered Dutch Slough to be suitable giant garter snake habitat (IES 2000). In addition, EBRPD scientists and USFWS experts believe the area supports giant garter snakes (PWA et. al. 2004).

Biological surveys of the lower zone of Marsh Creek (a tributary to Big Break) found that the existing aquatic community is dominated by exotic species. Introduced crayfish and bullfrogs thrive in the warm perennial flows of lower Marsh Creek and prey on or compete against the larval, juvenile, or adult developmental phases of many sensitive native species (Robins and Cain 2002).

LOWER SHERMAN ISLAND

Sherman Island (adjacent to Lower Sherman Island to the east) is identified for recovery efforts in the Draft Recovery Plan for Giant Garter Snakes (USFWS 1999). One giant garter snake was found in 1998 near Sherman and Decker Islands, but it is not known whether this snake represented a resident population in the western Delta or was washed into the Delta from high-water flows in the winter. Another garter snake was observed at the north end of the Antioch Bridge before the mid 1980s (IES 2000).

Gopher snake, western pond turtle, American beaver, American mink, black-tailed jackrabbit, common muskrat, desert cottontail (*Sylvilagus auduboni*), northern river otter, raccoon, striped skunk, and Virginia opossum are thought to be present at Lower Sherman Island (DFG 2004).

4.8 INVASIVE SPECIES OF CONCERN

This section focuses on two invasive species that have considerable effect on water quality and the ecosystem in the Delta: Brazilian waterweed (*Egeria densa*) and Asiatic clam (*Corbicula fluminea*).

4.8.1 EGERIA DENSA

GENERAL DESCRIPTION

Egeria densa (Egeria), commonly known as Brazilian waterweed, is a freshwater aquatic plant species introduced to California. This aquatic pest plant has spread extensively in the Delta since its introduction, and its dense infestations have created problems for navigation, recreation, agriculture, and processes supporting the Delta's aquatic ecosystem, such as nutrient cycling and sedimentation. The California Invasive Plant Council (CalIPC), an organization researching California's invasive pest plants, has created a list that ranks nonnative plant species with potential to cause significant problems in wildland areas. Egeria is on CalIPC List A-2, Most Invasive Wildland Pest Plants (in particular regions) (CalIPC 1999). Because of the invasive capabilities of this species and the detrimental impacts to the economy and environment that its uncontrolled growth has caused, Egeria has been studied by researchers and agencies to discern its biology and ecology and determine how this species affects its surrounding environment.

Egeria was likely introduced approximately 30 years ago by the draining of ship ballasts and/or the dumping of aquariums, and it currently infests approximately 6,000 acres of waterways throughout California (DBW 2004). It is a popular aquarium plant and is sold by most pet shops under the name Anacharis. Although Egeria was initially established over 30 years ago, it did not become a significant problem until approximately 12 years ago following the initiation of a water hyacinth (*Eichhornia crassipes*) abatement program. Water hyacinth forms large floating beds that prevent light infiltration and reduce oxygen levels below its canopy. The removal of the water hyacinth, in conjunction with a 6-year drought, allowed for the rapid growth and expansion of Egeria (CALFED 2000Dc).

Egeria is a submerged perennial herb in the waterweed (Hydrocharitaceae) family. It is typically rooted to a substrate, but its stems may grow up to 20 feet long to reach the water's surface. The plant may also occur as a free-floating mat or as floating fragments at or near the water's surface. Habitats that support this species include the still and flowing waters of lakes, ponds, pools, ditches, and slow-flowing drainages (Washington State Department of Ecology 2004). When conditions are appropriate, the uncontrolled growth of this species results in the formation of dense homogenous stands that cover large expanses. Egeria becomes senescent in the fall, but warm water temperatures (greater than 86°F) and high light concentrations cause premature senescence (Western Aquatic Plant Management Society 2004). The species' distinguishing features include the presence of three to six smooth-margined leaves whirled around the stem at each node and two to three staminate white flowers on threadlike pedicels. Egeria is dioecious, and only staminate plants occur in California (Hickman 1993). Therefore, the primary means of reproduction and dispersal is the fragmentation of shoots and rhizomes; the production of seed has not been observed in California (Bossard et al. 2000).

Egeria originates from Argentina, Brazil, and Uruguay. The aquarium trade has distributed this species worldwide, and it is considered naturalized in many countries (Bossard et al. 2000). Egeria goes through a reproductive process called fragmentation in spring. During this process, fragments break off from the stems of parent plants allowing for the establishment of new infestations. Fragments are also generated throughout the growing season by waves, waterfowl foraging, watercraft activity, and high-velocity water flows (Bossard et al. 2000).

The conditions necessary to support the proliferation of Egeria are not well understood, but it appears that the nutrient and light requirements of this species are similar to those of other members of the waterweed family. As with many aquatic plant species, biomass accumulation is controlled by environmental factors, such as nutrient availability, light intensity, day length, temperature, and water velocities (Bossard et al. 2000). Egeria prefers low-light conditions, and it is particularly adapted to grow in shaded environments (Anderson, pers. comm., 2004). The ability of Egeria to thrive in low-light conditions means that turbid waters are likely to favor rather than inhibit its growth. Egeria fares poorly under higher-light conditions. Exposure to high-light intensities for longer than 2 weeks causes damage to its chloroplasts, as is evidenced by pigment discolorations (Bossard et al. 2000). Research indicates that Egeria can thrive under a wide range of nutrient concentrations. Higher nitrogen concentrations, in the form of ammonium in the water column and total nitrogen in sediments, correlate to increased growth (Bossard et al. 2000). Although it prefers fresh water, the species can tolerate salinity levels of 10 to 12 parts per million (ppm) for short durations (e.g., a few days). Under drought conditions, large die-offs may occur owing to extended periods of increased salinity levels (Anderson, pers. comm., 2004).

ECOLOGICAL AND ECONOMIC IMPLICATIONS

Waters of the Delta provide many ecological and economic services to Californians, such as irrigating farmland, generating electricity, supplying drinking water, and providing essential habitat for diverse species of wildlife, fish, and endemic plants. Egeria infestations diminish the quality of some of these vital services by impeding water flow and disrupting ecosystem processes. It can also obstruct navigation, which hinders recreational and commercial opportunities for swimming, boating, and fishing (Bossard et al. 2000).

Dr. Lars Anderson, a plant physiologist at the University of California, Davis and recognized expert on Egeria, has been studying infestations of this pest plant in the Delta (Anderson pers. comm., 2004). Observations made during these studies indicate that the growth and proliferation of Egeria is primarily regulated by substrate elevation and stability, and water velocity. The species generally does poorly or cannot invade areas that have high water velocities and unconsolidated, sandy substrates that are high enough that they periodically become dry. Egeria can not survive in areas exposed for long durations during low tides because it desiccates with prolonged exposure to air. Anderson reports that Egeria is hindered when it is allowed to stand 1 foot above low tide for at least 4–6 hours. Periodic exposures during low tides for shorter durations do not appear to limit Egeria. Growth appears to be particularly inhibited in areas where Egeria beds are subject to wind and wave action. Dr. Anderson has observed Egeria growing in the Delta at depths ranging from 3 to 14 feet, as measured at high tide. Studies conducted by Dr. Anderson at Franks Tract indicate that increased sediment accumulation via the presence of Egeria may eventually lead to the creation of shallower areas in open-water habitat, with the exception of areas that experience high water velocities (i.e., areas within 100 to 150 feet of high water velocities)(Anderson, pers. comm.. 2004). However, average rates of sediment accumulation have not been determined.

Egeria forms dense monotypic infestations that outcompete and eventually replace native aquatic plants. Research indicates that the presence of Egeria reduces seed abundance and diversity of native submerged aquatic plants (Bossard et al. 2000). Egeria appears to trap sediments in the water column, which further reduces habitat for native aquatic plant beds (Anderson, pers. comm., 2004). The reduction and/or elimination of native aquatic vegetation and the addition of these nonnative infestations disturb the Delta's food web and a number of biogeochemical cycles supporting its ecosystem function. For instance, Egeria increases organic inputs during winter because the species dies off in fall, resulting in a large flush of organic carbon into the system (Anderson, pers. comm., 2004). These thickly vegetated beds also provide limited habitat for native fish. It is likely that native fish occasionally utilize Egeria beds during spawning, but dense Egeria beds harbor nonnative game species that prey on native fish (Anderson, pers. comm., 2004). It is possible that the pest plant could create toxic conditions for fish following the flush of dissolved organic carbon in the winter (Anderson, pers. comm., 2004). However, by trapping sediments and creating less turbid waters, Egeria may be supporting the increased growth of phytoplankton in the system, but it is unknown whether chemicals produced by Egeria inhibit phytoplankton accumulation (Lucas, pers. comm., 2004). These sediment-trapping capabilities may also be affecting mercury levels in the vicinity of Egeria beds. The initial results from unpublished data collected by the U.S. Geological Survey (USGS) indicate that areas vegetated by Egeria have sediments with high rates of methyl mercury production (Marvin-DiPasquale, pers. comm., 2004). Egeria's sediment trapping capabilities and the large fluxes of organic carbon it provides seem to create a superior environment for the production of methyl mercury (Marvin-DiPasquale, pers. comm., 2004). The densely vegetated Egeria beds may hinder waterfowl from diving for forage, and the increased sedimentation produced by the beds may modify benthic species populations and their predators (CALFED 2000Dc).

Research is currently being conducted by the University of California, Davis to determine the effect of submerged aquatic vegetation (SAV) on water quality, residence time, and sediment transport in the Delta. A study of the hydrodynamics in and near beds of SAV, which were predominantly Egeria, was performed in Franks Tract to provide a greater understanding of the effects of SAV to this flooded island and help create a model to predict its effects throughout the Delta (Sereno and Stacey 2004). Water velocity, turbulence, temperature, conductivity, and suspended sediments were measured under varying SAV growth conditions at Franks Tract. Results indicate that water velocities are significantly reduced in SAV beds, supporting the potential for increased residence times. However, this process appears to become more complicated when the SAV canopy did not reach the water surface. With submerged canopies, faster water velocities were observed above the SAV, creating a strong mixing layer near the top of the canopy that allows for an exchange between the faster moving waters above the SAV and the slower waters in the SAV (Sereno and Stacey 2004). The mechanism supporting this mixing layer may affect water quality by influencing the residence time and travel time of constituents (Sereno and Stacey 2004).

CONTROL METHODS

Information gathered by Bossard et al. (2000) on control methods indicates that effective techniques for abating infestations of Egeria include manual/mechanical removal, biocontrol, and herbicide applications. Manual/mechanical techniques typically employ hand pulling, cutting, and harvesting with machines. These methods tend to be costly and encourage fragmentation, thus promoting dispersal and reestablishment (Bossard et al. 2000). Anderson (2004) observed that dredging can effectively control Egeria infestations, but precautions should be taken to capture broken fragments generated during the process.

Biocontrol efforts have focused on two fish, the white amur or Chinese grass carp (*Ctenopharyngodon idella*) and the Congo tilapia (*Tilapia melanopleura*) (Bossard et al. 2000). Only the sterile Chinese grass carp is approved for use in six southern California counties (Imperial, San Diego, Riverside, San Bernardino, Los Angeles, and Ventura). However, the California Department of Fish and Game permits the introduction of Chinese grass carp in other parts of California, provided that specified restrictions are observed (Bossard et al. 2000). Interest in locating insects from South America that may control this species has heightened (Anderson, pers. comm., 2004). Herbicides that appear to be effective at controlling Egeria infestations and permitted in California for application in aquatic habitats include diquat; copper-containing products; acrolein; and fluridone (San Francisco Estuary Institute 2003). Application of herbicides in aquatic habitats should only be performed by a licensed applicator specializing in aquatic pest plants. Studies are currently being conducted at Franks Tract on both the effectiveness of the copper-containing herbicide Komeen for treating Egeria infestations, as well as its effects on the environment following application. A study of Corbicula clams at Franks Tract indicates that high concentrations of copper accumulated in the clams in areas near the herbicide application sites. While the levels of copper in the water rapidly decreased within two days following a Komeen application, it persisted in clam tissues, thereby creating a potential hazard for birds and fish consuming the clam (Brown and Luoma 2004). An aquatic specialist should be consulted prior to the application of herbicides in aquatic habitats, and herbicide treatments should always be performed by a licensed applicator. Dr. Lars Anderson is currently researching cost-effective herbicide treatments for controlling Egeria.

AREAL EXTENT IN THE STUDY AREA

In 1997, the California Department of Boating and Waterways (DBW) hired researchers at the Romberg Tiburon Center for Environmental Studies (RTC) to estimate the areal extent of Egeria and assess the effects of various control protocols on wildlife and fish. Estimates of the areal extent were made through spectral analysis of aerial photographs taken during low tide, followed by site verification. This areal estimation technique is complicated by many factors that obscure Egeria infestations, such as diffraction of water, growth of algae on the plant's surfaces, and the presence of other plants that produce a similar signature (Anderson, pers. comm., 2004). Cover estimates have been published for monitoring surveys conducted in 1997, 1999, and 2000; more recent cover estimates were not available for inclusion in this report. Unfortunately, the aerial photographs for the 2001 survey year were taken at high tide, making the interpretation of Egeria coverage difficult. The estimated percent cover of Egeria was determined by dividing the areal extent of Egeria at each flooded island by the total acreage of open water at the flooded island and multiplying by 100. Exhibit 4.8-1 is a map produced by RTC in 2000 that depicts the approximate coverage values of Egeria throughout the Delta.

Franks Tract

Estimates from the last published survey in 2000 indicate that the areal extent of Egeria at Franks Tract was approximately 1,697 acres, or approximately 61% of this flooded island's open water area (RTC 2004). The estimated coverage of Egeria has increased overall at Franks Tract since the initial 1997 survey. Egeria coverage estimates were approximately 35% in 1997 and 26% in 1999 (RTC 2004).

Lower Sherman Lake

The areal extent of Egeria at Lower Sherman Lake was approximately 590 acres in 2000, or approximately 30% of this flooded island's open water area (RTC 2004). Previous surveys estimate that Egeria coverage was approximately 25% in 1997 and 32% in 1999 (RTC 2004).

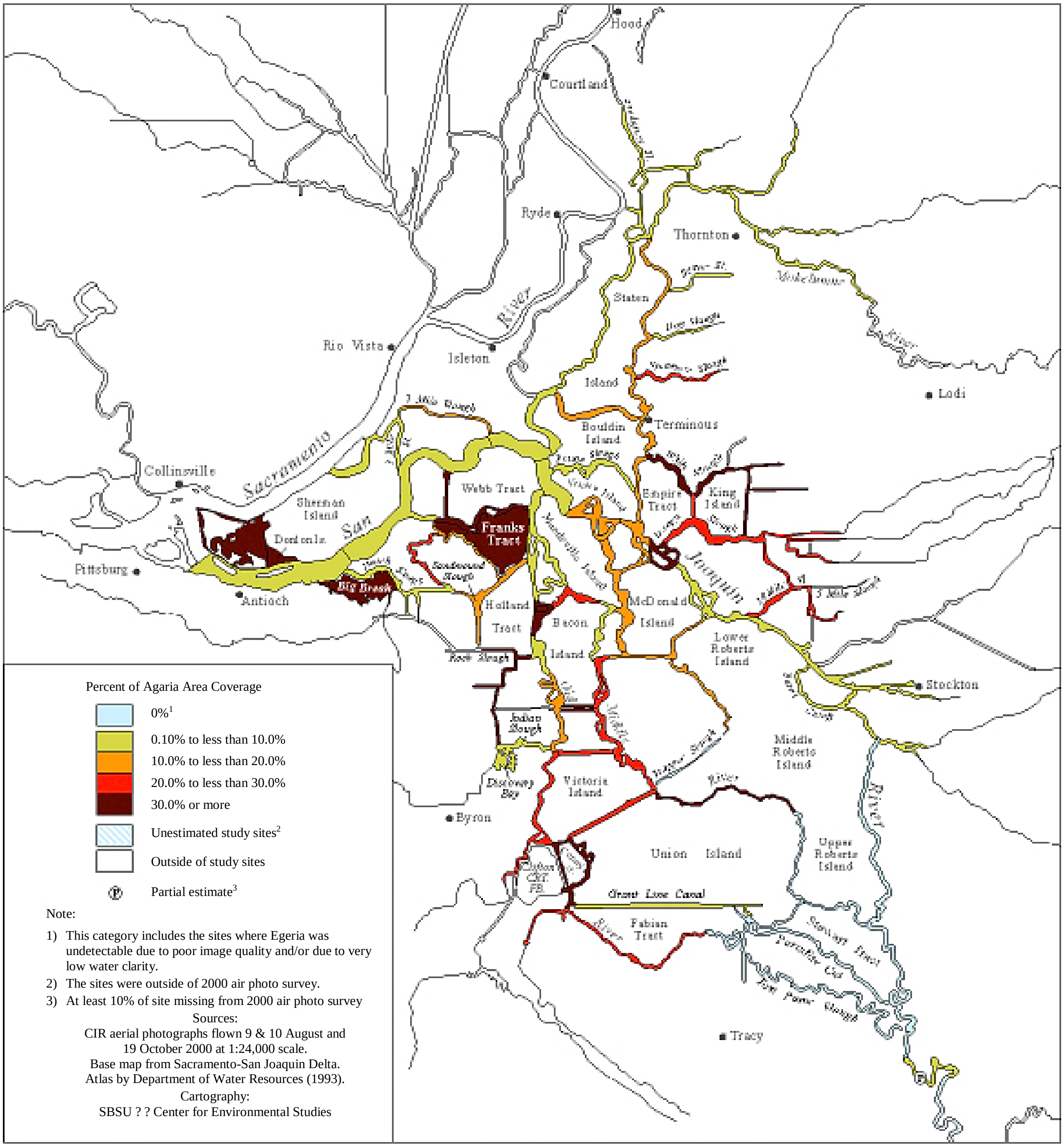
Big Break

The areal extent of Egeria at Big Break was approximately 724 acres in 2000, or approximately 52% of this flooded island's open water area (RTC 2004). Previous surveys estimate that Egeria coverage was approximately 38% in 1997 and 21% in 1999 (RTC 2004). The DBW is currently treating Egeria infestations in Big Break (Anderson, pers. comm., 2004).

4.8.2 CORBICULA FLUMINEA

GENERAL DESCRIPTION

Corbicula fluminea, a freshwater clam native to Asia, was first recorded in North America in the Columbia River in 1938, and was discovered in the Sacramento River in 1945 (Gleason 1984). Today, *Corbicula* is the most widespread and abundant freshwater clam in California. It is found throughout lower elevation warm-water systems, is the dominant mollusk and the third most abundant benthic organism in the Delta, and is one of the most commonly identified benthic organisms in fish stomachs. Densities of 2,000 young clams per square meter are common, and populations may range up to 20,000 clams per square meter. Spring flows carry



Source: Romberg Tiberon Center for Environmental Studies 2000

Egeria Cover in 2000

EXHIBIT 4.8-1

0 1.5 3
MILES
NORTH

EDAW

young *Corbicula* to Suisun Bay, where they are sometimes collected as far west as Martinez (Cohen and Carlton 1995).

It is unknown how *Corbicula* was introduced to the U.S. It is speculated that Asian immigrants, who used the clam in their homeland, introduced *Corbicula* in much the same way that Europeans introduced brown trout and common carp. Or, it may have been accidentally transported across the Pacific in the bilges of ships (Gleason 1984). *Corbicula's* spectacular spread in and between watersheds in North America may have resulted from transport for use as bait, food, or aquarium pets, or in river gravels dredged for use as aggregate. However, some argue that natural means of dispersal were paramount, including passive downstream transport of juveniles in currents, upstream transport in fish stomachs, and upstream or between-watershed transport on birds (Cohen and Carlton 1995).

For many years, there was debate as to whether the species of *Corbicula fluminea* present in the United States was *Corbicula fluminea, Corbicula manilensis,* or a third species. In 1977, biologists at the First International *Corbicula fluminea* Symposium decided that *Corbicula. manilensis* was actually the same species as Corbicula *fluminea*. Because *Corbicula fluminea* was described first, this name was adopted. However, a study published in 1982 describes two distinct types of *Corbicula* established in the United States, and both types occur in California. The scientific community continues to refer to both species as *Corbicula fluminea* (Gleason 1984).

Morphology

Corbicula has two triangular–to-oval shaped shells (or valves) that are attached to each other by a hinge ligament. Near the ligament, each valve has a prominent knob called an umbo (plural: umbones), or beak. The valves are "inflated" at the umbones so that, seen from the side, the shell is heart-shaped. *Corbicula* is distinguished by coarse-to-fine concentric ridges on the outer shell surfaces. These rings are lines of shell growth (Gleason 1984).

The valves consist of three layers. The periostracum is the thin, shiny outer layer and can be yellow-green, brown, or black. Often the periostracum has completely worn off near the umbones. The middle, prismatic layer is white and forms the bulk of the shell. The inner, nacreous layer is purple or has pale lavender to purple concentric bands on a white background.

The valves of the shell are closed by two large adductor muscles. Faint scars can be seen on the inside of the shell where these muscles were attached. When the valves are closed, the hinge ligament stretches; thus, when the adductor muscles relax or the clam dies, the shell gapes open.

To prevent slipping, the valves have interlocking teeth and sockets along the hinge line of the shell just below the ligament. There are two long, narrow lateral teeth on one side of the valve, one lateral tooth on the opposite side of the valve, and three small cardinal teeth in the center.

The shell is secreted by the mantle, thin sheets of tissue underlying the shell and enclosing the viscera. One mantle lobe is attached to the shell along the edges of each valve. At the posterior end of the clam, the mantles are fused together to form two muscular tubes called siphons. Just under each mantle lobe lies a pair of gill plates, or lamellae. The plates are lightly striated and lie over the rounded visceral mass. This mass, covered by a thin membrane, is the digestive tract, circulatory system, reproductive organs, and kidney. A pair of leaf-shaped labial palps are just anterior to the gills. Along the ventral edge of the visceral mass is the muscular foot (Gleason 1984).

Locomotion

The primary function of the foot is locomotion. *Corbicula* has two types of movement: burrowing and a horizontal "crawling." *Corbicula* burrows by opening the shell, then pushing the foot into the substrate. Fluid is forced into the tip of the foot causing it to swell and act as a small anchor. The muscles in the foot contract, the shell closes slightly, and the animal pulls itself toward the foot tip. These motions are repeated as the animal gradually buries itself. Usually a small portion of the posterior part of the shell remains uncovered and the siphons project into the water.

Alhough the foot is generally used to dig, very young clams use it to crawl over the substrate to find suitable habitat. A newly released juvenile settles to the bottom and extends its foot as far as possible from the shell. The "sole" of the foot produces a sticky mucus and eventually the tip adheres to the substrate. The foot muscles contract rapidly, the shell is pulled forward, and the process is repeated.

Once the small clam has found a suitable habitat, a small gland on the "heel" of the foot (i.e., opposite the tip), called the byssal gland, secretes a sticky substance that hardens on contact with water. This byssal secretion is formed into several threads that attach to the substrate and anchor the clam. The anchor, or byssus, is kept for 1 year. After that, the ability to produce a byssus is lost (Gleason 1984).

Respiration And Feeding

Corbicula are fairly hardy, tolerating several months without food and 7–27 days out of water (Cohen and Carlton 1995). *Corbicula* prefer somewhat turbulent water (Balcom 1994) because they draw both food (phytoplankton) and oxygen from the water around them. Water is pumped in through the inhalant siphon, filtered through the gills, and then ejected through the exhalant siphon. The gills serve several functions. It is there that food is strained from the water, and oxygen and carbon dioxide are exchanged (Gleason 1984). *Corbicula* requires high levels of dissolved oxygen (Balcom 1994).

Although the entire clam body is exposed to water and participates in respiration (especially the inner mantle surface), most respiration takes place in the gills. Water enters the inhalant chamber through the inhalant siphon and then flows through the ostia and into the tubes (the "corrugations") of the lamellae. The blood receives oxygen as water moves up the tubes.

Oxygen diffuses from the water through the tissue membranes and into the blood; carbon dioxide moves in the opposite direction. The water then flows into the suprabranchial chamber and exits from the clam via the exhalant siphon (Cohen and Carlton 1995).

Corbicula is primarily a filter feeder, straining out and eating microscopic food particles in the water. As water is drawn through the gill, plankton and other food particles are trapped in mucus on the outside of each gill plate. Mucus and food are moved down grooves in the lamellae and forward along a food groove on the outer edge of the inner lamellae. The labial palps sort the particles; food goes to the mouth and rejected particles are transferred back to the mantle. Here they are collected into a soft ball and eventually ejected through the inhalant siphon. The digestive tract consists of a mouth, esophagus, stomach, style and style sac, intestine, and rectum. The rectum opens into the exhalant siphon. Waste products are ejected along with water from the gills through the exhalant siphon (Cohen and Carlton 1995).

Corbicula appear to grow better with green algae, although alternative sources of food will support growth. The algae *Ankistrodesmus, Pedinomonas, Chlamydomonas, Chlorella, and Scenedesmu* appear to be superior food sources. *Selenastrum* is toxic because its filtrate inhibits *Corbicula* filtration (Foe 1985).

Foe (1985) also conducted experiments to ascertain the effect of suspended sediment and phytoplankton concentrations on the growth of *C. fluminea*. Clam tissue growth was found to be independent of silt concentration but increased with higher chlorophyll levels. Results demonstrated that *Corbicula* populations are food-limited most of the growing season in the northern and western portions of California's eutrophic Sacramento–San Joaquin Delta, where chlorophyll a levels average less than the lower of experimental values (Foe and Knight 1985). Other studies support the conclusion that food availability may be as important for recruitment as thermic regimes (Cataldo 1998, Mouthon 2001).

Hakenkamp (1999) compared *Corbicula*'s influence on the ecosystem by filtering dissolved organic carbon in the water column and by pedal-feeding on organic matter in the sandy streambed. It was found that *Corbicula* consumed significant quantities of organic material in the streambed when conditions favored pedal-feeding, but increased levels of buried organic matter stores when filter-feeding promoted deposition of organic matter (by production of feces and pseudofeces).

Reproduction and Early Development

Corbicula becomes sexually mature when about 1.3 cm long (0.5 in.), usually during its first year. It is a hermaphrodite; that is, each individual produces both eggs and sperm. Sperm are released through the exhalant siphon and enter other clams through their inhalant siphons. *Corbicula* may also be able to fertilize its own eggs (Gleason 1984).

Mature eggs are released from the gonads, fertilized in the suprabranchial chamber, and then held in the inner gill lamellae, which are specifically developed as brooding chambers. Here the embryos develop through two larval stages, the trochophore and the veliger. Although most freshwater mussel larvae are parasites in fish gills, *Corbicula* and other clam larvae are free-living and so do not need a fish host. *Corbicula* are released from the parent in an advanced larval stage called pediveligers. At this stage, the foot is already well developed. These larvae are primarily crawlers, not swimmers (Gleason 1984). Because the juveniles are weak swimmers, they usually remain near the bottom of the water column (Balcom 1994). They slowly sink to the bottom and then crawl along the substrate. When searching for a suitable habitat, they can move upstream or downstream.

There is a close relationship between water temperature and the release and development of eggs. Although spawning activity ceases when the water temperature drops too low, eggs and sperm remain in the reproductive tissues, signaling that the mollusks are ready to spawn as soon as the environment becomes favorable (Balcom 1994). Eggs are present all year long, but they only mature when water temperatures are about 16ºC (61°F) or warmer. Reproduction stops when temperatures exceed 24–28ºC (75–82ºF). As a result, *Corbilual* typically reproduce during spring and early summer; reproduction slows considerably in midsummer, and resumes for a short time in the fall. However, given the right temperatures, *Corbicula* may be able to reproduce throughout the year (Gleason 1984).

Corbicula are prolific. A single clam may produce as many as 8,000 young annually. During the peak of the reproductive season, an adult clam may carry several thousand embryos and larvae, in different developmental stages, in its gills.

A moderately sized population of 2,000 clams/m^2 (195 clams/ft^2) can produce 1–1.5 million larvae. Although mortality of the young is high, survival of only 0.1% will maintain the same population density. This high reproductive potential, combined with incubation of the developing young, hermaphrodism, nonparasitic larvae, and tolerance of a wide range of environmental conditions, have contributed to *Corbicula's* rapid colonization of California (Gleason 1984).

In the lower Sacramento–San Joaquin Delta the clam exhibits two predominant spawning periods per year. The first occurs in April and May, the second in July and August. Differences in larval production during the second period lead to significant annual differences in the size-specific reproductive output of individuals from each population. Data suggests that spring-spawned *Corbicula* grow larger faster than fall-spawned clams. All populations exhibited evidence of reproductive senescence in larger animals (Foe and Knight 1981)

Age and Growth

As mentioned, *Corbicula* in California release larvae twice yearly, and two size groups of clams are produced annually. Juveniles grow quickly at first. Spring-spawned juveniles may grow 15–18 mm (0.6–0.7 in.) by the following spring, whereas fall-spawned juveniles are likely to be 10–12 mm (0.4–0.5 in.) by spring. Shell length of 2-year-old clams averages 20–35 mm (0.8–1.4 in.). *Corbicula* rarely grow longer than 50 mm (2 in.) (Gleason 1984).

Although the clam's maximum lifespan is 7 years, it varies according to habitat; the average lifespan is 2 to 4 years (NBII 2004).

Habitat Preferences and Distribution in the Delta

Although present in lakes, ponds, and rivers, *Corbicula* is most often found in reservoirs, canals, domestic water systems, pumping and cooling systems, fire mains, and other water distribution systems. It appears to do better in artificial or disturbed situations than in areas unchanged by human activity. In the Delta–Mendota Canal of central California, densities may reach 10,000–20,000 clams/m^2 (900–1,850 clams/ft^2) (Gleason 1984).

The clam is a shallow burrower, sheltering in mud, sand, gravel, organic debris, or under rocks. When it cannot burrow, as in a cement-lined canal, it will lie on the surface. It can also live in closed pipes (Gleason 1984).

Corbicula lives in still as well as moving waters. Depth does not seem to be restrictive; the clam is found from intertidal areas to depths of over 12 m (39.4 ft) in lakes and reservoirs. In the latter situation, temperature and chemical limitations may control distribution (Gleason 1984).

Although it is considered a freshwater mollusk, the clam's physiology enables it to withstand brackish water with salinities up to 17% (sea water is about 34 %) (Gleason 1984). *Corbicula* survival rates vary in saline waters, depending on the degree of acclimation provided. At 4.5% salinity, the clam attains 50% sodium saturation in the tissues, a value considerably higher than that reported for most freshwater organisms (Evans et al. 1977). It does well in the intertidal areas of river deltas, where it is exposed to daily and seasonal changes in water depth and salinity.

Gleason (1984) states that *Corbicula* is highly resistant to drying out; its shells close so tightly that in cooler months when waters recede, it can survive several days completely exposed to the air. If buried in mud, it can survive up to 2 months (Gleason 1984). However, McMahon (1977) conducted experiments that showed that *Corbicula* is relatively intolerant of prolonged emergence compared to other freshwater bivalve species.

Corbicula can become used to temperatures from 2° to 32°C (36° to 90°F). Water temperatures greater than 30°C (86°F) impair the organism's metabolic and reproductive functions, whereas water temperatures of less than 2°F can kill the clam (Balcom 1994). Optimal clam growth occurs near 20°C, negative growth occurs above 29°C, and high tissue growth is maintained at temperatures as low as 16°C. Temperatures of 32°C will kill the clam (Foe 1985, Foe and Knight 1986).

Although *Corbicula* was introduced to the Delta in 1945, little is known about its distribution and less about its effect on the ecosystem. This is primarily because of the lack of ecological studies preceding its invasion (Canuel and Thompson 2003). No published results of *Corbicula* distribution in the Delta are available; however, research is currently being compiled, and results are anticipated in spring 2005 (Thompson pers. comm.). *Corbicula* biomass and density were examined at 156 stations throughout the Delta in May 2002. The stations were assigned to strata based on temperature, conductivity, habitat type, bathymetry, and current velocities. In the Sacramento River and its associated tributaries, relatively few *Corbicula* were found. The highest densities of *Corbicula* were found in the western reaches of the San Joaquin River, including the areas around Franks Tract and Mildred Island. Age distributions throughout most of the Delta were skewed toward small *Corbicula*. Large *Corbicula* (>10 mm) were found in Cash Slough, Georgiana Slough, Mokelumne River, Old River and its tributaries, Franks Tract and the nearby waterways, the waterways around Mildred Island, and in the San Joaquin River, near Suisun Bay (Parchaso and Thompson 2004). During a wet year when higher levels of fresh water coming from the Sacramento and San Joaquin rivers dilute saltwater coming from the San Francisco Bay, *Corbicula* can be found as far east as Grizzly Bay. During dryer years, increased salinity causes an increase in juvenile mortality in the brackish Delta waters, thus reducing densities of *Corbicula* in the western Delta (Thompson pers. comm.).

Effects of Introduction

The spread of *Corbicula* from one river drainage to another is usually caused by human activity (release of bait and aquarium clams, dredge and fill operations, and barge activity). Once spread, the establishment of populations is probable, as the clam is highly adaptable. Relatively high reproductive rates quickly make it the most common mollusk present (Gleason 1984).

Biofouling

Corbicula is a major contributor in the formation of extensive sediment beds in large canals and drains. After only 2–3 years of successful colonization in concrete-lined canals, the clams can cause deposits 2 or 3 feet deep, consisting of live clams, dead shells, silt, sand, mud, and a binding mucus secreted by the clams. These sediment beds reduce the carrying capacity of constructed waterways (Gleason 1984).

Competition

Competition with *Corbicula* has been cited as a cause of recent drastic declines in native mussel populations in Florida, Georgia, and Tennessee. , In California, direct competition with *Corbicula* may pose a similar threat to the survival of native benthic species (Gleason 1984). *Cobricula* also competes with non-benthic native species in other trophic levels of the food chain, like zooplankton and fish, by depleting supplies of phytoplankton.

Corbicula *as bioindicators*

Because clams are filter feeders, they can concentrate heavy metals and organic wastes. This allows *Corbicula* to be used successfully as a bioindicator. For example, copper (Cu) is an ingredient in the herbicide Komeen, which is being tested for *Egeria densa* eradication in the Delta. USGS has used *Corbicula* to evaluate accumulation of Cu in the Delta ecosystem and its affects on nontarget species. Copper in Komeen appeared to be bioavailable to *Corbicula*, accumulating to high concentrations in clams near herbicide trials, including trials at Franks

Tract. The Cu persisted in clam tissues either because of slow loss rates or environmental recycling (Brown and Luoma 2004). Birds and fish that consume *Corbicula* in and around Franks Tract and other Komeen application areas could be exposed to high concentrations of Cu through biomagnification, thus having the potential to affect higher trophic levels of the food web.

A series of control and transplant studies were conducted using *Corbicula* to determine the temporal and spatial pattern of methyl mercury uptake in the pelagic food web of the estuary and the primary factors controlling it. Site-specific changes in methyl mercury tissue concentration were determined primarily by changes in methyl mercury quantities. Results from the clam transplant study were used to develop a conceptual model of methyl mercury accumulation in primary consumers in the Delta (Foe et al. 2004) (Foe et al. 2002).

Corbicula are also being tested for use as natural monitors of levels of algal growth and dissolved oxygen (DO) (both very important to water quality) in the San Joaquin River system (Bemis and Kendall 2004). See section 4.4 for further discussion on water quality in the Delta.

Corbicula *in the Bay–Delta food web*

Phytoplankton biomass has been declining throughout much of the Sacramento–San Joaquin Delta and northern San Francisco bay in the last two decades. Grazing losses by the bivalve *Potamocorbula amurensis* (see above) are one cause of the declines in phytoplankton biomass in the northern bay. *Corbicula* could be exerting similar controls on phytoplankton in the Delta (Parchaso and Thompson 2004). *Corbicula* have substantially reduced phytoplankton biomass in other systems (McMahon 1999, in Lucas et al 2002). Preliminary conclusions from research currently being conducted (discussed above) suggest that *Corbicula* are capable of locally controlling phytoplankton biomass in waterways where adult *Corbicula* are present, but populations in other portions of the Delta are not mature enough to exert similar control. Although it is unknown why *Corbicula* do not appear to grow to adult sizes in large areas of the Delta, Foe (1985) suggested that they were food-limited throughout much of this system. If true, expectations are that any increase in phytoplankton in portions of the system where large populations of immature *Corbicula* were observed may result in larger bivalves and potentially in populations that can reduce the phytoplankton biomass (Parchaso and Thompson 2004).

Because grazing by *Corbicula* appears to significantly reduce phytoplankton biomass in some flooded islands (such as Franks Tract), and because phytoplankton biomass in flooded islands with large populations of *Corbicula* is within the range known to be food limiting for some zooplankton, "over-grazing" by *Corbicula* has the potential to limit the viability of some habitats as sources of high-quality food for zooplankton, and ultimately for fish and species in higher trophic levels. Therefore, there are trophic implications of creating habitat that is suitable for *Corbicula* in combination with restoration in the Delta. Although the interior of some flooded islands, such as Mildred's Island, may be nearly devoid of *Corbicula*, the surrounding channels may have areas with very large *Corbicula* populations. However, the high grazing rates in these channels will not necessarily decrease the phytoplankton biomass if the water-depth-to-grazing rate ratio is large (i.e., if the phytoplankton growth rate is high relative to the vertical mixing rate, biomass will not be limited by bivalve grazing). Other flooded islands, such as Franks Tract, show the opposite distribution pattern, with large populations residing in the interior of the lake and in general, smaller populations living in the surrounding channels and rivers. Because *Corbicula* is believed to be food-limited in the Delta, the low biomass of phytoplankton available to filter-feeders in channels such as those surrounding Franks Tract appear to restrict bivalve growth and thus population size (Thompson et al. 2004).

In the Delta, the water column can become temperature stratified in areas with less current action (turbulence). This results in a warm top layer where plankton are produced, and a cooler bottom layer where the clams filter. Therefore, the key to phytoplankton production is residence time; a longer residence time with less mixing of the water column results in more phytoplankton growth and less phytoplankton consumption by clams (Burau,pers. comm., 2004). See Section 4.6 for further discussion of the Delta food web.

Control

Corbicula has become a serious pest in North America; few natural predators or disease organisms control its numbers, a typical situation when exotic animals are introduced in an area where no close relatives are present. Efforts to control the clam have had mixed results (Gleason 1984). Factors that may affect population density and distribution include excessively high or low temperatures, salinity, drying, low pH, silt, hypoxia, pollution, bacterial, viral and parasitic infections, inter- and intraspecific competition, predators, and genetic changes (Foster et al 1999).

Corbicula is tolerant of some toxic chemicals and low oxygen, as its presence in sewage outfall structures proves. Like many freshwater clams, *Corbicula* is relatively intolerant of potassium. When exposed to potassium concentrations above 25 ppm, the foot swells, extends to the exterior, and does not draw back into the shell when touched. The condition is reversible, but prolonged exposure to potassium can be fatal (Gleason 1984). Chlorine is often used for control of clams in closed water systems. One ppm chlorine for 2-weeks can be an effective control agent in closed systems (Gleason 1984). Chlorine and copper sulfate treatments have been unsuccessful in natural systems in most cases because of dilution factors and limitations on the use of these chemicals (Gleason 1984).

Corbicula is eaten by several species of fish, raccoons, rats, skunks, foxes, herons, coots, and most diving ducks, but only incidentally to their principal foods. Blue catfish were introduced in some California waters to help control clam numbers, but as clams are only a minor portion of their diet, control of *Corbicula* was not successful (Gleason 1984).

McMahon (1977) suggests that because *Corbicula* is relatively intolerant of prolonged emergence and usually restricted to shallow, near-shore habitats in lentic environments, periodic reservoir draw-downs and subsequent exposure of resident populations to air could be one means of controlling clam densities.

Large-scale commercial harvest of clams has also been proposed to control *Corbicula* populations. Clams can be used for fish bait, biofilters or bioindicators, or in agriculture for poultry and animal feed (clams are high in calcium and protein). The major drawback in commercial enterprises is the inability to obtain sufficient and constant supplies to maintain a market. In spite of this problem, *Corbicula* supports a moderate bait industry and a small but growing market for human consumption. However, an effective control of the clam that is neither polluting nor too expensive has not been found (Gleason 1984).

FRANKS TRACT

Because Franks Tract represents a large portion of Delta water volume (Monsen 2001, in Lucas et al 2002) ecosystem processes in this subenvironment may have Delta-scale effects. Franks Tract, with its large open water area, is unique in the Delta for its potential to create a large amount of carbon. Little Franks Tract currently provides for high carbon production; it is a phytoplankton incubator. Its geometry and orientation result in less mixing of the water column from tides and wind fetch, thus allowing for more phytoplankton production. However, in the larger section of Franks Tract, this potential is decreased by wind fetch. Franks Tract is a large carbon sink, particularly in the southwest corner, where it is densely populated by *Corbicula* (Burau pers. comm.). *Corbicula* consume a large carbon source, phytoplankton. The presence of the clams corresponds with Franks Tract's water jets. (The increased water movement increases the amount of food that reaches the clams at the bottom of the water column.) It is thought that carbon flows from the west toward the east through the nozzle. The clams can filter through the entire water column. The key to more phytoplankton production in Franks Tract is to create a longer residence time, therefore decreasing consumption by *Corbicula* (Burau pers. comm., 2004).

Corbicula is abundant throughout Franks Tract, where calculated grazing rates correspond to between 60 to 2,100 *Corbicula* per square meter. The calculated abundance of *Corbicula* reported for Franks Tract is representative of its abundance in this subenvironment, as shown by summer abundances measured by the California Department of Water Resources at one station in Franks Tract from 1977 to 1995 (DWR, in Lucas et al 2002). Calculations show *Corbicula* in Franks Tract consuming a net 2,300 kg of carbon per day (respiration and benthic grazing losses exceeded photosynthesis) (Lucas et al. 2002), demonstrating that Franks Tract is a carbon sink (Exhibit 4.6-2).

Dispersive transport coupled with spatially variable biological processes could have important general implications. Given the vigorous tidal interaction between Franks Tract and adjacent channels, the influence of the local benthic sink probably extends beyond Franks Tract; because conservative riverine particles may slosh into Franks Tract and ultimately slosh out, phytoplankton cells may be permanently removed from the water column by *Corbicula* in the lake and thus prevented from out-sloshing (the "Roach Motel Syndrome") (Lucas et al. 2002). See Section 4.6 for further discussion on phytoplankton and food webs in Franks Tract.

Lower Sherman Island

Lower Sherman Island has the most saltwater influence of the three flooded islands. In addition, the tides turn an hour earlier on the Sacramento River side of the island than on the San Joaquin River side. This creates much mixing and water flow through Lower Sherman Island (thus reducing phytoplankton production) (Burau, pers. comm., 2004). The salinity and hydrology of Lower Sherman Island might decrease the island's habitat suitability for *Corbicula*.

Big Break

No information on *Corbicula* specific to Big Break was found.

4.9 LAND USE

This section includes a discussion of the agencies with planning responsibility for the flooded islands and the region, a general description of the existing uses in the region, and a specific description of the existing uses on the flooded islands and adjacent areas. This section also includes descriptions of the agricultural land uses in the nearby areas, as well as designated energy resource areas.

4.9.1 PLANNING AND AGENCY JURISDICTION

GENERAL DESCRIPTION:

For regulatory purposes, the region within which the flooded islands are located is the "Legal Delta" as defined in Section 12220 of the Water Code. The Legal Delta covers approximately 738,239 acres. For the purposes of the Baseline Report, the Legal Delta is synonymous with "the Delta."

State planning law (California Government Code Section 65300 et seq.) establishes the obligation of cities and counties to adopt and implement general plans for areas not owned by the State or the federal government. The general plan is a comprehensive, long-term plan that designates land uses and defines planning policies for the territory of the City or County. The general plan addresses a broad range of topics, including, at a minimum, land use, circulation, housing, conservation, open space, noise, and safety. In addressing these topics, the general plan identifies the goals, objectives, policies, principles, standards, and planned land uses that support the City's or County's vision for the area. The general plan is a long-range document that typically addresses the character of the plan area over a 20-year period. Although the general plan serves as a blueprint for future development and identifies the overall vision for the planning area, it remains general enough to allow for flexibility in the approach taken to achieve the plan's goals.

State agencies managing property owned by the State have various approaches for land use plans and policies. The laws governing each of the State agencies define the scope and requirements for land use planning. For example, State Parks prepares and adapts General Plans for its lands, in accordance with Public Resource Code Section 5000 et seq. Furthermore, the actions being evaluated in the Feasibility Study would be under the jurisdiction of DWR. State agencies are exempt (as established by Hall vs. City of Taft (1952) 47 Cal.2d177.) from complying with local or county plans, policies, or zoning regulations. Nevertheless, state agencies must comply with State laws and regulations, including CEQA, and, in so doing, minimize environmental effects, such as conflicts with nearby land uses. For this reason, DWR considers local land use policies and regulations when making land use planning decisions.

PLANNING RESPONSIBILITIES OF STATE AND LOCAL AGENCIES IN THE DELTA

Each of the state and local agencies that have planning responsibilities over the Delta are described below.

State Lands Commission

The State Lands Commission (SLC) has jurisdiction over submerged lands of the state. Because many parts of the Delta, including the flooded islands, were previously above-water areas that have become flooded for the foreseeable future, the jurisdictional boundary of SLC over many parts of the Delta are unclear. SLC may own submerged lands and require approval of a lease for their use. Also, SLC protects public trust values of submerged lands. The public trust easement is for water-borne commerce, navigation, fisheries, recreation, and open space. Protection of these public trust values may be required for areas that are subject to the State's sovereign interest. These easements would be held by SLC's, and they must be considered when uses of submerged land, including installation of new levees or the alternation of the waters, are proposed. (EBRPD 2001). SLC does not have a comprehensive use plan for the submerged lands, but manages them according State laws and regulations.

Delta Protection Commission

The passage of the Delta Protection Act of 1992 (California Water Code §12220) established the Delta Protection Commission (DPC). The DPC has land use planning jurisdiction over the Primary Zone, which generally consists of the central portion of the Delta, as shown in Exhibit 1-2. The Primary Zone, which comprises 487,625 acres or approximately 66 percent of the Delta, encompasses portions of five counties: Solano, Yolo, Sacramento, San Joaquin, and Contra Costa. The Secondary Zone, over which the DPC does not have land use jurisdiction, includes portions of these five counties, as well as portions of several incorporated cities (e.g., City of Oakley) and unincorporated communities (e.g., Bethel Island).

The DPC is charged with preparation of a regional plan for the Primary Zone. The purpose of this regional plan is to address land uses and resource management for the Legal Delta, with particular emphasis on agriculture, wildlife habitat and recreation. The Delta Protection Act defines the primary use of this zone to be agriculture. Recreational uses, wildlife habitat, and nature preserves can also be approved uses within the Primary Zone.

DPC adopted its Land Use and Resource Management Plan for the Primary Zone of the Delta (Delta Plan) on February 23, 1995. In 2000, the policies within the Delta Plan were adopted as regulations (California Code of Regulations, Title 14, Chapter 3. Regulations Governing Land Use and Resources Management in the Delta). The Delta Plan was revised and reprinted in May 2002 (DPC 2004).

The Delta Plan has been forwarded to the five counties covering the Primary Zone for incorporation into their General Plans and Zoning codes, as described below. Through this incorporation process, the counties implement the Delta Plan. In addition, local government actions may be appealed to the DPC. If any person believes a local government has taken an action, or approved a project, which is not in conformance with the Delta Protection Act or the Delta Plan, that local government action can be appealed to the DPC. The appeal "suspends" the local approval, allowing the DPC the opportunity to review the action. If DPC finds the local government action to be in conformance with the Delta Protection Act and the Delta Plan, it can go forward. If the DPC finds lack of conformity, the DPC can forward its findings to the local government for further review.

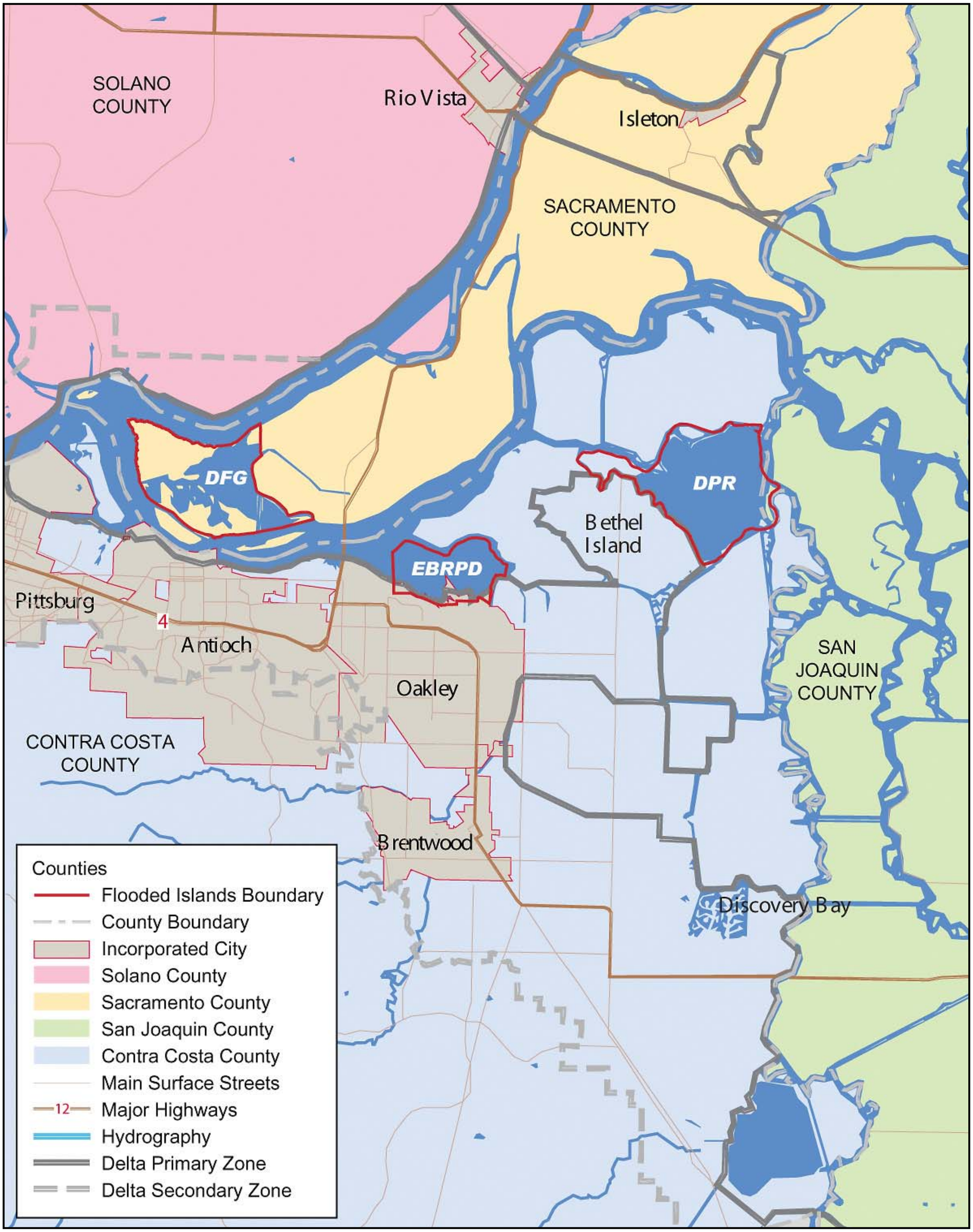
Department of Parks and Recreation

Most of Franks Tract is owned and managed by State Parks as a State Recreation Area (SRA), as shown in Exhibit 4.9-1. According to Public Resources Code Section 5019.56, the SRA classification denotes an area selected, developed, and operated to provide outdoor recreation opportunities to meet other than purely local needs. Improvements to provide for urban or indoor formalized recreational activities shall not be undertaken within SRAs. The declaration of purpose for Franks Tract SRA, approved by the State Park and Recreation Commission in 1996, is as follows:

> The purpose of the Franks Tract State Recreation Area is to perpetuate, as a recreation resource, the flooded island in the Sacramento-San Joaquin Delta known as "Franks Tract", and to provide permanently the opportunity for water-related recreational activities so that the recreational, scenic, historic, scientific, and natural values of "Franks Tract" and related portions of the Delta may be enjoyed by the people.
>
> The function of the Department of Parks and Recreation at Franks Tract State Recreation Area is to provide facilities and services for public enjoyment of the features and recreational opportunities afforded by this unit, in accordance with its declared purpose, and to protect and enhance the area's recreational and natural values as a part of the Park System program for public recreation in the Sacramento-San Joaquin Delta.

Guidance on land use is provided by the objectives and policies in the *General Plan for Brannan Island and Franks Tract State Recreation Areas* (CDR, UCD & EDAW, 1988). For example, one of the policies in the SRA General Plan promotes "creating landforms by depositing sand and peat to form new ecosystems within [Franks Tract SRA]." The Land Use and Facilities Goals and Recommendations are listed in the Land Use and Facilities Element of the SRA General Plan.

Several factors were considered in developing the land use map for Franks Tract SRA. A primary factor is allowable land use intensity, which establishes the limits of development and use an area can sustain without an unacceptable degree of deterioration in the character and value of the scenic, natural, and cultural resources; determination area based on analysis and integration of resource management objectives as described in the SRA General Plan, resource constraints, and resource sensitivities. Other factors considered include classification and



Source: Source: State of California Teale Data Center – GIS 1990 and Delta Protection Commission 1995

City, County, and Legal Delta Boundaries

EXHIBIT 4.9-1

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purpose, described above, recreation needs, design considerations, and social carrying capacity. The Land Use Intensity map includes four allowable land use intensity categories: Open Water, Low, Low (New Land Areas), and Moderate (New Land Use Areas). Most of Big Franks Tract is designated Open Water, with the remaining showing as existing or new islands with Low or Moderate land use intensity. Little Franks Tract is shown as Low land use intensity. Because this map was created in compliance with the Public Resource Code §5001.96, which calls for the definition of carrying capacity, future projects that deviate from this map may require the approval of a SRA General Plan amendment to this map.

The SRA General Plan also includes a Land Use and Facilities map, which is a diagram of recommended locations for a series of created islands. The SRA General Plan states that this diagram is for planning purposes only and should not be used to determine the consistency of future projects with the SRA General Plan. This map shows a series of islands with riparian woodland, some with attached sandy beach areas and wetland marsh areas. Many of the islands include boat-in camping areas. The map also delineates an area for hunting, as well as an interpretive trail.

Department of Fish and Game

Lower Sherman Island and Lake are owned and operated by the Department of Fish and Game (DFG). DFG currently does not have a Land Management Plan developed for Lower Sherman Lake, but is in the process of developing one, with an expected completion date in 2006. Currently, Lower Sherman Island Wildlife Area is unimproved. Management of this unit is conducted based on compliance with the Public Resource Code, but is without unit-specific goals, policies, and objectives.

Sacramento County

The Lower Sherman Lake study area is located in Sacramento County. The Sacramento County General Plan was most recently adopted in 1993. The Sacramento County General Plan Land Use Diagram identifies Sherman Island and Lower Sherman Lake with the Recreation designation and Lower Sherman Island with the Natural Preserve designation. The Recreation designation provides areas for active public recreational uses. The purpose of the Natural Preserve designation is to identify critical natural habitat for priority resource protection. The designation includes riparian valley oak woodland and permanent or seasonal marshes with outstanding wildlife value, the extent of which has declined greatly throughout the Central Valley during the 20th Century. This designation includes both public and privately owned land (Sacramento County. 1993). It is noted that Lower Sherman Island is owned and managed by DFG and is thus not subject to land use planning by Sacramento County. Nonetheless, these designations indicate that Lower Sherman Island would remain used for primarily resource protection and resource- and water-oriented recreation.

Contra Costa County

The majority of Franks Tract and all of the Big Break study areas are located in Contra Costa County. The Contra Costa County General Plan was adopted in July 1996. Franks Tract is designated Water (WA), Open Space (OS), Parks and Recreation (PR). It is noted that Franks Tract is owned and managed by DPR and is thus not subject to land use planning by Contra Costa County. Big Break is designated WA, PR, OS, and Delta Recreation and Resources (DR) (Contra Costa County 1996). Big Break is owned by East Bay Regional Park District (EBRPD), a local agency, and is under the land use planning jurisdiction of Contra Costa County. Portions of Big Break, namely the Lauritzen site, that are within the boundaries of Oakley are within the land use jurisdiction of that city rather than Contra Costa County.

Allowable uses in the WA designation include transport facilities associated with ports and wharves and water-oriented recreation uses; residential and commercial uses are inconsistent with the designation. Allowable uses in the PR designation include passive and active recreation-oriented activities and ancillary commercial uses such as snack bars and restaurants; new residential and commercial uses are inconsistent with the designation. The OS designation is applied to unbuildable landed deeded to EBRPD and other publicly or privately owned open space. Allowable uses in the OS-designated areas include resource management, local recreation uses; aside from one residence on existing lots, new residential uses are inconsistent with the OS designation. The DR designation is applied to areas prone to flooding and/or contain valuable wildlife habitat. Allowable uses in the DR-designated areas include agricultural production and processing; water- and resource-based recreation and residential uses may be allowed (Contra Costa County 1996).

Other land use designations for areas near Franks Tract include OS on nearby small islands; Commercial Recreation (CR), Mobile Home (MO), Single Family Residential-High (SH), and Single Family Residential-Low (SL) near the shores of Bethel Island; Commercial Marina designation along the shoreline of Bethel Island; and DR on Webb Tract to the north and on Holland Tract to the south(Contra Costa County 1996). These designations indicate that future uses adjacent to Franks Tract will remain primarily resource protection and resource- and water-oriented recreation, with some residential uses.

Areas near Big Break are designated Public/Semi-Public (PS) on Jersey Island to the north and east, WA to the northwest on San Joaquin River, and DR to the southwest. These designations indicate that the areas within Contra Costa County surrounding Big Break would remain primarily in agricultural, resource protection, and resource- and water-oriented recreation, with the exception of Jersey Island, which may be converted to a sanitary waste disposal area by the Ironhouse Sanitary District (EBRPD 2001).

The unincorporated community of Bethel Island, which is located adjacent to Franks Tract, is under the land use jurisdiction of Contra Costa County. The Contra Costa General Plan contains several policies specific to Bethel Island, such as policies on residential density. New residential and commercial uses on Bethel Islands are allowable and are expected, but they would not occur along the shoreline adjacent to Franks Tract.

City of Oakley

A small portion of Big Break is located within the incorporated limits of the City of Oakley, most of which is immediately to the south of Big Break. This small portion of Big Break is designated for Delta Recreation (DR) and Public and Semi-Public (PS), according to the City of Oakley's 2020 General Plan (City Of Oakley, 2002).

The Delta Recreation designation denotes areas that are subject to periodic flooding. The Oakley General Plan considers this area to have substantial recreational value and is important for public access to the Oakley waterfront, including parklands and trails offering public access. Agriculture and wildlife habitat are also considered appropriate uses of these areas. Additional uses that may, at the City's discretion, be allowed within this designation include but are not limited to marinas, shooting ranges, duck and other hunting clubs, campgrounds, golf courses and other outdoor recreation complexes. Conditional uses allowed in the Delta Recreation land use designation shall be limited to those low- to medium-intensity establishments that do not rely on urban levels of service or infrastructure, and that will not draw large concentrations of people to flood-prone areas (City Of Oakley, 2002).

A wide variety of public and private uses are allowed in areas designated Public and Semi-Public; however, construction of private commercial uses will be limited to uses related to the public or semi-public activity, and residential subdivision is not allowed (City Of Oakley, 2002).

Areas within the City of Oakley's boundaries near Big Break are designated Commercial and Delta Recreation to the southwest; Single Family-High, Delta Recreation, and Public and Semi-Public to the south; and Delta Recreation to the southeast. Where the designation allows for development (i.e., Commercial, Single-Family-High), there are existing developed uses. However, redevelopment of the area designated for Commercial is a possibility, allowing for higher use intensity adjacent to Big Break (City Of Oakley, 2002).

San Joaquin County

A small portion of Franks Tract is located in San Joaquin County. San Joaquin County prepared a review and revision of the County General Plan in 2000. This General Plan 2010 Review includes maps of existing and expected future urban growth areas through the year 2020. The small portion of Franks Tract located in San Joaquin County is designated General Agriculture (A/G). This designation denotes areas generally committed to agriculture with viable commercial agricultural enterprises that require large land areas to efficiently produce their crops. It is noted that Franks Tract is owned and managed by DPR and is thus not subject to land use planning by San Joaquin County. However, the areas in San Joaquin County near Franks Tract are all designated A/G and are within San Joaquin County's land use jurisdiction. Typical uses in A/G-designated areas are crop production, feed and grain storage and sales, aerial crop spraying, and animal raising and sales. Additional activities in this district include resource recovery, dairy and canning operations, stockyards, and animal feedlots. Other types of land uses are presumed to be incompatible for reasons that include adverse environmental effects on agriculture (County of San Joaquin 1992).

Solano County

None of the study areas are located in Solano County; however, the area to the north of Lower Sherman Lake across the Sacramento River is located in Solano County. The land use plan for this area is the Collinsville-Montezuma Hills Area Plan and Program (1979), an element of the Solano County General Plan. This area is designated for Water-Dependent Industrial use (5-30% Slope), which denotes waterfront areas along the Sacramento River within feasible distance from the existing ship channel for future provision of channel access. This designation is reserved for water-dependent industrial uses with processes that can be sustained by ship-to-shore transfer of materials by pipeline or conveyor and the facilities of which can be accommodated on a terrace or series of terraces. Acceptable uses may include waterfront storage facilities, waterfront manufacturing or processing facilities, water-using facilities (e.g., power plants, desalination plants), and associated support uses.

FRANKS TRACT

As stated above, most of the Franks Tract project site is owned and managed by State Parks. San Joaquin County and Contra Costa County also have land use plans for the study area.

LOWER SHERMAN LAKE

Lower Sherman Lake is owned and managed by DFG, Sacramento County, and SLC.

BIG BREAK

Most of Big Break is owned by EBRPD, a local agency without land use planning jurisdiction. Most of the project site is classified by EBRPD as Big Break Regional Shoreline. The *Big Break Regional Shoreline Land Use Plan* was completed in 2001 (EBRPD 2001). The Shoreline Land Use Plan designates two recreational areas on the Lauritzen site that would contain developed facilities such as picnic tables, piers, parking areas, and boat ramps.

Agencies with land use planning jurisdiction include State Lands Commission, City of Oakley, and Contra Costa County. See above for land use designation for the Big Break project site.

4.9.2 REGIONAL, ADJACENT, AND PROJECT SITE LAND USES

GENERAL DESCRIPTION

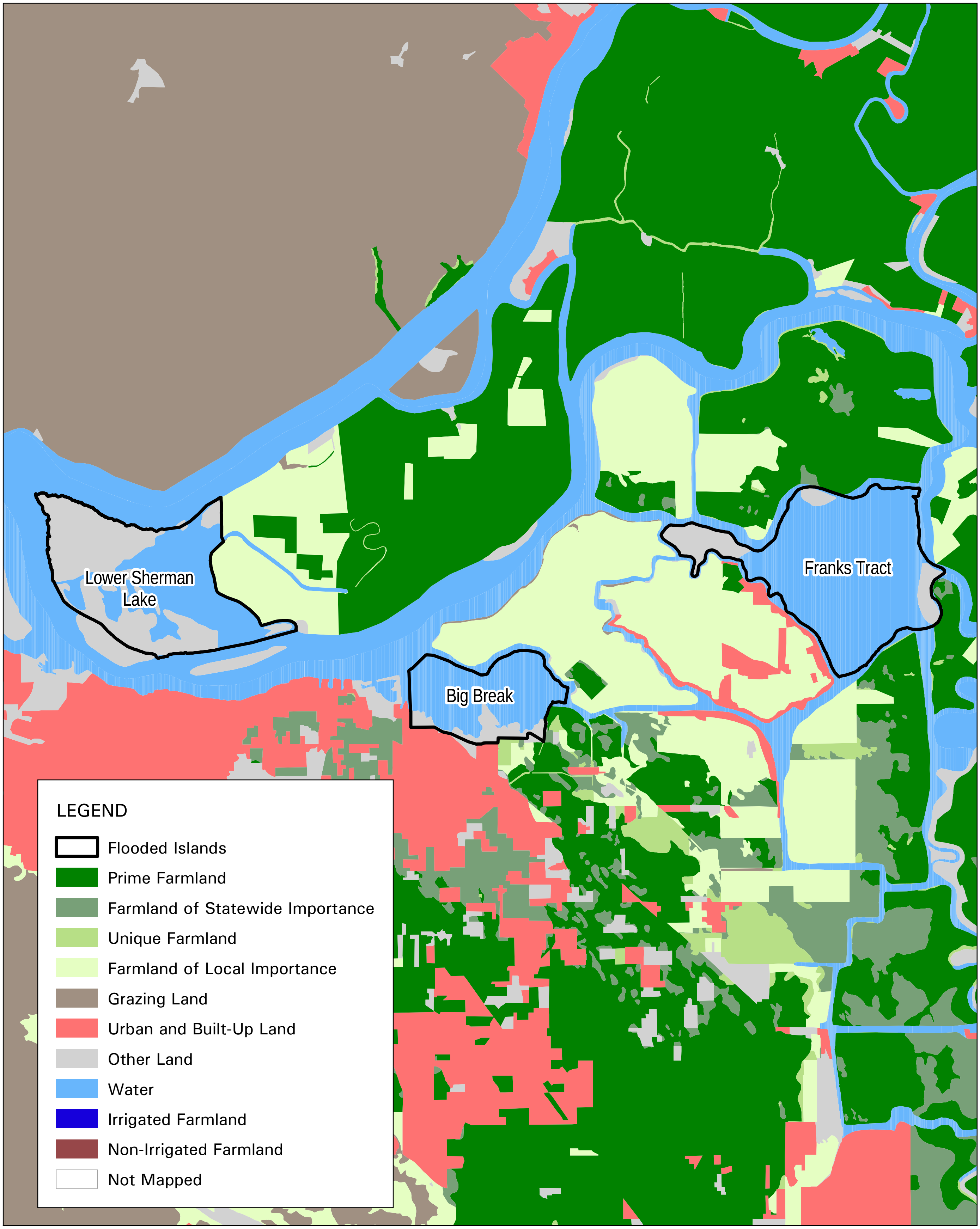
Most of the Delta is used for recreation and agriculture; see Section 4.11 for description of the recreation uses. Delta farming both past and present includes a variety of smaller specialized farms and larger general crop production operations. Early specialization crops included wheat and barley, followed by beans and potatoes. Most Delta farmers specialize in only a few crops grown under a rotation system. Wheat, barley, potatoes, onions, and beans have been grown and sold successively in the Delta region since the 1860s. Bartlett pears, nut trees, asparagus, tomatoes, and rice are among the more valuable crops from this region. Pasture land and dairy farming are also important components of Delta agricultural land use. The five counties with land inside the Delta; Sacramento, San Joaquin, Solano, Yolo, and Contra Costa, account for over $2 billion of California's $27 billion in total agricultural production.

California Department of Conservation's (CDC's) Important Farmland Inventory System classifies agricultural land in the categories shown below:

- Prime Farmland - Land that has the best combination of features for the production of agricultural crops
- Farmland of Statewide Importance - Land other than Prime Farmland that has a good combination of physical and chemical features for the production of agricultural crops
- Unique Farmland - Land of lesser quality soils used for the production of the state's leading agricultural cash crops
- Farmland of Local Importance - Land that is of importance to the local agricultural economy
- Grazing Land - Existing vegetation that is suitable to grazing
- Urban and Built-up Lands - Occupied by structures in density of at least one dwelling unit per 1.5 acres
- Land Committed to Nonagriculture Use - Vacant areas; existing lands that have a permanent commitment to development but have an existing land use of agriculture or grazing lands
- Other Lands - Does not meet criteria of remaining categories (CDC 2001)

Farmland, Farmland of Statewide Importance, Unique Farmland, and Farmland of Local Importance are often described together under the term "Important Farmland." As shown in Exhibit 4.9-2, most of the land areas near the project sites are classified as Important Farmland. The major exceptions are the shoreline of Bethel Island, next to Franks Tract, and City of Oakley, just south of Big Break.

Most of the farmland around the project site is under California Land Conservation Act (Williamson Act) protection. The Williamson Act, administered by the CDC, was enacted to voluntarily restrict development on property in exchange for lower tax assessments. Lands under the Williamson Act contracts are limited under subdivision to minimum 10-acre parcels, and they are required to incorporate a 200-foot setback from incompatible adjacent uses (CDC 2001). The State of California passed Article 13 that allows Williamson Act contracts to be entered into for recreational, scenic, and natural resource areas in addition to crop production. Contracts are entered for a ten-year period and can only be exited by cancellation or non-renewal. Cancellation involves an extensive review and approval process, in addition to a payment of fees of up to 12.5 % of the property value. A non-renewal would allow for tax rates



Source: FMMP 2002

Important Farmlands

EXHIBIT 4.9-2

Flooded Islands Feasibility Study Report

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to gradually increase over the remainder of the contract, in order to reach the original rate by the end of the term (CDC 2001).

The project sites are also surrounded by delta channels, flood control infrastructure, agricultural uses and wildlife habitat.

FRANKS TRACT

Franks Tract consists of two connected open water areas surrounded by water ways and islands based on remnant levees. Existing uses are water navigation, recreation and natural resource conservation. No other land uses exist, although the site was considered for natural gas extraction.

Franks Tract is surrounded by Bethel Island, Holland Tract, and Quimby Island to the south; Mandeville Island to the east; Webb Tract to the north; and Bradford Island and Jersey Island to the west. Bethel Island is used for agriculture, recreation (e.g., marina, resort, camping), and, to an increasing extent, urban development. Most of the uses on other surrounding islands consist of agriculture.

LOWER SHERMAN LAKE

The project site consists of three main parts: Lower Sherman Lake, Donlon Island, and Lower Sherman Island. Donlon Island is located between Sherman Island and Lower Sherman Island and is to the south of Lower Sherman Lake.

Lower Sherman Lake consists of an open water area that also separates Sherman Island from Lower Sherman Island. Lower Sherman Lake is connected to both the Sacramento and San Joaquin Rivers, and provides a major hydrological linkage between the two rivers just before their confluence. The existing uses are water navigation, recreation, and resource protection.

Lower Sherman Island is an above-water area interspersed with waterways; it is located at the confluence of the Sacramento and San Joaquin Rivers. Lower Sherman Island is an open space area that is used primary for wildlife management and hunting. There is a boat ramp on the northeast corner of Lower Sherman Island, and a developed area in the southeast corner near the tip of nearby Kimball Island.

Donlon Island is an open space area, most of which is submerged and the remaining areas dominated by marsh vegetation. Donlon Island was flooded in 1937 but portion of it has since been filled with dredged materials. Uses on Donlon Island are water navigation, recreation, and resource protection.

To the east of Lower Sherman Lake is Sherman Island, to the south and west is San Joaquin River and Kimball Island, and to the north is Sacramento River. Sherman Island is owned by DWR and is primarily under agricultural use with scattered residential and boat docking facilities. Farther north is agricultural land in Solano County. This area is designated for water-dependent industrial uses, but has not been developed for such use. Most surrounding areas are currently used for recreation, resource protection, and agriculture.

BIG BREAK

Most of Big Break project site consists of shallow open water areas; the remaining areas include islands, marshland along the shoreline and islands, and an upland area along the shoreline. There are no developed facilities on the Big Break project site, with the exceptions of a roadway on the 40-acre Lauritzen site and on the Ironhouse Sanitary District property. Big Break is approximately 2.5 miles long and 1-mile wide.

Big Break is generally contiguous with the 1,648-acre Big Break Regional Shoreline, with the major exception of the inclusion of portions of Ironhouse Sanitary District property and Vintage Marsh in the project site. Big Break Regional Shoreline is currently not open to the public, aside from the open water area that is available for boating by right of public domain. The Big Break project site is used for fishing and hunting, water navigation, and resource protection, and includes one residential dwelling.

The Big Break Regional Shoreline is surrounded by a variety of land uses. To the north, it adjoins the San Joaquin River, Dutch Slough and Jersey Island. Jersey Island is currently an open space area but may be converted into a sanitary waste disposal site. To the west is privately held land; the adjacent parcel is owned by Foundation Constructors Inc., next to which is the DuPont property. The DuPont property contains the Big Break Marina and was the former DuPont plant site. Along the DuPont property is marshland, including Little Break (EBRPD 2001).

To the south of Big Break Regional Shoreline, from west to east, is the Vintage Parkway neighborhood, portions of the Vintage Marsh, and the Ironhouse Sanitary District property that contains administrative offices, sewage treatment ponds, irrigated, grazed fields, and the Big Break Regional Trail. Ironhouse Sanitary District processes all of its effluent and does not discharge surface water into Big Break. On the east side of Big Break Regional Shoreline is Marsh Creek that drains a 100-square-mile watershed. Marsh Creek is channelized and is maintained by Contra Costa County Flood Control and Water Conservation District. Marsh Creek was historically a steelhead reproduction area. To the east of Marsh Creek are undeveloped lands owned by Emerson Dairy (EBRPD 2001).

4.9.3 MINERAL AND ENERGY

GENERAL DESCRIPTION

The Delta is located in an area with considerable natural gas resources. The Delta contains natural gas drilling sites, gas fields, wells, storage fields, and distribution pipelines. To protect valuable mineral resources, the California Surface Mining and Reclamation Act was enacted in 1975 by the State Legislature to regulate activities related to mineral resource extraction. This act encourages both the conservation and production of extractive mineral resources, requiring the State Geologist to identify the state's varied extractive resource deposits. CDC identifies significant mineral deposits, such as aggregates, in the Delta.

Franks Tract

There are no identified mineral deposits in Franks Tract (Contra Costa County 1996). The Franks Tract project site is not located in a gas field with the exception of a portion of Little Franks Tract that is within the Dutch Slough gas field. There are several completed gas wells, plugged and abandoned gas and oil wells, as well a plugged and abandoned dry holes, in and near Franks Tract (CDC date unknown). While Franks Tract SRA is owned by DPR, the mineral and surface rights of many parcels in it are held by various owners. Several of these parcels are drilling site reservations. While most of these drilling site reservations occur on the levee remnants surrounding Big Franks Tract, two are located in the middle of the unit (CDR and EDAW 1988). Texaco at one time had wanted to conduct test drilling for natural gas underneath Franks Tract. Texaco applied for encroachment permits in 1998 and 1999 but did not obtain them due, allegedly, to DFG interference. There are high pressure natural gas lines owned by Tri-Cities in the western end of Franks Tract (Galloway 2004).

Lower Sherman Lake

There are no identified mineral deposits in Lower Sherman Lake (Sacramento County 1993). There are also no identified gas fields in Lower Sherman Lake. There are four "plugged and abandoned dry holes near the Lower Sherman Lake project site: three on Sherman Island and one in San Joaquin River near Lower Sherman Island (CDC 2003).

Big Break

No mineral and energy exploration activities are known at Big Break. There are no identified mineral deposits in Franks Tract (Contra Costa County 1996). The southern portion of Big Break is located within the River Break Gas Field. There are plugged and abandoned gas and oil wells, as well a plugged and abandoned dry holes, in and near Big Break project site (CDC date unknown).

4.10 WATER USE

This section includes information on the existing water resources in the Delta, the existing and expected water diversions from the Delta, and the associated infrastructure.

4.10.1 WATER RESOURCES

Water resources in the Delta consist primarily of surface water and groundwater. The source of the majority of this water is freshwater drainage inflow, with the remainder being rainfall and recycled water from wastewater treatment plants. Surface water and groundwater are interactive hydrological resources. As surface flows make their way into the valleys, some of the water percolates into the ground, depending on the permeability of the soil and the capacity of the geologic formations to hold water. In some years when the base flow of a stream or river is low, flow to the surface may be provided by groundwater in areas where groundwater is close to the ground surface. Because the methods of uptake of water from these two sources are different, it is useful to make the distinction.

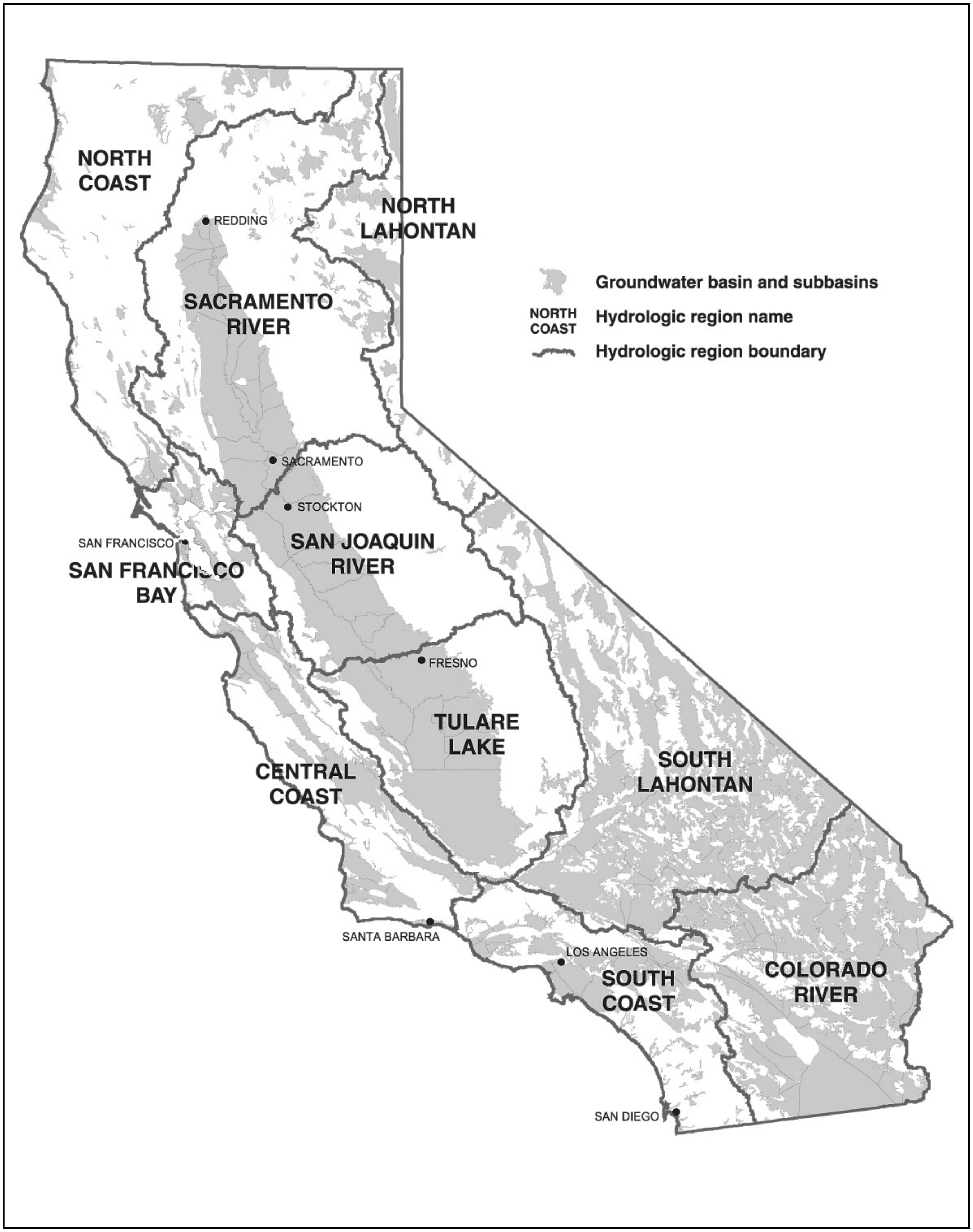
SOURCES AND VOLUME OF WATER

Based on water data from 1980 to 1991, the average annual freshwater inflow into the Delta was 27,840,000 acre-feet (AF) during that time period. Aside from drainage inflows, precipitation directly contributes another 990,000 AF in the Delta (DPC 2000). The volume of freshwater inflow fluctuates every year, even while the fluctuation is moderated by storage in upstream reservoirs and dams and redistribution via canals and pipelines. In the 20th century alone, California experienced multiyear droughts in 1912–1913, 1918–1920, 1922–1924, 1929–1934, 1947–1950, 1959–1961, 1976–1977, and 1987–1992 (DWR 1998).

Wastewater treatment plants also contribute water into the Delta; however, the source of this water is comprised mostly of surface water from within the same drainage systems, and the recycled water is thus considered a subset of the surface water resource.

SURFACE WATER RESOURCES

The Sacramento-San Joaquin Delta is at the confluence of 2 major rivers that drain the Central Valley and as such, is the terminus of the state's largest natural drainage system From the north, the Sacramento River, including flows via the Yolo Bypass, provides approximately 80 percent of the fresh water draining into the Delta. This drainage area is known as the Sacramento River Hydrological Region (SRHR) (DWR 2003a). The 27,200-square-mile Sacramento River Hydrological Region constitutes the northern portion of the Central Valley (Exhibit 4.10-1). The annual runoff averages 22.4 million acre feet (MAF), which is nearly one-third of the State's total natural runoff. Approximately 8 MAF from the SRHR is used for urban, industrial, and agricultural uses, with approximately 5.5 MAF being sourced from surface water. The remaining 2.5 MAF is sourced from groundwater. The other 14.4 MAF of the runoff is dedicated as natural flows that support various environmental requirements, including in-stream fishery flows and flushing flows in the Delta. There are 40 major surface



Source: DWR 2003

Hydrological Regions

EXHIBIT 4.10-1

Flooded Islands Feasibility Study Baseline Report
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water reservoirs in the SRHR. Surface water supplies 69 percent of the urban and agricultural water use in the SRHR; groundwater supplies the remaining 31 percent (DWR 2003a).

From the south, the San Joaquin River contributes another 15 percent of the inflow to the Delta, with the balance of 5 percent from other eastside rivers and streams (e.g., Mokelumne River, Cosumnes River) (DPC 2000). These rivers and streams drain the 15,200-square-mile San Joaquin River Hydrologic Region (SJRHR). Approximately 30 percent of the urban and agricultural water uses in the SJRHR are sourced from groundwater; the remaining 70 percent is surface water. (DWR 2003a).

GROUNDWATER RESOURCES

The vast majority of California's groundwater that is accessible in significant amounts for extraction is stored in alluvial groundwater basins. The three flooded islands are located on two alluvial groundwater basins. Lower Sherman Lake is located on the South American Subbasin of the Sacramento Valley Groundwater Basin. The deposits occurring along the western margin of the subbasin adjacent to the Sacramento River consist primarily of silts and clays but may be locally interbedded with stream channel deposits of the Sacramento River. Because of their fine-grained nature, the flood basin deposits have low permeability and generally yield low quantities of water to wells. A review of 18 long-term hydrographs dating back to the 1960s depicts a consistent pattern of water level trends through much of the basin. Groundwater elevations generally declined consistently from the mid-1960s to about 1980 on the order of 20 feet. From 1980 through 1983 water levels recovered by about 10 feet and remained stable until the beginning of the 1987 through the1992 drought. From 1987 until 1995, water levels declined by about 15 feet. From 1995 to 2000, most water levels recovered by up to 20 feet leaving them generally higher than levels prior to the 1987 through 1992 drought. Basin inflows include natural and applied water recharge, totaling 257,168 AF. Subsurface inflow and outflow are not known specifically, but the model indicates that there is a net subsurface outflow of 29,676 AF annually. Other groundwater outflows include annual urban extraction of 68,058 AF and agricultural extraction of 162,954 AF. (DWR 2004c).

Big Break and Franks Tract are on the Tracy Subbasin of the San Joaquin Valley Groundwater Basin. Flood basin deposits in the Delta portion of the Subbasin, consist primarily of silts and clays. Occasional interbeds of gravel occur along the present waterways. Because of their fine-grained nature, the flood basin deposits have low permeability and generally yield low quantities of water to wells. Occasional zones of fresh water are found in the basin deposits, but they generally contain poor quality groundwater. Review of hydrographs for the Tracy Subbasin indicate that except for seasonal variation resulting from recharge and pumping, the majority of water levels in wells have remained relatively stable over at least the last 10 years (DWR 2004c).

4.10.2 WATER DIVERSIONS

GENERAL DESCRIPTION:

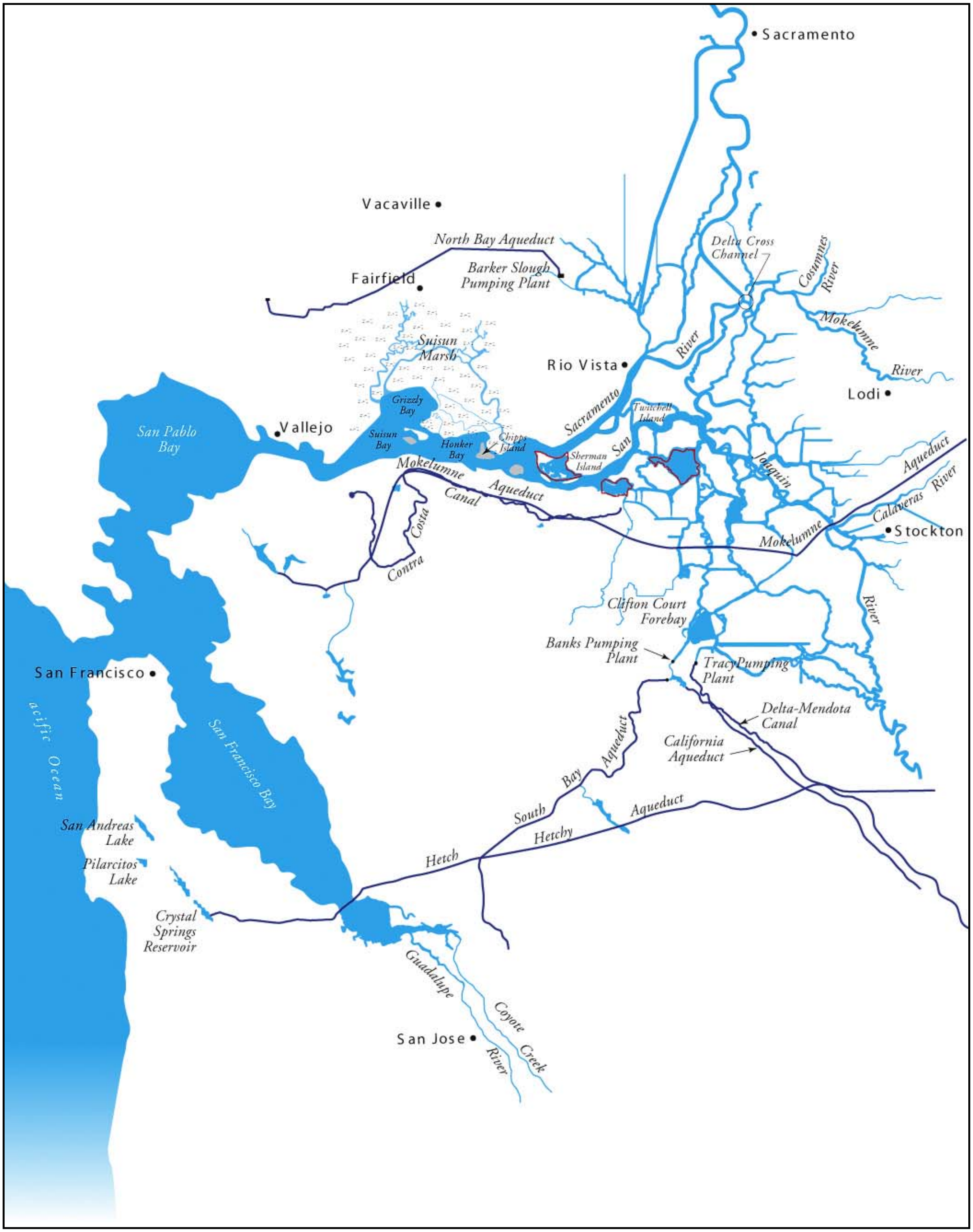
The Delta is the primary source of the State's freshwater, whereas most of the population of the State resides elsewhere. Approximately 75 percent of the State's freshwater originates north of the City of Sacramento, while 75 percent of the water needs are generated south of Sacramento. The Delta is the southern most point from which substantial quantities of freshwater of sufficient quality can be extracted from the Sacramento River before draining into the Bay. For this reason, the Delta has been developed into the hub of the State's water redistribution system.

While water diversions from the Delta vary on a year-to-year basis, on average, 18.4 percent of the freshwater in the Delta is directly diverted at the three main pumping stations, including Contra Costa, Banks, and Tracy Pumping Plants, as depicted in Exhibit 4.10-2. Approximately 75.5 percent of the water flow out from the Delta to the Bay. The remaining 6.1 percent of the water is directly used in the Delta (i.e., direct diversion by 1,800 intakes into irrigation channels for 520,000 acres of agricultural lands in the Delta and lost via evapotranspiration) and lost in the channels (DPC 2000).

The two main water diversion programs are the State Water Project and Central Valley Project (Exhibit 4.10-3). Local agencies, such as the City of Vallejo, also operate their own diversion programs, using Contra Costa Canal, North Bay Aqueduct, and other local diversion infrastructure, Direct diversion by private entities, such as Western Delta Industry and 1,800-plus agricultural users, also occur in the Delta (DWR 2004c). Because both the Central Valley Project and the State Water Project convey water in the Sacramento River and the Delta, facility operations are coordinated based on the Coordinated Operating Agreement, the Bay-Delta Plan Accord, and many other agreements.

Central Valley Project

The federal Central Valley Project (CVP), administered by the United States Bureau of Reclamation, stores and transports water from the Sacramento and San Joaquin rivers for irrigation uses in the Central Valley, as well as municipal uses in Contra Costa Water District's service area and elsewhere. The CVP Delta Division provides for the transport of water through the central portion of the great Central Valley, including the Sacramento-San Joaquin Delta. The main features of the division are the Delta Cross Channel, Contra Costa Canal, Tracy Pumping Plant, and Delta-Mendota Canal, all constructed and operated by the Bureau of Reclamation (USBR). This system provided full and supplemental water, as well as temporary water service, for approximately 380,000 acres of farmland in 1992 (DPC 2000). CVP supplies water to more than 250 long-term water contractors for a maximum annual delivery of approximately 9,300,000 AF.



Source: DWR 2003

Water Infrastructure in the Delta

EXHIBIT 4.10-2

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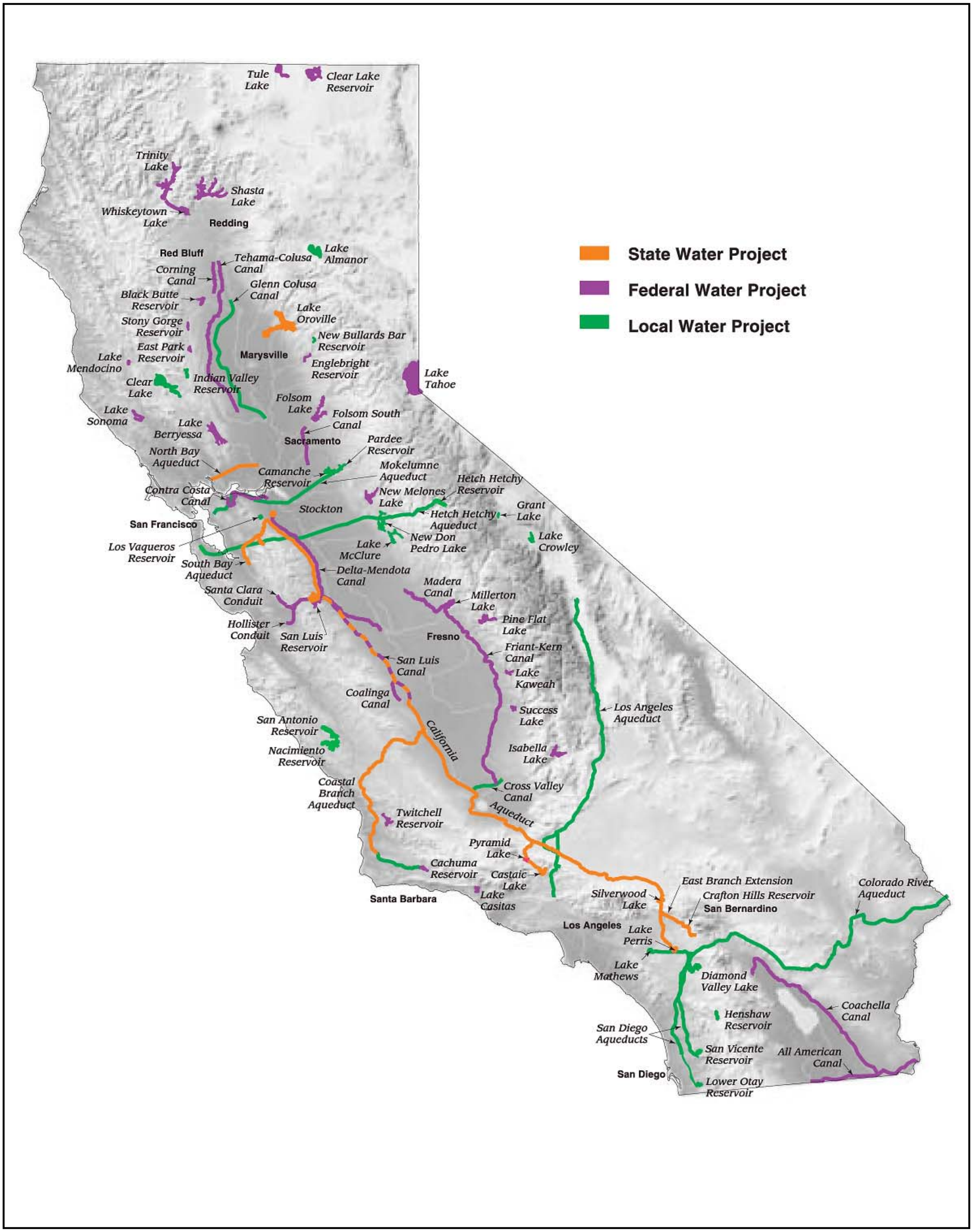

Source: DWR 2003

Major Developed Water Infrastructure

EXHIBIT 4.10-3

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State Water Project

The State water Project (SWP), administered by DWR, captures, stores, and conveys water to 29 water agencies throughout the state. Approximately two-thirds of the people in the state received at least a part of their drinking water from the SWP. In the Delta, SWP diverts water at two points. First, water is pumped from the Barker Slough Pumping Station into the North Bay Aqueduct that serves Napa and Solano counties. Second, water is pumped by Banks Pumping Plant into the 444-mile-long California Aqueduct (DWR 2004c).

SWP water supply is derived from storage at Lake Oroville and other reservoirs and high runoff flows in the Delta. Long-term contracts for a combined maximum of 4.12 million acre feet were signed with public water agencies, known as the SWP contractors. Water deliveries have ranged from 1.4 million acre-feet in dry years to almost 4.0 million acre-feet in wet years. Five contractors use SWP water primarily for agricultural purposes (mainly southern San Joaquin Valley); the remaining 24 primarily for municipal purposes (Delta Protection Commission, Background report on Delta Water Issues, 2000).

4.10.3 WATER USE

GENERAL DESCRIPTION:

Water derived in the Delta is used for a variety of purposes, including irrigation, domestic consumption, industrial use (i.e., power plant cooling), and environmental protection (i.e., habitat maintenance, water quality improvement, Wild and Scenic rivers requirements). Water use and the volume of water available for use are in part dedicated by compliance with water quality standards for water bodies in California, enforced by SWRCB and the nine RWQCBs and based on the beneficial uses designated in region-specific water quality control plans (basin plans). See also Section 4.4.for a discussion of water quality and some of the substances considered to be contaminants for drinking water purposes. Because water resources in the Delta are used throughout the State, water use discussion is based on statewide uses. Each of the primary water uses is described below.

Agricultural Water Use

Existing and future water uses were estimated in DWR's 1998 California Water Plan. Crop water use information and irrigated acreage data are combined to generate the 1995 agricultural water use level of 33.8 MAF during average year and 34.6 in drought years. DWR estimated that there were 9.5 million acres or irrigated crop land in 1995. Based on estimates of agricultural land conversion to other land uses, the 2020 agricultural water use estimate shows a reduction from 1995 water use level. The total irrigated crop acreage is forecasted to decline by 325,000 acres from 1995 to 2020, primarily in the San Joaquin Valley and South Coast areas. The 2020 agricultural water uses are estimated as 31.5 MAF during average years and 32.3 MAF during drought years. (DWR 1998).

Urban Use

Statewide urban use at the 1995 base level is 8.8 MAF in average water years and 9.0 MAF in drought years. (Drought year demands are slightly higher because less precipitation is available to meet exterior urban water uses, such as landscape watering.) Forecasted 2020 use increases to 12.0 MAF in average years and 12.4 MAF in drought years. Because these 2020 estimates are based on population growth forecasts, actual water use may differ substantially. (DWR 1998).

Environmental Uses

DWR 1998 California Water Plan defines environmental water use as the following:

- Dedicated flows in State and federal wild and scenic rivers
- Instream flow requirements established by water right permits, DFG agreements, court actions, or other administrative documents
- Bay-Delta outflows required by SWRCB
- Applied water demands of managed freshwater wildlife areas

This definition recognizes that certain quantities of water have been set aside or otherwise managed for environmental purposes, and that these quantities cannot be put to use for other purposes in the locations where the water has been reserved or otherwise managed. (DWR 1998). These water uses are required by a number of federal, State, and local laws and regulations. An Example is Fish and Game Code Section 5937, which provides protection to fisheries by requiring that the owner of any dam allow sufficient water to pass downstream to keep in good condition any fisheries that may be planted or exist below the dam.

Statewide, the applied environmental water use in 1995 was 36.9 MAF during average years and 21.2 during drought years. By 2020, the demand is estimated to increase by 40,000 AF during average years and by 30,000 AF during drought years.

Future Demand

Demand for the Delta's water resources will increase in the foreseeable future due to population growth, decrease of water available from the Colorado River, contamination of water resources elsewhere in the state, potential loss of snow pack as a result of global warming. It is noted that the demand will exceed existing water resources in the State.

Table 4.10-1 Historic and Estimated Future State-wide Water Use by Land Use Type			
	1995	*2020*	*Change*
Population (million)	32.1	47.5	+15.4
Irrigated crops (million acres)	9.5	9.2	-0.3
Urban water use (maf)	8.8	12.0	+3.2
Agricultural water use (maf)	33.8	31.5	-2.3
Environmental water use (maf)	36.9	37.0	+0.1
Percent of total			
Urban water use (%)	11	15	+4
Agricultural water use (%)	43	39	-4
Environmental water use (%)	46	46	0
Source: DWR 1998			

4.10.4 WATER INFRASTRUCTURE

This subsection describes the major water infrastructure in the Delta (Exhibit 4.10-3). There are no major developed water facilities at the three flooded islands. However, in the Delta there are several major canals, pipelines, reservoirs, and pumping plants. Some of these facilities are described below according to the associated programs.

CENTRAL VALLEY PROJECT

Delta Cross Channel

The Delta Cross Channel is a controlled diversion channel between the Sacramento River and Snodgrass Slough. Water is diverted from the river into the slough through a short, excavated channel near Walnut Grove. The channel has a bottom width of 210 feet and a capacity of 3,500 cubic feet per second. Fresh water is drawn from the Sacramento to the Mokelumne rivers to combat salt water intrusion in the Delta and to dilute local pollution. The water then flows through natural channels for about 50 miles to the vicinity of the Tracy Pumping Plant. The diversion provides an adequate supply of water to the intakes of the Contra Costa and the Delta-Mendota canals, and improves the irrigation supplies in the Sacramento-San Joaquin Delta. USBR advocated that the Delta Cross Channel and the training works in the San Joaquin River were necessary to prevent the highly polluted low water flows of the San Joaquin River from getting into the Tracy Pumping Plant. The intrusion could raise salinity in the adjoining waters above the standards set in the Water Exchange Contract for low water flow. USBR closes the control gates of the Delta Cross Channel during high water to prevent flood stages in the San Joaquin River section of the Delta**.** After the flood danger passes, USBR opens the gates to allow Sacramento River water through to the Tracy Pumping Plant (U.S. Bureau of Reclamation 2004).

Contra Costa Canal

The Contra Costa Canal originates at Rock Slough, about 4 miles southeast of Oakley,, where it intercepts natural flow in the Sacramento–San Joaquin Delta. Water for irrigation and municipal and industrial use is lifted 127 feet by a series of four pumping plants. The 47.7 mile-long canal terminates in Martinez Reservoir. The initial diversion capacity is 350 cubic feet per second, which gradually decreases to 22 cubic feet per second at the terminus. (U.S. Bureau of Reclamation 2004).

Tracy Pumping Plant

The Tracy Pumping Plant consists of an inlet channel, pumping plant, and discharge pipes. Water in the Delta is lifted 197 feet into the Delta–Mendota Canal. Each of the six pumps at Tracy is capable of pumping 767 cubic feet per second. The water is pumped through three 15-foot-diameter discharge pipes and carried about 1 mile up to the Delta-Mendota Canal. The intake canal includes the Tracy Fish Screen, which was built to intercept downstream migrant fish so they may be returned to the main channel to resume their journey to the ocean.

Delta–Mendota Canal

The Delta–Mendota Canal carries water southeasterly from the Tracy Pumping Plant along the west side of the San Joaquin Valley for irrigation supply, for use in the San Luis Unit, and to replace San Joaquin River water stored at Friant Dam and used in the Friant–Kern and Madera systems. The canal is about 117 miles long and terminates at the Mendota Pool, about 30 miles west of Fresno. The initial diversion capacity is 4,600 cubic feet per second, which is gradually decreased to 3,211 cubic feet per second at the terminus.

STATE WATER PROJECT

Clifton Court Forebay

The Clifton Court Forebay, located about 10 miles northwest of the City of Tracy in the southwestern portion of the Delta, is a shallow reservoir with a dam at the head of the California Aqueduct. The forebay provides storage and regulation of flows into Banks Pumping Plant. The forebay was constructed in 1969. The John F. Skinner Delta Fish Protection Facility, constructed adjacent to the Clifton Court Forebay and two miles upstream of the Banks Pumping Plant, contains a giant fish screen to keep most fish away from the pumps that lift water into the California Aqueduct (DWR 1999).

Harvey O. Banks Delta Pumping Plant

Harvey O. Banks Delta Pumping Plant, also known as Banks Pumping Plant or Delta Pumping plant, is located 20 miles southwest of the City of Stockton. Banks Pumping Plant, completed in 1969 and expanded in 1986, lifts water into the 444-mile-long California Aqueduct during both dry and wet months to fill offstream storage reservoirs and groundwater basins south of the Delta (DWR 1999).

California Aqueduct

The 444-mile-long California Aqueduct, completed in 1968, originates at the Clifton Court Forebay, travels south adjacent to the western foothills of the San Joaquin Valley. It is the primary canal that carries water from northern California into southern California. The Bethany Dams and Reservoir, located on the California Aqueduct, includes an arm on which the South Bay Pumping Plant lifts water into the South Bay Aqueduct, which carries water to the southern portion of the San Francisco Bay Area (DWR 1999).

Barker Slough Pumping Plant

Located on the northwestern edge of the Delta, the Barker Slough Pumping Plant marks the beginning of the North Bay Aqueduct. This pumping plant lifts water from Barker Slough and was completed in 1987.

North Bay Aqueduct

The North Bay Aqueduct, which serves Napa and Solano counties, is an underground pipeline that extends for 27.6 miles to the end of the Napa Pipeline and the Cordelia Pumping Plant and Forebay. This aqueduct was completed in two phases, ending in 1968 and 1988.

4.11 RECREATION

This section describes the recreational activities in the Delta and their economic value, the existing recreational facilities and the need for additional facilities, and the relationship between environmental improvement programs and recreational uses in the Delta.

4.11.1 RECREATIONAL ACTIVITIES

GENERAL DESCRIPTION

The Delta is a major recreational resource for northern California, and recreation is an important economic activity for the communities in and around the Delta. Water-based recreation activities in the Delta include cruising, water-skiing, fishing and hunting from a boat, sailing, and boat camping. The two most popular activities are boating and fishing.

In 1997, the Department of Parks and Recreation (DPR) prepared the *Sacramento-San Joaquin Delta Recreation Survey* (DPR 1997) for the Delta Protection Commission (DPC) and the Department of Boating and Waterways (DBW). The purpose of the survey was to determine the number of boaters and anglers who use the Delta, their length of stay, the areas where they recreate, the activities in which they participate, the amount of money they spend, and the adequacy of recreational facilities. The project sites are located in the West Delta (Recreation Area Zone D), which the survey found was the most popular area in the Delta for recreational activities of most types (e.g., shore, boat, and tournament fishing; other boating; board sailing or wind surfing; RV camping; tent camping; swimming; biking; walking; hunting on land; wildlife viewing; photography; sightseeing). Although boating was the most popular activity, non-boating recreational activities among people who also participate in boating include, in order of popularity, sightseeing, viewing wildlife, fishing, and board sailing. Among those who participated in fishing, other popular recreational activities include sightseeing, boating, and wildlife viewing.

Both anglers and boaters, on average, drove 70 miles to reach the Delta. However, more than 50% traveled less than 50 miles each way. Counties of residence of the fishing recreationists, in order of number of residents who come to the Delta, were Sacramento, San Joaquin, Alameda, Santa Clara, Solano, San Mateo, Placer, Los Angeles, and Stanislaus. For boating recreationists, the counties of origins, in order of popularity, were Contra Costa, Sacramento, Alameda, Santa Clara, Los Angeles, and San Joaquin. More than half of both boating and fishing recreationists spent less than 1 day in the Delta; more than 40% of those who spent more than one day in the Delta stayed in the Delta, generally for 1 to 2 nights.

A large percentage of boaters and anglers in California come to the Delta to recreate, generating considerable expenditures to the local economy. On a per-capita basis, boaters in the Delta spend an average of $17.20 inside the Delta ($2.97 for lodging, $4.72 for food and drinks, $6.42 for supplies, and $3.09 for recreational activities). Fishing recreationists, on a per-capita basis, spent $13.57 inside the Delta (DPR 1997).

As with the rest of the Delta, boating and fishing, in particular, are popular pastimes at the project sites. These and other recreational activities are described below.

Boating

Boating is one of the Delta's most popular activities and accounts for a majority of the recreation use. There were estimated 6.4 million boating-related visitor days in 2000. The types of boats used, in the order of popularity, are powerboats, personal watercraft, sailboats, paddleboats, and houseboats. Most boating activities take place during daylight hours in summer, evenly split between weekends and weekdays (DPR 1997).

With miles of channels and connecting sloughs to navigate and explore, the extensive and intricate configuration of navigable waterways offers a unique boating experience. The historic role of the Delta as an effective means of travel is still a viable and important feature. The Delta is a travel corridor to and from the Bay Area and upper Central Valley, as well as a means for travel between the adjoining communities in and around the Delta. The linear arrangement of the many channels offers road-like qualities with unimpeded accessibility. In the 1800s, the fastest and most direct means of travel between Sacramento and San Francisco was by ferryboat through the Delta. Large commercial tour boats follow the same route today. The Delta is also less restrictive than many other state reservoirs and bodies of water in terms of types of water crafts permitted, number of boat users (all classes) allowed per day, and types of engines or fuel systems allowed.

Because of its size and geographic position as the outflow of an extensive natural drainage area, the Delta offers a uniquely dependable freshwater recreation opportunity for boaters. Unlike the majority of the state's reservoirs, which are subject to drought and fluctuating water levels, the Delta provides consistency of water levels through dry and wet years with dependability for water-oriented recreation use year after year. An important consequence of reduced water levels is the reduction in actual surface area available for water recreation uses. During the drought years of 1976–77 and 1987–92, although other reservoirs were severely depleted, the Delta offered the same recreation opportunities as in nondrought years.

The boating resource provided by the Delta is unique in other ways as well. Recreational watercraft share use of the Sacramento Deep Water Channel and the San Joaquin River with large oceangoing ships, which use those waterways to reach inland ports in Sacramento and Stockton. At the same time, many out-of-the-way sloughs provide quiet, secluded spots for boats to anchor for the day or to stay overnight or for a longer time. Several favorite anchorage areas have a long history of use by houseboaters and others who may stay in that spot for an entire summer season, an opportunity available at few other places in the region. Water skiers and jet skiers are attracted to the area by the relatively calm and protected water available in many parts of the Delta, unlike conditions on the several large reservoirs in the region.

Boaters are served by more than 20 large (over 200 berths) marinas in the Delta, most of which are privately owned, and several dozen smaller marinas, also mostly privately owned. These marinas are located throughout the Delta, as shown in Exhibit 4.11-1. Many of the marinas provide services, such as holding tank pump-out, fueling, and food and beverages. Most of these facilities have been in place for more than 20 years and many have existed for more than 40 years.

Franks Tract

Owing to its central location and the expanse of open water, Franks Tract is considered the hub for the Delta's recreational boating. In particular, Franks Tract is referred to as the "Delta Triangle." Adjacent to Franks Tract, there are four marinas on Bethel Island, as shown in Exhibit 4.11-1. However, Franks Tract itself is not generally considered a destination, except by fishermen who prize the abundance and size of striped bass found there. Because of its limited land base, lack of public access, exposure to strong winds, and fluctuations in water level that result in areas with water less than 10 feet deep, Franks Tract provides limited recreational opportunity, aside from boat fishing and hunting. The nearest public launching area is located at Brannan Island State Recreation Area; adjacent private marinas provide additional launching opportunities closer to Franks Tract (DPR 1997).

Boat fishing takes place primarily along the northwestern and southern levee remnants. The sloughs are used for waterskiing because of the calmer water. The open water area is used for sailing and motorboating. Because of the lack of access on the windward side, boardsailing does not occur at Franks Tract. Waterfowl hunting from boats is permitted from October through January (CDR & EDAW 1988).

Although boat traffic primarily travels in the adjacent waterways surrounding Franks Tract, some boat traffic does utilize Franks Tract. DPR at one time attempted, without success, to reestablish the levees on Little Franks Tract. The resulting rock piles, however, hinder boating navigation.

Lower Sherman Lake

Information on boating activities at Lower Sherman Lake is limited. However, boaters do use the area. At Lower Sherman Lake, there is one marina, Martin's Sherman Lake Marina, and three nearby boat launches, Herman Island Launch Ramp, Antioch Marina, and Antioch Municipal Boat Ramp (DPR 1997).

Big Break

Boating is also popular at Big Break, owing to its accessibility to rivers and sloughs. Boaters enjoy sunbathing on the islands north of the Lauritzen site. Occasional water skiiers and jet-skiiers use the Big Break project site. Big Break Regional Shoreline is not open to the public because regional recreational facilities have not been constructed. However, boaters, including fishermen and hunters, have access because boaters have the right to use navigable waters of the public domain. Along Big Break, there are three adjacent and nearby marinas (DPR

Source: Delta Protection Commission 1997

Boat Launch Facilities

EXHIBIT 4.11-1

Flooded Islands Feasibility Study Baseline Report

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1997). Big Break Marina, which is near but not on the project site, has boat ramps for motorized boats but not for nonmotorized boats, such as kayaks and canoes.

FISHING

General Description

Angling, both by boat and from land, is another widespread and popular activity in the Delta. Game-fish species include catfish, sturgeon, steelhead, striped bass, largemouth (black) bass, American shad, chinook salmon, crappie, bluegill, and carp. Striped bass is the most popular game species among shore anglers and boat anglers (DPR 1997).

The Delta is one of the most productive trophy bass fisheries in the nation, and it hosts several world-class bass tournaments every year. The 1997 survey showed that 45% of all State fishing tournaments occurred in the West Delta.

The three primary methods for striped bass fishing are baitfishing, trolling, and spooning, also known as jigging. Baitfishing is done during winter when water temperatures are below 55ºF and/or the water clarity is poor. Some popular baits are threadfin shad, mudsuckers, sardines, anchovies, minnows, bullheads, bloodworms, and pileworms, although striped bass can be caught on many other types of bait. Although most baitfishing is done while anchored, some anglers will drift with live minnows. Another popular method for catching striped bass is trolling, which is most effective when the water clarity is good and water temperatures are above 55ºF. A popular trolling technique is done by lowering the lure near the bottom of a sandbar while the boat is cruising at low speeds. The third technique, spooning, involves lowering and jigging heavy slabs of metal, designed to imitate baitfish, to the bottom, then raising and lowering them about 2 to 4 feet off the bottom while the boat is drifting.

The Delta is also well known for its sturgeon and salmon fishing opportunities. Commercial guides operate in several areas to take advantage of the diverse angling resource. Bank anglers park along many roadsides in the Delta, where they gain access to the water from the levee banks. Approximately one-third of the fishing recreationists also participate in night fishing (DPR 1997).

Recreational fishing within Suisun Bay and the Delta in the vicinity of the flooded islands includes shore fishing, and small-craft, and charter-boat fishing. Information on these fishing activities is summarized below.

Shore Fishing

Shore fishing is common all around the Bay–Delta estuaries, including many of the channels and shore access locations adjacent to the flooded islands. As a result of poor access from land, there is relatively little shore angling in Franks Tract, Sherman Lake, or Big Break. Shore anglers primarily target species such as striped bass, catfish, and sturgeon. Anglers fish from levees and several public and private access locations.

Small Boat Fishing

Recreational angling from small boats (i.e., 12–40 feet) is common throughout Suisun Bay and the Delta, including the flooded islands. Most angling takes place on weekends from April through October or November. Public boat launches and marinas exist in Suisun Bay and the western and central Delta in the vicinity of Franks Tract, Sherman Lake, and Big Break. Several hundred small boats may launch at the marinas in the area on a weekend day, depending on time of year and weather, to fish in the Delta channels and flooded islands. Although small boat angling takes place throughout the year, peak months for recreational fishing are April, May, and June, when target species are striped bass, largemouth bass, and catfish. Many recreational anglers fishing in the Bay–Delta, including Franks Tract, Sherman Lake, and Big Break, participate in local bass tournaments.

Charter-Boat Fishing

As many as 50 commercial party boats operate out of the Bay–Delta ports, but many of them are small six-passenger boats (6 pacs) that operate seasonally. Commercial party boats target striped bass and sturgeon in Suisun Bay and the central Delta. Small 6-pac charter boats take passengers to fish in Suisun Bay and the Delta, including the flooded islands, targeting species such as striped bass and sturgeon. Although party boat passengers fish in the estuary throughout the year, the peak months for fishing are April, May, and June, when striped bass are most abundant.

Franks Tract

Fishing activities take place primarily along the northwestern and southern levee remnants (CDR & EDAW 1988). Of the more than 100 fish species inhabiting the Delta, at least 26 species have been caught in and around Franks Tract. The most numerous species are the introduced largemouth bass, white catfish, striped bass, and native tule perch. Franks Tract is particularly well-known for its striped bass, also known as "stripers." False River, on the northern margin of Franks Tract, is a spawning site for striped bass during the spring (CDR & EDAW 1988). Many fishermen prefer to fish along tule marshes and along the fringes and in the sloughs (Galloway, pers. comm., 2004).

Lower Sherman Lake

Most of Lower Sherman Lake is not accessible except by boat. Boating fishing takes place at Lower Sherman Lake, but the level of activity is not known. Shore fishing at areas around Herman Island launch ramp is possible.

Big Break

Bass fishing is the most popular recreation activity at Big Break. The number of anglers at Big Break has increased dramatically since the mid-1990s because of promotion of Big Break as a largemouth bass tournament site (EBRPD 2001). Bass fishing is a year-round activity, but the tournaments take place in the summer and fall. Up to 600 boats congregate for a small- to medium-sized tournament after permits are acquired from Brannan Island. Boats are launched from Bethel Island, Big Break, and Brannan Island (Galloway, pers. comm., 2004).

Big Break Regional Shoreline is not open to the public because recreational facilities have not been constructed. However, boaters, including fishermen, are able to access Big Break because of its designation as a navigable water of the public domain. Illegal night fishing has been reported at this site as well.

HUNTING

General Description

There is a long history of hunting in the Delta in association with privately owned agricultural lands. In addition, 19 private duck hunting clubs are located in the Delta, nearly all in Yolo County in the north Delta. Hunting is also permitted on a few publicly owned properties in the Delta and several publicly owned water-covered areas, such as the project sites. All three flooded islands are popular for hunting from boats (DPR 1997).

Franks Tract

DPR currently operates a duck hunting program during the duck season, which runs from mid-October to January. Hunters pay for blind permits, of which there is a quota of 24 due to safe distance limits. The blinds are mostly in the northern central region of Frank's Tract. The blinds are removed at the end of the season. The fee collected goes to the State Parks' general fund and partly goes to abatement costs for boats. Most of the hunters return every year. According to staff at the SRA, the level of monitoring of the duck hunters is not adequate currently due to the small number of DPR staff available for the task. Because there are no launch ramps within the Franks Tract project site, the hunters generally launch from marinas on Bethel Island or elsewhere in the Delta (Galloway, pers. comm., 2004).

Lower Sherman Lake

DFG owns the Lower Sherman Island and Lower Sherman Lake and allows hunting within the Wildlife Area it manages. Hunting blinds are available for use on a first-come basis. While hunting is known to occur at Lower Sherman Lake, data on the existing level of hunting activities is not available.

Big Break

Big Break Regional Shoreline is currently not open to the public, but boaters, including hunters, have been accessing it. Hunting waterfowl from floating duck blinds in Big Break during the hunting season is allowed by State law. Hunters may not hunt from land areas owned by EBRPD and may not construct permanent duck blinds.

OTHER RECREATIONAL ACTIVITIES

General Description

The far western side of the Delta, along the Sacramento River, has become renowned throughout the western United States as one of the premier wind sports locations in the country. It has gained this reputation due to the strong and steady summer winds that blow from the San Francisco Bay and are constrained between hills and low mountain ranges on either side of the river. Windsurfers and kite boarders make use of several developed and informal access points in that portion of the Delta.

Camping and recreational vehicle (RV) use is also available at several locations in the Delta, primarily at larger parks, resorts, and marinas. However, facilities at private resorts and marinas are generally available only to tenants and their guests, not the general public. Public camping facilities are relatively few in number. Among the largest is Brannan Island State Recreation Area in the west Delta, which provides over 120 RV and tent campsites, along with 32 berthing slips for boat campers and a boat ramp. There are no camping and RV facilities at any of the project sites. The nearest RV and camping area are private resorts on Bethel Island next to Franks Tract. Recreational activities on all three project sites are constrained by the relative inaccessibility, aside from access by boat.

Franks Tract

In terms of sightseeing and wildlife viewing, the open, wide, and flat surface of Franks Tract affords expansive views of the water and of the perimeter vegetation on remnant levees and in-channel islands within and around Franks Tract. While residences and marinas line the northeastern shoreline of Bethel Island, they are intermittently screened by levee remnants along Piper Slough.

Lower Sherman Lake

There are no trails on Lower Sherman Lake project site. Aside from the picnic sites at the Herman Island launch ramp, there are no developed vantage points to view Lower Sherman Lake from within the project site. Views of Lower Sherman Lake is enjoyed from the adjacent marina.

Big Break

The upland portion of Big Break project site is connected to the developed area, but there is only one road that provides access to Big Break. Currently, trail users are allowed to access the perimeter of the parkland on the adjacent Big Break Regional Trail through Ironhouse Sanitary District property.

4.11.2 RECRECREATION FACILITIES

EXISTING FACILITIES

In the DBW-designated West Delta, which includes all three project sites, there are eleven large marinas, 15 medium sized marinas, and 26 small marinas (DPR 1997). There are no marinas or developed facilities on the project sites, aside from publicly owned Herman Island Launch Ramp, which includes picnic sites, on the Lower Sherman Lake project site. This launch ramp is often used by day users, such as water-skiers, to launch personal watercraft and by fishermen. Fishermen particularly like to have access to launch facilities early in the morning (DPR 1997).

DEMAND FOR FACILITIES

In the recreation survey conducted in 1997, the limited number, as well as the age and condition of many types of facilities have found to be of concern in terms of public recreation access. The most prominent facility needs have been identified as restrooms, beach and other day-use facilities, mooring buoys, boat launch ramps, non-motorized boating access, and pump-out, fuel, and similar services. Many of the private facilities in the Delta are old and have been found to have problems associated with deferred maintenance. Funding for both public and private facility improvement and maintenance is seen as key to improving Delta recreation by facility users and operators (DPR 1997).

Recreational facility constraints include public swimming beaches, public parks and trails, dedicated bicycle lanes and trails, public restrooms, fishing piers, fish cleaning stations, hunting areas, courtesy docks, and shoreline areas accessible from the water (DPR 1997).

In the 1997 survey, among boat owners who live within an hour of the Delta but do not use their boats in the Delta, “not familiar with recreation opportunities” and “not enough time” were the most commonly cited reasons (DPR 1997). This suggests that if additional publicity was conducted, the demand for recreational facilities may increase. For each of the project sites, it is likely that there is demand for most types of recreational facilities, provided adequate access.

FRANKS TRACT

Most of Franks Tract is currently submerged and, thus, cannot be developed for recreational uses unless additional fill is placed to create new islands. On the existing islands, the peat soils are poorly suited to the development of recreational facilities, roads, and buildings because they subside when they are dried or if pressure is exerted on them by developed facilities or fill. Potential geologic hazards at Franks Tract also constrain development potential in Franks Tract. Wave-generated erosion of the existing islands and remnant levees, as well as new islands, is another development constraint. A policy against construction of new structures and facilities in areas subject to erosion was approved; any new structure and facilities in such areas must be expendable or movable (CDR & EDAW 1988).

LOWER SHERMAN LAKE

Most of the Lower Sherman Lake project site is not accessible except by boat; for this reason, the recreational opportunities would only be available to boaters. Extensive recreational development within the Sherman Island Wildlife Management Area may also not be compatible with DFG's policies. The existing Herman Island launch ramp is accessible from land and presents the best opportunity to accommodate additional recreational activities for recreationists without boats.

BIG BREAK

There are no developed recreational facilities on the Big Break project site. Along Big Break, there are three adjacent and nearby marinas (DPR 1997). Big Break Marina, which is near but not on the project site, has boat ramps for motorized boats but not for non-motorized boats such as kayaks and canoes.

The Delta Science Center (DSC) was conceived to study the wildlife, the river resources, and the history of the Delta. EBRPD and Los Medanos College have formed a partnership to design, construct and operate the first phase of the Delta Science Center on the Lauritzen site (BDSC 2004).

4.11.3 ENVIRONMENTAL IMPROVEMENT AND RECREATION

Studies conducted in the Delta during the past 10 years have identified several key recreation issues. Perceptions of poor water quality have been found to be common among many Delta users, along with related concerns about improper disposal of boat wastes. Also related to water conditions are concerns about obstacles and debris in the water, and a need for more exotic vegetation removal and dredging to maintain navigability and usability of boating facilities.

For water contact activities, the RWQCB has established water quality standards for fecal coliform bacteria concentration, which may be increased by faulty septic tank or sewage treatment facilities, overflows of animal yard holding ponds, release from boats, urban runoff, and other sources (DPR 2000).

The CALFED Bay Delta program has proposed 12 actions that are primarily aimed at improving ecological conditions and modifying the flow and diversion of water in the Delta. Most of these have potential negative impacts to recreation, such as displacement of existing facilities and restrictions on boat travel, as well as potential benefits. Potential benefits would primarily be due to improved water quality, a key recreation issue in the Delta, and habitat restoration that would enhance nature-related pursuits such as non-motorized boating, wildlife viewing, and fishing. Some actions may also provide opportunities for development of new facilities to serve both boaters and land-based recreationists (DPR 1997).

4.12 MATERIALS FOR RESTORATION

This section discusses methods and materials used for restoring subsided islands, levees, and habitat, with an emphasis on the reuse of dredged material. This section begins with an overview of regulations governing the use of fill materials. The discussion in this section is not specific to any of the project sites, because the same material sources and methods may be applied to any of the three project sites.

4.12.1 REGULATIONS

REGULATORY FRAMEWORK FOR DREDGING

When planning a restoration project it is important to address the quality of fill and observe the regulatory framework for dredging and fill materials.

The U.S. Army Corps of Engineers (USACE) issues federal permits for dredging projects pursuant to Section 404 of the Clean Water Act, and the U.S. Environmental Protection Agency (EPA) provides oversight of the USACE regulatory program (RWQCB 2001).

As part of the Section 404 permitting process, the dredging permit applicant must seek water-quality certification from the State of California, in accordance with Section 401 of the Clean Water Act. After the Regional Water Quality Control Board (RWQCB) reviews a proposed project, the RWQCB may either grant or deny certification. Additionally, the RWQCB may choose to act under the authority of the state Porter-Cologne Water Quality Control Act by issuing waste discharge requirements for the project in conjunction with the water-quality certification. Water-quality certifications and waste-discharge requirements often contain conditions to protect water resources that the permittee must meet during the term of the permit.

REGULATORY GUIDANCE FOR QUALITY OF AQUATIC SEDIMENT

There are no regulatory criteria pertaining to ambient concentrations of chemical constituents in aquatic sediments. However, if a project results in the removal of sediment, the material is subject to state and federal hazardous waste regulations and a RWQCB-designated waste classification program. The California Department of Health Services (DHS) administers the hazardous waste regulations that are based on numerical concentration criteria and govern the disposal options for the material. EPA also has established preliminary remediation goals (PRGs) that are concentration values based on human health risks for classifying hazardous-waste conditions in soil material using specific assumptions about receptor exposure. PRGs are guidance values only and are not legally binding enforcement criteria. PRGs are established for industrial and residential sites.

For those sediments that are not classified as hazardous, the RWQCB method is used to classify material as "designated," "nonhazardous," or "inert." Designated levels of allowable total and soluble contaminant concentrations are established based on the site-specific water bodies that may be affected through reuse of the material, beneficial uses of those water resources, potential of the waste to impair water quality, and factors of environmental attenuation and leachability of the contaminants from the material. Wastes having contaminant concentrations exceeding the designated levels must be directed to waste-management units (i.e., landfills) for disposal.

The RWQCB also administers the reuse of contaminated sediment for creation, enhancement, and restoration of wetlands. The wetland reuse criteria were developed in part based on Effects Range-Low (ER-L) and Effects Range-Median (ER-M) criteria originally developed by the National Oceanographic and Atmospheric Administration (NOAA Fisheries) (DWR 1995b). The ER-L and ER-M criteria reflect the concentration levels that adverse biological effects may be expected to occur at less than 10% of the time and less than 50% of the time, respectively.

The RWQCB criteria specify the allowable use based on two categories:

- Use for wetland noncover where exposure to the aquatic environment would be limited; and

- Wetland cover or levee construction where sediments would be exposed to the water.

Quality of Dredge Spoils

The Central Valley RWQCB requires the applicant to submit a report for the discharge of dredge spoils to land (Baillie, pers. comm., 2004). The report must include a project description, identification of the amount and location of material to be discharged, and a physical and chemical characterization of the dredge spoils. It is important for the applicant to demonstrate that the material is inert and therefore the proposed activity would not degrade groundwater or surface water quality.

The quality and makeup of spoil materials is mostly determined by their origin. Two primary concerns associated with the reuse of dredge material are salinity and pollutants, because they can adversely affect water quality. Salinity may be an issue in areas that are tidally influenced. Dredge spoils from the Suisun Bay, for example, often contain high concentrations of salt. Additionally, trace mineral content such as copper, iron, and aluminum are commonly found in dredge spoils, as well as polychlorinated biphenyls (PCBs) and pesticides. Pesticides are associated with dredge spoils from the Delta. The Basin Plan prohibits organochlorine (OC) pesticides, which are sometimes found in dredge material.

For beneficial reuse projects involving the enhancement or creation of wetlands, Alex Baillie of the Central Valley RWQCB expressed concern regarding the concentration of methyl mercury, which can occur in spoils from areas that receive or have received mining drainage (see Section 4.5.3 Mercury) (Baillie, pers. comm., 2004).

Mark Marvin-DiPasquale of USGS also stressed the importance of determining the amount of bioavailable methyl mercury in the fill material (Marvin-DiPasquale, pers. comm., 2004). In most sediments, methyl mercury comprises 10% of the total mercury content. However, sandy sediments may have a higher ratio of methyl to total mercury than organic soils. Marvin-DiPasquale suggested that spoils from the storage area on Decker Island may be a potential source for fill material for the Flooded Islands project, but emphasized that if dredge materials are to be used, they should first be tested for total and methyl mercury content. Soils that are tin-reducible are assumed to be bioavailable.

In general, areas that experience a higher frequency of dredging produce cleaner dredge material, whereas areas that are infrequently dredged, such as agricultural sloughs, tend to have higher concentrations of pollutants.

4.12.2 DREDGE SPOIL

DREDGE SPOIL REUSE

Beneficially reusing dredge spoil materials is a promising approach for simultaneously addressing a portion of the Delta subsidence problem and the dredge spoil disposal issue. Dredge spoils can be used to strengthen existing levees, build new cross levees, and raise small areas to near sea level for tidal marsh restoration.

The relatively small volume of total dredge spoils limits its application for broad-scale subsidence reversal. The limited availability of dredge spoils is further aggravated by the tendency of organic soils to compact appreciably when overlain by dredge spoils. For this reason, dredge spoils should be used primarily to repair existing levees, construct new levees on mineral soil, and in combination with less dense fill material such as rice-straw bales for subsidence reversal efforts.

Dredging Activities

Dredging is an ongoing activity in the Sacramento–San Joaquin Delta to maintain or deepen navigation channels, maintain or increase flood control and water conveyance capacity, and to obtain material for levee maintenance and repair. Disposal of dredged material has historically been relegated to designated disposal sites. More recently, dredged materials (or spoils) have been used as fill to restore wetlands, fill uplands, strengthen and repair levees, and cover landfills. This practice is often described as the beneficial reuse of dredged material as fill.

The Department of Water Resources (DWR) has expended considerable effort in establishing a program to demonstrate the feasibility of beneficially reusing dredged materials. Reuse of clean dredged materials represents a unique opportunity to reduce costs for ecological restoration.

In 2002, the Natural Heritage Institute (NHI) researched and prepared a study that discusses methods of rebuilding subsided islands and restoring habitat that includes reusing dredge spoils and importing rice-straw fill material to expedite the rebuilding process. The following discussion is taken directly from that report (NHI 2002). Although the NHI study focused on the restoration of subsided islands, the discussion of restoration techniques and potential fill materials would also apply to restoration and habitat creation within the three Flooded Island project sites.

Material Availability Analysis

NHI estimated material available from dredge spoils in the Delta, future dredging, and imported materials. Available dredge spoils in the Delta were then quantified and located based on interviews with local experts, published documents, and reports regarding past dredging activities.

Future dredging was considered either near future or long term, based on existing and anticipated sediment import into the Delta. NHI estimated quantities for near-future activities based on environmental impact reports pertaining to proposed dredging in the next 10 years, then determined long-term sediment availability from published sediment budget studies. NHI estimated the availability of additional fill material based on estimates of nearby stored non-dredge spoil sediments (e.g., Montezuma Hills) and other out-of-Delta fill material sources (e.g., rice straw).

Quantity and Location of Dredge Spoils

The largest quantities of dredge spoils in the Delta are derived from the dredging of the Sacramento and the Stockton shipping channels. Smaller-scale dredging activities provide valuable material for local restoration, but in negligible quantities owing to the scale of island subsidence reversal. For example, all marina-related dredging in the south Delta in the next 4 years will generate only 97,000 cubic yards of material (DWR 2000b). This is less than .001% of the total volume of islands below sea level.

Table 4.12-1 lists the quantity available at each site. Approximately 42 million cubic yards (mcy) of dredge spoils are stored in the Delta, primarily from dredging the Sacramento and Stockton shipping channels.

In addition to known dredge spoil locations, government agencies have estimated potential future quantities from dredging activities. Table 4.12-2 lists the locations and estimated quantities. These total approximately 10 mcy of additional dredge spoils available in the next 10 years.

Krone (1996) projects an average of 500,000 cubic yards of annual Delta sediment deposition from now until 2035. This translates to an additional 17 million cubic yards of dredge material possibly available in the next 34 years (as determined in 2002). In summary, approximately 60 mcy of dredge spoils will be available for use. This is about one-tenth of the total subsided volume of western Delta islands.

Table 4.12-1 Quantity and Location of Available Dredge Spoils		
Site	Owner	Existing Quantity (cubic yards)
Augusta	Port of Sacramento	1,000,000[1]
Brannan Island State Park	State of California, Department of Parks and Recreation	9,300,000[2]
Bradford Island	–	1,000,000[1]
Decker Island	DWR, Mega Sands, Port of Sacramento	20,000,000[1]
Grand Island	USACE	N/A[1]
Los Ulpinos	USACE	2,300,000[2]
McCormack Tract	–	N/A[1]
Old Scour Pond	DWR	N/A[1]
Roberts Island #1	Port of Stockton	N/A[3]
Roberts Island #2	Port of Stockton	N/A[3]
S-12 (Prospect Island)	Port of Sacramento	1,710,000[4]
S-16 (Rio Vista)	USACE	3,000,000[5]
S-35 (Collinsville)	DOW Chemical Company	890,000[4]
Sacramento North Shore (across from Sherman Lake)	USACE	3,000,000[2]
Spud Island	Port of Stockton	N/A[3]
Webb Tract	–	N/A[1]
Total		**42,200,000**

N/A- Quantity estimate not available.
[1]C. Schmutte, DWR, pers. comm., 2000.
[2]Betchart, 1998.
[3]USACE, 1988.
[4]CRWQCB, 1988.
[5]I. Tavana, USACE, pers. comm., 2000.

Source: NHI 2002

Table 4.12-2 Near Future Dredging Activities and Quantities	
Location	Quantity (cubic yards)
Mokelumne River	6,500,000[1]
South Delta	3,000,000[2]
Total	**9,500,000**

Source: NHI 2002
[1] CALFED 2000a
[2] Roberts, pers. comm., 2000

Out-of-Delta Sources and Quantity of Dredge Spoils

In 1998, 5 mcy of materials were dredged from the San Francisco Bay. Forty-three percent of this material was deposited at a deep ocean disposal site, 50 miles from the Golden Gate Bridge . A smaller percentage (<16%) made its way to upland disposal sites, including Winter Island, just west of Sherman Island (BCDC 1999). The Port of Oakland estimates that its own dredging will create another 15 mcy of material in the next 5 years (Port of Oakland 2000).

Rather than dispose of this material in ocean dumping grounds, it could be used to construct and/or enhance islands in the Delta. Some of this material is used at upland restoration sites such as the Hamilton Wetland site and the Montezuma Wetlands for similar activities (BCDC 1999).

The Long Term Management Strategy (LTMS) and the environmental impact report (EIR) for Oakland Harbor dredging considered Delta Island disposal. The LTMS evaluated the possibility of using the Sherman Island scour pond site but expressed concerns regarding the salinity impacts of San Francisco Bay dredge spoils. The Oakland Harbor Dredging EIR rejected the proposal based on the high cost of transport. USACE expressed interest in placing dredged materials on Delta islands, but DWR denied their request because of uncertainty regarding effects of saline dredge spoils (BCDC 1999).

Given the potential benefits, the use of saline dredge spoils in the Delta should be further examined. The prospect of using saline dredge materials may provide benefits at San Francisco Bay ports, where there is a need for disposal locations, and Delta islands, where there is a need for material.

Ongoing Initiatives

The LTMS is a cooperative effort of the EPA, the USACE, the State Water Resources Control Board (SWRCB), the RWQCB, and the San Francisco Bay Conservation and Development Commission to develop a new approach to dredging and dredged material disposal in the San Francisco Bay area (CALFED 2000e).

The long-range goals of the LTMS are to reduce disposal in the estuary and to find beneficial uses for dredged material. The LTMS has designated a deep-ocean disposal site 50 miles offshore of San Francisco that is an ecologically superior alternative to disposal in the estuary itself. Because use of the ocean disposal site began in late 1995, over 4 mcy of dredged material have been diverted from disposal in the San Francisco Bay. In addition, overall Bay disposal has dropped from historical averages of about 6 mcy annually, to approximately 2.5 mcy annually.

However, this may be the short-term approach until beneficial-use projects can be initiated. Using clean sediments from dredging projects, the LTMS agencies have participated in pilot levee maintenance projects and have constructed the Sonoma Baylands wetland restoration project. LTMS is considering other projects that would beneficially reuse dredged materials. A specific policy of LTMS is to pursue habitat restoration projects that are consistent with habitat goals and plans worked out in other venues, including the CALFED Bay–Delta Program. Of particular interest are the cost-sharing opportunities of working with entities that must pay for dredging, including the USACE. These parties could provide the clean material to restoration projects much more efficiently than the restoration project proponents could acquire the material. It is anticipated by the participants that the CALFED Bay–Delta Program and LTMS agencies will coordinate on potential joint levee-construction and habitat-restoration projects.

As noted on DWR's website, demonstration projects that utilize dredge material for levee construction purposes continue to be completed (DWR 2002b). Dredge material from Clifton Court Forebay was used for a levee reconstruction/restoration project on Twitchell Island, and dredge material from New York Slough was used on a demonstration project at Jersey Island included levee restoration. An example of an ongoing project is the disposal of dredge material from the Stockton and Sacramento Ship Channels at a stockpile site on Sherman Island, where it is used by the district for levee repairs. USACE has a large disposal site near Rio Vista, and despite offering the material for free, no one has accepted the material. The high costs of transporting the material will continue to be an issue.

SUBSIDENCE MANAGEMENT AND REVERSAL TECHNOLOGY

Aside from using dredge spoils as fill materials, there are a number of other fill materials and methods for restoring levees and constructing islands. Subsidence management techniques arrest or reduce future subsidence, one of the main causes of flooding. Subsidence reversal techniques entail importing or creating fill material to physically rebuild subsided islands to sea level. The issues that are relevant to the Flooded Islands project sites include:

- Use of rice-straw bales;
- Island capture of bed load and suspended sediment moving through the Delta;
- Importation of soil from upland sites.

The potential use of the above alternative fill materials is constrained by cost, availability, time, geotechnical, or transportation requirements. Table 4.12-3 depicts the estimated cost per cubic yard for each type of fill material, based upon research conducted by NHI. The suitability of these alternative fill materials as substrate for tidal marsh establishment was not evaluated, but it was assumed that the fill approaches itemized above would be suitable for supporting tidal marsh.

Table 4.12-3
Fill Cost Estimates

Source	Average cost per cubic yard ($)	Cost range per cubic yard ($)
Bay Dredge Spoil (beyond 10-mile radius)	15.00	10.00–41.00
In-Delta Dredge Spoil (within 10-mile radius)	8.00	5.00–10.00
Dredge Spoil Reuse from Delta Islands	5.00	1.50–12.00
Bed-load capture	5.00	5.00
Suspended Sediment Capture	5.00	5.00
Rice Straw	0.70	0.55–0.87
Fresh Water	0.10	0.06
Source: NHI 2002		

Rice-Straw Bale Fill

Rice is grown on 400,000 acres a year in the Sacramento Valley. After harvest, 2–3 tons of straw, or approximately 1 million tons of straw a year, remain on each acre of land (Bainbridge 1995). Rice straw used for construction is baled at a density of 7 pounds per cubic foot (State of California 1994). Assuming this density, 1 million tons of rice straw creates over 10 million cubic yards of rice straw.

Laws restricting disposal by burning have created a surplus of rice-straw bale material. Therefore, the use of rice straw provides a significant opportunity for synergistic use of a waste material. Currently, farmers either use scarce water to break down rice straw in winter or they simply stockpile excess rice-straw bales.

The greatest advantages of rice straw relative to other fill materials are its relatively low density, low cost, and abundance. Furthermore, rice straw approximates the character of decomposed tules that originally formed the Delta's peat soil more than any other fill material considered in this study. Unlike dredge spoils and other mineral soils, relatively large volumes of rice straw can be deposited on the Delta's organic soils without causing large amounts of soil compaction. Table 4.12-3, above, suggests that rice-straw costs are less than $1 per cubic yard delivered to the site, compared to more than $5–$20 per cubic yard for dredge spoils.

Anaerobic decomposition of inundated rice straw could degrade water quality. Decomposing organic matter creates dissolved organic carbons (DOCs). Drinking water treatment processes react with DOCs to form harmful disinfectant by-products, such as trihalomethane. Currently, about 40-45% of DOCs in the Delta comes from agricultural island drainage; the rest comes from rivers, upland runoff, wetlands, and microbial production (Bergamaschi, Fram, and Fujii. 2000).

DOCs themselves do not pose a threat to ecosystem health in the Delta. Degrading rice straw may produce fewer DOCs than the agricultural practices it replaces. The possibility that it may impact drinking water mandates caution when applying this strategy to islands close to the Delta Pumps and the Contra Costa water intakes in the south Delta.

Fluvial Sediment

Strategies that capture sediment suspended in the river and moving along the bed of the channel attempt to mimic historical sediment deposition processes and could reduce the need to dredge future accumulations of sediment from navigation and flood conveyance channels. Although promising, strategies to capture suspended and bed-load sediment are limited by the same constraints as dredge spoil reuse. The supply of sediment transported to the Delta is very small relative to the area of subsided lands, and placement of captured sediment on organic soils may result in significant compaction.

Delta Sediment Budget

Ninety percent of the Delta's fluvial sediment supply is from the Sacramento River (Bay Institute 1998). Much of the sediment in the San Joaquin River in the Delta is of Sacramento River origin (Dinehart 2000).

The system of artificial levees (essentially complete by 1930) isolates 97% of historical marshland in the Delta (Bay Institute 1998). Waters that historically spread out across the deltaic plain to deposit their sediment loads are now confined to narrow channels and carry their loads out to San Francisco Bay.

At the same time, modifications in the upper watershed have greatly decreased available sediment sources. Large, lowland dams control 73% of the Sacramento and San Joaquin river basins. These dams trap 90% of all incoming sediment, including 20.4 million cubic yards of suspended load (Bay Institute 1998). In an undammed system, some of this would still deposit in sediment sinks upstream, but fine clays and sands would travel all the way to the Delta.

Table 4.12-4 shows the Delta Sediment Budget. In 1990, an estimated 6.1 million cubic yards of sediment entered the Delta. Water exports removed 1.6 million cubic yards (in the form of suspended sediments) from the Delta, dredging removed another 0.5 million cubic yards, and the remaining sediment passed through the Delta to the San Francisco Bay (Beeman 1992). The remaining sediment equals approximately 4 million cubic yards; 95% of which is suspended load. Forty-five percent of this suspended load is carried in the winter months (Shoellhamer 2000).

Table 4.12-4
Delta Sediment Budget

	Pre 1985 (mcy) [1]	1849–1914 average (mcy) [1]	1955–1990 average (mcy) [2]	1990 (mcy) [2,3]	2035 (mcy) [2,3]
Inflow	2.0	22.9	7.7	6.1	6.0
Deposition	0.4	4.5	0.0	0.0	0.0
Dredging	-	-	0.5	0.5	0.5
Water withdrawals	-	0.0	1.3	1.6	2.0
Outflow to Bay	1.6	18.4	5.9	3.9	3.5

Source: NHI 2002
[1] Gilbert 1917
[2] Krone 1996
[3] Beeman 1992

Methods of Suspended Sediment Capture

Sediment transport in rivers is a function of particle characteristics and stream characteristics. Particle characteristics include diameter, shape, specific gravity, and settling velocity. Stream characteristics include flow velocity, velocity pulsation, water density, kinematic viscosity, depth of flow, and surface slope (Shoellhamer 2000).

To induce deposition in the Delta, channels could be widened to decrease flow velocity and depth, or to direct flow across shallow, rough terraces, enhanced with subsurface features (e.g., fences, recycled Christmas trees) that reduce velocity and induce sediment deposition.

One approach for capturing a small amount of bed load and suspended sediment is to construct setback levees that widen the floodplain to encourage deposition of sediment on re-exposed historic point bars. Over many decades, this approach would take advantage of the existing hydrologic regime to rebuild island surfaces, provide flood attenuation benefits, reduce shear stress on existing peripheral levees in the event of high water, and slightly reduce the inflow of unwanted sediment to San Francisco Bay.

Methods of Bed-load Capture

Bed load consists of less than 5% of the total sediments transported through the Delta; approximately 200,000 cubic yards a year (Shoellhamer 2000). Relative to the total subsidence volume of 600 mcy in the western Delta, this quantity is minor.

Shoaling of bed materials in the Delta may offer an untapped, local source of fill materials in the Delta. In the same way that dredge spoils from aggraded channels provide material, shoals of sand that deposit after high-flow events could provide fill material for enhancement projects.

USGS is investigating the processes associated with bed-load transport in the Delta. A comprehensive mapping of shoaling will not be completed for many years. Studies in Threemile Slough provide anecdotal insight into potential enhancement opportunities provided by the use of shoaling (Oltmann, Schoellhamer, Dinehart 1999). Threemile Slough connects the Sacramento and the San Joaquin rivers above the eastern end of Sherman Island. After high-flow events, the river creates wave-like bed forms in the southern end of the slough that migrate toward the Sacramento River at a rate of 100 tons a day. Assuming a specific weight for migrating sand of 1,900 kg/cubic meter, this equals approximately 70 cubic yards of sand a day moving through and out of Threemile Slough.

USGS has also located similar shoaling phenomena in the Mokelumne River and alongside Decker Island, suggesting that there may be many sites throughout the Delta with fluvial sediment available for use in enhancement projects.

OTHER IMPORTED FILL

The Montezuma Hills, immediately north of the Sacramento River, offer a nearly limitless supply of rock and soil. Examination of USGS 7.5-minute quad maps reveals

11.5 million cubic yards of sediment deposits between the Sacramento River and the hills. The hills are composed of thousands of acres of rock and fill material that could be used should it become desirable to extract this material for use in the Delta.

5 DATA GAPS AND RECOMMENDED FUTURE STUDIES

Based on an review of the existing information included in Chapter 4 of this document and of the preliminary objectives identified for the Feasibility Study in the CALFED grant application, a discussion of data gaps between available information and information that would be useful in and may be collected for the Feasibility Study is included below, listed by sections from Chapter 4. Where applicable, the data gap is divided between those that may be studied before the completion of the initial design phase, estimated to end in 2006, and those that require long-term research but may be useful in the subsequent adaptive management phase. It is noted that given time and budget constraints, it is not feasible to develop data for most of the data gaps identified herein. The identification of data gaps is useful in and of itself for the understanding of the uncertainties involved in working with dynamic nature of the Delta.

The complexities of the ecological and water quality processes of the Delta and availability of only short-term information regarding specific study areas make it difficult to assess existing conditions and probable ecosystem responses to variable changes in the Delta. Depending on the degree of changes to environmental conditions following restoration, the data gaps may hamper the ability to make accurate predictions of effects. The adaptive management approach that may be included in the Feasibility Study would allow for filling of remaining data gaps through direct and indirect evidence collected and reported over the implementation period associated with the Feasibility Study. Monitoring, evaluating, and adaptively adjusting the design and function of an associated enhancement program can increase the probability of long-term success.

5.1 SECTION 4.1 BATHYMETRY, TOPOGRAPHY, AND SEDIMENTATION

5.1.1 DESIGN PHASE DATA GAPS

The bathymetric data appears of sufficient detail to support future modeling scenarios on a large scale; however, more site-specific surveys may be needed for detailed assessments of specific study areas. The least understood factor is the potential for sedimentation at Franks Tract. It would be useful to assess present trends by replicating the detail of the 1992 bathymetric survey, and by assessing suspended load supply in the upper water column.

There appears to be sufficient wind data available to develop and assessment of wind wave energy within Lower Sherman Lake. It would also be instructive to assess historical erosion rates at shorelines in and around the study area as a means to assess potential erosion.

5.1.2 SUBSEQUENT PHASE DATA GAPS

It may be instructive to apply some of the recent assessment of sedimentation rates and data compiled for the IRWA and BREACH projects for restored intertidal areas as a means to predict potential sedimentation rates in created islands and intertidal areas.

5.2 SECTION 4.2 GEOLOGY, SOILS, AND SEISMICITY

5.2.1 DESIGN PHASE DATA GAPS

Detailed information regarding the soil types within the three study areas is generally lacking. In general, it is known the material is mostly comprised of peat, however, there may be localized areas of silt and sand that would be better suited for construction of habitat features (i.e. islands). Additional soil data from within the flooded portions of the study areas would be helpful for determining soil type availability within the habitats. Phillip Williams and Associates has recently taken core samples from Franks Tract for the BREACH project. This data could provide valuable information regarding localized distribution of sediment types throughout Franks Tract.

In order to be able to construct islands or recreational facilities at the three flooded islands, it is critical to know the soil composition and therefore investigation of this is recommended.

5.2.2 SUBSEQUENT PHASE DATA GAPS

None are identified at this time.

5.3 SECTION 4.3 METEOROLOGY AND CLIMATOLOGY

5.3.1 DESIGN PHASE DATA GAPS

None are identified at this time.

5.3.2 SUBSEQUENT PHASE DATA GAPS

The specific effects of climate, particularly winds and atmospheric pressure, on hydrodynamics and shore erosion (and associated processes) in the Delta and at the three flooded islands study areas are not well understood (see bathymetry, topography, and sedimentation data gaps above). An increased understanding of seasonal and episodic climatic influences on existing conditions and potential restoration alternatives would be useful.

Trends in global warming are apparent and recognized but the effects on the Delta are not well defined. Additional information is needed regarding global warming and the potential effects on restoration efforts and overall management of the Delta. Changes in sea level, precipitation, snowpack, and/or seasonal runoff have the potential to greatly alter the Delta from its current state.

5.4 SECTION 4.4 WATER QUALITY

This Baseline Report provides detailed information on the primary water quality issues related to the Feasibility Study. In general, the description of the sources, transport, processes, and considerations apply to the Delta as a whole with site specific information provided where available. Additional information specific to each of the study areas would be useful to better understand the unique complexities and dynamics and to help anticipate how restoration activities may influence changes in water quality locally and throughout the Delta. The forthcoming *Task 3: Develop and Calibrate Model* of the overall Feasibility Study will serve to increase this site specific knowledge of water quality processes at each of the three flooded islands sites.

5.4.1 SALINITY

DESIGN PHASE DATA GAPS

Multi-dimensional hydrodynamic and salinity modeling should be completed in order to assess the needs for future project feasibility and design purposes, and to assess the need for supplemental analysis that may be necessary for a defensible environmental impact analysis. Modeling suggestions are as follows:

- Complete calibration and validation of the coding and the existing conditions at the sites.
- Use the model to evaluated salinity and hydrodynamic conditions under several restoration project scenarios. Scenario development should be sufficient to demonstrate the potential range of effects associated with individual sites and on a cumulative basis.
- Utilize multi-dimensional modeling alone, or potentially with DSM2, to evaluate need for wide-scale Delta effects modeling over longer time scales and in relation to other major future Delta projects being developed (i.e., South Delta Improvements, in-Delta Storage).
- Because Frank's Tract is centrally located with adjacent agricultural areas subject to freshwater flows, restoration opportunities that increase salinity in surrounding channels may require detailed evaluation. Modeling and operations staff should evaluate existing information and simulated conditions to identify whether additional in-Delta monitoring stations would need to be constructed to adequately verify existing conditions and project-related effects to agricultural users.
- For feasibility planning, salinity evaluations need to be closely coordinated with aquatic biologists and botanists to identify suitable methods and metrics for the evaluation of salinity effects on ecosystem processes.
- For feasibility planning, long-term climatic changes and potential variability in Delta salinity conditions should be explicitly evaluated to describe the potential relationships to restoration effects.

SUBSEQUENT PHASE DATA GAPS

Because the restoration activities have the potential to influence salinity conditions for Delta water users, modeling data and information gained through the more detailed EIR evaluation process should be used to identify whether additional water quality monitoring stations will be required to accurately assess project effects and/or provide appropriate information for adaptive management actions.

5.4.2 Mercury

Design Phase Data Gaps

None are identified at this time.

Subsequent Phase Data Gaps

The following are identified:

- Additional research is needed to better understand the specific processes and combination of environmental factors that promote or potentially inhibit mercury methylation in the Bay-Delta. The scale and level of effort needed to further describe and assess methyl mercury processes depend on the degree of changes expected in environmental conditions at the study areas following restoration activities.
- The availability of inorganic mercury for methylation can vary greatly, and newly deposited mercury may be much more reactive than mercury that has been residing in the ecosystem. The relative bioavailability of mercury derived from atmospheric deposition versus residual mercury from mining sources is an important information gap, one that hinders the confirmation of mercury sources contributing to internal production of methyl mercury in this Bay-Delta ecosystem.
- Additional research is needed to quantify the production of methyl mercury in the wetland habitats and determine the contribution these habitats make with respect to the mercury budget of the Bay-Delta.
- Additional information on major source locations, speciation, mobility, and bioavailability (for methylation) of mercury from mercury and gold mining would be useful for developing strategies for upstream remediation.
- Additional understanding of the contribution of contaminated sediments to overall budgets for mercury and methyl mercury, with emphasis on active pools that contribute methyl mercury to the benthic and pelagic food webs.

5.4.3 Organic Carbon

Design Phase Data Gaps

Additional information on water residence time in the study areas, especially Franks Tract, is needed to determine phytoplankton incubation potential.

SUBSEQUENT PHASE DATA GAPS

Additional information on the role restored tidal wetlands might play in influencing carbon sources, transport, and processes. Specifically, how these influences effect drinking water quality and ecosystem function. Regarding drinking water quality, the issues are the quantity and quality factors of organic carbon from the different sources in the Delta to form THMs and other DBPs of concern. Ecosystem issues revolve around the different types and amounts of organic carbon production possible in tidal wetlands including primary production by benthic microalgae, vascular plants, and phytoplankton. Conceptually, minimizing DOC export from restored tidal wetlands would be beneficial; however, it is unclear how such reductions could be accomplished for large areas of tidal wetlands.

Additional information on how location of tidal wetlands (or other sources of organic carbon) and hydrodynamics interact to determine if tidal wetland organic carbon is utilized by primary consumers and/or exported by the water projects or exported into Suisun Bay.

5.5 SECTION 4.5 AQUATIC, WETLAND, AND TERRESTRIAL VEGETATION AND HABITATS

5.5.1 DESIGN PHASE DATA GAPS

Detailed vegetation surveys and mapping for the emergent portions Franks Tract and Lower Sherman Lake would be helpful to determine percentage of native species, overall cover, and locations of invasive plant species. Surveys would also be needed to refine the existing vegetation maps in order to ensure a higher level of accuracy. This information would be useful in determining level of impacts (if any) to emergent vegetation from project implementation. In addition, determining elevations and types of plant communities located on in-channel islands and around the perimeter of the flooded islands can serve as analog sites to model future habitat creation endeavors.

5.5.2 SUBSEQUENT PHASE DATA GAPS

None are identified at this time.

5.6 SECTION 4.6 AQUATIC COMMUNITIES AND FOOD WEB

5.6.1 DESIGN PHASE DATA GAPS

None are identified at this time.

SUBSEQUENT PHASE DATA GAPS

The discussion presented on aquatic communities and the food web is generalized for the Delta and no study area-specific data was provided. Specific information for each of the study areas would be useful to better understand the existing biological interactions and processes and how restoration alternatives may influence their function.

5.7 SECTION 4.7 FISH AND WILDLIFE

5.7.1 FISHERIES

DESIGN PHASE DATA GAPS

The fisheries community composition for each study area was largely characterized based on sampling data from locations in the vicinity of each area. Fish sampling data for locations in the study areas is extremely limited and, therefore, the fisheries existing conditions may not fully capture differences in community structure related to each of the individual study areas and at different habitats within each area. An additional gap relates to fish movement through the study areas and how restoration activities might affect passage. An ongoing fish movement study by Dave Vogel (under contract with DWR) may provide valuable information on this subject.

SUBSEQUENT PHASE DATA GAPS

Additional information on fish community structure at each of the three study areas would be useful to better understand existing conditions as well as fish responses to potential restoration alternatives. Restoration efforts should look at what phytoplankton species and associated habitat conditions provide the best foraging opportunities for desirable fish species.

5.7.2 AVIAN AND OTHER WILDLIFE SPECIES

DESIGN PHASE DATA GAPS

Surveys of the three study areas can provide more specific information regarding species that are likely utilizing the study areas. This information can help guide habitat creation efforts by modeling design specifications on desirable habitat types (e.g., in-channel islands).

SUBSEQUENT PHASE DATA GAPS

Salinity levels at Big Break and Lower Sherman Lake would be helpful in determining if restoration could include the creation of habitat for salt-marsh harvest mouse. For the same purpose, flooding frequency would be helpful for Lower Sherman Lake.

5.8 SECTION 4.8 INVASIVE SPECIES OF CONCERN

5.8.1 EGERIA

DESIGN PHASE DATA GAPS

Information that we were unable to obtain for this report is the current egeria mapping data and coverage estimates from the Romberg Tiburon Center for Environmental Studies at San Francisco State University (requested on November 17, 2004 from Patricia G. Foschi, Professor of Geography). In addition, research is continuing on control methods, distribution, and hydrodynamics in relation to this species. Currently Dr. Lars Anderson is conducting additional research on effective treatment for egeria removal and the effects of herbicide treatments on the ecology and biology of the flooded islands. This information would be valuable in determining the feasibility and methods for egeria control in the flooded islands. Additionally, Sereno, D.M. and M.T. Stacey. (U.C. Davis) are conducting research regarding the effects of SAV on hydrodynamics of the flooded islands. This information could be useful to future water quality modeling including project alternative scenarios modeling.

SUBSEQUENT PHASE DATA GAPS

Information is lacking regarding whether egeria is causing increased sedimentation and whether this is occurring at rates that would cause shoaling over a given period of time. Another gap is the hydrodynamic relationship between egeria and phytoplankton, salinity concentration tolerances, as well as pollutant uptake by them.

5.8.2 CORBICULA

DESIGN PHASE DATA GAPS

Although calculated Corbicula densities are probably sufficient for Franks Tract, actual densities within Franks Tract, and the extent of colonization in Big Break and Lower Sherman Island would be helpful.

SUBSEQUENT PHASE DATA GAPS

Residence times and circulation (i.e. hydrology) for all three study areas would be helpful in determining phytoplankton production and its correlation with Corbicula grazing. This information would be essential for restoration design if one of the objectives of restoration would be to attempt to increase phytoplankton production to stabilize Delta fish populations and other trophic levels of the food web.

Carbon production (e.g. phytoplankton production) for all three study areas would be essential for restoration design if one of the objectives of restoration would be to attempt to increase productivity of the ecosystem.

Understanding why Corbicula do not grow in south Mildred Island would help us predict the results of project design on Corbicula colonization, and possible effects on phytoplankton consumption.

Gaps in knowledge include factors that affect the clams and their lifecycles, as well as pollutant uptake by clams.

5.9 SECTION 4.9 LAND USE

5.9.1 DESIGN PHASE DATA GAPS

Identification of the ownership of Vintage Marsh at the Big Break study area would be essential in order to establish working relationships with the property owner.

5.9.2 SUBSEQUENT PHASE DATA GAPS

None are identified at this time.

5.10 SECTION 4.10 WATER USE

5.10.1 DESIGN PHASE DATA GAPS

Water resource and water use information have been well studied and are available. With the publication of the forthcoming update of the California Water Plan, water shortages and potential solutions, some of which are expected to be associated with the study areas, would be identified. Coordination between the Feasibility Study and the Water Plan update is essential.

5.10.2 SUBSEQUENT PHASE DATA GAPS

No data gap is identified at this time.

5.11 SECTION 4.11 RECREATION

5.11.1 DESIGN PHASE DATA GAPS

Recreation uses at rate of use at each of the study areas are not well known, although empirical information is available from EBRPD and from DPR, as stated in this document. Additional surveys of the study areas would be useful to identify key areas for existing recreational uses.

5.11.2 SUBSEQUENT PHASE DATA GAPS

Monitoring of recreational use of any restored islands would be useful to assess compatibility of recreational uses with habitat restoration and water quality goals.

5.12 SECTION 4.12 MATERIALS FOR RESTORATION

5.12.1 DESIGN PHASE DATA GAPS

Identification of sources of materials available and the associated costs would be useful for the design phase.

5.12.2 SUBSEQUENT PHASE DATA GAPS

None are identified at this time.

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