Chapter 2
Existing Ecological Conditions

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Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
af	acre-feet
BDCP or the Plan	Bay Delta Conservation Plan
BiOp	biological opinion
CDFW	California Department of Fish and Wildlife
Central Valley Water Board	Central Valley Regional Water Quality Control Board
cfs	cubic feet per second
CNPS	California Native Plant Society
CVP	Central Valley Project
DPS	distinct population segment
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
ESA	Endangered Species Act
GIS	geographic information system
LiDAR	Light Detection and Ranging
LSZ	low-salinity zone
mg/L	milligrams per liter
MHHW	mean higher high water
MLLW	mean lower low water
MMU	minimum mapping units
NAIP	National Agriculture Imagery Program
NCCPA	California Natural Community Conservation Planning Act
NWR	National Wildlife Refuge
PG&E	Pacific Gas and Electric
POD	pelagic organism decline
ppt	parts per thousand
Reclamation	Bureau of Reclamation
SAIC	Science Applications International Corporation
SR	State Route
SWP	State Water Project
TMDL	total maximum daily load
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Chapter 2
Existing Ecological Conditions

2.1 Introduction

This chapter describes the existing ecological conditions present in the Bay Delta Conservation Plan (BDCP or the Plan) Plan Area, including specific information to meet the requirements of the federal Endangered Species Act (ESA) and the California Natural Community Conservation Planning Act (NCCPA). The Plan Area encompasses approximately 862,703 acres, and includes the statutory Delta as defined in the California Water Code, Section 12220, Suisun Marsh (approximately 107,837 acres), and the upper Yolo Bypass (approximately 16,762 acres) (Figure 1-1, *Plan Area Location*, in Chapter 1, *Introduction*).

Section 2.2, *Historical Conditions*, provides a brief summary of the physical and biological conditions that were historically present within the Plan Area, as well as historical conditions upstream and downstream of the Delta as they relate to supporting conditions of the historical Delta. Current physical and biological conditions of the Plan Area are described in Section 2.3, *Existing Ecological Conditions,* which provides descriptions of natural processes in the Plan Area, its physical environment, and its biological communities. Section 2.4, *Biological Diversity*, provides a summary of the biological diversity within the Plan Area.

A total of 56 species are proposed for coverage under the BDCP. Detailed information about each of these species is provided in Appendix 2.A, *Covered Species Accounts*, including life-history characteristics, historical and current distribution, designated critical habitat, essential habitat, and key stressors that affect species distribution and abundance.

The ecological information presented in this chapter and in Appendix 2.A support the evaluation of the potential effects of covered activities on proposed covered species and natural communities and for the development of measures to address the conservation of covered species and natural communities.

2.2 Historical Conditions

This section provides a brief overview of historical physical and biological environmental conditions of the Plan Area and environmental conditions present upstream and downstream of the Plan Area as they relate to supporting the description of conditions within the Plan Area.

2.2.1 Hydrologic and Geomorphic Conditions

Much of the broad scale geology of the Central Valley, Delta, and Suisun Marsh was formed before the Pleistocene epoch (more than 2 million years ago), while finer details wrought by younger geologic formations, including the recent uplift and movement of the Coast Range and the deposition of broad alluvial fans along both sides of the Central Valley, formed during the Pleistocene epoch from 2 million to 15,000 years ago (Loudeback 1951; Olmsted and Davis 1961; Lydon 1968, Shelmon 1971; Atwater et al. 1979; Marchandt and Allwardt 1981; Helley and Harwood 1985;

Sarna-Wojcicki et al. 1985; Weber-Band 1998; Unruh and Hector 1999; Graymer et al. 2002; Weissmann et al. 2005; Unruh and Hitchcock 2009). Approximately 21,000 years ago, the last glacial maximum ended and the eustatic (worldwide) sea level began to rise from the lowstand (lowest sea level bathymetric position or depth during a geologic time) of -394 feet (-120 meters) in a series of large meltwater pulses interspersed by periods of constant rising elevation. The rise continued until the Laurentide ice sheet had completely melted 6,500 years ago and the rate of sea level rise slowed dramatically (Edwards 2006; Peltier and Fairbanks 2006). During this change from glacial to interglacial period, runoff brought enormous quantities of sediment from the Sierra Nevada and Coast Range that formed alluvial fans and altered stream channels in the Central Valley (Olmsted and Davis 1961; Shelmon 1971; Marchandt and Allwardt 1981; Helley and Harwood 1985; Weissmann et al. 2005).

The modern Delta formed sometime between 10,000 and 6,000 years ago when the rising sea level inundated a broad valley that occupied the Plan Area region. Despite its name, the Sacramento-San Joaquin Delta is not simply the merging of two river deltas, but is instead an elongated and complex network of deltas and flood basins with flow sources that include Cache Creek, Putah Creek, Sacramento River, Mokelumne River, San Joaquin River, and Marsh Creek. Based on current unimpaired flow estimates, the Sacramento River is the largest source of flows and has contributed an average of 73% of historical inflows into the Delta. The eastside tributaries, including the Mokelumne River, contribute about 6%, and the San Joaquin River contributes 21% (California Department of Water Resources 2007a).

Currently, during high-flow events, approximately 80% of flows from the Sacramento River pass through the Yolo Bypass (Roos 2006). The flood stage flows can have many sources, including direct flows from tributaries such as the Feather and American Rivers, as well as through a system of passive and active weirs (James and Singer 2008; Singer et al. 2008; Singer and Aalto 2009). The Yolo Bypass also serves as a conduit for Cache Creek and Putah Creek as their waters do not reach the Sacramento River until they pass through Cache Slough at the southern end of the Yolo Bypass. The San Joaquin River discharges into a broad network of sloughs and channels, and the Mokelumne River delta merges with the San Joaquin River delta on the eastern side of the Delta. On the southwest side of the Delta, the Marsh Creek delta merges with the San Joaquin River delta.

While flooding has always been a regular occurrence along the Sacramento River (Thompson 1957, 1960, 1961, 1965), the natural geomorphic processes and hydrologic regimes were completely disrupted through the enormous increase in sediment and debris supply generated by hydraulic mining operations in the central Sierra Nevada from 1853 to 1884 (Gilbert 1917; Mount 1995). Large volumes of mining sediment remain in the tributaries today (James 2004a, 2004b). The portion of the estimated 1.5 billion cubic feet of sediment that poured into the Sacramento Valley filled river channels and increased flooding severity and peak flows (Gilbert 1917; Kelley 1989; Mount 1995; James 2004a; Hitchcock et al. 2005; William Lettis & Associates 2005; James 2006; Central Valley Regional Water Quality Control Board 2008; James and Singer 2008; James et al. 2009). In the 1900s, another pulse of mining sediment was discharged into the Sacramento River watershed (James 1999). While it is often assumed the mining sediment has already passed through the Delta or is stored behind dams, large amounts remain within the system (James 1999, 2004a, 2004b, 2006; James and Singer 2008; James et al. 2009). Other Central Valley streams, such as the Cosumnes River, have been affected to a lesser extent by similar mining or agriculture-derived sources of sediment (Florsheim and Mount 2003). The initial pulse of sediment made its way into the San Francisco Estuary where it filled shallow tidal bays, but with current reduced sediment loads, these sediments are being eroded and transported into the Pacific Ocean (Cappiella et al. 1999; Ganju and Schoellhamer 2010).

Soils in the Plan Area are extremely variable in texture and chemical composition. In the interior of the Delta, soils are generally a combination of peat beds in the center of islands with relatively coarse textured inorganic sediments deposited in the channels and along the margins of the islands (William Lettis & Associates 2005; Unruh and Hitchcock 2009; Deverel and Leighton 2010). Ancient dune deposits on the islands and shoreline of the western Delta near the San Joaquin River predate the peat beds (Carpenter and Cosby 1939; San Francisco Estuary Institute 2010). The soils in the Suisun Marsh area are generally peat or fine textured mineral soils in and along the islands closest to Suisun Bay, and fine textured mineral soils are found closer to the border of the marsh where it abuts the uplands. The soils of the Cache Slough area are primarily mineral soils that are either fine-textured and of local origin, or coarse-textured material that is a legacy of gold mining in the Sierra Nevada and streams leading from the Sierra Nevada. The uplands north of Suisun Marsh and west of the Sacramento River are generally alkaline clays (Mann et al. 1911; Bryan 1923; Thomasson Jr. et al. 1960; State of California 1987; Graymer et al. 2002). The soils of the Yolo Basin are alkaline clays on the west side, a mixture of clay, sand and peat on the bottom of the basin, and silts with sand splays on the natural levee of the Sacramento River (Anonymous 1870; Mann et al. 1911; Andrews 1970). The soils along the southwestern border of the Delta are sands to the north and alkaline clays to the south (Carpenter and Cosby 1939; Natural Resources Conservation Service 2009; San Francisco Estuary Institute 2010). Along the eastern border of the Plan Area, the soils are heterogeneous patches of clays, loams, and peat (Florsheim and Mount 2003; Natural Resources Conservation Service 2009).

It is estimated that prior to reclamation actions (filling, levee construction, diking, and draining), nearly 60% of the Delta was inundated by daily tides. The tidal portion of the Delta consisted of backwater areas, tidal sloughs, and a network of channels that supported highly productive freshwater tidal marsh and other wetland habitats (CALFED Bay-Delta Program 2000). Similar complex drainage networks, ponds, and salt panes existed in tidal brackish marshes in Suisun Marsh and along the north shore of east Contra Costa County (Suisun Ecological Workgroup 2001; Brown 2004; Grossinger 2004; San Francisco Estuary Institute 2010). The soils in these marshes were generally peat beds that accumulated and were preserved under anoxic conditions. In contrast, soils in channels and along the higher energy channel margins of islands tend to be comprised primarily of mineral sediment (William Lettis & Associates 2005; Unruh and Hitchcock 2009).

Reclamation occurred over vast areas in the Delta, Yolo Basin, Suisun Marsh, and the south shore of Suisun Bay between the 1850s and the early 1930s, completely transforming their physical structure (Figure 2-1) (Thompson 1957, 1965; Suisun Ecological Workgroup 2001; Brown 2004; Grossinger 2004; San Francisco Estuary Institute 2010; Whipple et al. 2012). Levee ditches were built to drain land for agriculture, human habitation, mosquito control, and other human uses while channels were straightened, widened, and dredged to improve shipping access to the Central Valley and to improve downstream water conveyance for flood management. During this period, over 300,000 acres of tidal marshes in the Delta were diked, drained, and converted to agriculture (Anonymous 2012:4-5). Thus, the complex, shallow, and dendritic marshlands were replaced by simplified, deep, and barren channels. This hydrogeomorphic modification fragmented aquatic and terrestrial habitats, and decreased the value and quantity of available estuarine habitat (Herbold and Vendlinski 2012; Whipple et al. 2012).

Floodplain includes areas that are inundated by overbank flow during the winter and spring peak flows. Inundation can last for up to several months. In presettlement times, floodplain was arguably one of the most productive natural communities in the Delta and its loss can be linked to the decline of many native Delta species. Reclamation, channel modification for flood control, and water removals for agriculture and export have resulted in a substantial reduction in floodplain areas. Floodplains provide important habitat for rearing, migrating, and adult fish; migratory waterfowl; and terrestrial amphibians, reptiles, and mammals native to the Delta.

Under natural conditions, inflows from both the Sacramento and San Joaquin Rivers were much lower from July through November compared to the December to June period (The Bay Institute 1998) and in drought periods likely lead to salinity intrusions. This difference was more dramatic in the San Joaquin River. The San Joaquin River has an upper watershed consisting of impermeable granitic rock that does not support dry season groundwater discharge. In contrast, the upper watershed of the Sacramento River is composed of permeable volcanic rock. As a result, groundwater discharge from this volcanic system historically maintained a summer base flow at Red Bluff of approximately 4,000 cubic feet per second (cfs) without which the Sacramento River would have nearly dried up each fall (The Bay Institute 1998).

Water diversions in the San Joaquin Valley began earlier than those in the Sacramento Valley; and by 1870, flows of the San Joaquin River were significantly reduced (California Department of Water Resources 1931; Jackson and Patterson 1977). Sacramento River diversions, particularly late spring and summer diversions for rice irrigation, increased dramatically from 1912 to 1929. The combination of significant drought periods and increased diversion during the annual low-flow period resulted in an unprecedented salinity intrusion into the Delta in fall 1918 (California Department of Water Resources 1931; Jackson and Patterson 1977; The Bay Institute 1998; Contra Costa Water District 2010). The economic impacts of these diversion-caused saltwater intrusions ultimately led to the creation of the Central Valley Project (CVP) and the construction of dams for the storage and release of fresh water to prevent salinity intrusion (Jackson and Patterson 1977). Construction of dams and diversions on all major rivers contributing to the Delta between the 1930s and 1960s resulted in substantial changes to Delta hydrodynamics (The Bay Institute 1998; Contra Costa Water District 2010). Four dams (Shasta, Oroville, Trinity, and Monticello) in the Sacramento Valley have a storage capacity greater than 1 million acre-feet (af) (12 million af total); an additional four dams (New Melones, Don Pedro, New Exchequer, and Pine Flat) with storage capacity greater than 1 million af (6.5 million af total) drain into the San Joaquin Valley (California Department of Water Resources 1993).

The main effect of this upstream water development was the dampening of the seasonal high and low flows into the Plan Area (Contra Costa Water District 2010). Reclamation of the Delta and upstream water development also accentuated salinity intrusions into the Plan Area. Current water management regulations have reduced the annual fluctuations in saltwater intrusion, but have also shifted the boundary between fresh and salt water significantly further into the Delta (Contra Costa Water District 2010). In combination with dam construction, flood management and water operations have greatly transformed the geometry and hydrology of the Delta, as well as for downstream locations including Suisun Bay and Suisun Marsh (Section 2.3.2, *Ecosystem Processes*).

2.2.2 Biological Conditions

Prior to the Gold Rush era (c. 1850), the predominant vegetation of the Delta consisted of bulrushes and tules (*Schoenoplectus*[1] spp.), which are adapted to the range of salinity present in the Delta from fresh water to as much as 2 parts per thousand (ppt) in the western Delta in the later summer (Thompson 1957; Atwater and Belknap 1980). The area was described as a vast, sea-level swamp with tracts of intertidal wetland and a network of channels of various sizes. The characterization of the historical Delta as a vast tule marsh, however, is an oversimplification from an ecological standpoint, and fails to reflect the considerable habitat complexity and diversity that allowed the Delta ecosystem to support such an unusually rich and diverse native biological community (The Bay Institute 1998).

Generally, the current vegetation of the Delta is similar to the historical vegetation, and the vegetation of the tidal freshwater areas of the central Delta down to about 18 inches below mean lower low water (MLLW) falls into two general categories. Tules (generally *Schoenoplectus californicus*), cattails (*Typha* spp.), and willows (*Salix* spp.) dominate the vegetation along the Sacramento River, while throughout the San Joaquin River area of the Delta bulrushes (generally *Schoenoplectus acutus*), tules, common reed (*Phragmites australis*), and willows are more often the dominant species (Atwater 1980; Simenstad et al. 2000; Watson 2006; EDAW 2007a; Hickson and Keeler-Wolf 2007; Watson and Byrne 2009).

Further west, from about the vicinity of Collinsville, the tidal brackish marsh vegetation is characterized by bulrush, tules, common reed, and cattail (Culberson 2001; Suisun Ecological Workgroup 2001; Watson and Byrne 2009; San Francisco Estuary Institute 2010). These same large species occur as clumps in the tidal channel to the marsh plain transition zone and share that zone with many other species such as saltgrass (*Distichlis spicata*), Baltic rush (*Juncus balticus*), and seaside arrowgrass (*Triglochin maritima*). The borders of the smallest channels (first order channels and mosquito ditches) are also habitat for Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*), which is a covered species. The boundary between the distant edge of the transition zone and marsh plain is gradual as there is very little change in the elevation of the marsh plain; and this is where soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*), a covered species, occurs with pickleweed (*Salicornia pacifica,* formerly *Salicornia virginica or Sarcocornia pacifica*), saltgrass, salt marsh dodder (*Cuscuta salina*), and spearscale (*Atriplex triangularis*). The marsh plain proper is dominated by a variable mixture of pickleweed and saltgrass.

Historically, the perimeter of the Plan Area consisted of tidal and nontidal wetlands and mudflats that merged with upland vegetation types that included nontidal wetlands, meadows, oak savanna, alkali grasslands, vernal pools, and alkali sink scrub. Due to their productivity and heterogeneity, vegetation in the uplands formed complex physical habitats that consisted of herbaceous species (grasses and dicots), shrub species (willows, blackberries [*Rubus*], wild roses [*Rosa*]), and a mixture of tree species such as oak (*Quercus*), sycamore (*Platanus*), alder (*Alnus*), walnut (*Juglans*), and cottonwood (*Populus*). Mammals using these upland habitats included tule elk (*Cervus elaphus nannodes*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), grizzly (*Ursus arctos*), coyote (*Canis latrans*), American badger (*Taxidea taxus*), ground squirrel (many spp.), pocket gopher (*Thomomys*), cottontail (*Sylvilagus audubonii*), and black-tailed jackrabbit (*Lepus californicus*) in drier areas (Grinnell et al. 1937; Thompson 1957). Much of this flora and fauna was

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[1] The genus was formerly *Scirpus.*

severely reduced with reclamation and the development of agriculture that began in the early 1850s.

High tule productivity combined with the rich organic sediments of the basins along the Sacramento and San Joaquin Rivers and the channels and channel-to-marsh plain transition zones of Suisun Marsh provided large amounts of organic matter support for the aquatic foodweb. This organic matter input probably resulted in abundant biomass of zooplankton (detritivores, scavengers, and filter-feeding planktivores) (The Bay Institute 1998). The large and complex foodweb also likely supported an abundant assemblage of fishes.

Because the Delta environment and its fish species assemblage has changed significantly and was not documented prior to the changes, there is limited knowledge of the ecology of native fishes in the past (Moyle 2002). It is known that the historical assemblage of fish in the Delta was very different from the current assemblage. For example, thicktail chub (*Gila crassicauda*) was driven to extinction in the 1950s, most likely due to marsh reclamation impacts and the introduction of nonnative fish species (Schulz and Simons 1973). Also, the Sacramento perch (*Archoplites interruptus*), once very abundant in sloughs off main channels, was extirpated from the Delta for the same reasons (Rutter 1908). Conversely, a large number of nonnative species of fish have been deliberately introduced (e.g., striped bass [*Morone saxatilis*], channel catfish [*Ictalurus punctatus*], and largemouth bass [*Micropterus salmoides*]), or introduced into the system as cast offs (e.g., goldfish [*Carassius auratus auratus*]). Further, the abundance of many species of native fish was much greater historically than currently. For example, Chinook salmon (*Oncorhynchus tshawytscha*) were once very abundant throughout the Delta and Sacramento–San Joaquin Rivers and tributaries, but today their abundance is low for many reasons (Appendix 2.A, *Covered Species Accounts*). The freshwater range of anadromous fish, such as salmonids (Salmonidae) and sturgeon (*Acipenser*) was much greater historically before the construction of dams, and the degradation of suitable habitat below dams significantly reduced the extent of spawning habitat. Fish likely fed on dominant crustaceans, such as the mysid *Neomysis*, the amphipod *Corophium*, and cyclopoid copepods (Moyle 2002), which have been replaced as dominant species by multiple nonnative copepod species, including *Limnoithona*, *Pseudodiaptomus*, and *Acanthomysis* (Sommer et al. 2007).

2.3 Existing Ecological Conditions

2.3.1 Data Sources and Natural Community Classification

2.3.1.1 Data Sources

Background data for the BDCP were collected through an extensive search of various sources, including current scientific literature, reports, technical documents, agency-maintained data (e.g., CALFED, Interagency Ecological Program, California Department of Fish and Wildlife [CDFW], and California Department of Water Resources [DWR]), and BDCP documents (e.g., BDCP Independent Science Advisors Report [Reed et al. 2007]). A full list of background data sources is provided in Section 2.5, *References Cited*. Where data were not available, or where significant uncertainties were identified through initial data gathering and synthesis, technical experts were engaged to provide unpublished data and best professional scientific judgment. Various technical experts participated in developing, writing, and reviewing the descriptions of the natural communities (Section 2.3.4, *Natural Communities*) and the accounts of covered species (Appendix 2.A, *Covered Species Accounts*).

Citations and references pertaining to individual covered species are embedded in the species accounts in Appendix 2.A.

Map data layers were compiled from existing spatial datasets, primarily produced by state and federal agencies and available on their websites, or by data transfer. Modifications that have been made to help refine the map data layers (particularly for the vernal pool complex) are summarized in Appendix 2.B, *Vernal Pool Complex Mapping and Modifications to Natural Community Mapping*. The sources and types of spatial information used in this report are presented in Table 2-1.

Table 2-1. Spatial Data Sources

Map Layer	Data Type	Data Source
Bathymetry	Raster	DWR, USGS
Conservation lands	Vector	CPAD, CDFW, CaSIL
Geology	Vector	USGS
Hydrography	Vector	USGS, CDFW, CaSIL
Land cover type/vegetation community type	Vector	CDFW, Yolo County, DWR
Land ownership	Vector	DWR, CDFW, CPAD
Land use/farmland	Vector	DWR, USDA
Levees and major water projects	Vector	DWR
Major water operations	Vector	DWR, CaSIL
NAIP aerial imagery	Raster	USDA
Parcel boundaries	Vector	Solano, Sacramento, Yolo, San Joaquin, Alameda, and Contra Costa Counties
Physical geography/Delta legal boundary	Vector	CaSIL
Road, rail and communication infrastructure	Vector	CaSIL, DWR, TIGER
Soils	Vector	NRCS
Species distribution and habitat range	Vector	CDFW, USFWS
Topography/elevation	Vector/raster	DWR, USGS, CDC
Vernal pool complex	Vector	DWR, SSURGO, CDFW
Water diversions	Vector	CDFW, DWR

Notes:
CaSIL = California Spatial Information Library
CDFW = California Department of Fish and Wildlife
DWR = California Department of Water Resources
USDA = U.S. Department of Agriculture
SSURGO = Soil Survey Geographic Database
NRCS = Natural Resources Conservation Service
USGS = U.S. Geological Survey
CDC = California Department of Conservation
TIGER = Topologically Integrated Geographic Encoding and Referencing
CPAD = California Protected Areas Database
NAIP = National Agriculture Imagery Program

Natural communities (Section 2.3.4) were defined and described using the CALFED Bay-Delta Program (2000) Ecosystem Restoration Program Volume 1 and the *Multi-Species Conservation*

Strategy, and were further refined and augmented by input from CDFW staff participating in the BDCP Terrestrial Resources subgroup in 2009.

Data sources for the legal Delta, Suisun Marsh, and the Upper Yolo Bypass (each described below) were merged to generate a single, compiled vegetation cover dataset for the entire Plan Area. The finer scale vegetation classifications in these datasets were rolled up to create the 13 natural community types described in Section 2.3.4, *Natural Communities*, and these data were also used to model the habitat of covered species (Appendix 2.A, *Covered Species Accounts*).

2.3.1.2 Vegetation Dataset Sources for the Legal Delta

The Vegetation and Land Use Classification map of Sacramento-San Joaquin River Delta and associated geographic information system (GIS) shape files (Hickson and Keeler-Wolf 2007) were used to create the initial vegetation dataset for the legal Delta portion of the Plan Area. CDFW has classified and mapped vegetation within the legal Delta, excluding Chipps Island and Van Sickle Island in the far western portion of the Delta, for use in conjunction with the Delta Regional Ecosystem Restoration Implementation Plan.

The 2007 CDFW map was produced by conducting vegetation sampling using the California Native Plant Society Rapid Assessment Protocol (California Native Plant Society 2007). In the area sampled, 377 rapid assessments were conducted in the field and 52 vegetation alliances were identified by a clustering algorithm, including 45 plant associations defined by Sawyer and Keeler-Wolf (1995)[2]. When positive association identification was not possible, vegetation was identified to alliance or phase.

These field-surveyed classification units were directly or indirectly used to develop 129 fine-scale to mid-scale geospatial map classifications. Due to issues of scale or remote sensing limitations, in some cases field data were condensed or aggregated to create the map classifications. Therefore, these map classifications represent a mix of field vegetation identification levels including association, suballiance (aggregation of associations), alliance, phase, generic, stand, and mapping unit. For a crosswalk between the vegetation classification of field-surveyed data and related map classification of geospatial data in the Legal Delta, see Hickson and Keeler-Wolf (2007).

Land cover features were mapped by CDFW using minimum mapping units (MMU) as follows.

- Land use: MMU = 2 acres (minimum width of 25 meters).
- Isolated land use: MMU = 1 acre (minimum width of 10 meters).
- Water: MMU = 1 acre (minimum width of 10 meters).
- Vegetation: MMU = 2 acres (minimum width of 10 meters).
- Critical vegetation: MMU = 1 acre (minimum width of 10 meters).

Features were occasionally mapped below MMU or minimum width because those features were so distinct or important compared to their surroundings that omitting them would have distorted the

[2] *A Manual of California Vegetation* by Sawyer and Keeler-Wolf published in 1995 has since been superseded by a 2009 edition. However, because habitat modeling and mapping began prior to the release of the 2009 version, the BDCP will continue to use the 1995 version for consistency purposes. The 1995 document is referenced throughout Chapter 2; however, this footnote will only appear once.

representation of the area. Each polygon was coded with both a vegetation type and one of 25 land use types. Base imagery used to map the vegetation was true color 1-foot resolution aerial photography from spring 2002, and additional marginal areas of the mapped area were supplemented by aerial photography from summer 2005. A more detailed description of the classification and mapping process is available in Hickson and Keeler-Wolf (2007).

The vegetation categories produced by CDFW were combined into the corresponding broad biological community classifications used in the BDCP. Polygons from the fine-scale CDFW map were combined using GIS. Science Applications International Corporation (SAIC) ecologists used U.S. Department of Agriculture National Agriculture Imagery Program 1-meter resolution color aerial photography to delineate the portion of the Plan Area not sampled by CDFW during the Delta mapping project into a GIS (U.S. Department of Agriculture 2005). This imagery was photographically interpreted to identify the natural communities present in portions of the Plan Area that were not sampled by CDFW.

2.3.1.3 Vegetation Dataset Sources for Suisun Marsh

The Vegetation Mapping of Suisun Marsh, Solano County California GIS dataset from 2006 (Boul and Keeler-Wolf 2008), in which CDFW classified and mapped vegetation within Suisun Marsh, as well as Chipps Island and Van Sickle Island, was used to create the initial vegetation dataset for Suisun Marsh. This dataset represents the most comprehensive and detailed vegetation survey available for the Suisun Marsh region[3]. *The Manual of California Vegetation* (Sawyer and Keeler-Wolf 1995) was used as the classification protocol and is based on the National Vegetation Classification System (Grossman et. al. 1998). The vegetation classification process described by Keeler-Wolf and Vaghti (2000) was reapplied in 2003 and 2006 in an effort to document vegetation changes within the Suisun Marsh. It should be noted that this dataset has registration issues when comparing it to the National Agriculture Imagery Program (NAIP) or the U.S. Geological Survey (USGS) standardized regional imagery. The original dataset was developed in 1999. It involved registering and "rubber sheeting" over 100 1:9,600 true color photos. The aerial photos were rectified to a registered SPOT base satellite image and the mapping was then tied to these registered and mosaic-defined photographs.

Developing the relationships and equivalencies of the Suisun Marsh mapped vegetation cover types and the corresponding natural community classifications used in the Plan Area proved problematic. The classification of communities within the Suisun Marsh was primarily driven by changes in species compositions due to wetland management strategies being applied in the region. Because of the presence of these management strategies, vegetation classes could be found to occur within multiple natural communities types. For example, the *Distichlis spicata* vegetation type was often found within both the managed wetland and the tidal brackish emergent wetland communities. Therefore, instead of developing a procedure to link the Suisun Marsh vegetation classes to the natural communities, the spatial extents of wetland management strategies were used to categorize the 2006 Suisun Marsh mapped vegetation.

The EcoAtlas (San Francisco Estuary Institute 1998) GIS dataset provides a reasonable estimate of land use classifications, and was used to support the categorization of Suisun Marsh vegetation

[3] Users will observe that internal alignment inconsistencies are present when comparing the mapped land cover features to standardized imagery (e.g., USGS Digital Orthophoto Quarter Quadrangles, NAIP). Currently, there is no work planned to refine the alignment inconsistencies (Keeler-Wolf pers. comm.).

classes into the natural communities. The EcoAtlas mapped Suisun Marsh using general categories that were loosely lumped into high-elevation tidal marsh, low- to mid-elevation tidal marsh, muted tidal marsh, managed marsh, diked marsh, farmed bayland, grazed bayland, ruderal, storage basins, deep bay or ocean, and shallow bay. These land use categories were grouped into the equivalent natural community types (Table 2-2). The resulting categorized Suisun Marsh vegetation dataset was then visually compared to NAIP 2005 aerial imagery (U.S. Department of Agriculture 2005) and refined as necessary.

Table 2-2. EcoAtlas Land Use Classifications of Suisun Marsh and Equivalent Natural Community Type

EcoAtlas Land Use Classification of Suisun Marsh	Equivalent Natural Community Designation
Tidal marsh	Tidal brackish emergent wetland
Managed marsh Diked marsh Storage basin	Managed wetland
Farmed bayland Ruderal	Cultivated land
Deep bay or ocean Shallow bay	Tidal perennial aquatic
Grazed bayland	Grassland

2.3.1.4 Vegetation Dataset Sources for the Upper Yolo Bypass

The Yolo Natural Heritage Program's Regional Vegetation GIS dataset (Technology Associates International Corporation 2008) was used to define vegetation cover for the upper Yolo Bypass that extends from the north legal Delta boundary northward to the Sacramento River. The dataset was clipped to the boundaries established for the Yolo Bypass. The vegetation classification categories assigned to the Yolo County dataset were evaluated to determine the appropriate corresponding natural community with which each vegetation category should be associated.

2.3.1.5 Vernal Pool Complex Dataset Development

In addition to the BDCP vegetation cover dataset, a vernal pool complex natural community dataset was separately generated to more effectively capture the vernal pool complex natural community (pools and supporting uplands) present within the Plan Area. Details of the process used to map the vernal pool complex can be found in Appendix 2.B, *Vernal Pool Complex Mapping and Modifications to Natural Community Mapping.*

2.3.1.6 Natural Community Classification in the Expanded Plan Area

The Plan Area was expanded in 2012 by 4,332 acres (less than 1%) to capture several additional areas targeted for restoration and other covered activities. These expansion areas included land adjacent to Conservation Zone 2 west of Yolo Bypass and land adjacent to Conservation Zones 1, 8, and 11. Additionally, a small portion of the Plan Area (18,422 acres), previously unmapped, was mapped by ICF ecologists in 2011. Detailed vegetation alliance data were not available for the plan expansion areas or the previously unmapped areas, so natural communities were mapped in these areas based on aerial imagery, GIS-based vegetation data from Solano and Yolo Counties, and ground-truthing (ICF 2012). Land use data for the cultivated land natural community in the expansion areas were obtained from publicly available California Department of Water Resources GIS datasets (California Department of Water Resources 2000, 2003, 2004, and 2008).

2.3.2 Ecosystem Processes

The ecosystems of the Plan Area are dynamic and driven by a complex set of interacting physical, chemical, geomorphical, and biological processes that originate from internal and external causes (Figure 2-2). These processes vary at multiple spatial and temporal scales, typically along gradients rather than at well-defined boundaries (Kimmerer 2004). Organisms that evolved in these ecosystems are adapted to this variability as it historically existed. Anthropogenic factors have altered the ecosystems in many ways and global climate change is expected to alter it further.

2.3.2.1 Aquatic Ecosystem Processes

2.3.2.1.1 Physical Processes

Major physical factors driving ecological conditions in the Plan Area include water flow, salinity, and turbidity. The most conspicuous physical forcing factor is water flow, which varies daily, seasonally, and annually. Water flow directly or indirectly influences nearly all other ecosystem processes in the Plan Area. Large-scale hydrodynamics in the Plan Area are driven largely by tides, freshwater inflows, water exports, cumulative effects of local diversions, and atmospheric forcing. Local hydrodynamics are driven by water depth, channel geometry, and bathymetry at bends and channel junctions. Local conditions are not static and the cross-sections and beds of most Delta channels are dynamic and change at time scales of years to decades in response to flow rates, wind, and other physical drivers.

Flow patterns are driven by the interaction between upstream (freshwater) flows entering the Delta and oceanic tides moving in and out of the Delta twice a day. While tidal flows drive the large majority of water movement in the Delta (Kimmerer 2004), they contribute little to net flow out of the Plan Area. Average tidal flow rates are 170,000 cfs, but can exceed 300,000 cfs during high tidal flow events (Mount 1995). In contrast, inflows from the upstream rivers average an order of magnitude lower. The average daily total Delta outflow from 1955 to 2007 was 33,715 cfs and has been as low as 4,200 cfs during dry periods (California Department of Water Resources 2007a). While tidal influence dissipates at approximately the same location upstream on both the Sacramento and San Joaquin Rivers (at approximately river mile 50), because freshwater inflow from the Sacramento River is much larger than inflow from the San Joaquin River (Section 2.3.3.3, *Hydrologic Conditions*) a much larger tidally driven volume of water or tidal prism moves in and out of the San Joaquin River. The overall pattern shows that hydrodynamic processes (e.g., transport, dispersion, etc.) in the western portion of the Delta are governed primarily by tidal exchange, while hydrodynamics in the northern and southern portions of the Delta are governed primarily by river flow.

In the region where fresh and oceanic waters first mix a longitudinal salinity gradient is formed. This gradient is intensively monitored and is spatially indexed by X2, which is the distance (in kilometers) from the Golden Gate Bridge at which channel-bottom water salinity is 2 ppt (Jassby et al. 1995). The spatial and temporal characteristics of this gradient vary daily and seasonally and are driven by freshwater inflow and tidal action. X2 shifts upstream during a flood tide and downstream during an ebb tide. Similarly, X2 is farther downstream during high Delta outflows and farther upstream during periods of low outflows. Theoretically, within the salinity gradient, an estuarine salinity field and density gradient, also called a salt wedge, may form in which denser salt water is located at the bottom farther upstream and fresh water is located at the surface farther downstream; however, due to turbulent mixing, this rarely occurs in the Delta or Suisun Bay (Kimmerer 2004).

Temporal and spatial patterns in flow can directly affect the concentration and distribution of nutrients and contaminants, water density, salinity gradients, and floodplain inundation frequency and duration (Kimmerer 2004). Flow patterns also directly affect the transport of dissolved and suspended particles, including nutrients, gases, organic matter, toxics, sediment, and organisms (Kimmerer 2002; Jassby 2008). Although concentrations of particles do not necessarily increase with higher flows (but often do because of resuspension), the overall load (i.e., delivery) of particles increases with higher flow rates. The residence time of particles, the duration that they occur in a defined area, is inversely related to water flow rates. There are both positive and negative effects of increased residence time, depending on the effect of the particle on the biological process. Longer residence time of nutrients and organic matter may have beneficial effects on biological processes, but some of those processes (e.g., feeding by invasive bivalves, discussed in Section 2.3.2.1.4, *Ecosystem Energetics and Productivity*) may not be beneficial to native organisms. Longer residence times may also allow greater uptake of toxics such as methylmercury (discussed in Section 2.3.2.1.5, *Effects of Anthropogenic Influence and Future Climate Change*), resulting in harmful effects on biological processes. When residence time is too great, biological consumption of dissolved oxygen at particular depths in the water column may exceed oxygen supply rates that are driven by atmospheric exchange processes and mixing at different depths and lead to anoxic conditions, which are lethal for many organisms. Conversely, short residence time of nutrients and organic matter in the Delta may not allow organisms sufficient time to optimally use the resources to support primary and secondary productivity.

Turbidity is an indirect method for quantifying how the transmission of light through water is attenuated by particles and dissolved substances, and is influenced primarily by suspended sediments and secondarily by suspended and dissolved organic material and plankton (Kimmerer 2004). Although still high relative to other aquatic ecosystems, turbidity in the western region of the Delta (in and near the low-salinity zone [LSZ]) has declined tenfold over the past three decades (Lehman 2000; Kimmerer 2004). This may be due to reduced sediment supply, reduced phytoplankton biomass, or the localized trapping of particles caused by an increase in the extent of submerged aquatic vegetation, particularly the nonnative and highly invasive Brazilian waterweed (*Egeria densa*) (Grimaldo and Hymanson 1999; Kimmerer 2004). This decrease is an indicator of extensive changes in the aquatic foodweb that may be manifested in a number of ways. Regardless of current declines in turbidity, primary productivity in the Delta is limited by low light transmission through the still relatively turbid water column (Cole and Cloern 1984; Kimmerer 2004).

2.3.2.1.2 Chemical Processes

Major chemical processes driving ecological conditions in the Delta include the cycling of nutrients, carbon, and other organic matter. Some important dissolved inorganic nutrients include, but are not limited to, nitrogen in the form of nitrate, nitrite, and ammonia[4] (chemical species varies with pH), phosphorus in the form of phosphate, and silicate (Kimmerer 2004). The relative proportions of

[4] Ammonia in water generally forms some amount of ammonium. Therefore, the use of the term *ammonia* implies that both ammonia and ammonium may be present.

total nitrogen and total phosphorus are also very important, as discussed in Section 2.3.2.1.3, *Geomorphic Processes*. Dissolved organic nitrogen and phosphorus are also present in the system and can be easily recycled by the consumption of organic material by animals and microbes. Sources of nitrogen and phosphorus to the Delta include sewage, urban runoff, oceanic inputs, and agricultural runoff. As noted above, it is generally accepted that, for most of the year in most locations of the Delta, primary productivity is not nutrient-limited; instead, turbidity appears to limit primary productivity as a result of low light levels (Section 2.3.2.1.4, *Ecosystem Energetics and Productivity*) (Cole and Cloern 1984; Kimmerer 2004). High nutrient concentrations in the Delta are not necessarily beneficial and can cause blooms of harmful phytoplankton species that pose risks to both the aquatic ecosystem and humans, as has occurred in other estuaries (Anderson et al. 2002). For example, blooms of the toxic cyanobacteria, *Microcystis*, have increased since it was first documented in the Delta in 1999 (Lehman and Waller 2003, cited in Lehman et al. 2005), and the blooms may contribute to the reduced concentrations of zooplankton (pelagic organism decline [POD]) (Resources Agency et al. 2007). However, recent work suggests that nutrient concentration explains a small percentage of *Microcystis* abundance patterns (Lehman et al. 2008).

The primary sources of organic carbon for the Delta are its upstream tributaries (Jassby and Cloern 2000). Secondary sources include local phytoplankton and bacterial production and agricultural drainage within the Delta. Most organic carbon from agricultural drainage is derived from peat soils (Jassby et al. 2003). Tertiary sources include discharges from wastewater treatment plants, exports from tidal marsh areas, and possibly aquatic macrophyte production. Benthic microalgal production, urban runoff, and other sources appear to be negligible throughout the Delta.

Organic carbon concentrations are generally reported as particulate until below a threshold size, where they are considered dissolved. Within the Delta, biological production of particulate organic carbon is derived primarily from phytoplankton, although heterotrophic bacteria may contribute a significant proportion of organic carbon to the foodweb, particularly in the Delta and Suisun Marsh. Jassby et al. (2002) identified declines in phytoplankton biomass in Suisun Bay from 1975–1995, but Jassby 2008 has seen increases in phytoplankton biomass in the Delta and no change in Suisun Bay since 1996. Unlike particulate organic carbon, most dissolved organic carbon (i.e., extremely small particles of organic matter) must be consumed and transformed into larger particles by bacteria before it can be consumed by larger organisms. Since it is a transformation of existing organic carbon and not the production of new organic carbon through photosynthesis by cyanobacteria or phytoplankton, the bacterial transformation of dissolved organic carbon does not add new organic carbon to the foodweb (Jassby et al. 2003).

Seasonally inundated floodplains such as those in the Yolo Bypass and adjacent to the Cosumnes River provide an allochthonous (export) subsidy of organic matter to other regions of the Delta. Some of this floodplain-generated organic carbon, such as phytoplankton, is especially labile (available to organisms) (Jassby and Cloern 2000; Moyle et al. 2007). Also, since these floodplains are shallower, have longer residence times, and are generally warmer than the mainstem river, they have greater rates of phytoplankton production than do the channels of the rivers (Sommer et al. 2001a).

The oxygen concentration of the aquatic environment is influenced by exchange with the atmosphere, photosynthesis, aerobic and anaerobic respiration, vertical exchange, water temperature, and wind and wave action (Kimmerer 2004). In general, the water in the channels of the Delta is saturated (at equilibrium with the atmosphere) with dissolved oxygen in most areas during most of the year. One common exception occurs during late summer and early fall in the

Stockton Deep Water Ship Channel on the San Joaquin River. At that particular location the combination of low river flows, high concentrations of oxygen-demanding organisms (algae from upstream, bacterial uptake of effluent from the City of Stockton Regional Wastewater Control Facility, and other unknown sources), and channel geometry causes rates of biological oxygen demand to exceed rates of gas exchange with the atmosphere and results in a sag (locally depleted concentration) in dissolved oxygen concentration in the Stockton Deep Water Ship Channel (Lee and Jones-Lee 2002; Kimmerer 2004; Jassby and Van Nieuwenhuyse 2005). An oxygen diffuser experiment is currently being conducted in the Stockton Deep Water Ship Channel to meet total maximum daily load (TMDL) objectives for dissolved oxygen concentrations established by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) (2005) (above 6.0 milligrams per liter [mg/L]) from September 1 through November 30 and above 5.0 mg/L at all times). Low dissolved oxygen concentrations have also been documented in Old River near the Tracy Boulevard Bridge and occur in multiple dead-end sloughs near Stockton (e.g., Pixley Slough, Mosher Slough, and Five Mile Slough) (Central Valley Regional Water Quality Control Board 2009).

Chemical processes can also be important drivers of physical process. For example, low oxygen concentrations in areas with dense growth of tidal emergent vegetation leads to peat formation, which allows the surface of the submerged soil to accumulate peat at a rate that maintains its surface at the same relative elevation to sea level. Prior to reclamation activities, natural peat formation was widespread in the Plan Area, and it remains important for maintaining the elevation of the marsh plain of Suisun Marsh. Additionally, in tidal areas of the western Delta and Suisun Marsh, salinity levels, as well as water and soil water oxygen concentrations, are responsive to the frequency and timing of inundation. In these areas, salinity and dissolved oxygen concentrations are the primary factors that determine the physical structure and species composition of tidal marsh plant communities, and the rate of peat accumulation. In the Suisun Marsh, changes in salinity cause corresponding changes in species composition, which in turn cause different rates of belowground productivity that then leads to different rates of peat accumulation in the marsh plain (Culberson 2001; Culberson et al. 2004). Variation in peat accumulation rates is likely to result in variation in the rate the marsh can respond to sea level rise.

2.3.2.1.3 Geomorphic Processes

Major geomorphic processes driving ecological conditions in the Delta include sediment transport and erosion. Fluvial and tidal forces (hydrodynamics) directly influence terrestrial as well as aquatic communities. Geomorphic attributes of the Delta are largely determined by the interactions among sediment sources, water flow, and aquatic and terrestrial biota.

The rate of sediment transport into the Delta depends on the magnitude of upstream erosion and downstream transport. Sediment loads increase with higher flows both because the delivery rate is higher and because sediment concentrations in the water column increase due to greater turbulent mixing and scour, leading to resuspension of sediment (Ruhl and Schoellhamer 2004; McKee et al. 2006). Sediment can act as a sink of multiple biologically active materials, including toxics such as pyrethroids and mercury that have settled into or are bound to the sediment. These biologically active materials are then moved with resuspended sediment. Sediment inputs in the Delta are not in equilibrium with exports to the San Francisco Bay and Pacific Ocean, and there are active areas of erosion within the Delta (Ruhl and Schoellhamer 2004; McKee et al. 2006; Cappiella et al. 1999; Ganju and Schoellhamer 2010). Local sediment deposition occurs in low-velocity waters, such as near emergent vegetation or in shallower backwaters. These relatively stable deposits can provide suitable substrate for colonization by plants and ultimately may develop into an emergent vegetation community that traps sediment at greater rates by impeding flow and reducing wave energy (Simenstad pers. comm.). This vegetation-sedimentation feedback loop leads to gradients of natural community types that correspond to characteristic bathymetric profiles.

Sediment yields have declined by about 50% since 1957 through the depletion of erodible sediments that were deposited by mining activity in the 1800s and 1900s, sediment trapping within reservoirs, riverbank erosion protection, levees, and altered land uses (e.g., agriculture) (James 1999, 2004a, 2004b; Wright and Schoellhamer 2004; James 2006; McKee et al. 2006; James and Singer 2008; Singer et al. 2008; James et al. 2009; Singer and Aalto 2009; Ganju and Schoellhamer 2010). This sediment supply reduction may become particularly problematic under predicted future climate change models as it may prevent marsh surface elevations from tracking sea level rise (Section 2.3.2.1.5, *Effects of Anthropogenic Influence and Future Climate Change*).

2.3.2.1.4 Ecosystem Energetics and Productivity

This section focuses on aquatic environments in the channels of the tidal waters of the Delta (biological processes for each of the natural communities are discussed in Section 2.3.4, *Natural Communities*). Primary and secondary productivity and energy transfer to higher trophic levels are the biological processes that fuel the ecosystems of the Delta. In the channel waters of the Delta, phytoplankton biomass and production are low relative to other larger estuaries around the world (Jassby et al. 2002). Historically, chlorophyll concentration, a measure of phytoplankton biomass, decreased significantly in each season except spring (April through June) from 1975 to 1995 (Jassby et al. 2002, 2003), and remains low (Kimmerer 2004). A major driver of this decline may be the 1986 invasion of the overbite clam (*Potamocorbula amurensis*) (Kimmerer and Orsi 1996) (Section 2.3.2.1.5, *Effects of Anthropogenic Influence and Future Climate Change*), but various other drivers doubtless have contributed to the decline, at least at some sites and in some timeframes. Among these are human-caused additions of nitrogen and pesticides to Delta waters (Dugdale et al. 2007; Weston and Lydy 2010). There are spatial gradients within the Delta as chlorophyll concentrations are greater in the southern and eastern Delta, presumably due to longer residence time and greater water clarity (Kimmerer 2004).

In the absence of other factors such as *Potamocorbula*, nutrients do not limit the development of primary producers in the Delta; instead, light levels within the water column appear to control primary productivity (Cole and Cloern 1984; Kimmerer 2004). Light penetration through the water column has an inverse exponential relationship with suspended particulate matter at a given depth. Therefore, the large majority of phytoplankton production occurs near the surface. If the current pattern holds and water clarity continues to increase in the Delta as it has done over the past few decades (Lehman 2000), higher phytoplankton production is expected. However, the growth rate, depth distribution, and extent of *Egeria* and other nonnative invasive aquatic plants may respond positively to increasing water clarity due to reduced particulate matter concentrations and their dense and extensive canopies may drive down light levels (Kimmerer 2004). High concentrations of ammonia and ammonium, which are derived primarily from wastewater treatment plants, may also contribute to reduced productivity in the Delta and bays of the Plan Area by suppressing the uptake of nitrate by diatoms and phytoplankton (Dugdale et al. 2007; Dugdale 2008). Elevated ammonium concentrations may also directly impair primary productivity (Parker et al. 2010). Glibert (2010) has found evidence that spatio-temporal patterns in ratios of ammonia, nitrate, and phosphate concentrations can explain spatial and temporal patterns in algal functional groups (i.e., diatoms, and flagellates), and cyanobacteria in the Delta, and may also explain zooplankton and pelagic fish abundance.

A high abundance of benthic microalgae occurs in shallow subtidal habitat and intertidal mudflats, which compose a significant portion of aquatic habitats in the Delta. While this appears to be a potential source of primary productivity, the actual contribution of benthic microalgae to overall organic carbon production appears to be small (Jassby and Cloern 2000; Kimmerer 2004).

Benthic dwelling filter-feeders, particularly *Potamocorbula*, may be responsible for major inter- and intra-annual variation in phytoplankton abundance in the brackish water areas of the western Plan Area. Similarly, in the freshwater areas of the central and eastern Delta the abundance of the Asian clam is inversely related to phytoplankton biomass in subsided islands that have flooded. Together, the combined grazing impacts of these clams may have a major influence in the Delta foodweb (Lucas et al. 2002). Conversely, grazing on phytoplankton by zooplankton does not appear to be a major sink for primary production in the Delta (Kimmerer 2004).

Within the Delta, the general foodweb is highly complex and variable at multiple spatial and temporal scales, and no attempt has been made to fully reconstruct it. Zooplankton play a critical role in the foodweb as they represent an important link between primary producers and higher trophic levels. Zooplankton population sizes are very dynamic at short time scales (i.e., weeks to months) (Kimmerer 2004). They are also dynamic over longer time scales as there has been a large decline in zooplankton abundance throughout the Delta since the mid-1970s, and it is hypothesized that the decline is due to a combination of factors that include reduced organic inputs, increased water exports, reduced phytoplankton biomass, and toxic substances in the water (Kimmerer 2004).

Zooplankton community composition varies spatially where copepods are numerically dominant in the brackish water region of the Plan Area, while cladocerans dominate the freshwater region. In the LSZ between those two regions, macrozooplankton, including mysids and epibenthic amphipods, are important food items for many fish species (Kimmerer 2004) as most fish species consume zooplankton for at least part of their lives. Changes in the composition and abundance of the zooplankton community of the Plan Area that are driven by biological invasions and changing water conditions have forced native fish species to adapt to new prey species and caused a reduction of overall carrying capacity of fish in the Plan Area (Bennett 2005).

Both fish and larger epibenthic invertebrates (e.g., crabs and shrimp) have complex life cycles, and their abundances are regulated by multiple environmental factors (Kimmerer 2004). For example, many fish species, because of their anadromous life history, respond to both oceanic and Delta conditions and transfer energy between both foodwebs. Additionally, a diverse species assemblage of birds, mammals, amphibians, and reptiles comprise higher trophic levels of the Delta’s aquatic foodweb and consume a variety of invertebrate and fish species. While predation impacts by these species are significant, their overall impact on prey populations is less well understood compared to other sources of mortality (Sommer et al. 2007).

2.3.2.1.5 Effects of Anthropogenic Influence and Future Climate Change

This section focuses on aquatic environments in tidal channels of the Plan Area (biological processes for each of the natural communities are discussed in Section 2.3.4, *Natural Communities*).

Ecosystem processes within the Delta have been greatly modified by a variety of anthropogenic influences and are predicted to continue to be modified with future sea level rise and climatic changes. The large extent of wetland reclamation, flood management infrastructure, and channel modifications have transformed the geometry of the Delta from one with a complex structure of branching channels to one of interconnected channels around leveed and diked islands. These channels have created linear and circular flow patterns that are different from the dendritic channel structure that existed before these modifications occurred (Grossinger 2004; Grossinger et al. 2008). Flow rates through the modified channels tend to be greater than in dendritic channels, reducing residence time and leading to a reduction in overall productivity of the Delta. Levees have removed important elevational gradients that historically existed at the interface between aquatic and terrestrial ecosystems.

The construction of dams and reservoirs has dampened the variation that was present in the historical hydrograph of the Delta and has changed the timing of flows through the Delta. Upstream diversions reduce flows into the Delta and in-Delta diversions, including State Water Project (SWP) and CVP facilities and over 2,200 nonproject diversions, have reduced flow out of the Delta. Operations of the SWP/CVP facilities (including the Delta Cross Channel, Victoria Canal, and the pumping stations) have altered in-Delta hydrodynamics by altering the direction of water flow such that east to west flows are lower than they were historically, and north to south flows are greater than they were historically.

Return flows from wastewater treatment plants, island drainage, and groundwater seepage have introduced toxic substances into the Delta. Barriers and new channels that were constructed and are operated to maintain water quality (e.g., Head of Old River barrier, and Delta Cross Channel) have significantly altered flow, transport, and mixing of suspended particles, dissolved gases, and dissolved salts in the Delta.

In conjunction with the depletion of erodible sediments from mining, riverbank protection and levees, and altered land uses, the dams and reservoirs have also greatly reduced loads of sediment transported to the Delta and suspended in the water column. Lower sediment load is of particular concern in relation to future climate change because current sediment loads may be insufficient to support a rate of accretion that will keep pace with projected sea level rise.

Nonnative invasive species introductions and population expansions have altered a variety of ecosystem processes in the Delta. *Potamocorbula* has, since its introduction in 1986, had a substantial impact on the aquatic ecosystem (Kimmerer and Orsi 1996; Kimmerer 2004) and that impact has had a greater effect on the Delta's foodweb than any other known invasion since long-term monitoring in the Delta began. As described above, the clam has caused a loss of summertime phytoplankton in Suisun Bay, declines in phytoplankton in the Delta, reductions in turbidity in both regions, changes in species composition and abundance of zooplankton, alterations of pathways and efficiencies of energy transfer through the foodweb, and restructuring of the benthic community in downstream bays. Serial invasions and numerical dominance of multiple zooplankton species (e.g., copepods and mysids) have changed the diet composition and breadth of multiple fish species. The introductions of multiple centrarchids species (e.g., largemouth bass and sunfishes) are thought to have directly contributed to the local extinction of Sacramento perch in the Delta (Cohen and Carlton 1995). The introduction of two nonnative invasive aquatic plants, water hyacinth and *Egeria*, has reduced habitat quantity and value for many native fishes in the Plan Area. Because water hyacinth forms dense floating mats that greatly reduce light penetration into the water column, it can significantly reduce primary productivity in the underlying water column (National Marine Fisheries Service 2004). *Egeria* grows along the margins of channels in dense stands that prohibit access by native juvenile fish to shallow water habitat. In addition, the thick cover of these two invasive plants provides excellent habitat for nonnative ambush predators, such as bass and sunfish, which prey on native fish species. *Egeria* is thought to reduce turbidity through a reduction in water velocity, resulting in higher local particle sediment rates, which has been hypothesized to increase predation rates on native fish (Brown and Michniuk 2007).

Toxic substances can interfere with ecosystem processes by reducing growth, reproduction, and survival of species. Herbicide applications can locally limit phytoplankton growth and production rates (Jassby et al. 2003). Many of the pesticides used to control agricultural pests are also toxic to zooplankton. Other sources of flows of toxic substances in the ecosystems of the Plan Area include wastewater treatment plants, urban runoff, and upstream sources. Although there is considerable uncertainty regarding the effects of some of these toxics on fish, at least three mechanisms have been identified through which toxics could affect fish. First, direct exposure to toxics could have negative impacts on fish, especially to more vulnerable life stages such as eggs and larvae. Second, toxic substance-induced mortality of zooplankton, a source of food for nearly all fish species at one or more life stages, could limit food to fish species and result in reduced growth rates, reproductive output, and survival rates. Third, the bioaccumulation of toxics such as mercury and selenium by *Potamocorbula* is well documented, and likely occurs in other organisms as well. Because some fish (e.g., sturgeon and splittail) and aquatic birds (e.g., surf scoter, American coot, and scaup) forage on organisms that bioaccumulate mercury and/or selenium, their tissue can bioaccumulate these toxics, thus reducing growth, reproduction, and survival (Luoma and Presser 2000).

If the reduced dry season flows into the Delta and increased sea level due to global climate change occur as predicted by climate models, they will combine to cause saltwater intrusion and tidal influence to shift farther upstream. This shift will likely affect biological processes that are dependent on salinity (e.g., rearing habitat for delta native fishes). Reduced flow into the Delta during summer and fall could lead to substantial increases in residence time during those seasons, which would increase water temperature and reduce dissolved oxygen levels to the detriment of native fish and other organisms. With reduced flows into and out of the Delta, toxic substances may accumulate in channels during the summer and fall. The predicted effects of global climate change are discussed in more detail in Section 2.3.3.2, *Climate*.

2.3.2.2 Terrestrial Ecosystem Processes

Terrestrial ecosystems dominate the Plan Area. The present extent of the aquatic ecosystem, as defined by the tidal perennial aquatic natural community, is a relatively small 86,236-acre portion (11%) of the 786,125-acre Plan Area. Most of the terrestrial portion of the Plan Area, however, is dominated by human-modified landscape. Intensively managed cultivated lands and managed wetlands comprise 572,623 acres (73%) of the Plan Area. Grassland, which is primarily composed of managed and cultivated grasslands on Delta islands and levees, constitutes another 77,495 acres. Together, these three human-managed communities constitute 81% of the Plan Area. The ecosystem processes of these communities are almost entirely controlled by human management activities that include disturbance by tilling and disking; regulation of the water cycle by irrigation; chemical enhancement of soil fertility with fertilizers; and control of species composition with herbicides, pesticides, and cultivation.

Cultivated lands retain some natural ecosystem functions. For example, flooded rice fields provide surrogate wetland habitats for species such as the giant garter snake, a covered species. Hay crops and some annually cultivated crops provide important foraging habitat for raptors. Winter-flooded croplands provide essential foraging and roosting habitat for the greater sandhill crane, a covered species, as well as waterfowl and shore birds. Managed wetlands provide productive seasonal wetlands interspersed with permanent wetlands. These wetlands feed large populations of waterfowl and shorebirds through the production of seeds and invertebrates; and their structure is managed to provide nesting, resting, and loafing areas. Managed wetlands also provide habitat for covered species such as salt marsh harvest mouse, sandhill crane, and giant garter snake. The majority of the grassland natural community is managed as vacant, typically abandoned croplands, while a small portion is managed as a source of primary productivity to feed domestic grazing animals.

The other terrestrial and wetland natural communities in the Plan Area support more natural ecological processes and native species but constitute only a small portion of the Plan Area relative to human-managed communities. The Plan Area supports 17,930 acres of valley/foothill riparian natural community and 17,298 acres of combined tidal freshwater and tidal brackish emergent wetlands. These three natural communities constitute 4% of the Plan Area. The valley/foothill riparian natural community provides a number of ecological functions. It serves as the hydrologic connection between terrestrial uplands and aquatic ecosystems and provides water quality benefits by processing and filtering runoff. It is a source for organic material (e.g., falling leaves), insect food, and woody debris in waterways, and can influence channel dynamics. Riparian forest and scrub provides habitat for the greatest diversity of any terrestrial community in the Plan Area. In the Delta, these riparian functions are greatly diminished, as most riparian habitat is present on levees and within cultivated lands separated from floodplains and natural hydrodynamics and substrates. Most of the riparian areas remaining in the Plan Area consist of long and narrow patches that do not provide functional habitat for riparian obligate species such a western yellow-billed cuckoo, which need riparian patch sizes of greater than 100 acres (Laymon 1998). Tidal freshwater and brackish emergent wetland communities provide ecosystem functions as wildlife habitat, natural chemical filters, and buffers to wave action, and provide resources to adjacent aquatic ecosystems through their contributions of nutrients and organic material to the shared foodweb. Tidal wetlands also accumulate peat, which controls the surface elevation and productivity of the Delta's wetlands. Tidal freshwater and brackish emergent wetland vegetation provides rearing habitat for fish species.

Several specialized natural communities of limited distribution in the Plan Area and statewide provide unique ecological conditions that support unique assemblages of plants and wildlife, including many rare species that are covered species under the BDCP. These communities include vernal pool complex, alkali seasonal wetlands complex, and inland dune scrub; collectively they constitute approximately 1% of the Plan Area.

2.3.3 Physical Environment

2.3.3.1 Geomorphic Setting

The Delta, Yolo Bypass, and Suisun Marsh are the expression of numerous spatial and temporal variations in regional and local physical processes that, in combination, have established the hydrologic and geomorphic conditions that are present today. One of the most visually apparent physical features is the enormous north-south Central Valley that is nearly surrounded by mountains and has a single westerly outlet near its midpoint. In and around this valley, tectonic activity has assembled a diverse mixture of elements and minerals, raised the surrounding mountains, and elevated or subsided various sections of the valley floor and regulated its connection to the ocean.

The Central Valley and its surrounding mountains are perched on the Sierra Nevada/Great Valley tectonic microplate, which is more or less solidly attached to the North American tectonic plate to its east. Its western boundary is being distorted by friction caused by the contrary motion of the North American and Pacific tectonic plates as they slide past and buffet each other with the microplate trapped in between (Argus and Gordon 2001; Fay and Humphreys 2008). The distortion of the western margin of the microplate has led to bursts of mountain building in the Coast Range as well as extensive networks of faults that serve to release the built up strains. Both the Coast Range and faults are features that are expressed by the microplate through a thick pavement of oddly shaped and sized blocks composed of shallower and younger layers of the earth's crust. Two of these blocks, the Suisun and the Montezuma Hills, together gave birth to the current opening of the Central Valley to the Pacific Ocean approximately 500,000 years ago and have maintained the opening in the face of extensive tectonic activity in the Coast Range on either side of the gap in the mountains (Loudeback 1951; Sarna-Wojcicki et al. 1985; Weber-Band 1998).

The geology of the mountain ranges that surround the Central Valley is extremely complex and beyond the scope of this document (Jennings et al. 1977; Alt and Hyndman 2000, U.S. Geological Survey 2005). However, generally described, the geology and rock of the bordering mountains differ when comparing the southern San Joaquin Valley with the northern San Joaquin and Sacramento valleys. The Sierra Nevada range to the east of southern San Joaquin Valley consists primarily of granitic rock while the Coast Range to the west is composed of marine sedimentary rock. Northward, the Sierra Nevada is composed of volcanic lahars near the valley floor, metamorphic and mixed types of igneous rock in the foothills, granitic rocks in the mountains, and a cap of volcanic rock along the crest of the Sierra Nevada. The Coast Range consists of two bands of very different rock. Immediately along the border of the valley is the Great Valley sequence of marine sedimentary rock whereas to the west is the Franciscan complex consisting of marine sedimentary rock, metamorphic rock, igneous rock, and patches of volcanic rock.

Sediment is produced in the mountains and delivered to the Central Valley as locally and regionally heterogeneous mixtures that correspond to the geology of the four mountainous regions described above (Wakabayashi and Sawyer 2001; Curtis et al. 2005). These sediments have different physical and chemical attributes that directly affect the geomorphology of the rivers and streams both upstream and within the Delta, as well as the quality of the water that they deliver to the Delta. Additionally, the rate at which the sediments are delivered to the Delta is partially determined by whether they are detained or trapped in a subsiding region of the valley floor. Precipitation, which produces and transports the sediment, occurs less in the south and varies from east to west as the parallel set of north-south trending mountain ranges along the longitudinal axis of the valley creates precipitation shadows on their lee faces and large orographic increases on their windward faces (Dettinger et al. 2004; National Atlas of the United States 2009). The amount and type of precipitation intercepted by the mountains is also greatly influenced by glacial/interglacial climatic variation and by periodic deviations from seasonal averages. When precipitation accumulates high in the southern and north-central Sierra Nevada as glaciers, the glaciers grind away at the granitic rock, which is delivered to the Valley as fine material in glacial meltwaters. In contrast, during warm humid periods, chemical weathering of the granitic rock leads to deep and unstable deposits of a sand-like material called *grus* that is delivered to the valley as deep and permeable alluvial fans (Wahrhaftig 1965; Weissmann et al. 2005). In the central and northern Sierra Nevada, glacial effects have been smaller and erosion is the primary force that delivers material from its diverse rock types to the Valley (James et al. 2002; James 2003; Curtis et al. 2005) and supplies sediment from a diversity of rock types to the Sacramento River (Singer and Dunne 2001). Along the entire Coast Range, erosion attacks the southern marine mudstone and sandstone, Great Valley sequence, and Franciscan complex and delivers fine clay material and a mixture of dissolved elements (mercury, chrome, sodium, magnesium, boron, and selenium) to the Central Valley where they settle out in broad and relatively impermeable alkaline clay plains (Bureau of Soils 1909; California State Mining Bureau 1918; Bryan 1923; Belitz 1988; Deverel and Gallanthine 1989; Peters 1991; Donnelly-Nolan et al. 1993; Davisson et al. 1994; Graymer et al. 1994; Graymer et al. 2002; The Natural Heritage Institute 2003; Domagalski et al. 2004a; Domagalski et al. 2004b; Williamson et al. 2005; Hothem et al. 2007; Sommer et al. 2008).

Subtle surface and hidden subsurface factors also directly control the rate and type of sediment and dissolved chemical delivery to the Delta. Underlying the more recent alluvium in the San Joaquin Valley and southernmost region of the Sacramento Valley to near the Dunnigan Hills is the thick and impermeable Corcoran clay that formed the bed of Corcoran Lake, which covered the San Joaquin Valley and southernmost Sacramento Valley until it drained through the new opening of the Central Valley to the Pacific Ocean approximately 500,000 years ago (Thomasson Jr. et al. 1960; Sarna-Wojcicki et al. 1985; Belitz 1988). This relatively shallow clay layer controls groundwater/surface water interactions that affect the hydrology and selenium content of the overlying San Joaquin River. Underlying the majority of the Sacramento Valley is the thick and relatively permeable Tuscan Formation that was derived from volcanic ash and mudflows (Olmsted and Davis 1961; Lydon 1968; Jennings et al. 1977; Helley and Harwood 1985; Page 1985; U.S. Geological Survey 2005). Because the Tuscan Formation lies on top of the surface of the lower Sierra Nevada foothills before steeply dipping under the Sacramento Valley, and because it is permeable, it intercepts and stores some surface flow as well as deeply percolating water from local sources. Both the Corcoran Clay and the Tuscan Formation contain or control regional aquifers that are used as alternatives to surface flows. Because of tectonic controls and alluvial deposition that are associated with the Sierra Nevada, the San Joaquin River flows northward over its sandy bed along the western border of its valley to the Delta (Weissmann et al. 2005). In contrast, the Sacramento River shifts back and forth across its valley as it flows southward along the Willows Fault, is deflected to the east by the subsurface Colusa Dome, and is deflected to the east again by the delta of Cache Creek (Larsen et al. 2002; Singer 2008; Singer et al. 2008). Gravels are largely trapped upstream of the Colusa Dome while sand and finer sediment are carried downstream (Singer 2008).

Because of its lesser gradient, greater proportion of sand to finer sediment, and smaller flows, the San Joaquin River is a braided river with numerous sloughs as it flows northward toward the Delta. In contrast, the Sacramento River is bordered by broad and high natural levees that isolate it from seven adjacent flood basins as it flows southward to the Delta, and its single channel becomes increasingly stable as it approaches and enters the Delta (Hitchcock et al. 2005; Singer et al. 2008). The natural levees were formed when overbank flow deposited suspended sediment. When the deposits were made into floodplain waters at equal elevation to the main channel, the result was steep levees with coarse material that rapidly graded into fine deposits in the floodplain (Adams et al. 2004). Alternatively, when sediment was deposited by floodplain waters at lower levels than the main channel, the result was more gently sloped broad levees where sediment texture fined less rapidly (Adams et al. 2004). The banks of the levees can be stabilized by vegetation (Thompson 1961; Stainstreet and McCarthy 1993; Larsen et al. 2002; Adams et al. 2004) and channels or crevasses connecting the channel to the river can exist for hundreds to thousands of years (Rowland et al. 2009). The Sacramento River levee from the upper end of the Yolo Basin to Cache Slough has a number of crevasses with characteristic sand splays and connecting sloughs (Thompson 1960; Robertson 1987; Hitchcock et al. 2005; Singer et al. 2008). Both Cache Creek and Putah Creek discharge into the Yolo Basin, and their waters do not join the channel of the Sacramento River until Cache Slough near the center of the Delta. Under historical flood conditions, the combined flow through Cache Slough was often greater than the flow in the Sacramento River Channel and under natural conditions created a hydraulic dam at their confluence, which backed up the Sacramento River (Thompson 1960, Roos 2006, James and Singer 2008, Singer et al. 2008). The Mokelumne River discharges into the San Joaquin River on the eastern side of the Delta and only became tidally influenced within the last 1,000 years compared to approximately 6,000 years ago for the rest of the Delta (Shelmon 1971; Brown and Pasternack 2005). Marsh Creek, on the southwestern edge of the delta, has migrated back and forth across its broad alkaline clay alluvial plain and has discharged at different points into that area of the Delta (The Natural Heritage Institute 2003; San Francisco Estuary Institute 2010).

Approximately 21,000 years ago, the last glacial maximum ended and eustatic sea level began to rise from the lowstand of -394 feet (-120 meters) in a series of large meltwater pulses interspersed by periods of constant rising elevation until the Laurentide ice sheet had completely melted 6,500 years ago and the rate of sea level rise slowed dramatically (Edwards 2006; Peltier and Fairbanks 2006). The modern Delta formed sometime between 10,000 and 6,000 years ago when rising sea level flooded a broad valley. The inlet elevation to the valley is constrained by river-cut notches in the bedrock under the Carquinez Strait and the east end of Sherman Island at depths of -131 feet (-40 meters) and -121 feet (-37 meters) below current sea level respectively, which are elevations that would have been flooded by rising sea levels approximately 10,000 years ago (Shelmon 1971; Peltier and Fairbanks 2006; Drexler et al. 2009a). Until approximately 6,700 years ago, sediment deposits in the central and western Delta were primarily composed of mineral alluvium. Since that time, peat has accumulated from depths of approximately -30 feet (-9 meters) to the current sea level (Goman and Wells 2000; Drexler et al. 2009a). These deposits could have only accumulated under anaerobic conditions present in a permanently flooded Delta, likely maintained by high sea levels (Drexler et al. 2009a). This hypothesis is supported by fluctuating levels of oceanic-derived salinity as indicated by shifts in the dominance of aquatic plant species that are adapted to either brackish or freshwater conditions (Goman and Wells 2000; Byrne et al. 2001; Malamud-Roam and Ingram 2004; Malamud-Roam et al. 2006; Malamud-Roam et al. 2007; Watson and Byrne 2009).

At Browns Island in the western Delta, the transition to peat was apparently interspersed with periods dominated by fine mineral sediments, whereas peat developed abruptly and continuously in the central Delta (Drexler et al. 2009a). Sea level would have been approximately -13 feet (-4 meters) below its current level 6,000 years ago (Peltier and Fairbanks 2006). There is currently no explanation for the approximately 13 feet (4 meters) of additional peat in the central Delta, the difference between sea level 6,000 years ago and peat deposits that extend to a depth of approximately -26 feet (-8 meters) (Drexler et al. 2009a), although at least a portion of this difference could be attributed to tectonic subsidence as there is a 10-foot-high scarp along the Midland Fault in this area (Unruh and Hitchcock 2009).

Although the geomorphology of the Delta has often been described as a typical “bird’s foot” delta, this description inaccurately describes the complex system of alluvial fans and flood basins that were converted into multiple deltas when they were drowned by rising sea level and that are visually apparent when viewing historical maps and aerial photographs (Hitchcock et al. 2005; Grossinger et al. 2008). The complex geomorphology of sea level induced deltas is just beginning to be studied and understood (Shelmon 1971; Blum and Tornqvist 2000; Parker et al. 2008). Under these dynamic conditions, deltas can be single-thread linear channels, large fans, or complex combinations of different forms (Atwater et al. 1979; Blum and Tornqvist 2000; Hitchcock et al. 2005; Kim et al. 2009; Van Dijk et al. 2009).

Suisun Marsh lies immediately to the west of the Delta in a subsiding basin (Unruh and Hector 1999) between the bedrock notches of Carquinez Strait and Sherman Island, and because the base elevation of Suisun Bay is controlled by the bedrock notches upstream and downstream, it probably was flooded by rising sea level at the same time as the central Delta. Two studies conducted at Rush Ranch, which is at the northern end of the marsh and distant from the main channel that runs from Suisun Bay to the San Francisco Bay, indicate that marsh vegetation at that location established between approximately 3,000 and 2,500 years ago (Byrne et al. 2001; Malamud-Roam and Ingram 2004). Suisun Marsh is unique in that its water is brackish with salinities that have varied from fresh at its eastern end to nearly saline at its western end depending on the combined flow volume of the Sacramento and San Joaquin Rivers (Goman and Wells 2000; Byrne et al. 2001; Malamud-Roam and Ingram 2004; Malamud-Roam et al. 2006; Malamud-Roam et al. 2007; Watson and Byrne 2009). Additionally, flows into the north end of the marsh from Green Valley Creek can reach 5,000 cfs and can affect the salinity of the water both in the channels and on the marsh plain (Burau 2004). Increasing salinity levels can shift the species composition from highly productive freshwater-adapted plants to much less productive salt-adapted plants (Byrne et al. 2001; Culberson 2001; Boul and Keeler-Wolf 2008; Watson and Byrne 2009), influencing the rate of peat bed development and the elevation of the marsh surface above sea level (Culberson et al. 2004). Early charts of the marsh display classic tidal channel geomorphology with channels interspersed with ponds and the boundary of the upper margin of the marsh traced with salt pannes (Grossinger 2004). A salinity gradient exists as salt accumulates in areas more distant from channels that are not flushed by the tides during the rainless summer months (Sanderson et al. 2000; Culberson 2001; Culberson et al. 2004; Watson and Byrne 2009). The duration of tidal inundation also affects the distribution of plant species at the upper margin of the marsh (Culberson 2001; Watson and Byrne 2009) and establishes bare mudflats at the lowest areas of the marsh adjacent to Suisun Bay (Cappiella et al. 1999).

The natural geomorphology of the Delta, Yolo Bypass, and Suisun Marsh has been greatly altered by anthropogenic changes in sediment supply, flood management projects including levee building and draining, mosquito ditches in Suisun Marsh, and by large water dam and diversion projects throughout its watershed. The impact of the enormous pulse of sediment produced by hydraulic mining from 1853 to 1884 has been well-documented (Gilbert 1917; Kelley 1989; Mount 1995; Kimmerer 2004; Shvidchenko et al. 2004; James and Singer 2008; Keller 2009), but it is less well-known that additional mining sediment was produced between 1893 and 1953, and that large quantities of sediment still remain in reaches below dams (James 1999, 2006; James et al. 2009). The initial pulse of sediment increased flooding along the Sacramento River and built extensive mudflats on the outer margin of Suisun Marsh as the sediment made its way to the San Francisco Bay (Gilbert 1917; Kelley 1989; Mount 1995; Keller 2009). Current sediment supply rates are too low to sustain those mudflats and other features that were created prior to the building of large debris dams and water storage dams, and those features have been eroding for many years (Cappiella et al. 1999; Kimmerer 2004; Wright and Schoellhamer 2004; McKee et al. 2006; Ganju and Schoellhamer 2010). Levee building has affected the Plan Area in diverse ways. Upstream of the Delta along the Sacramento River and in the various flood basins, levee building has both trapped and sped the delivery of sediment to the Delta (James 1999; Singer and Dunne 2001; James 2004a, 2004b, 2006; Mikhailov et al. 2006; James and Singer 2008; Singer 2008; Singer et al. 2008; James et al. 2009; Singer and Aalto 2009). In the Delta proper, levees and various land uses have reduced the depth of peat soils within the confines of the levees to depths of -24 feet (-7.25 meters) (Drexler et al. 2009b), which creates an enormous volume of accommodation space that, in the event of a levee break, will bring saline and brackish water from the west further into the Delta (Mount and Twiss 2005).

As noted above, the alluvium underlying the Sacramento-San Joaquin Delta is dominated by Quaternary alluvial deposits in the channels and on the levees and peat beds in the center of the islands (Figure 2-3). The peat beds, combined with historical floodwater alluvial deposits of fine mineral particles, have provided highly fertile and productive soils to support the agriculture industry throughout the Plan Area (Figure 2-4). The smaller extent of mineral soils, including soils in the map units Zamora-Rincon-Capay-Brentwood, Veritas-Tinnin-Delhi, and Willows-Waukena-Pescadero-Fresno, are located primarily along the western and southern edges of the Plan Area (Figure 2-4).

Prior to reclamation for agriculture, much of the vegetation of the Delta (approximately 380,000 acres; 1538 square kilometers was dominated by tidal marshes (Atwater 1980; The Bay Institute 1998). By 1930, island reclamation was complete, and by 1980, only about 16,000 acres (65 square kilometers) of marshes remained (Atwater 1980; The Bay Institute 1998). Today, these areas of former tidal marshes consist primarily of channelized waterways surrounding highly productive row-cropped agricultural islands that are protected from flooding by over 1,300 miles (2,093 kilometers) of levees. Dewatering of the marshes and plowing the peat soils for farming have led to peat oxidation losses, soil compaction, and erosion of the islands, resulting in surface subsidence. The result is that the interiors of many Delta islands have substantially subsided and are now depressions well below the level of the surrounding water, protected only by a ring of levees (Figure 2-5).

2.3.3.2 Climate

The climate in the Sacramento-San Joaquin Delta region is spatially variable, but is generally characterized as hot Mediterranean (Köppen climate classification) (McKnight and Hess 2005). The general climate becomes milder from east to west due to marine influence as it is affected by influxes of winds off the Pacific Ocean.

Summers are hot with average summer highs in the upper 80 degrees Fahrenheit (°F) to lower 90°F, with little to no precipitation and low humidity. Heat waves are common in summer months, during which temperatures can reach triple digits for consecutive days. Periodically, a “Delta breeze” of cool and humid air from the ocean moves onshore and cools the Central Valley in the vicinity of the Delta by up to 7°F (3.9 degrees Celsius [°C]) (Pierce and Gaushell 2005). Winters are mild (average daily highs during November through March are in the mid-50 to mid-60°F) and wet. Approximately 80% of annual precipitation occurs between November and March. The primary origin of precipitation is the seasonal arrival of low-pressure systems from the Pacific Ocean. Very dense ground fog (tule fog) is common between periods of precipitation in the Plan Area from November through March.

The climate of the Plan Area is predicted to change in complex ways. Although there is high uncertainty, temperatures in the Plan Area are projected to increase at an accelerating pace from 3.6 to 9°F (2 to 5°C) by the end of the century (Cayan et al. 2009). Depending upon the general-circulation model used, there are variable predictions for precipitation change, with most models simulating a slight decrease in average precipitation (Dettinger 2005, California Climate Change Center 2006). The Mediterranean seasonal precipitation experienced in the Plan Area is expected to continue, with most precipitation falling during the winter season and originating from North Pacific storms. Although the amount of precipitation is not expected to change dramatically over the next century, seasonal and interannual variation in precipitation will likely increase as it has over the past century (California Department of Water Resources 2006). This could lead to more intense winter flooding, greater erosion of riparian habitats, and increased sedimentation in wetland habitats (Field et al. 1999; Hayhoe et al. 2004).

Global sea level rise predictions vary. One model predicts that by the end of this century, global sea level will increase by 7 to 23 inches (18 to 59 centimeters); with an additional 6 inches (15 centimeters) of sea level rise if the rate of Greenland ice-melt intensifies (Intergovernmental Panel on Climate Change 2007). Another model projection for sea level rise has produced middle range estimates from 28 to 39 inches (70 to 100 centimeters) by the end of this century, with a full range of variability from 20 to 55 inches (50 to 140 centimeters) (Rahmstorf 2007). Recently issued U.S. Army Corps of Engineers (USACE) guidance on incorporation of sea level rise in civil works projects suggests end of century sea level rise in the range of 20 to 59 inches (50 to 150 centimeters) (U.S. Army Corps of Engineers 2009).

Predicted warmer temperatures will affect the rate of snow accumulation and melting in the snowpack of the Sierra Nevada. Some projections predict reductions in the Sierra Nevada spring snowpack of as much as 70 to 90% by the end of the century (California Climate Change Center 2006). Knowles and Cayan (2002) estimated that a projected warming of 3°F (1.6°C) by 2060 would cause the loss of one-third of the watershed's total April snowpack, whereas a 4°F (2.1°C) warming by 2090 would reduce April snowpack by 50%. The loss of snowpack is predicted to be greater in the northern Sierra Nevada than in the southern Sierra Nevada because of differences in the relative amounts of low- and mid-elevation snowpack (California Department of Water Resources 2006). Measurements taken to track the water content of snow (snow water equivalent) since 1930 show that peak snow mass in the Sierra Nevada has been occurring earlier in the year by 0.6 day per decade (Kapnick and Hall 2009). These predicted changes in the dynamics of the snowpack will influence the timing, duration, and magnitude of inflow from the Sacramento and San Joaquin River watersheds. For example, with more precipitation falling as rain instead of snow and the snowpack melting earlier, greater peak flows will result during the rainy season and lower flows during the dry season. Knowles and Cayan (2004) predict that inflows will increase by 20% from October through February and decrease by 20% from March through September. Storm surges (tidal and wind-driven) associated with the more intense storms predicted for the future will also exacerbate Delta flooding.

2.3.3.3 Hydrologic Conditions

2.3.3.3.1 River Hydrology

The hydrology of the Plan Area is primarily influenced by freshwater inflows from the Sacramento River from the north and the San Joaquin River from the south (Figure 2-6). Eastside streams, particularly the Mokelumne River, also contribute inflows to the Plan Area. Numerous upstream dams and diversions greatly influence the timing and volume of water flowing into the Delta. Multiple upstream tributaries to the Sacramento and San Joaquin Rivers influence flow into the Plan Area. The Feather and American Rivers and many large creeks drain directly into the Sacramento River while the Cache and Putah Creeks drain into the Yolo Bypass, which joins the Sacramento River in the Cache Slough area. The Yuba and Bear Rivers drain into the Feather River before its confluence with the Sacramento River. The Calaveras, Stanislaus, Tuolumne, Merced, and Kings Rivers drain into the San Joaquin River upstream of the Delta. The Cosumnes River drains directly into the Mokelumne River, and both drain into the San Joaquin River after entering the Delta. In addition to the Sacramento and San Joaquin Deltas, the Mokelumne Delta in some ways can be viewed as a third important river delta.

Regardless of water-year type, the large majority of unimpaired upstream flow into the Delta originates from the Sacramento River and its tributaries, and a lesser extent originates from the San Joaquin River and its tributaries (Figures 2-7, 2-8, and 2-9). The Cosumnes and Mokelumne Rivers and other smaller tributaries, collectively called the eastside tributaries in Figures 2-7, 2-8, and 2-9, contribute only a small percentage of inflows. Upstream diversions reduce the total inflow from upstream rivers and tributaries. Only a small proportion of water, relative to upstream flows, enters the Plan Area through precipitation. In the 2000 water year, an above-normal water year, 69% of water entering the Delta passed through the system as outflow, 6% was consumed within the Delta, less than 1% was diverted via the North Bay Aqueduct Water District and Contra Costa Water District (CCWD), and 24% was exported via SWP/CVP facilities (Figure 2-8). Additional water was taken upstream of the Delta in upstream diversions and reservoirs that accounted for an additional 7,525 thousand af (Governor's Delta Vision Blue Ribbon Task Force 2008). These values vary by water-year type and the inflows associated with the water year. For example, in the 2001 water year, a dry year, approximately 51% of water entering the Delta passed through the system as outflow, 12% was consumed within the Delta, and 37% was exported via SWP/CVP facilities (Figure 2-9). Because exports and in-Delta use are relatively consistent across years, inflows affect Delta outflow most significantly, with a lower proportion of water exiting the system as outflow during drier years and a higher proportion during wetter years.

The hydrograph of the Delta is highly variable both within and across years (Figure 2-10). Within years, water flow is generally greatest in winter and spring with inputs of wet season precipitation and snowpack melt from the Sierra Nevada and lowest during fall and early winter before significant rainfall. The construction of upstream dams and reservoirs for flood protection and water supply has dampened the seasonal variation in flow rates. Water is released from reservoirs year-round, and flooding is much less common than it was before dam and levee construction. As a result, the frequency of small- to moderate-sized floods has been significantly reduced since major dam construction, although the magnitude and frequency of large floods has not been significantly altered; additionally, because of climatic changes there have been more large floods in the last 50 years than the previous 50 years. Across years, wet and dry periods (defined as periods during which unimpaired runoff was above or below average, respectively, for three or more years) occurred numerous times in the last 100 years; although the duration and magnitude of the wet and dry periods have increased in the last 30 years, including the 6-year drought of 1987 to 1992 and the prolonged periods of wetness in the early to mid-1980s and the middle to the late 1990s (California Department of Water Resources 2007a). The wet and dry periods recorded over the last 150 years, however, are less severe and shorter than the prolonged wet and dry periods of the previous 1,000 years.

The Yolo Bypass is an important physical feature affecting river hydrology during high-flow events in the Sacramento River watershed. The bypass is a 59,280-acre engineered floodplain that conveys flood flows from the Sacramento River, Feather River, American River, Sutter Bypass, and western tributaries and drains (Figure 2-11) (Harrell and Sommer 2003). The leveed bypass protects Sacramento and other nearby communities from flooding during high-water events. Most water enters the Yolo Bypass by spilling over the Fremont and Sacramento weirs and returns to the Sacramento River in the Delta approximately 5 miles upstream of Rio Vista. The Yolo Bypass floods seasonally in approximately 70% of years (Sommer et al. 2001b), in which approximately 10% of the floodwaters are from westside tributaries. The Yolo Bypass can convey up to 80% of flow from the Sacramento basin during flood events (Sommer et al. 2001a).

2.3.3.3.2 Tides

The Delta, lower portion of the Yolo Bypass, and Suisun Marsh are tidally influenced by the Pacific Ocean, although tidal range and influence decreases with increasing distance from the San Francisco Bay (Kimmerer 2004; Siegel 2007). Tides are mixed semidiurnal with two highs and two lows each day, one large magnitude high and low, and one lower magnitude high and low. A typical diurnal range is 3.3 to 4.6 feet (1 to 1.4 meters) in the western Delta (Orr et al. 2003). The entire tidal cycle is superimposed upon the larger 28-day lunar cycle with more extreme highs and lows during spring tides and depressed highs and lows during the neap tides. In addition, annual tidal elevations are highest in February and August. The multiple temporal scales at which these cycles occur causes significant variation in draining and filling of the Delta, and therefore, in patterns of mixing of the waters (Kimmerer 2004). Additionally, variation in sea level can also be caused by changes in atmospheric pressure and winds.

2.3.3.3.3 Water Supply Facilities and Facility Operations

Over 3,000 diversions remove water from upstream and in-Delta waterways for agricultural, municipal, and industrial uses; 722 of these are located in the mainstem San Joaquin and Sacramento Rivers and 2,209 diversions are in the Delta (Herren and Kawasaki 2001). In the Delta, the CVP managed by the Bureau of Reclamation (Reclamation) and SWP managed by DWR use the Sacramento and San Joaquin Rivers and other Delta channels to transport water from river flows and reservoir storage to two water export facilities in the south Delta (Figure 2-12). The C. W. “Bill” Jones Pumping Plant (herein referred to as the Jones Pumping Plant) is operated by the CVP and the Harvey O. Banks Delta Pumping Plant (herein referred to as the Banks Pumping Plant) is operated by the SWP. Water from these facilities is exported for urban and agricultural water supply demands throughout the San Joaquin Valley, southern California, the central coast, and the southern and eastern San Francisco Bay area.

Water enters the Banks Pumping Plant via the Clifton Court Forebay (Figure 2-12). Large radial arm gates control inflows to Clifton Court Forebay during the tidal cycle to reduce approach velocities, prevent scouring of adjacent channels, and by allowing water to enter the Clifton Court Forebay at times other than low tide, reducing water level fluctuation in the south Delta (U.S. Fish and Wildlife Service 2005). The Banks Pumping Plant operates to move water from Clifton Court Forebay into the 440-mile (708-kilometer) California Aqueduct. Water in the California Aqueduct travels to O’Neill Forebay; where a portion of the water is diverted to the joint-use SWP/CVP San Luis Reservoir for storage. The remaining water flows southward via the joint-use San Luis Canal, and to the South Bay Pumping Plant and South Bay Aqueduct.

Water from Old River in the Delta is pumped by the Jones Pumping Plant into the Delta-Mendota Canal. The Jones Pumping Plant facility does not have an associated forebay. The Delta-Mendota Canal sends water southward, providing irrigation water along the way, towards the O’Neill Forebay where a portion of the water is diverted into the San Luis Reservoir. The remaining water continues in the Delta-Mendota Canal, providing irrigation water along the way, until it reaches the Mendota Pool, where water is returned to the San Joaquin River to replenish downstream flows.

The Delta Cross Channel is operated by Reclamation to improve through-Delta flows from the Sacramento River toward the pumping facilities in the south Delta, with benefits for water quality and salmonid migration (Figure 2-12). Water is diverted into Snodgrass Slough, a tributary of the Mokelumne River, through which it travels into the central Delta. Two large radial gates on the Delta Cross Channel can open or close to control flows into the central Delta. Reasons for closure include reduction in scour in the channels on the downstream side of the Delta Cross Channel, reduction in flood flows into the Mokelumne River, and fish protection.

The Barker Slough Pumping Plant is operated by the SWP and draws water from Barker Slough into the North Bay Aqueduct (Figure 2-12). The intake is located just upstream of where Barker Slough empties into Lindsey Slough, which is approximately 10 miles (16 kilometers) from the mainstem Sacramento River. Water from the Barker Slough Pumping Plant is delivered to Napa and Solano Counties for municipal and industrial uses. The North Bay Aqueduct is operated by DWR as part of the SWP and delivers wholesale water to the Solano County Water Agency and the Napa County Flood Control and Water Conservation District. The 27.6-mile North Bay Aqueduct extends from Barker Slough to the end of the Napa Turnout Reservoir. Water is pumped from the Delta at the Barker Slough Pumping Plant, which is located 7 river miles upstream from the confluence of Barker Slough with the Sacramento River in southeast Solano County. Water is then diverted to the Travis Surge Tank where it flows by gravity through the North Bay Aqueduct to the Cordelia Pumping Plant.

The South Delta Temporary Barriers project consists of the installation of four rock barriers each spring in south Delta channels: the head of Old River, Old River at Tracy, Grant Line Canal, and Middle River. The head of Old River barrier is also installed during the fall for dissolved oxygen reasons. The head of Old River barrier is considered a fish barrier because it is installed to keep migrating juvenile Chinook salmon in the San Joaquin River. The other three barriers are agricultural barriers, meaning they are installed to maintain water quality and water levels for agricultural uses in the south Delta. The head of Old River barrier was not installed in spring 2009 or 2010 as the U.S. Fish and Wildlife Service (USFWS) biological opinion (BiOp) (2008a) prohibited the installation of the barrier for the protection of delta smelt. The rock barriers are not installed in years when San Joaquin River flows are high, such as during 1998.

The CCWD diverts water from the Delta to the Contra Costa Canal and the Los Vaqueros Reservoir using four intake locations: Rock Slough, Old River, Mallard Slough, and Middle River (on Victoria Canal) (Figure 2-12). The Contra Costa Canal and its pumping plants have a capacity of 350 cfs and were built by Reclamation from 1937 to 1948 as part of the CVP. The Contra Costa Canal is owned by Reclamation but operated and maintained by CCWD. The screened Old River Pump Station (250 cfs capacity) was built in 1997 as part of the Los Vaqueros Project to improve water quality for CCWD. The Old River pump station connects via pipelines to a transfer pump station (200 cfs) used to pump water into Los Vaqueros Reservoir (160,000 af capacity) and from the transfer station via gravity pipeline to the Contra Costa Canal. The screened Mallard Slough intake (39 cfs capacity) was constructed in the 1920s and rebuilt to make it seismically protected in 2001. It is used primarily in winter and spring during wet periods when water quality is sufficiently high. The screened Middle River intake and pump station (250 cfs capacity) were completed in 2010 to provide additional operational flexibility and improved water quality. The Middle River intake connects to the Old River Pump Station via pipe that crosses Victoria Island and tunnels underneath Old River. The Middle River intake is used primarily in late summer and fall to provide better water quality than is obtainable from the other three intakes.

East Contra Costa Irrigation District provides water supplies to the city of Brentwood, portions of Antioch and Oakley, the unincorporated community of Knightsen, and surrounding unincorporated rural areas (Dudek 2007). The East Contra Costa Irrigation District operates a diversion located at Indian Slough on Old River in combination with canals and pumping stations for distribution within the service area. The primary purpose of the diversion is to provide raw water for irrigation of cultivated lands, landscape, and recreational uses (e.g., golf courses). The district has agreements with CCWD and City of Brentwood to make surplus water available for municipal use.

The city of Antioch, located in eastern Contra Costa County, supplies water through diversions directly from the San Joaquin River, raw water purchased from CCWD that is delivered through the Contra Costa Canal, and treated water delivered through CCWD's Multi-Purpose Pipeline (Dudek 2007). Antioch receives approximately 85% of its water supplies from CCWD. The majority of the water is provided for municipal and residential use, with industrial (11%) and agricultural (13%) uses in the service area.

Byron Bethany Irrigation District provides water for agricultural, industrial, and municipal uses to portions of Alameda, Contra Costa, and San Joaquin Counties (San Joaquin County Planning Division 2008). The district maintains two water diversions from the Delta under a pre-1914 appropriative water right and a riparian water right on Old River. Water diversions occur from the SWP intake channel, located between the Skinner Fish Protection Facility and the Banks Pumping Plant. Two diversions serve the Byron Division and the Bethany Division. The District also operates a series of pumping stations and canals for water distribution.

East Bay Municipal Utility District's Mokelumne Aqueduct traverses the Delta, carrying water from Pardee Reservoir on the Mokelumne River to the East Bay (Figure 2-12). East Bay Municipal Utility District, in partnership with Sacramento County, constructed a major new diversion from the Sacramento River at Freeport. This new diversion, sized at 185 million gallons/day capacity, feeds into the Mokelumne Aqueduct and the Vineyard Surface Water Treatment Plant for central Sacramento County use.

There are over 2,200 water diversions in the Delta, most of which are unscreened and used for in-Delta agriculture irrigation (Figure 2-13) (Herren and Kawasaki 2001). Industrial diversions in the Plan Area include the Mirant Power plants at Pittsburg and Antioch. Water from these diversions cools generators producing electric power at the plants.

Suisun Bay and Suisun Marsh are important ecosystems connected to the Delta, and habitat conditions and facility operations in Suisun Bay and Marsh can affect ecosystem conditions in the Delta (Figure 2-12 and Figure 2-13). A system of levees, canals, gates, and culverts in Suisun Marsh was constructed in 1979-80 and is currently operated by DWR to lower salinity in privately managed wetlands in the marsh. The Suisun Marsh Salinity Control Gates are composed primarily of a set of radial gates that extend across the entire width of Montezuma Slough. The control gates are used to reduce salinity from Collinsville through Montezuma Slough and into the eastern and central parts of Suisun Marsh, and to reduce intrusion of saltwater from downstream into the western part of Suisun Marsh. In addition to radial gates, the Suisun Marsh Salinity Control Gates consist of permanent barriers adjacent to the levee on either side of the channel, flashboards, and a boat lock. The gates have been operated historically from September to May and open and close twice a day during full operation to take advantage of tidal flows. The gates are opened during ebb tides to allow fresh water from the Sacramento River to flow into Montezuma Slough and are closed during flood tides to prevent higher salinity water from downstream from entering Montezuma Slough. Gate operations have been curtailed in recent years, to allow for salmon passage while still meeting the salinity requirements outlined within Decision-1641.

2.3.3.4 Non-Water Supply Plan Area Infrastructure and Uses

The Plan Area supports a substantial amount of infrastructure related to urban development, transportation, agriculture, recreation, energy, and other uses. Portions of six counties are included in the legal Delta: Yolo, Sacramento, Solano, Contra Costa, Alameda, and San Joaquin (California Department of Water Resources 2006).

The major land use for the Plan Area is agriculture, which represents approximately two-thirds of all surface area. There is increasing residential, commercial, and industrial land use in the Plan Area, most of which occurs around the periphery of the Delta. Major urban development within the cities of Sacramento, West Sacramento, Stockton, Tracy, Antioch, Brentwood, and Pittsburg are in the Plan Area. Small towns located wholly within the Delta include Clarksburg, Hood, Walnut Grove, Isleton, Collinsville, Courtland, Locke, Ryde, Bethel Island, and Discovery Bay. Much of this development occurs in the secondary zone of the Delta (as defined in Section 12220 of the Water Code).

Several interstate highways (Interstates 5, 80, 205/580, and 680) and one state highway (State Route [SR] 99) are on the periphery of the Delta, and three state highways (SR 4, SR 12, and SR 160) and multiple county roads cut across the Delta (Figure 2-13). Three major railways cross through the Delta. The Plan Area contains a network of electrical transmission lines (over 500 miles [805 kilometers]) and gas pipelines (over 100 lines). Natural gas extraction and storage is another important Plan Area use. In addition to approximately 95 public and private marinas (Lund et al. 2007), two major ports (Stockton and Sacramento) and their associated maintained ship channels are in the Delta. These ports can handle high tonnage (55,000-ton class) ships to move cargo to and from the Pacific Ocean. Much of the Plan Area, including 635 miles (1,022 kilometers) of boating waterways, is used for a variety of recreational purposes including water sports, fishing, hunting, and wildlife viewing (Lund et al. 2007).

2.3.4 Natural Communities

Under an approved planning agreement (Section 2800 of the NCCPA), natural communities are "those species and their habitat identified by the department that are necessary to maintain the continued viability of those biological communities." There are 13 natural communities in the Plan Area. (Table 2-3; Figure 2-14). Cultivated lands, while not a natural community, are included in the analysis for the habitat benefits they provide, as discussed in Section 2.3.4.14, *Cultivated Lands.*

As discussed in Section 2.3.1, *Data Sources and Natural Community Classification*, the descriptions of the natural communities that follow are generally based on those originally developed for the CALFED Bay-Delta Program (2000) *Multi-Species Conservation Strategy*. These community types were refined and augmented by input from CDFW staff participating in the BDCP Terrestrial Resources subgroup in 2009.

The extent of each natural community in the Plan Area is presented in Table 2-3, and the covered species that are supported in those natural communities are identified in Table 2-4. The distribution of natural communities in the Plan Area is presented in Figure 2-14.

Table 2-3. Extent of Natural Communities in the Plan Area

Natural Community	Acreage
Tidal perennial aquatic	86,266
Tidal mudflat	NA[a]
Tidal brackish emergent wetland	8,501
Tidal freshwater emergent wetland	8,953
Valley/foothill riparian	18,132
Nontidal perennial aquatic	5,509
Nontidal freshwater perennial emergent wetland	1,245
Alkali seasonal wetland complex	3,723
Vernal pool complex	8,547
Managed wetland	64,897
Other natural seasonal wetland	276
Grassland	78,624
Inland dune scrub	20
Cultivated lands	506,627
Total	**791,320**

Notes:

[a] Tidal mudflats are not mapped separately, and occur at the edges between tidal perennial aquatic, tidal freshwater emergent, and tidal brackish emergent.

These natural communities provide habitat for animals and plants that are covered under the Plan Area, or in some cases, constitute a source of food organisms for covered fishes. Covered fish, wildlife, and plant species that could be present within these natural communities or could consume food resources produced in these natural communities are presented in Table 2-4.

A generalized schematic of the distribution of natural communities in the Plan Area relative to tidal levels and representative species associated with each of the communities is depicted in Figure 2-15. All of the communities and covered species are discussed in more detail in the following sections and in Appendix 2.A, *Covered Species Accounts*. The following sections describe the 13 natural communities (and cultivated lands) and discuss the physical and biological attributes associated with each.

Table 2-4. Covered Species that Are Present In or Are Supported By the Natural Communities of the Plan Area

Common Name *Scientific Name*	**Plan Area Natural Communities**													
	TPA	**TM**	**TBEW**	**TFEW**	**VFR**[a]	**NPA**	**NFPEW**	**ASWC**	**VPC**	**MW**[b]	**ONSW**	**G**	**IDS**	**CL**[b]
Fish														
Delta smelt *Hypomesus transpacificus*	X	X	X	X						X				X
Longfin smelt *Spirinchus thaleichthys*	X	X	X	X						X				X
Chinook salmon, Sacramento River winter-run *Oncorhynchus tshawytscha*	X	X	X	X	X					X				X
Chinook salmon, Central Valley spring-run *Oncorhynchus tshawytscha*	X	X	X	X	X					X				X
Chinook salmon, Central Valley fall-run and late fall–run *Oncorhynchus tshawytscha*	X	X	X	X	X					X				X
Steelhead, Central Valley DPS *Oncorhynchus mykiss*	X	X	X	X	X					X				X
Sacramento splittail *Pogonichthys macrolepidotus*	X	X	X	X						X				X
Green sturgeon *Acipenser medirostris*	X	X	X	X						X				X
White sturgeon *Acipenser transmontanus*	X	X	X	X						X				X
Pacific lamprey *Entosphenus tridentatus* (formerly *Lampetra tridentata*)	X	X	X	X						X				X
River lamprey *Lampetra ayresii*	X	X	X	X						X				X
Mammals														
Riparian brush rabbit *Sylvilagus bachmani riparius*					X							X		

Common Name *Scientific Name*	Plan Area Natural Communities													
	TPA	**TM**	**TBEW**	**TFEW**	**VFR**[a]	**NPA**	**NFPEW**	**ASWC**	**VPC**	**MW**[b]	**ONSW**	**G**	**IDS**	**CL**[b]
Riparian woodrat (San Joaquin Valley) *Neotoma fuscipes riparia*					X									
Salt marsh harvest mouse *Reithrodontomys raviventris*			X							X		X		
San Joaquin kit fox *Vulpes macrotis mutica*									X			X		
Suisun shrew *Sorex ornatus sinuosus*			X							X		X		
Birds														
California black rail *Laterallus jamaicensis coturniculus*			X	X			X			X				
California clapper rail *Rallus longirostris obsoletus*		X	X	X										
Greater sandhill crane *Grus canadensis tabida*								X	X	X	X	X		X
Least Bell's vireo *Vireo bellii pusillus*					X									
Suisun song sparrow *Melospiza melodia maxillaris*			X	X						X				
Swainson's hawk *Buteo swainsoni*					X			X	X	X	X	X		X
Tricolored blackbird *Agelaius tricolor*			X	X	X		X	X	X	X	X	X		X
Western burrowing owl *Athene cunicularia hypugaea*								X	X	X	X	X		X
Western yellow-billed cuckoo *Coccyzus americanus occidentalis*					X									
White-tailed kite *Elanus leucurus*					X			X	X	X	X	X		X

Common Name *Scientific Name*	**Plan Area Natural Communities**													
	TPA	**TM**	**TBEW**	**TFEW**	**VFR**[a]	**NPA**	**NFPEW**	**ASWC**	**VPC**	**MW**[b]	**ONSW**	**G**	**IDS**	**CL**[b]
Yellow-breasted chat *Icteria viriens*					X									
Reptiles														
Giant garter snake *Thamnophis gigas*	X			X		X	X	X	X	X		X		X
Western pond turtle *Actinemys marmorata*	X		X	X	X	X	X			X		X		X
Amphibians														
California red-legged frog *Rana draytonii*				X	X	X	X	X	X	X		X		X
California tiger salamander (Central Valley distinct population segment [DPS]) *Ambystoma californiense*								X	X			X		
Invertebrates														
California linderiella *Linderiella occidentalis*								X	X					
Conservancy fairy shrimp *Branchinecta conservatio*								X	X					
Longhorn fairy shrimp *Branchinecta longiantenna*								X	X					
Midvalley fairy shrimp *Branchinecta mesovallensis*								X	X					
Valley elderberry longhorn beetle *Desmocerus californicus dimorphus*					X							X		
Vernal pool fairy shrimp *Branchinecta lynchi*								X	X					
Vernal pool tadpole shrimp *Lepidurus packardi*								X	X					
Plants														
Alkali milk-vetch *Astragalus tener* var. *tener*									X					

Common Name ***Scientific Name***	**Plan Area Natural Communities**													
	TPA	**TM**	**TBEW**	**TFEW**	**VFR**[a]	**NPA**	**NFPEW**	**ASWC**	**VPC**	**MW**[b]	**ONSW**	**G**	**IDS**	**CL**[b]
Boggs Lake hedge-hyssop *Gratiola heterosepala*									X					
Brittlescale *Atriplex depressa*								X	X			X		
Carquinez goldenbush *Isocoma arguta*								X	X			X		
Delta button celery *Eryngium racemosum*					X			X	X			X		
Delta mudwort *Limosella subulata*		X	X	X	X									
Delta tule pea *Lathyrus jepsonii* var.*jepsonii*			X	X	X									
Dwarf downingia *Downingia pusilla*									X					
Heartscale *Atriplex cordulata*								X	X			X		
Heckard's peppergrass *Lepidium latipes* var. *Heckardii*									X					
Legenere *Legenere limosa*									X					
Mason's lilaeopsis *Lilaeopsis masonii*		X	X	X	X									
San Joaquin spearscale *Atriplex joaquiniana*								X	X			X		
Side-flowering skullcap *Scutellaria lateriflora*					X									
Slough thistle *Cirsium crassicaule*					X									
Soft bird's-beak *Cordylanthus mollis ssp. Mollis*			X											

Common Name *Scientific Name*	Plan Area Natural Communities													
	TPA	**TM**	**TBEW**	**TFEW**	**VFR**[a]	**NPA**	**NFPEW**	**ASWC**	**VPC**	**MW**[b]	**ONSW**	**G**	**IDS**	**CL**[b]
Suisun Marsh aster *Symphyotrichum lentum*			X	X	X									
Suisun thistle *Cirsium hydrophilum* var. *Hydrophilum*			X											

Notes:

[a] Valley/foothill riparian natural community support salmonids by providing riparian shade, cooler water temperatures and undercut bank cover and through detrital and terrestrial insect export that supports the aquatic foodweb.

[b] Managed wetland and cultivated lands support aquatic species through both directly through habitat accessible during periods of flooding (e.g., to splittail and Chinook), as well as through detrital export that supports phytoplankton and zooplankton communities and thus provides aquatic foodweb support.

Natural community codes:

TPA = tidal perennial aquatic
TM = tidal mudflat
TBEW = tidal brackish emergent wetland
TFEW = tidal freshwater emergent wetland
VFR = valley/foothill riparian
NPA = nontidal perennial aquatic
NFPEW = nontidal freshwater perennial emergent wetland
ASWC = alkali seasonal wetland complex
VPC = vernal pool complex
MW = managed wetland
ONSW = other natural seasonal wetland
G = grassland
IDS = inland dune scrub
CL = cultivated lands

2.3.4.1 Tidal Perennial Aquatic

The tidal perennial aquatic natural community includes deep water aquatic (greater than 10 feet [3 meters] deep from mean low low tide (lowest of the low tide in a day), shallow aquatic (less than or equal to 10 feet [3 meters] deep from mean low low tide), and unvegetated intertidal (i.e., mudflat) zones of estuarine bays, river channels, and sloughs (CALFED Bay-Delta Program 2000). Under present water operation conditions in the Plan Area, tidal perennial aquatic is mainly fresh water, with brackish and saline conditions occurring in Suisun Bay at times of high tides and low freshwater inflows. The distribution of the tidal perennial aquatic natural community in the Plan Area is shown in Figure 2-14.

2.3.4.1.1 Vegetation

The tidal perennial aquatic natural community is largely unvegetated. Where vegetation exists, it can be separated into two categories: submerged aquatic vegetation and floating vegetation (both rooted and unrooted) (Cowardin et al. 1979). The classification units used to map the tidal perennial aquatic natural community are shown in Table 2-5. The geographic extent of this vegetation is highly dynamic through time and space because it is largely dependent on physical factors that are highly variable, such as depth, turbidity, water flow, salinity, substrate, and nutrient availability.

Submerged aquatic vegetation consists of aquatic plants that cannot tolerate drying, and as a result, maintain leaves at or below the water surface. Submerged vascular plant species in the tidal perennial aquatic natural community include native water primrose and the highly abundant and invasive nonnative *Egeria.* The introduction of *Egeria* has been detrimental to native fishes in the Plan Area (Section 2.3.4.1.3, *Nonnative Species*). Another common submerged nonnative invasive plant is the Eurasian watermilfoil. In addition to plants, algae and cyanobacteria can be common during summer and fall months in areas with clear water and little shade. Blooms of the nonnative floating toxic cyanobacteria, *Microcystis*, were first documented in the Delta in 1999, and its distribution has subsequently expanded eastward (Lehman et al. 2005). Periphyton, a thin layer of organisms (mostly diatoms and bacteria) and their exudates, forms on substrates throughout this community. The ecologically important eelgrass grows in soft sediment in the subtidal estuarine habitat, primarily in the far western Suisun Bay where salinities are sufficiently high for this brackish/saltwater species. Dense eelgrass beds can provide suitable habitat for young fish and other aquatic organisms and are an important food source for waterfowl, although their occurrence in the Plan Area is very limited.

Floating aquatic vegetation in this habitat generally consists of free-floating beds of plants at the surface or in the water column. Wind and water movement can be important factors in determining its distribution. Species in this group include native duckweed, native floating water fern, and nonnative invasive water hyacinth. Reddish carpets of native floating water fern occur in calm waters of sloughs supporting tidal perennial aquatic. This water fern has a symbiotic relationship with a nitrogen-fixing bacterium that lives within its tissues (Armstrong 1979). Water hyacinth grows in dense mats that can have harmful effects on native fish species (Section 2.3.4.1.3, *Nonnative Species*).

1 **Table 2-5. Map Classifications in the Tidal Perennial Aquatic Natural Community in the Plan Area**

Map Classification[a]	Acreage in Plan Area
Water	56,101
Undetermined[b]	22,256
Ditches and sloughs[c]	3,489
Brazilian Waterweed (*Egeria - Myriophyllum*) Submerged	2,883
Algae	328
Tidal Mudflat	326
Generic Floating Aquatics	239
Floating Primrose (*Ludwigia peploides*)	133
Water Hyacinth (*Eichhornia crassipes*)	128
Milfoil - Waterweed (generic submerged aquatics)	65
Typha species (generic)	64
Ludwigia peploides	53
Scirpus (californicus or acutus)-Typha sp.	48
Scirpus californicus/S. acutus	36
Tidal mudflats	28
Scirpus (californicus or acutus)/Wetland	20
Scirpus (californicus or acutus)/Rosa	8
Hydrocotyle ranunculoides	7
Wetland herbs [b]	6
Pondweed (Potamogeton sp.)	5
Eucalyptus globulus	4
Phragmites australis	4
Typha angustifolia/Distichlis	3
Distichlis (generic)	3
Scirpus americanus/S. Californicus-S. acu	3
Rosa/Baccharis	3
Calystegia/Euthamia	2
Structure	2
Flooded Managed Wetland	2
Annual Grasses generic	2
Lepidium (generic)	2
Phragmites/Scirpus	2
Raphanus sativus (generic)	1
Typha angustifolia/Phragmites	1
Rosa californica	1
Rubus discolor	1
*Typha angustifoli*a/S. americanus	1
Foeniculum vulgare	1
Tall Wetland Graminoids	1
Total	**86,263**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] This map classification is located in a portion of the Plan Area for which California Department of Fish and Wildlife did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Natural Community Classification*, these areas were delineated to natural community from aerial photography interpretation.

[c] California Department of Fish and Wildlife vegetation types were combined in order to condense the list.

2.3.4.1.2 Fish and Wildlife

Zooplankton in the foodweb of the tidal perennial aquatic natural community consume phytoplankton and detritus, and are fed upon by other consumers, such as fish and macroinvertebrates. Water salinity is a major factor that influences the distribution of zooplankton species in the tidal perennial aquatic natural community. In the brackish portions of the Plan Area, calanoid copepods (*Eurytemora*, *Pseudodiaptomus*) and cyclopoid copepods (*Limnoithona*) are the primary zooplankton species, and mysid shrimp (*Neomysis*) is the dominant macrozooplankton. In freshwater regions, cladocerans (*Daphnia*) and calanoid copepods (*Diaptomus*, *Limnocalanus*) are the dominant zooplankton present (Kimmerer and Orsi 1996; Kimmerer 2004; Gewant and Bollens 2005; Winder and Jassby 2010).

The tidal perennial aquatic natural community supports over 50 species of fish, approximately one-half of which are native (Table 2-6). It is used as habitat by fish for foraging, spawning, egg incubation and larval development, juvenile nursery areas, and migratory corridors. Most species spend their entire lives in the community while others may spend certain seasons or part of their lives in habitats outside of the tidal perennial aquatic natural community depending on the state of physical factors such as salinity, turbidity, dissolved oxygen, flow rates, and water temperature. Tidal perennial aquatic habitat is the primary habitat type for all covered fish species (Table 2-4). The covered giant garter snake is a terrestrial species known to forage in tidal perennial aquatic habitat (Table 2-4).

Table 2-6. Native and Nonnative Fish Species Found in the Plan Area

Family	Common Name	Scientific Name
Native Species		
Acipenseridae	Green sturgeon	*Acipenser medirostris*
	White sturgeon	*Acipenser transmontanus*
Atherinopsidae	Topsmelt	*Atherinops affinis*
Catostomidae	Sacramento sucker	*Catostomus occidentalis*
Clupeidae	Pacific herring	*Clupea pallasii*
Cottidae	Prickly sculpin	*Cottus asper*
	Pacific staghorn sculpin	*Leptocottus armatus*
Cyprinidae	California roach	*Hesperoleucus symmetricus*
	Hitch	*Lavinia exilicauda*
	Hardhead	*Mylopharodon conocephalus*
	Sacramento blackfish	*Orthodon microlepidotus*
	Sacramento splittail	*Pogonichthys macrolepidotus*
	Sacramento pikeminnow	*Ptychocheilus grandis*
Embiotocidae	Tule perch	*Hysterocarpus traskii*
Engraulidae	Northern anchovy	*Engraulis mordax*
Gasterosteidae	Threespine stickleback	*Gasterosteus aculeatus*
Gobiidae	Chameleon goby	*Tridentiger trigonocephalus*
Osmeridae	Delta smelt	*Hypomesus transpacificus*
	Longfin smelt	*Spirinchus thaleichthys*
Petromyzontidae	River lamprey	*Lampetra ayresii*
	Pacific lamprey	*Entosphenus tridentatus* (formerly *Lampetra tridentata*)

Family	Common Name	Scientific Name
Pleuronectidae	Starry flounder	*Platichthys stellatus*
Salmonidae	Rainbow/steelhead trout	*Oncorhynchus mykiss*
	Chinook salmon	*Oncorhynchus tshawytscha*
Nonnative Species		
Atherinopsidae	Inland silverside	*Menidia beryllina*
Centrarchidae	Pumpkinseed	*Lepomis gibbosus*
	Warmouth	*Lepomis gulosus*
	Green sunfish	*Lepomis cyanellus*
	Redear sunfish	*Lepomis microlophus*
	Bluegill	*Lepomis macrochirus*
	Redeye bass	*Micropterus coosae*
	Smallmouth bass	*Micropterus dolomieu*
	Spotted bass	*Micropterus punctulatus*
	Largemouth bass	*Micropterus salmoides*
	Black crappie	*Pomoxis nigromaculatus*
	White crappie	*Pomoxis annularis*
Clupeidae	American shad	*Alosa sapidissima*
	Threadfin shad	*Dorosoma petenense*
Cyprinidae	Goldfish	*Carassius auratus auratus*
	Red shiner	*Cyprinella lutrensis*
	Common carp	*Cyprinus carpio*
	Golden shiner	*Notemigonus crysoleucas*
	Fathead minnow	*Pimephales promelas*
Fundulidae	Rainwater killifish	*Lucania parva*
Gobiidae	Yellowfin goby	*Acanthogobius flavimanus*
	Shokihaze goby	*Tridentiger barbatus*
	Shimofuri goby	*Tridentiger bifasciatus*
Ictaluridae	Brown bullhead	*Ameiurus nebulosus*
	Black bullhead	*Ameiurus melas*
	White catfish	*Ameiurus catus*
	Channel catfish	*Ictalurus punctatus*
Moronidae	Striped bass	*Morone saxatilis*
Osmeridae	Wakasagi	*Hypomesus nipponensis*
Percidae	Bigscale logperch	*Percina macrolepida*
Poeciliidae	Western mosquitofish	*Gambusia affinis*
Source: U.S. Fish and Wildlife Service, Stockton Office, unpublished data.		

In addition to its value as habitat for fish, the tidal perennial aquatic natural community provides reproduction, feeding, and resting habitat for many species of mammals and birds. Open water areas supply habitat for rest and foraging by water birds, especially during heavy winter storms when open coastal waters become rough. Bird species that use open water include loons, gulls, cormorants, and diving ducks (CALFED Bay-Delta Program 2000). A number of state and federally listed birds feed on fish in the tidal perennial aquatic natural community, including the bald eagle, and California least tern.

2.3.4.1.3 Nonnative Species

The tidal perennial aquatic natural community has been heavily affected on nearly every trophic level by the introductions of a number of nonnative species. These nonnative species have had substantial adverse effects on the physical habitat and the foodweb, ultimately affecting the growth and survival of the species covered under the BDCP. Successful nonnatives tend to be better suited than natives to anthropogenic changes to the tidal perennial aquatic natural community. Successful nonnatives generally do not experience the same population controls (i.e., competition, predation, parasitism, and disease) that were present in their place of native origin, resulting in rapid population expansion where they are introduced.

The introduction of two nonnative invasive aquatic plants, water hyacinth and *Egeria*, has reduced habitat quantity and value for many native fishes in the Plan Area. Water hyacinth primarily occurs in the south Delta upstream of Antioch (CalFlora 2011). Under ideal conditions, it is capable of extremely rapid growth and can tolerate wide ranges in nutrient concentration, pH, and temperature (Batcher 2000). The species grows as dense floating mats that can greatly reduce primary productivity within the water column (National Marine Fisheries Service 2004). *Egeria* is widely distributed in freshwater areas of the Delta, growing along the margins of channels and in shallow bays in dense stands that restrict the access of juvenile fish to shallow water habitat. The dense vegetative cover created by these two invasive species provides excellent habitat for nonnative ambush predators such as bass and sunfish. *Egeria* is also thought to reduce turbidity by reducing water velocity, resulting in higher local precipitation of suspended matter from the water column. The increased visibility creates better hunting conditions for nonnative ambush predators (Brown and Michniuk 2007).

Introduction of the highly efficient filter-feeding *Potamocorbula* led to a decline in abundance of the native copepod, *Eurytemora*, This was followed by establishment of a nonnative copepod, *Pseudodiaptomus* (Kimmerer and Orsi 1996). *Eurytemora* can still be abundant during spring, but its populations are replaced by *Pseudodiaptomus* in late spring. Although native fishes, including delta smelt and larval longfin smelt, can switch between these two copepod prey species, because *Pseudodiaptomus* is more elusive than *Eurytemora*, a decrease in the abundance of *Eurytemora* can lead to lower fish foraging efficiency leading to reduced growth rates and the starvation of native fishes (Moyle 2002). More recently, the cyclopoid copepod, *Limnoithona,* has rapidly become the most abundant copepod in the Delta after its introduction in 1993 (Hennessey and Hieb 2007). This species is hypothesized to be a low-quality food source and intraguild predator of calanoid copepods such as *Eurytemora* and *Pseudodiaptomus* (Resources Agency et al. 2007).

A variety of macroinvertebrates has been introduced into the tidal perennial aquatic natural community with varying impacts. The Chinese mitten crab experienced a population bloom in 1997 that overwhelmed the fish screening facilities associated with the Jones and Banks Pumping Plants, but has been uncommon since then. Other potential adverse effects of Chinese mitten crab include physical impacts, because the crabs burrow into soft sediment and reduce levee stability; ecological impacts, because the crabs are omnivorous, voracious, and experience population booms; and economic impacts, because the crabs are known to eat rice shoots. The introductions of two clams from Asia, *Potamocorbula* and the Asian clam, have led to major alterations in the foodweb in the Delta. *Potamocorbula* is most abundant in brackish and saline water while the Asian clam is most abundant in fresh water; therefore, *Potamocorbula* is most abundant in Suisun Bay and the western Delta, and the Asian clam is most abundant in the central Delta. These species are highly efficient filter feeders that significantly reduce phytoplankton and zooplankton concentrations in the water column, which results in reduced food availability for native fishes, such as delta smelt and young Chinook salmon (Kimmerer and Orsi 1996; National Marine Fisheries Service 2004; Center for Biological Diversity 2007). In addition to its adverse effects on *Eurytemora*, *Potamocorbula* clam has been implicated in the reduction of the native opossum shrimp, *Neomysis*, a preferred food of Delta native fishes such as Sacramento splittail and longfin smelt (Feyrer 1999; Moyle 2002).

There is also a high level of concern that the Delta will, within the next decade, suffer invasion by the dreissinid mussels, *Dreissena polymorpha* (the zebra mussel) and *Dreissena bugensis* (the quagga mussel). These European species were introduced in eastern North America (the Great Lakes) in 1988 and have spread rapidly since then, with the first California detections along the lower Colorado River in 2007 and then at San Justo Reservoir near Salinas in 2008. These filter feeders threaten the stability of foodwebs and represent a potentially major maintenance problem at water diversion facilities. However, these species require fresh water with a suitable concentration of dissolved calcium in order to survive. The potential distribution of dreissinid mussel habitat in the Delta has been described by Claudi and Prescott (2011), who examined water chemistry data for sites in the SWP and found that, within the Plan Area, the Sacramento River at Hood does not provide suitable water chemistry, but that marginally suitable water chemistry occurs at most SWP facilities in the south Delta. The south Delta can therefore be regarded as at risk for dreissinid mussel invasion.

A large number of nonnative fishes have been introduced into the tidal perennial aquatic natural community of the Delta. Many of the species were introduced for sportfishing (striped bass, largemouth bass, smallmouth bass, bluegill, and sunfish); as forage for sportfish (threadfin shad, golden shiner, and fathead minnow); for human food use (common carp, brown bullhead, and white catfish); and from either deliberate or undeliberate release from the aquarium trade or from ballast water release (yellowfin goby, shimofuri goby, and shokihaze goby) (Moyle 2002). Although no introduction of a nonnative fish has unambiguously caused the extinction of a native species in the Delta (Cohen and Carlton 1995), it is suspected that nonnative introductions have significantly contributed to the decline of some native species due to predation and competition for shared resources. For example, smallmouth bass have been associated with the decline in hardhead, a native minnow found in the Delta, and introductions of several centrarchid species (sunfish and black basses) have been associated with the extirpation of the native Sacramento perch from the Delta.

2.3.4.1.4 Ecosystem Functions

The physical habitat provided by the tidal perennial aquatic natural community supports much of the aquatic Delta foodweb. This is an extremely complex system, and many details are provided in the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Foodweb Model (Durand 2008). Use of the habitat by individual species is often determined by multiple physical factors (e.g., flow, water salinity, wind, tide, and temperature), many of which vary at multiple temporal scales (Kimmerer 2004). Phytoplankton and zooplankton spend their entire lives in the water medium. As described above, resident and migratory fish use tidal perennial aquatic habitat for spawning, rearing, foraging, and escape cover (CALFED Bay-Delta Program 2000). Young Chinook salmon forage in these productive waters as fry and juveniles to put on critical weight before entering the ocean. Changes in physical attributes of the water column, such as flow and water temperature, provide environmental cues for some species to trigger the timing of biological events, such as migration and spawning.

The tidal perennial aquatic natural community is used for foraging, resting, and escape cover by shorebirds, wading birds, and waterfowl. River otters and beavers use this habitat for much of their semiaquatic lives. The tidal perennial aquatic natural community supports a soft sediment community consisting primarily of invertebrates, including mollusks, crustaceans, and worms.

The tidal perennial aquatic natural community plays a primary role in the formation and maintenance of tidal wetlands (Culberson et al. 2004). As sediments accumulate in the tidal aquatic bed, areas of shallow water increase, and the opportunity for establishment of emergent vegetation increases. Over time, this vegetation may give rise to wetland and riparian communities.

2.3.4.1.5 Environmental Gradients

The tidal perennial aquatic natural community includes an ecologically important water depth gradient. Many species of phytoplankton, zooplankton, macroinvertebrates, and fish occupy different depths along this gradient depending on their individual physical needs (e.g., light level, temperature, and water velocity). The tidal perennial aquatic natural community also serves as an important link between upstream and downstream ecosystems. Much of the productivity, organic matter, and inorganic sediment from upstream waterways and marshes eventually move into this community and moves downstream to the Pacific Ocean. In the Plan Area, saline water from coastal oceanic water is diluted by fresh water flowing in from rivers (Ellison 1983). This mixture of fresh and oceanic water forms a salinity gradient that varies by area and location with seasonal variations in freshwater outflow and tidal action. This gradient drives the location of species that depend on a specific salinity level. The location of this gradient varies on multiple time scales: daily tides, monthly lunar cycle, intra-annual (seasonal) flow patterns, interannual flow variation from interannual rainfall variation, and long-term global climate change (Section 2.3.4.1.6, *Future Conditions with Climate Change*) (Kimmerer 2004). CCWD (2010), reviewing available data on salinity changes during historical times, concluded that "the boundary between salt and fresh water is now 3 to 15 miles farther into the Delta than it would have been without the increased diversions of fresh water that have taken place in the past 150 years."

The tidal perennial aquatic natural community extends shoreward to shallower subtidal zone habitat where light penetrates to the bottom under normal conditions. In this habitat, a distinct benthic flora and fauna exist that rely on light for energy.

2.3.4.1.6 Future Conditions with Climate Change

As described in Section 2.3.3.2, *Climate*, atmospheric temperatures are projected to increase at an accelerating pace from 3.6 to 9°F (2 to 5°C) by the end of the century (Cayan et al. 2009). Depending upon the general-circulation model used, there are variable predictions for precipitation change, with most models simulating a slight decrease in average precipitation (Dettinger 2005; California Climate Change Center 2006). The Mediterranean-type climate seasonal precipitation experienced in the Plan Area is expected to continue, with most precipitation falling during the winter season and originating from North Pacific storms. Although the amount of precipitation is not expected to change dramatically over the next century, seasonal and interannual variations in precipitation will likely increase as it has over the past century (California Department of Water Resources 2006). With more precipitation falling as rain instead of snow and the snowpack melting earlier, greater peak flows will result during the rainy season and lower flows during the dry season. Knowles and

Cayan (2004) predict that inflows will increase by 20% from October through February and decrease by 20% from March through September. This change in the annual hydrograph could affect species in the tidal perennial aquatic natural community in a number of ways. Many species that inhabit the tidal perennial aquatic natural community have evolved to use environmental cues, such as changes in flows and temperature, to trigger the timing of biological events, such as migration and spawning. Changes in these factors due to global climate change may lead to confusion by these species as to the timing of these natural events and may affect their growth, production, and survival. Reduced outflow from the Delta during the dry season and rising sea level would increase the extent of saltwater intrusion into the Delta (Knowles and Cayan 2002, 2004). Such changes could relocate the extent of tidal influence and the LSZ farther upstream. This relocation of the LSZ could influence the amount of rearing habitat available to native estuarine species (U.S. Fish and Wildlife Service 2004). Reduced flow into the Delta during summer and fall could also lead to increased residence time during these seasons, likely exacerbating high water temperature and low dissolved oxygen problems that already occur in localized areas of the Delta. Toxic substances may also accumulate during the summer and fall as the flow-driven flushing action decreases.

Sea level rise could have negative effects on fish that rely on shallow water habitat by deepening preferred shallow water areas of the Delta and changing them to the less-preferred deepwater zones. At the same time, sea level rise will inundate lands that are not currently flooded, potentially creating more shallow water and floodplain areas. This will benefit species that use floodplains as rearing habitat.

Sea level rise is predicted to be an especially significant factor in the Plan Area, where much of the land has subsided to below sea level and is currently protected from flooding by levees. The current subsided island condition, combined with higher sea level, increased winter river flooding, and more intense winter storms, will significantly increase the hydraulic forces on the levees. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major seawater intrusion and flooding throughout the reclaimed lands of the Delta, altering the tidal prism, and causing substantial changes to the tidal perennial aquatic natural community (Mount and Twiss 2005).

Warmer water temperatures from future climate change would be detrimental to temperature-dependent native fish species in the tidal perennial aquatic natural community by altering the timing of optimal temperature regimes needed for fish spawning, rearing, and migration (Bennett 2005; Lindley et al. 2007). High temperatures can also cause sublethal (e.g., heat shock proteins) and lethal effects to specific life stages of some fish and other organisms in the community. Warmer temperatures could promote the success of nonnative species, such as centrarchids (e.g., black basses, sunfish) and cyprinids (e.g., carp), that spawn during periods with warmer water temperatures (Moyle 2002).

2.3.4.2 Tidal Mudflat

The tidal mudflat natural community typically occurs as mostly unvegetated sediment deposits in the intertidal zone between the mean higher high tide and the MLLW. The community is typically associated with the tidal freshwater and tidal brackish emergent wetland communities at its upper edge and the tidal perennial aquatic community at its lower edge. The tidal mudflat natural community is ephemeral and owes its physical existence to sediment erosion and deposition processes that differ throughout the Delta and Suisun Marsh, and its biological characteristics to plant succession (Golden and Fiedler 1991; Fiedler and Zebell 1993; Witham and Kareofelas 1994;

Zebell and Fiedler 1996; Cappiella et al. 1999; Meisler 2002; Ruhl and Schoellhamer 2004; McKee et al. 2006; Witham 2006). Inflows to the Delta import suspended sediment, and the resuspension and deposition of that sediment are critical accretion factors. Wave energy dissipation and levee maintenance are typical erosion factors. The rate of plant succession on the sediments will vary depending on the supply of plant propagules and the distance to plants that can colonize the sediment by extending their root systems.

The tidal mudflat natural community was not mapped separately in the GIS datasets used for the BDCP. Instead, it was subsumed within the mapped areas of tidal freshwater emergent wetland, tidal brackish emergent wetland, and tidal perennial aquatic natural communities. GIS models were used to estimate the extent of habitat for species that use mudflats (Appendix 2.A, *Covered Species Accounts*).

2.3.4.2.1 Vegetation

The tidal mudflat natural community is generally not vegetated when considered at fine scales, but patches of two small covered plant species, covered plant species Mason's lilaeopsis and delta mudwort (Table 2-4), are found in this community type. The former is more abundant in brackish areas and the latter is more abundant in freshwater areas (Golden and Fiedler 1991; Fiedler and Zebell 1993; Zebell and Fiedler 1996; Meisler 2002; Fiedler et al. 2007). Plant species in mudflats are quite sensitive to inundation period and the plant community changes with very slight changes in elevation and inundation period.

2.3.4.2.2 Fish and Wildlife

An important wildlife habitat function of the tidal mudflat natural community is as foraging habitat for probing shorebirds, including godwits, willets, and sandpipers. This habitat function only exists for shorebirds when the area of mudflat is exposed by the tides. This community supports an extensive invertebrate community that consists of benthic and interstitial species (crustaceans, bivalves, gastropods, aquatic insects, and polychaetes) that provide forage to shorebirds. Other wildlife may access the tidal mudflat natural community occasionally, but there is little habitat value for these species.

When the tidal mudflat natural community is inundated, it serves as shallow open water habitat for pelagic fish species. These species can use tidal mudflat habitat as a shallow water refugia from predators and forage on benthic invertebrates. Smaller benthic fish species, such as gobies, flatfish, and sculpin inhabit the tidal mudflat natural community at low tide if depressions in the mud support pooled water. All of the covered fish species benefit from the refugia habitat and foodweb contribution of the tidal mudflat community (Table 2-4). California clapper rail is a covered wildlife species that is supported by the tidal mudflat community (Table 2-4).

2.3.4.2.3 Nonnative Species

There are no available data regarding the impacts of nonnative invasive species on this community. Where tidal mudflat exists within the valley/foothill riparian natural community, problematic plant species are likely to include giant reed (*Arundo donax*) and perennial pepperweed (*Lepidium latifolium*).

2.3.4.2.4 Ecosystem Functions

At lower intertidal elevations, the tidal mudflat natural community functions as foraging area for waterfowl and shorebirds; and at higher intertidal elevations, it also functions as unoccupied sediment that can be colonized by small stature plant species such as Mason's lilaeopsis and delta mudwort, which are covered species.

2.3.4.2.5 Environmental Gradients

The tidal mudflat natural community occupies a narrow transition zone between tidal perennial aquatic and tidal brackish emergent wetland, tidal freshwater emergent wetland, or valley/foothill riparian. In general, it provides habitat in the lower portion of the tidal range between the mean low tide and extreme low tide where emergent plants typically cannot establish. However, in disturbed sediment depositional areas along natural and artificial levees it provides ephemeral microhabitats within other natural communities when vegetation is removed.

2.3.4.2.6 Future Conditions with Climate Change

Sea level rise is expected to shift the tidal mudflat natural community to higher elevations in areas where the topography rises gradually; however, where steep levee sides are present, it would diminish in areal extent. The tidal mudflat natural community is sensitive to sedimentation and erosion processes (Ruhl and Schoellhamer 2004). If sediment delivery rates do not match sediment export rates, the extent of the tidal mudflat natural community will change until a steady state between supply and export is reached. It is unclear how climate change will affect these processes, but a lack of sediment supply to the Delta and Suisun Marsh will likely decrease the extent of this community (Cappiella et al. 1999; Ganju and Schoellhamer 2010).

2.3.4.3 Tidal Brackish Emergent Wetland

The tidal brackish emergent wetland natural community is a transitional community between the tidal perennial aquatic and terrestrial upland communities. In the Plan Area, tidal brackish emergent wetland exists from near Collinsville westward to the Carquinez Strait. While it is also present on the south side of Suisun Bay and on islands in midchannel, most of its extent is within Suisun Marsh. The distribution of the tidal brackish emergent wetland natural community in the Plan Area is shown in Figure 2-14 and the classification units used to map the community are provided in Table 2-7.

Table 2-7. Map Classifications in Tidal Brackish Emergent Wetland Natural Community in the Plan Area

Map Classification	Acreage in Plan Area
Scirpus californicus/S. acutus	1,131
Typha species (generic)	1,032
Scirpus (californicus or acutus)-Typha sp.	920
Typha angustifolia/S. americanus	849
Scirpus (californicus or acutus)/Wetland	544
Annual Grasses generic	331
Distichlis-Juncus-Triglochin-Glaux	326
Phragmites australis	293

Map Classification	Acreage in Plan Area
Distichlis/S. americanus	277
Scirpus (californicus or acutus)/Rosa	246
Scirpus americanus/Potentilla	218
Scirpus americanus (generic)	211
Typha angustifolia/Distichlis	190
Undetermined[b]	173
Typha angustifolia/Phragmites	167
Lepidium (generic)	162
Phragmites/Scirpus	116
Ditches and Sloughs[c]	104
Distichlis/Annual Grasses	103
Calystegia/Euthamia	97
Flooded Managed Wetland	84
Distichlis spicata	78
Scirpus americanus/S. Californicus-S. acu	73
Rosa californica	65
Rubus discolor	46
Salicornia/Annual Grasses	44
Distichlis/Salicornia	41
Eucalyptus globulus	41
Wetland Herbs[b]	36
Distichlis/Juncus	36
Potentilla anserina (generic)	36
Typha angustifolia/Polygonum-Xanthium-Ech	36
Wetland Graminoids[c]	31
Lolium (generic)	29
Rosa/Baccharis	28
Scirpus americanus/Lepidium	25
Raphanus sativus (generic)	22
Arundo donax	20
Lepidium/Distichlis	20
Polygonum-Xanthium-Echinochloa	16
Typha angustifolia (dead stalks)	16
Foeniculum vulgare	14
Baccharis/Annual Grasses	13
Salicornia virginica	12
Annual Grasses/Weeds	12
Lolium/Rumex	11
Conium maculatum	10
Bare Ground	10
Juncus balticus/Lepidium	9

Map Classification	Acreage in Plan Area
Juncus balticus	8
Atriplex triangularis	8
Distichlis/Lotus	6
Structure	5
Upland Herbs[c]	5
Scirpus maritimus	5
Tidal Mudflat	5
Rumex (generic)	5
Atriplex/Distichlis	5
Distichlis (generic)	4
Centaurea (generic)	4
Leymus (generic)	4
Juncus balticus/Potentilla	4
Brassica nigra (generic)	4
Lotus corniculatus	3
Salicornia (generic)	2
Medium Upland Shrubs	2
Cortaderia selloana	2
Grindelia stricta var *stricta*	2
Phalaris aquatica	2
Scirpus maritimus/Salicornia	1
Freshwater Drainage	1
Distichlis/S. maritimus	1
Landscape Trees	1
Perennial Grass	1
Distichlis/Cotula	1
Carpobrotus edulis	1
Cotula coronopifolia	1
Salicornia/Atriplex	1
Atriplex/Annual Grasses	1
Fraxinus latifolia	1
Total	**8,501**

[a] Due to the large number of very fine scale mapping units the units shown here are the totals based on the dominant species. Additionally, for Suisun Marsh, San Francisco Estuary Institute (2005) tidal data were used and intersected with the Boul and Keeler-Wolf (2008) vegetation data. For detailed information on these mapping units and plant associations/alliances, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).

[b] Additional mapping efforts undertaken in 2011 and 2012 in Suisun Marsh classify mapping units to the natural community type as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

[c] CDFW vegetation types were combined in order to condense the list.

The tidal brackish emergent wetland natural community in the Plan Area is found in undiked areas of Suisun Marsh such as Rush Ranch and Hill Slough, along undiked shorelines on the south shore of Suisun Bay, and on undiked in-channel islands such as Brown's Island. Prior to anthropogenic hydrologic modifications, the tidal brackish emergent wetland natural community comprised an estimated 69,000 acres of Suisun Marsh (Boul and Keeler-Wolf 2008) but only 12%, or 8,351 acres, remain. At any particular place within this community, the composition of the dominant plant species is controlled by salinity in the channel water and in soil pore water (Culberson 2001; Culberson et al. 2004). Salinity levels in the channels are controlled by local sources of fresh water, seasonal outflow through the Delta and long term climatic variations, semidiurnal tides, and through the operation of a number of water control structures (Byrne et al. 2001; Culberson 2001; Suisun Ecological Workgroup 2001; Brown 2004; Culberson et al. 2004; Malamud-Roam and Ingram 2004; Malamud-Roam et al. 2006; Malamud-Roam et al. 2007; Watson and Byrne 2009).

The effects of channel water salinity are attenuated with distance away from the channel. Evapotranspiration through the dry season drives increases in soil pore water salinity that is not flushed away by tidal influences (Culberson 2001; Culberson et al. 2004; Watson and Byrne 2009). This results in higher salinity in the soil pore water of the channel/marsh transition zone and highest salinity levels in the marsh plain (Culberson 2001; Culberson et al. 2004). Additionally, within the marsh plain, depressions and small ponds may support vegetation adapted to less saline conditions (Suisun Ecological Workgroup 2001). Because soil pore water salinity and distance from channel, and not elevation, are the primary drivers of vegetation composition in these brackish marshes, the distributions of saltgrass and pickleweed in the marsh plain proper are driven by subtle differences in inundation duration (Culberson 2001; Culberson et al. 2004; Watson and Byrne 2009). Because the extent of the community is determined by dynamic salinity gradients, the vegetation is also naturally spatially and temporally variable and this variability leads to high plant diversity compared to tidal saline marshes (Watson and Byrne 2009).

Soils underlying the tidal brackish emergent wetland natural community are heavily influenced by suspended sediment along the channels and by the formation of peat beds away from the channels (Culberson 2001; Culberson et al. 2004). The rate of peat accumulation in the marsh plain is slow due to the low productivity of the small stature dominant plants, but has been sufficiently rapid to maintain its surface with increases in sea level (Culberson et al. 2004).

2.3.4.3.1 Vegetation

The tidal brackish emergent wetland natural community in the Plan Area is characterized by tall herbaceous hydrophytes that line the channels down to approximately 18 inches below MLLW with species that include hard-stem bulrush (*Schoenoplectus acutus*), California bulrush (*Schoenoplectus californicus*), common reed (*Phragmites australis*), and cattail (*Typha* spp.) (Culberson 2001; Suisun Ecological Workgroup 2001; Watson and Byrne 2009). The borders of first order channels and mosquito ditches, which mimic small channels, are also habitat for Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*), a covered species (U.S. Fish and Wildlife Service 2009a). These same large species occur as clumps in the channel to marsh transition zone and share the zone with many other species such as saltgrass (*Distichlis spicata*), Baltic rush (*Juncus balticus*), and seaside arrow grass (*Triglochin maritima*). The boundary between the distant edge of the transition zone and marsh plain is gradual, and this is where the soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*), a covered species, occurs with pickleweed, saltgrass, salt marsh dodder (*Cuscuta salina*), and spearscale (*Atriplex triangularis*) (Grewell 2005; U.S. Fish and Wildlife Service 2009b). The marsh plain proper is dominated by a variable mixture of pickleweed and saltgrass. Covered plant species that depend on the tidal brackish emergent wetland natural community include Delta tule pea[5], Mason's lilaeopsis, and Suisun Marsh aster (Table 2-4).

2.3.4.3.2 Fish and Wildlife

The tidal brackish emergent wetland natural community in the Plan Area is productive wildlife habitat. The vegetation and associated waterways provide food and cover for numerous species of birds (e.g., waterfowl, wading birds), mammals, reptiles, and emergent aquatic insects. Many species rely on these emergent wetlands for their entire life cycle. Covered wildlife species that depend on the tidal brackish emergent wetland natural community include salt marsh harvest mouse, Suisun shrew, California black rail, California clapper rail, and Suisun song sparrow. Western pond turtle also uses this natural community, and it provides potential roosting habitat for tricolored blackbird during the nonbreeding season (Table 2-4).

When inundated, the tidal brackish emergent wetland natural community provides high-value fry and juvenile rearing habitat for a variety of fish species adapted to low salinities, such as Pacific lamprey, river lamprey, splittail, salmonids, and sturgeon. In addition, organic material is exported from the community to provide food to nearby pelagic species, such as delta and longfin smelt.

2.3.4.3.3 Nonnative Species

The tidal brackish emergent wetland natural community and native plant and wildlife species present in the community have been, and continue to be, significantly affected by invasive nonnative taxa. Invading plant species can potentially alter the species composition of the vegetation, its structure, and its chemical characteristics. Invasions of perennial pepperweed, which are often accompanied by fennel (*Foeniculum vulgare*), are one of the most serious threats to this community (Brown 2004; Vaghti and Keeler-Wolf 2004; Grewell 2005; San Francisco Estuary Institute 2006; Environmental Science Associates 2007; Fiedler et al. 2007; Hickson and Keeler-Wolf 2007; Boul and Keeler-Wolf 2008; Andrew and Ustin 2009; U.S. Fish and Wildlife Service 2009a; U.S. Fish and Wildlife Service 2009b). This tall species commonly forms dense patches that exclude native species including covered species such as soft bird's-beak and Suisun thistle (Grewell 2005; Fiedler et al. 2007; U.S. Fish and Wildlife Service 2009a; U.S. Fish and Wildlife Service 2009b). Other large-stature invasive plant species that are problematic include pampas grass (*Cortaderia selloana*), giant reed (*Arundo donax*), and the nonnative genotype of common reed (*Phragmites australis*). These species commonly establish and spread along channels, in the marsh plain transition zone, and along the upland/marsh transition zone. Additionally, small nonnative annual grasses, particularly barbgrass (*Hainardia cylindrical*) and rabbitsfoot grass (*Polypogon monspeliensis*), have significantly affected covered species soft bird's-beak by functioning as ineffective host plants to this hemiparasite (Grewell 2005).

A number of nonnative animals are serious predators of native wildlife and have been shown to significantly reduce populations of salt marsh harvest mouse, California black rail, and California clapper rail, which are covered species (Suisun Ecological Workgroup 2001; Brown 2004). These invasive and high-impact nonnative wildlife species include red fox (*Vulpes vulpes*), feral cats (*Felis domesticus*), and rats (*Rattus* spp.) (Brown 2004; Takekawa et al. 2006). Additionally, ground

[5] Although *delta* is not capitalized in the delta smelt, delta button celery, and delta mudwort, it is capitalized in Delta tule pea (CalFlora: http://www.calflora.org/cgi-bin/species_query.cgi?where-calrecnum=4606).

disturbances caused by foraging by feral pigs (*Sus scrofa*) are significantly affecting the covered Suisun thistle (Fiedler et al. 2007; U.S. Fish and Wildlife Service 2009a).

2.3.4.3.4 Ecosystem Functions

Because it is connected to the Plan Area through the semidiurnal tidal cycle, the tidal brackish emergent wetland natural community has both local ecosystem characteristics and is part of other ecosystems through its contribution to the shared foodweb. Local effects are dominated by vegetation productivity and decomposition rates, which affect tidal channel morphology and tidal plain elevation (Culberson 2001; Culberson et al. 2004; Pearce 2004). Because the soil away from the immediate channel margins is primarily peat, a dynamic equilibrium exists between sea level changes, underground biomass production, and decomposition rates that control the extent of emergent vegetation (Culberson 2001; Culberson et al. 2004). Additionally, the structure of the vegetation provides cover for aquatic species in the channels and over the transition zone and marsh plain when high tides flood the marsh (Brown 2004). Organic carbon and invertebrates produced within this community are transported to the channels and then to the Delta where they contribute significantly to the greater foodweb (Brown 2004).

2.3.4.3.5 Environmental Gradients

The tidal brackish emergent wetland natural community exists at the intersection of many gradients that are spatially and temporally variable. The gradients are primarily determined by tidal flows, which range from 300,000 to 600,000 cfs between Chipps Island and Carquinez Strait and 6,500 to 50,000 cfs in Montezuma Slough (Brown 2004). These large flows create fast currents in the smaller channels, but the transport of materials into and out of the community depends on complex flow dynamics (Brown 2004). The tidal surges create a large-scale salinity gradient that is manifested by brackish water conditions that exist because of the mixing of fresh water from the Delta and local creeks with oceanic water from San Francisco Bay. The longitudinal boundary between fresh and brackish water is not discrete but generally occurs over a distance of several miles from Sherman Island to the Carquinez Strait with smaller local boundaries where tributaries enter the northern portion of Suisun Marsh. There is no clear definition of brackish water, but a salinity range of 5 to 15 ppt generally describes the channel water salinity in the areas where the tidal brackish emergent wetland natural community is found (Conomos et al. 1985; Goman and Wells 2000; Culberson 2001; Kimmerer 2004). The amount of fresh water available to dilute oceanic water is generally determined by water management operations, sewage effluent discharge, and by winter creek and Sacramento River flows. Within this community, a secondary soil pore water salinity gradient develops between the channels and the marsh plain during the dry season as salts accumulate away from the channels through evapotranspiration (Culberson 2001). An elevational gradient also exists between the channels and the marsh plain with the dividing elevation at mean higher high water (MHHW) (Goman and Wells 2000). Below MHHW, large clonal species dominate, while above MHHW are mixtures of various large and small species. The combination of the salinity and elevational gradients creates a wide range of physical habitats that lead to a high diversity of species compared to salt and freshwater marshes (Watson and Byrne 2009).

2.3.4.3.6 Future Conditions with Climate Change

As with all intertidal communities, the tidal brackish emergent wetland natural community is by definition directly linked to sea level as well as the ratio of salt to fresh water. As a result, it is particularly sensitive to long-term sea level rise associated with global climate change and changes in Delta discharge. In order to persist, the tidal brackish emergent wetland natural community must be able to accrete sediments at sufficient rates to keep their surfaces intertidal (Watson and Byrne 2009); that rate will depend upon how changing salinity and inundation duration affects the species composition of the wetland (Culberson et al. 2004; Watson and Byrne 2009).

2.3.4.4 Tidal Freshwater Emergent Wetland

The tidal freshwater emergent wetland natural community is typically a transitional community between the tidal perennial aquatic, and valley/foothill riparian and various terrestrial upland communities across a range of hydrologic and edaphic conditions. In the Plan Area, the tidal freshwater emergent wetland natural community often occurs at the shallow, slow-moving, or stagnant edges of freshwater waterways in the intertidal zone and is subject to frequent long duration flooding. The distribution of the tidal freshwater emergent wetland natural community in the Plan Area is shown in Figure 2-14, and the mapping classification units are provided in Table 2-8.

Table 2-8. Map Classifications in the Tidal Freshwater Emergent Wetland Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
Scirpus acutus -Typha latifolia	2,168
Scirpus acutus - (*Typha latifolia*) - *Phragmites australis*	1,546
Scirpus acutus Pure	1,386
Scirpus acutus - Typha angustifolia	768
Scirpus californicus - Scirpus acutus	676
California Bulrush (*Scirpus californicus*)	419
Mixed Scirpus / Submerged Aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex	378
Common Reed (*Phragmites australis*)	354
Mixed Scirpus Mapping Unit	336
Mixed Scirpus / Floating Aquatics (*Hydrocotyle - Eichhornia*) Complex	323
Hard-stem Bulrush (*Scirpus acutus*)	170
American Bulrush (*Scirpus americanus*)	133
Narrow-leaf Cattail (*Typha angustifolia*)	96
Undetermined[b]	84
Scirpus californicus - Eichhornia crassipes	14
Typha angustifolia - Distichlis spicata	3
California Hair-grass (*Deschampsia caespitosa*)	1
Deschampsia caespitosa - Lilaeopsis masonii	1
Total	**8,856**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] Portions of the Plan Area for which CDFW did not delineate plant alliances were mapped only to the natural community level as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

The tidal freshwater emergent wetland natural community is distributed in narrow, fragmented bands along island levees, in-channel islands, shorelines, sloughs, and shoals. Prior to the 1860s, it comprised an estimated 87% of the Delta, with extensive marshes forming dense stands of vegetation bisected by meandering channels (The Bay Institute 1998; Grossinger et al. 2008). Today, remnant patches of this community are found in the western portion of the Delta near the confluence of the Sacramento and San Joaquin Rivers, along Lindsey Slough and the Yolo Bypass, along the mainstem and several channels of the San Joaquin, Old, and Middle Rivers, Lost Slough, and the area where the Cosumnes and Mokelumne Rivers join the Delta. The loss and degradation of its historical extent is due to its conversion to agriculture as well industrial and urban development; and those losses have led to dramatic reductions in habitat that is available for associated fish and wildlife species (The Bay Institute 1998; CALFED Bay-Delta Program 2000). Channelization, levee-building, removal of vegetation to stabilize levees, and upstream flood management have also reduced the extent of this community and altered its ecological function through changes to flooding frequency, inundation duration, and quantity of alluvial material deposition.

The tidal freshwater emergent wetland natural community occurs along a hydrologic gradient in the transition zone between open water and riparian vegetation or upland terrestrial vegetation such as grasslands or woodlands. In the Plan Area, there are often abrupt transitions to agricultural habitats and managed wetland natural communities and along the boundaries formed by levees and other artificial landforms. The environmental conditions that support the tidal freshwater emergent wetland natural community are dynamic with frequent flooding disturbances and geomorphologic changes (i.e., alluvial deposition and scouring). Its constituent species composition and ecosystem functions are consequently variable in space and time (The Bay Institute 1998). Because of the different sources of variability and the anthropogenically restricted area in which it can occur, the community vegetation may be distributed in small patches or in occasional large areas.

Soils underlying the tidal freshwater emergent wetland natural community are heavily influenced by inundation period, water flow, and alluvial deposition. They are hydric soils and when mineral-based, their texture can vary from clay to sand; and when based on organic material, can form peat beds (Goman and Wells 2000; Hitchcock et al. 2005; Drexler et al. 2009a). The soils are typically anaerobic due to frequent or permanent saturation with slow decomposition rates resulting in the accumulation of organic debris in various stages of decomposition. The composition of the vegetation is limited to relatively few dominant species that are tolerant of inundation and anaerobic soil conditions and typically are not tolerant of saline or brackish conditions (Holland and Keil 1995).

The natural topography of the Plan Area that supports this community is virtually flat, draining gradually toward the center of the Delta and then westward toward Suisun Bay. Under natural hydrologic conditions, deposits of alluvial material sometimes shifted due to scouring and redeposition, and elevational differences of the vegetation from place to place were a function of alluvium elevation and tidal inundation levels (Grossinger et al. 2008). Today, artificial levees provide topographic barriers adjacent to waterways, and the inboard areas of many of the leveed islands that historically supported this community have subsided below sea level (CALFED Bay-Delta Program 2000). In some cases, where levees have been breached and not repaired, portions of the islands that have not significantly subsided support tidal freshwater emergent wetland (e.g., northern Liberty Island); however, other deeply subsided islands that have flooded and have not been reclaimed support the tidal perennial aquatic natural community due to deeper inundation by floodwaters (e.g., Franks Tract, southern Liberty Island).

2.3.4.4.1 Vegetation

The tidal freshwater emergent wetland natural community is characterized by erect herbaceous hydrophytes (Holland and Keil 1995). There are 17 plant community alliances (i.e., unique species assemblages) mapped in the Plan Area that fall within the tidal freshwater emergent wetland natural community (Table 2-8) (Sawyer and Keeler-Wolf 1995; Hickson and Keeler-Wolf 2007). The typical vegetation of this type, as mapped by CDFW and adopted for vegetation mapping purposes, is dominated by tall, perennial monocots that reproduce by seed as well as vegetatively through rhizomes. However, the CDFW vegetation classification was based on vegetation structure and species composition and did not consider ecosystem functions such as location within or above the intertidal region along drainages. In many areas of what is functionally tidal freshwater emergent wetland, woody species, especially willows (Salix spp.), occur in the intertidal region and codominate the vegetation (Atwater 1980; Watson 2006; EDAW 2007a; Watson and Byrne 2009). These intertidal areas with woody vegetation were not distinguishable in the CDFW dataset.

Cattails (*Typha* spp.) dominate the vegetation of this community along the Sacramento River; while throughout the San Joaquin River area, bulrushes (*Schoenoplectus americanus* and *Bolboschoenus maritimus*), tules (*Schoenoplectus californicus* and *S. acutus*), and common reed (*Phragmites australis*) are more often the dominant species (Atwater 1980; Watson 2006; EDAW 2007a; Hickson and Keeler-Wolf 2007; Watson and Byrne 2009). In the far western portion of the Delta, where tidal waters are generally fresh but may be brackish during periods of low outflow, saltgrass becomes common (Boul and Keeler-Wolf 2008). Numerous native and nonnative dicots and rooted aquatics also commonly occur in the tidal freshwater emergent wetland natural community. Covered plant species associated with the tidal freshwater emergent wetland natural community are presented in Table 2-4, and include delta mudwort, Delta tule pea, Mason's lilaeopsis, and Suisun Marsh aster.

2.3.4.4.2 Fish and Wildlife

The tidal freshwater emergent wetland natural community provides productive habitat for wildlife. Its vegetation and associated waterways provide food and cover for numerous species of birds (e.g., waterfowl, wading birds), mammals, reptiles, emergent aquatic insects, and amphibians. All of the covered fish species use tidal freshwater emergent wetland habitat for foraging, juvenile rearing, and refugia. Covered terrestrial wildlife species that rely on tidal freshwater emergent wetland for habitat include California black rail, Suisun song sparrow, tricolored blackbird, giant garter snake, western pond turtle, and California red-legged frog. (Table 2-4).

Although the remaining areas of tidal freshwater emergent wetlands in the Plan Area are highly altered, they remain critical wintering grounds for migratory birds. A small number of wetland-associated species, such as waterfowl and egrets, have successfully adapted to foraging on some types of croplands that were converted from historical wetland areas (California Department of Fish and Game 2005).

Many of the species of fish that use the tidal perennial aquatic natural community for habitat will also use the tidal freshwater emergent wetland natural community as habitat when it is inundated. Younger stages (e.g., larvae and fry) of some species rear in shallow waters that support emergent vegetation. Further, many fish species use emergent vegetation as refuge from predation and high flows (The Bay Institute 1998).

2.3.4.4.3 Nonnative Species

One important invasive nonnative species that has become established in the tidal freshwater emergent wetland natural community is giant reed (*Arundo donax*). This species grows as dense monocultures, which shade and crowd out native plant species in this community (Dudley 2000). Giant reed also consumes large amounts of water and has been known to dry up otherwise low-flowing, perennial streams. It is found growing along natural and artificial watercourses throughout the Plan Area, but the acreage of the invasion is unknown (Hickson and Keeler-Wolf 2007). By eliminating native plants, giant reed reduces food and habitat for a number of birds, insects, and other wildlife.

This natural community is also at risk from potential invasion by dreissinid mussels, as detailed in Section 2.3.4.1.3, *Nonnative Species*.

2.3.4.4.4 Ecosystem Functions

The tidal freshwater emergent wetland communities provide critical biogeochemical, hydrologic, and geomorphic functions, as well as habitat for a variety of fish and wildlife; however, island reclamation throughout the Delta, channelization, and anthropogenic changes to flow patterns have dramatically altered the ecosystem function and habitat value of these wetlands in the Plan Area (California Department of Fish and Game 2005). The tidal freshwater emergent wetland natural community in the Delta provides habitat for microorganisms, macroinvertebrates, and insects that form the base of the aquatic food chain. The vegetation also releases organic debris (drift) into the waterways that is a source of nutrients and cover. The warm, shallow water and dense vegetation that is often present in this community provides cover for some species and can be a key source of aquatic food or prey for birds and larger wildlife (The Bay Institute 1998). Additionally, it provides allochthonous sources of food and prey for fish and other aquatic species.

The tidal freshwater emergent wetland natural community also naturally absorbs or processes influxes of nutrients that find their way into the aquatic system (nutrient transformation), thereby acting as a biogeochemical buffer and contributing to the aquatic foodweb.

2.3.4.4.5 Environmental Gradients

The tidal freshwater emergent wetland natural community provides habitat on virtually all exposures and slopes provided the surface is saturated or at least periodically flooded by tidal action. However, level topography dominates in the Plan Area, and on the water-side of levees from a depth of approximately 18 inches below MLLW, the community occurs as a distinct transition to the levee bank upland vegetation. The upland limit of the habitat is generally the boundary between hydric soils supporting predominantly hydrophytic vegetation and nonhydric soils on the levees with primarily nonaquatic vegetation (Cowardin et al. 1979). The boundary between habitat associated with the tidal freshwater emergent wetland natural community and deepwater habitats is approximately 18 inches below MLLW (Atwater et al. 1979; Simenstad et al. 2000).

Where brackish conditions occur at the western edge of the Delta, Suisun Bay, and Suisun Marsh, the tidal freshwater emergent wetland natural community merges into the tidal brackish emergent wetland natural community that supports plant and wildlife that are tolerant of brackish water or saline soil conditions. Physical factors that drive the location of gradients between community types include elevation, salinity, and flow patterns at multiple temporal scales (e.g., daily tidal, lunar, seasonal, interannual) (Culberson 2001; Watson 2006; Watson and Byrne 2009).

2.3.4.4.6 Future Conditions with Climate Change

As with all intertidal communities, the tidal freshwater emergent wetland natural community is by definition directly linked to sea level. As a result, it is particularly sensitive to long-term sea level rise associated with global climate change (Nicholls et al. 1999). Higher sea level will relocate the natural community to higher elevations in the Delta. Further, tidally influenced waterways would be relocated upstream, thus shifting the tidal freshwater emergent wetland natural community farther upstream. Because much of the Delta is armored with levees, the sea level driven relocation of the intertidal zone would be primarily vertical and not horizontal, likely resulting in a reduction in the extent of the tidal freshwater emergent wetland natural community as it is replaced by deepwater habitat (i.e., tidal perennial aquatic natural community) adjacent to steep-sided levees. The greatest increase in the extent of this natural community will primarily occur along the periphery of the Delta where there are gently sloping areas of upland (Knowles 2006).

In order for its extent to remain constant the tidal freshwater emergent wetland natural community must accrete sediments, both influxes of mineral soil as well as local accumulations of peat, at a rate high enough to keep its lowest surface above an elevation of 18 inches below MLLW (Atwater et al. 1979; Simenstad et al. 2000; Kimmerer 2004). Given the reductions in sediment loads over the past half century (Section 2.3.2, *Ecosystem Processes*) (Cappiella et al. 1999; Wright and Schoellhamer 2004; Ganju and Schoellhamer 2010), and the possibility that peat accumulation may not keep pace with accelerating sea level rise in the late long-term, it is likely that the extent of this community will be reduced where its vegetation cannot colonize newly inundated uplands.

2.3.4.5 Valley/Foothill Riparian

Broadly defined, the valley/foothill riparian natural community is often found as a transition zone between aquatic and terrestrial habitats and often expresses a wide range of environmental conditions (e.g., variable light and nutrient availability) (Holland and Keil 1995; The Bay Institute 1998; Vaghti and Greco 2007). In the Plan Area, the valley/foothill riparian natural community occurs along the margins of low-gradient perennial and intermittent waterways, floodplains, tidal areas, or where the water table is sufficiently high to provide water to plants year-round (e.g., oxbows) (CALFED Bay-Delta Program 2000; Vaghti and Greco 2007). The distribution of the valley/foothill riparian natural community is shown in Figure 2-14, and the mapping classification units used to represent its constituent vegetation elements are presented in Table 2-9.

The valley/foothill riparian natural community usually occurs in the Plan Area as long, linear patches separating other terrestrial biological communities and agricultural or urban land, or in low-lying, flood-prone patches near river bends, canals, or breached levees (Figure 2-14). Such areas are located along many of the major and minor waterways, oxbows, and levees in the Plan Area, including the Sacramento River, Deep Water Ship Channel, Yolo Bypass, and channels of the San Joaquin River and the Delta. Patches of riparian vegetation are also found on the interior of leveed Delta islands, along drainage channels and pond margins, and in abandoned low-lying fields.

1 **Table 2-9. Map Classifications in the Valley/Foothill Riparian Natural Community in the Plan Area**

Map Classification[a]	Acreage in Plan Area
Valley Oak (*Quercus lobata*)	2,021
Salix gooddingii - Populus fremontii - (*Quercus lobata-Salix exigua-Rubus discolor*)	1,741
Salix lasiolepis - Mixed brambles (*Rosa californica - Vitis californica - Rubus discolor*)	1,537
Blackberry (*Rubus discolor*)	1,196
Salix exigua - (*Salix lasiolepis - Rubus discolor - Rosa californica*)	1,100
Cornus sericea - Salix lasiolepis / (*Phragmites australis*)	823
Undetermined[b]	809
Quercus lobata / Rosa californica (*Rubus discolor - Salix lasiolepis / Carex* spp.)	802
Salix gooddingii / Wetland Herbs	652
Fremont Cottonwood (*Populus fremontii*)	646
Black Willow (*Salix gooddingii*)	638
Intermittently or Temporarily Flooded Deciduous Shrublands	537
Salix lasiolepis - (*Cornus sericea*) / *Scirpus* spp.- (*Phragmites australis - Typha* spp.) complex unit	488
Arroyo Willow (*Salix lasiolepis*)	461
Salix gooddingii - Quercus lobata / Wetland Herbs	429
Fremont Cottonwood - Valley Oak - Willow (Ash - Sycamore) Riparian Forest NFD Alliance	428
Alnus rhombifolia / Salix exigua (*Rosa californica*)	419
Quercus lobata - Alnus rhombifolia (*Salix lasiolepis - Populus fremontii - Quercus agrifolia*)	371
Quercus lobata - *Fraxinus latifolia*	304
Narrow-leaf Willow (*Salix exigua*)	294
White Alder (*Alnus rhombifolia*)	150
Salix gooddingii / Rubus discolor	143
Temporarily or Seasonally Flooded - Deciduous Forests	142
Cornus sericea - Salix exigua	122
Mixed Willow Super Alliance	117
California Dogwood (*Cornus sericea*)	117
California Wild Rose (*Rosa californica*)	98
Valley Oak (*Quercus lobata*) restoration	96
Black Willow (*Salix gooddingii*) - Valley Oak (*Quercus lobata*) restoration	93
Acacia - Robinia	86
Coast Live Oak (*Quercus agrifolia*)	84
Horsetail (*Equisetum* spp.)	83
Shining Willow (*Salix lucida*)	78
Quercus lobata - Acer negundo	68
Intermittently Flooded to Saturated Deciduous Shrubland	63
Giant Cane (*Arundo donax*)	61
Baccharis pilularis / Annual Grasses & Herbs	53
Box Elder (*Acer negundo*)	45
Valley Oak Alliance - Riparian	42

Map Classification[a]	**Acreage in Plan Area**
Alnus rhombifolia / Cornus sericea	32
Acer negundo - Salix gooddingii	32
Restoration Sites	31
Coyotebush (*Baccharis pilularis*)	28
Hinds walnut (*Juglans hindsii*)	21
Mexican Elderberry (*Sambucus mexicana*)	17
Pampas Grass (*Cortaderia selloana - C. jubata*)	16
White Alder (*Alnus rhombifolia*) - Arroyo willow (*Salix lasiolepis*) restoration	8
Buttonbush (*Cephalanthus occidentalis*)	7
Landscape Trees	5
Rubus discolor	4
Tobacco brush (*Nicotiana glauca*) mapping unit	2
Blackberry NFD Super Alliance	1
Oregon Ash (*Fraxinus latifolia*)	1
Microphyllous Shrubland	0
Eucalyptus	0
Mixed Fremont Cottonwood - Willow spp. NFD Alliance	0
Total	**17,644**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] Portions of the Plan Area for which CDFW did not delineate plant alliances were mapped only to the natural community level as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

The current extent of the valley/foothill riparian natural community represents only a small proportion of its historical extent in the Plan Area (Thompson 1961; The Bay Institute 1998). Historically, valley oak (*Quercus lobata*) and cottonwood (*Populus fremontii*) occurred on coarser textured soils along natural levees and ranged from scraggy trees in the vicinity of Brannan Island to larger trees upriver (Thompson 1957). Similarly, in mineral soil areas of the south Delta, valley oak occurred sporadically as scraggy trees near drainage channels (Norris 1851). In contrast to historical conditions, these species occur on sporadically on engineered levees throughout the Delta where vegetation control has not been a constant practice. In contrast to valley oak, under both historical and current conditions, extensive stands of willows occur throughout the Delta with box elder (*Acer negundo*), red alder (*Alnus rubus*), Redosier dogwood (*Cornus sericea*) and Oregon ash (*Fraxinus latifolia*), becoming increasingly common upstream from the Lower Sherman Island (Atwater 1980; EDAW 2007b; Hickson and Keeler-Wolf 2007). The loss of riparian vegetation throughout California is estimated to be between 85 to 95%, and was caused by human activities such as river and stream channelization, levee building, removal of vegetation to stabilize levees, and extensive agricultural and urban development (Riparian Habitat Joint Venture 2004).

2.3.4.5.1 Vegetation

CDFW identified 41 plant community alliances (i.e., unique species assemblages) in the Delta that fall within the valley/foothill riparian natural community (Table 2-9) (Sawyer and Keeler-Wolf 1995; Hickson and Keeler-Wolf 2007). The most common riparian plant associations in the Plan Area are dominated by valley oak, Fremont cottonwood, and Gooding's black willow in the overstory and Himalayan blackberry, narrow-leaf willow, arroyo willow, and California wild rose in the understory or as riparian scrub. A recent Delta CDFW survey discovered areas of valley/foothill riparian vegetation dominated by redosier dogwood (*Cornus sericea*). Other native trees and shrubs that may be locally dominant or important include white alder, California sycamore, buttonbush, California dogwood, Oregon ash, red willow, Pacific willow, box elder, Mexican elderberry, and Hinds' walnut. California wild grape is a vine commonly found climbing upon other riparian vegetation.

Due to the wide range of abiotic environmental conditions in which the valley/foothill riparian natural community is found (e.g., substrate, flood frequency and duration, groundwater level, salinity), species composition and vegetation density and structure varies widely, from tall-canopied riparian forests dominated by deciduous, broad-leaved trees, to riparian scrub dominated by shorter stature trees, shrubs, and brambles. Species composition overlaps among the various riparian vegetation associations, and the structure and density of vegetation may vary even at relatively small spatial scales. The vegetation alliances, which make up the valley/foothill riparian natural community as identified by CDFW in the Plan Area, can be placed into riparian forest, woodland, and scrub categories, based largely on the canopy height and the structure of the dominant plant taxa (Holland and Keil 1995). Riparian forest is dominated by broad-leaved, winter deciduous trees, such as valley oak and Fremont cottonwood, that form closed canopies up to 115 feet (35 meters) tall (Griggs et al. 1993; Tu 2000; Griggs and Golet 2002; Trowbridge 2002; Trowbridge et al. 2005). This type of riparian vegetation is typically found along perennial or intermittent streams and tends to consist of relatively even-aged trees that reproduce episodically after flood events (Trowbridge 2005; Vaghti and Greco 2007). Riparian woodland may have similar species composition to the forests and are typically dominated by tall, broad-leaved, winter deciduous trees. However, woodland canopies tend to be more open, likely due to hydrologic conditions and the species adaptations to the flooding regime. These conditions are found in few areas in the Delta today. Thickets dominated by one or more shorter stature willows (typically narrow leaf willow or arroyo willow) are categorized as riparian scrub, and are common along newly or frequently flooded waterways. Riparian scrub may contain saplings of riparian trees, other fast-growing shrubs, and vines that recolonize quickly following flood disturbance.

The understory in riparian forest and woodland may contain immature canopy species and species commonly found in the riparian scrub community. All three structural types of the valley/foothill riparian natural community typically contain diverse mixtures of herbaceous plant species in the understory, often including graminoids such as rushes, bulrushes, sedges, flat-sedges, and grasses, as well as forbs such as monkeyflowers, stinging nettle, and watercress. Woody vines or lianas are also common and may form a dense understory composed of species such as honeysuckles, poison oak, and California wild grape (Holland and Keil 1995; Vaghti and Greco 2007).

Covered plant species found or likely to be found in the valley/foothill riparian natural community in the Plan Area are listed in Table 2-4, and include delta button celery, delta mudwort, Delta tule pea, Mason's lilaeopsis, side-flowering skullcap, slough thistle, and Suisun Marsh aster.

2.3.4.5.2 Fish and Wildlife

Although significantly altered and reduced in extent since initial European settlement (Katibah 1984), riparian habitats continue to support the greatest diversity of wildlife species of any habitat in California. The rich and complex vegetation composition and structure present in the valley/foothill riparian natural community provides habitat for over 225 bird, mammal, and reptile species (Riparian Habitat Joint Venture 2004). Over 80% of all wildlife species in the Sacramento Valley use riparian areas during a part of their life cycle for nesting, movement, cover, or forage (Riparian Habitat Joint Venture 2004). Salmonids rely on riparian shade and the resulting cooler water temperatures that control basic metabolic processes. Salmonids also benefit from contributions of the riparian community to the aquatic foodweb in the form of terrestrial insects and leaf litter that enter the water. Riparian vegetation also supports the formation of steep, undercut banks that provide cover for salmonids (Table 2-4). Covered terrestrial wildlife species that are associated with the valley/foothill riparian natural community include the riparian brush rabbit, riparian woodrat, least Bell's vireo, Swainson's hawk, tricolored blackbird, western yellow-billed cuckoo, white-tailed kite, yellow-breasted chat, western pond turtle, California red-legged frog, and valley elderberry longhorn beetle (Table 2-4).

Mammals that use the valley/foothill riparian natural community as habitat or movement corridors include ringtails, muskrats, raccoons, deer, coyotes, mountain lions, bobcats, woodrats, and mice. Two covered mammal species, riparian brush rabbit and riparian woodrat, are dependent upon the valley/foothill riparian natural community in the Plan Area. Riparian brush rabbit, a federally listed endangered species, relies on the community for its entire lifecycle. The riparian woodrat (San Joaquin Valley woodrat), federally listed as endangered and a state species of concern, inhabits riparian areas in the Plan Area. Bats are also found in greater densities near riparian areas feeding on the abundant swarms of aquatic insects and use riparian areas for roosting habitat.

Abundant micro- and macro-invertebrate wildlife inhabit both the belowground and aboveground portions of the valley/foothill riparian natural community, contribute to ecosystem function and foodweb diversity. Soil invertebrates are a critical factor controlling decomposition and nutrient cycling (Power and Rainey 2000).

Riparian habitat is considered the most important habitat to landbird species in California (Manly and Davidson 1993; Davidson 1995). Migratory birds use riparian areas as stopover points. Major direct and indirect anthropogenic and nonanthropogenic impacts on this community in the Plan Area that affect avian species include degradation and fragmentation of habitat, nest parasitism, disruption of hydrologic processes by levees, clearing for agricultural and urban development, and biological invasions. Special-status bird species that are riparian habitat specialists include Swainson's hawk, bank swallow, yellow warbler, yellow-billed cuckoo, common yellowthroat, Wilson's warbler, and yellow-breasted chat.

Riparian vegetation directly influences the value of aquatic habitat for fish, affecting cover, food, instream habitat complexity, streambank stability, and water temperature regulation. Large woody debris recruited from streamside trees provides instream cover and habitat complexity, an essential component of fish habitat. In smaller streams, riparian vegetation also provides shade and an insulating canopy that moderates water temperatures in both summer and winter. Riparian vegetation provides a filter that reduces the transport of fine sediment to the stream, and the roots provide streambank stability and cover for rearing fish. Riparian vegetation influences the food chain of a stream, providing organic detritus and terrestrial insects. Riparian vegetation also controls aquatic productivity dependent on solar radiation (Meehan 1991).

2.3.4.5.3 Nonnative Species

Riparian environments, with their high edge-to-area ratios and frequent disturbance regime, are prone to biological invasions (Planty-Tabacchi et al. 1996). In the valley/foothill riparian systems, introduced nonnative woody and herbaceous plant species may replace native species, and once established, can be extremely difficult to control or eradicate. Problematic nonnative invasive plant species in riparian areas include tree-of-heaven, *Sesbania*, Chinese tallowtree, black locust, tamarisk, Russian olive, bluegum eucalyptus, Himalayan blackberry, palm trees (multiple genera), giant reed, and perennial pepperweed. For example, the introduction of giant reed has negatively affected the valley/foothill riparian natural community because the species grows in very dense monocultures, displacing natives and changing hydrologic regimes (Dudley 2000). By eliminating native plants, giant reed removes food and habitat for a number of birds, insects, and other wildlife.

Many nonnative invasive wildlife species such as red-eared sliders and black rats have also affected the valley/foothill riparian natural community. Feral domestic cats are another important nonnative species that can affect many native bird species in this community.

2.3.4.5.4 Ecosystem Function

The valley/foothill riparian natural community provides disproportionately higher ecosystem services and wildlife habitat compared to other terrestrial communities (National Research Council 2002). Riparian areas serve as the hydrologic connection between terrestrial uplands and aquatic ecosystems, receiving water from precipitation, overland runoff, groundwater discharge, and flow from an adjacent water body or alluvial aquifer (Vaghti and Greco 2007). They provide benefits to water quality by processing and filtering runoff, retaining and recycling nutrients, and trapping sediments (National Research Council 2002). Within the Plan Area, these ecosystem functions have been substantially negatively affected due to the destruction and fragmentation of the community.

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

2.3.4.5.5 Environmental Gradients

Due to its location in the transition zone between aquatic and terrestrial ecosystems, the valley/foothill riparian natural community is characterized by biotic (e.g., species composition) and abiotic (e.g., hydrologic) gradients (Vaghti and Greco 2007). These gradients interact to form highly diverse and complex communities, both structurally and functionally. They also interact strongly with and influence the aquatic, emergent, and upland habitats along their edges.

The valley/foothill riparian natural community is associated with active and remnant hydrologic features in the Plan Area, as well as areas with a high water table that are periodically inundated. Plant community composition and structure is tightly coupled with fluvial processes (Strahan 1984).

Vegetation density is inversely related to frequency of flooding; low-stature annual and perennial species on frequently inundated sandbars and low-elevation ground give way to taller, longer-lived species further upland. In the Plan Area, there are abrupt transitions to agricultural cover, managed wetlands, or boundaries formed by levees and other engineered landforms.

Although the valley/foothill riparian vegetation is found on a range of soil types, the vast majority of soil types are mineral or intermixed with peat in the Plan Area (Figure 2-4) (Hitchcock et al. 2005; Unruh and Hitchcock 2009). Soil conditions associated with this vegetation type are also typically influenced by current and past hydrologic conditions (Figure 2-6).

2.3.4.5.6 Future Conditions with Climate Change

Future climate change (Section 2.3.3.2, *Climate*) is expected to alter the valley/foothill riparian natural community in a variety of ways. Rising sea level will affect the location, extent, and composition of the valley/foothill riparian natural community because of increased water elevation and increased saltwater intrusion. As water levels rise, riparian vegetation at the water's edge will become more frequently flooded, and many species intolerant of this longer inundation will migrate upslope if suitable habitat and hydrologic regimes are present. The ability to colonize new ground by shifting away from water's edge will depend on the availability of space in adjacent higher elevation areas and the ability of individual riparian species to colonize any new spaces (e.g., via seed dispersal or clonal growth).

Future vegetation composition and extent of the valley/foothill riparian natural community will also depend on the tolerance levels of individual plant species to the higher salinity associated with saltwater intrusion. Changes in channel water salinity may cause species shifts in the lower Delta by eliminating tree species that are not willows, but the effect will be difficult to determine even qualitatively due to the inherent variability of the system.

Changes to the timing, duration, and magnitude of Delta inflows associated with future climate change are anticipated to result in more intense winter flooding and greater erosion of riparian habitats (Field et al. 1999; Hayhoe et al. 2004). The hydrodynamics of stream channels and the width of riparian corridors will be altered, resulting in losses or shifts in species composition of riparian vegetation.

Increased variability in precipitation is expected to produce prolonged droughts that make riparian vegetation more prone to fires. Thus, the frequency of wildfires in the valley/foothill riparian natural community is expected to increase in the future.

2.3.4.6 Nontidal Perennial Aquatic

The nontidal perennial aquatic natural community in the Delta can range in size from small ponds in upland areas to small lakes, such as the North and South Stone Lakes. The nontidal perennial aquatic natural community can be found in association with any terrestrial habitat and often transitions into nontidal freshwater perennial emergent wetland and valley/foothill riparian. The distribution of nontidal perennial aquatic is shown in Figure 2-14. The littoral zone of the nontidal perennial aquatic community is defined as the portion of the water column penetrable by light and that occurs at the edges of lakes and throughout most ponds (Moss 1998; Scheffer 2004). The limnetic zone extends below the littoral zone to the deepest part of the water body. Light penetration is inversely related to turbidity. Water temperature varies with depth; colder water generally occurs deeper due to the inverse relationship between water temperature and density. The oxygen concentration in nontidal perennial aquatic waters is low relative to that of flowing water. Only a small portion of water is in direct contact with air at the surface, where gas exchange with the atmosphere occurs. Dead organic material typically sinks to the bottom and decomposes, increasing biological oxygen demand near the bottom of some water bodies. Because of the stratification of these physical variables, there is a distinct zonation in plants and animals living in the nontidal perennial aquatic natural community (California Department of Fish and Game 2005).

2.3.4.6.1 Vegetation

The plant mapping classification units within the nontidal perennial aquatic natural community are described in Hickson and Keeler-Wolf (2007) and listed in Table 2-10. Nonplant primary producers such as diatoms, desmids, and filamentous green algae often form the base of the foodweb where they dominate open water habitat. Plant species found in this community vary with inundation depth and distance from shore, from submerged aquatics (e.g., pondweed and *Egeria*) to floating aquatic vegetation (e.g., duckweed and water hyacinth) that are found closer to shore and which may increase the rates of sediment and organic matter accumulation (California Department of Fish and Game 2005).

Table 2-10. Map Classifications in the Nontidal Perennial Aquatic Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
Water	4,793
Generic Floating Aquatics	216
Brazilian Waterweed (*Egeria - Myriophyllum*) Submerged	112
Undetermined[b]	111
Water Hyacinth (*Eichhornia crassipes*)	96
Algae	69
Floating Primrose (*Ludwigia peploides*)	53
Ludwigia peploides	34
Milfoil - Waterweed (generic submerged aquatics)	6
Total	**5,489**

Notes:

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classification units and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] Portions of the Plan Area for which CDFW did not delineate plant alliances were mapped only to the natural community level as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

Shallow bodies of water, such as ponds and small lakes, generally are found in either a clear-water state with rooted and floating aquatic plants or in a turbid-water state dominated by algae with very few aquatic plants (Moss 1998; Scheffer 2004). These states can be stable or can oscillate between each other depending on a large number of factors that primarily affect the density of *Daphnia* zooplankton populations (Moss 1998; Scheffer 2004). The submerged portions of the plants provide a substrate for smaller algae and cover for smaller aquatic animals, including fish. Floating aquatics provide food and support for herbivorous crustaceans and mollusks (Smith 1974). Vegetation cover in the nontidal perennial aquatic natural community ranges from continuous to open (CALFED Bay-Delta Program 2000). There are no covered plant species associated with the nontidal perennial aquatic natural community (Table 2-4).

2.3.4.6.2 Fish and Wildlife

A thin layer of floating duckweed often covers the surface of shallow nontidal perennial aquatic waters. Desmids, diatoms, protozoans, crustaceans, hydras, and snails live on the under-surface of the layer, whereas mosquitoes and other aquatic insect larvae may live in between the plants.

Zooplankton, such as rotifers, copepods, and cladocerans, live suspended in the water column and graze on phytoplankton (Smith 1974). Together with phytoplankton, these organisms compose the base of the nontidal perennial aquatic foodweb. A variety of aquatic insects (e.g., dipterans, coleopterans, chironomids, trichopterans, plecopterans, and ephemeropterans) and collembolans use the nontidal perennial aquatic habitat for their larval stage. Native fish that can (or could in the past) be found in some nontidal perennial aquatic communities include the Sacramento perch, hitch, and tule perch (Moyle 2002).

A variety of wildlife species use the nontidal perennial aquatic natural community for resting and foraging, including waterfowl, shorebirds, semiaquatic mammals (e.g., beaver, muskrat, and river otter), piscivorous birds (e.g., bald eagles and osprey), and insectivorous birds and bats that prey on insects that gather over open water. Ponds and other small bodies of open water also serve as important brooding habitat for ducks nesting in nearby upland habitats. Many water-dependent species (e.g., western pond turtle) require adjacent upland, riparian woodlands, or emergent wetlands for cover or nesting habitat. Covered species associated with the nontidal perennial aquatic natural community are giant garter snake, western pond turtle, and California red-legged frog (Table 2-4).

2.3.4.6.3 Nonnative Species

Many nonnative species have invaded the nontidal perennial aquatic community. Common invasive plants found in this habitat include *Egeria*, Eurasian watermilfoil, and water hyacinth (California Department of Boating and Waterways 2006, 2008). These plants form thick mats that exclude native vegetation and associated wildlife (San Francisco Estuary Institute 2003).

The nontidal perennial aquatic natural community in the Plan Area supports many nonnative freshwater fish species, including centrarchids, common carp, inland silverside, fathead minnow, and western mosquitofish. Additionally, the nonnative bullfrog is frequently present. These nonnative species prey on or compete with native fish and amphibian species both directly and indirectly for resources, including the covered California red-legged frog and California tiger salamander.

This natural community is also at risk from potential invasion by dreissinid mussels, as detailed in Section 2.3.4.1.3, *Nonnative Species*.

2.3.4.6.4 Ecosystem Functions

The nontidal perennial aquatic natural community is embedded in other communities, and generally the most significant ecosystem functions include providing an alternative source of primary productivity through its aquatic foodweb and an aquatic habitat for native fish, amphibians, and reptiles such as giant garter snake, a covered species. As described above, the source of primary productivity can be either algal phytoplankton or aquatic plants depending on whether the body of water is in a turbid- or clear-water state. The identity of the primary consumers and their feedback effects on the ecosystem depend in complex ways on many factors and cause impacts on the secondary consumers such as planktivorous or benthivorous (cyprinids) fish (Scheffer 2004).

2.3.4.6.5 Environmental Gradients

Within the water column of the nontidal perennial aquatic natural community there are gradients of light, oxygen and other chemicals, pH, and temperature, which combine in various ways and result in a range of micro-habitat types (Moss 1998; Scheffer 2004). External gradients to terrestrial ecosystems always exist at the boundary of this community and vary from direct transitions to riparian forest, grassland, or cultivated lands in the Plan Area.

2.3.4.6.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the nontidal perennial aquatic natural community. Where this community exists at elevations at or below current sea level, rising sea level will alter its location, extent, and composition and potentially result in increased saltwater intrusion through an altered tidal hydrologic regime. Also, where this community exists in flooded depressions in upland areas, which presumably already support the nontidal perennial aquatic community, it is not likely that natural processes could replace the area that will be lost.

2.3.4.7 Nontidal Freshwater Perennial Emergent Wetland

The nontidal freshwater perennial emergent wetland natural community is composed of perennially saturated wetlands, including meadows, dominated by emergent plant species that do not tolerate perennial saline or brackish conditions (CALFED Bay-Delta Program 2000). Nontidal freshwater perennial emergent wetland communities in the Plan Area occur in small fragments along the edges of the nontidal perennial aquatic and valley/foothill riparian natural communities (Figure 2-14). Soils are predominantly silt and clay, although coarser sediments and organic material may be intermixed (Cowardin et al. 1979). In some areas, organic soils (peat) may constitute the primary growth medium (U.S. Army Corps of Engineers 1978).

The extent of nontidal freshwater perennial emergent wetland in California, including the Delta, has declined dramatically over the past century due to reclamation and conversion of the habitat to other uses, primarily agriculture (Gilmer et al. 1982; The Bay Institute 1998). Only 1,135 acres of this natural community remain within the Plan Area. The extent of this natural community in the Delta has been dramatically reduced in the past century, with a corresponding reduction in habitat function for associated fish and wildlife species (The Bay Institute 1998).

2.3.4.7.1 Vegetation

The nontidal freshwater perennial emergent wetland natural community is distinguished by environmental conditions that support erect, rooted herbaceous plant species that can tolerate long inundation periods. All patches of these wetlands mapped in the Plan Area are dominated by broad-leaf cattail (Table 2-11) (Hickson and Keeler-Wolf 2007). This plant community frequently includes tules, bulrushes, sedges, rushes, and other emergent plant species. No covered plant species are associated with nontidal freshwater perennial emergent wetlands (Table 2-4).

Table 2-11. Map Classifications in the Nontidal Freshwater Perennial Emergent Wetland Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
Scirpus acutus -Typha latifolia	383
Broad-leaf Cattail (*Typha latifolia*)	362
Scirpus acutus - (*Typha latifolia*) - *Phragmites australis*	158
Undetermined[b]	124
Scirpus acutus Pure	103
Mixed Scirpus Mapping Unit	96
Mixed Scirpus / Submerged Aquatics (*Egeria-Cabomba-Myriophyllum* spp.) complex	42
Scirpus (californicus or acutus)-Typha sp	34
Mixed Scirpus / Floating Aquatics (*Hydrocotyle* - *Eichhornia*) Complex	22
Common Reed (*Phragmites australis*)	18
Hard-stem Bulrush (*Scirpus acutus*)	16
American Bulrush (*Scirpus americanus*)	14
Scirpus acutus - *Typha angustifolia*	7
Narrow-leaf Cattail (*Typha angustifolia*)	3
Cultivated Annual Graminoid	1
Flooded Managed Wetland	1
Salicornia/Annual Grasses	1
Perennial Pepperweed (*Lepidium latifolium*)	0
California Bulrush (*Scirpus californicus*)	0
Water	0
Total	**1,385**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] Portions of the Plan Area for which CDFW did not delineate plant alliances were mapped only to the natural community level as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

2.3.4.7.2 Wildlife

The nontidal freshwater perennial emergent wetland natural community is among the most productive wildlife habitat in California (California Department of Fish and Game 2005). It provides food, cover, and water for numerous mammals, reptiles, amphibians, and birds. Many species rely on fresh emergent wetlands for their entire life cycle (e.g., giant garter snake). Others use the habitat primarily for breeding (e.g., California red-legged frog), feeding and hunting (e.g., bald eagle), or foraging and loafing habitat (e.g., migrating waterfowl). Within the Plan Area, the ecological functions provided by nontidal freshwater perennial emergent wetlands in support of wildlife are very limited because this community is highly fragmented and occurs in small patches (e.g., the 1,135 acres of this natural community are distributed among 159 mapped polygons). Covered wildlife species that may use nontidal freshwater perennial emergent wetlands include California black rail, tricolored blackbird, giant garter snake, western pond turtle, and California red-legged frog (Table 2-4).

2.3.4.7.3 Nonnative Species

Many nonnative species have invaded the nontidal freshwater perennial emergent wetland natural community. Common invasive plants found in this habitat include *Egeria*, Eurasian watermilfoil, and water hyacinth (California Department of Boating and Waterways 2006, 2008). These plants form thick mats that exclude native vegetation and associated wildlife (San Francisco Estuary Institute 2003).

Nontidal freshwater perennial emergent wetland natural community in the Plan Area supports many nonnative freshwater fish species, including centrarchids, common carp, inland silverside, fathead minnow, and western mosquitofish. Additionally, the nonnative bullfrog is frequently present. These nonnative species prey on or compete with native fish and amphibian species both directly and indirectly for resources.

This natural community is also at risk from potential invasion by dreissinid mussels, as detailed in Section 2.3.4.1.3, *Nonnative Species*.

2.3.4.7.4 Ecosystem Functions

Nontidal freshwater perennial emergent wetland natural community generally forms the boundary around the nontidal perennial aquatic natural community, and with that community is embedded in other communities. Generally, its most significant ecosystem functions include providing an alternative source of primary productivity through its aquatic foodweb and providing an aquatic habitat for native fish, amphibians, and reptiles such as giant garter snake, a covered species. Its importance as a source of primary productivity can increase or decrease if the body of water is dominated by algal phytoplankton or aquatic plants depending on whether the body of water is in a turbid- or clear-water state. The contribution of primary consumers and their feedback effects on the ecosystem depend on many factors and cause impacts to the secondary consumers such as planktivorous or benthivorous (cyprinids) fish (Scheffer 2004). Additionally, this community provides the structural substrate for predator avoidance and nesting of wildlife.

2.3.4.7.5 Environmental Gradients

Within the water column of the nontidal freshwater perennial emergent wetland natural community there are gradients of light, oxygen and other chemicals, pH, and temperature, which combine in various ways and result in a range of micro-habitat types (Moss 1998; Scheffer 2004). External gradients to terrestrial ecosystems always exist at the boundary of this community because the boundary lies between open-water habitat and ecotonal transitions into riparian forest, grassland, or cultivated lands in the Plan Area.

2.3.4.7.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the nontidal freshwater perennial emergent wetland natural community. Sea level rise will affect the location, extent, and composition of this community in places where it exists at or below current sea level because of increased water elevation, increased saltwater intrusion, and the tidal hydrologic regime. Nontidal freshwater perennial emergent wetland locations that exist at the water's edge will become more deeply immersed, or in the case of overtopped levees, deeply flooded. Where this community exists in flooded depressions in upland areas, which presumably already support the nontidal freshwater perennial emergent wetland natural community, it is not likely that natural processes could replace the area that will be lost.

2.3.4.8 Alkali Seasonal Wetland Complex

The alkali seasonal wetland complex natural community occurs on fine-textured soils that contain a relatively high concentration of dissolved salts. This natural community includes both saturated wetlands, sometimes with areas of shallow ponding during the wet season, and a surrounding matrix of various types of vegetation. It is typically found either at the historical locations of seasonal ponds in the Yolo Basin in and around the CDFW's Tule Ranch Preserve (Witham 2003; EDAW 2007a) where salts accumulated through evaporation, or in upland situations such as basin rims and seasonal drainages that receive salts in runoff from upslope salt-bearing bedrock such as areas near Suisun Marsh and the Clifton Court Forebay. Associations dominated by saltgrass cover the largest extent of the alkaline wetland alliances in the Plan Area (Hickson and Keeler-Wolf 2007), and the area of undetermined vegetation adjacent to Suisun Marsh is likely dominated by saltgrass (Table 2-12). Vegetation associations containing salt-adapted shrubs and subshrubs, generally located in the Clifton Court Forebay area (San Francisco Estuary Institute 2010), constitute most of the remaining acreage. Depending on its location, this community often transitions into other natural communities such as tidal brackish emergent wetland, vernal pool complex, grassland, valley/foothill riparian, and agricultural habitats. The distribution of the alkali seasonal wetland complex natural community in the Plan Area is shown in Figure 2-14.

2.3.4.8.1 Vegetation

Dominant species in the alkali seasonal wetland complex natural community include saltgrass, Baltic rush, pickleweed, iodine bush, and alkali heath (Table 2-12) (Hickson and Keeler-Wolf 2007). Other abundant plant species include toad rush, bush seepweed, brass buttons, gum plant, and perennial pepperweed. Annual grasses associated with this natural community include the native Pacific foxtail as well as nonnative grasses such as rabbitsfoot grass, swamp timothy, and Italian ryegrass. In associations that are dominated by woody plants in the Clifton Court Forebay area, shrubs characteristic of desert regions such as iodine bush (*Allenrolfea occidentalis*) may form an open shrub cover with an intermittent herbaceous strata that is dominated by saltgrass, wild barley, and curved sicklegrass (Hickson and Keeler-Wolf 2007).

Table 2-12. Map Classifications in the Alkali Seasonal Wetland Complex Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
Distichlis spicata - Annual Grasses	3,044
Undetermined[b]	233
Saltgrass (*Distichlis spicata*)	122
Salt scalds and associated sparse vegetation	47
Juncus balticus - meadow vegetation	45
Distichlis spicata - *Juncus balticus*	30
Allenrolfea occidentalis mapping unit	29
Alkaline vegetation mapping unit	28
Frankenia salina - Distichlis spicata	24
Annual Grasses generic	22
Suaeda moquinii - (*Lasthenia californica*) mapping unit	21
Distichlis spicata - Salicornia virginica[c]	20
Pickleweed (*Salicornia virginica*)[c]	15
Freshwater Drainage	12
Annual Grasses/Weeds	10
Bare Ground	5
Salicornia virginica - Distichlis spicata[c]	5
Creeping Wild Rye Grass (*Leymus triticoides*)	3
Salicornia virginica - Cotula coronopifolia[c]	3
Alkali Heath (*Frankenia salina*)	2
Salicornia virginica[c]	1
Typha species (generic)	1
Salicornia/Annual Grasses	0
Flooded Managed Wetland	0
Distichlis/S. maritimus	0
Total	**3,723**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] Portions of the Plan Area for which CDFW did not delineate plant alliances were mapped only to the natural community level as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

[c] *Salicornia virginica* is now *Salicornia pacifica*

Covered plant species that occur in the alkali seasonal wetland natural community include brittlescale and heartscale growing in alkaline drainages, Carquinez goldenbush, delta button celery growing on alluvium in the Discovery Bay area, and San Joaquin spearscale on basin rims.

The vernal pool complex natural community is sometimes interspersed within the alkali seasonal wetland natural community complex. Covered plant species that occur in these inclusions include alkali milk-vetch, brittlescale, Boggs Lake hedge-hyssop, heartscale, Heckard's peppergrass, and San Joaquin spearscale (Table 2-4).

2.3.4.8.2 Fish and Wildlife

In the Plan Area, the alkali seasonal wetland complex natural community, and in particular saltgrass-dominated grassland, supports breeding and/or foraging habitat for covered vertebrate species, including San Joaquin kit fox, greater sandhill crane, Swainson's hawk, tricolored blackbird, western burrowing owl, white-tailed kite, giant garter snake, California red-legged frog, and California tiger salamander (Table 2-4).

The vernal pool complex natural community, which is sometimes scattered within this community, supports covered invertebrate species, which include vernal pool tadpole shrimp, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, midvalley fairy shrimp, and California linderiella (Table 2-4).

2.3.4.8.3 Nonnative Species

The primary problematic nonnative plant species in this community are perennial pepperweed (Witham 2006; EDAW 2007a; Environmental Science Associates 2007) and annual ryegrass (*Lolium multiflorum*) (Dawson et al. 2007), which form dense patches that exclude many native plant species. There are no data describing their effects on wildlife.

2.3.4.8.4 Ecosystem Functions

The alkali seasonal wetland complex natural community is found on relatively impermeable clay alluvial soils (Graymer et al. 2002; Water Resources & Information Management Engineering Inc. 2006; Natural Resources Conservation Service 2009) that remain saturated throughout the wet season and during the early part of the dry season. The two contrasting types of typical vegetation, either dominated by the perennial saltgrass as is the case in most areas, or the woody iodine bush scrub near the Clifton Court Forebay, largely control the ecosystem functions of this community. Saltgrass-dominated areas are generally vegetated more or less uniformly and provide a very simple and herbaceous physical structure with relatively fast nutrient and carbon cycling. In contrast, iodine bush-dominated areas tend to have a patchy distribution of shrubs that provide more structural variation and sequester nutrients and carbon for longer periods. Saltgrass areas are typically grazed by native wildlife and domestic livestock and function as grasslands. They are also relatively open habitat that provides foraging habitat for raptors. Iodine bush habitat provides open areas for foraging by wildlife as well as closed canopy areas for cover.

2.3.4.8.5 Environmental Gradients

The alkali seasonal wetland complex natural community transitions into wetter areas such as the tidal brackish emergent wetland natural community in the Suisun Marsh area (Collins and Grossinger 2004; Grossinger 2004) and the tidal freshwater emergent wetland in the Delta (Grossinger et al. 2008) and often has vernal pool inclusions in areas with depressions. In other areas, such as near the Montezuma Hills, it transitions into the drier grassland natural community (Collins and Grossinger 2004; Grossinger 2004; Grossinger et al. 2008).

2.3.4.8.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the alkali seasonal wetland complex natural community. Because this community is generally located well above sea level it will not be directly affected by rising sea level except at locations where it abuts tidal communities, which will move upslope, thus reducing its extent. The primary impact of climate change on this community will be driven by changes in the hydrologic regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrologic conditions such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how the increased variability in seasonal hydrology will affect the plants and animals inhabiting this community, but because these species are adapted to current conditions, the impacts will likely result in changes to species composition. In addition, rising average temperatures could result in increased evapotranspiration rates and therefore more extended dry periods for this community; the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.9 Vernal Pool Complex

The vernal pool complex natural community is characterized by interconnected and isolated groups of vernal pools and seasonal swales that are generally within a matrix of either grassland or alkali seasonal wetland vegetation. This natural community is rare in the Plan Area and is generally found only in a few locations along the very margin of the Plan Area (Figure 2-14). The vernal pool complex natural community was mapped specifically for the BDCP using a range of methods because there were no available datasets with the appropriate level of detail or spatial extent. Details of the methods used to map vernal pool complex are presented in Section 2.3.1.5, *Vernal Pool Complex Dataset Development*, and an in-depth discussion is presented in Appendix 2.B, *Vernal Pool Complex Mapping and Modifications to Natural Community Mapping*. Regions of the Central Valley to the east and west of the Plan Area support large areas of vernal pool complex natural community, especially in San Joaquin, Sacramento, and Solano Counties.

In the Plan Area, vernal pools are found west of the Sacramento River from Putah Creek south to the gently sloped terraces immediately to the north and east of the Montezuma Hills, east of the Sacramento River in the Stone Lakes area, and west of the San Joaquin River from Byron to Discovery Bay (Witham 2003; Environmental Science Associates and Yolo County 2005; Leigh Fisher Associates 2005; Williamson et al. 2005; Witham 2006; Baraona et al. 2007; Kleinschmidt Associates 2008; Rains et al. 2008; San Francisco Estuary Institute 2010). The pools on the west side of the Delta formed on clay soils with relatively high salt content, while those on the east side formed on clays with little salt content. The plant communities and species in vernal pools (Table 2-13) are generally adapted to a hydrologic regime of standing water in winter and spring and desiccated soils in summer (CALFED Bay-Delta Program 2000; Solomeshch et al. 2007). Vernal pools in California are also known for providing habitat for a number of endemic and rare species (Jain 1979; Jones & Stokes Associates 1990; Skinner and Pavlik 1994; Solomeshch et al. 2007). A single vernal pool may support over 100 species of native plants and animals (U.S. Fish and Wildlife Service 2007). The conversion of large extents of the vernal pool complex natural community to agriculture and developed areas has led directly to greatly reduced population sizes of covered species such as alkali milk-vetch, Heckard's peppergrass, and legenere (Table 2-4).

Table 2-13. Map Classifications in the Vernal Pool Complex Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
California Annual Grasslands - Herbaceous	4,636
Degraded Vernal Pool Complex - California Annual Grasslands - Herbaceous	2,343
Distichlis spicata - Annual Grasses	1,645
Undetermined[b]	1,581
Allenrolfea occidentalis mapping unit	234
Annual Grasses generic	232
Vernal Pools	205
Degraded Vernal Pool Complex - Italian Rye-grass (*Lolium multiflorum*)	202
Suaeda moquinii - (*Lasthenia californica*) mapping unit	50
Annual Grasses/Weeds	23
Saltgrass (*Distichlis spicata*)	18
Salt scalds and associated sparse vegetation	18
Italian Rye-grass (*Lolium multiflorum*)	17
Ruderal Herbaceous Grasses & Forbs	14
Degraded Vernal Pool Complex - Ruderal Herbaceous Grasses & Forbs	14
Seasonally Flooded Grasslands	14
Degraded Vernal Pool Complex - Vernal Pools	13
Salicornia virginica[c]	7
Distichlis/S. maritimus	6
Salicornia/Annual Grasses	5
Distichlis/Annual Grasses	4
Degraded Vernal Pool Complex - Rabbitsfoot grass (*Polygpogon maritimus*)	3
Mixed Scirpus Mapping Unit	1
Agriculture	0
Distichlis spicata	0
Distichlis (generic)	0
Total	**11,284**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] Portions of the Plan Area for which CDFW did not delineate plant alliances were mapped only to the natural community level as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

[c] *Salicornia virginica* is now *Salicornia pacifica.*

Vernal pools are uniquely defined by their hydrology and by the presence of endemic plant and invertebrate species (Keeley and Zedler 1998). The hydrologic regime has three components: the source of water, the durations of the inundated and the waterlogged soil phases, and the seasonal timing of these phases. In general, rainfall is the primary source of water to vernal pools as it falls directly into the vernal pool or is transported a short distance across the watershed of the vernal pool. This direct rainfall and watershed model is the simplest case, but there may be groundwater transport to the vernal pool through a shallow perched aquifer or a combination of rainfall and creek flooding (Environmental Science Associates and Yolo County 2005; Williamson et al. 2005; Rains et al. 2008). The duration and timing of the inundation and waterlogged soil phases are also variable with hardpan vernal pools generally having shorter phases centered during the middle of the wet season while claypan and clay vernal pools have longer phases extending earlier and later into the wet season (Environmental Science Associates and Yolo County 2005; Williamson et al. 2005; Rains et al. 2008). Similar complications occur in determining the presence of the characteristic endemic species. Using endemic plants as an example, the cover of many of them can vary by orders of magnitude from season to season, and they may only be present in the soil seed bank in some years (Barbour et al. 2007). These unique characteristics can also be blurred to varying degrees by human-driven impacts such as land leveling and ripping, altering the supply of water through flood irrigation, or through the intentional or inadvertent introduction of exotic plant species.

Note that the vernal pool complex natural community was mapped separately from the other vegetation data used for the BDCP and the mapped polygons of the community overlay of CDFW vegetation types that are described in this chapter. The Plan Area contains 7,908 acres of the vernal pool complex natural community (including both wetted surface and upland matrix), of which 4,730 acres are found in annual grassland vegetation, 1,673 acres are found in saltgrass vegetation, 233 acres are found in iodine bush scrub, and 196 acres were mapped as vernal pools by CDFW.

2.3.4.9.1 Vegetation

The flora of vernal pools has adapted in different ways to the unique physical and chemical constraints imposed by the inundated lacustrian phase. The duration of inundation strongly correlates with two clear functional groups (Zedler 1987, 1990; Barbour et al. 2003, 2005, 2007). An edge-of-pool plant functional group is adapted to the fluctuating hydrology of shallow vernal pools or to the edges of deep vernal pools, while the long inundation functional group is adapted to the deeply inundated basins of vernal pools. The edge or saturated soil species are especially prone to elimination by competition with upland exotic grass species or through thatch accumulation (Barry 1995; Griggs 2000; Marty 2005), while the basins are prone to invasion by low mannagrass (Gerlach et al. 2009).

The vernal pool complex natural community in the Plan Area can be classified into four fairly uniform types: annual grassland vernal pool complexes in the Stone Lakes area; clay alluvium vernal pools and playa pools running from Putah Creek south to Cache Slough; Montezuma Block vernal pools and playa pools in the Jepson Prairie/Montezuma Hills area; and alkaline sink/meadow vernal pools near the Byron/Clifton Court Forebay area. Covered vernal pool plants include alkali milk-vetch, Boggs Lake hedge-hyssop, brittlescale, delta button celery, dwarf downingia, heartscale, Heckard's peppergrass, legenere, and San Joaquin spearscale (Table 2-4).

Annual grassland vernal pool complexes have uplands that are dominated by Eurasian annual grasses with a varying mixture of native grasses and herbs depending on the farming history of the site. These vernal pools are found in the lowest local topographic positions on soils that were deposited in and alongside ancient stream channels and are underlain by a discontinuous claypan (Williamson et al. 2005; Rains et al. 2008) or clay alluvial lens. The endemic plant species present in the vernal pools are generally considered adapted to nonalkaline soils, but some characteristic species of alkaline vernal pools, such as Heckard's peppergrass (Table 2-4) or saline clover, may be present. Typical plant species found in these vernal pools are: Pacific foxtail (*Alopecurus saccatus*), bristled downingia (*Downingia bicornuta* var. *bicornuta*), low mannagrass (*Glyceria declinata*), rayless goldfields (*Lasthenia glaberrima*), shining peppergrass (*Lepidium nitidum* var. *nitidum*), small stipitate popcorn-flower (*Plagiobothrys stipitatus* var. *micranthus*), Sacramento mesamint (*Pogogyne zizyphoroides*), and woolly marbles (*Psilocarphus brevissimus*).

Clay alluvium vernal pools and playa pools have uplands that are dominated in the spring by either Eurasian annual grasses or a variable mixture of saltgrass and native herbs, and are dominated in the summer by native tarweeds or the exotic yellow starthistle. These vernal pools and playa pools can be found on extremely thick clay alluvium (Bryan 1923; Thomasson Jr. et al. 1960; State of California 1987) in a range of topographic positions, from scoured areas above the main flood distribution channels of Putah Creek to middle elevations where a swale may connect a series of vernal pools (Environmental Science Associates and Yolo County 2005), to low-elevation playas in the Yolo Bypass that are periodically flooded by the Sacramento River (Witham 2003), to much older vernal pools and playa pools in the greater Jepson Prairie area (Bryan 1923; Thomasson Jr. et al. 1960; Witham and Kareofelas 1994; Williamson et al. 2005; Witham 2006; Baraona et al. 2007; Rains et al. 2008). The rare endemic species found in these vernal pools and playa pools include Solano grass and Colusa grass, as well as alkali milk-vetch, San Joaquin spearscale, dwarf downingia, legenere, and Heckard's peppergrass which are covered plant species (Table 2-4).

Montezuma Block vernal pools and playa pools have uplands that are similar to those of the clay alluvium vernal pools and playa pools, but extensive areas are also in agricultural production as dry-farmed wheat. These vernal pools and playa pools can also be found in a range of topographic positions from intermittent stream channels in the Montezuma Hills, to the mid-elevation divide that is characteristic of the Jepson Prairie area, to the near tidal elevation vernal pools found along Cache Slough (Witham and Kareofelas 1994) and upland of Suisun Marsh (Wildlands Inc. 2005; San Francisco Estuary Institute 2006). The rare endemic species found in these vernal pools and playa pools include Colusa grass, as well as alkali milk-vetch, San Joaquin spearscale, dwarf downingia, legenere, and Heckard's peppergrass, which are covered plant species (Table 2-4).

Alkaline sink/meadow vernal pools, as the name implies, are found scattered within alkaline meadows and alkaline sinks near the Byron/Clifton Court Forebay area (Carpenter and Cosby 1939; San Francisco Estuary Institute 2010). Hydrologically, these vernal pools are similar to the clay alluvium vernal pools and playa pools as their hydrology is a mixture of local rainfall, groundwater flow, and long distance stream transport. The surrounding vegetation is unique as it is typically dominated by native grasses such as saltgrass and alkali ryegrass, or by woody shrubs like iodine bush (*Allenrolfea occidentalis*) and subshrubs such as bush seepweed (*Suaeda moquinii*) and alkali heath (*Frankenia salina*). Recent BDCP field surveys (California Department of Water Resources 2009 and 2010 unpublished data) found that the herbaceous vernal pool species include: Pacific foxtail (*Alopecurus saccatus*), brass-buttons (*Cotula coronopifolia*), rayless goldfields (*Lasthenia glaberrima*), Heckard's peppergrass (*Lepidium dictyotum* var. *dictyotum*), alkali milkvetch (*Astragalus tener* var. *tener*), San Joaquin spearscale (*Atriplex joaquiniana*), heartscale (*Atriplex cordulata*), brittlescale (*Atriplex depressa*), small stipitate popcorn-flower (*Plagiobothrys stipitatus* var. *micranthus*), and Sacramento mesamint (*Pogogyne zizyphoroides*).

2.3.4.9.2 Wildlife

Much less is known about the adaptations of animals to vernal pool conditions than about the adaptations of vernal pool plants. Most animals that are endemic to vernal pools have a combination of behavioral, structural, and physiological adaptations to avoid, resist, or tolerate desiccation during the dry season or during long droughts. Amphibians such as California tiger salamander use vernal pools for breeding and then retreat to upland refugia, primarily rodent burrows, during the rest of the year. It is likely that California red-legged frogs historically used vernal pools for breeding, but in the Plan Area this is not considered primary habitat. Giant garter snakes may use vernal pools for foraging and historically this habitat type may have played an important winter and spring foraging role, but similar to the California red-legged frog, this habitat type is no longer considered primary for the species. The six crustacean species covered under the BDCP (California linderiella, midvalley fairy shrimp, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, and vernal pool tadpole shrimp) tend to occur in separate vernal pools with different inundation periods (Table 2-4). These species are typically not found in vernal pools that have been heavily invaded by low mannagrass, as the fauna of these invaded vernal pools is typically dominated by mosquito and midge larvae (Rogers 1998). Waterfowl may forage in vernal pools during the wet season with ducks and shorebirds consuming invertebrates and geese consuming vegetation (Medeiros 1976; Reiner and Swenson 2000).

The upland watersheds associated with the vernal pool complex natural community provide foraging habitat for covered species such as San Joaquin kit fox, greater sandhill crane, Swainson's hawk, tricolored blackbird, western burrowing owl, and white-tailed kite (Table 2-4).

2.3.4.9.3 Nonnative Species

Vernal pools in the vernal pool complex natural community are invaded by different nonnative species at different points along the moisture gradient. The margins of vernal pools throughout the Central Valley are often dominated by the nonnative annual ryegrass. The deeper portions of many pools are being rapidly invaded by low mannagrass (Gerlach et al. 2009). Other parts of vernal pool complexes are being invaded by perennial pepperweed (Swiecki and Bernhardt 2002; Witham 2003; Environmental Science Associates and Yolo County 2005; Witham 2006; Environmental Science Associates 2007).

2.3.4.9.4 Ecosystem Functions

This is essentially an amphibious ecosystem with greatly differing functions depending on whether it is in its flooded or dry stages. When flooded, this community supports an aquatic foodweb that is functionally similar to that found in shallow lakes (Alexander 1976; Barclay and Knight 1981; Scheffer 2004, Williams 2006). As the water recedes, its ecosystem characteristics change from those of an aquatic system to those of a wetland and then to those of a terrestrial ecosystem (Williams 2006), and its foodweb linkages break down as the community becomes more integrated with the terrestrial landscape in which it is embedded. When flooded, it teems with a variety of ephemeral pond-adapted invertebrates, the immature stages of amphibians, and waterfowl. When dry, it is integrated with the surrounding terrestrial ecosystems and provides foraging habitat for native wildlife, and is typically managed as rangeland and grazed by sheep or cattle.

2.3.4.9.5 Environmental Gradients

The dominant environmental gradient in the vernal pool complex natural community is driven by the different chemical and physical attributes of water versus air. Water is a polar solvent that is important in many chemical exchanges, and those exchanges control pH and the oxidation state of many chemicals and compounds. It also has a high heat capacity so temperature changes are buffered, and it is extremely viscous compared to air so exchanges between the air and water as well as movement within the water are very slow (Scheffer 2004; Williams 2006). Ecological gradients in vernal pools are characterized by depth and ponding/saturation duration from the pool center to the surrounding grassland community.

2.3.4.9.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the vernal pool complex natural community. Because this community is generally located at elevations that will not be directly affected by rising sea level, the primary impact of climate change is predicted to be driven by changes in the hydrologic regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrologic conditions such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how increased variability in pool hydrology would affect the plants and animals inhabiting them, but because these species are adapted to current conditions, the impacts will likely result in changes to species composition. In addition, rising average temperatures could result in increased evapotranspiration rates and therefore shorter wetted periods for vernal pools; the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.10 Managed Wetland

The managed wetland natural community consists of areas that are intentionally flooded and managed during specific seasonal periods to enhance habitat values for specific wildlife species (CALFED Bay-Delta Program 2000). Ditches and drains associated with this community are also included. The managed wetland natural community includes some areas of the CALFED Ecosystem Restoration Program *managed seasonal wetlands habitat*, and it fits into the *fresh emergent wetland classification* from the California Wildlife Habitat Relationships (California Department of Fish and Game 2005).

Soils are composed predominantly of silts and clays, although coarser sediments and organic material may be intermixed. In some areas, such as Suisun Marsh, organic soils (peat) may constitute the primary growth medium.

Managed wetland is distributed largely in the northern, central, and western portions of the Delta, as well as in Suisun Marsh (Boul and Keeler-Wolf 2008; Hickson and Keeler-Wolf 2007). Substantial acreage of this type occurs in the Yolo Bypass, Stone Lakes National Wildlife Refuge (NWR), Cosumnes River Preserve, and Suisun Marsh (Suisun Ecological Workgroup 1997; Suisun Ecological Workgroup 2001; Brown 2004; EDAW 2007a; U.S. Fish and Wildlife Service 2007; Kleinschmidt Associates 2008). Several islands in the central Delta support large areas of this community type, including Mandeville Island, Medford Island, Holland Tract, and Bradford Island. The far western edge of the Delta, including Van Sickle and Chipps islands, and Suisun Marsh also includes managed wetland (Figure 2-14). Water at the far western border of the Plan Area and in the Suisun Marsh can be more brackish compared to other portions of the Delta where this community occurs (Suisun Ecological Workgroup 1997; Suisun Ecological Workgroup 2001; Brown 2004).

The typical hydrologic management regime includes flooding during the winter in anticipation of the arrival of migratory birds followed by a slow drawdown of water to manage plant seed production (Fredrickson and Taylor 1982; Naylor 2002) and to control mosquito populations (Kwasny et al. 2004). Summer irrigation may also be conducted (U.S. Fish and Wildlife Service 2007). The management of Suisun Marsh is unique as water salinity is a significant management issue, and water use is tightly regulated (Suisun Ecological Workgroup 1997; Suisun Ecological Workgroup 2001; Brown 2004).

2.3.4.10.1 Vegetation

The managed wetland natural community is characterized by robust, perennial emergent vegetation and annual-dominated moist-soil grasses and forbs in freshwater areas (Fredrickson and Taylor 1982; Naylor 2002; Hickson and Keeler-Wolf 2007) and often by pickleweed and brass buttons in brackish water areas. The vegetation communities present and their extent within the managed wetland natural community are shown in Table 2-14. Vegetation that is important to waterfowl includes alkali bulrush, grand redstem, brass buttons, smartweed, barnyard grass, burhead, and swamp timothy (Fredrickson and Taylor 1982; Suisun Ecological Workgroup 1997; Suisun Ecological Workgroup 2001; Naylor 2002; Brown 2004). During periods when water is drained from the habitat, a wide variety of annual grasses and forbs germinate and grow beneath and in the interstitial space around the emergent plants.

Table 2-14. Map Classifications in the Managed Wetland Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
Flooded Managed Wetland	7,924
Managed Annual Wetland Vegetation (Non-specific grasses & forbs)	6,402
Salicornia virginica	4,472
Annual Grasses generic	4,291
Intermittently or temporarily flooded undifferentiated annual grasses and forbs	3,620
Managed alkali wetland (*Crypsis*)	2,917
Salicornia/Annual Grasses	2,654
Scirpus spp. in managed wetlands	2,426
Typha species (generic)	2,392
Distichlis/Salicornia	2,179
Perennial Pepperweed (*Lepidium latifolium*)	1,671
Bare Ground	1,551
Distichlis spicata	1,490
Scirpus maritimus	1,352
Distichlis/Annual Grasses	1,332
Ditch	1,304
Scirpus (californicus or acutus)-Typha sp	1,291
Annual Grasses/Weeds	1,010
Scirpus maritimus/Salicornia	804
Seasonally flooded undifferentiated annual grasses and forbs	802
Medium Wetland Graminoids	791
Undetermined[b]	785
Poison Hemlock (*Conium maculatum*)	765
Polygonum-Xanthium-Echinochloa	757
Rabbitsfoot grass (*Polypogon maritimus*)	722
Typha angustifolia/Distichlis	701
Slough	669
Salicornia (generic)	659

Map Classification[a]	Acreage in Plan Area
Medium Wetland Herbs	593
Distichlis (generic)	591
Scirpus californicus/S. acutus	583
Phragmites australis	569
Salicornia/Atriplex	526
Short Wetland Herbs	434
Distichlis/S. maritimus	428
Crypsis spp. - Wetland Grasses - Wetland Forbs NFD Super Alliance	402
Lepidium (generic)	378
Shallow flooding with minimal vegetation at time of photography	370
Typha angustifolia/Polygonum-Xanthium-Ech	364
Typha angustifolia/S. americanus	338
Typha angustifolia/Phragmites	338
Distichlis/Juncus	325
Atriplex/Distichlis	289
Atriplex triangularis	289
Polygonum amphibium	267
Scirpus americanus (generic)	263
Raphanus sativus (generic)	257
Juncus balticus	242
Conium maculatum	240
Atriplex/Annual Grasses	237
Cotula coronopifolia	236
Salicornia/Cotula	231
Sesuvium verrucosum	220
Elytrigia pontica	190
Lolium (generic)	189
Lotus corniculatus	189
Distichlis/S. americanus	185
Upland Herbs	166
Scirpus maritimus/Sesuvium	157
Eucalyptus globulus	141
Lepidium/Distichlis	137
Medium Upland Graminoids	135
Phragmites/Scirpus	124
Distichlis/Lotus	116
Distichlis/Cotula	114
Salicornia/Polygonum-Xanthium-Echinochloa	108
Short Wetland Graminoids	101
Baccharis/Annual Grasses	98
Salicornia/Sesuvium	96
Juncus balticus/Conium	95
Foeniculum vulgare	86
Scirpus (californicus or acutus)/Rosa	72
Tall Wetland Graminoids	72

Map Classification[a]	Acreage in Plan Area
Crypsis schoenoides	70
Frankenia (generic)	67
Scirpus (californicus or acutus)/Wetland	67
Rubus discolor	66
Atriplex/S. maritimus	63
Smartweed Polygonum spp. - Mixed Forbs	59
Structure	58
Rosa californica	56
Lepidium latifolium - Salicornia virginica - Distichlis spicata	54
Bulrush - Cattail Fresh Water Marsh NFD Super Alliance	52
Typha angustifolia (dead stalks)	51
Fallow Disced Field	42
Atriplex triangularis (generic)	40
Medium Upland Herbs	38
Rosa/Baccharis	34
Frankenia/Distichlis	33
Lolium/Lepidium	31
Atriplex lentiformis (generic)	30
Perennial Grass	29
Agrostis avenacea	28
Sesuvium/Distichlis	28
Polypogon monspeliensis (generic)	26
Wetland Herbs	26
Centaurea (generic)	26
Freshwater Drainage	24
Scirpus americanus/S. Californicus-S. acu	23
Juncus balticus/Lepidium	20
Intermittently Flooded Perennial Forbs	19
Tidal Mudflat	19
Cultivated Annual Graminoid	18
Phalaris aquatica	18
Cynodon dactylon	17
Sesuvium/Lolium	14
Phragmites/Xanthium	10
Distichlis-Juncus-Triglochin-Glaux	9
Bromus spp/Hordeum	9
Vernal Pools	9
Medium Upland Shrubs	8
Tall Wetland Herbs	8
Temporarily Flooded Grasslands	8
Carpobrotus edulis	7
Spergularia/Cotula	6
Leymus (generic)	6
Atriplex/Sesuvium	6
Cortaderia selloana	6

Map Classification[a]	Acreage in Plan Area
Scirpus americanus/Lepidium	5
Eucalyptus	5
Willow Trees	5
Salix laevigata/S. lasiolepis	5
Arundo donax	3
Brassica nigra (generic)	3
Lolium/Rumex	2
Fraxinus latifolia	2
Salicornia/Crypsis	2
Scirpus americanus/Potentilla	2
Frankenia/Agrostis	2
Oaks	2
Calystegia/Euthamia	2
Quercus agrifolia	2
Short Upland Graminoids	1
Vulpia/Euthamia	1
Rumex (generic)	1
Landscape Trees	1
Juncus balticus/Potentilla	1
Total	**70,698**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. Additionally, for Suisun Marsh, San Francisco Estuary Institute (2005) tidal data were used and intersected with the Boul and Keeler-Wolf (2008) vegetation data. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007) and Boul and Keeler-Wolf (2008).

[b] Portions of the Plan Area for which CDFW did not delineate plant alliances were mapped only to the natural community level as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

2.3.4.10.2 Fish and Wildlife

Managed wetland is managed specifically to promote use by wildlife, particularly birds, and as a result, a wide variety of waterfowl and other birds migrating along the Pacific Flyway use the habitat when inundated (Fleskes et al. 2005; EDAW 2007a; U.S. Fish and Wildlife Service 2007; Kleinschmidt 2008). Sandhill cranes forage and roost, and many ducks, California black rail, geese, wading birds, and shorebirds commonly forage and loaf in managed wetland in the Plan Area (U.S. Fish and Wildlife Service 2007). This natural community includes abundant and diverse plant assemblages and invertebrate populations that provide important food resources for migrating waterfowl, bats, and many other wildlife species that forage in and over these wetlands. During winter flood flow inundation, the managed wetland areas in the Yolo Bypass floodplain can provide spawning and rearing habitat for Sacramento splittail and refuge habitat for other fish species (Feyrer et al. 2006; Sommer et al. 2007) (Table 2-4). In Suisun Marsh, managed wetland provides habitat for waterfowl, rails, Suisun song sparrow, and salt marsh harvest mouse (Suisun Ecological Workgroup 1997; Suisun Ecological Workgroup 2001; Brown 2004).

Covered wildlife species that are associated with the managed wetland natural community within the Plan Area include salt marsh harvest mouse, Suisun shrew, California black rail, greater sandhill crane, Suisun song sparrow, Swainson's hawk, tricolored blackbird, western burrowing owl, white-tailed kite, giant garter snake, western pond turtle, and California red-legged frog (Table 2-4).

2.3.4.10.3 Nonnative Species

Managed wetland is subjected to the same invasive nonnative plant taxa as tidal brackish emergent wetland and tidal freshwater emergent wetland natural communities; however, because management operations include discing and the manipulation of flooding duration, there are more control opportunities. Perennial pepperweed (*Lepidium latifolium*) is one of the most serious threats to this community. It is difficult to control and may be spread through discing (Brown 2004; Vaghti and Keeler-Wolf 2004; EDAW 2007a; Environmental Science Associates 2007; Boul and Keeler-Wolf 2008). Other large stature invasive plant species that are problematic include pampas grass (*Cortaderia selloana*), giant reed (*Arundo donax*), and the nonnative genotype of common reed (*Phragmites australis*) (Vaghti and Keeler-Wolf 2004; Boul and Keeler-Wolf 2008). Managed wetland supports nonnative animals, including red fox (*Vulpes vulpes*), feral cats (*Felis domesticus*), and rats (*Rattus* spp.) (Brown 2004; Takekawa et al. 2006), that are predators of native wildlife and have been shown to significantly reduce populations of covered species including salt marsh harvest mouse, California black rail, and California clapper rail (Suisun Ecological Workgroup 2001; Brown 2004).

This natural community is also at risk from potential invasion by dreissinid mussels, as detailed in Section 2.3.4.1.3, *Nonnative Species*.

2.3.4.10.4 Ecosystem Functions

As a surrogate for natural marshes, managed wetland is managed to support highly productive seasonal wetlands interspersed with permanent wetlands to sustain large populations of waterfowl and shorebirds through the production of seed and invertebrates (Brown 2004; EDAW 2007a). The structure of the community is managed to provide nesting and resting or loafing areas. The nutrients and primary productivity are often transferred to adjacent natural wetlands through water management activities (Brown 2004) and by the daily and seasonal movements of waterfowl and shorebirds.

2.3.4.10.5 Environmental Gradients

Because they are often confined behind levees, environmental gradients in managed wetland are generally controlled through management actions. Discing and soil contouring provide a variety of ponding depths and widths of shallow water habitat (Brown 2004; EDAW 2007a). Flooding timing, duration, and water quality control species composition, primary productivity, water temperature, salinity, and the timing of exports of primary productivity.

2.3.4.10.6 Future Conditions with Climate Change

The managed wetland community is particularly sensitive to increased variability in precipitation associated with global climate change (Nicholls et al. 1999). Reduced and more variable water flows through the Central Valley are likely to reduce the amount of water available for management actions that require the flooding of the managed wetland community at precise times of the season to provide habitat and food for waterfowl. Additionally, sea level rise is expected to be especially significant in the Delta, where much of the land has subsided to below sea level and is currently protected from flooding by levees. The current subsided island condition, combined with higher sea level, increased winter river flooding, and more intense winter storms, will significantly increase the hydraulic forces on the levees. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major seawater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism, and causing substantial changes to the community (Mount and Twiss 2005). Areas within the levees that are currently covered by the managed wetland community would be lost.

2.3.4.11 Other Natural Seasonal Wetland

The other natural seasonal wetland natural community encompasses all the remaining natural (not managed) seasonal wetland communities that are not the vernal pool complex and alkali seasonal wetland complex natural communities (Figure 2-14). The vegetation types included in the other natural seasonal wetland natural community, as mapped by CDFW (Hickson and Keeler-Wolf 2007), include seasonally ponded, flooded, or saturated soils dominated by grasses, sedges (*Carex* spp.), or rushes (*Juncus* spp.). A review of the aerial photography (Google 2009) indicated that approximately half of the other natural seasonal wetland natural community consists of seasonally ponding areas in agricultural fields, and the other half consists of a temporarily flooded perennial forbs vegetation type that is exclusively found in a field near the Cosumnes River that has been the subject of restoration efforts through a levee breach and the creation of two ponds (Trowbridge 2005; Trowbridge et al. 2005) (Figure 2-14).

Table 2-15. Map Classifications in the Other Natural Seasonal Wetland Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
Temporarily Flooded Perennial Forbs	185
Undetermined[b]	76
Santa Barbara Sedge (*Carex barbarae*)	15
Total	**276**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

[b] Additional mapping efforts undertaken in 2012 classify mapping units to the natural community type as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

2.3.4.11.1 Vegetation

Vegetation found in the other natural seasonal wetland natural community consists of a mixture of exotic and native perennial forbs, grasses, sedges, and rushes tolerant of temporary flooding, ponding, or soil saturation during winter and spring months.

2.3.4.11.2 Fish and Wildlife

The other natural seasonal wetland natural community supports common invertebrates that are the main source of food for waterfowl and shorebirds (Silveira 1998), which also use the wetlands in their dry state as resting and seed foraging areas (U.S. Fish and Wildlife Service 2007; Kleinschmidt Associates 2008). The covered species that use the other natural seasonal wetland natural community include greater sandhill crane, Swaison's hawk, tricolored blackbird, western burrowing owl, and white-tailed kite (Table 2-4).

2.3.4.11.3 Nonnative Species

Problematic invasive nonnative plant species in the other natural seasonal wetland natural community include low mannagrass, Italian ryegrass, and perennial pepperweed (Hogle et al. 2006; Dawson et al. 2007; Gerlach et al. 2009).

2.3.4.11.4 Ecosystem Functions

When flooded, this natural community supports an aquatic foodweb that is functionally similar to undisturbed vernal pools (Alexander 1976; Barclay and Knight 1981; Scheffer 2004; Williams 2006). As the water recedes, its ecosystem characteristics change from an aquatic system to a terrestrial ecosystem (Williams 2006), and its foodweb linkages break down as the community becomes more integrated with the terrestrial landscape in which it is embedded.

2.3.4.11.5 Environmental Gradients

The dominant environmental gradient in the other natural seasonal wetland community is driven by the different chemical and physical attributes of water versus air. Water is a polar solvent that is important in many chemical exchanges, and those exchanges control pH and the oxidation state of many chemicals and compounds. It also has a high heat capacity so temperature changes are buffered; and it is extremely viscous compared to air, so exchanges between the air and water as well as movement within the water are very slow (Scheffer 2004; Williams 2006). The ecological gradient between seasonal wetlands and surrounding terrestrial communities is marked by transitions in plant and wildlife species and is most pronounced during the wetted phase.

2.3.4.11.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) is expected to alter the other natural seasonal wetland natural community. The primary impact of climate change will be driven by changes in the hydrologic regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrologic conditions, therefore increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how the increased variability in seasonal hydrology would affect the plants and animals inhabiting this community; however, because these species are adapted to current conditions, the impacts will likely result in changes to species composition. Additionally, rising average temperatures could result in increased evapotranspiration rates and therefore shorter wetted periods for this community; the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.12 Grassland

The grassland natural community encompasses a management spectrum ranging from natural to intensively managed vegetation dominated by grasses. At the more natural end of the spectrum, it is comprised of upland vegetation associations dominated by introduced or native annual and perennial grasses and forbs (herbaceous species that are not grasses) (D'Antonio et al. 2007; Keeler-

Wolf et al. 2007). At the intensively managed end of the spectrum, it includes nonirrigated pasturelands (CALFED Bay-Delta Program 2000). The grassland natural community is often found adjacent to wetland and riparian habitats and is the dominant community on managed levees in the Plan Area (Hickson and Keeler-Wolf 2007). The distribution of the grassland natural community in the Plan Area is shown in Figure 2-14.

The extent of this community in its natural landscape position around the periphery of the Plan Area has declined over the past century due to land conversion to intensive agriculture and losses to urban development (CALFED Bay-Delta Program 2000; San Francisco Estuary Institute 2010). Anthropogenic changes to the natural disturbance regimes (e.g., dry-land grain farming, grazing, and diseases) since European settlement have also eliminated many native plant communities (D'Antonio et al. 2007; San Francisco Estuary Institute 2010). Depending upon how intensively and how long a natural variant of the grassland natural community has been affected, its suite of native species may have largely been replaced by nonnative species (D'Antonio et al. 2007) and is often dominated by near monocultures of nonnative annual grasses and forbs (D'Antonio et al. 2007; U.S. Fish and Wildlife Service 2007). In the historical tidal areas of the Delta, grassland has expanded on the dry land created on and behind levees.

Vegetation types dominated by native grasses in the Plan Area were historically limited to a narrow border of either alkaline or freshwater meadows on clay rich soils in the uplands, adjacent to either marshes or alkaline sink scrub and dominated by saltgrass (*Distichlis spicata*). In higher topographic positions on coarser textured soils, there was a unique community with a significant component of native perennial and annual grasses (*Distichlis*, *Elymus*, *Melica*, *Nassella*, *Poa*, and *Vulpia*), geophytes (*Calochortus*, *Chlorogalum*, *Dichelostemma*, and *Triteleia*), and a phenological succession of many species of early spring-, spring-, and summer-flowering annual dicots (Bryan 1923; Thomasson Jr. et al. 1960; Collins and Grossinger 2004; Grossinger 2004; Grossinger et al. 2008; San Francisco Estuary Institute 2010).

In the southwestern portion of the Plan Area, from the Clifton Court Forebay to Oakley, there was a narrow band of alkali meadow dominated by saltgrass, which was sandwiched between tidal marshes and alkaline sink scrub on one side and oak savanna on the other (Carpenter and Cosby 1939; San Francisco Estuary Institute 2010). Similar conditions occurred around the Montezuma Hills (Collins and Grossinger 2004). Using the historical conditions of the south San Francisco Bay, old charts, and current floras to reconstruct the vegetation, along the borders of Suisun Marsh and the Cache Slough area there were alkali meadows dominated by saltgrass located between the marshes with the unique seasonal community in higher topographic positions (Collins and Grossinger 2004; Grossinger 2004).

Along the west side of the Yolo Basin from the Cache Slough area to the current sinks of Putah Creek, there was a unique landform called the Putah Plain that consisted of numerous small floodwater distributaries of Putah Creek (Bryan 1923; Thomasson Jr. et al. 1960; Graymer et al. 2002; Witham 2003; Grossinger et al. 2008; Gerlach et al. 2009). The distributaries were aligned perpendicular to the Yolo Basin as a continuous parallel repeating geomorphic series of shallow basin, low natural levee, channel, low natural levee, shallow basin features. These hydrologic features disappear at lower elevations in the Yolo Basin because they were periodically eroded away by large Sacramento River flood events into the Yolo Basin. The channels were, and where they are still intact, are dominated by vernal pool species characteristic of nonalkaline, short inundation period, clay-bottom, swale/pool complexes. Good examples are the relatively undisturbed channels at the CDFW Tule Ranch. The basins in topographically higher positions than the channels were likely highly alkaline areas that resulted from the accumulation of salts transported by floodwaters from west of the Yolo Basin. These basins are dominated by saltgrass, tarweeds, tarplants, and seepweed at higher elevation edges and by typical clay-bottom vernal pools species and saltpan species at their bottoms. These bottoms are the local habitat of Solano grass and Colusa grass; a good example is found at the Yolo County Grasslands Regional Park (Witham 2003; Environmental Science Associates and Yolo County 2005; Gerlach et al. 2009).

Along the east side of the Plan Area in the vicinity of Stone Lakes NWR there are areas of the unique seasonal community interspersed with partially filled former tidal drainages of the Cosumnes Basin that grade upslope into claypan vernal pool/swale complex as reflected in the current flora and aerial imagery (U.S. Fish and Wildlife Service 2007; Google 2009). These communities abut tidal and reclaimed former tidal marshes and are periodically cut by small creeks and tidal channels running down to the Cosumnes Basin.

Direct and indirect anthropogenic influences on the landscape of the Plan Area have resulted in the reduction, conversion, and fragmentation of the meadows and unique seasonal communities. These changes have led to diminished ecological conditions necessary for sustaining well-functioning grassland natural community. In the Plan Area, the grassland natural community currently comprises one of the most common natural communities, but a large portion of this grassland is in areas that were historically tidal marsh and the vegetation is dominated by invasive nonnative grasses. While many native plant species have been reduced in abundance or distribution through these processes, they persist and coexist with nonnative plant species where the meadows and unique seasonal community once existed. Some animal species have also adjusted well to the new type of grassland community. Thus, the current grassland natural community still offers valuable habitats to many grassland-dependent species.

2.3.4.12.1 Vegetation

The vegetation classification units present and their extent within the grassland natural community are shown in Table 2-16. Common nonnative annual grass species in this natural community include Italian ryegrass, soft chess, ripgut brome, red brome, wild barley, wild oats, and foxtail fescue. Native perennial grasses are generally found only in areas that have not been plowed and include creeping wildrye, blue wildrye, saltgrass, California melic, California brome, meadow barley, tuffed hairgrass, one-sided bluegrass, and purple needlegrass (Witham 2003, 2006; Hickson and Keeler-Wolf 2007; U.S. Fish and Wildlife Service 2007). If unplowed, the grassland natural community can be rich in species in the lily family that may include Ithuriel's spear, white hyacinth, harvest brodiaea, gold nugget, paper onion, blue dicks, common muilla, and narrow-leaved soap plant. In some parts of the Plan Area, the grassland natural community is interspersed with the vernal pool complex, alkali seasonal wetland complex, and other natural seasonal wetland natural community types (Witham 2003, 2006; Baraona et al. 2007). The *Manual of California Vegetation* (Sawyer et al. 2009) recognizes the broad spectrum of grassland types and includes vegetation types that are completely dominated by nonnative annual grasses to grasslands that are dominated by perennial native grasses. Plant species that can sometimes be found within grassland that contains patches of other natural communities addressed by the BDCP include alkali milk-vetch, brittlescale, Carquinez goldenbush, delta button celery, heartscale, Heckard's peppergrass, and San Joaquin spearscale (Table 2-4).

1 **Table 2-16. Map Classifications in the Grassland Natural Community in the Plan Area**

Map Classification[a]	Acreage in Plan Area
Ruderal Herbaceous Grasses & Forbs	25,779
California Annual Grasslands - Herbaceous	24,255
Undetermined[b]	16,643
Italian Rye-grass (*Lolium multiflorum*)	5,019
Upland Annual Grasslands & Forbs Formation	1,817
Annual Grasses generic	1,230
Bromus diandrus - Bromus hordeaceus	838
Pasture	244
Annual Grasses/Weeds	226
Lolium multiflorum - Convolvulus arvensis	36
Seasonally Flooded Grasslands	36
Distichlis/Annual Grasses	28
Centaurea (generic)	24
Cultivated Annual Graminoid	22
Perennial Grass	19
Rabbitsfoot grass (*Polypogon maritimus*)	14
Foeniculum vulgare	11
Bare Ground	11
Distichlis (generic)	9
Salicornia/Annual Grasses	8
Juncus bufonius (salt grasses)	6
Baccharis/Annual Grasses	5
Leymus (generic)	5
Landscape Trees	5
Foolded Managed Wetland	5
Distichlis spicata	4
Eucalyptus globulus	3
Structure	2
Salicornia/Polygonum-Xanthium-Echinochloa	2
Distichlis/Salicornia	2
Distichlis/Lotus	1
Medium Wetland Herbs	1
Lolium (generic)	1
Lepidium (generic)	1
Polygonum-Xanthium-Echinochloa	1
Distichlis/S. maritimus	1
Upland Herbs	1
Conium maculatum	1
Tall & Medium Upland Grasses	1
Medium Wetland Graminoids	1
Total	**76,315**

[a] In many areas of the Delta, Yolo Bypass, and Suisun Marsh, slightly different vegetation units were mapped at a very fine scale. Plant alliances dominated by the same groups of species, such as nonnative annual grasses, were combined into a composite mapping unit. For more detailed information concerning the original mapping units and plant associations/alliances, as well as the methods of classification used, see Hickson and Keeler-Wolf (2007), Boul and Keeler-Wolf (2008), and Technology Associates International Corporation (2008).

[b] Additional mapping efforts undertaken in 2012 classify mapping units to the natural community type as described in Section 2.3.1, *Data Sources and Natural Community Classification*.

2.3.4.12.2 Wildlife

The grassland natural community provides important breeding and foraging habitat for many species of wildlife. Common mammals found in grasslands include mule deer, California ground squirrel, California vole, pocket gopher, desert cottontail, black-tailed jackrabbit, coyote, and badger. Grasslands are important to raptors and nesting waterfowl (CALFED Bay-Delta Program 2000). Raptors for which grasslands provide important foraging habitat include Swainson's hawk, white-tailed kite, red-tailed hawk, northern harrier, golden eagle, American kestrel, burrowing owl, great horned owl, and barn owl. Common songbirds that use the grasslands include loggerhead shrike, horned lark, water pipit, western bluebird, savannah sparrow, and western kingbird. Common reptiles and amphibians in the grasslands include gopher snake, common garter snake, California king snake, western fence lizard, Pacific tree frog, and western toad.

Grasslands provide habitat for many covered wildlife species, including salt marsh harvest mouse, San Joaquin kit fox, greater sandhill crane, Swainson's hawk, tricolored blackbird, western burrowing owl, white-tailed kite, giant garter snake, western pond turtle, California red-legged frog, California tiger salamander, and valley elderberry longhorn beetle (Table 2-4).

2.3.4.12.3 Nonnative Species

California's grasslands have been invaded by a large number of exotic plant species, which were primarily introduced and spread through farming and ranching agricultural practices (D'Antonio et al. 2007). A large number of exotic annual grass species dominate nonirrigated grasslands (D'Antonio et al. 2007; Keeler-Wolf et al. 2007) with annual ryegrass, medusahead (*Taeniatherum caput-medusae*) and barbed goatgrass (*Aegilops triuncialis*) being the most problematic in the Plan Area (Swiecki and Bernhardt 2002; Witham 2003; Environmental Science Associates and Yolo County 2005; U.S. Fish and Wildlife Service 2007; Hopkinson et al. 2008). Dicot species that are especially problematic include Italian thistle (*Carduus pycnocephalus*), purple starthistle (*Centaurea calcitrapa*), yellow starthistle (*Centaurea solstitialis*), and perennial pepperweed (*Lepidium latifolium*) (Swiecki and Bernhardt 2002; Witham 2003; Environmental Science Associates and Yolo County 2005; Witham 2006; U.S. Fish and Wildlife Service 2007; Hopkinson et al. 2008). Much of the grassland natural community in the Plan Area is classified as ruderal vegetation because it is dominated by nonnative opportunistic plants on disturbed soils such as levees and old tilled fields.

Problematic vertebrate exotic species that adversely affect wildlife in the grassland natural community include feral dogs (*Canis lupus familiaris*) and feral cats (*Felis silvestris*) (U.S. Fish and Wildlife Service 2007).

2.3.4.12.4 Ecosystem Functions

The grassland natural community in the Plan Area is primarily managed for its function as a source of primary productivity to feed domestic grazing animals (Jackson and Bartolome 2007). Burrows excavated by small rodents provide terrestrial habitat for California tiger salamander and nesting habitat for California burrowing owl (Witham 2006; EDAW 2007a; U.S. Fish and Wildlife Service 2007). Other ecosystem functions include effects on carbon sequestration and on the water and nutrient cycles by the grassland natural community (Eviner and Firestone 2007; Jackson and Bartolome 2007; Reever-Morghan et al. 2007).

2.3.4.12.5 Environmental Gradients

Because of its extensive distribution in California, the grassland natural community often serves as the matrix in which other natural communities are embedded. In the Plan Area, it is generally located in higher topographic positions with steep environmental gradients to lower and wetter communities such as the alkali seasonal wetland complex and valley/foothill riparian natural community. A less obvious gradient exists between subsurface environments such as rodent burrows, which maintain high humidity for California tiger salamander during the hot dry season (Storer 1925; Loredo and Van Vuren 1996; Petranka 1998; Trenham 1998).

2.3.4.12.6 Future Conditions with Climate Change

Ongoing and future climate change (Section 2.3.3.2, *Climate*) may negatively affect the grassland natural community; although, there is no consensus on what the impacts will be (Dukes and Shaw 2007; Jackson et al. 2009). Because this community is generally located at elevations that will not be directly affected by rising sea level, the primary impact of climate change will be driven by the increased variability in precipitation. The species present in this community are adapted to the existing precipitation regime, and an increase in the variability of precipitation is likely to lead to a shorter and more variable wet season. It is uncertain how the community or its individual species may respond to this increased variability (Dukes and Shaw 2007).

2.3.4.13 Inland Dune Scrub

Inland dune scrub is a dense to open shrub and sub-shrub dominated community of remnant dune soils with a unique mix of rare, endemic species of plants and insects. Inland dune scrub occurs only on the disturbed remnants of the former dune that existed along the southern shore of the San Joaquin River, immediately east of the city of Antioch (Figure 2-14). The 190-acre dune paralleled the shore for 2 miles, and was 0.15-mile wide and 120 feet tall (Howard and Arnold 1980; San Francisco Estuary Institute 2010). Beginning in 1865, the sand of the dune was mined to manufacture pottery, and in the late 1880s, the sand was mined to manufacture bricks. The rate of sand mining greatly accelerated after the 1906 San Francisco earthquake for the manufacturing of bricks to rebuild the city. In the 1920s, mining increased again for the manufacture of asphalt and concrete. Sand mining then continued at a declining rate until World War II when it increased again.

After World War II, extensive commercial development spread across the area where the dune had been mined away, and sand mining continued eastward. The mining continued on the last two parcels of the dune even as USFWS was negotiating to establish the 55-acre Antioch Dunes NWR. By the time the purchase was complete, the highest elevations of the remains of the dune were only 50 feet above MHHW of the San Joaquin River, with a slightly more dune-like area on an adjacent 12-acre Pacific Gas and Electric (PG&E) transmission line corridor 80 feet above MHHW (Howard and Arnold 1980; U.S. Fish and Wildlife Service 1984; 2001; San Francisco Estuary Institute 2010). When measured from the landward side, the highest point on the Antioch Dunes NWR is 30 feet; the PG&E elevation is 60 feet.

A description of the combined area of the Antioch Dunes NWR and PG&E properties with dune-like characteristics at the time of acquisition stated that "only an extremely small percentage of the area is in the configuration of a dune" (U.S. Fish and Wildlife Service 1984). Management actions to increase the dune-like characteristics of Antioch Dunes NWR have included creating small dunes with 7,000 cubic yards of dredged sand material that had been stockpiled on the PG&E property (which proved unsuitable due to its clay content), and bulldozing the residual sand on the Antioch Dunes NWR into the shape of small dunes (U.S. Fish and Wildlife Service 1984, 2001).

The geological origin of the dune has not been determined; however, regardless of its original source, the sand was sorted from a mixture of fine- and coarse-textured material and redeposited by wind (not water), as indicated by its extremely low clay content (soil survey), and it appears to have had a deep, older layer as well as a more recent layer (U.S. Fish and Wildlife Service 2001). It has been speculated that the sand was brought to the location by the San Joaquin River approximately 140,000 years ago, and that the most recent dune probably established prior to the post-ice age sea level rise approximately 15,000 years ago (U.S. Fish and Wildlife Service 1984, 2001).

Most accounts incorrectly describe the sand as the result of glaciation even though glaciated material would consist of very fine clay and silt-like particles (glacial milk). Instead, the sand probably originated during warm, humid periods as the granitic rock of the southern Sierra Nevada was chemically transformed into grus and then transported to the San Joaquin Valley during enormous slope failures (Wahrhaftig 1965; Twidale and Vidal Romaní 2005; Graham et al. 2010). While the dune was a unique formation, the sand is distributed southwestward from the dune in a 5.5-miles-by-2-miles oblong patch (Carpenter and Cosby 1939; San Francisco Estuary Institute 2010).

In the 1933 soil survey of the area, the sand was classified as the Oakley sand soil series, and it was determined to be infertile, slightly acidic, and consisting of 2% coarse sand, 65% fine sand and 1% clay (Carpenter and Cosby 1939). In contrast, the much more heterogeneous riverine deposit of Piper fine sandy loam on the low islands of the nearby Delta is slightly alkaline and consists of 12% coarse sand, 45% fine sand, and 4% clay.

2.3.4.13.1 Vegetation

The vegetation communities present and their extent within the inland dune scrub natural community are shown in Table 2-17. Inland dune scrub is more similar to the vegetation of sandy soils in the San Joaquin Valley and Mohave Desert than to coastal scrub communities (Howard and Arnold 1980). Unfortunately, the predisturbance species composition of the vegetation was never well described before the sand mining and extensive oak cutting in the early 1900s and post-World War II (U.S. Fish and Wildlife Service 2001). Based on early charts and a postcard dating from the early 1900s, the vegetation contained widely scattered large valley oaks, live oaks, various shrub species, and numerous herbaceous species (Howard and Arnold 1980; San Francisco Estuary Institute 2010). Very similar vegetation occurred 1.5 miles southeast of the dune as a 3-mile by 1.5-mile, 3,000-acre oblong patch on the Oakley sand soil southwest of Oakley (San Francisco Estuary Institute 2010). That area of chaparral/scrub was described as nearly impenetrable, but was cleared for grain production, later planted as almond orchards, and now is almost entirely developed (San Francisco Estuary Institute 2010).

Table 2-17. Map Classifications in the Inland Dune Scrub Natural Community in the Plan Area

Map Classification[a]	Acreage in Plan Area
Lupinus albifrons - Antioch Dunes	15
Lotus scoparius - Antioch Dunes	5
Total	**19**

[a] Some of the map classifications provided here are directly representative of associations, alliances, or phases identified through field surveys. Others represent amalgamations of field data due to issues of scale or remote sensing. For more detailed information concerning these map classifications and plant associations/alliances/phases, as well as methods of classification used, see Hickson and Keeler-Wolf (2007).

Antioch Dunes NWR vegetation surveys conducted by Susan Bainbridge of the UC Berkeley Jepson Herbarium and the California Native Plant Society (CNPS) were used by CDFW (Hickson and Keeler-Wolf 2007) to map two Antioch Dunes unique vegetation types that have one or more shrubs in the overstory, which may have very sparse cover. The data were not formally analyzed by the CDFW Delta mapping project, and the inland dune scrub community is defined by the presence of either of the two vegetation types. One vegetation type consists of a broadleaf shrubland that was classified as the *Lupinus albifrons* Antioch Dunes alliance (5 acres), and the other is a dwarf shrub vegetation type classified as the *Lotus scoparius* Antioch Dunes alliance (15 acres). Given that *L. albifrons* is primarily a coastal species, while the vegetation of the dune is primarily the northern-most expression of desert vegetation, it is more likely the species is the *L. excubitus*, an interior and desert species that is indistinguishable from *L. albifrons* (Rosatti ed. 2010). Other plant species present include ripgut brome (*Bromus diandrus*), yellow starthistle (*Centaurea solstitialis*), elegant clarkia (*Clarkia unguiculata*), naked stem buckwheat (*Eriogonum nudum* var. *auriculatum*), California poppy (*Eschscholzia calfornica*), California croton (*Croton californicus*), Grindelia (*Grindelia* spp.), California matchweed (*Gutierrezia californica*), telegraph weed (*Heterotheca grandiflora*), vetch (*Vicia* spp.), and Russian thistle (*Salsola tragus*) (U.S. Fish and Wildlife Service 2001)(Table 2-4).

2.3.4.13.2 Wildlife

Recent observations of wildlife on the Antioch Dunes NWR include coyote (*Canis latrans*), long-tailed weasel (*Mustela frenata*), muskrat (*Ondatra zibethica*), raccoon (*Procyon lotor*), Townsend's mole (*Scapanus townsendi*), Beechy ground squirrel (*Otospermophilus beecheyi*), black-tailed jackrabbit (*Sylvilagus bachmani*), Botta's pocket gopher (*Thomomys bottae*), gray fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), racers (*Coluber constrictor*), gopher snake (*Pituophis melanoleucus*), western fence lizard (*Sceloporus occidentalis*), and common side-blotched lizard (*Uta stansburiana*). Numerous bird species have been observed on the Antioch Dunes NWR (migratory and resident), and gadwalls (*Anas strepera*) and mallards (*A. platyrhynchos*) have nested there. Historically, the dunes represented the northernmost occurrences for reptiles adapted to arid conditions, including the California legless lizard (*Anniella pulchra*), glossy snake (*Arizona elegans*), San Joaquin whipsnake (*Masticophis flagellum ruddocki*), and side-blotched lizard (*Uta stansburiana*) (Howard and Arnold 1980; U.S. Fish and Wildlife Service 1984, 2001, 2008b).

2.3.4.13.3 Invertebrates

The Antioch Dunes have been known as an entomological hotspot since the 1930s, when research entomologists began collecting in what is now the Sardis Unit of the Antioch Dunes NWR (Howard and Arnold 1980; Arnold 1983). The area attracted extensive academic attention for its large and colorful species with desert affinities. In the 1930s, many species of wasps and flies, particularly the giant flower-loving fly (*Thaphiomydas trochilus*), were completely new to the region's collectors. A total of 27 taxa were described from the Antioch Dunes during that decade. Eight of those taxa are endemic to the Antioch Dunes; four are now extinct, three are of uncertain status, and one is the federally and state endangered Lange's metalmark butterfly (*Apodemia mormo langei*).

2.3.4.13.4 Nonnative Species

The primary problematic nonnative plant species in this community are annual grasses such as ripgut brome, vetches, and yellow starthistle (*Centaurea solstitialis*), which form dense patches that crowd native plant species and reduce habitat value for wildlife and invertebrates (U.S. Fish and Wildlife Service 2001).

2.3.4.13.5 Ecosystem Functions

The inland dune scrub natural community is found on infertile sandy soil that historically was a large dune. There are only two patches totaling 19 acres of this natural community currently in existence, all of which have been severely degraded by a century of sand mining. Currently, the degraded remnants of the community are being managed exclusively for the three endangered species for which the Antioch Dunes NWR was established to protect.

2.3.4.13.6 Environmental Gradients

Inland dune scrub transitions into the tidal brackish emergent wetland natural community along its border with the San Joaquin River (U.S. Fish and Wildlife Service 1984, 2001). Its other three sides are bordered by commercial developments.

2.3.4.13.7 Future Conditions with Climate Change

Because this community is generally located at elevations that will not be directly affected by rising sea level, the primary impact of climate change is predicted to be driven by changes in the hydrologic regime due to increased variability in precipitation. The species present in this community are adapted to a highly variable precipitation, and it is uncertain how they will be affected by increased variability.

2.3.4.14 Cultivated Lands

The majority of lands in the Delta are currently cultivated lands (Figure 2-14). Major Delta region cultivated crops and cover types include small grains (such as wheat and barley), field crops (such as corn, sorghum, and safflower), truck crops (such as tomatoes and sugar beets), forage crops (such as hay and alfalfa), pastures, orchards, and vineyards (CALFED Bay-Delta Program 2000; California Department of Water Resources 2007b). Of the total Plan Area, 66% is cultivated. Of the total acreage of irrigated land in the Delta, which encompasses both seasonally flooded and upland cropland, corn is currently the predominant cover type (28%), followed by alfalfa (21%), pasture (12%), and tomatoes (8%). Orchards cover 4% of the total irrigated land acreage in the Delta, and asparagus covers 3% (California Department of Water Resources 2007b). The distribution of seasonal crops in the Plan Area varies annually, depending upon crop-rotation patterns and market forces. Vegetable crops are the most abundant crops in the region (Fleskes et al. 2005). Changes in agricultural crops in the Delta over the past 30 to 40 years have shown dramatic trends, including a six-fold reduction in asparagus acreage (lowering it from the number one crop to the number eight crop in acreage grown), a two-fold increase in corn acreage (making it the number one crop in acreage grown), and an 18-fold increase in vineyards (California Department of Water Resources 2007b). These changes can have substantial effects on the habitat value of cultivated lands for wildlife, particularly for birds.

2.3.4.14.1 Vegetation

Vegetation in the cultivated lands natural community is variable and dynamic in terms of structure, growth, and harvesting patterns. Croplands do not conform to natural habitat successional stages. Instead, cropland is regulated by the artificial crop cycle. Vegetation can be either annual or perennial and can germinate at various times of the year. The largest proportion of the Plan Area landscape includes annually cultivated irrigated croplands that are rotated seasonally or annually to conserve soil nutrients and maintain soil productivity (Table 2-18). This portion of the landscape, which includes most field, truck, and grain crops, changes seasonally as crops grow, are harvested, and with the rotational sequence of different crop types. These changes influence the value and use of cultivated habitats to covered wildlife species on a seasonal basis. Other cover types, such as orchards, vineyards, rice, and irrigated pasture remain uncultivated for many years and are considered perennial crop types because they do not seasonally or annually rotate to other crop or cover types. Still other crops, particularly alfalfa and other hay crops, while regularly harvested, may remain uncultivated for multiple years, but eventually are rotated to other uses and are thus referred to as semi-perennial crop types.

While planting timeframes are variable, most annually cultivated croplands are planted in spring and harvested in late summer or early fall. Much of the Plan Area remains unplanted and bedded during the winter season, although a second crop may be planted during the same growing season in some areas. Cropland vegetation is grown as a monoculture, using tillage or herbicides to eliminate unwanted vegetation.

However, interspersed within the cultivated lands are small patches or linear corridors of natural vegetation and other natural features, such as riparian woodland and scrub, wetlands, ponds, hedgerows, tree rows, and small patches of isolated native or nonnative trees. Cultivated lands in the Plan Area are not known to support any covered plant species (Table 2-4). Soil often dictates the type of crops grown in the Plan Area. Corn, for instance, requires better soil than barley, which can grow in poor-quality soil; and rice does well in clay soil not suitable for other crops. Leaching can remove contaminants in areas of high salt or alkali levels, making the soil highly productive. Local climate variation also influences the type of crops grown (California Department of Fish and Game 2005).

Orchard crops are categorized as deciduous or evergreen, with deciduous orchards far more common in the Delta region than evergreen orchards. Deciduous orchards include commercially productive tree crops in which the trees lose their leaves at some point in the year and include fruit and nut trees (e.g., pear and walnut), and bush crops. Bush crops are similar to orchards, but they may be configured in rows rather than a matrix, and are much shorter. Evergreen orchards include commercially productive tree crops, including citrus, avocado, and olive groves, in which the trees retain their leaves throughout the year (Hickson and Keeler-Wolf 2007). Cultivated lands also include eucalyptus, tree-of-heaven, and other exotic vegetation stands.

Table 2-18. Map Classifications in the Cultivated Lands in the Plan Area

Map Classification[a]	Acreage in Plan Area
Corn	100,933
Alfalfa & Alfalfa mixtures	80,948
Vineyards	33,857
Tomatoes (processing)	31,297
Mixed pasture	30,576
Misc grain and hay	27,667
Native Vegetation	26,869
Misc semi-ag	20,602
Deciduous fruits and nuts	19,897
Safflower	15,410
Asparagus	11,301
Rice	10,259
Native Pasture	8,376
Cropped within the past three years	8,143
Sudan	6,297
Beans (dry)	6,005
Wheat	4,731
Miscellaneous field	4,571
Melons, squash, and cucumbers (all types)	4,427
Turf farms	3,740
Non-irrigated native pasture	3,465
Potatoes	3,053
Non-irrigated mixed pasture	2,995
Farmsteads (includes a farm residence)	2,119
Other Ag Lands	2,028
Misc truck	1,585
non-irrigated Misc. Grain and Hay	1,303
Sunflowers	1,175
Dairies	830
Farmsteads (without residence)	820
Wild Rice	578
Other Pasture	577
Peppers	535
Sugar Beets	445
Misc grasses	422
Grain and Hay Crops	401
Marsh lands, tules and sedges	350
Grain sorghum	324
Hybrid sorghum/sudan	305
Onions/garlic	303

Map Classification[a]	Acreage in Plan Area
Citrus and Sub-tropical	264
New lands being prepped for crop production	235
Cabbage	222
Bush berries	218
Water surface	206
Carrots	197
Livestock feedlots	180
Beans (green)	122
Flowers, nursery, Christmas trees	114
Celery	105
Cotton	78
Oats	74
Field Crops	71
Barren and wasteland	68
Mixed	39
Poultry farms	38
Clover	32
Mixed grain and hay	32
Rye grass	29
Lettuce	20
Strawberries	18
Broccoli	13
Semi-agricultural and incidental	5
non-irrigated Mixed grain and hay	2
Natural high water table meadow	2
Market Tomatoes	2
Total	**481,908**

[a] Source: California Department of Water Resources 2007b (Land Use)

2.3.4.14.2 Fish and Wildlife

Cultivated lands in the Plan Area formerly consisted of extensive wetlands, open grasslands, broad riparian systems, and oak woodlands. The conversion of natural vegetation to agriculture has eliminated large areas of these native habitats. However, although they generally support a less diverse community of wildlife compared with most native habitats, agricultural systems continue to support abundant wildlife and provide essential breeding, foraging, and roosting habitat for many resident and migrant wildlife species (Fleskes et al. 2005; EDAW 2007a; U.S. Fish and Wildlife Service 2007; Kleinschmidt 2008). Cultivated lands in the Plan Area provide habitat for several federal and California listed species covered by the BDCP, including greater sandhill crane, Swainson's hawk, tricolored blackbird, western burrowing owl, white-tailed kite, giant garter snake, western pond turtle, and California red-legged frog (Table 2-4).

Cultivated lands in the Delta provide essential upland habitat for many wildlife species. Crop patterns that include a variety of hay, grain, and row crops support abundant rodent populations. Field edges, woodlots, and watercourses that support riparian habitat also provide breeding sites and refugia for prey species and other wildlife. Because of this abundance of food, the Central Valley supports one of the largest concentrations of raptors during the winter and breeding seasons. Raptors, such as red-tailed hawk, Swainson's hawk and white-tailed kite, nest throughout the Central Valley and forage in a variety of agricultural crop types including hay, grain, row crops and irrigated pastures. Conversion of pastures, row crops, and similar agricultural habitats to orchards and vineyards has been noted as a factor affecting raptors such as Swainson's hawk (Estep in prep). Grain, corn, and rice fields also provide important foraging habitats for sandhill cranes, waterfowl, wading birds, and shorebirds. Upland and seasonally flooded agricultural habitats and wetlands of the Delta support an estimated 10% of the waterfowl population that winter annually in California (CALFED Bay-Delta Program 1998).

The Yolo Bypass Wildlife Area is an example of an area that utilizes agriculture to manage wildlife habitats while providing income from agriculture (EDAW 2007a). Many agricultural practices occurring in the Yolo Bypass Wildlife Area provide habitat for a diverse assemblage of wildlife species. Rice is grown, harvested, and flooded to provide food for thousands of waterfowl. Cornfields are harvested to provide forage for geese and cranes. Working with local farmers, the Yolo Bypass Wildlife Area provides fields of grain sorghum, corn and sudan grass specifically for wildlife forage purposes. Crops such as safflower are cultivated and mowed to provide seed for upland species such as ring-necked pheasant and mourning dove (EDAW 2007a).

When inundated, the Yolo Bypass provides habitat for at least 42 fish species, 15 of which are native (Sommer et al. 2001a). The bypass seasonally supports several covered species, including delta smelt, splittail, green sturgeon, steelhead, and spring-run and winter-run Chinook salmon (Table 2-4). The majority of the floodplain habitat is seasonally dewatered and therefore cannot be dominated by nonnative fish species except in perennial waters. Typical winter and spring spawning and rearing periods for native Delta fishes coincide with the timing of the flood pulse (Sommer et al 2001a). Evidence suggests that splittail and Chinook salmon benefit from Yolo Bypass inundation because of increased seasonal floodplain habitat that is used for rearing and spawning due to the increased food supply, lower water velocity, and warmer water.

Native and nonnative vegetation growing along field margins and riparian vegetation growing along permanent agricultural ditches also provides habitat for migrant and resident songbirds, raptors, reptiles, amphibians, and small mammals. Filter strips of vegetation planted in agricultural areas to improve water quality also provide wildlife habitat. Natural seasonal wetlands associated with agricultural drainage and irrigation channels provide habitat for a number of wildlife and fish species.

The wildlife habitat value of cultivated lands is a function of several variables, including accessibility to prey, prey density, and proximity to other habitat types. However, due to the dynamic nature of the cultivated land, to best evaluate the wildlife value of agricultural cover types in the Plan Area over a long timeframe, cover types can be characterized at a broad scale according to seasonal or perennial condition. Although perennial or semi-perennial cover types can be evaluated independently, seasonal crop types are best evaluated more generally by combining all seasonally and annually cultivated crop types into a single category. Specific crop type requirements or preferences can be addressed at the species-specific or preserve management level. Cultivated lands in the Plan Area are characterized and evaluated by the crop types presented in Figure 2-16. Those crop types that provide the greatest habitat value for covered species are summarized in Table 2-19 and described in the text below.

Table 2-19. Acreages of Cultivated Land Categories in the Plan Area

Cultivated Lands Subtype	Plan Area Acreage
Alfalfa	80,948
Irrigated pasture	70,623
Rice	10,837
Orchards	20,161
Vineyards	33,857
Other cultivated crops[a]	238,234
Other cultivated lands[b]	27,248
Total	**481,908**

Source: California Department of Water Resources 2007b (Land Use)

[a] Other cultivated crops primarily include field crops, truck, nursery, and berry crops, and nonirrigated pasture.

[b] Other cultivated lands consist of livestock feedlots, dairies, poultry farms, and cropland-associated infrastructure such as roads, ditches, houses, etc.

Alfalfa. Alfalfa is an ungrazed irrigated hay crop used for livestock feed. Alfalfa is regarded as a semi-perennial crop type typically remaining uncultivated for 4 to 5 years, and occasionally longer. During this time, it is not rotated to other crop types. Alfalfa is considered the agricultural cover type with the highest foraging value to Swainson's hawk and the white-tailed kite, and is an important foraging cover type for the greater sandhill crane and tricolored blackbird. Its value is largely a function of its relatively low vegetation structure, and the practice of regular mowing and flood irrigating during the spring and summer, which enhances prey accessibility for foraging birds. This crop type is distributed throughout the Plan Area, including portions of the Yolo Bypass.

Irrigated Pasture. Irrigated pastures are irrigated grasses or hays grazed by livestock and periodically cut for hay. They include large pasturelands found in the Yolo Bypass, Sherman Island, and other Delta islands, and smaller pastures associated with farm residences or smaller cattle operations. While smaller irrigated pastures may be rotated to other cover types periodically, most irrigated pasturelands remain intact for many years. Like alfalfa, irrigated pastures provide foraging value to several covered species, including Swainson's hawk, white-tailed kite, burrowing owl, greater sandhill crane, and tricolored blackbird.

Rice. Because rice cultivation requires a narrow range of soil conditions and because of the infrastructure required to effectively manage rice fields, this crop is not typically rotated and remains for many consecutive years, sometimes decades. Thus, rice is also considered a perennial crop type. Rice fields are active beginning as early as March when fields are initially flooded, to September, October, and November when fields are drained and harvested. During the fall and winter, some rice fields are flooded to provide habitat for wintering waterfowl. Rice fields provide important aquatic habitat for giant garter snakes during the active season, as well as foraging habitat for many bird species during the active and inactive seasons.

Orchards. Orchards are perennial crops that provide limited wildlife value, particularly to covered species. Orchards develop a vegetation overstory that generally precludes access by foraging

Swainson's hawks, white-tailed kites, burrowing owls, and other cultivated land-associated covered species. Orchards are planted in rows and eventually develop a dense overstory canopy. Some bats and birds find roosting and nesting opportunities in orchard trees, but overall, orchard trees receive limited use and are of negligible value to covered species.

Vineyards. Like orchards, the structure of vineyards also limits use by covered species and most other wildlife. This crop type also remains for many consecutive years and is considered a perennial cover type. Planted in rows, a relatively dense overstory develops that prohibits use by most agriculture-associated wildlife species. The increase in vineyard acreage in the Plan Area has removed other agricultural habitats more suitable to wildlife.

Other Cultivated Crops. This type is defined as areas dominated by crop patterns that involve annual or seasonal cultivation and rotation. This is the dominant cover type in the Plan Area and consists of most of the field, truck, and grain crops. These types are generally characterized as having seasonal or fluctuating habitat value depending on the planting and harvesting regime and vegetation structure. Thus, there is substantial variation in habitat value among the many crop types included within this category. Because they are rotated seasonally or annually, the value of individual fields changes each year. In addition, lands that are farmed to rotated irrigated crops generally have periods—usually during the fall post-harvest and winter months—when the fields are disked or bedded and support no vegetation. Therefore, for purposes of general classification and modeling habitat value, these crop types are not differentiated based on their individual seasonal value but are instead combined into a category of seasonally rotated croplands.

2.3.4.14.3 Nonnative Species

The cultivated land within the Plan Area supports primarily nonnative cultivated crops interspersed with small linear features (e.g., riparian corridors) or small patches (e.g., wetlands) that support native vegetation. The modified and disturbed conditions inherent to agricultural habitats have also encouraged a variety of undesirable nonnative species, commonly referred to as agricultural weeds, that occur around the perimeter of agricultural fields and that rapidly germinate in idle fields. These nonnative agricultural weeds usually require ground disturbance, such as tillage and irrigation, to establish and persist. Many have been persistent in the cultivated land for generations. Active and ongoing agricultural activity, including regular cultivation and herbicide application, is required to suppress expansion in active fields.

Cultivated lands also attract a variety of nonnative wildlife species, particularly where patches of natural habitat persist within the landscape that provides refuge from regularly cultivated lands. Nonnative birds, such as the European starling and house sparrow, and nonnative mammals such as the Norway rat and house mouse commonly occur in cultivated lands and adjacent riparian and wetland habitats in the Delta and throughout the Central Valley. These and other nonnative wildlife species are not unique to cultivated lands, but also occur in many natural habitats. In cultivated lands, nonnative species are generally considered with respect to their impacts on cropland productivity and agricultural economics; however, some species can also invade adjacent riparian and wetland habitats.

2.3.4.14.4 Ecosystem Functions

While important for providing essential human services (e.g., food, fuel, fiber), cultivated lands are generally considered detrimental to most ecosystem functions. The regular and intensive cultivation of lands within the Delta can be contrary to the natural patterns of nutrient cycling, soil and sediment retention, water flow and water quality regulation, climate and air quality regulation, flood protection, and the protection of biodiversity. While some elements of ecosystem function can be partially retained, such as providing flooded habitat for wintering waterfowl and other waterbirds, a more comprehensive approach to cultivated land management that incorporates natural systems and functions is generally required to retain or enhance most ecosystem functions, such as incorporation of small patches or linear corridors of natural vegetation or wetlands.

The native Delta landscape was an extensive tidal marsh complex made up of freshwater and brackish marshes. By the mid-1800s, reclamation of wetlands began to transform the Delta into an agricultural region with a complex system of channelized waterways and Delta "islands." This transformation of the Delta into intensively managed cultivated lands has substantially reduced its ecosystem functions and led to the development of several major resource issues that have affected agricultural productivity and stability of the Delta environment including flooding, salinity intrusion, and subsidence.

Cultivated lands can, however, provide important habitats for wildlife; and if appropriately managed, can serve as surrogate habitats for native grasslands and wetlands that were converted to cultivated lands. Several covered species rely on cultivated lands to meet life requisites. For example, flooded rice fields provide surrogate wetland habitats for the giant garter snake and western pond turtle during the spring and summer, hay crops and some annually cultivated crops provide important foraging habitat for the Swainson's hawk and the white-tailed kite, and winter-flooded croplands provide essential foraging and roosting habitat for the greater sandhill crane as well as waterfowl and other waterbirds along the Pacific Flyway.

2.3.4.14.5 Environmental Gradients

In general, cultivated lands have a detrimental effect on natural gradients due to the removal of native habitats, grading and leveling of land, and changes in both groundwater and surface water movement. As a result, environmental gradients associated with cultivated lands tend to be abrupt. The majority of the Plan Area consists of cultivated lands with little to no topographic relief. These lands transition to grassland habitats in several areas, including portions of the southwestern, northeastern, and western edges of the Plan Area, and portions of the Yolo Basin. Tidal perennial aquatic habitats occur within cultivated lands, such as Franks Tract, Clifton Court Forebay, and the Sacramento and San Joaquin Rivers; however, because these areas are confined by levees and water flow is highly regulated, there is little natural transition between these features and cultivated lands. Cultivated lands also transition to some wetland habitats, primarily in the Yolo Basin.

2.3.4.14.6 Future Conditions with Climate Change

Cultivated lands may be particularly sensitive to long-term sea level rise associated with global climate change (Section 2.3.3.2, *Climate*) (Nicholls et al. 1999). More variable flows through the Central Valley could reduce the reliability of water supply available for irrigating crops at critical times of the year. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees; leading to major saltwater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism and causing substantial changes to agricultural areas (Mount and Twiss 2005). Areas within levees that are currently farmed would be affected by the floodwaters.

Crop types are anticipated to change with elevated ambient temperatures. Jackson et al. (2009) asserted that over the next 50 years, cultivation of some warm season crops, such as tomatoes, cucumbers, sweet corn, and peppers, is expected to decline; whereas cultivation of hot season crops, including melons and sweet potatoes, are expected to increase because of climatic changes.

2.4 Biological Diversity

California is considered a global hotspot for biological diversity, where species diversity, endemism, and threats to this diversity are particularly high (Myers et al. 2000; Stein et al. 2000). California is particularly rich in unique plant species and contains globally important sites of plant diversity (Davis et al. 1997).

By most measures of biological diversity, California stands out as unique in North America. For example, California contains more native biological diversity than any other state, including more endemic species than any other state (1,295 species) (Stein 2002). Compared to other states, California is ranked first in the United States in the number of endemic species of freshwater fish, vascular plants, amphibians, reptiles, and mammals (Stein et al. 2000). In terms of total species, California supports approximately one-third of all species of vascular plants and reptiles in the United States, 47% of mammal species, and 56% of bird species (California Department of Fish and Game 2003).

The Plan Area supports a great diversity of habitats. CDFW has identified over 100 different plant associations, as defined by Sawyer and Keeler-Wolf (1995), in the Plan Area within the general biological communities of aquatic, seasonal wetlands, tidal and nontidal perennial wetlands, grasslands, riparian, and agricultural lands (Hickson and Keeler-Wolf 2007). The Delta is part of the Pacific flyway, one of the major north-south migratory routes for avifauna in the Americas. Surveys of the California Central Valley, including the Delta, document that it is one of the most important regions in western North America to migratory and wintering shorebirds (Shuford et al. 1998).

One measure of the degree of biological diversity in the Plan Area is the number of species known to inhabit the Delta and surrounding uplands. Based on information from various sources, an estimated 345 species of vertebrates could occur in the biological communities of the Plan Area, representing approximately 40% of all the vertebrate species known to occur in California (Table 2-20). Table 2-20 presents the number and percentage of species found in the Plan Area compared with the entire State of California by taxonomic group. The Plan Area represents less than 1% of the land area of California but is disproportionately rich in fish and bird species. Nearly 50% of all of California's bird species potentially use the Plan Area, a testament to its importance as part of the Pacific flyway. The Plan Area has a high diversity of native fish species with 61% of California's native fish species found in the Delta (31 of 51 species) (see list of fish species in the tidal perennial aquatic natural community in Table 2-6). Of all fish species found in California, both native and nonnative, nearly half can be found in the Delta.

Over 300 taxa (species, subspecies, and varieties) of native and nonnative (naturalized) vascular plants were recorded in sampled vegetation stands in the Plan Area by CDFW during its vegetation mapping effort (Hickson and Keeler-Wolf 2007). Since this mapping effort only sampled at various specific sites across the Plan Area, the total number of vascular plant taxa in the Plan Area is certainly much higher.

Table 2-20. Number of Vertebrate and Vascular Plant Species Present in the Plan Area Compared with Number in California

Taxonomic Group	Number of Species in Plan Area	Number of Species in California[a]	Percent of California Species in Plan Area
Vertebrates	345	876	39%
Mammals	58[b]	197	29%
Birds	200[c]	433	46%
Reptiles	22[d]	84	26%
Amphibians	9[e]	51	18%
Fish	55[f]	111[g]	49%
Vascular plants	Over 300[h]	6,272	Over 4%
Total	**Over 643**	**7,231**	**Over 8%**

[a] California Department of Fish and Game 2003
[b] Eder 2005
[c] Sibley 2006
[d] California Department of Fish and Game 2008
[e] U.S. Fish and Wildlife Service no date
[f] Moyle 2002 51 nonnative and 60 native fish species (approximately)
[g] Hickson and Keeler-Wolf 2007

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2.5.1 Literature Cited

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2.5.2 Personal Communications

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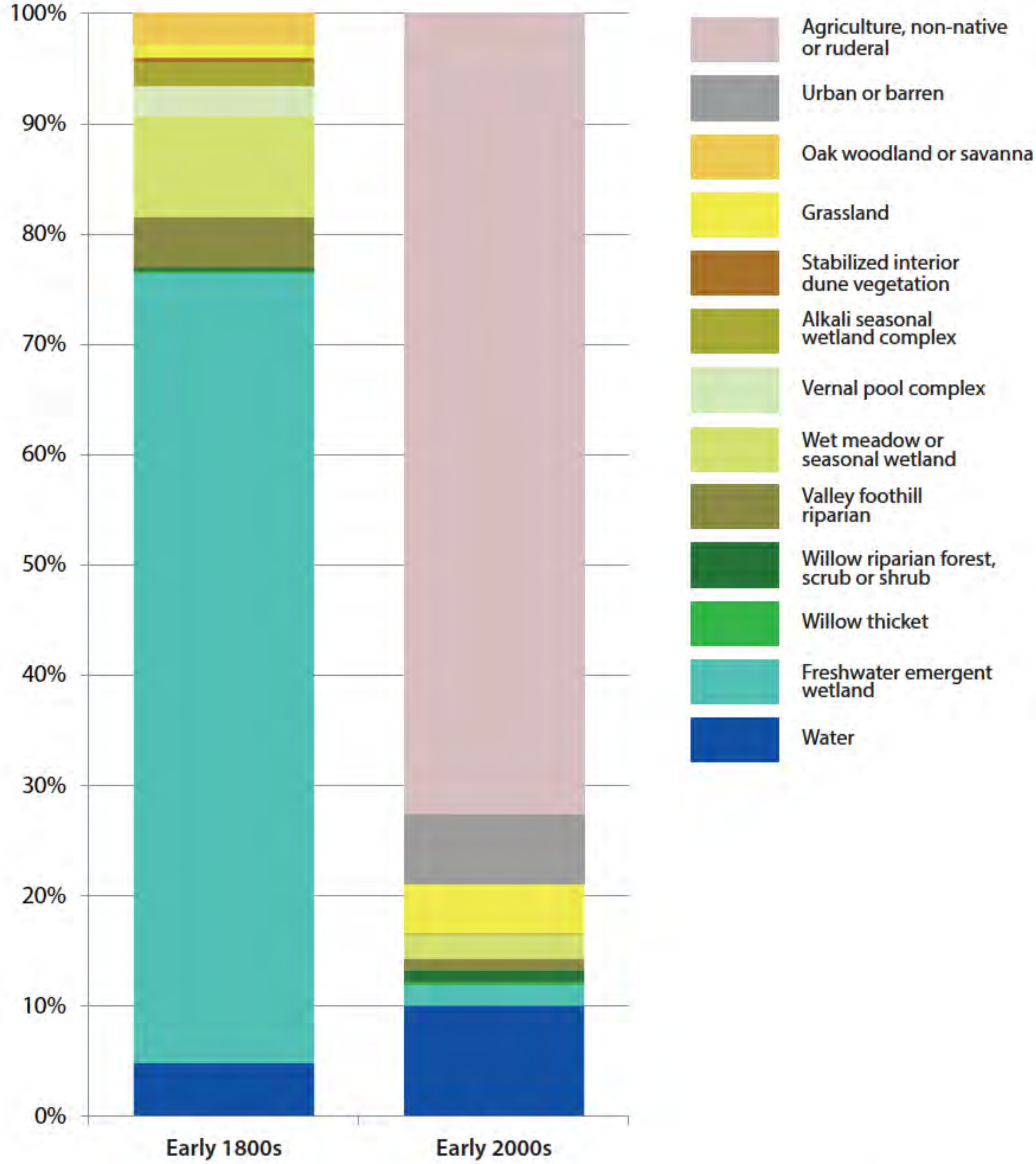
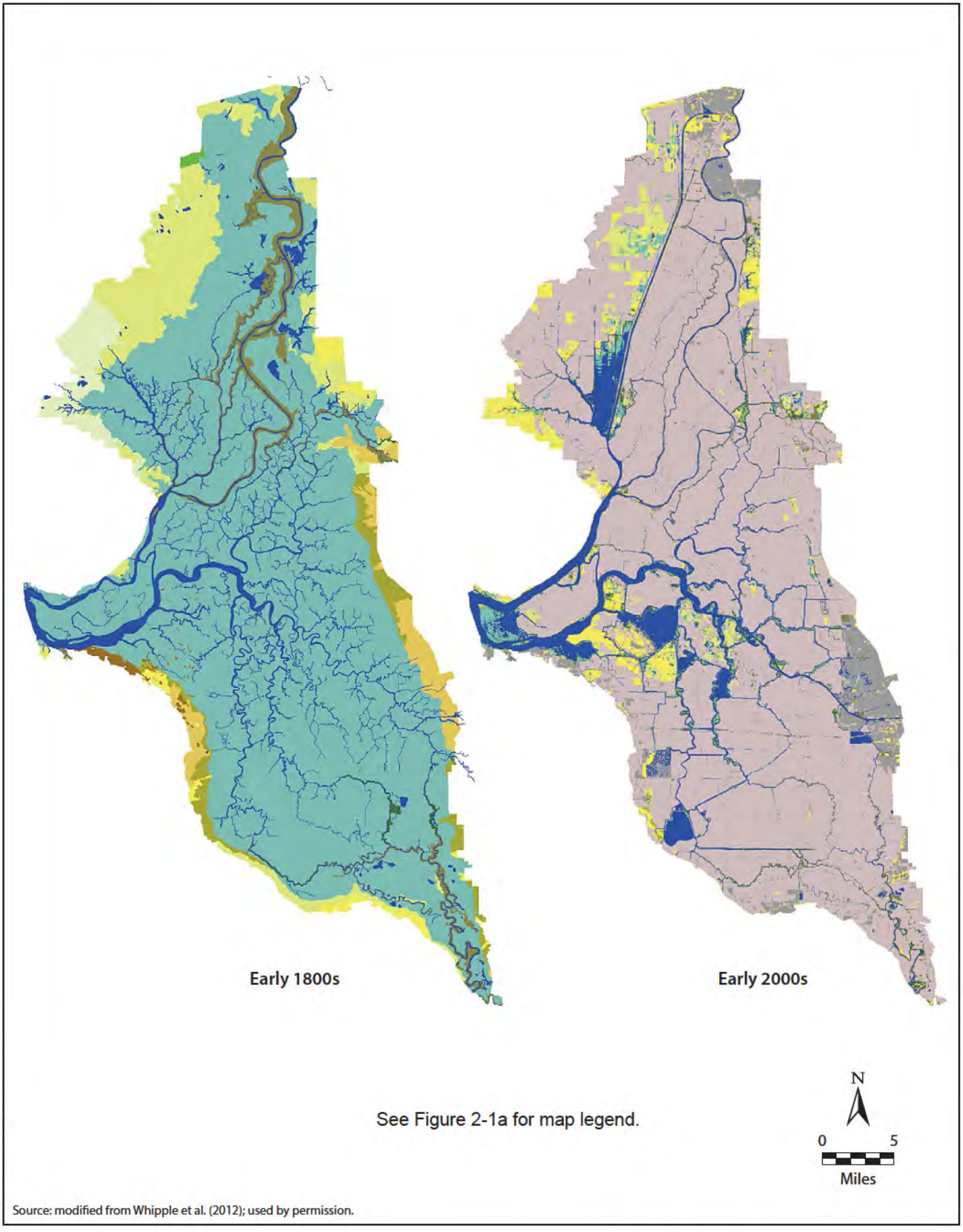


The change in land cover within the Delta is illustrated in bar chart (Figure 2-1a) and map (Figure 2-1b) form. The dramatic shift from a majority of freshwater emergent wetlands historically to agriculture and urban development today is the most strikingly visible change. The area of open water (including areas of floating aquatic vegetation) has actually increased, in large part due to flooding in subsided islands.

Source: modified from Whipple et al. (2012); used by permission.

Graphics ... BDCP Other Chapters 10-29-2012 TM

Figure 2-1a
Land Cover Change in the Delta between the Early 1800s and Early 2000s



Graphics ... BDCP Other Chapters 10-29-2012 TM

Figure 2-1b
Land Cover Change in the Delta between the Early 1800s and Early 2000s

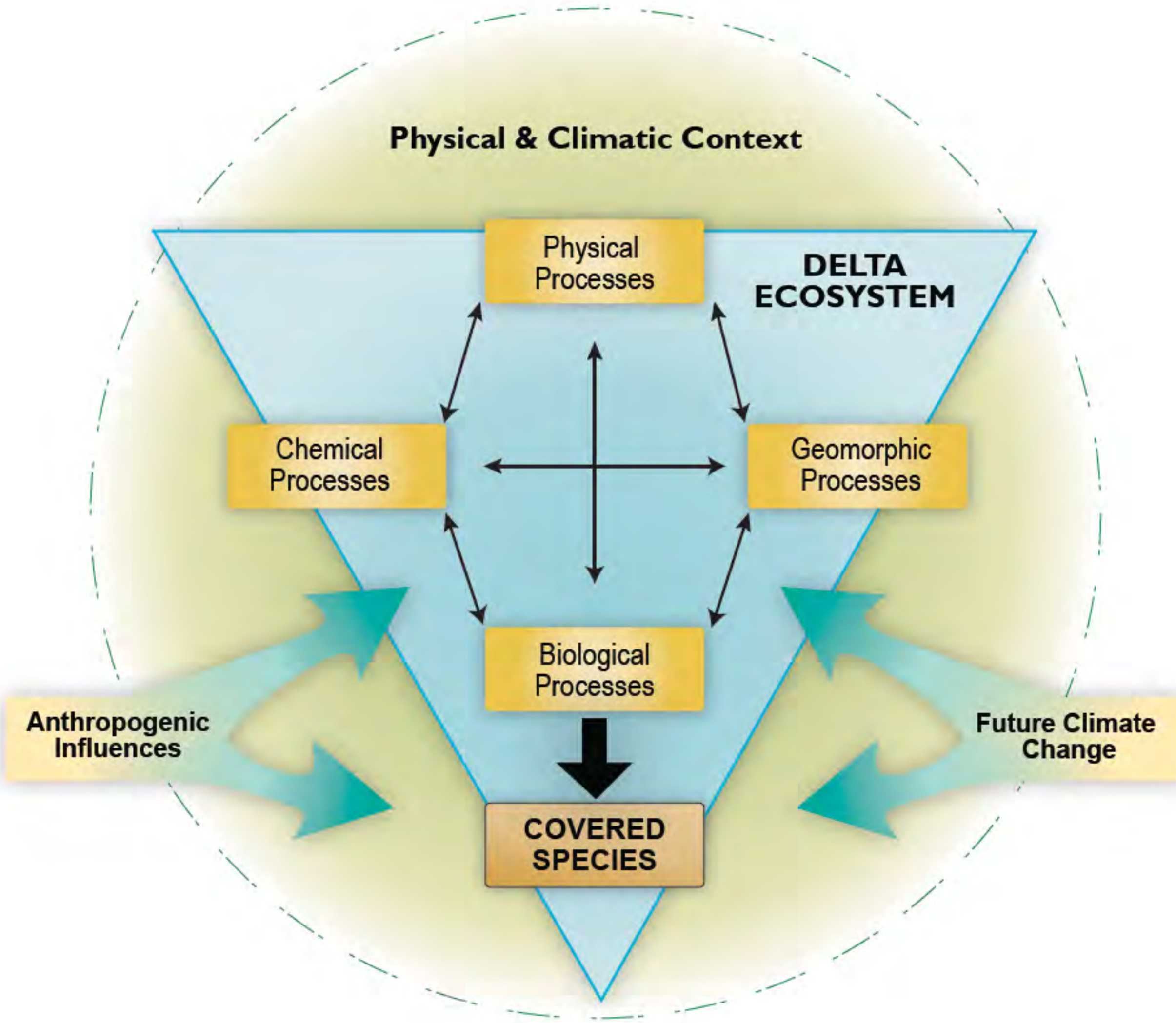


Figure 2-2
Ecosystem Processes in the Delta

Graphics… BDCP Other Chapters Rev. 4/18/12 JD

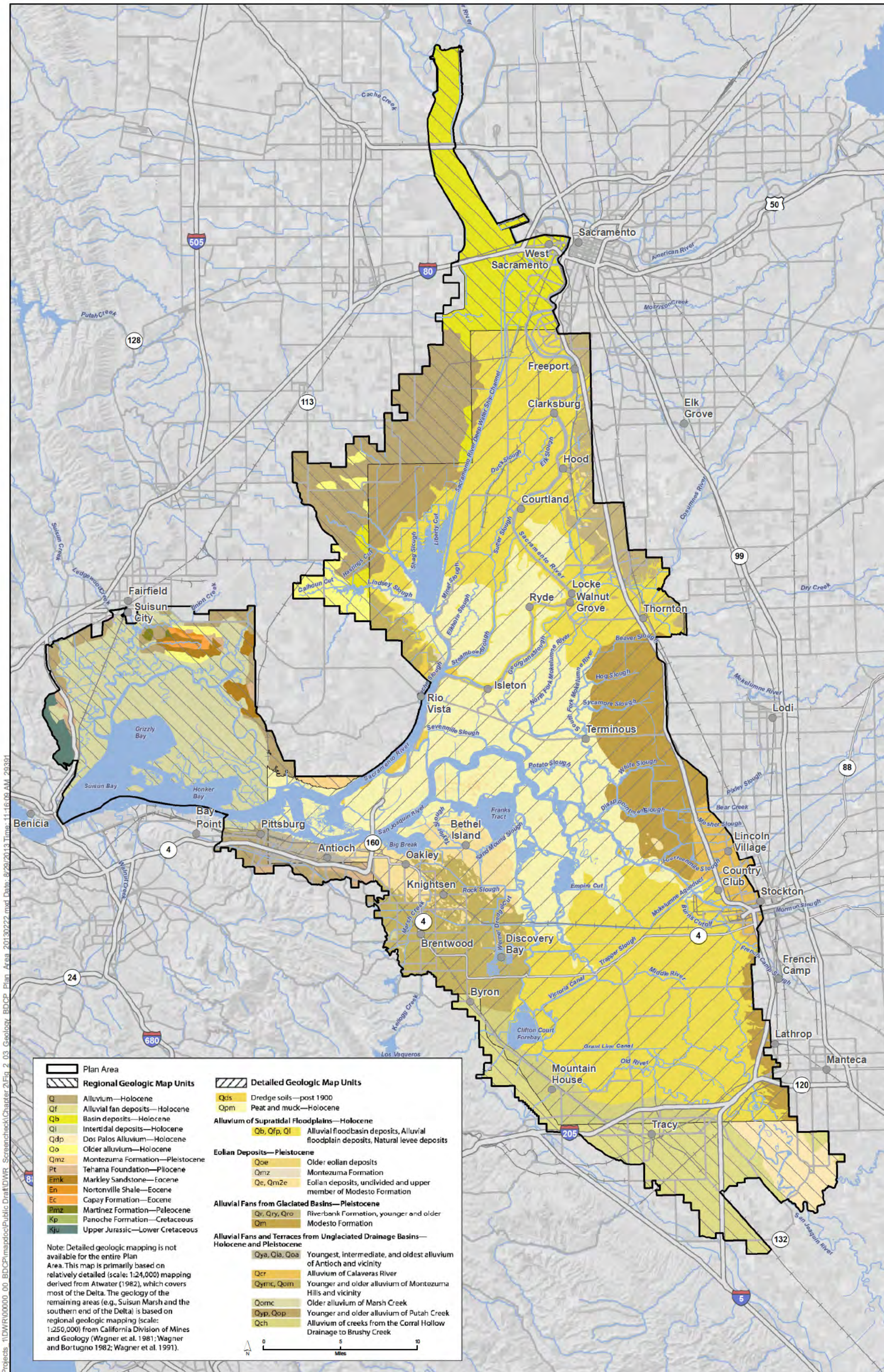


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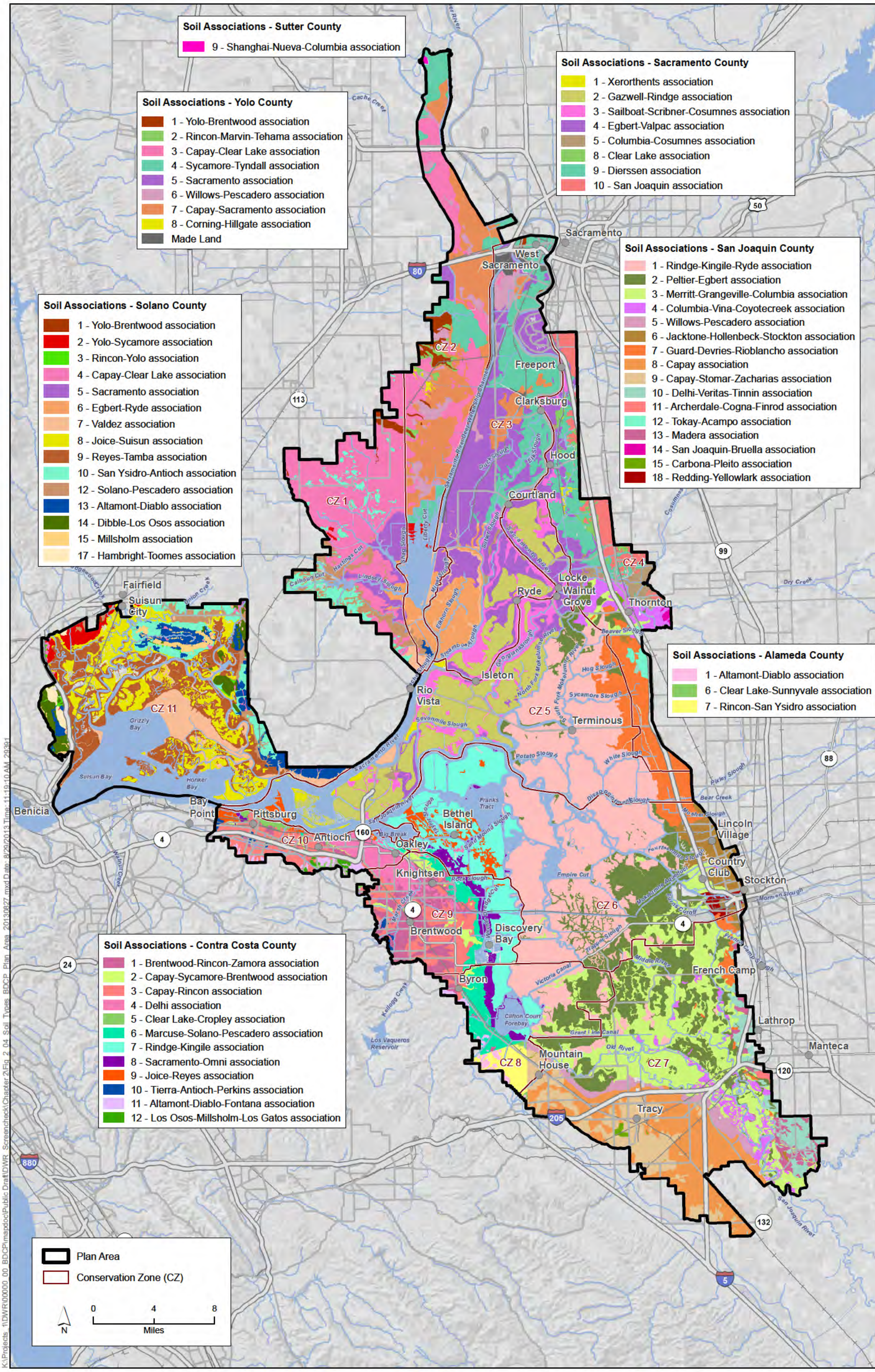
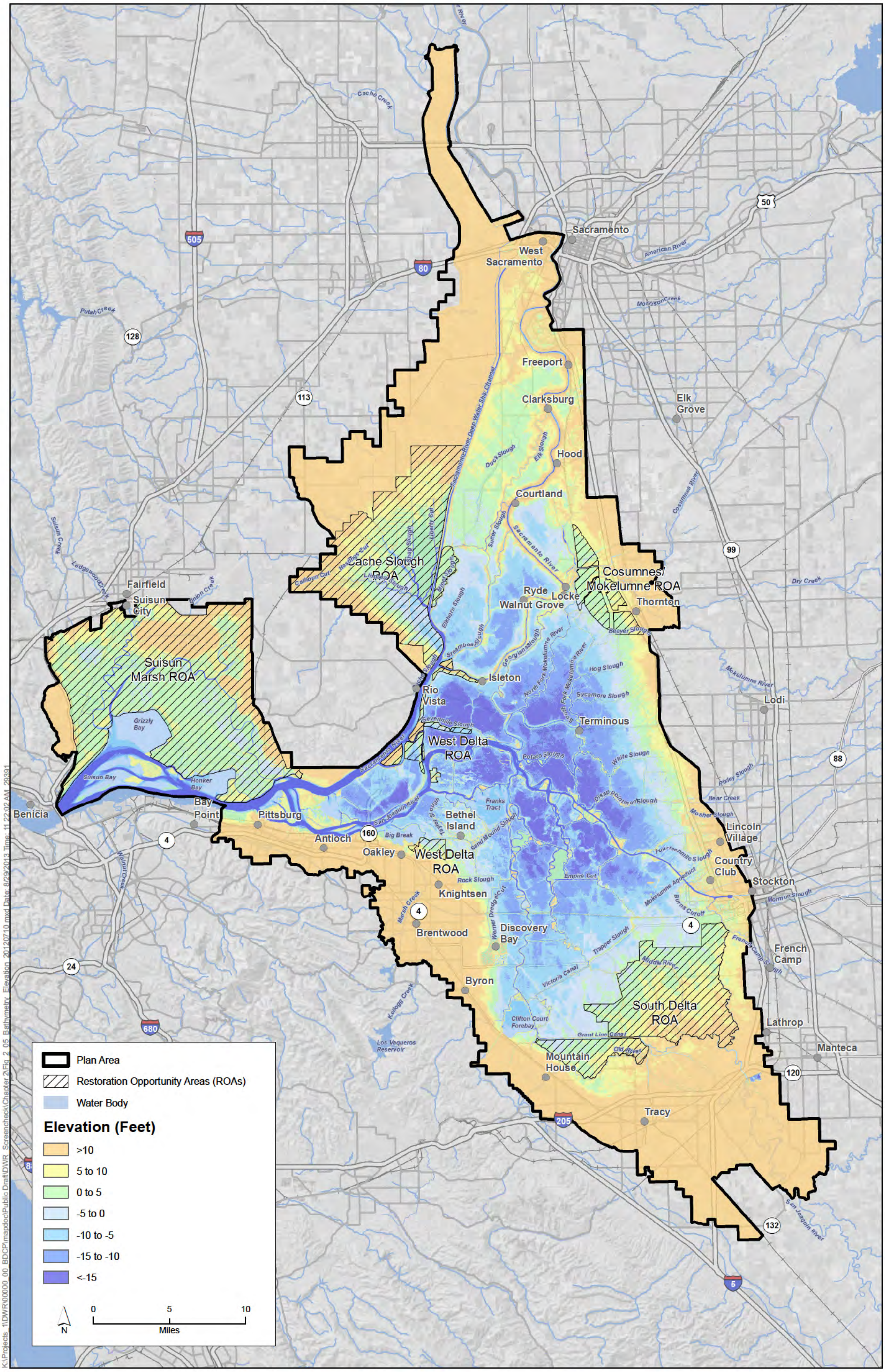
Figure 2-3
Geology of the Plan Area



GIS Data Source: Conservation Zones, SAIC 2012; Soils, SSURGO 2010.

Figure 2-4
Soil Types of the Plan Area



GIS Data Source: Restoration Opportunity Area, SAIC 2011;
Bathymetry, URS 2007.

Figure 2-5
Bathymetry and Elevation Data

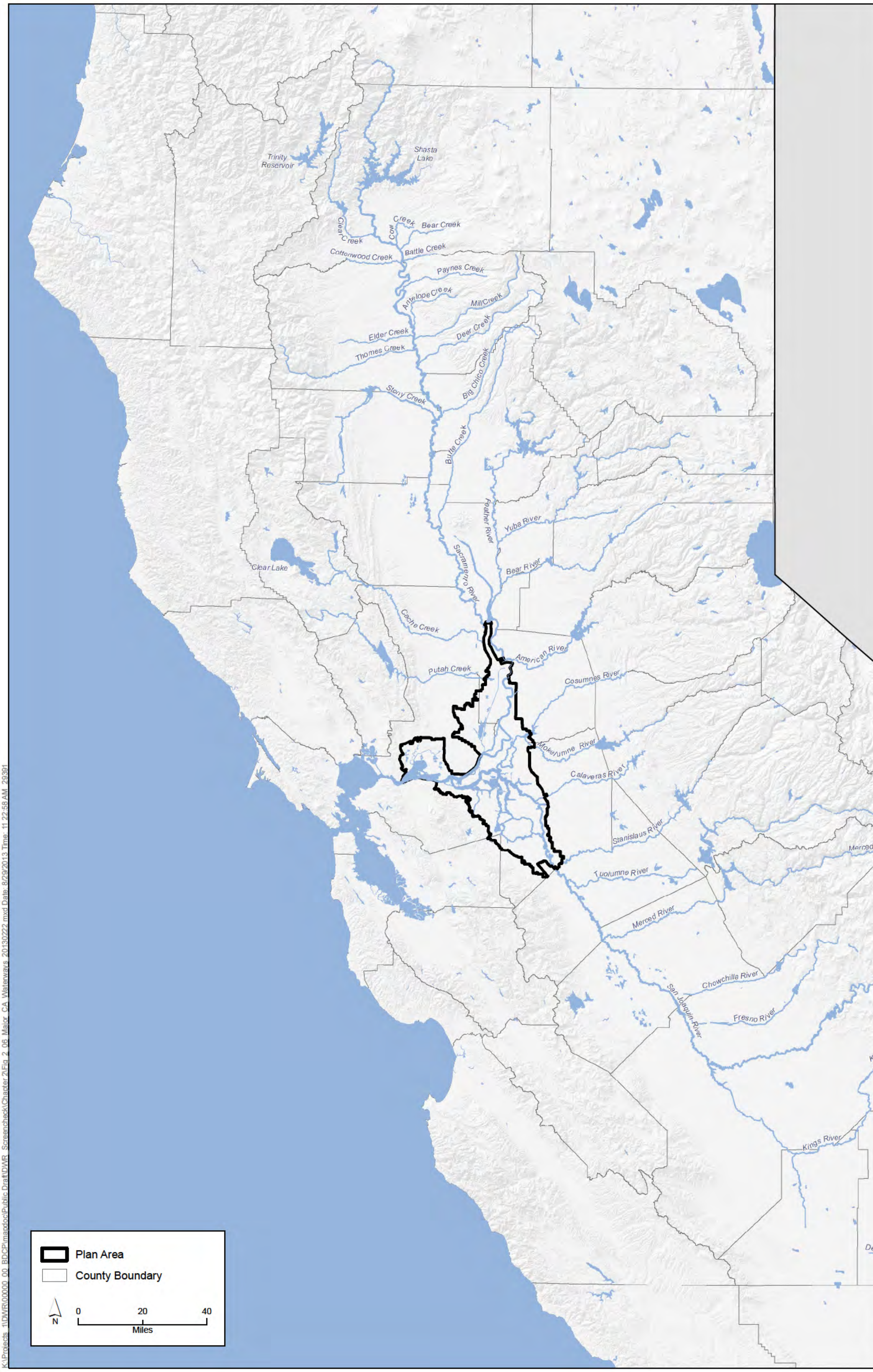


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Figure 2-6
Major California Waterways Influencing the Plan Area

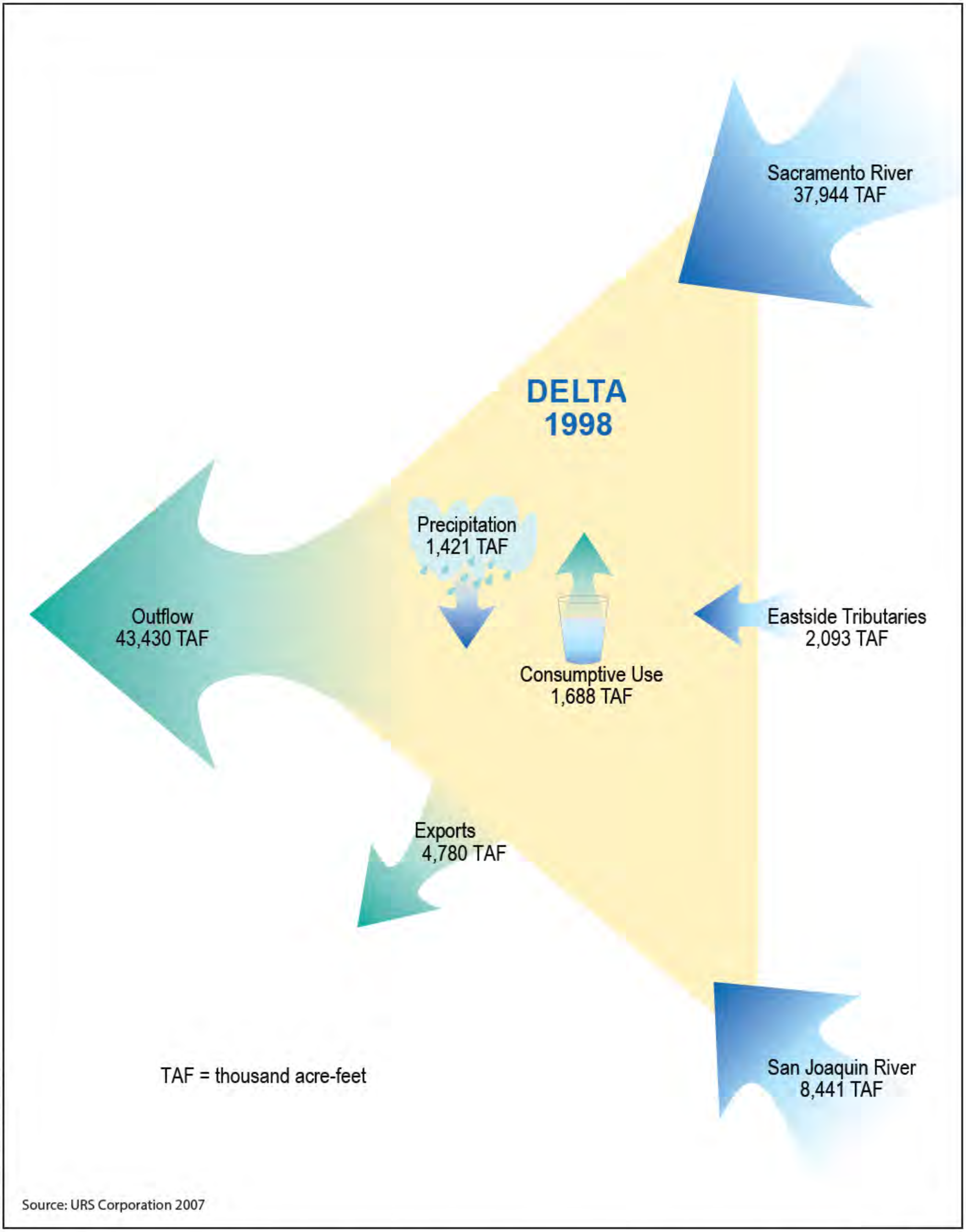
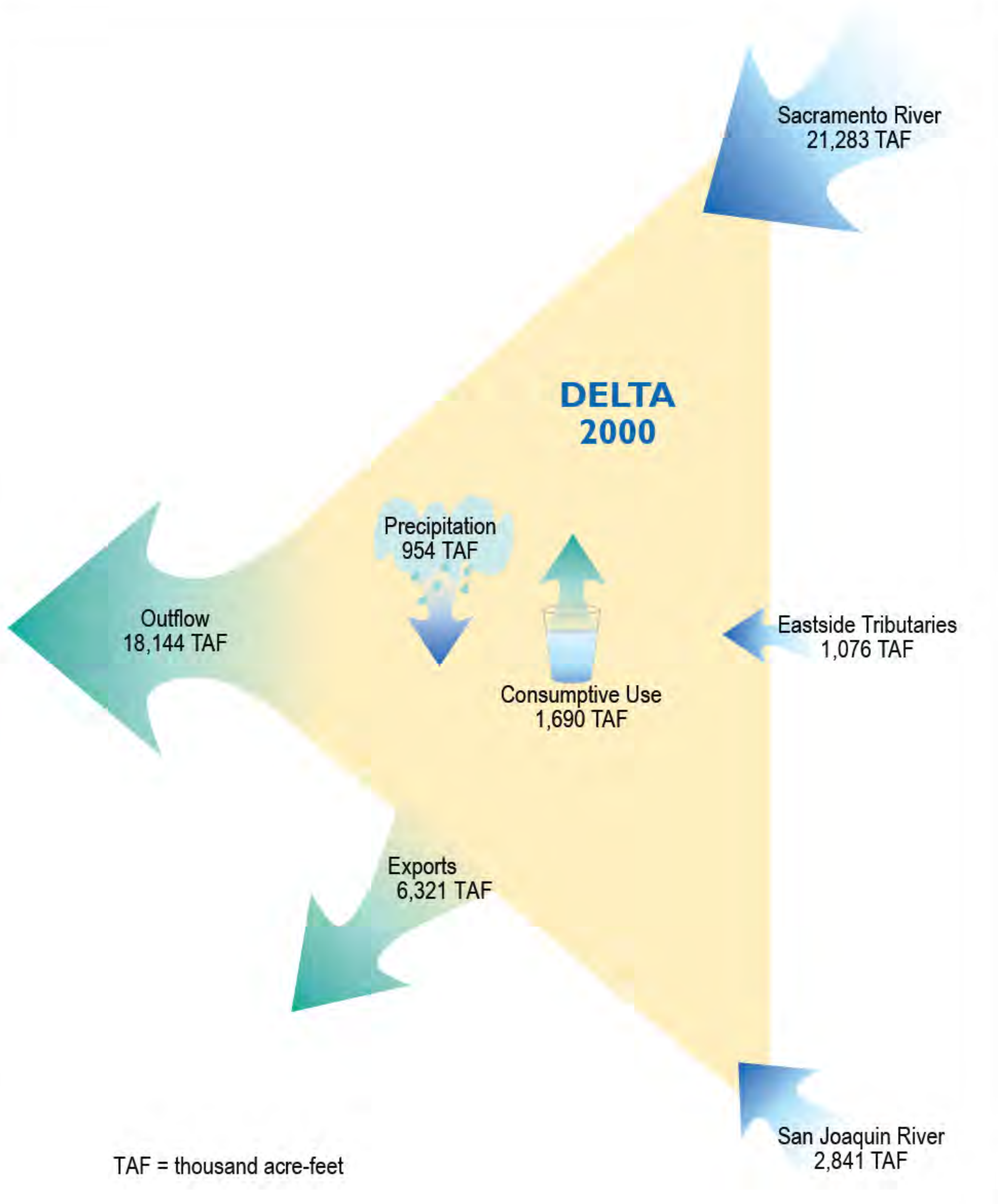


Figure 2-7
Example Delta Water Balance for 1998 Water Year, a Wet Water Year—All Inflow and Outflow Values Represent Unimpaired Flows

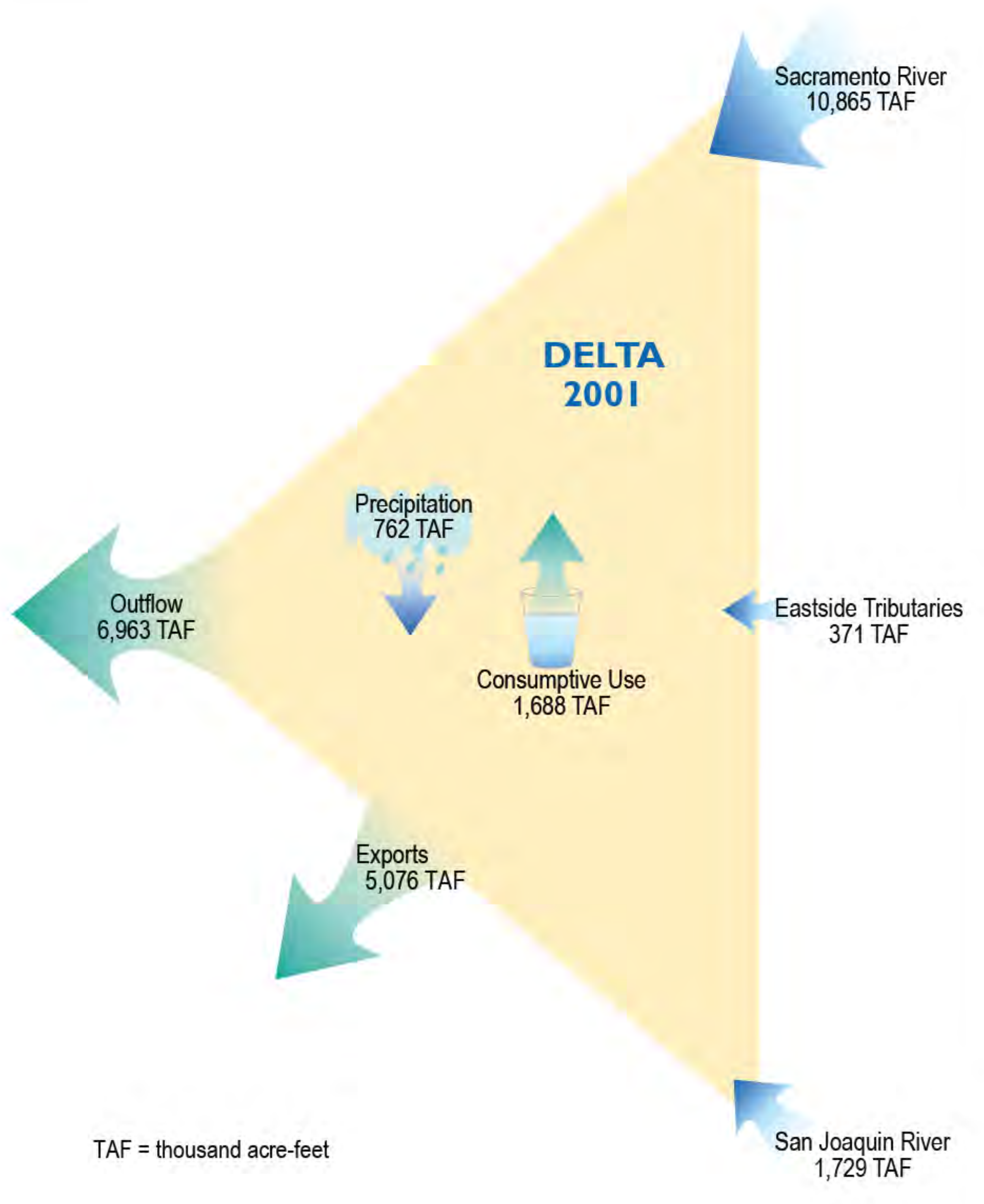
Graphics… BDCP Other Chapters 10-29-12 TM



Source: URS Corporation 2007

Graphics… BDCP Other Chapters 6-21-12 TM

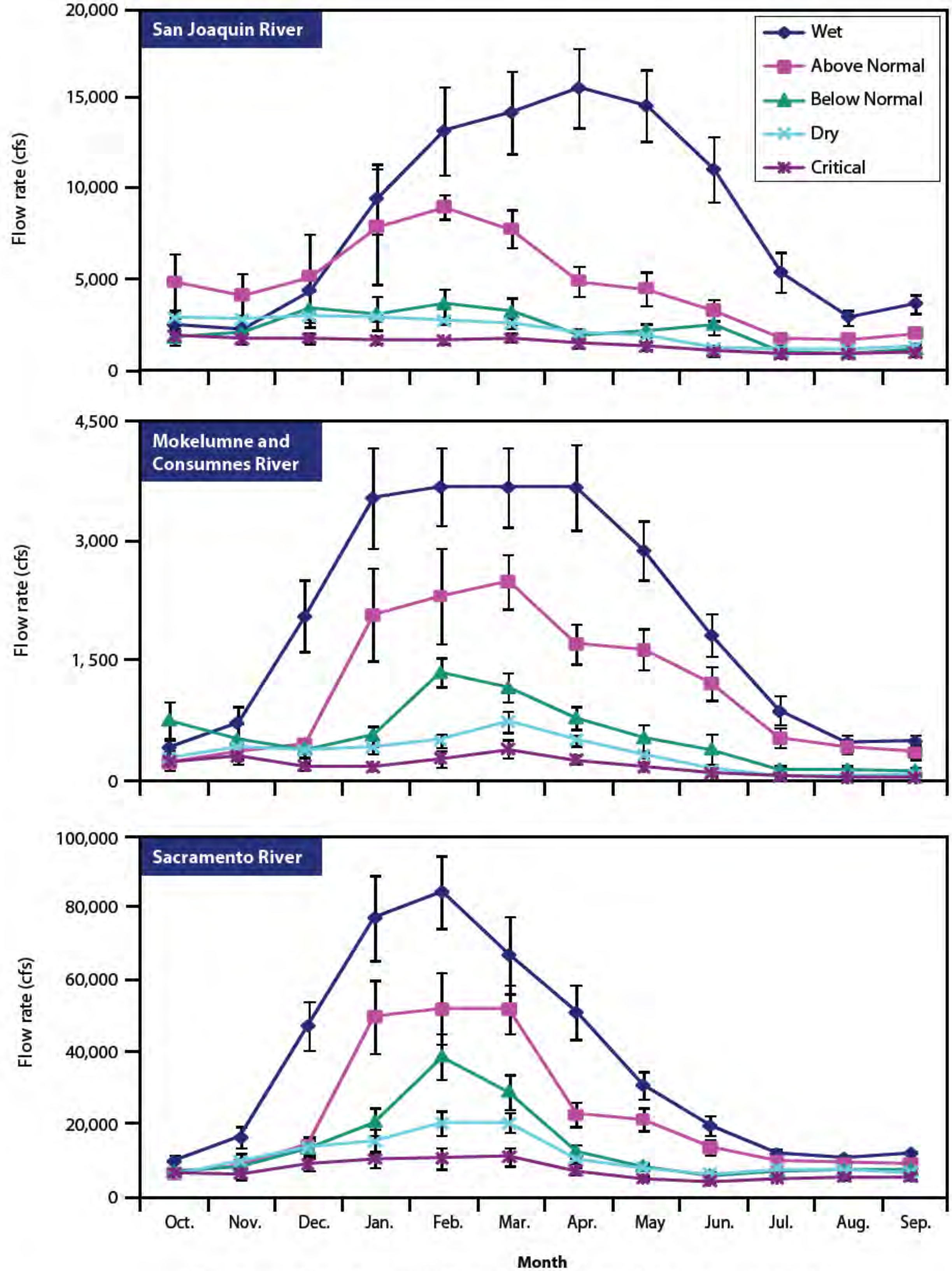
Figure 2-8
Example Delta Water Balance for 2000 Water Year, an Above Normal Water Year—All Inflow and Outflow Values Represent Unimpaired Flows



Source: URS Corporation 2007

Graphics ... BDCP Other Chapters 6-21-12 TM

Figure 2-9
Example Delta Water Balance for 2001 Water Year, a Dry Water Year—All Inflow and Outflow Values Represent Unimpaired Flows

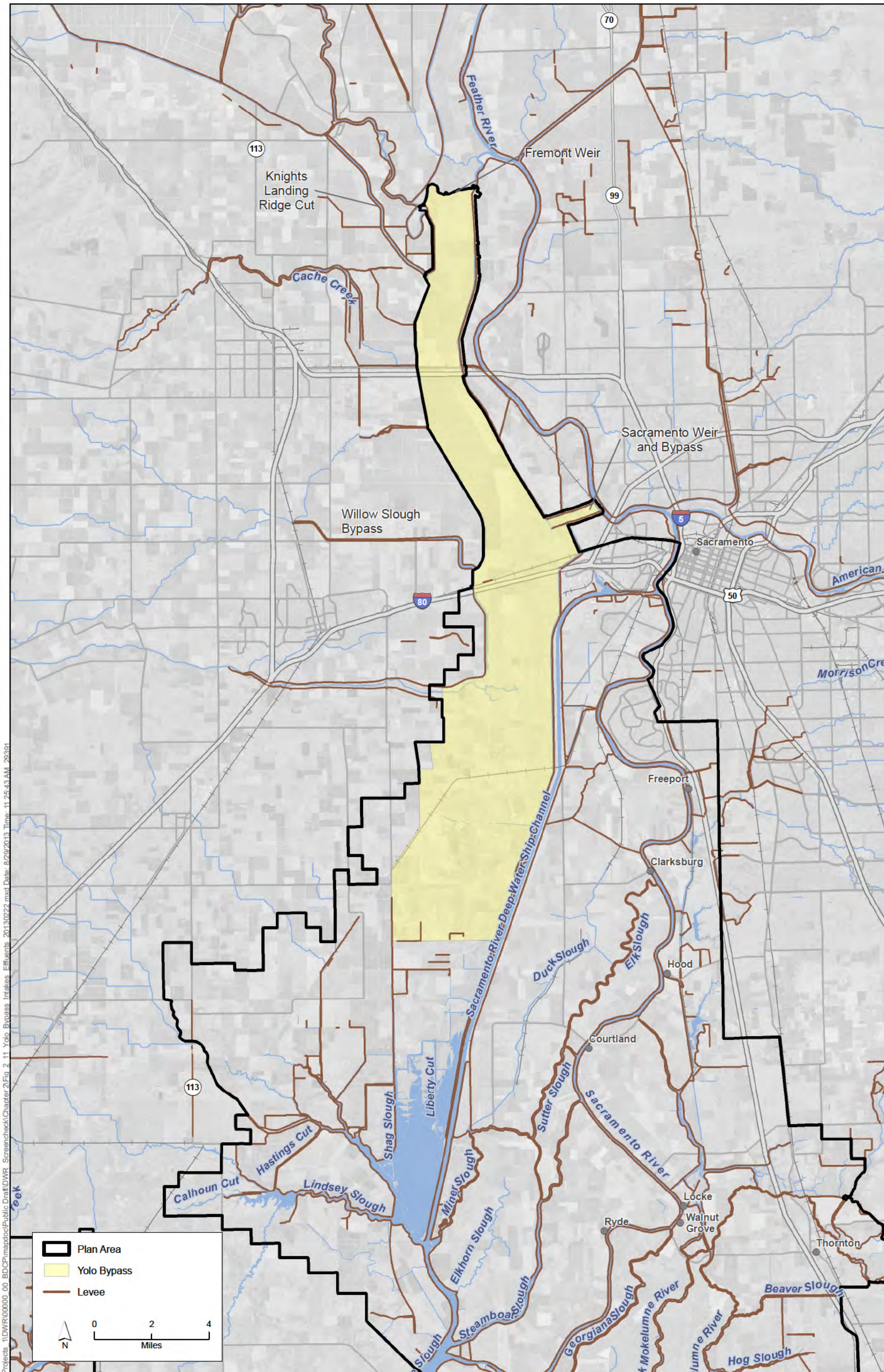


Error bars ± 1 standard error. Note change in scale of Y-axis among panels.

Source: California Department of Water Resources. 2007. *Dayflow: An Estimate of Daily Average Delta Outflow*. Available: <http://iep.water.ca.gov/dayflow/index.html>. Accessed: October–December 2007.

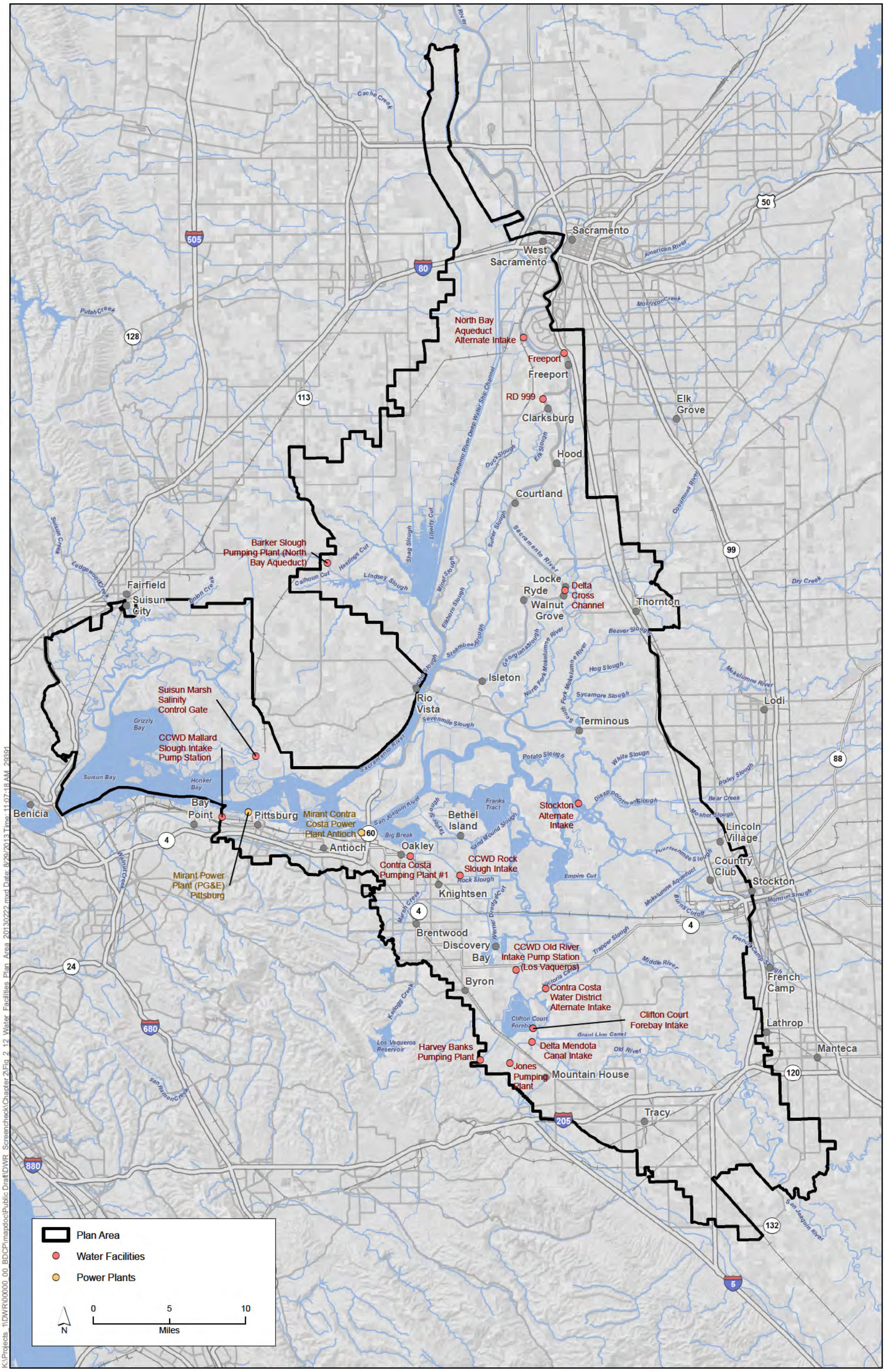
Graphics... BDCP Other Chapters 6-21-12 TM

Figure 2-10
Average Monthly Flow Rates in San Joaquin, Mokelumne and Cosumnes, and Sacramento Rivers by Water Year Type between 1956 and 2006



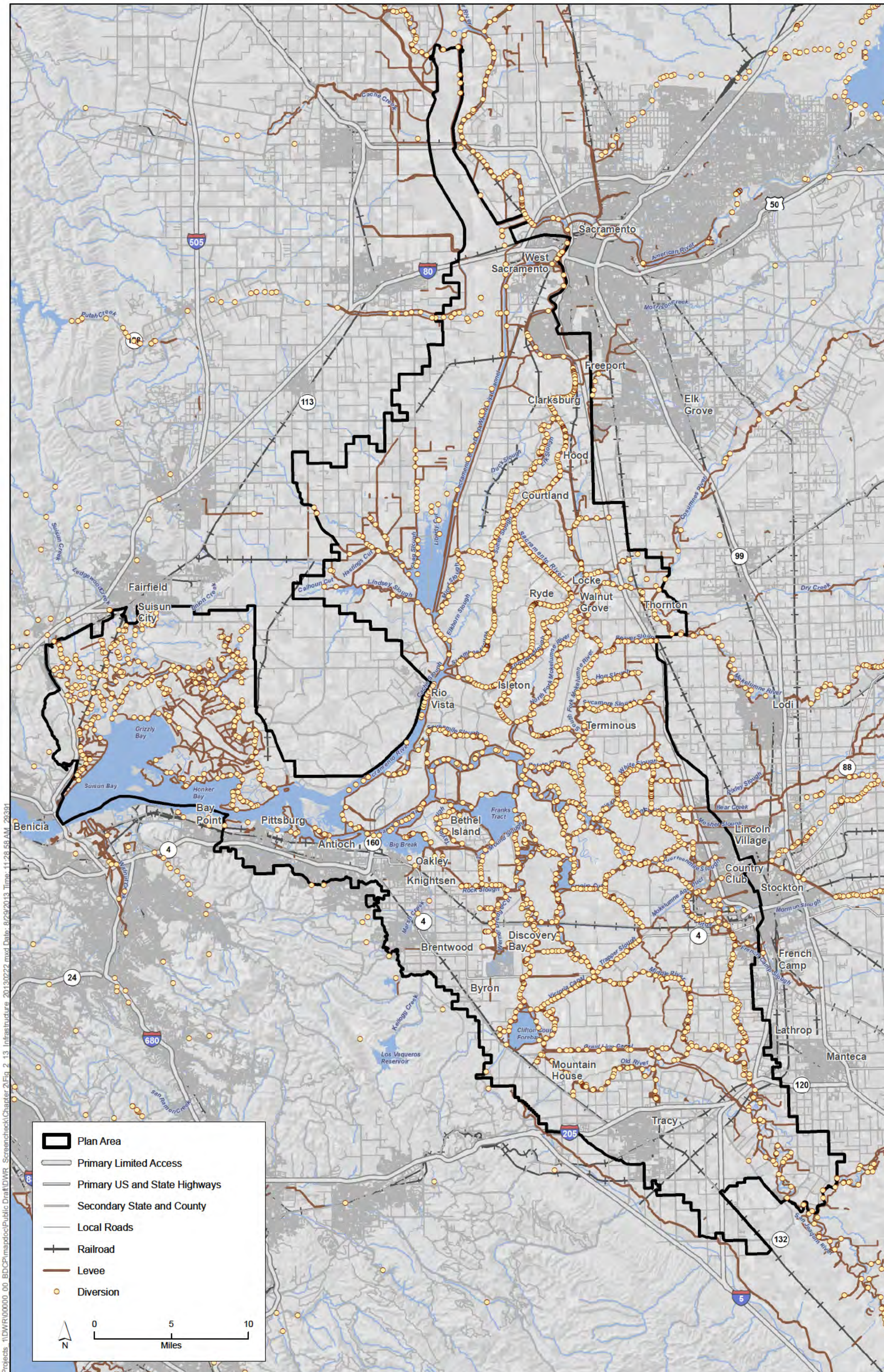
GIS Data Source: Levee, DWR 2009.

Figure 2-11
Yolo Bypass Intakes and Effluents



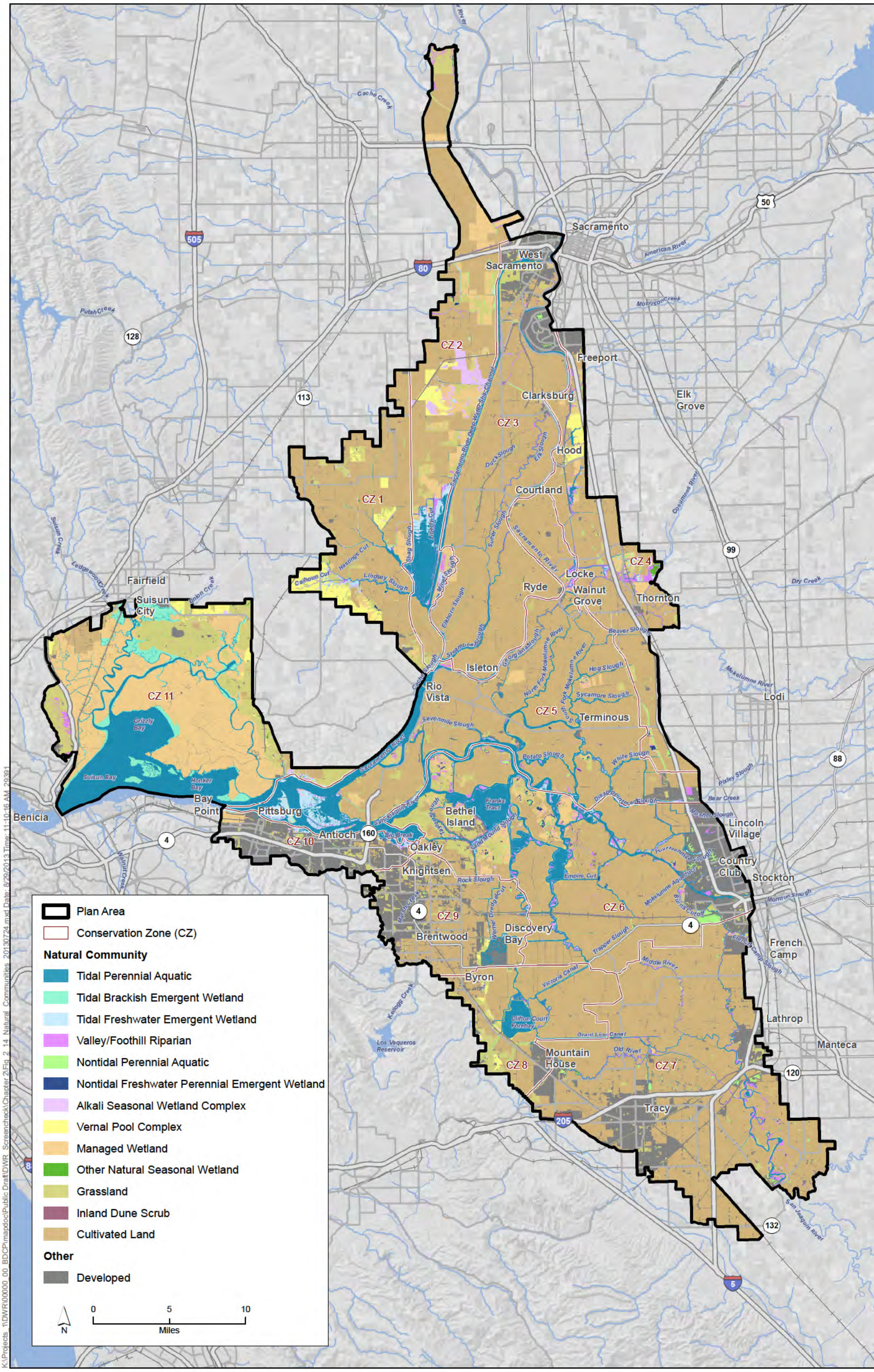
GIS Data Source: Water Facilities, DWR 2002 and DWR 2010; Power Plants, DWR 2007.

Figure 2-12
Water Facilities in the Plan Area



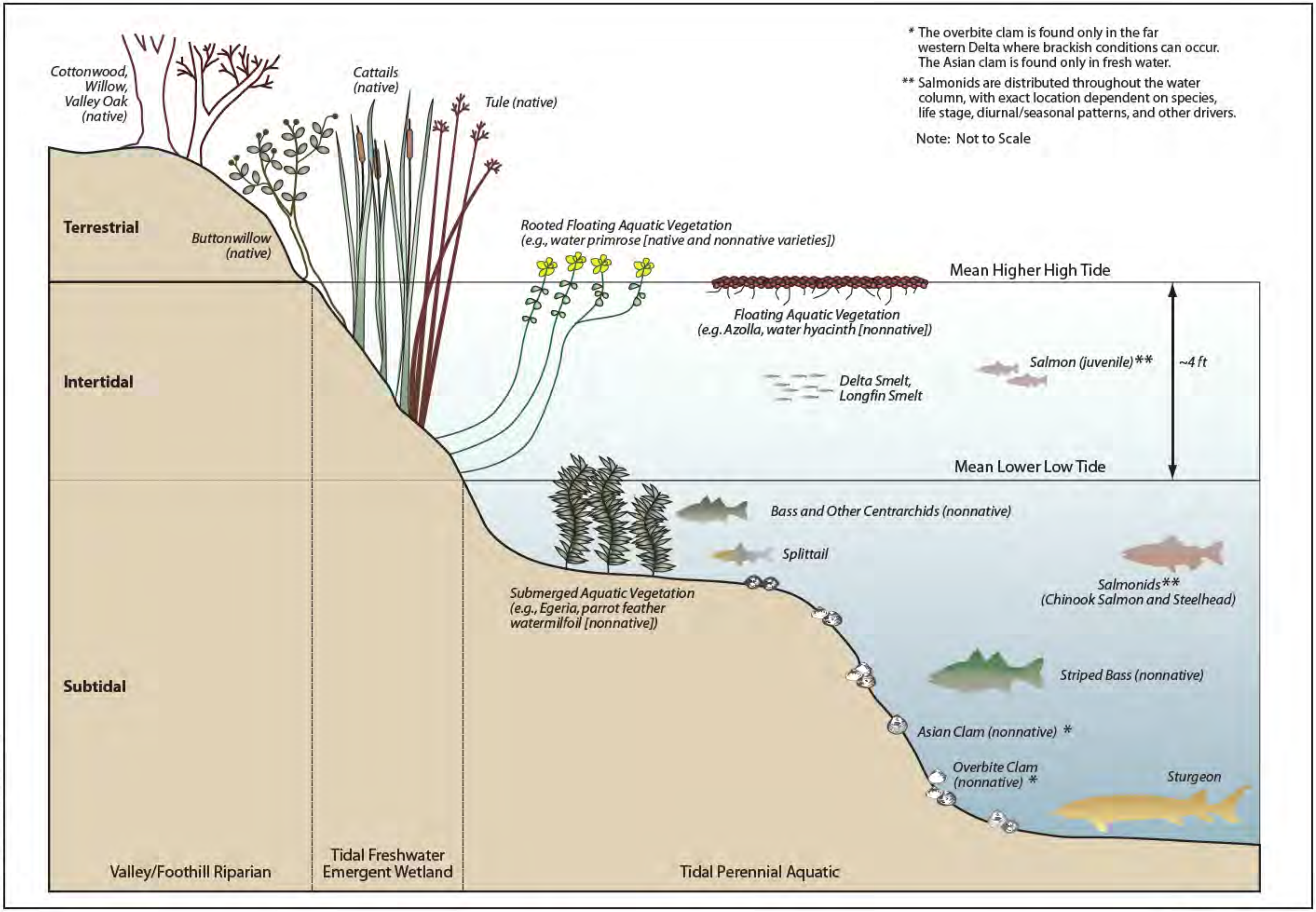
GIS Data Source: Barriers, DFG 2011; Levee, DWR 2009.

Figure 2-13
Infrastructure in the Plan Area



GIS Data Source: Conservation Zones, SAIC 2012.

Figure 2-14
Distribution of Natural Communities and Urban Land Cover in the Plan Area



Graphics... BDCP Other Chapters 6-21-12 TM

Figure 2-15
Generalized Schematic of Valley/Foothill Riparian, Tidal Freshwater Emergent Wetland, and Tidal Perennial Aquatic Natural Communities

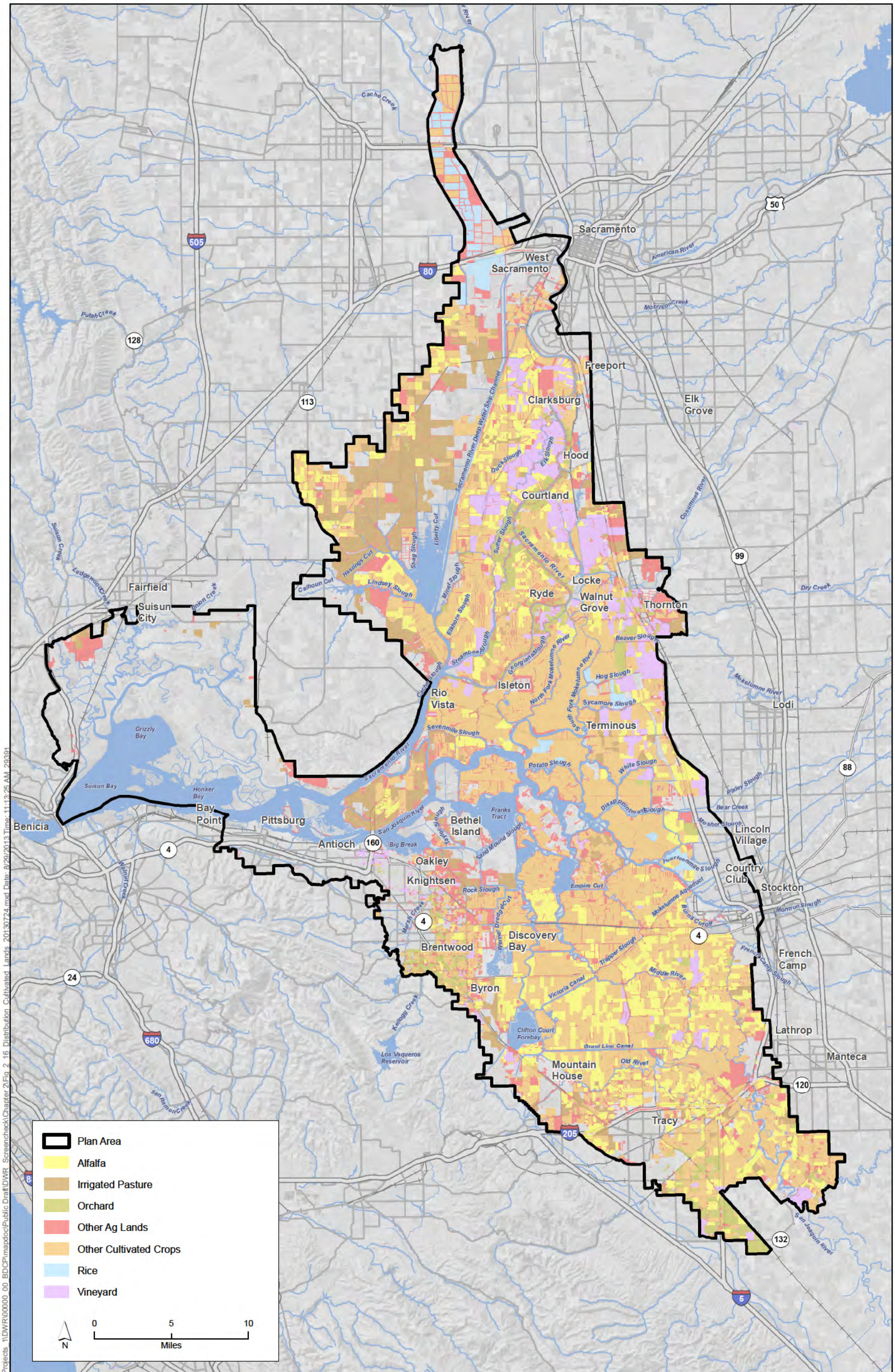


Figure 2-16
Distribution of Cultivated Land Subtypes in the Plan Area