DEPARTMENT OF WATER RESOURCES
AGREEMENT # 4600009291

DRAFT REPORT ◦ NOVEMBER 2015

Fish Restoration Program
Cache Slough Complex Conservation Assessment
Volume 1 Characterization Report

Stillwater Sciences

Suggested Citation:

Department of Water Resources and Department of Fish and Wildlife. 2015. Fish Restoration Program Cache Slough Complex Conservation Assessment. Draft Volume 1: Characterization Report. Prepared by California Dept. of Water Resources and California Dept of Fish and Wildlife with assistance from Stillwater Sciences, Davis, California. Contract No. 4200009291. November.

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ACRONYMS AND ABBREVIATIONS

μm/sec	micrometers per second
BDCP	Bay Delta Conservation Plan
BOD	biochemical oxygen demand
BSPP	Barker Slough Pumping Plant
CALFED	CALFED Bay Delta Program
CAL-IPC	California Invasive Plant Council
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
cfs	cubic feet per second
CGS	California Geological Survey
CHRIS	California Historical Resources Information System
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
COC	contaminant of emerging concern
CRHR	California Register of Historic Resources
CSC	Cache Slough Complex
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board (Regional Board)
CVFED	Central Valley Floodplain Evaluation and Delineation Program
CWA	Clean Water Act
DCC	Delta Cross Channel
DMCP	Delta Mercury Control Program
DO	dissolved oxygen
DOC	dissolved organic carbon
DPS	Distinct Population Segment
DWR	Department of Water Resources
DWSC	Sacramento Deep Water Ship Channel
EFH	Essential Fish Habitat
EIR	environmental impact report
EPA	Environmental Protection Agency
ERP	Ecosystem Restoration Program
ESA	Endangered Species Act
ESU	Environmentally Significant Unit
ETM	estuarine turbidity maximum
ft	feet
FMMP	Farmland Mapping and Monitoring Program
FRP	Fish Restoration Program
FRPA	Fish Restoration Program Agreement
HCP	Habitat Conservation Plan
IBA	Important Bird Area
IPCC	Intergovernmental Panel on Climate Change

ITP	incidental take permit
Ksat	saturated hydraulic conductivity
LiDAR	Light Detection and Ranging
MAF	million acre feet
MeHg	methylmercury
mg/L	milligrams per liter
MHHW	mean higher high water
MHW	mean high water
mi	mile
MLLW	mean lower low water
MTL	mean tide level
NAVD88	North American Vertical Datum of 1988
NBA	North Bay Aquaduct
NCSS	National Cooperative Soil Survey
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Program
NOS	National Ocean Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NTU	nephelometric turbidity unit
NWIC	Northwest Information Center of the California Historical Resources Information System
OHP	State Office of Historic Preservation
POD	Pelagic Organism Decline
POTW	Publicly Owned Treatment Works
RD	Reclamation District
RPA	reasonable and prudent alternative
RWQCB	Regional Water Quality Control Board
SCWA	Solano County Water Agency
SDTB	South Delta Temporary Barriers Project
SFEI	San Francisco Estuary Institute
SLR	sea level rise
SSC	suspended sediment concentration
ST	state-listed as Threatened
SWP	State Water Project
SWS	Stillwater Sciences
TCP	Traditional Cultural Properties
TMDL	Total Daily Maximum Load
TSS	total suspended sediment
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey

WWR	Wetlands and Water Resources, Inc
WWTP	wastewater treatment plant
X2	distance in kilometers from the Golden Gate to the 2ppt salinity line, mixing zone
YBF	Yolo Basin Foundation

1 INTRODUCTION

Landscape scale restoration efforts in a region such as the Cache Slough Complex (CSC) require an understanding of current and historic conditions. This characterization report (Volume 1) consolidates what is known of the region and lays the foundation for a regional Conservation Assessment effort to address key questions surrounding tidal wetland function and restoration in the region.

The primary purpose of the overall CSC Conservation Assessment is to build strategies for ecologically coherent restoration and pragmatic implementation of those strategies. Specifically, the Conservation Assessment will provide guidance for regional implementation of tidal wetland restoration, taking into account intended ecological outcomes for Fish Restoration Program (FRP) species of concern, costly impediments to restoration, and socioeconomic factors that restoration can affect. FRP species of concern include Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), winter-run and spring-run salmon (*Oncorhynchus tshawytscha*) and Central Valley Steelhead (*O. mykiss*).

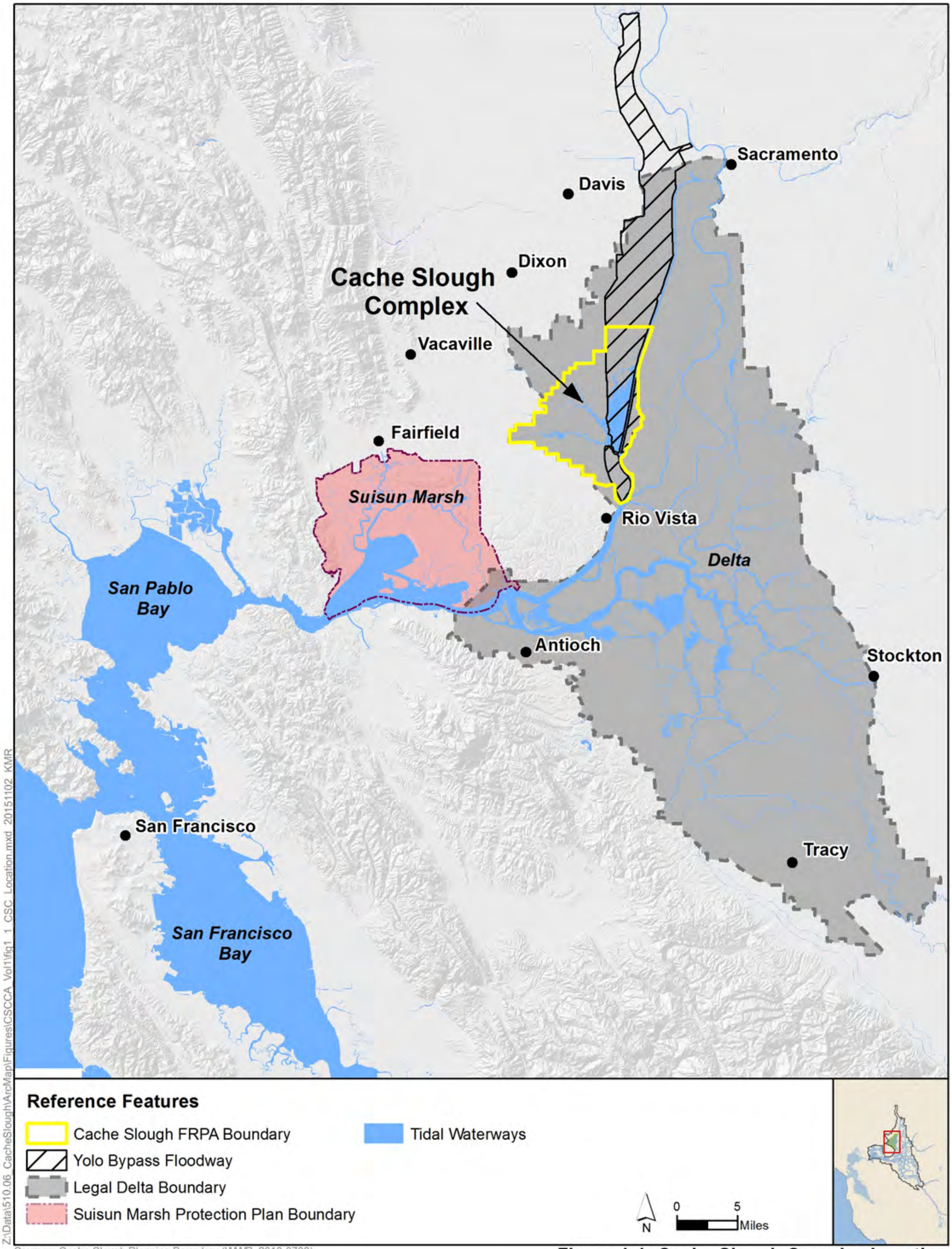
Volume 2 of the CSC Conservation Assessment, The Strategic Plan, will provide the scientific foundation for the conservation efforts of the CSC. In particular, it will:

1. Provide overarching restoration goals, principles and strategies;
2. Define key drivers for restoration outcomes;
3. Discuss compatibility with other regional plans; and
4. Provide a model to assess the suitability and feasibility of restoring specific parcels.

1.1 Description of Study Area

The 53,000-acre (ac) CSC is located in the northwest corner of the Sacramento-San Joaquin River Delta (Delta). It is situated at the downstream end of the Yolo Bypass, separated from the northeast corner of Suisun Marsh by low-lying grasslands and seasonal wetland/vernal pool complexes, and linked directly to the Sacramento River via Miner and Steamboat Sloughs (Figure 1-1). The corridor between the CSC and Suisun Marsh contains conservation lands (e.g., the UC Reserve System Jepson Prairie, conservation banks), pasture, and the Travis Air Force Base. The cities of Fairfield and Suisun City lie farther to the west. To the northwest, the cities of Vacaville, Dixon, and Davis are within watersheds that drain to the CSC. The region historically supported extensive tidal and seasonal wetland habitats, but is currently made up primarily of diked agricultural land. Despite past habitat alterations, the region retains some historical habitat characteristics, including remnant and restored wetlands and tidally influenced dendritic channel structure. The CSC boundary used for purposes of this Characterization Report is shown in Figure 1-2.

There are several unique characteristics that have made the CSC a focus for large-scale tidal wetland restoration since the early development of the CALFED Ecosystem Restoration Program (ERP) in the 1990s. There has been relatively modest land subsidence and the hydrodynamic and habitat variability in the region supports or has the potential to support a range of native species. Further, the very gradual alluvial slopes of the surrounding land may accommodate sea level rise through lateral marsh expansion. The CSC also benefits from natural flood pulse flows due to its proximity to the Yolo Bypass and the distributary channels of the lower Sacramento River. These areas provide seasonal migration, spawning, and rearing habitats for adult and juvenile native and anadromous fish. During inundation and high flow events, the flood plains and distributary channels are primary sources for food web productivity, winter sediment supply from the Sacramento River watershed, and winter storm flows. Two very large, naturally restored islands—Liberty Island (1998) and Little Holland Tract (1982)—now support a mix of emergent tidal marsh, intertidal flats, and shallow to moderate depth subtidal aquatic habitats. These flooded islands have demonstrated the ecological potential of tidal restoration in the CSC. Finally, the CSC is adjacent to a broad, lowland grassland/vernal pool complex. This biologically unique complex, in turn, connects to Suisun Marsh, to the west (Figure 1-3). The proximity of these biologically-rich areas should favorably affect efforts to revitalize CSC species populations by providing important ecotones and ecological corridors.



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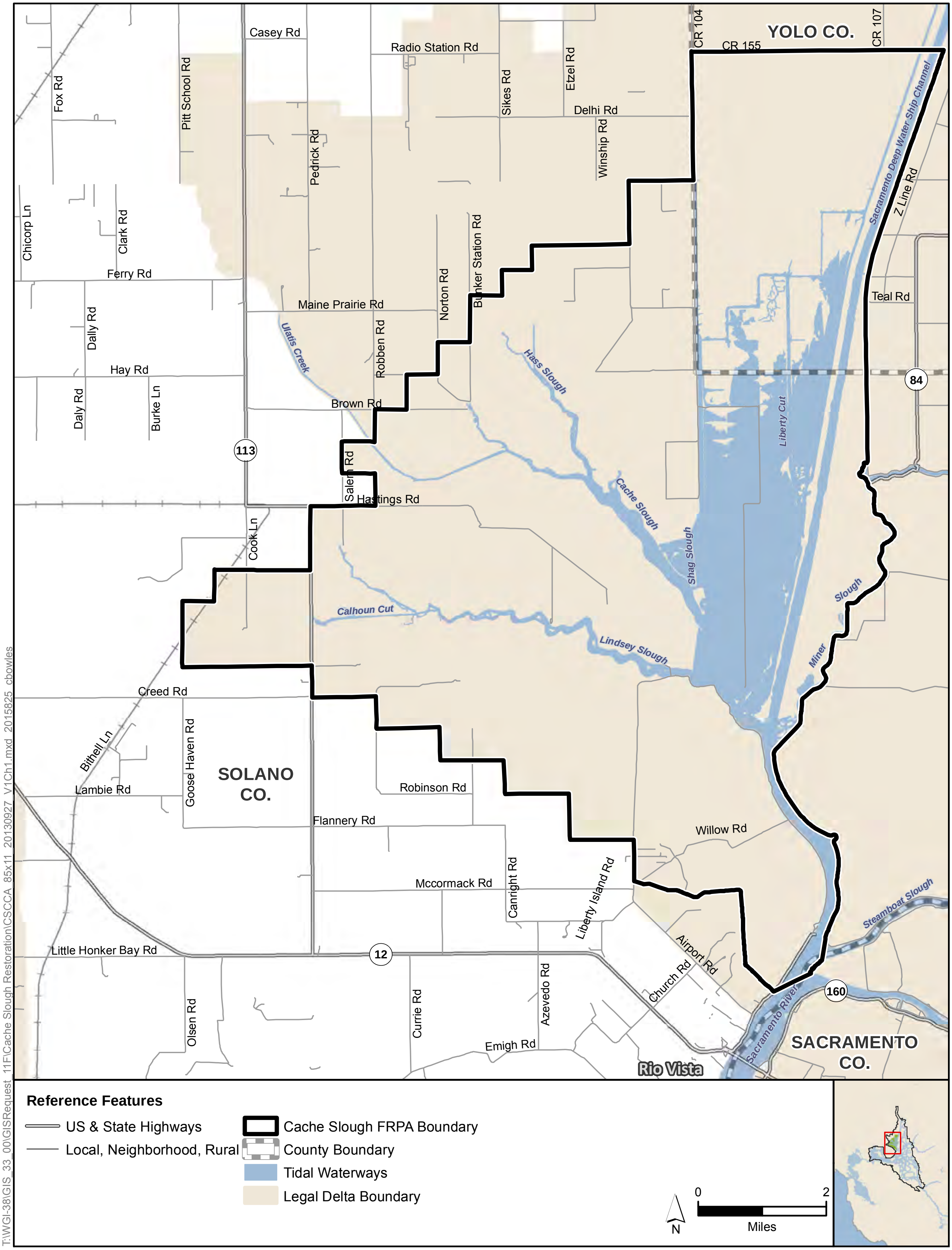
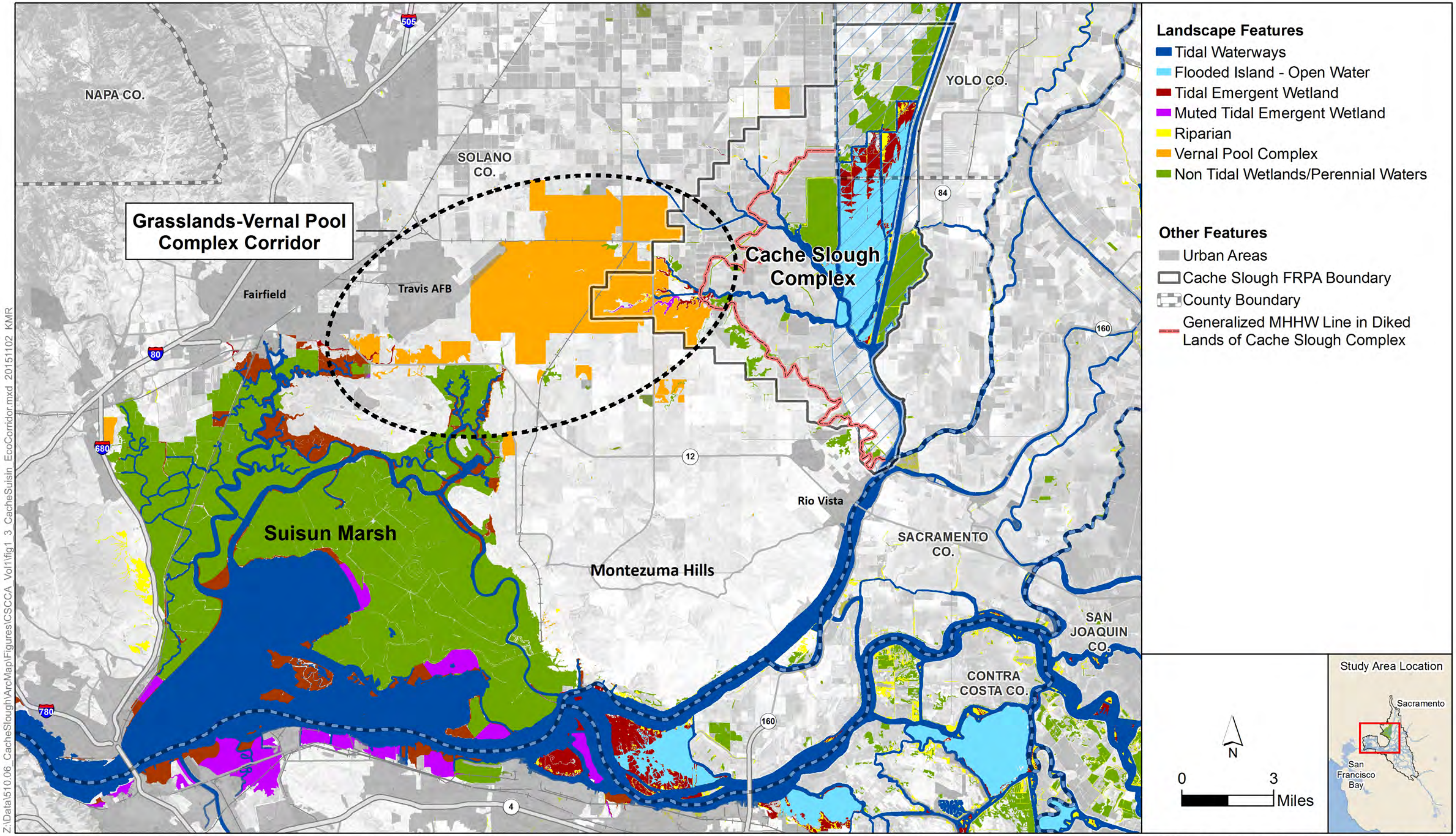
Sources: Cache Slough Planning Boundary (WWR, 2013-0708);
Delta Boundary (DWR, 2002); Suisun Marsh Plan Boudnary (BDCP, 2011);
Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013)

Figure 1-1: Cache Slough Complex Location within the Estuary and Delta
Cache Slough Complex Conservation Assessment



Sources: Cache Slough Complex Planning Boundary (WWR, 20130708)
Transportation Network (US Census/TIGER 2008, ESRI, 2008)
Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 1-2: Assessment Area Boundary
Cache Slough Complex Conservation Assessment



Sources: Natural Communities (BDCP, 2012 and SFEI, 1998 - WWR mod, 2013);
Cache Slough Planning Boundary (WWR, 2013-0708);
Legal Delta Boundary (DWR, 2002); Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013)

Figure 1-3: Cache-Suisun Ecological Corridor
Cache Slough Complex Conservation Assessment

1.2 Restoration Goals and Objectives

The 2008 Delta Smelt Biological Opinion (BiOp) from the United States Fish and Wildlife Service (USFWS) requires the Department of Water Resources (DWR) to restore 8,000 acres of tidal wetlands in the Delta and Suisun Marsh to improve habitat and food web resources for Delta Smelt. The National Marine Fisheries Service (NMFS) 2009 Biological Opinion for salmonids and Green Sturgeon and the California Department of Fish and Wildlife (CDFW) Incidental Take Permit (ITP) for Longfin Smelt place additional habitat restoration requirements on DWR. The BiOps and ITP are intended to mitigate State Water Project and Central Valley Project (CVP) operations (USFWS 2008, CDFG 2009, NMFS 2009a). In October 2010, the Fish Restoration Program Agreement (FRPA) was executed, which directs DWR and CDFW to work jointly to implement and monitor the required tidal wetland restoration.

Because the Cache Slough region has been identified as a high priority restoration area by multiple planning efforts and management directives, it will be a target area for fulfillment of tidal habitat restoration requirements. The CSC Conservation Assessment will focus on tidal restoration efforts that could benefit the FRP species (see Section 1) and may also benefit other native fish species.

The restoration goals for the FRP (DWR 2012b) are:

1. Identify and implement actions that will address the habitat restoration requirements of the Biological Opinions and Incidental Take Permit (ITP);
2. Facilitate interagency planning discussions to achieve the above goal;
3. Facilitate interagency project planning forums to achieve a process that will include public openness and the interests of stakeholders;
4. Utilize and incorporate sound science and current available information in developing restoration and enhancement designs;
5. Maintain consistency with the Bay Delta Conservation Plan (BDCP)[1], Delta Stewardship Council's (DSC) Delta Plan, Ecosystem Restoration Program (ERP) strategies, and other large-scale planning efforts.

The specific objectives to achieve these goals are:

1. Restore 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh, including 800 acres of mesohaline habitat to

[1] As of July 2015, the BDCP is no longer the preferred project. The conveyance component of the former BDCP has been transitioned to California Water Fix (http://www.californiawaterfix.com/), and the restoration component of the former BDCP will now fall under the new state initiative California EcoRestore (http://resources.ca.gov/ecorestore/).

benefit Longfin Smelt, to enhance food production and availability for native Delta fishes;
2. Restore processes that will promote primary and secondary productivity and tidal transport of resources to enhance the pelagic food web in the Delta;
3. Increase the amount and quality of salmonid rearing and other habitat;
4. Increase through-Delta survival of juvenile salmonids by potentially enhancing beneficial migratory pathways.

These goals for tidal habitat restoration in the CSC are consistent with the ERP Stage 2 Conservation Strategy for the Sacramento-San Joaquin Delta (CDFG et al. 2010), which have been incorporated into the Delta Plan (DSC 2013).

The CSC offers notable conservation value for resident and anadromous fish native to the Delta, and for other native plant and animal species associated with tidal wetland habitats, seasonal wetlands (including vernal pools), and grasslands in and around the Delta. In recent years, fish surveys have established the CSC as the only known freshwater Delta location supporting non-migratory year-round populations of endangered Delta Smelt, as well as providing spawning and rearing habitat for populations of this species that migrate from the Estuary's low salinity zone. Importantly, undeveloped lowland grasslands and ranch land span the short distance between the CSC and Suisun Marsh to the west. This ecological corridor offers opportunities to facilitate the movement of wildlife between the two areas (CDFG et al. 2010), and thereby to contribute to the recovery of the overall health and vigor of native species populations.

2 LANDSCAPE SETTING

In this chapter we discuss the CSC landscape in terms of the hydrogeomorphic (HGM) classification approach (Brinson 1993b). We also describe possible constraints to and opportunities for restoration projects, including infrastructure, land ownership, existing and planned restoration and conservation projects, regulatory framework, and the historical conditions. CSC watersheds are described later in Chapter 4 Hydrology (Section 4.4 Local Watersheds).

2.1 Hydrogeomorphic Landscape Classification

Landscape classification provides a means to relate different habitats within a region to a broad suite of ecological functions. The CSC Conservation Assessment uses the HGM classification scheme, an approach that has been identified as useful for the characterization of wetlands and aquatic habitats for conditions assessments and restoration planning (Brinson 1993b, a, Smith et al. 1995, Brooks et al. 2013). Within the HGM classes are their associated natural communities.

In this Conservation Assessment, the HGM classes are used in the following ways:

1. Characterizing existing conditions of natural communities (see Chapter 8)
2. Characterizing the use of the various natural communities by a wide range of species (see Chapters 8, 9, 0).
3. Developing and evaluating restoration strategies aimed at providing benefits for FRP species (Volume 2).

Though natural community types are repeated across the HGM classes, the functions of these same natural communities may actually be significantly different within different HGM classes. For example, tidal emergent wetland located along channel margins (generally narrow bands of limited species diversity) may provide different habitat benefits than tidal emergent wetland within flooded islands (generally broad expanses with dense vegetation and potentially greater species diversity). In addition, the accessibility of each habitat to specific fish and wildlife species may vary across HGM classes.

2.1.1 Distribution and general attributes of the hydrogeomorphic classes

The present-day CSC encompasses approximately 53,000 ac within the boundaries defined for this Conservation Assessment. Of this total area, approximately 16,500 ac of currently diked lands are below high tide and thus at suitable elevations to restore tidal and subtidal habitats. The lands within the CSC consist predominantly of agricultural lands behind constructed levees and on uplands adjacent to those diked lands; flooded islands; a branching network of dead-end tidal sloughs and waterways; the southern terminus of the Yolo Bypass floodway; and the central reach of the Sacramento Deep Water Ship Channel (DWSC).

These lands have been organized into five HGM classes, each with a suite of associated natural communities:

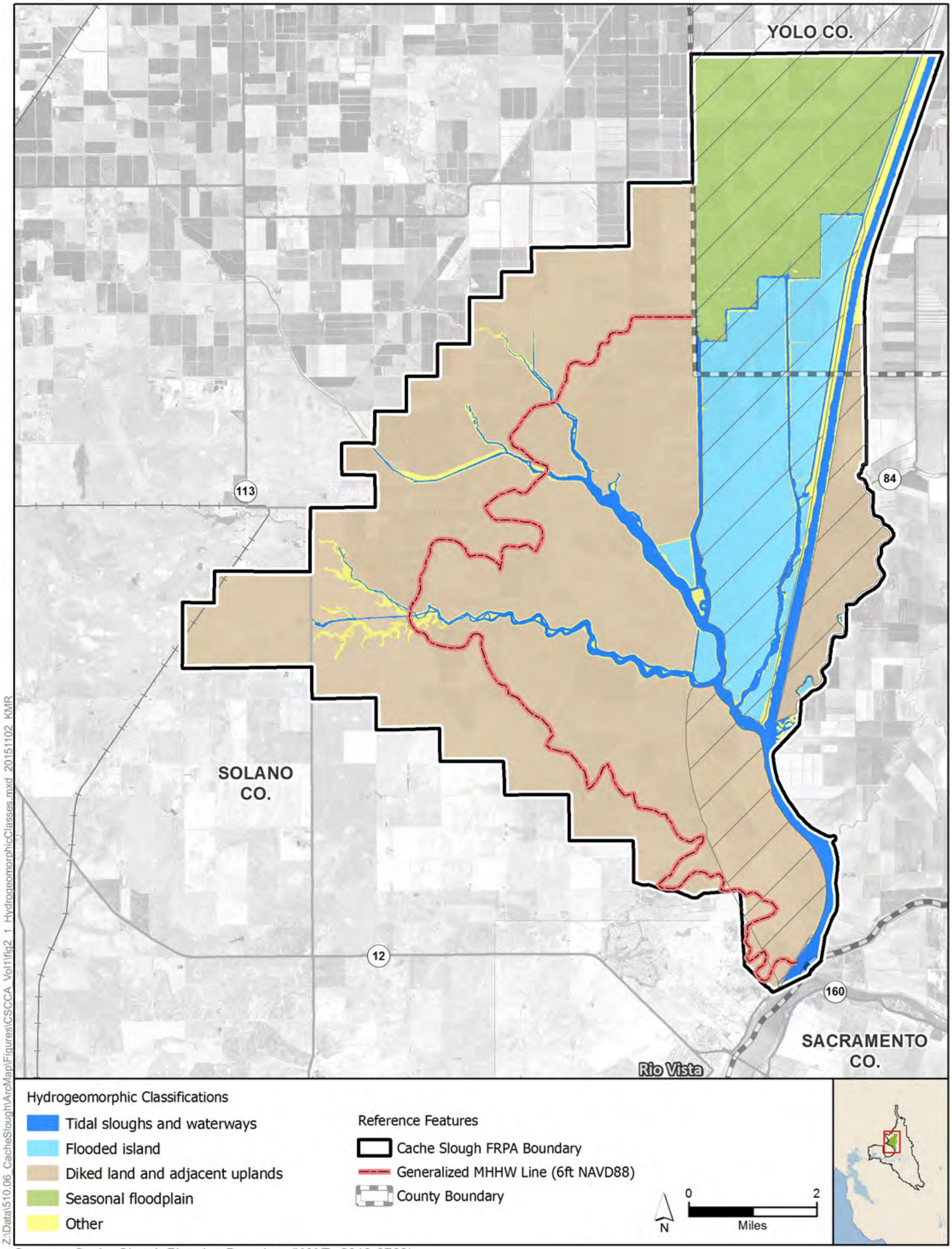
1. **Diked Lands and Adjacent Uplands**—includes levees, diked lands, and adjacent uplands around the outer margins of the CSC, including seasonal wetlands, vernal pools, grasslands, agriculture, and developed land. Within this class, cultivated land is the dominant natural community.
2. **Seasonal Floodplain**— includes lands within the Yolo Bypass north of the Stair Step, which are subject to Yolo Bypass flood inundation events. Within this class, the two dominant natural communities are cultivated lands and managed wetland.
3. **Tidal Sloughs and Waterways**—includes tidal channels, both natural and constructed. Does not include tidal waters within flooded islands. The only natural community is tidal perennial aquatic.
4. **Flooded Islands**—encompasses all elements interior to the original levees. The dominant natural community is tidal perennial aquatic.
5. **Other**—catch-all for the many, mostly small, miscellaneous areas that do not fall into the above four classes located along channel margins, in-channel islands, and remnant levees. The dominant natural communities are grassland and valley foothill riparian.

Figure 2-1 depicts the HGM classes in the CSC, Figure 2-2 shows the natural communities within each of these HGM classes. Figure 2-3 provides a hypothetical cross section through all these HGM classes and natural communities to illustrate their relative landscape positions. Table 2-1 describes the general vegetative characteristics of HGM classes, example locations of where they occur, and the natural communities therein. Table 2-2 provides the acreages of each HGM class and its associated natural communities.

2.1.1 Diked lands and adjacent uplands

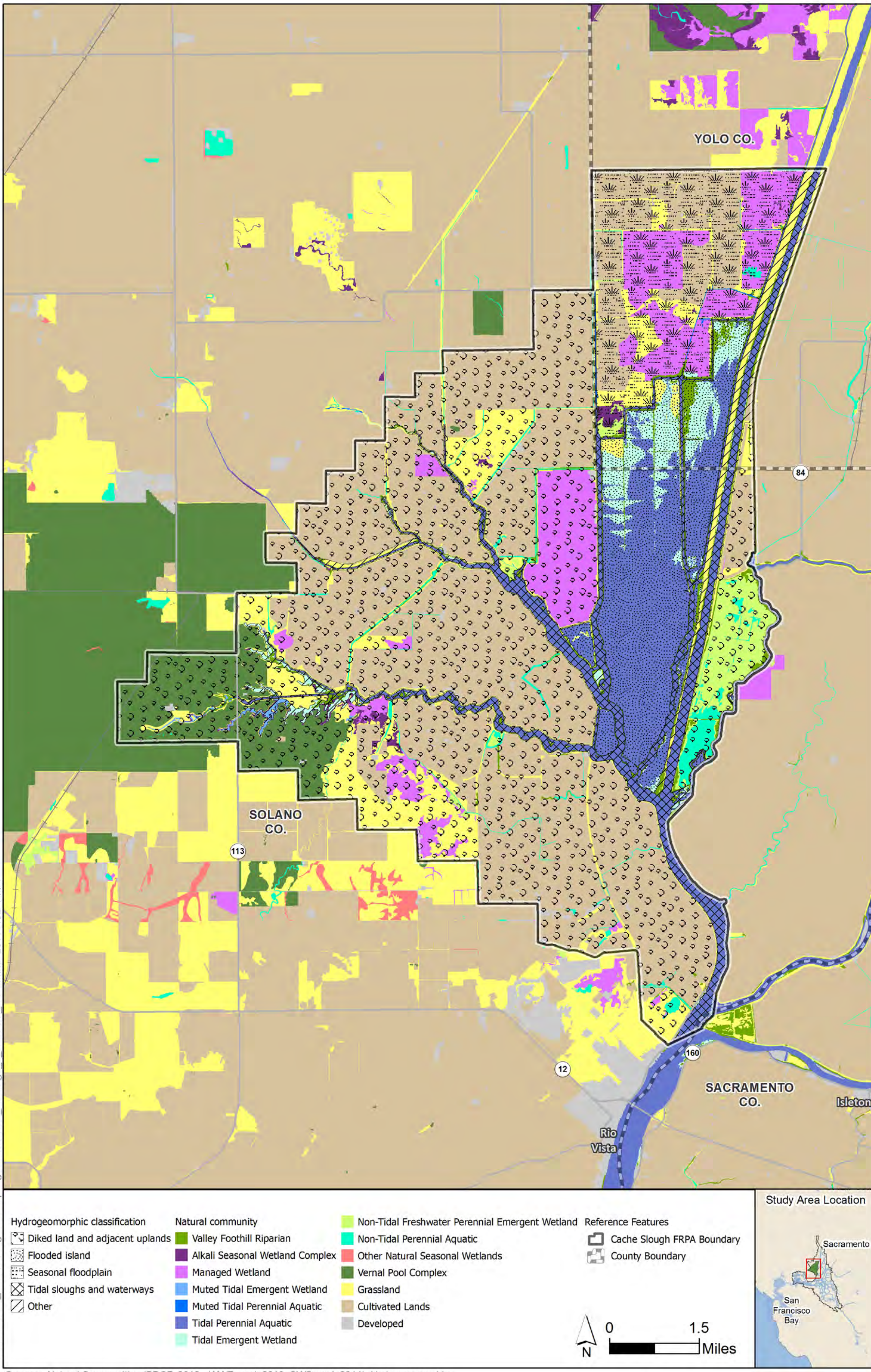
About 34,000 ac within the CSC are diked lands and adjacent uplands. These lands consist of diked lands below high tide that are potentially restorable to tidal action (roughly 16,500 acres not accounting for tidal range effects of future restoration); adjacent sea level rise accommodation space (roughly another 12,000 ac for 5 ft of SLR); adjacent grasslands, vernal pools, and seasonal wetlands; and the lowland wildlife corridor to Suisun Marsh. The degree of subsidence of these diked lands varies across the planning area, and encompasses considerable acreage of diked lands lying at or below intertidal elevations. Figure 2-4 shows the topography within diked lands of the CSC, with the distribution of land elevations (topography) described in greater detail in Chapter 5.

Within diked lands and adjacent uplands are eleven natural community types (see Table 2-1 and Table 2-2 for a full list, descriptions, locations, acreages).



Sources: Cache Slough Planning Boundary (WWR, 2013-0708);
Hydrogeomorphic Classifications (WWR, 2013);
MHHW Line (WWR, 2013)

Figure 2-1: Hydrogeomorphic Classifications
Cache Slough Complex Conservation Assessment



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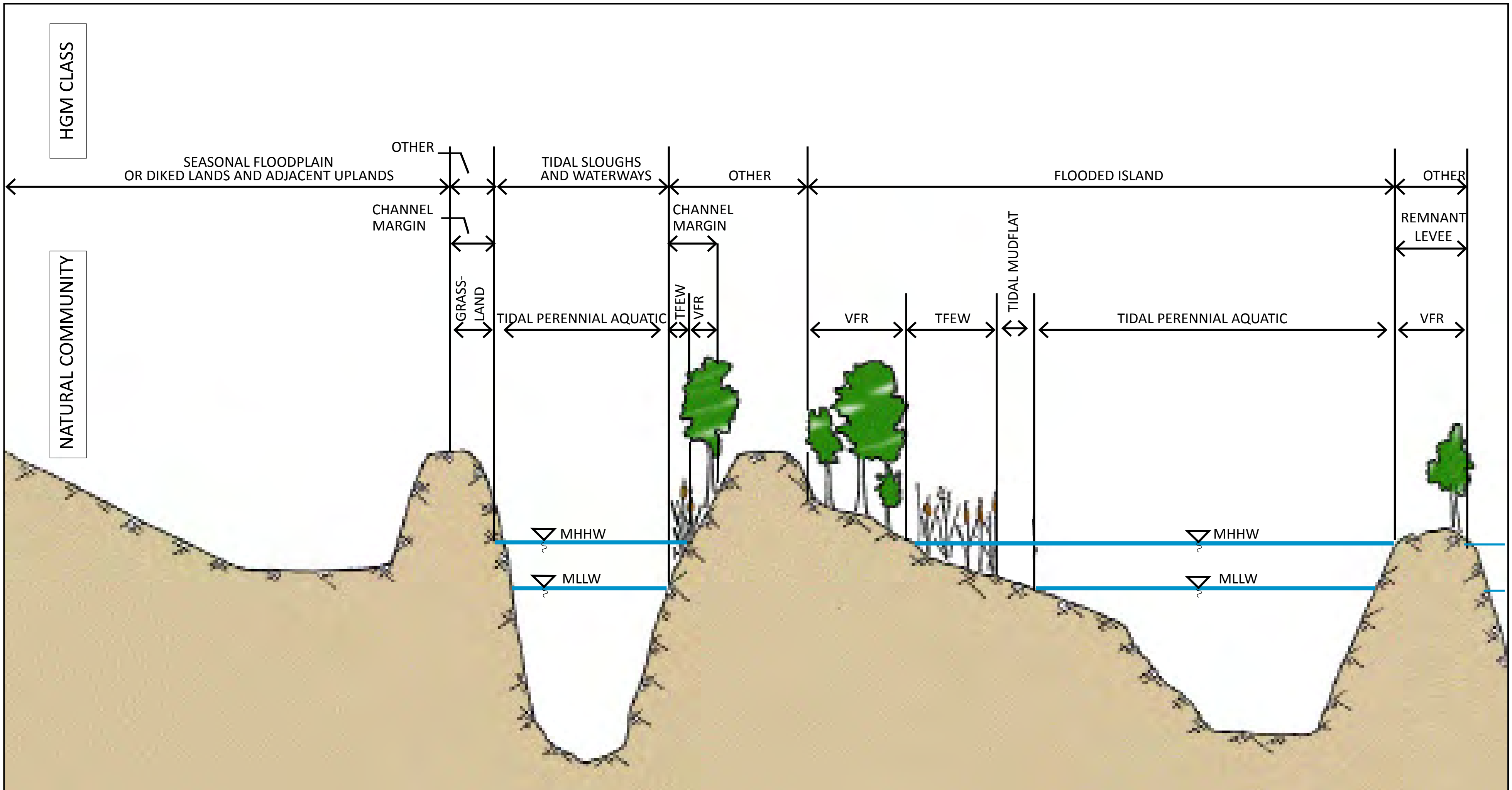
Sources: Natural Communities (BDCP, 2012 - WWR mod, 2013, SWS mod, 2014); Hydrogeomorphic Classifications (WWR, 2013); Cache Slough Planning Boundary (WWR, 2013-0708); Tidal Waterways (CDFG 2005 and BDCP 2012, WWR mod, 2013); MHHW Line (WWR, 2013)

Figure 2-2: Natural communities within each of the Hydrogeomorphic classes Cache Slough Complex Conservation Assessment

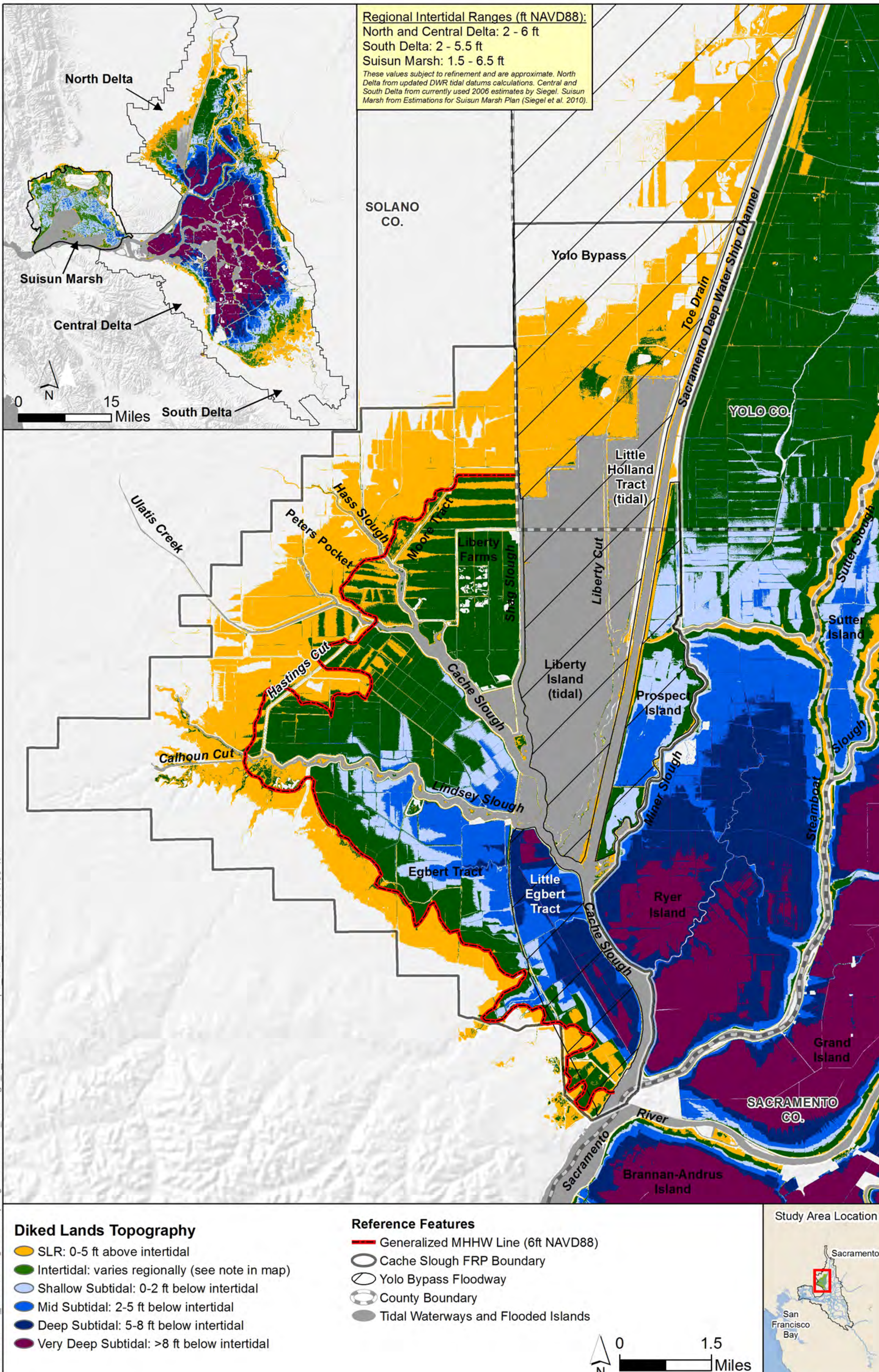


TFEW: Tidal Freshwater Emergent Wetland
VFR: Valley Foothill Riparian
MHHW: Mean Higher High Water
MLLW: Mean Lower Low Water

Note:
Not all natural communities possible in each hydrogeomorphic (HGM) unit are shown.
"Other" HGM unit is a catch-all for the many, mostly small, miscellaneous areas that do not fall in the other HGM units, such as lands on the outboard sides of levees and natural land-water interfaces.

Not to Scale

Figure 2-3: Hydrogeomorphic Classification Example Cross Section
Cache Slough Complex Conservation Assessment



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Sources: DEM (DWR, 2007 and SFCWA, 2011);
Cache Slough Planning Boundary (WWR, 2013-0708);
Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013);
Yolo Bypass (URS, 2007 - WWR mod, 2010)

Figure 2-4: Diked Lands Topography
Cache Slough Complex Conservation Assessment

Table 2-1. Hydrogeomorphic Classes and Natural Communities.

Hydro-geomorphic Class	Landscape Unit	Natural Community Type	Brief Description	Examples
Tidal Sloughs and Waterways			Tidally influenced open waters not within flooded islands	See Figure 5-7 for extent and bathymetry in Cache region
	Tidal Perennial Aquatic			
		Major Sloughs	Wide, deep sloughs and rivers	Lower Cache Slough, Deep Water Ship Channel
		Minor Sloughs	Narrower, shallower sloughs	Lindsey Slough, Toe Drain
Flooded Islands			Formerly diked lands, now subject to tidal action where elevations are appropriate	Six total: Liberty Island, Little Holland Tract, Little Hastings Tract, Liberty Farms Tip, Prospect Island West, Hall Island. See Figures 1-1 and 5-7
	Tidal Perennial Aquatic		Unvegetated open water portions of Flooded Islands	See Figure 5-7 (Flooded Island and Tidal Waterways Bathymetry)
		Intertidal	Exposed at low tide, up to about 4 ft deep at high tide, may be hard or soft substrate, >MLLW	Northern Liberty Island open water area closest to the emergent marsh, northern half of Little Holland Tract, variable hard to soft substrate depending on sediment accumulation history
		Shallow Subtidal	Shallow water at low tide, up to about 6 ft deep at high tide, may be hard or soft substrate, MLLW to 2ft below MLLW	Middle reach of Liberty Island, southern portion of Little Holland Tract, perimeter of Little Hastings Tract and Liberty Farms Tip
		Mid Subtidal	Depths of 6 to 9 ft depending on tide stage, 2 to 5 ft below MLLW	Southern ~ third of Liberty Island, interior of Little Hastings Tract and Liberty Farms Tip, much of Prospect Island West
		Deep Subtidal	Depths more than 9 ft depending on tide stage, More than 5 ft below MLLW	Scour hole at southern end of Liberty Island primary breach

Hydro-geomorphic Class	Landscape Unit	Natural Community Type	Brief Description	Examples
	Tidal Freshwater Emergent Marsh		Fully tidal marsh comprised of emergent marsh vegetation	Upper ends of Liberty Island and Little Holland Tract, margins of remnant levees
		Upland Transition	Upland edges of tidal marsh, provide wildlife refugia during extreme high tides	Very northern end of Liberty Island and Little Holland Tract. Outside of flooded islands found at Peterson Ranch and parts of Yolo Ranch
		High Marsh (>MHHW)	Infrequent tidal inundation, characterized by lower-height emergent vegetation such as rushes (*Juncus*)	Possibly found at northern ends of Liberty Island and Little Holland Tract. Outside of flooded Islands found at Southcentral "Stair Step" of Yolo Ranch, perhaps some around Calhoun Cut/Lindsey Slough area
		Mid Marsh (MTL to MHHW)	Tidal inundation daily except at highest elevations, characterized by tall emergent vegetation such as tules (*Schoenoplectus*) and cattails (*Typha*)	Upper ends of Liberty Island and Little Holland Tract. Outside of flooded islands found at Calhoun Cut/Lindsey Slough, slough margins
		Low Marsh (~-2 ft MLLW to MTL)	Tidal inundation majority of the time and lowest elevations always submerged, characterized by tall emergent vegetation similar to mid marsh	Little if any in region. Small amount may exist at CDFW Miner Slough Wildlife Area. A little found in western Delta flooded islands (Sherman, Donlin)
	Valley Foothill Riparian		Fields of mesic woodland and scrub/shrub communities within Flooded Islands, on seasonally flooded lands. When not in flood stage, riparian is not adjacent to water except at edges. Not the same as channel margin riparian.	Primarily in northern reaches of Little Holland Tract
	Non Tidal Wetlands		Permanently or seasonally saturated wetlands characterized by dense stands of tules and cattails	Stair step region of Liberty Island

Hydro-geomorphic Class	Landscape Unit	Natural Community Type	Brief Description	Examples
	Upland		Grassland, agriculture, and seasonal wetlands within the upland portion of the flooded island. This area is also within the Yolo Bypass and subject to seasonal flooding	Stair step region of Liberty Island, two islands on Liberty Farms tip
Diked Lands and Adjacent Uplands			Lands behind levees and the contiguous uplands	Throughout region.
	Agriculture and Related Cover Types		Variety of lands used for or in association with agricultural operations	
		Developed	Buildings and other man-made structures, related to agricultural operations and local home sites	Scattered throughout area
		Agricultural	Cultivated lands, grazed lands, irrigated pastures	Throughout region
		Grasslands	Non-native and native annual and perennial grasses and forbs and managed pasturelands	Uplands around upper reaches of Lindsey and Barker Sloughs, portions of Yolo Ranch, north side of Hass/Duck Slough confluence
		Seasonal Wetlands	Interconnected and isolated, seasonally inundated depressions/ swales in the matrix of the grassland natural community	Along toe of Montezuma Hills
		Vernal Pool Complexes	Interconnected and isolated vernal pool wetlands in the matrix of the grassland natural community	Jepson Prairie
	Non Tidal Wetlands and Perennial Waters			

Hydro-geomorphic Class	Landscape Unit	Natural Community Type	Brief Description	Examples
		Non-Tidal Freshwater Emergent Wetland	Permanently or seasonally saturated wetlands characterized by dense stands of tules and cattails	Prospect Island
		Managed Wetlands	Hydrology and/or vegetation managed to promote specific wetland types, for waterfowl or cattle forage	Liberty Farms, Yolo Ranch, some areas on Egbert Tract
		Non-Tidal Perennial Aquatic	Drainages and creeks that are perennially aquatic, including muted tidal perennial aquatic sloughs	Drainage ditches, Hastings Cut, The Big Ditch
	Valley Foothill Riparian		Mesic woodland and scrub/shrub communities within diked areas near standing water	Around the interior edge of Prospect Island, along Hastings Cut, Liberty Farms, and other upland drainage ditches
	Muted Tidal Freshwater Emergent Wetland		Marsh with hydrologically muted waters, but maintains some tidal influence	DFW Calhoun Cut Enhancement Project
Seasonal Floodplain			Lands within Yolo Bypass subject to seasonal flooding. All areas, except for riparian trees, are submerged when floodplain inundated	Located only within the Yolo Bypass north of the Stair Step channel
	Agriculture and Related Cover Types			
		Development	Buildings	Scattered in the Northwest section of the Yolo Bypass within the Cache Slough Complex
		Agricultural	Row crops	Throughout region

Hydro-geomorphic Class	Landscape Unit	Natural Community Type	Brief Description	Examples
		Grassland	Non-native and native annual and perennial grasses and forbs and managed pasturelands	Throughout region
		Seasonal Wetlands	Interconnected and isolated, seasonally inundated depressions/ swales in the matrix of the grassland natural community	Largest seasonal wetland located just north of the western stair step
	Non Tidal Wetlands and Perennial Waters			
		Non-Tidal Freshwater Emergent Wetland	Permanently or seasonally saturated wetlands characterized by dense stands of tules and cattails	North of the western stair step
		Managed Wetlands	Hydrology and/or vegetation managed to promote specific wetland types, for waterfowl or cattle forage	North of the stair step and along the Toe Drain
		Non-Tidal Perennial Aquatic	Drainages that are perennially aquatic, including muted tidal perennial aquatic sloughs	Drainage ditches throughout region
	Valley Foothill Riparian		Mesic woodland and scrub/shrub communities found on channel margins of sloughs	Just north of the stair step
	Tidal Freshwater Emergent Marsh		Fully tidal marsh comprised of emergent marsh vegetation found on channel margins	Just north of the stair step
Other			Lands on outboard side of levees and natural land-water interfaces: channel margins, in-channel islands, and remnant levees	Along most sloughs

Hydro-geomorphic Class	Landscape Unit	Natural Community Type	Brief Description	Examples
	Agriculture and Related Cover Types			
		Agricultural	Row crops, abandoned orchards	Areas not behind levees, but along channel margins in a few locations along Cache Slough
		Grasslands	Non-native and native annual and perennial grasses and forbs and managed pasturelands	Along Cache Slough, Ulatis Creek, Hass Slough, Barker Slough, Lindsey Slough, Miner Slough, and the Deep Water Ship Channel
		Developed	Rock rip rap levees and buildings	Along the Deep Water Ship Channel, Cache Slough, Lindsey Slough and Miner Slough
	Non Tidal Waters		Levee borrow ditches	North bank of lower Ulatis Creek
	Valley Foothill Riparian		Mesic woodland and scrub/shrub communities found on channel margins of sloughs and within in-channel islands. Adjacency to water is key characteristic of channel margin riparian and offers shaded water potential. Not the same as floodplain riparian.	Along most sloughs within the Cache Slough Complex
	Tidal Freshwater Emergent Marsh		Fully tidal marsh comprised of emergent marsh vegetation found on channel margins of sloughs and around edges of in-channel islands	Along Barker Slough, Big Ditch Calhoun, and a few places along Lindsey Slough, Cache Slough, and Miner Slough

Table 2-2. Acreage by Natural Communities within each Hydrogeomorphic Class

Hydrogeomorphic Classes and Natural Community	**Acres in CSCCA Area**		
	Subtotal acres	**% Total area in natural community**	**Total by HGM Class**
Diked Land and Adjacent Uplands (portions of this HGM class represent potentially restorable lands)			**33,959**
a. Alkali Seasonal Wetland Complex	181	< 1%	
b. Cultivated Lands	21,652	64%	
c. Developed	229	< 1%	
d. Grassland	4,215	12%	
e. Managed Wetland	2,313	7%	
f. Muted Tidal Emergent Wetland	32	< 1%	
g. Muted Tidal Perennial Aquatic	33	< 1%	
h. Non-Tidal Freshwater Perennial Emergent Wetland	1,217	4%	
i. Non-Tidal Perennial Aquatic	745	2%	
j. Valley Foothill Riparian	219	< 1%	
k. Vernal Pool Complex	3,123	9%	
Seasonal Floodplain (portions of this HGM class represent potentially restorable lands)			**6,648**
a. Alkali Seasonal Wetland Complex	86	1%	
b. Cultivated Lands	2,854	43%	
c. Developed	27	< 1%	
d. Grassland	897	14%	
e. Managed Wetland	2,539	38%	
f. Muted Tidal Perennial Aquatic	29	< 1%	
g. Non-Tidal Freshwater Perennial Emergent Wetland	80	1%	
h. Non-Tidal Perennial Aquatic	38	1%	
i. Tidal Emergent Wetland	11	< 1%	
j. Valley Foothill Riparian	87	1%	
Tidal Sloughs and Waterways			**3,440**
a. Tidal Perennial Aquatic	3,440	100%	
Flooded Islands			**6,468**
a. Alkali Seasonal Wetland Complex	1	< 1%	
b. Grassland	147	2%	
c. Tidal Emergent Wetland	1,324	20%	
d. Tidal Perennial Aquatic	4,768	74%	
e. Valley Foothill Riparian	228	4%	

Hydrogeomorphic Classes and Natural Community	Acres in CSCCA Area		
	Subtotal acres	% Total area in natural community	Total by HGM Class
Other			**2,347**
a. Cultivated Lands	78	3%	
b. Developed	40	2%	
c. Grassland	1,033	44%	
d. Muted Tidal Emergent Wetland	55	2%	
e. Non-Tidal Freshwater Perennial Emergent Wetland	2	< 1%	
f. Tidal Emergent Wetland	278	12%	
g. Tidal Perennial Aquatic	35	2%	
h. Valley Foothill Riparian	826	35%	
TOTAL ACREAGE			**52,862**

2.1.2 Seasonal floodplain

The Yolo Bypass north of the stair step tidal channel is defined as seasonal floodplain. All areas except for riparian trees are submerged when the floodplain is fully inundated. Nearly 6,700 ac within the CSC are considered seasonal floodplain, of which approximately 265 ac are below high tide and thus at suitable elevations to restore tidal and subtidal habitats. These lands are almost entirely within the proposed Lower Yolo Restoration Project. Most lands within the seasonal floodplain are slightly above high tide elevations.

Within seasonal floodplain there are ten natural community types (see Table 2-1 and Table 2-2 or a full list, descriptions, locations, acreages).

2.1.3 Tidal sloughs and waterways

Tidal sloughs and waterways occupy approximately 3,500 ac of the CSC. Remnant natural waterways include Cache, Lindsey, Barker, Hass, Prospect, Miner, and portions of Shag sloughs. Constructed waterways include the Sacramento Deep Water Ship Channel (DWSC), Toe Drain, Liberty Cut, Calhoun Cut, Duck Slough, Stair Step, and the upper end of Shag Slough. Some of the natural waterways have been straightened in some reaches. Chapter 5 describes the bathymetry of these tidal waterways.

Within tidal sloughs and waterways there is one natural community type – tidal perennial aquatic (see Table 2-1 and Table 2-2) for descriptions, locations, and acreages).

2.1.4 Flooded islands

There are six flooded islands within the CSC, totaling about 6,500 ac. Liberty Island (4,525 ac) and Little Holland Tract (1,425 ac) are the two largest flooded islands and the only two that have elevations ranging from subtidal to upland. Both islands flooded as a result of natural levee failures (in 1998 and 1982, respectively) that were left unrepaired. The western remnants of Prospect Island (275 ac) were isolated from the main body of the island when the DWSC was constructed, flooded through natural levee failures around 1963. Little Hastings Tract (160 ac) at the confluence of Lindsey and Cache Slough breached naturally after 1992. Liberty Farms Tip (170 ac) was breached in 1991 as the Cache Slough Mitigation Project. The sixth flooded island, Hall Island (14 ac), lies between Miner Slough and the southern portion of Prospect Island, where Miner Slough appears to have been straightened and the cutoff island levees have failed naturally.

Within flooded islands there are five natural community types (see Table 2-1 and Table 2-2 for descriptions, locations, and acreages).

2.1.5 ‘Other’

As noted above, the ‘other’ class is a catch-all unit for the many, mostly small, miscellaneous areas that do not fall into the above four classes. These areas encompass tidal freshwater emergent wetlands, valley foothill riparian, and upland areas located along channel margins, in-channel islands, and remnant levees. Within ‘other’ there are eight natural community types (see Table 2-1 and Table 2-2 for descriptions, locations, and acreages).

2.2 Infrastructure

The presence of infrastructure can exert considerable constraints on ecosystem restoration potential due to the costs, regulatory complexity, and coordination efforts needed to accommodate it. The major infrastructure elements present within the CSC are described below.

2.2.1 Diversions and drains

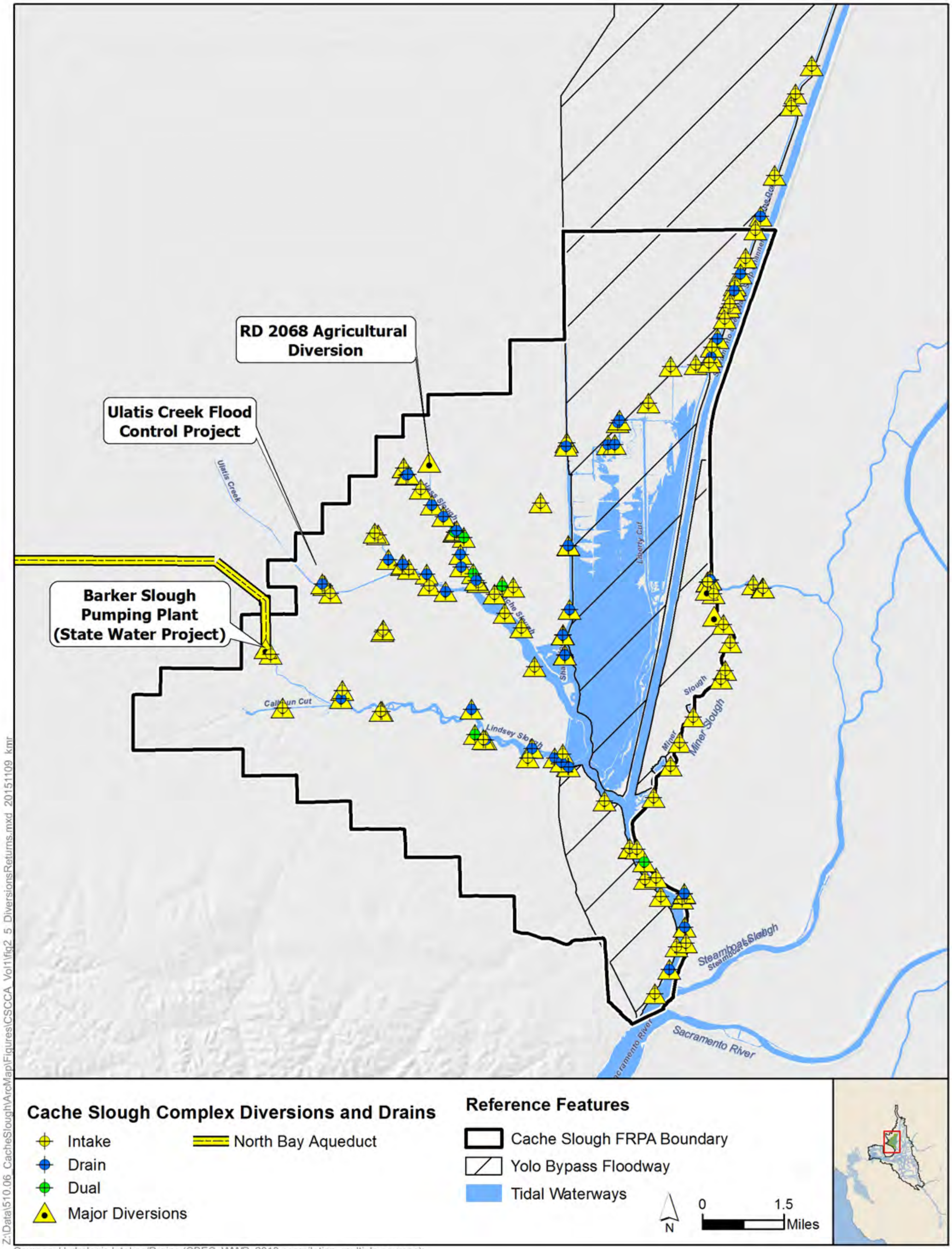
The CSC supports numerous agricultural diversions and one municipal diversion, along with numerous agricultural and stormwater drains (Figure 2-5). These features are the Barker Slough Pumping Plant, Reclamation District 2068 diversion, Ulatis Creek Flood Control Project, and numerous small agricultural diversions and drains. All these features are discussed further in Chapter 4.

2.2.2 Mineral Rights

Mineral rights of individual parcels allow the owner to exploit, mine, and/or produce any or all of the minerals lying below the surface of the property, such as natural gas. Natural gas fields and associated pipelines are present throughout the Delta and within the CSC (Figure 2-6). The operational and mineral rights associated with these facilities must be understood at the property/parcel level in order to assess potential ramifications for restoration feasibility.

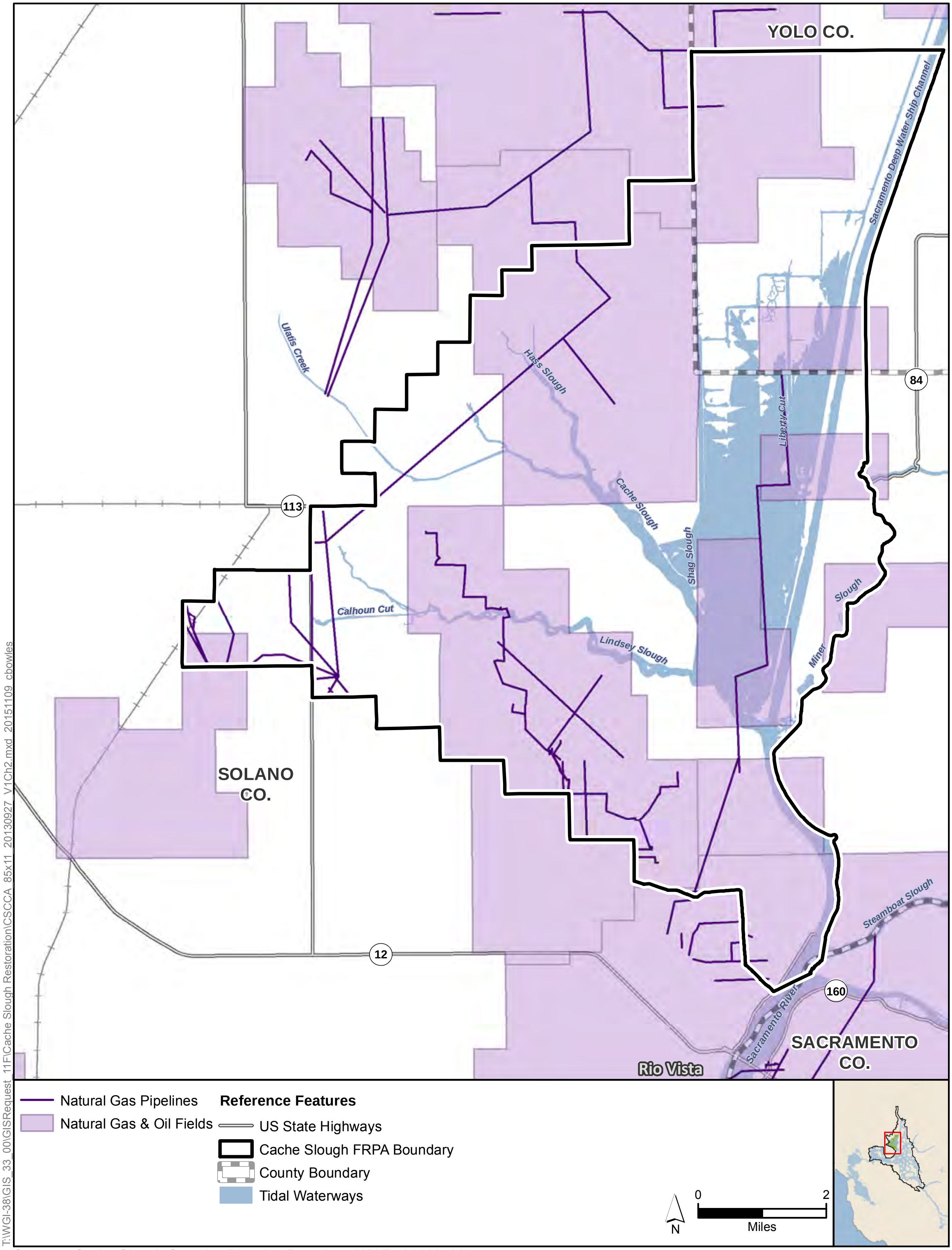
2.2.3 Electrical transmission

Overhead transmission lines also cross the CSC (Figure 2-7). One major high voltage transmission route intersects numerous diked areas and spans Lindsey and Cache sloughs and a second route intersects the upstream end of Lindsey Slough. The necessity for reinforcement of power-line tower foundations (required when transitioning from predominantly dry to wet soil conditions) and means to address line-sag clearance-height requirements over navigable waters could be costly to address. The region is also replete with low-voltage transmission lines. Remediation to address impacts to these lines would depend on the extent of changes to infrastructure serviced by them at and around potential restoration sites. Modifications to lower-voltage transmission lines, while still expensive, are usually less costly than those necessary for the high-voltage lines.



Sources: Hydrologic Intakes/Drains (CBEC, WWR, 2013 compilation, multiple sources);
Cache Slough Planning Boundary (WWR, 2013-0708);
Yolo Bypass (URS, 2007 - WWR mod, 2010);
Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013)

Figure 2-5: Diversions and Drains
Cache Slough Complex Conservation Assessment



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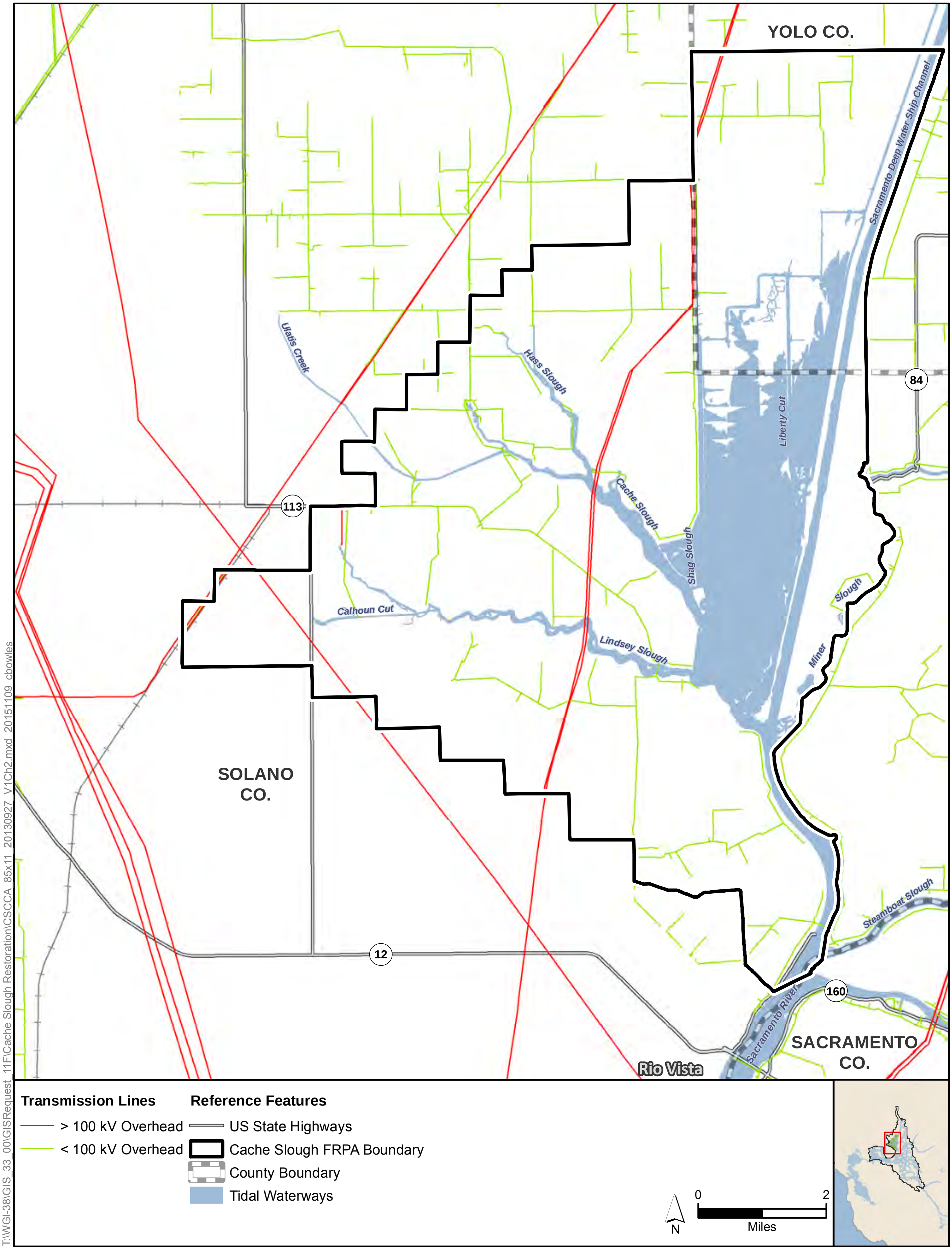
Sources: Cache Slough Complex Planning Boundary (WWR, 20130708)
Natural Gas Pipelines (PG&E, 2012; DWR, 2009)
Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 2-6: Natural Gas Pipelines and Fields
Cache Slough Complex Conservation Assessment



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Sources: Cache Slough Complex Planning Boundary (WWR, 20130708)
Transmission Lines (CEC, 2008; PG&E, 2012; SMUD, 2010)
Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 2-7: Transmission Lines
Cache Slough Complex Conservation Assessment

2.2.4 Transportation Infrastructure

Relatively few roads and bridges exist within the CSC (Figure 1-2). The major roadways—State Highways 12, 84, 113 and 160—are located around the margins of the assessment area and should not be affected by tidal habitat restoration. Highway 113 just west of the upper reaches of Lindsey Slough and its tributaries may at some point in the future require protection, due to sea level rise. The only rail lines within the CSC cross its western-most boundary, through uplands adjacent to the Jepson Prairie.

2.2.4.1 Sacramento Deep Water Ship Channel (DWSC)

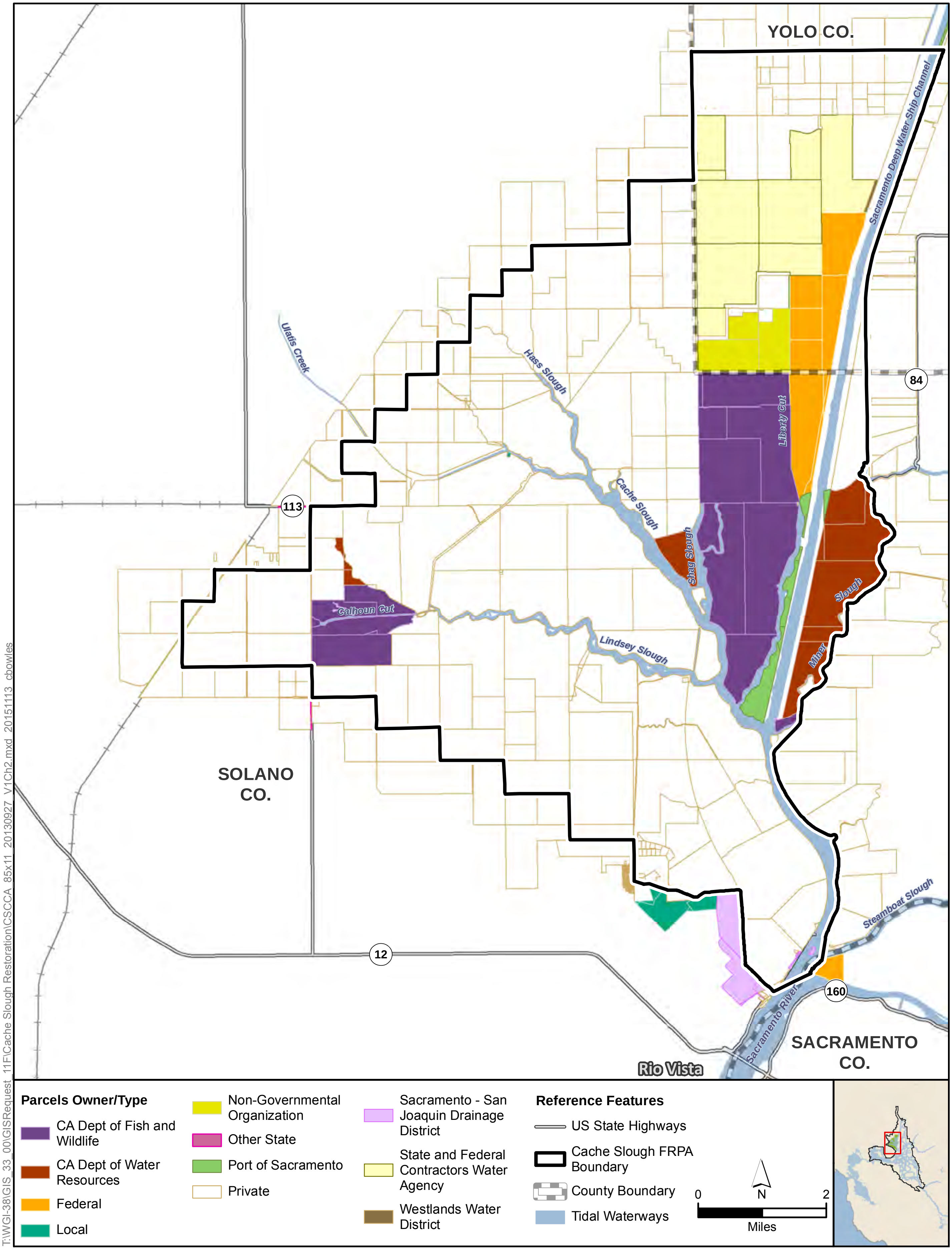
Originally authorized by the Rivers and Harbors Act of July 24, 1946, the Sacramento Deepwater Ship Channel is a 43 mile long shipping channel extending from Suisun Bay to the Port of West Sacramento in West Sacramento. The DWSC has been dredged regularly (every two to four years) (M. Lukin, Port of West Sacramento, pers. comm., February 2013). The Port owns fee title or easements along much of the lands adjacent to the DWSC for dredge spoils placement. Dredging, as currently conducted, does not appear to affect Delta Smelt spawning in the DWSC (Moyle 2002, CDFW 2013). Ship wake has the potential to erode channel banks, with the potential for loss of channel margin habitats including emergent marsh and riparian natural communities.

2.3 Land Ownership

Land owners may present opportunities or constraints to restoration. Most land within the CSC is privately owned (Figure 2-8). Land owners and the specific or general natures of the properties they own are:

- **Private land owners** own a majority of land in the region.
- **Department of Water Resources** owns Prospect Island, several parcels on and south of the Barker Slough Pumping Plant, and Liberty Farms Tip (restored by DWR as mitigation in 1991).
- **California Department of Fish and Wildlife (CDFW)** owns the majority of Liberty Island (the portion within Solano County), the Miner Slough Wildlife Area at the southern tip of Prospect Island, and the Calhoun Cut Ecological Reserve at the head of Lindsey Slough.
- **Port of West Sacramento** owns lands along the Deep Water Ship Channel.
- **U.S. Army Corps of Engineers (USACE)** owns Little Holland Tract.

- **Westlands Water District** owns Yolo Ranch at the southern end of the Yolo Bypass
- **Wildlands Inc.** owns the mitigation bank, constructed in 2010, at the north end of Liberty Island.
- **Trust for Public Land** owns Liberty Island within Yolo County.
- **UC Natural Reserve System** owns the Jepson Prairie Reserve, at the very western tip of the CSC.



Sources: Cache Slough Complex Planning Boundary (WWR, 20130708)
Parcels (County Assessor Rolls, 2012, 2015)
Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 2-8: Land Ownership Type
Cache Slough Complex Conservation Assessment

2.4 Local Ecosystem Restoration Efforts

There have been five tidal restoration events due to unplanned levee-breaches. In addition, there are four constructed restoration projects, with several future restorations either currently in planning or being considered (Figure 2-9, Table 2-3).

Restoration planning is prompted both by long-term ecosystem restoration planning and by federal Endangered Species Act mitigation required of the State Water Project and Central Valley Project. Planning for restoration in the CSC was originally envisioned with the CALFED program; then by the ERP Stage 2 Conservation Strategy (CDFG et al. 2010), the concepts of which are incorporated into the recent Delta Plan (DSC 2013). The federal Endangered Species Act (ESA) directives to the State and federal water projects were codified in the USFWS (2008) and NMFS (2009a) Biological Opinions on the two water projects. California EcoRestore is a recent state initiative that will assist in the implementation of individual ecosystem restoration projects to meet the Biological Opinions, along with additional restoration targets.

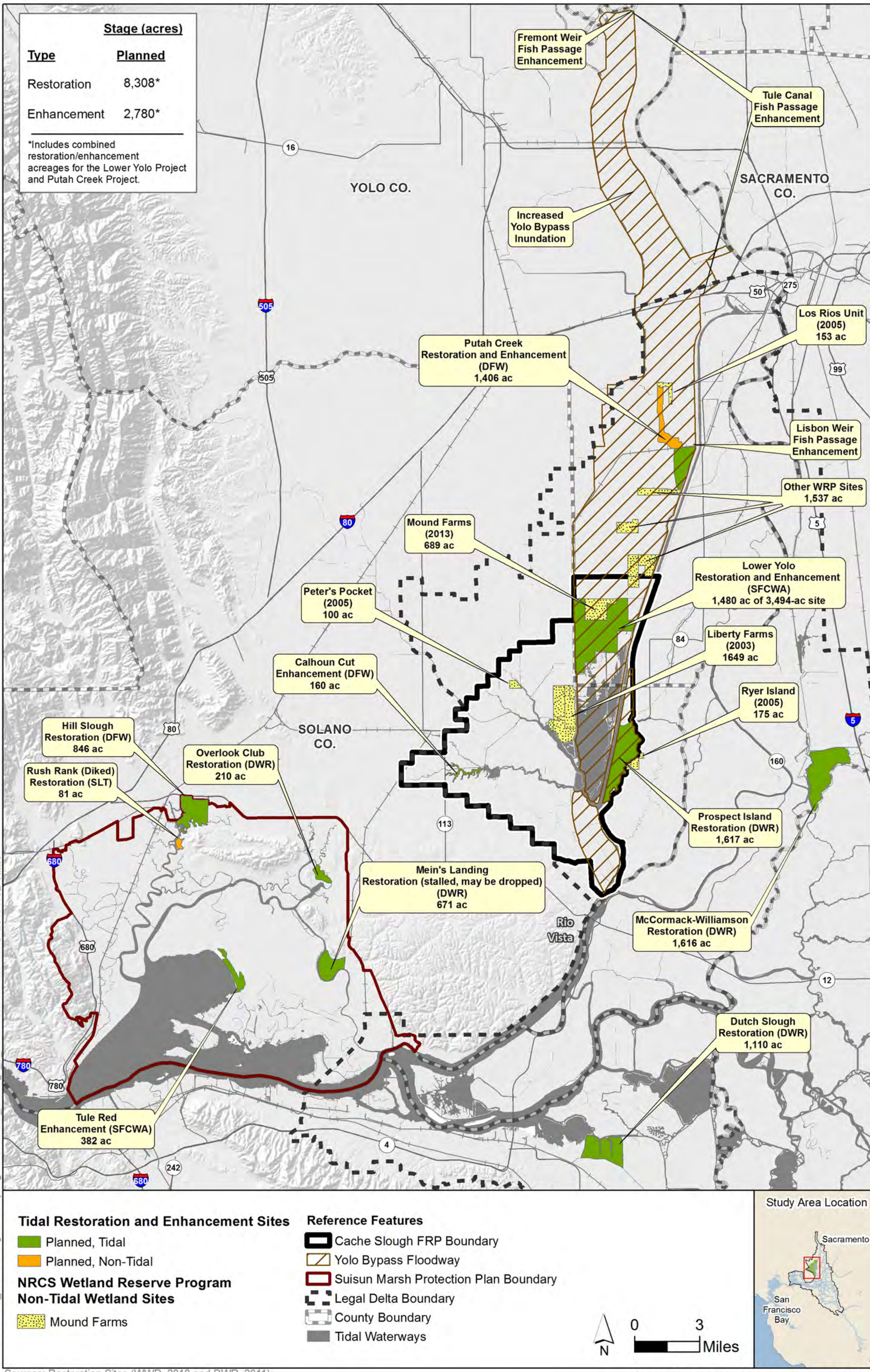
Other regulatory-based planning efforts with geographic overlap in the CSC are the Solano County Habitat Conservation Plan, drafted by the Solano County Water Agency (SCWA 2012), the Methylmercury Total Maximum Daily Load promulgated in 2010 by the Central Valley RWQCB, the Central Valley Flood Protection Plan being prepared by the Central Valley Flood Protection Board and grantees under it, the Bay-Delta Water Quality Control Plan updates being prepared by the State Water Resources Control Board, and ecosystem enhancement efforts being developed for the Yolo Bypass.

There are several non-regulatory planning activities under way by various organizations that have geographic overlap in the CSC. These activities include efforts of the Solano Land Trust, a nonprofit organization whose mission is to permanently protect and preserve farmland, ranch land, and open space in Solano County, the North Bay Aqueduct Alternative Intake Project being pursued by DWR and Solano County Water Agency (SCWA), the Delta Conservancy Strategic Plan, the Delta Protection Commission's Economic Sustainability Plan called for in the Delta Reform Act.

A number of Yolo Bypass floodplain enhancements are currently in the planning stage (DWR and USBR 2012). These efforts are designed to meet the goals of NMFS Biological Opinion RPAs I.6.1 and I.7: (a) to modify the Yolo Bypass to increase the frequency, duration, and magnitude of floodplain inundation, and (b) to improve passage and habitat conditions for listed fish species. Enhancement would allow parts of the Yolo Bypass to flood in drier years and for longer durations, using a new gate on the Fremont Weir. Relative to CSC restoration, more frequent outflows from the inundated Yolo Bypass floodplain would contribute zooplankton and phytoplankton biomass to the CSC food web, supporting native Delta fish and wildlife populations.

Within and adjacent to the CSC are lowland grassland-seasonal wetland-vernal pool complexes, some of which are in preserves and others part of active ranch lands. These areas link directly to Suisun Marsh (Figure 1-3). Jepson Prairie is one of the largest and most well-preserved vernal pool landscapes remaining in California, and is host to a multitude of rare, threatened, and endangered species. Jepson Prairie is considered a high-value conservation area in the Solano County Habitat Conservation Plan (SCWA 2012). The Solano Land Trust and other conservation groups are actively trying to preserve additional lands within Jepson Prairie through multiple strategies, including conservation easements and outright property acquisitions. The continued preservation and enhancement of this corridor would help to maintain ecological linkages between the CSC and Suisun Marsh and increase the ecological benefits to the many species that utilize these contiguous natural communities.

There are currently two mitigation banks planned or built in the CSC, both located on the Yolo County portion of Liberty Island. The planned North Delta Fish Conservation Bank is on the west side of northern Liberty and includes a thin strip of property on the north side of Stair Step Slough. This 811-acre property is owned by the Trust for Public Lands and Reclamation District 2093 and is sponsored by Liberty Island Holdings II, LLC (Wildlands). Proposed species and habitats credits include: Delta Smelt and salmonids, as well as riparian scrub shrub, riparian shaded riverine aquatic, tidal emergent marsh, tidal channel, tidal marsh complex, tule shaded riverine aquatic, and upland levee. The completed Liberty Island Conservation Bank is on the eastern side of northern Liberty Island. This 186-acre property is owned and sponsored by Liberty Island Holdings I, LLC (Wildlands). Proposed species and habitats credits include: Delta Smelt and salmonids, as well as emergent marsh, floodplain wetland, riparian shaded riverine aquatic, riparian wetlands, seasonally inundated floodplain, tidal channels, tule marsh shaded riverine aquatic, uplands, riparian uplands, and levee uplands.



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Sources: Restoration Sites (WWR, 2010 and DWR, 2011);
Cache Slough Planning Boundary (WWR, 2013-0708);
Tidal Waterways (CDFG, 2005 and BDCP, 2012, WWR mod, 2013);
Yolo Bypass (URS, WWR mod, 2010)

Figure 2-9: Public Agency and NGO Tidal and Floodplain Planned Restoration
Cache Slough Complex Conservation Assessment

Table 2-3. Natural, Constructed, and Planned Ecosystem Restoration Efforts in the CSC.

Name	Size (ac)	Hydrology	Year
NATURAL RESTORATIONS (all are Flooded Islands)			
Prospect Island West	372	Tidal	~1963
Little Holland Tract	1,456	Tidal	1983, 1992
Little Hastings Tract	160	Tidal	~1992
Liberty Island	4,339	Tidal	1998
Hall Island	14	Tidal	No date
CONSTRUCTED RESTORATIONS AND ENHANCEMENTS			
North Bay Aqueduct Barker Slough Mitigation Area	4	Tidal	1988
Cache Slough Mitigation Area (Liberty Farms Tip)	170	Tidal	1991
Liberty Farms	1,705	Non-Tidal	2003
Liberty Island Conservation Bank	185	Tidal and floodplain	2010
Mound Farms	689	Non-Tidal	2013
Calhoun Cut (also referred to as Lindsey Slough) Enhancement (DFW)	160	Tidal	2014
PLANNED RESTORATIONS			
Lower Yolo (SFCWA)	1,480	Tidal and floodplain	
Prospect Island (DWR)	1,617	Tidal	
Northern Liberty Island Fish Conservation Bank	809	Tidal	

2.5 Regulatory Framework

Several key state and federal regulatory requirements will apply to restoration projects. Laws and agencies governing these programs include the:

- Federal Clean Water Act (Sections 401, 402 and 404),
- Federal Rivers and Harbors Act (Section 10),
- State and federal endangered species acts,
- State Fish and Game Code,
- California Title 23 and United States Code Section 408 for flood protection,
- Delta Reform Act (that formed the Delta Stewardship Council and the Delta Conservancy),
- Delta Protection Act (that formed the Delta Protection Commission),
- Porter-Cologne Water Quality Control Act,
- Reclamation Districts,
- Central Valley Flood Protection Board, and
- State Water Resources Control Board.

The entire CSC falls within the “Primary Zone” of the Delta, as designated by the Delta Protection Act of 1992, and is subject to the Delta Protection Commission’s *Land Use and Resource Management Plan* (LURMP; DPC 2010). Restoration projects within the CSC are also subject to the Solano County General Plan, which contains policies that pertain to hydrology. Other regulatory programs may apply depending on the specifics of any given restoration project, including the:

- Federal Magnussen-Stevens Act for essential fish habitat,
- Federal Migratory Bird Treaty Act,
- Federal navigation regulations,
- California State Leasing and Permitting, and

2.6 Historical Conditions

A conceptual understanding of how the physical CSC area and greater Delta system functioned in the past will help guide development of sustainable restoration strategies. This section presents a brief account of relevant historical conditions, based on SFEI’s historical ecology investigation of the Delta (Whipple et al. 2012).The historical Yolo Basin extended over 40 miles along the west side of the Sacramento River, ultimately terminating in the tidal sloughs of the CSC (Figure 2-10). Prior to Euro-American settlement of California in the 1800s, the

CSC was a landscape shaped predominately by the interface between tidal, fluvial, and floodplain processes.

Prior to Euro-American settlement of California in the 1800s, the Delta comprised three broadly distinct ecogeomorphic regions: the northern riverine-flood bypass-estuarine region, the central estuarine region, and the southern floodplain-estuarine region. The CSC, within the northern region, was a landscape shaped predominately by the interface between tidal, fluvial and floodplain processes. The historical Yolo Basin extended over 40 miles along the west side of the Sacramento River, ultimately terminating in the tidal sloughs of the CSC.

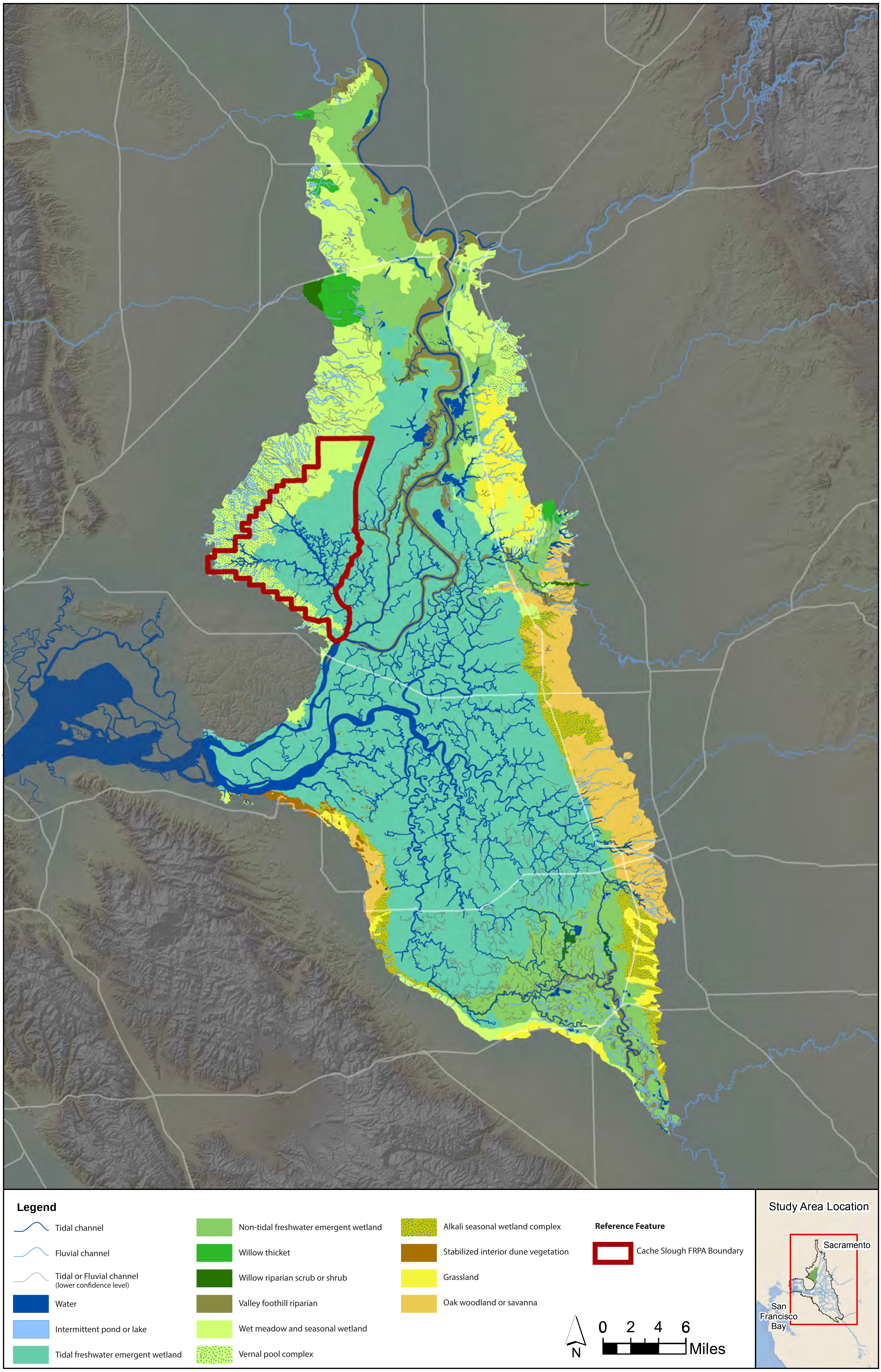
Water that entered the Yolo basin in high tide and flood events drained slowly and supported vast areas of perennial tidal freshwater emergent wetlands (Figure 2-11). Where tidal influence was slight or non-existent in the upper basins, wetlands were interspersed with large lakes but few channels. Historically, hydraulic connectivity and the duration of inundation were higher, allowing more time for waters to interact with the landscape as they flowed south. Seasonal flooding built natural levees of sand and silt along the Sacramento River and other distributaries, and deposited fine, organic laden silts and clays within the expansive flood basins behind them. Riparian forest and upland habitats historically encircled the basins. Riparian habitat along natural levees varied in width, ranging from narrow strips at the tidal end of the spectrum and along the smaller channels, to well over half a mile in width along the Sacramento River. At the mouth of Cache Slough grew mature and diverse riparian forests that extended upstream, finding ideal growing conditions in the well-drained, alluvial sediments of the natural levees that had formed along adjoining sloughs and rivers.

In the more tidally-influenced areas, numerous channels laced the wetland plain, adding to landscape complexity. At higher elevations, river drainage networks supported seasonal wetlands, wet meadows, grasslands, and vernal pool complexes. At lower elevations, the tidally influenced sloughs of the Cache Slough network were truncated in form with wide, fifth-order branches extending only a few miles before terminating into wetlands.

Hydrologic variability affected the ability of aquatic species to utilize the flood basin habitats and to access upper watersheds, such as those of Putah and Cache Creeks. Lakes were likely frequented by native and migratory fish during high flows, when rivers and lakes were functionally connected. Both migratory and resident waterfowl also used these lakes. The high residence time of waters retained in these lakes and in the basins likely resulted in a robust aquatic food web, and dynamic nutrient exchange between emergent marsh and aquatic environments. Riparian woodlands maintained a diverse and abundant array of birds and allowed terrestrial species such as elk, grizzly bear, and smaller mammals to access the region's wetland and aquatic environments.

The landscape of the CSC and the Delta has since changed significantly, due to a series of land-use developments which altered the geomorphic processes that historically shaped this landscape. Starting in the mid-1800s, reclamation efforts were undertaken to make the land suitable for farming and ranching. The extensive Tule canal, completed in 1864, connected the many lakes and sloughs of the Yolo Basin to facilitate drainage of the surrounding lands. In tandem, channelization and simplification of the slough network served to decrease landowner levee costs and increase efficiency of flood drainage. Dewatering of the basin lands followed by years of plowing and wind erosion, led to oxidation and subsidence of the underlying organic soils and subsequently, to the need for higher levees.

By the mid to late 1900s, upstream diversions and impoundments used to irrigate crops and for flood control purposes significantly decreased river flows and sediment loads entering the Delta. The extent of the Yolo Basin has been reduced and pushed to the west by the construction of the Sacramento DWSC. Water that once flowed slowly through a maze of wetlands and riparian forests now moves quickly through the system, descending to open water areas through an engineered drainage network. Tidal influence has also been altered by these modifications. During flood tides, the lack of shear stresses once imposed by wetland and riparian plants and reduced freshwater flow and storage now allow tidal influence to penetrate farther upstream.



Sources: Cache Slough Complex Plan Boundary (WWR 2013-0708); SFEI 2012

Figure 2-10: Delta historical ecology habitat types

Cache Slough Complex Conservation Assessment

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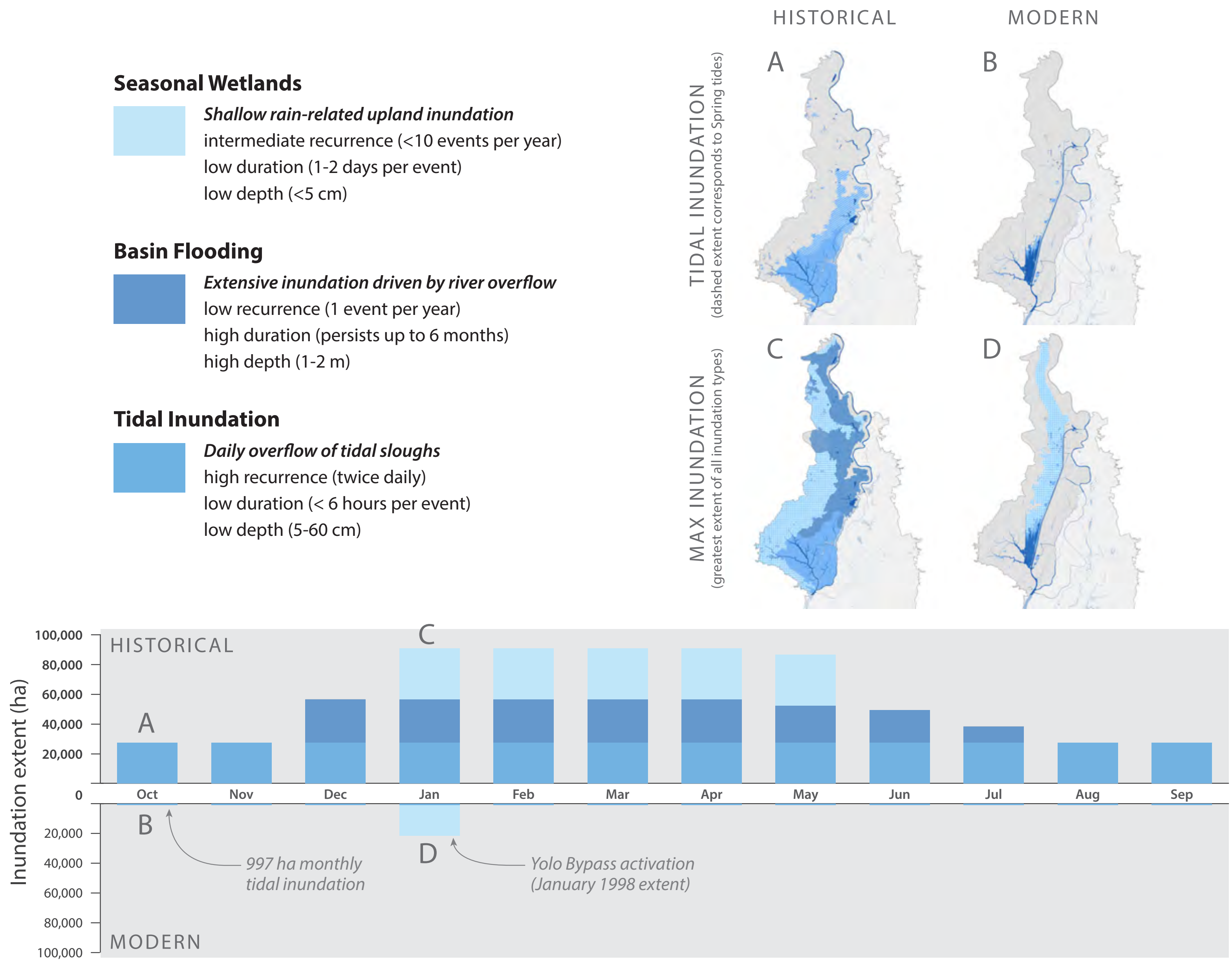

Data Source: SFEI 2012, SFEI 2013

Figure 2-11: Inundation duration, extent, timing

Cache Slough Complex Conservation Assessment

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3 LEVEES AND RECLAMATION DISTRICTS

The over 30,000 ac of diked lands and uplands in the CSC are protected by approximately 130 miles (mi) of levees. Approximately half of the levees are federal Sacramento River Flood Control Project levees and provide flood protection from tides and winter storm flows from the Sacramento River and Yolo Bypass. Levees along the Ulatis Creek flood control project provide local watershed flood protection. A majority of the levees along the DWSC are federal navigation levees as well as Project levees. In the Yolo Bypass, three locations have restricted height levees intended to provide flood storage during major flood events. The remaining non-federal levees protect various lands from tidal and storm flows.

3.1 Background

3.1.1 History of levees and reclamation districts

The California Legislature created the Board of Reclamation in 1861, which facilitated the formation of local reclamation districts (RDs) to collectively drain Delta wetlands and build levees. The Board of Reclamation also developed large-scale plans to provide flood protection in the Sacramento and Yolo Basins (Lund et al. 2007). The Sacramento River Flood Control Project was completed by local, state and federal agencies in 1948 to address Sacramento's basin-wide flooding and drainage problems. As part of the Flood Control Project, levees were constructed and strengthened along the Sacramento River and the Yolo Basin, creating the Yolo Bypass Floodway. Levees were also constructed or improved along many of the tidal waterways. Currently, ten RDs manage most, but not all of the lands protected by levees in or bounding the CSC (Figure 3-1).

3.1.2 Levee classifications and functions

The levee classifications used in this Characterization Report reflect several distinct functions and are sub-classes of two levee types recognized by the Central Valley Flood Protection Board (CVFPB): (1) Project levees - those constructed or improved under the Sacramento River Flood Control Project, and (2) Non-Project levees—all other levees. Table 3-1 describes the levee classifications and provides example locations where each levee type is found and the miles of each levee type. Figure 3-1 maps their locations.

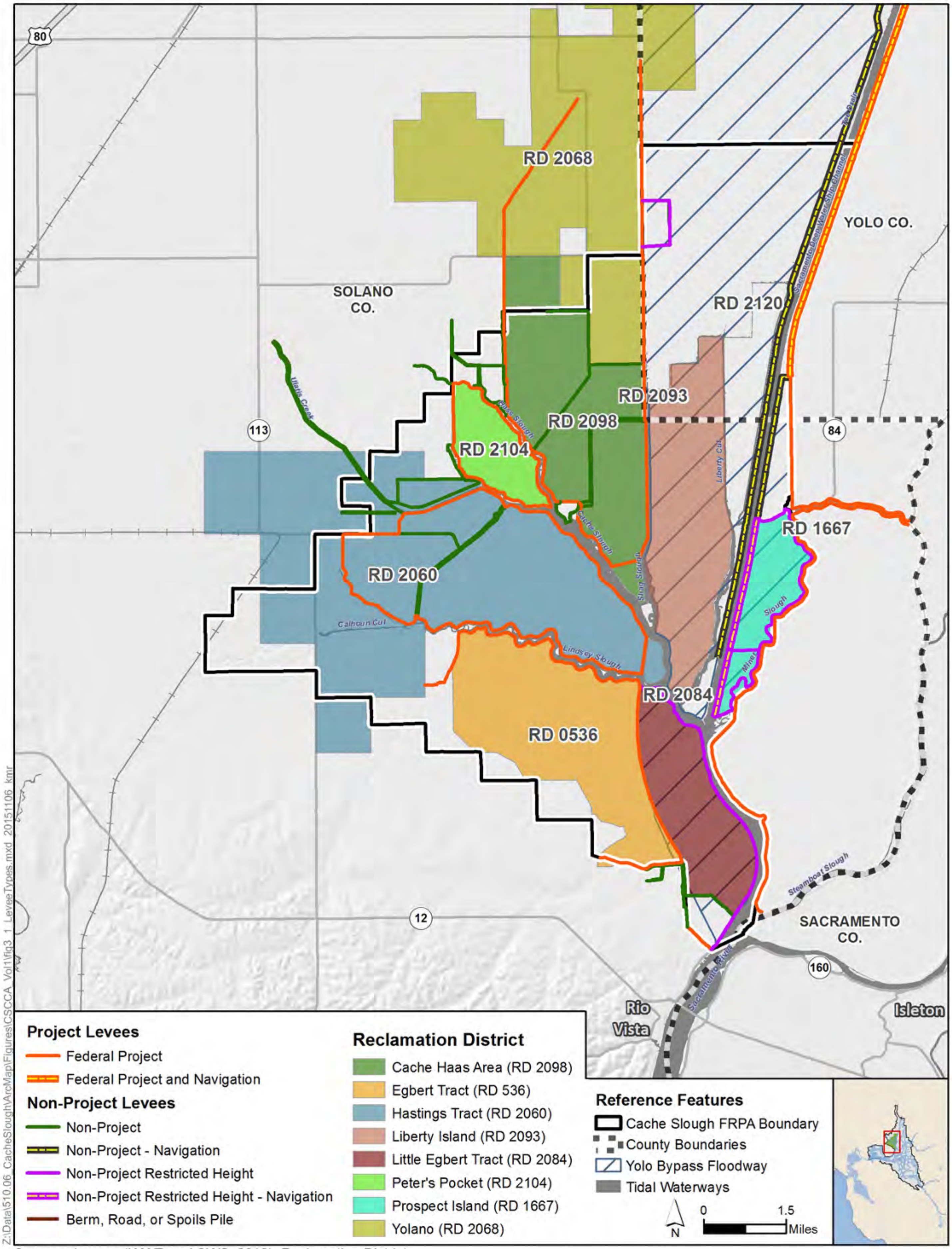
Table 3-1. Cache Slough Complex Levee Classifications.

Levee type	Description	Examples	Miles of levee
PROJECT LEVEES			
Federal project	Part of the Sacramento River Flood Control Project	Hastings Tract	59.5
Federal project and navigation	Doubles as DWSC federal navigation project levee	East side DWSC	4.6
Federal project breached	Breached levee, no further maintenance	Liberty Farms tip	1.6 *
NON-PROJECT LEVEES			
Non-project	Not part of the Flood Control Project	Hastings Cut	36.8
Non-project and navigation	Doubles as DWSC federal navigation project levee	West side DWSC	12.5
Non-project restricted height	Doubles as lower levee to allow protected area to be flood storage for major events	Prospect Island, Little Egbert Tract only	14.7
Non-project restricted height and navigation	Triples as DWSC navigation and flood storage	Prospect Island DWSC	3.7
Non-project breached	Breached levee, no further maintenance	Liberty Island, Little Holland Tract, Little Hastings Tract	24.9 *
Berm, road or spoils piles	Small elevated feature that can influence water movement	Calhoun Cut	21.2 *
Total miles, all levees:			**177.5**
Total miles, levees currently providing flood protection*:			**129.8**

* Three levee categories do not provide current flood protection: federal project breached, non-project breached, and berms, roads, or spoils piles

Both the Project and Non-Project levees contain sections that serve multiple functions. For example, DWSC levees include: sections that are Project navigation levees, supporting the Sacramento River Flood Control Project and ship navigation; non-Project navigation levees supporting ship navigation; and Non-Project navigation and restricted height levees, supporting both ship navigation and flood protection within the Yolo Bypass.

Most Project and Non-Project levees are classified as agricultural levees, meaning their main function is to protect agriculture from flood impacts (Betchart 2008). These levees generally fall under one of two condition standards—the Hazard Mitigation Plan (HMP) standard or the Public Law 84-99 (PL 84-99) standard. The HMP standard is recognized as providing a very basic level of flood protection. It provides marginal protection by establishing an interim, short-term levee design standard that lessens the likelihood of repeat flood damages, and is a precursor for Federal Emergency Management Agency (FEMA) disaster assistance. The PL 84-99 design standard is the minimum nationwide levee standard for all federal flood control project levees, but Non-Project (non-federally funded) levees may also qualify for inclusion in the PL 84-99 program. In the Delta, some Non-Project levees may achieve a "Delta-Specific" version of the PL 84-99 standard if they meet certain design criteria and pass an inspection. These levees are effective in providing basic flood protection and are eligible for USACE emergency assistance (Betchart 2008).



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Sources: Levees (WWR and SWS, 2013); Reclamation Districts (DWR, 2013); Cache Slough Planning Boundary (WWR, 2013-0708); Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013)

Figure 3-1: Levee Types and Reclamation Districts
Cache Slough Complex Conservation Assessment

3.2 Levee Conditions by Management Unit

Levees within the CSC Assessment area are described below by management entity. A majority of the levees are maintained by RDs, but some levees are also maintained by the USACE, the Port of West Sacramento, and DWR (Figure 3-2). DWR prepared a levee conditions assessment in 2012 for the Delta Stewardship Council (DWR 2012a). Table 3-2 summarizes levee types and compliance status for each management unit.

3.2.1 Little Egbert Tract (RD 2084)

This tract is composed of agriculture fields and is surrounded by levees on all sides. Little Egbert Tract is located within the most southern portion of the Yolo Bypass and is designed to function as a flood storage basin during major storms. Its eastern, waterside levee along Cache and Lindsey sloughs is a Non-Project, restricted height levee.

3.2.2 Egbert Tract (RD 536)

Egbert Tract is primarily agricultural land bordered by Little Egbert Tract to the east, agricultural infrastructure and Rio Vista to the south, additional agriculture and hillslopes to the south and west, and Lindsey Slough to the North. The levees around Egbert Tract are all Project levees, including the Yolo Bypass federal Project levee that borders Little Egbert Tract.

3.2.3 Hastings Tract (RD 2060)

Hastings Tract is a diked agricultural island, bordered by Wright Cut to the east, Lindsey Slough to the south, agricultural ditches to the west, and Cache Slough to the north. Interior to Hastings Tract are several Non-Project levees that border both sides of Hastings Cut and an agricultural ditch connected to Hastings Cut. The Mahoney-Ulatis Tract is also diked agricultural land located within RD 2060 just north of Ulatis Creek, west of the upper end of Cache Slough, and is surrounded on all sides by Non-Project levees.

3.2.4 Peter's Pocket (RD 2104)

Peter's Pocket is a diked agricultural island and is bordered by Hass Slough to the east and north, Cache Slough to the south, and agricultural fields to the west. The district has been inactive since 2003 (Michael Brandman Associates 2009). The levees around Peter's Pocket are all Project levees.

3.2.5 Cache Hass Area (RD 2098)

The levees bordering RD 2098 are all Project levees, which provide flood protection for the RD. Internally, there are several Non-Project levees along Duck Slough and other agricultural ditches, which provide both flood protection and support water management with the area. Land use within RD 2098 is comprised of agriculture and managed wetlands. At the southern-most tip of the Cache Hass Area is a small flooded island, Liberty Farms Tip, constructed by DWR in 1991 by breaching a Project levee to create the 166-ac Cache Slough Mitigation Area.

3.2.6 Yolano District (RD 2068)

RD 2068 is bordered by the Yolo Bypass to the east, RD 2098 to the south, and additional agricultural fields to the west and north. The Yolano District is comprised of agricultural fields. Both the Yolo Bypass levee to the east and the levees to the west are Project levees. The RD2068 water diversion and drain on Shag Slough are among the largest in the region.

3.2.7 Liberty Island (RD 2093)

As part of the original Sacramento River Flood Control Project, Liberty Island was one of the flood storage basins surrounded by restricted height levees. Liberty Island, leveed in 1917, has a long history of flooding, having flooded 27 times between 1917 and 1973 (Dickmann 1981). Flood flows were projected to increase across Liberty Island as a result of constructing the DWSC, from a target of 2.5 feet per second to 3.5 feet per second (USACE 1948). In 1995, a large portion of the levee at Liberty Island’s southern end crumbled, resulting in mass flooding. The levee was repaired but failed again in 1998. Since 1998, Liberty Island has remained flooded and the levees are not maintained. The levees are categorized as Non-Project, breached levees. Liberty Island is now a CDFW Ecological Reserve.

3.2.8 Little Holland Tract (RD 2120)

RD 2120 levees breached in 1983, were repaired in 1991, but breached again in 1992. Little Holland Tract was purchased by the USACE in 1999 for fish and wildlife mitigation for USACE civil works projects. The tract is now permanently flooded and the levees are not currently maintained by USACE.

3.2.9 Prospect Island (RD 1667)

The Prospect Island Reclamation District was active from 1963 to 1994, and was reactivated in 2014. Prospect Island, covering about 1,600 ac, is owned by DWR. Prospect Island lies within the Yolo Bypass, and thus all levees surrounding the island are Non-Project restricted height levees as part of the Sacramento River Flood Control Project. The western levee along the DWSC is also a federal navigation levee.

The levee along the southern Miner Slough side of the property is not actively maintained. A previously repaired levee breach of very large rock rip rap has deteriorated and this portion of Prospect Island is subjected to regular but muted tidal action.

Limited maintenance has occurred on the northern portion of the Miner Slough levee. USBR, which purchased this property in 1996 for restoration (which was never constructed) and then transferred the property to DWR in 2010, repaired breaches on multiple occasions but did not otherwise maintain the levees. DWR cleared levee vegetation in 2012 to allow inspection and future levee maintenance activities.

3.2.10 Non-Reclamation District maintained levees

The Port of West Sacramento, formerly the Sacramento-Yolo Port District, was formed in 1947 to develop and maintain a deep water ship channel and port. The District includes land and levees adjacent to the DWSC. Federal navigation levees line both sides of the DWSC. These levees are maintained by the USACE and Port of West Sacramento.

The Solano County Water Agency maintains two levee areas: (1) the Mellon levee along the far southern boundary of the CSC, north of Rio Vista and (2) the Ulatis Flood Control Channel at the western side of the CSC.

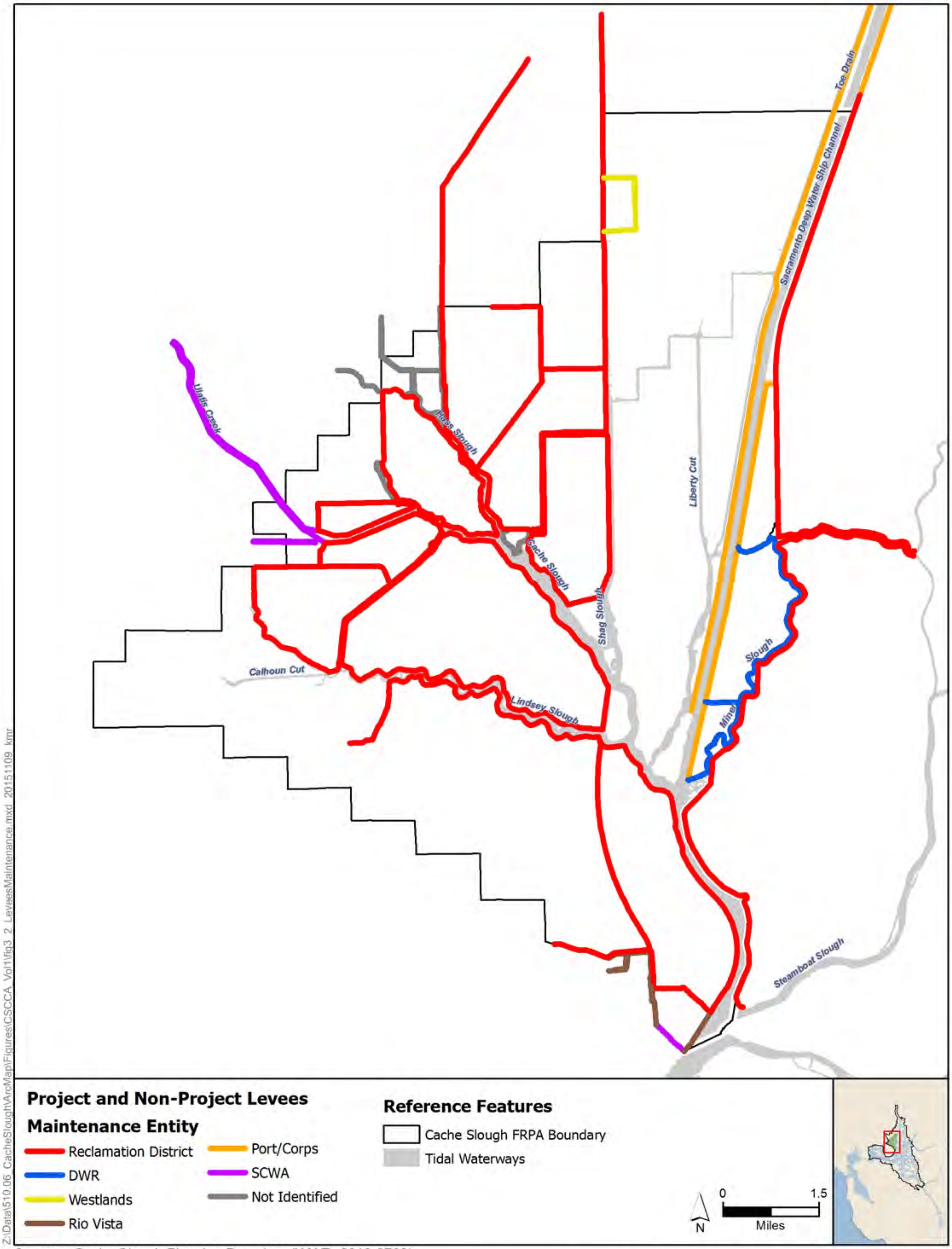
3.2.11 Adjoining lands—Ryer Island (RD 599) and Clarksburg (RD 999)

Two additional RDs are responsible for maintaining two adjacent segments of Project levees along the eastern boundary of the CSC. Ryer Island bounds Miner Slough immediately east of Prospect Island and RD 599 is responsible for maintaining the Ryer Island levee along Miner Slough. The Clarksburg Agricultural District bounds the eastern side of the CSC and the Yolo Bypass and

DWSC and RD 999 is responsible for maintaining the Project levee from Arrowhead Harbor north.

3.3 Summary of levee conditions

According to the Delta-Wide HMP Compliance and DWR Delta-Wide PL84-99 Compliance maps (DWR 2012a), the majority of the levees are below HMP standards (Table 3-2). It would cost roughly $0.5 million per mile to bring the levees up to HMP standards (Betchart 2008). In order to bring the levees up to PL 84-99 Delta-specific standards and qualify for USACE Emergency Levee Assistance and Rehabilitation funds, it would cost $1–2 million per mile, and up to $3.5 million per mile for levees with thick peat soils (Betchart 2008).



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Sources: Cache Slough Planning Boundary (WWR, 2013-0708);
Levees (DWR, 2013 - WWR mod, 2013);
Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013)

Figure 3-2: Levees by Maintenance Entity
Cache Slough Complex Conservation Assessment

Table 3-2. Cache Slough Complex Levee Summaries by Reclamation District

District name (RD number)	Year Est.	Status	Land size [1] (ac)	Subvention Program levee length [2] (miles)		Subvention claims [3] (5-year avg.)	Levee standards compliance [4] (miles)			Average levee elevations [5] (ft NAVD88)	
				Project	Non-project		Below HMP	HMP	PL 84-99	Project	Non-project
Little Egbert Tract (2084)	1946	Active	2,898		5.4						11-18
Egbert Tract (536)	1891	Active	5,689	10.6		$26,043		1.50	9.25	>20	
Hastings Tract (2060)	1922	Active	15,213	16		$67,995	0.38	0.76	9.28	>18	11-18
Peters Pocket (2104)	1964	Inactive	1,451	6.9						>18	
Cache Haas Area (2098)	1963	Active	6,132	11		$40,515		2.00	4.50	>20	11-18
Yolano Tract (2068)	1924	Active	14,151	8.7		$74,018			3.50	>18	
Liberty Island (2093)	1959	Inactive	4,694		16.5		11.36				
Little Holland Tract (2120)		Inactive	NA		12.1						
Prospect Island (1667)	1963, 2014	Active	1,676		7.1		9.87		0.57		11-18
Port of West Sacramento		Active								>20	
Solano County Water Agency										11-18	>11
Ryer Island (599)		Active								>20	
Clarksburg (999)		Active								>20	

Notes:
[1] RD acreage from DWR Reclamation District data set
[2] Levee miles as they relate to the Subventions program. This does not represent the total length of levees within a RD or the total length of levees in the CSC.
[3] Subventions claims from FY 2006-07 through 2010-11. This is the average amount claimed, not the amount the subventions program reimbursed
[4] Compliance data from DWR 2012 levees report to the Delta Stewardship Council. Not all levees were analyzed due to data availability.
[5] Levee elevation data extracted by Stillwater Sciences from DWR 2007 LiDAR data and levee crest centerline data.

4 HYDROLOGY

Delta hydrology is a key ecosystem driver of the CSC, affecting the quality and abundance of water, food, and habitat throughout the region. Within the CSC, the primary hydrologic influences are the tidal regime, stormwater runoff, flood control, local municipal and agricultural exports and returns, and meteorology. Three main features have greatly altered local runoff patterns and volumes: (1) levees, many of which are federal flood control levees designed to protect local farmland from flood flows of the Sacramento River and Yolo Bypass; (2) agricultural irrigation and drainage channels; and (3) stormwater pumps. In addition, operations of the State Water Project (SWP) and Central Valley Project (CVP), as well as construction of the Sacramento River Flood Control Project and the Sacramento Deep Water Ship Channel, have also influenced local hydrology.

4.1 Sacramento-San Joaquin River Delta Influences on Local Hydrology

The Delta is an expansive inland river delta which was formed at the western edge of the Central Valley by the confluence of the Sacramento and San Joaquin rivers. The Delta begins where the rivers reach the low-lying lands at the downstream ends of the Sacramento and San Joaquin valleys, and continues westward to the confluence of the two rivers where they enter Suisun Bay. The Delta covers roughly 1,150 square miles, including 78 square miles of open water (CVRWQCB 2011). The CSC is located within the Delta, at its northwest edge.

The Delta receives runoff from approximately 40% of the land area of California, and approximately 50% of California's total stream flow. Flows through the Delta vary greatly between seasons and years. In a typical year, the Delta receives approximately 28 million acre feet (MAF) of inflow from the watershed, with 75% coming from the Sacramento River, 15% from the San Joaquin River, and the remaining 10% from precipitation and small, eastern tributaries. Major influences of the hydrology of the CSC are discussed below.

4.1.1 Management of Tributary Inflows

Dams in the upper watersheds of the Sacramento and San Joaquin River tributaries capture water and reduce river flows during winter months, and increase flows during summer months. This managed hydrologic regime directly contrasts the unimpaired flow regime, which would exhibit high winter and spring flow volumes (from rainfall and snow melt) and low summer and fall flows (during the dry season). A primary objective of flow management is to reduce salinity intrusions from the Bay into the Delta, by forcing the salt water out with freshwater flows. Maintaining low salinity serves agricultural and municipal water supply purposes. Another primary objective of the flow management regime is to manage flooding by reducing peak flows within the Central Valley.

4.1.2 Diversions and exports

Pumping stations in the south Delta for the SWP and CVP are the largest export facilities in the Delta. The SWP also exports water at the Barker Slough Pumping Plant in the CSC. The Contra Costa Water District exports water at the Contra Costa Canal, Old River, and Middle River, all in the southwest Delta. A handful of seasonally-operated hydraulic flow structures are utilized to manage Delta waters for conveyance purposes: the Delta Cross Channel (an operable gate) and four south Delta temporary barriers (USBR 2013, DWR 2015). These withdrawals and seasonally-operated gates and barriers dominate the hydrology and hydraulics of the Delta, including the CSC.

4.1.2.1 Delta Cross Channel and South Delta Temporary Barriers

Operations of the Delta Cross Channel (DCC) and South Delta Temporary Barriers Project (SDTB Project) affect tide heights throughout the Delta, including in the CSC. The DCC is located on the Sacramento River in Walnut Grove, and diverts water from the Sacramento River into a branch of the Mokelumne River (USBR 2013). The DCC typically is closed in the winter and spring to keep migrating salmonids in the Sacramento River, and open in the summer and fall to manage salinity intrusion into the Delta, dilute local water pollution, and improve the quality of irrigation water supplies in the Central Valley (USBR 2013).

The SDTB Project is implemented by DWR in four locations in the South Delta: the Head of Old River, Old River at Tracy, Middle River, and Grantline Canal (DWR 2015). The SDTB Project installs rock barriers in channels to increase upstream water levels, influence circulation patterns, and improve water quality in the southern Delta area for local agricultural diversions. The barriers also help to improve operational flexibility of the SWP to reduce fishery impacts. The barrier at the Head of Old River functions as a fish barrier and can be installed in the spring and fall. The barriers at Old River near Tracy, Middle River, and Grantline Canal function primarily to benefit agricultural supply and can be installed from April 15 to September 30.

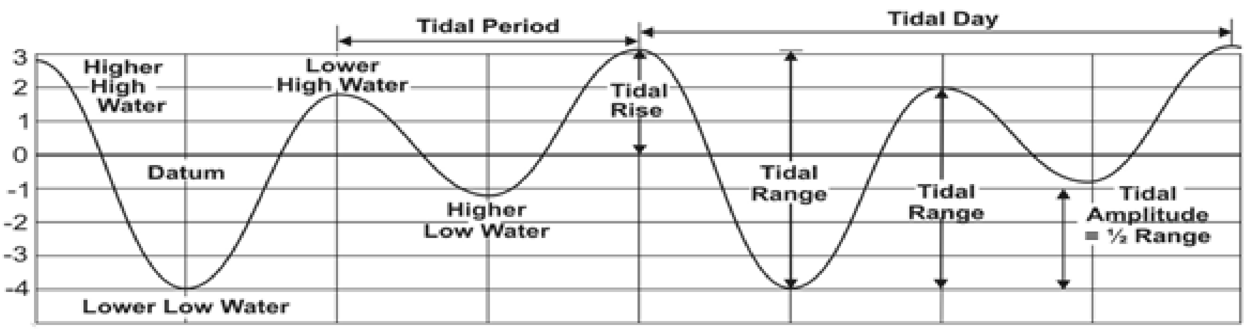
4.2 Tides

Tides influence the entire Delta, diminishing in range and rising in mean level as they reach the major river inputs. The reach of the tides varies in relation to river flows, with higher flows pushing the upstream extent of tidal influence downstream and lower flows allowing tides to reach further inland. Three aspects of the tides are relevant to hydrology: the regime of mixed semi-diurnal tides, tidal datums, and magnitude of daily tidal exchange.

4.2.1 Mixed semi-diurnal tides

The Estuary experiences a mixed, semi-diurnal tidal regime, with a 24.8-hour cycle during which two daily tides of unequal height occur (Figure 4-1). Three main periodic variables control tide stage patterns: (1) spring-neap tide cycle, tied to moon phase (approximately 2 weeks), (2) solstice-equinox cycle tied to the seasons (3 months), and (3) complex astronomical controls that comprise the 18.6-year tidal epoch.

Figure 4-1. Diagram of Mixed, Semi-Diurnal Tides of the San Francisco Estuary.



Source: National Ocean Service 2003.

Tides decrease in amplitude and mean sea level increases from the Golden Gate into the Delta (DWR 2004).This pattern reflects absorption of tidal energy as the tidal wave moves up the Estuary, and the tides meet river flows.

4.2.2 Tidal datums

Tidal datums describe the elevations of the tides relative to a geodetic (earth surface) datum, affecting establishment of riparian and wetland vegetation. Recognizing the hydrodynamics of waterways within the CSC can affect local tide ranges at particular locations, generalized tidal datums for the CSC (Table 4-1) are based upon average conditions over the 18.6-year tidal epoch cycle at the Sacramento River at Rio Vista Bridge tide gage in the Delta (USACE and

DWR 2001). The National Ocean Service updates tidal datums about every 25 years nationally, to adjust for long-term sea level rise. Additionally, changes in tide range due to tidal habitat restoration will also contribute to future differences in tidal datum calculations.

Table 4-1. Generalized Tidal Datums for the Cache Slough Region

Tidal Datum	Elevation (feet NAVD88)
Mean Higher High Water (MHHW)	6.5
Mean High Water (MHW)	5.9
Mean Tide Level (MTL)	4.4
Mean Low Water (MLW)	2.6
Mean Lower Low Water (MLLW)	2.1

Source: (USACE and DWR 2001)

The relationship between local tidal datums and the topography of a site proposed for tidal restoration will influence selection of restoration design elements such as the dimensions and excavated depths of tidal channels, levee breach locations, channel and breach and geometry, as well as grading of features designed to be exposed or submerged at various tidal elevations. Local tidal datums will interact with local hydrology, site topography, and restoration design elements to drive the resulting habitat evolution such as wetland and riparian vegetation establishment.

4.2.3 Magnitude of daily tidal influence on discharge

The daily volume of tidal exchange to the CSC is on the order of ±100,000 cfs, as measured in Cache Slough at Ryer Island (CDEC 2013). By convention, positive tide flows represent ebb tides (i.e., aligned with river flow direction) and negative tide flows represent flood tides. The extents and variations of tidal influence in CSC waterways vary on a daily basis with the factors controlling mixed semi-diurnal tides and with river flows.

4.3 Climate and Meteorology

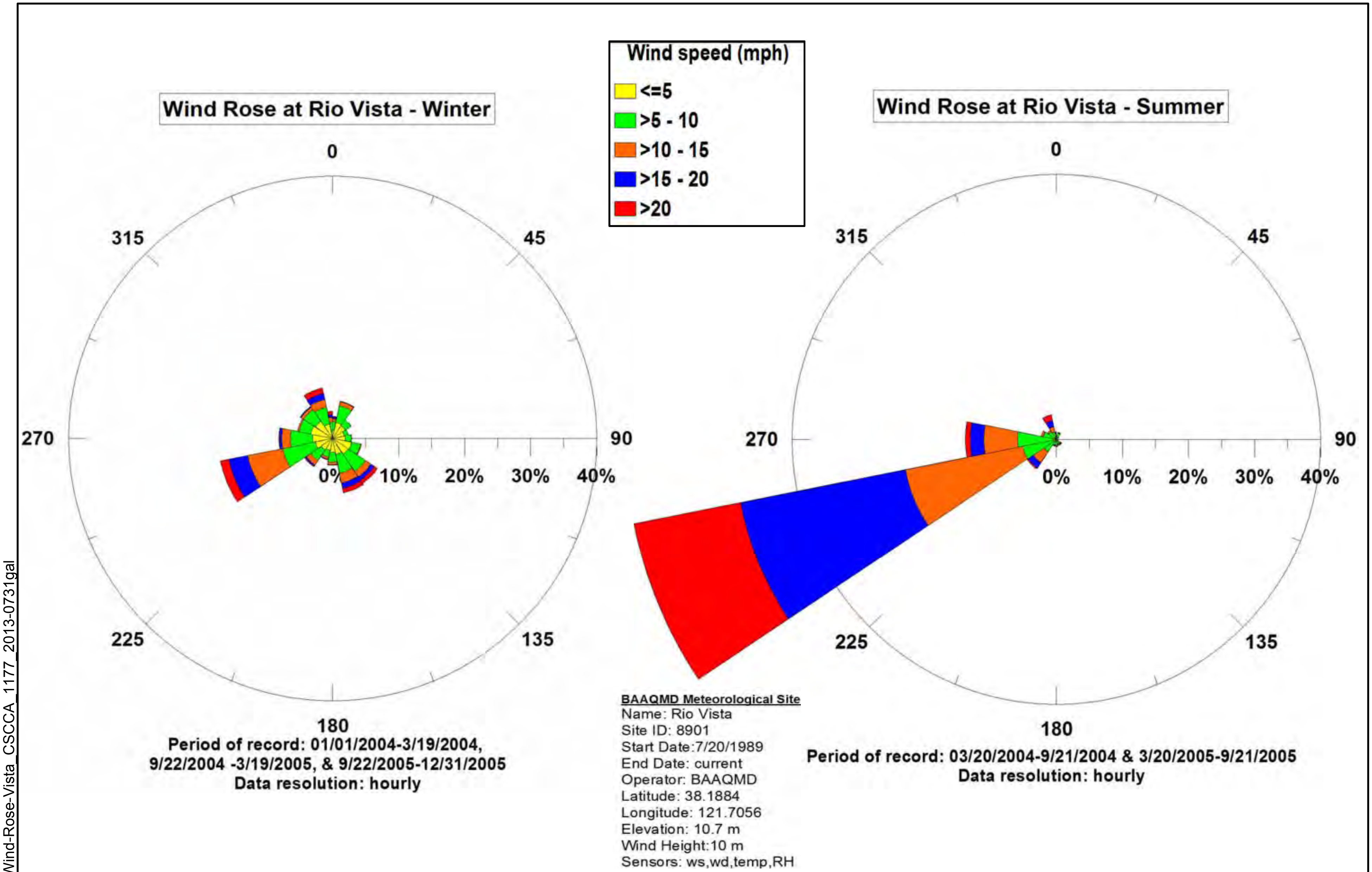
Flows and stage are affected by meteorological forces including rain, wind, air temperature, evaporation, and barometric pressure. These forces are generally co-varying, but are presented independently below.

4.3.1 Wind forcing

The prevailing wind is from the west and southwest. In the summer months, wind is generally strongly from the southwest and wind speeds are higher and more constant. In winter, wind direction is more variable and average wind speeds are significantly lower {Schoellhamer, 2012 #8, Figure 4-2}. Winds can affect tidal restoration potential by creating wave action and by reducing water temperatures.

Wind wave action is a function of wind speed, fetch, and water depth. Fetch (length of open water across which wind can blow uninterrupted) is an important factor in the development of wind waves, increasing wave amplitude with increasing fetch. Wind wave energy can affect sediment resuspension and turbidity in shallow waters and tidal wetland habitats. Increased wave action stirs up benthic organisms and other potential food items in the water column and can facilitate transport of this productivity to adjacent open waters.

Wind over shallow water can reduce water temperature by as much as 3.6°F (2°C), which can have beneficial effects for native fish (Enright et al. 2013b). Depending upon the orientation of channel landforms, wind can also raise water levels in the downwind direction if wind direction, speed, and duration are long enough. The orientations of sloughs and levees relative to prevailing winds can have important ramifications for wind wave erosion potential.



Data Source: Bay Area Quality Management District – www.baaqmd.gov

Figure 4-2: Seasonal Wind Speed and Direction In Cache Slough Complex Region

Cache Slough Complex Conservation Assessment

File: Figure 4-3 Wind-Rose-Vista_CSCCA_1177_2013-0731gal

4.3.2 Evaporation

Regional evaporative losses of water occur due to differences in vapor pressure at the air/water interface, as well as due to related evapotranspiration losses from vegetation. The driving forces in determining evaporation are solar insolation, air temperature, humidity, and wind speed. For purposes of this discussion, evaporative losses associated with agricultural practices are considered part of agricultural diversions. Evapotranspiration associated with vegetation in the region, particularly emergent marsh and channel margin riparian areas, creates a water demand. A cattail (*Typha* spp.), and tule (*Schoenoplectus* spp.) marsh can have evapotranspiration rates of between 1.0 to 10.3 ft of water per year, depending on air and water temperature and wind speed (Drexler et al. 2008).

4.3.3 Precipitation

Average annual rainfall in the Cache Slough region is 20 inches (National Climatic Data Center: https://www.ncdc.noaa.gov/); with most of this precipitation occurring during the rainy season (primarily between November and March). Some additional precipitation originates from ground fog, known regionally as tule fog, during late fall and winter after the first significant rainfall when atmospheric inversions generate fog.

4.4 Local Watersheds

CSC watersheds encompass approximately 280,000 ac and can be divided roughly into nine units, as defined by the primary receiving waterbody (Figure 4-3, Figure 4-4). Watershed topography is very flat within and near the CSC, with hills to the south (Montezuma Hills) and west. Flow routing into the CSC has been greatly altered from its natural state, with almost all of the waterbodies now separated from the surrounding watersheds by agricultural or flood control levees with drainage managed by pumps and drains. A general description of each watershed unit is provided below, working from north to south and from west to east and organized generally by receiving slough. Drainage characteristics and flood protection components help determine whether modifications to infrastructure or additional flood protection may be required at a given site as part of tidal restoration.

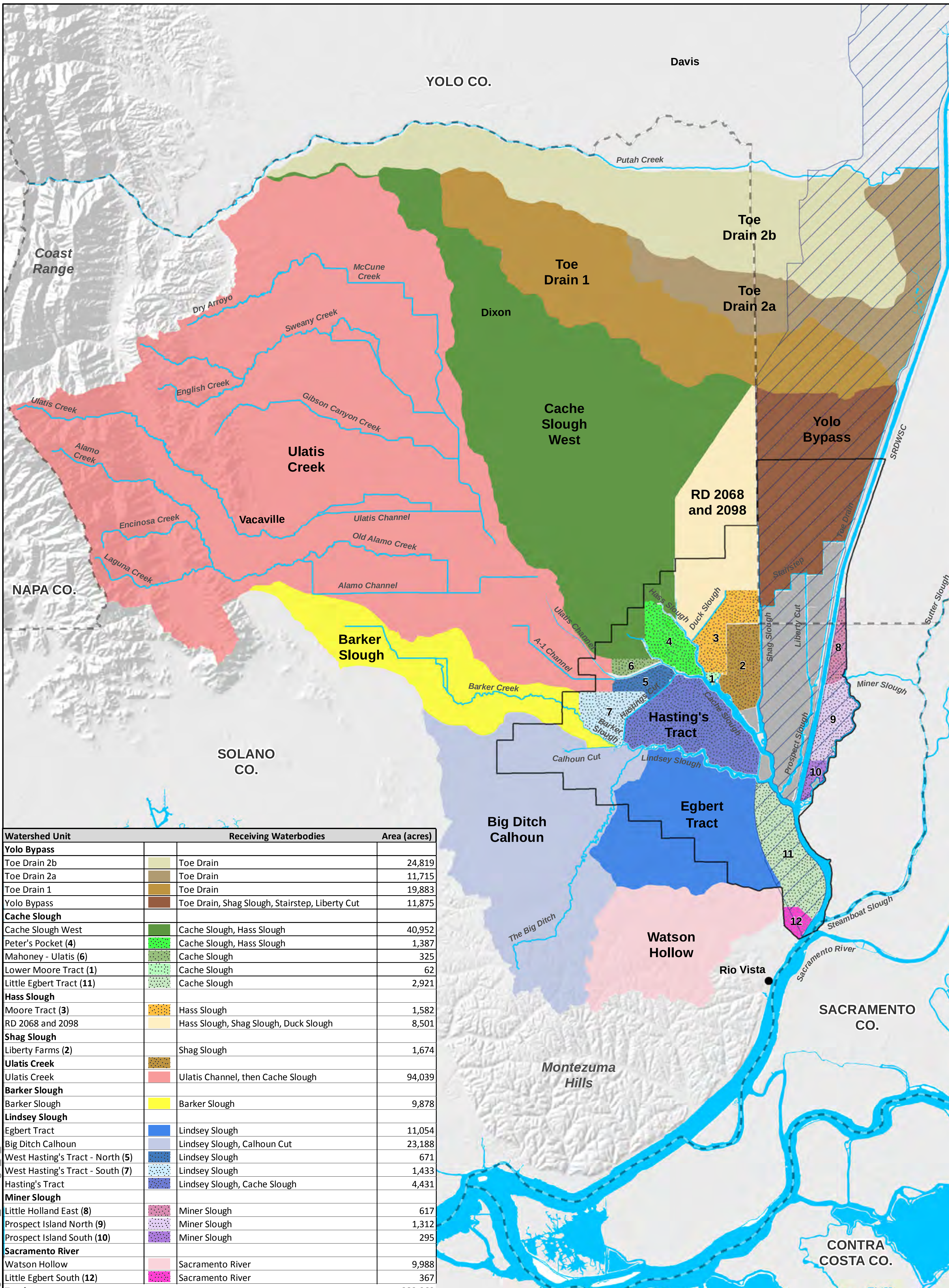
4.4.1 Yolo Bypass

The Yolo Bypass watershed unit is approximately 68,000 ac in size and includes four sub-watersheds: Toe Drain 2b, Toe Drain 2a, Toe Drain 1, and the Yolo

Bypass north of Putah Creek. Runoff from the Yolo Bypass watershed drains primarily into the Toe Drain through a network of agricultural canals and ditches. Portions of the Yolo Bypass sub-watersheds also drain into Shag Slough, the Stairstep, and Liberty Cut. In the winter, this watershed is often dominated by flood flows in the Yolo Bypass.

4.4.2 Cache Slough

Although Cache Slough is the most downstream receiving waterbody within the CSC, it has discrete contributing watersheds of approximately 45,600 ac. North of the Lindsey Slough confluence, Cache Slough receives contributions from about 43,000 ac of land. Between Lindsey Slough and the Sacramento River, Cache Slough receives drainage from Little Egbert Tract, which is approximately 2,900 ac in size. Cache Slough is completely diked off from the surrounding watersheds; all storm water drainage to Cache Slough occurs through pumps and gravity drains.



Watershed Unit		Receiving Waterbodies	Area (acres)
Yolo Bypass			
Toe Drain 2b		Toe Drain	24,819
Toe Drain 2a		Toe Drain	11,715
Toe Drain 1		Toe Drain	19,883
Yolo Bypass		Toe Drain, Shag Slough, Stairstep, Liberty Cut	11,875
Cache Slough			
Cache Slough West		Cache Slough, Hass Slough	40,952
Peter's Pocket (**4**)		Cache Slough, Hass Slough	1,387
Mahoney - Ulatis (**6**)		Cache Slough	325
Lower Moore Tract (**1**)		Cache Slough	62
Little Egbert Tract (**11**)		Cache Slough	2,921
Hass Slough			
Moore Tract (**3**)		Hass Slough	1,582
RD 2068 and 2098		Hass Slough, Shag Slough, Duck Slough	8,501
Shag Slough			
Liberty Farms (**2**)		Shag Slough	1,674
Ulatis Creek			
Ulatis Creek		Ulatis Channel, then Cache Slough	94,039
Barker Slough			
Barker Slough		Barker Slough	9,878
Lindsey Slough			
Egbert Tract		Lindsey Slough	11,054
Big Ditch Calhoun		Lindsey Slough, Calhoun Cut	23,188
West Hasting's Tract - North (**5**)		Lindsey Slough	671
West Hasting's Tract - South (**7**)		Lindsey Slough	1,433
Hasting's Tract		Lindsey Slough, Cache Slough	4,431
Miner Slough			
Little Holland East (**8**)		Miner Slough	617
Prospect Island North (**9**)		Miner Slough	1,312
Prospect Island South (**10**)		Miner Slough	295
Sacramento River			
Watson Hollow		Sacramento River	9,988
Little Egbert South (**12**)		Sacramento River	367
Total			**282,969**

Reference Features

- Yolo Bypass Floodway
- Cache Slough FRP Boundary
- Watershed Units Sorrounded By Levees
- Tidal Waterways
- Flooded Island

N 0 3 Miles

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Sources: Cache Slough Complex Plan Boundary (WWR 2013-0708); Watershed Boundaries (USGS 2012, WWR 2013); Tidal Waterways (CDFW 2005 and BDCP 2012 - WWR mod 2013)

Figure 4-3: Watersheds Draining into Cache Slough Region
Cache Slough Complex Conservation Assessment

4.4.3 Hass Slough

Like Cache Slough, Hass Slough is completely separated from its contributing watersheds by levees. It is the sole receiving waterbody for the Moore Tract unit (1,500 ac) and also receives drainage from the RD 2068/2098 unit (8,500 ac), and portions of both Cache Slough West and Peter's Pocket.

4.4.4 Shag Slough

Shag Slough is the receiving waterbody for the Liberty Farms unit (1,600 ac), and portions of the Yolo Bypass unit. Drainage from the RD2068/2098 unit is also contributes to Shag Slough.

4.4.5 Ulatis Creek

The Ulatis Creek watershed is approximately 94,000 ac in size, and spans the area from the central Coast Range west and northwest of Vacaville, through the urban and suburban areas of Vacaville, and east into agricultural areas. The upper watershed carries runoff from natural Coast Range headwaters into numerous creeks. The City of Vacaville's Easterly Wastewater Treatment Plant releases treated wastewater into Alamo Creek. In the lower parts of the watershed, Old Alamo and Ulatis creeks have been altered and diversion channels added to provide stormwater conveyance. A series of grade control structures and seasonal dams are operated to provide irrigation to agricultural lands in the Ulatis Creek and the Cache Slough West watersheds. The seasonal dams are removed prior to the rainy season to provide flood protection capacity for the Ulatis Flood Control Project. The Ulatis Flood Control Channel is designed to convey a 10-year design storm (9,000 cfs; SCWA 2008).

4.4.6 Barker Slough

The Barker Slough watershed is approximately 9,900 ac in size, and is comprised mostly of agricultural lands, with a small portion of the upper watershed encompassing parts of the City of Vacaville. Runoff from the Barker Slough watershed is impounded within Campbell Lake about 1.5 mi upstream of its connection with Barker Slough and the Barker Slough Pumping Plant (DWR 2002). Wintertime removal of a stacked board dam to prevent flooding allows Campbell Lake to overflow into Barker Slough during runoff events. Additionally, water is released from Campbell Lake via a drain flowing from the lake. Discharge from Campbell Lake flows to Barker Slough, where it is either diverted to the Barker Slough Pumping Plant or continues downstream to Lindsey Slough.

4.4.7 Lindsey Slough

Lindsey Slough receives drainage from around 40,000 ac of agricultural and grasslands encompassing five sub-watershed units: Hasting's Tract, West Hasting's Tract North, West Hasting's Tract South, Egbert Tract, and Big Ditch Calhoun. Big Ditch Calhoun unit is not separated from Lindsey Slough by levees; it drains a portion of the Montezuma Hills to the south. Water flows freely from the Big Ditch Calhoun sub-watershed into Lindsey Slough and Calhoun Cut. In contrast, the 'tract' sub-watersheds are separated from Lindsey Slough by flood control levees and drainage is pumped from the units into the slough.

4.4.8 Miner Slough

In contrast to sloughs of the western side of the CSC, Miner Slough is a continuous slough (rather than terminal or 'dead end' slough), connecting the Sacramento River to Cache Slough via Sutter Slough. Miner Slough has many agricultural diversions, mostly into Ryer Island. The three sub-watershed units in the CSC that contribute to Miner Slough are all diked islands within the legal boundaries of the Yolo Bypass. The Little Holland East is the only sub-watershed actively drained into Miner Slough through a drain near Arrowhead Harbor. Prospect Island South is passively connected to Miner Slough through leaking rock levee repair.

4.4.9 Confluence of Sacramento River, Steamboat Slough, and Cache Slough

The southern extent of the CSC boundary is where Cache and Steamboat sloughs meet the Sacramento River. The Little Egbert South sub-watershed appears to convey water from the adjacent Watson Hollow watershed. It appears to drain from south to north through a drainage ditch which runs along the south side of the federal flood protection levee, into Little Egbert South, and then discharging at the confluence of Cache Slough, Steamboat Slough, and the Sacramento River. Watson Hollow also drains a portion of the Montezuma Hills to the south.

4.5 Regional Land and Water Uses

Regional land and water uses that influence hydrology include municipal water uses, agricultural diversions and returns, and flood control operations.

4.5.1 Municipal water uses

The North Bay Aqueduct (NBA) is an underground pipeline that is part of the SWP and originates at Barker Slough. Water is pumped from Barker Slough into the NBA via the Barker Slough Pumping Plant (BSPP). Both the BSPP and the NBA are managed by DWR to provide municipal drinking water to the Solano County Water Agency (SCWA). Water is impounded in Campbell Lake and discharged to Barker Slough during limited dry season releases and winter rain events. BSPP diversions account for approximately one-third of SCWA's total water supply. Typical mean monthly diversion rates from BSPP range from a low of 10 cfs in the winter to a high of 120 cfs in the summer.

The City of Vacaville's Easterly Wastewater Treatment Plant operates year round and discharges treated wastewater into the CSC via Ulatis Creek. The plant was upgraded from secondary to tertiary treatment in May 2015. The plant is rated to treat 15 million gallons per day (mgd), but operates at an annual average of 7 mgd.

4.6 Agricultural diversion and drains

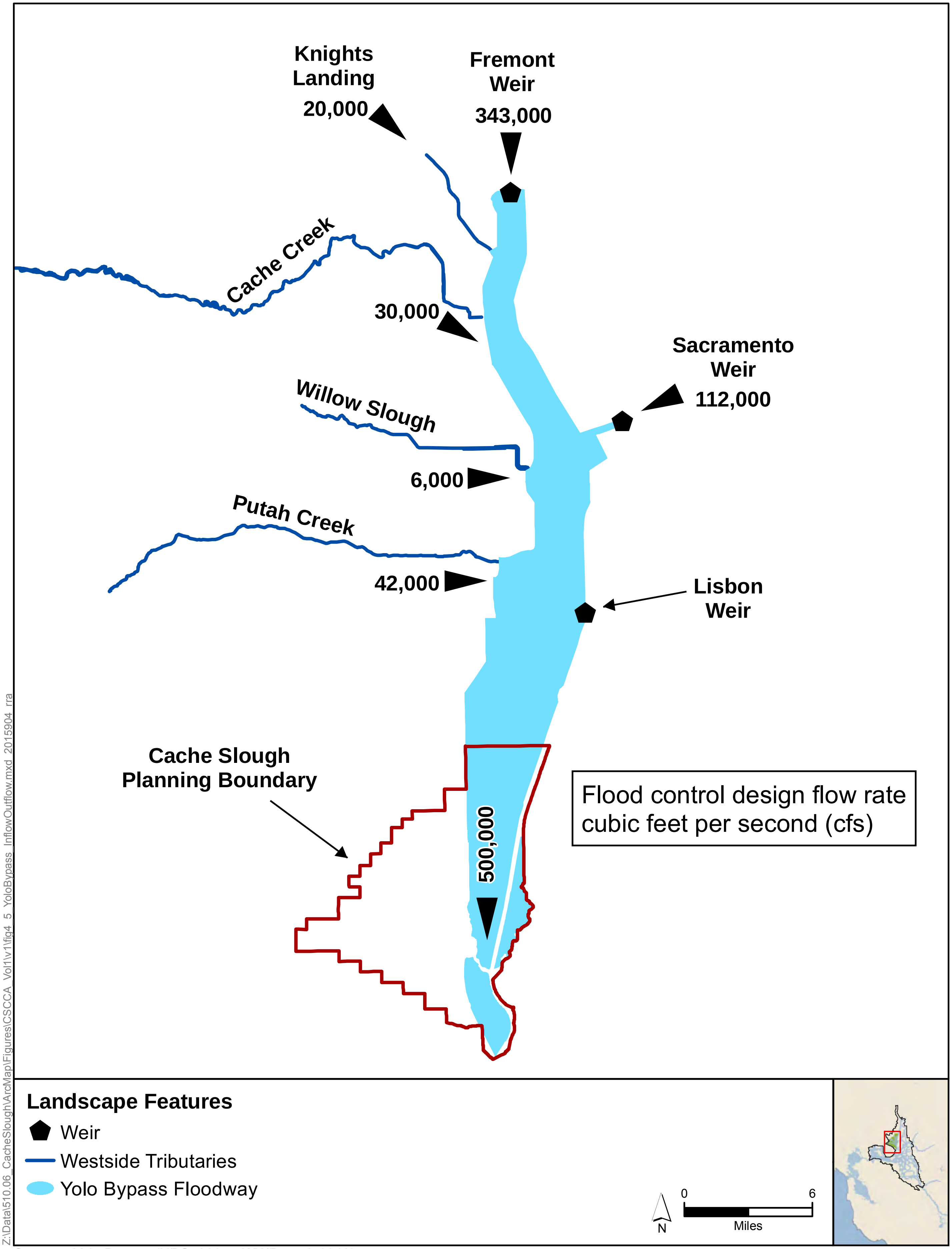
Agricultural diversions (Figure 2-5) include a mix of gravity siphons and pumps, varying in size from less than 15 inches to greater than 30 inches in diameter (SCWA 2010). The RD 2068 Pumping Plant on the northern end of Haas Slough is the largest such diversion in the CSC, with the capacity to divert up 325 cfs. Additionally, Lisbon Weir in the southern Yolo Bypass acts as a diversion. The weir is a riprap structure with flap-type tide gates located in the Toe Drain. During summer, flood tides flow through the gates and high tides overtop the weir. On ebb tide, water is retained in the Toe Drain north of the weir. This tidal charging above Lisbon Weir is essential to maintain water levels in the Toe Drain sufficient to serve irrigation diversions for agricultural operations in the southern Yolo Bypass.

4.6.1 Yolo Bypass floodway

The Yolo Bypass provides flood protection to the City of Sacramento and other nearby cities and farmland by diverting up to 455,000 cfs of floodwaters from the Sacramento River through the Fremont and Sacramento weirs (Figure 4-4) (CDFG and YBF 2008). The Yolo Bypass also receives flows from west side tributaries. The design flow of the Yolo Bypass ranges from 343,000 cfs at Freemont Weir to 500,000 cfs at the southern end. During low flows, the Yolo Bypass drains on its eastern side through the Toe Drain into Prospect Slough.

When inundated, the Toe Drain banks are overtopped and the Yolo Bypass also drains across the Stair Step into Liberty Island and Little Holland Tract, before continuing south through Cache Slough to the Sacramento River confluence. Little Egbert Tract and Prospect Island remain diked with restricted height levees to allow overtopping of flood flows in extreme flood events; these levees overtop at approximately 10 ft and 11 ft (NAVD88) respectively, with five overtopping events occurring since 1967 (1980, 1982, 1983, 1986, and 1997; (DWR 1995)).

The Yolo Bypass is 41 miles long and is bounded on the east and partially on the west by levees constructed in 1924 by the USACE (YBF 2001). Construction of the Sacramento Deep Water Ship Channel navigation levee in 1963 modified the eastern boundary of the bypass (CDFG and YBF 2008). There is no western levee for one section of the Yolo Bypass, south of Putah Creek, as in this location, the natural topography rises high enough to provide flood protection to adjacent lands.



Sources: Yolo Bypass (URS, 2007 - WWR mod, 2010); Cache Slough Planning Boundary (WWR, 2013-0708); Yolo Bypass Flow Data (CDFG & YBF, 2008)

Figure 4-4: Yolo Bypass Inflow and Outflow
Cache Slough Complex Conservation Assessment

4.6.2 Ulatis Flood Control Project

The Ulatis Flood Control Project (Ulatis Project) was constructed in the 1960s and early 1970s to provide 10-year flood protection to agricultural lands downstream of Vacaville (SCWA 2008). The project consisted of realigning, deepening, widening, and straightening 43.5 miles of natural channels. The Ulatis Flood Control Channel enters the CSC from the west and flows into the upstream-most portion of Cache Slough. During the summer, seasonal dams are installed along portions of Ulatis Project channels to provide irrigation water for the Solano Irrigation District and Maine Prairie Water District. These dams are removed prior to the rainy season to ensure flood control is provided as designed. The Ulatis Flood Control Channel is designed to convey a 10-year design storm (9,000 cfs) (Pate, T., SCWA, personal communication, June 2013).

4.7 Seasonal Hydrology

Hydrology exhibits distinctly different conditions and processes between summer (agricultural irrigation) and winter (conveyance of storm and flood flows).

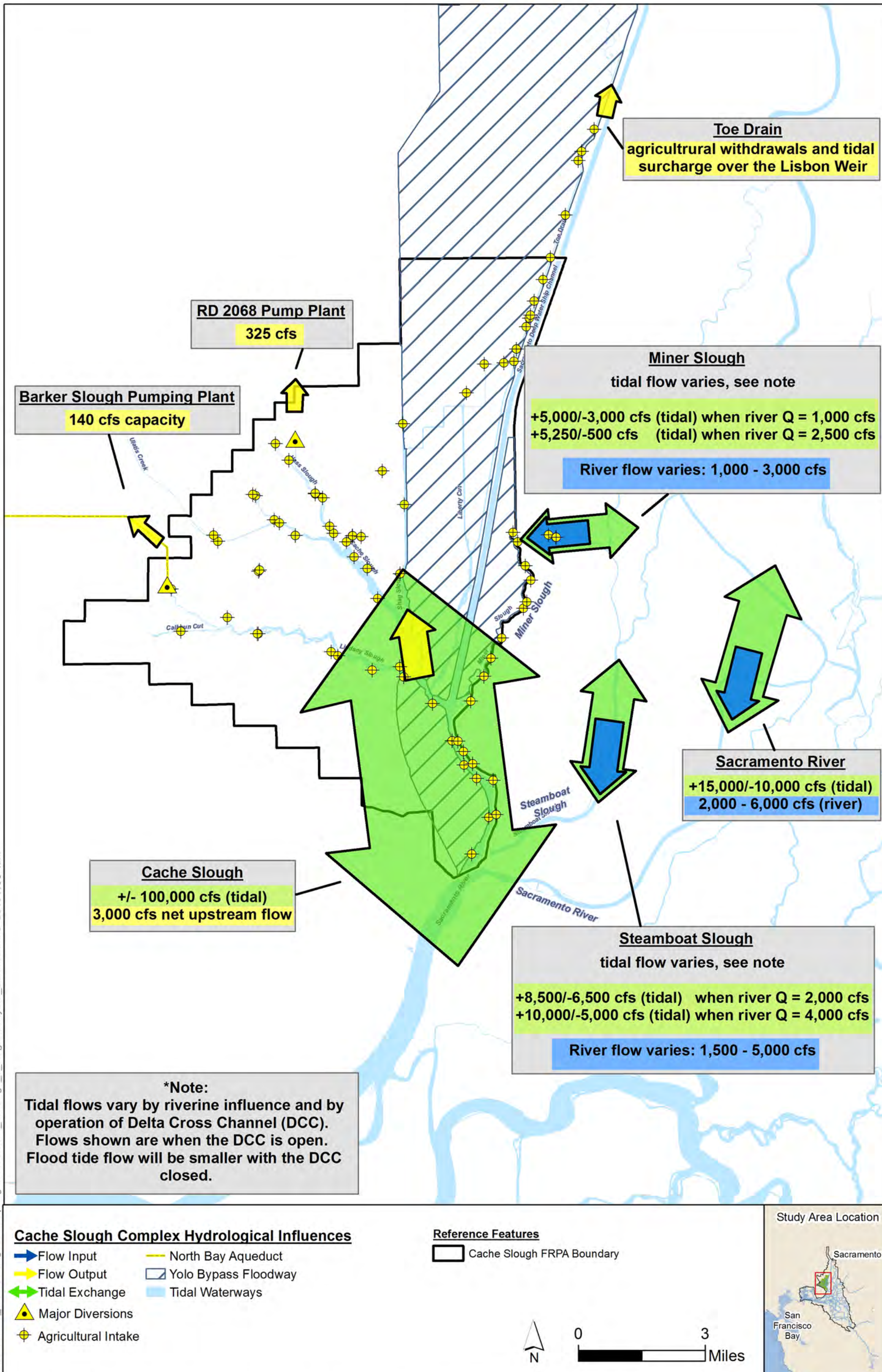
4.7.1 Summer hydrology

In the summer months, the hydrology of the CSC is primarily influenced by the tidal regime and agricultural and water supply diversions (Figure 4-5). The tidal exchange of the CSC (as measured at the USGS Cache Slough at Ryer Island station) is approximately ±100,000 cfs with smaller upstream flows into the southern end of Cache Slough during summer (see discussion below). Miner Slough, Steamboat Slough, and the Sacramento River all have a net downstream flow into the CSC in addition to their respective tidal exchanges. The Sacramento River has an average dry season tidal exchange of +15,000/-10,000 cfs, with average summer flows varying between 2,000 and 6,000 cfs. Miner Slough and Steamboat Slough vary between 1,000 and 3,000 cfs and 1,500 and 5,000 cfs, respectively. The tidal exchange varies with both river flow and DCC operation. In general, when the DCC is closed, the flood tide flow is lower.

One notable attribute of the CSC is that, during low flow periods, the region experiences net upstream flow. In summer conditions, more water enters the region from tides and Sacramento River flow than leaves with the outgoing tides (Jon Burau, personal communication). Due to the numerous agricultural diversions within the CSC, the water supply diversion at the Barker Slough Pumping Plant, and Yolo Bypass diversions via the Lisbon Weir in the Toe Drain, the system can experience a net flow of up to -3,000 cfs (i.e., upstream). This net upstream flow during summer can influence water quality and aquatic productivity throughout the region. Net upstream flows may be associated with longer residence times and reduced mixing between regional and downstream waters.

4.7.2 Winter hydrology

In the winter months, the hydrology of the CSC is dominated by storm flows, flood control operations, and pumped drainage from the diked agricultural lands (Figure 4-6). During non-storm events, tidal exchanges are similar to, but slightly larger than, summer flows. During storm events, river flows dominate Miner Slough, Steamboat Slough, and the Sacramento River, overwhelming the tidal exchange. These flows, combined with flow draining from the Yolo Bypass can cause Cache Slough to become river dominated with no flood tides observed (Figure 4-7).



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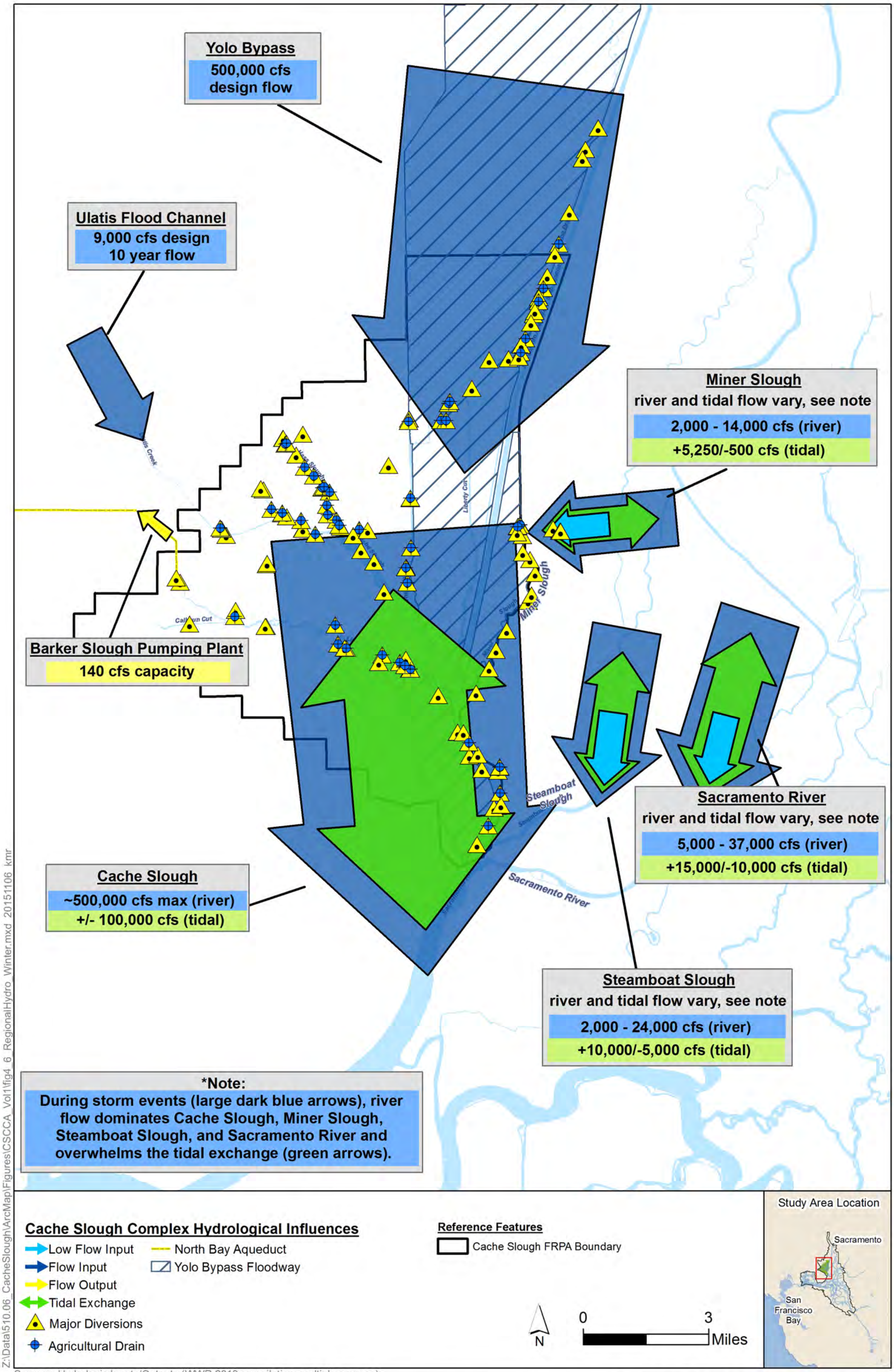
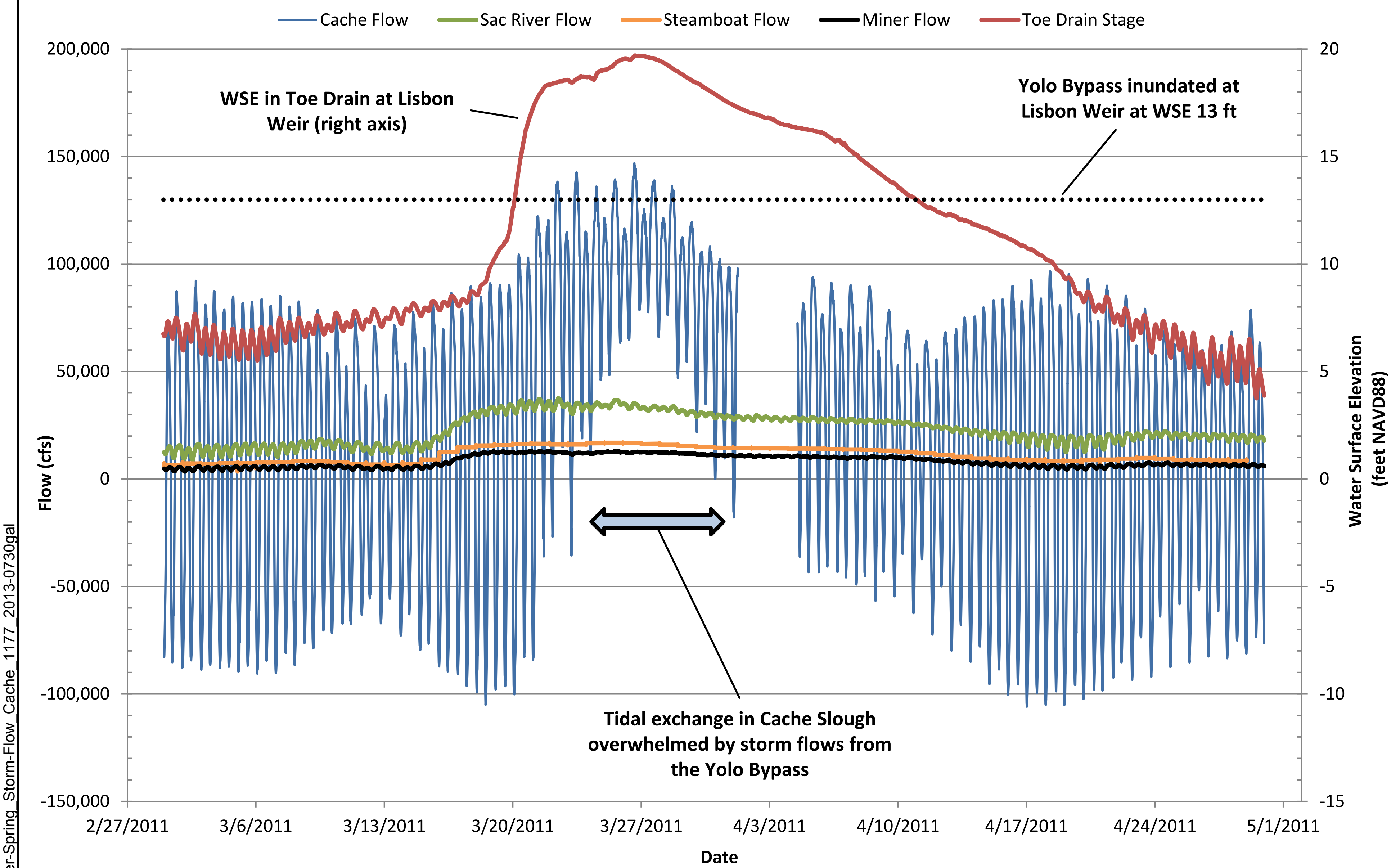
Sources: Hydrologic Inputs/Outputs (WWR 2013 compilation, multiple sources); Cache Slough Planning Boundary (WWR, 2013-0708); Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013); Yolo Bypass (URS, 2007 - WWR mod, 2010)

Figure 4-5: Regional Hydrology - Summer
Cache Slough Complex Conservation Assessment



Sources: Hydrologic Inputs/Outputs (WWR 2013 compilation, multiple sources); Cache Slough Planning Boundary (WWR, 2013-0708); Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013); Yolo Bypass (URS, 2007 - WWR mod, 2010)

Figure 4-6: Regional Hydrology - Winter
Cache Slough Complex Conservation Assessment



Data Source: Cache_Spring_Flood_2011_0301_to_2011_0430.xlsx

Figure 4-7: Comparison of Yolo Bypass Flows with Tidal Exchanges in Cache Slough

Cache Slough Complex Conservation Assessment

File: Figure 4-8_Winter-Spring_Storm-Flow_Cache_1177_2013-0730gal

5 GEOLOGY AND GEOMORPHOLOGY

The geology, soils, geomorphology of diked lands and estuarine and riverine waterways, hydrodynamics, and sediment transport dynamics within the CSC and the surrounding Delta exert primary influences on sedimentation patterns, bathymetry and topography. Changes in sediment supply and transport in particular is a key ecosystem driver affecting past, present, and potential future habitats and ecosystem functions across the landscape.

5.1 Geology

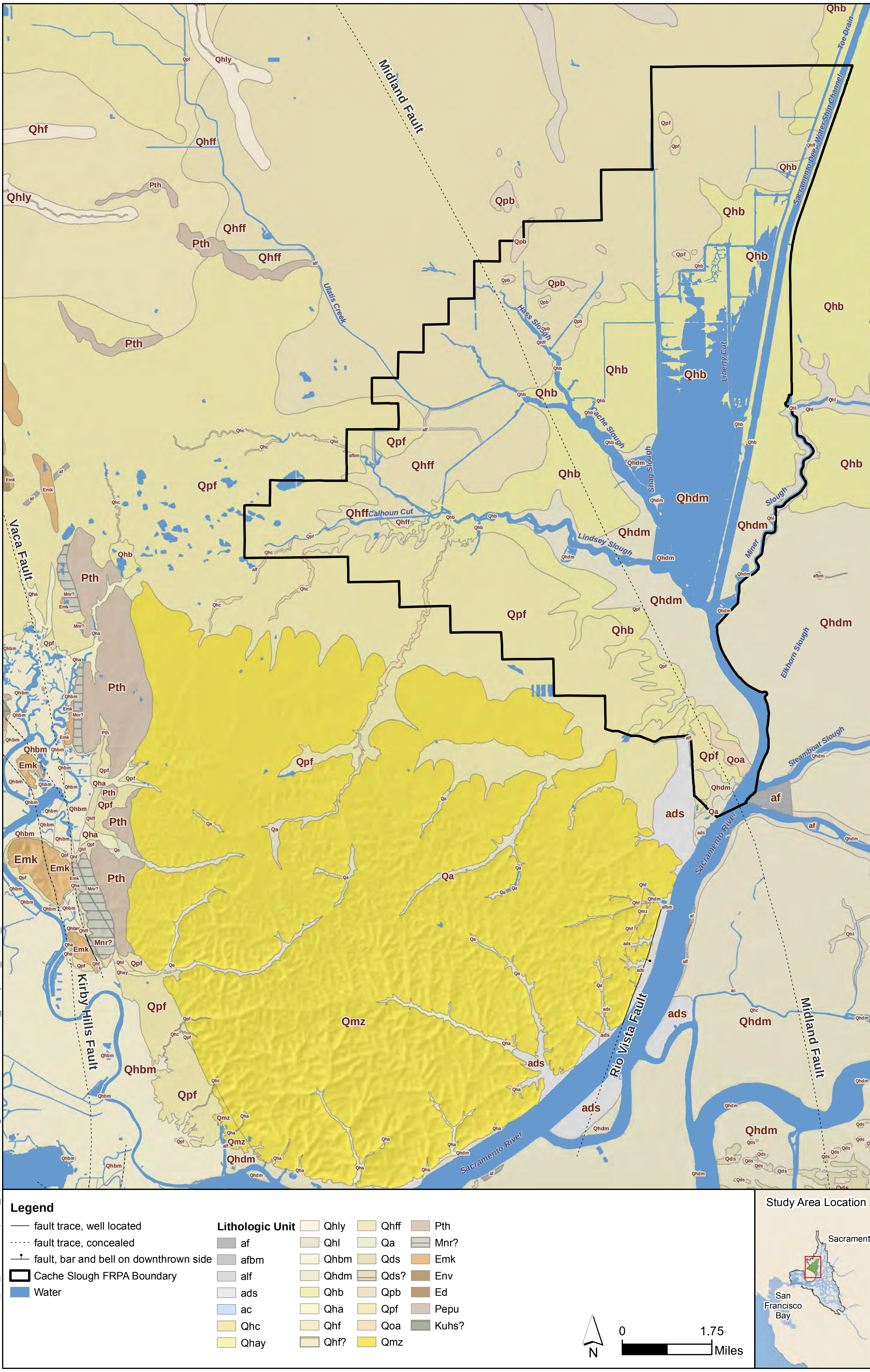
The tectonic setting and geologic history of the Delta occurs within a distinctive geologic province, composed primarily of alluvial sediments that have accumulated within a marine-terrestrial depositional basin since the mid-Mesozoic era. This section builds from the broader understanding of the regional geologic setting and summarizes pertinent information on the local surficial sediments (and soils) and tectonics within the CSC area.

5.1.1 Tectonic setting

The CSC lies within the Great Valley geomorphic province—a deep, alluvial basin principally fed by surrounding uplands of the Coast Ranges to the west and the Sierra Nevada to the east. The central portion of the Coast Range province is a tectonically active zone, composed primarily of right-lateral strike-slip (horizontal sliding motion) faults, separating the Pacific and North American tectonic plates. In contrast, the Great Valley province, which underlies the CSC, hosts few active faults. Shaking-hazard risk within the alluvial portion of the CSC is moderate—with probabilistic peak-ground motion of about 30% (CGS 2013). This is low in comparison to the higher shaking-hazard level predicted for much of the Coast Range (30–80 %), but not as low as that predicted for the middle of the Central Valley (less than 2%, CGS 2013).

There are other potentially active faults located closer to and within the CSC (Figure 5-1). A series of parallel, smaller faults, called the Vaca-Kirby Hills faults, with Late Quaternary activity (last movement estimated within the past 700,000 years), run along the Vaca Mountains and Montezuma Hills within the headwaters of the Cache Slough drainage (CGS 2010a). The Midland Fault Zone bisects the CSC with a north-south trace closely aligned with the Cache Slough channel. This fault is considered “potentially active” since past displacement is estimated sometime during the Quaternary period (CGS 2010a).

While the Delta is not directly affected by ground-rupture hazards, the Delta islands, such as those present in the CSC, are susceptible to liquefaction due to shallow groundwater depths and presence of sandy-peaty soils having low cohesive strength (Mount and Twiss 2005). These lands are also susceptible to levee damage caused by seismically induced failure (i.e., mass-failure, liquefaction) or focused wave-energy (i.e., seiches) in the Delta channels (Mount and Twiss 2005, Betchart 2008; see Chapter 3). However, the CSC area is estimated to have a low susceptibility to earthquake-induced levee failure, compared with the rest of the Delta (Torres et al. 2000). As described in Section 5.2 below, the soils of the CSC are more mineral in nature than those of the Central Delta, and thus should have lower liquefaction potential.



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Sources: Cache Slough Complex Plan Boundary (FRPA 20130129); Generalized Geology (Dawson 2009); Fault Lines (CGS 2010)

Figure 5 - 1: Geology of the Cache Slough Region
Cache Slough Complex Conservation Assessment

5.1.2 Surficial geology

The valley floor of the Great Valley geomorphic province is composed of unconsolidated to semi-consolidated, continental alluvium that has deposited during the Quaternary Period (last 2.6 million years;Wagner et al. 1981, Graymer et al. 2006, Dawson 2009, CGS 2010b). The vast majority of these sediments were delivered from alluvial processes of the Sacramento River and its major tributaries flowing from the Sierra-Nevada and Coast Ranges. Draining the leeward side of the central Coast Ranges, the upper Cache Slough catchment is underlain by old, marine sedimentary rocks of late Mesozoic and early Tertiary age that compose part of the Great Valley Complex and, together, underlie the younger surficial sediments found in the Delta.

The shallow sediments (and soils) reflect the pre-settlement morphodynamics of this region, when alluvial sediment was regularly deposited within submerged areas of the southern Yolo Basin and tidal marshlands and sloughs of the Delta. The CSC is underlain primarily by four distinct alluvial units, laterally encircling the Delta as a product of the interplay between fluvial and tidal forces over the past 100,000 years. The units described below follow the naming convention presented by the California Geological Survey (CGS) (Dawson 2009), and are further described with similarly mapped units published by Helley et al. (1979), Atwater (1979), Wagner et al. (1981), and Graymer et al. (2006; Figure 5-1).

- ***Qhdm*** (southeast side, majority of Delta; similar to *Qi* of Wagner et al. (1981)): Intertidal sediments (peaty mud) of late Holocene age deposited at or near sea level in tidal marshes of the Delta
- ***Qhb*** (central area, extending away from the Delta; similar to *Qb* of Wagner et al. (1981): Fine-grained alluvial flood-basin deposits of late Holocene age with horizontal stratification deposited in topographic lows
- ***Qhff*** (northwestern side, extending even farther away from the Delta; similar to *Q* of Wagner et al (1981): Unconsolidated and semi-consolidated fine-grained, moderately- to poorly-sorted, alluvial-fan sediments of Holocene age deposited by upland streams (e.g., Putah Creek) as debris flows, hyper-concentrated mudflows, or braided stream flows
- ***Qpf*** (southwest side, at base of Montezuma Hills; similar to *Qo* of Wagner et al. (1981): Older alluvial fan deposits of late Pleistocene age derived from Montezuma Hills composed of moderately- to poorly-sorted and bedded sand, gravel, silt, and clay sediments

Formation of surficial materials in the pre-settlement tidal marshlands of the Delta was driven by deposition of inorganic sediment from the Sacramento and San Joaquin rivers, and by *in situ* accumulation of organic matter (Atwater 1982), with the relative contributions of each process varying through time (Drexler 2011).

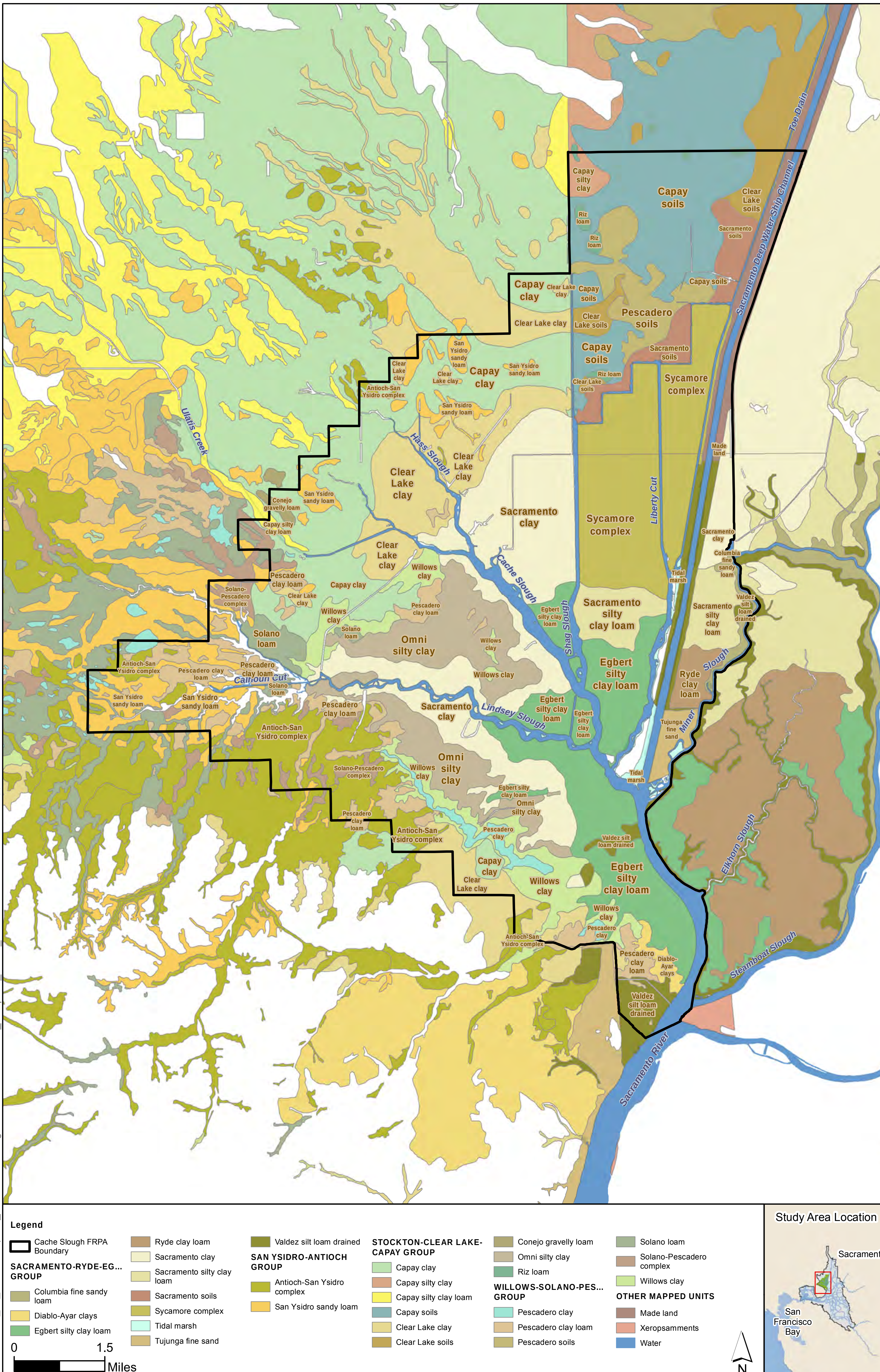
5.2 Soils

This section provides a description of the soils units and hydrologic soils groups, as well as a discussion of potential for soil seepage following restoration.

5.2.1 Mapped soils units

Soils mapped by the Natural Resources Conservation Service (NRCS) reflect the depositional pattern of surface sediments and *in situ* formation of soil materials (NCSS 2012). There are over 34 distinct natural soil units, composing four soil groups: Sacramento-Ryde-Egbert; Stockton-Clear Lake-Capay; Willows-Solano-Pescadero; and San Ysidro-Antioch (Appendix A, Table 5-1; Figure 5-2). These groups generally coincide with the four mapped surficial geologic units of Wagner et al. (1981) and Dawson (2009). In general, the soils are poorly drained, silty-clayey loams with mostly non-saline to slightly saline conditions. The slightly to moderately saline soils account for approximately 20% of the diked and tidal lands. There are also rare occurrences of sandy-gravelly soils with high infiltration potential. The silty-clayey soils have a relatively high potential for shrink-swell behavior, a primary characteristic of expansive soils[2] common to the Delta. This condition generally limits construction of structures without importation of artificial fill or implementation of other significant engineering solutions. Artificial fill is also present in the area, primarily as the dominant material used to construct the levees of the Sacramento Deep Water Ship Channel.

[2] Expansive soils are characterized by the ability to undergo significant volume change as a result of varying soil-moisture content. The 2010 California Building Code, Title 24, Part 2, Section 1803.5.3: Geotechnical Investigations defines an expansive soil as meeting the following provisions: (1) plasticity index of ≥15; (2) >10% soil particles pass a No. 200 sieve (0.075 mm); (3) >10% soil particles are <0.005 mm; and (4) expansion index of >20.



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Sources: Cache Slough Complex Plan Boundary (FRPA 20130708);
USDA Soils (NRCS 2010)

Figure 5 - 2: Soils Units
Cache Slough Complex Conservation Assessment

5.2.2 Soils seepage potential

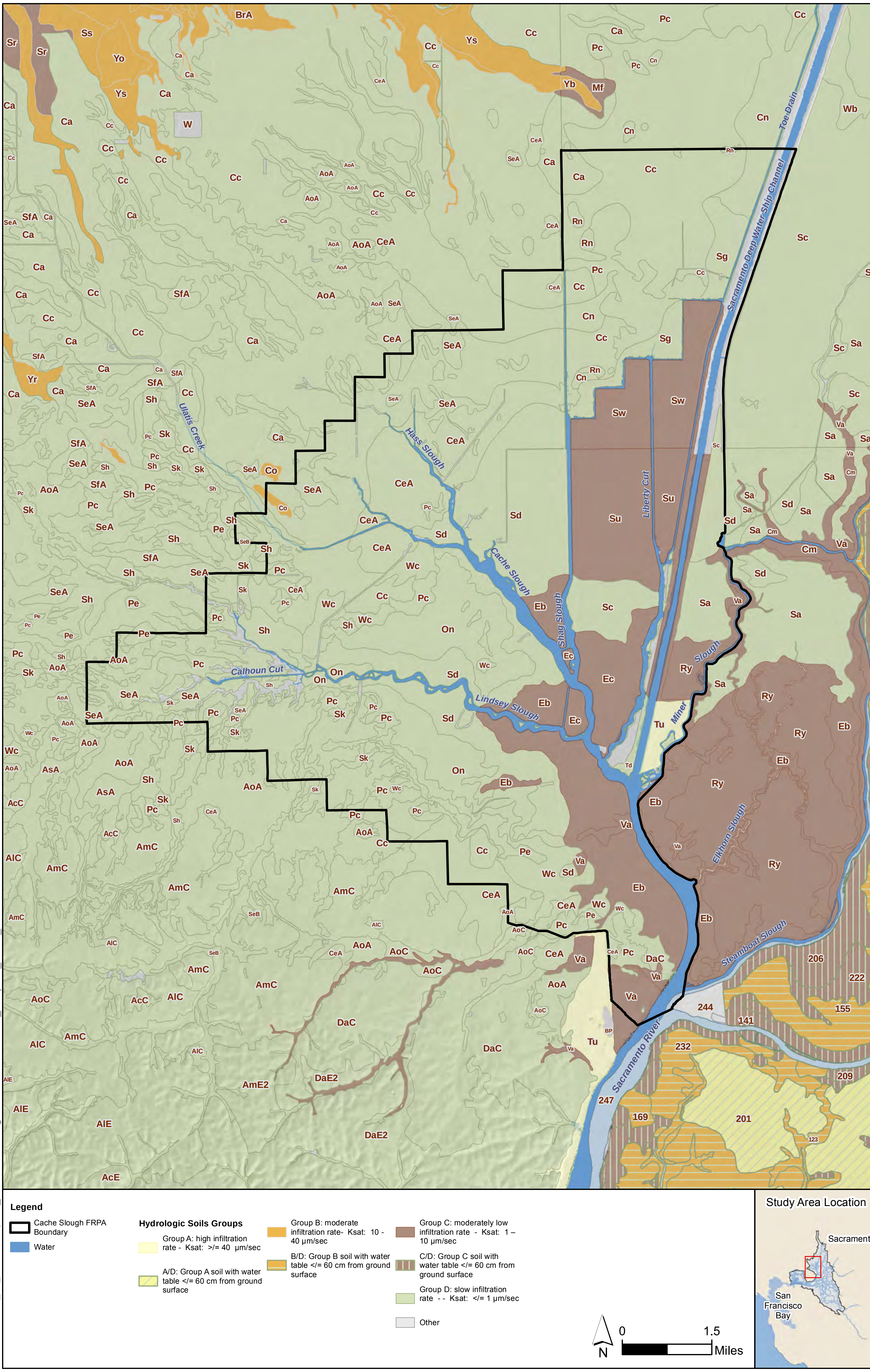
In addition to classifying soil units by series, as described above, the NRCS also classifies soil units within defined hydrologic soils groups, based upon their runoff characteristics. The classification for a given soil unit is determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity (Ksat) and depth to any layer that is more or less water impermeable (such as a fragipan or duripan) or depth to a water table (if present) (NRCS 2007).

In the CSC, soils generally have low seepage potential and fall almost entirely within two hydrologic soil groups:

- Group C soils are generally composed of 20 to 40% clays with less than 50% sands or gravels. These soils have “moderately high runoff potential”, Ksat = 1.42 inches (in) per hour
- Group D soils are generally composed of greater than 40% clays and less than 50% sands or gravels, and exhibit “high runoff potential”, Ksat $\leq$.14 in per hour

The exceptions are one area of soils in the southern portion of Prospect Island, which falls into hydrologic group A, with low saturated runoff potential, and a very small area along the western boundary of the CSC, with soils grouped into hydrologic soils group B, with moderate saturated runoff potential (Figure 5-1).Where soils have low runoff characteristics (i.e., high infiltration rates, even under saturated conditions), there may be potential that tidal inundation, seasonal flooding of restored sites, or both could cause groundwater seepage into adjacent diked lands.

The data presented in Figure 5-3 indicate that much of the eastern extent of the CSC is composed of soil units that are generally of low permeabilities that would not likely facilitate seepage to surrounding lands. This is supported by groundwater monitoring study conducted by DWR (DWR 2013b), which found that an Upper Clay hydrogeographic unit (HU) prevented groundwater connectivity between Prospect and Ryer Islands. The study found that seepage on Ryer Island was primarily related to the presence of a deep sand layer that connects with deeper channels in the region.



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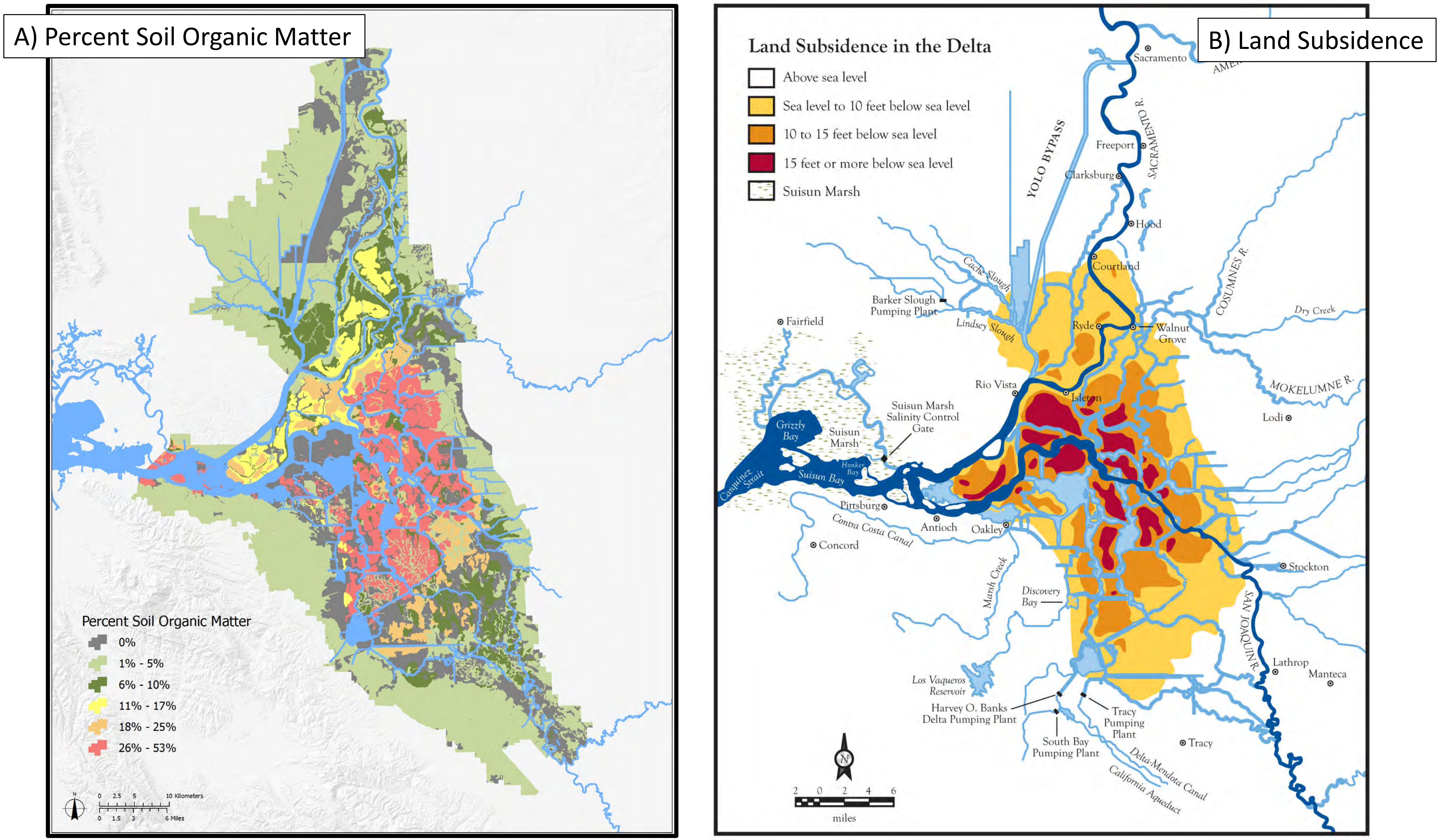
Sources: Cache Slough Complex Plan Boundary (FRPA 20130129); Generalized Soils (NRCS SSURGO 2007)

Figure 5 - 3: Hydrologic Soil Groups
Cache Slough Complex Conservation Assessment

5.2.3 Geographic patterns of subsidence in the CSC

Reclamation and subsequent agricultural practices have led to soil depletion and subsidence of the diked Delta islands (Deverel 2010). However, subsidence has occurred at lower magnitude in the CSC due to thinner peat deposits at the Delta basin edges (Mount and Twiss 2005).

Soil type and organic matter content are key factors that determine rates of subsidence. Within the CSC, inorganic, mineral surface soils (0 to 10% organic content) generally predominate (Figure 5-4) (Deverel 2010). Between zero and 10 ft of subsidence has been documented within the CSC, as compared to more than15 ft in the heart of the central Delta, along the San Joaquin River (Figure 5-4). Subsidence within the CSC has generally been localized in the south-eastern portion, where the soils contain the highest organic content (5 to 10%) (Figure 5-4). Based on future subsidence rates estimated by Deverel and Leighton (2010), these areas are projected to subside up to 1.6 ft more by the year 2050 (Figure 5-5).

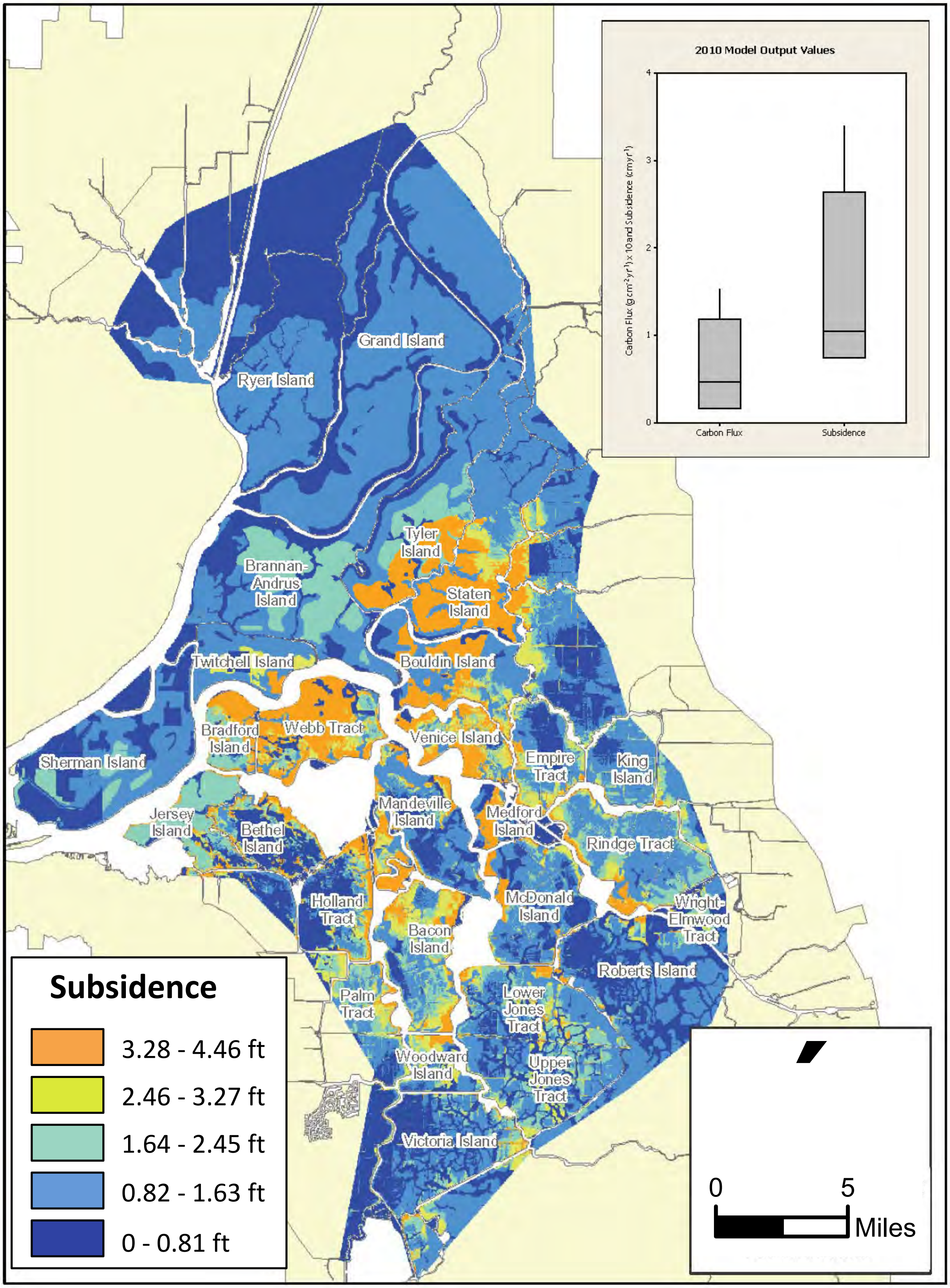


File: Figure 5-4_Organic-Matter_Subsidence_CSCCA_1177_2013-1230gal

Sources: Soils (SWS 2010 based on SSURGO);
Land Subsidence (Lund et al. 2007 based on DWR 1995)

Figure 5-4: Percent Soil Organic Matter and Subsidence throughout the Delta

Cache Slough Complex Conservation Assessment



Source: Deverel and Leighton 2010

Figure 5-5: Estimated Depth of Future Subsidence from 2007-2050

Cache Slough Complex Conservation Assessment

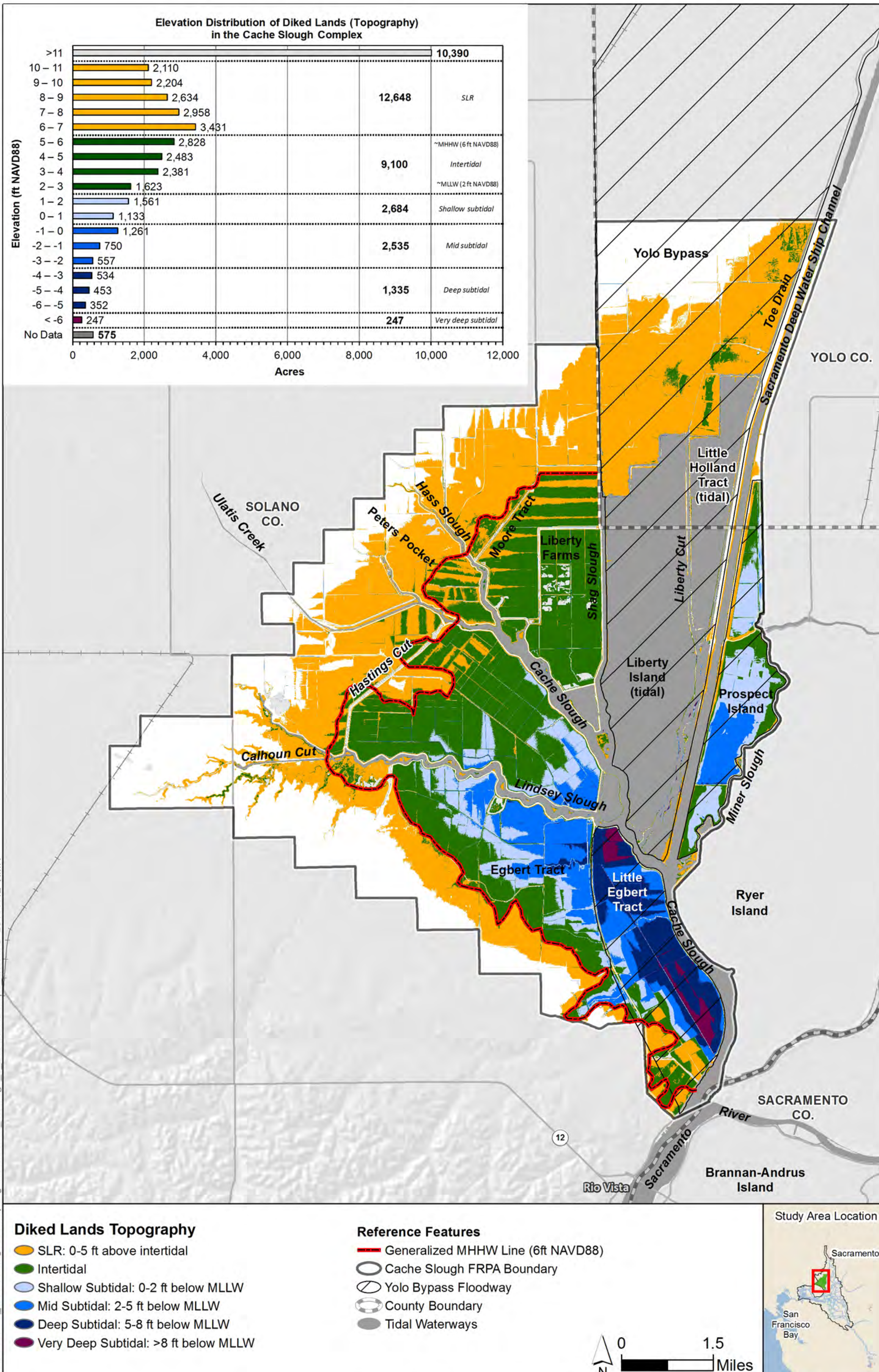
Fig-5-6_Estimated depth of future subsidence_1177-1230gal

5.3 Topography and Bathymetry

Topography and bathymetry are key factors in determining tidal restoration potential in the Delta. Knowledge of the topography of the land surface is important in order to understand the frequency, depth, and timing of inundation of potential restoration sites. Similarly, information regarding the bathymetry of any flooded portions of potential restoration sites helps inform restoration design. In addition, bathymetry of the adjacent tidal waterways is important in considering whether existing channels are of suitable size to convey increased tidal flows that would result from restoration, and whether channels might scour naturally or need to be dredged.

5.3.1 Diked lands topography

Figure 5-6 shows the elevation classifications and spatial distribution of the diked lands of the CSC. The elevations are divided into several categories (bands) relative to the tidal datums shown in Table 5-1.



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Sources: DEM (DWR, 2007 and SFCWA, 2011); marsh habitats (BDCP, 2012 - WWR mod, 2013);
Cache Slough Planning Boundary (WWR, 2013-0708);
Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod, 2013);
Yolo Bypass (URS, 2007 - WWR mod, 2010)

Figure 5-6: Diked Lands Topography
Cache Slough Complex Conservation Assessment

Table 5-1. Diked Lands Topographic Distribution by Elevation Category.

Elevation category	Tidal elevations (ft MHHW or MLLW)[a]	Orthometric elevations (ft NAVD88)	Area of diked lands (ac)	Percent of diked lands
Upland	>5 ft above MHHW	>11 ft	10,390	26%
Sea level rise accommodation	0-5 ft above MHHW	6 to 11 ft	12,648	32%
Intertidal	MLLW to MHHW	2 to 6 ft	9,100	23%
Shallow sub-tidal	0-2 ft below MLLW	0 to 2 ft	2,684	7%
Mid sub-tidal	2-5 ft below MLLW	-3 to 0 ft	2,535	7%
Deep sub-tidal	5-8 ft below MLLW	-6 to -3 ft	1,335	3%
Very deep sub-tidal	>8 ft below MLLW	< -6 ft	247	1%
Unmapped Areas			575	1%
Total			**39,514**	

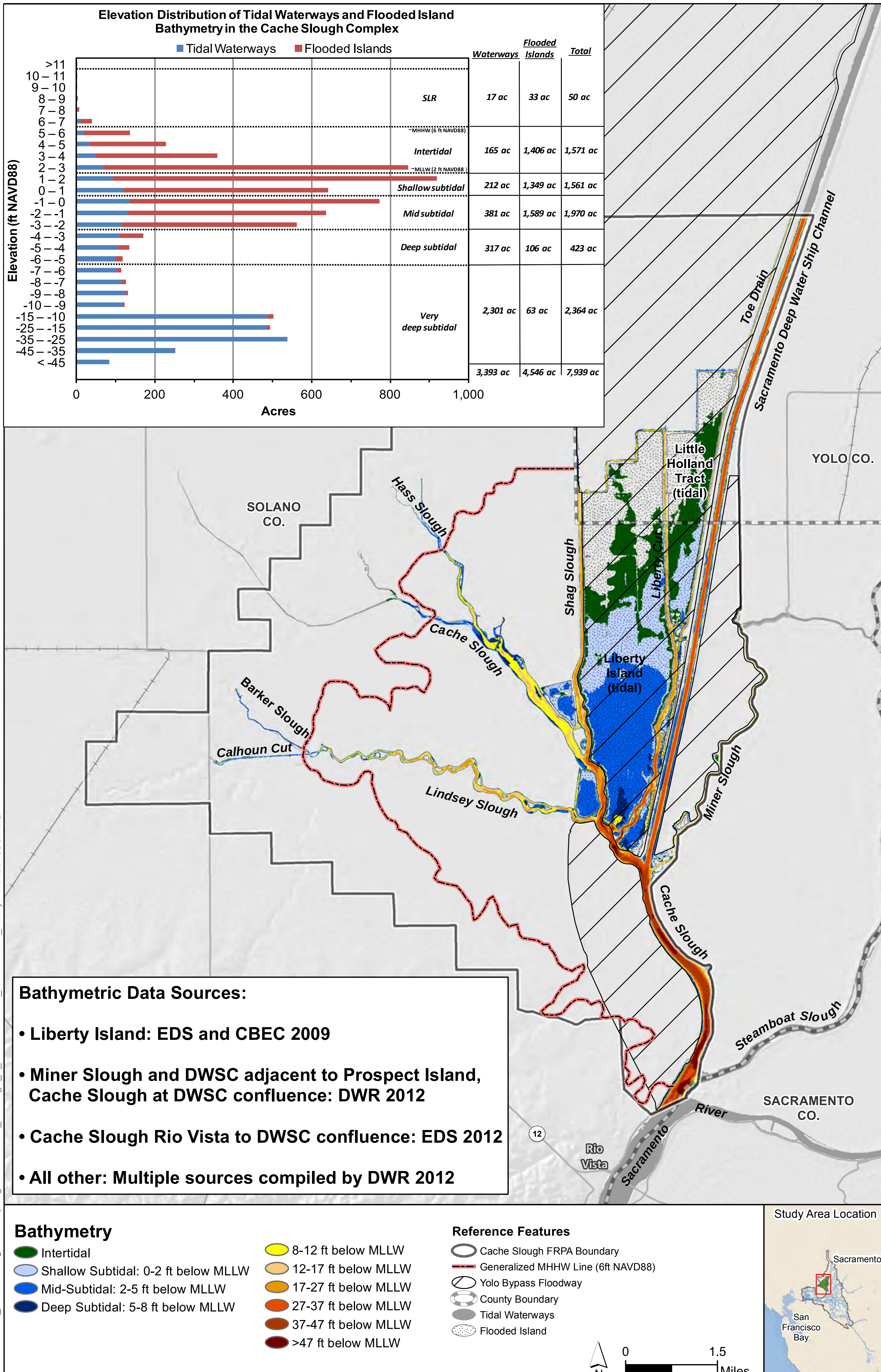
*a. Generalized tidal datums based upon USACE and DWR (2011)

The majority of diked lands within the CSC lie within the sea level rise accommodation (SLR) band (12,648 ac, 32% of the total area), upland elevation bands (10,390 ac, 26% of the total area), and the intertidal band (9,100 ac, 23% of the total area). Generally, surface elevations increase with lateral distance from the confluence of the slough network and the main stem of lower Cache Slough.

5.3.2 Flooded islands and tidal waterways bathymetry

Elevation classifications for the flooded islands and tidal waterways of the CSC are given in Figure 5-7 and Table 5-2. The largest of the flooded islands, Liberty Island, is dominated by middle to shallow sub-tidal zones, with intertidal elevations at the northern end. To the northeast, Little Holland Tract exists nearly equally within the shallow sub-tidal and intertidal elevation bands. The tidal waterways exhibit the lowest elevations with 68% (2,301 ac) of the total area within the very deep sub-tidal elevation interval (Table 5-2). The deepest areas (<-45 ft) are found within lower Cache Slough, between its confluence with Lindsey Slough and the southern extent of the CSC—just upstream of the Sacramento River (Figure 5-7).

Bathymetric changes have been observed in several sloughs within the CSC. In support of the Prospect Island restoration project, hydrodynamic modeling and comparison of USACE hydrographic data collected in 1997 to Central Valley Floodplain Evaluation and Delineation Program data revealed a general pattern of bed lowering in Hass Slough, Lower Cache Slough, Miner Slough, and portions of the DWSC (cbec 2011). This study speculated that the 1997–1998 floods and the increased tidal prism resulting from the breach of Liberty Island led to significant scour within the lower Sacramento River and consequent widening and deepening of Lower Cache Slough.



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Sources: DEM (see above); Cache Slough Planning Boundary (WWR, 2013-0708); Tidal Waterways (CDFW, 2005 and BDCP, 2012, WWR mod, 2013); Yolo Bypass (URS, 2007, WWR mod, 2010); MHHW Line (WWR, 2013)

Figure 5-7: Flooded Island and Tidal Waterways Bathymetry
Cache Slough Complex Conservation Assessment

Table 5-2. Flooded Islands and Tidal Waterways Elevation Interval Acreages and Percent Total Area

Elevation category	Tidal Waterway		Flooded Island		Total	
	Acreage	Percent area	Acreage	Percent area	Acreage	Percent area
> SLR	0	0%	0	0%	0	0%
SLR	17	1%	33	1%	50	1%
Intertidal	165	5%	1,406	31%	1,571	20%
Shallow subtidal	212	6%	1,349	30%	1,561	20%
Mid subtidal	381	11%	1,589	35%	1,970	25%
Deep subtidal	317	9%	106	2%	423	5%
Very deep subtidal	2,301	68%	63	1%	2,364	30%
Total	**3,393**		**4,546**		**7,939**	

5.4 Sediments and Sediment Supply

Suspended sediment concentrations (SSC) in the Delta have been measured continuously since the 1990s (Wright and Schoellhamer 2005). The Sacramento River is the largest contributor of suspended sediment to the Delta, and it is estimated that two-thirds of the sediment supplied is retained within the Delta's depositional environment (Schoellhamer et al. 2012). In general, a decreasing trajectory of sediment supply to the Delta has been observed, likely due to diminishment of the legacy hydraulic mining sediment pulse from the Gold Rush-era, deposition in flood bypasses, protection (hardening) of river banks, and impoundments behind dams (Schoellhamer et al. 2013). The information presented in this section is derived from the DRERIP sediment conceptual model (Schoellhamer et al. 2012) and from two recent papers examining sea level rise and sediment supply changes in Suisun Marsh (Ganju and Schoellhamer 2010, Schoellhamer 2011).

Recent work by the USGS (Schoellhamer 2011) hypothesizes that in 1999 the Estuary crossed a threshold, wherein the erodible sediment pool on the Estuary's bottom was depleted and suspended sediment concentrations changed from transport-regulated to supply-regulated. This pool is resupplied by watershed contributions from local sources and Delta outflow. The decline in sediment supply combined with deposition in areas that do not readily erode (e.g., tidal wetland restoration sites) are hypothesized to have contributed to the crossing of this threshold, and to support a trend toward reduced suspended sediment concentrations.

5.4.1 Hydraulic mining: major historical input of sediment to the estuary

Gold Rush-era hydraulic mining resulted in the downstream transport of unprecedented quantities of sediment, which caused major sedimentation in waterways and shallow bays from the Sierra Nevada to the Estuary. Gilbert (1917) estimated a nine-fold increase in sediment supply to San Francisco Bay during the mining period. Though the primary pulse of mining sediment has now moved through the system, remnant terrace deposits remain in many watersheds (James 1991) (Meade 1982, James 1991). Also, recent estimates of river sediment supply to the Delta are substantially higher than Gilbert's pre-mining estimate, but have continued to decrease since the mid-1950s, possibly indicating continued exhaustion of remnant mining-derived deposits (Wright and Schoellhamer 2005).

5.4.2 Ongoing sediment trapping behind dams

The Central Valley Project (CVP) (1938) and the State Water Project (SWP) (1951) include 20 reservoirs and 1,100 miles of canals in the Sacramento, Trinity, Feather, American, and San Joaquin river basins. Nilsson et al. (2005) in their recent study of flow regulation of the world's large river systems classified the Sacramento-San Joaquin basin as "strongly affected" by dams. The primary effect of dams on sediment supply is retention of sediment in reservoirs formed behind the dams; the channel immediately downstream from a dam typically erodes – providing a short-term sediment source – to reach a new equilibrium (Porterfield et al. 1987), but the long-term effect is decreased sediment supply (Williams and Wolman 1984, Ligon et al. 1995). Dams also affect the frequency, magnitude, timing and duration of river flow regimes, typically reducing high flows and increasing low flows (Singer 2007). This type of altered flow regime also has the effect of reducing downstream sediment supply.

The depletion of the Gold Rush-era hydraulic mining sediment pulse and the construction of dams led to a 50% decrease in sediment supply from the Sacramento River between 1957 and 2001 (Wright and Schoellhamer 2004). Sediment exchange between estuarine sub-embayments may become more important in the coming century, as watershed sediment loads continue to decrease (Ganju and Schoellhamer 2006).

5.4.3 General patterns of sediment supply to the CSC

In the absence of Yolo Bypass flood events, the CSC receives the bulk of its fine and erodible sediment from two sources: Miner Slough and Ulatis Creek (Morgan-King and Schoellhamer 2013). Miner Slough receives the majority of its sediment load from the Sacramento River during the first runoff event of the season (Morgan-King and Schoellhamer 2013). Suspended sediment loads from Ulatis Creek enter Upper Cache Slough, where turbidity measurements are generally greater than those within the DWSC, both because of its relation to Ulatis Creek and its tidal isolation (Morgan-King and Schoellhamer 2013).

During large flow events, turbid Sacramento River water overtops Fremont weir and enters the Yolo Bypass. The sediment budget estimates by (Wright and Schoellhamer 2005) during water years 1999–2002 captured one such event. Based on their analysis, it was estimated that the Yolo Bypass was the dominant source of suspended sediment to the CSC, and contributed an average annual suspended sediment load of 310 (±130) thousand metric tons, or approximately 19% of the total sediment entering the Delta.

5.4.4 Sediment accretion

Within the CSC, short term observations of vertical accretion during February 2011 through June 2012 revealed variable mean elevation changes ranging from -0.03 to 0.09 ft per year (Reed 2013).The areas with the greatest mean elevation change were located within the vegetated zone on the eastern side of Liberty Island. Long term elevation changes (1998–2012), measured at a mature marsh site near Lindsey Slough and a restored site on the southern tip of Liberty Island, showed lower average net accretions of approximately 0.009 and 0.03 ft per year at each site, respectively (Reed 2013). Within the natural colonization depths of emergent marsh vegetation (Hester et al. 2013), overall sediment accumulation rates within vegetated sites increased with increasing water depth and were generally lowest for mature marsh plains with the lowest water depths.

6 PHYSICAL AND CHEMICAL WATER QUALITY

The CSC receives water from the Yolo Bypass area, agricultural and suburban properties to the north and west, urban and wastewater discharges via Ulatis Creek, the adjacent Sacramento Deep Water Ship Channel, and the Sacramento River and connecting channels (e.g., Miner and Steamboat sloughs) to the south (see map, Figure 2-4). Because the CSC is regionally important as a nursery area for at-risk fish species such as Delta Smelt and juvenile Chinook salmon (Chapter 9), and early life stages of fish are often the most sensitive to physical or chemical stressors, water quality is an important consideration in planning habitat restoration.

6.1 Beneficial Uses and Water Quality Standards

The Central Valley Basin Plan (CVRWQCB 2011) designates a wide range of beneficial uses for waterbodies in the Sacramento-San Joaquin Delta (CVRWQCB 2011, Table II-1, p. II-8.00), including the CSC. Table 6-1 provides a summary of applicable beneficial uses, broadly divided into biologically-based and human-activity-based uses. The Basin Plan states “Beneficial uses vary throughout the Delta and will be evaluated on a case-by-case basis.” (CVRWQCB 2011; Table II-1, Footnote 8). Thus, the beneficial uses identified here for CSC waterways should be regarded as guidelines that may be subject to refinement during any future permitting and planning processes for tidal habitat restoration in the CSC.

The sections below address a limited number of water quality parameters potentially affecting beneficial uses shown in Table 6-1, with particular reference to the aquatic habitat uses (COLD, COMM, MIGR, SPAWN, WARM) as well as certain human-related uses (IND, MUN, PROC, REC-1, REC-2).

Table 6-1. Designated Beneficial Uses of Cache Slough Complex Waters (CVRWQCB 2011)

Designated beneficial use	Description
BIOLOGICALLY-BASED BENEFICIAL USES	
Warm Freshwater Habitat (WARM)	Uses of water that support warmwater ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Cold Freshwater Habitat (COLD)	Uses of water that support coldwater ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Migration of Aquatic Organisms (MIGR)	Uses of water that supports habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.
Spawning (SPAWN)	Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.
Wildlife Habitat (WILD)	Uses of water that support terrestrial or wetland ecosystems including, but not limited to, preservation or enhancement of terrestrial habitats or wetlands, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.
HUMAN ACTIVITY-BASED BENEFICIAL USES	
Municipal and Domestic Supply (MUN)	Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
Agricultural Supply (AGR)	Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation (including leaching of salts), stock watering, or support of vegetation for range grazing.
Commercial and Sport Fishing (COMM)	Uses of water for commercial or recreational collection of fish, shellfish, or other organisms, including, but not limited to, uses involving organisms intended for human consumption or bait purposes.
Industrial Process Supply (PROC)	Uses of water for industrial activities that depend primarily on water quality.
Industrial Service Supply (IND)	Uses of water for industrial activities that do not depend primarily on water quality, including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.
Navigation (NAV)	Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.
Water Contact Recreation (REC-1)	Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water skiing, skin and scuba diving, surfing, whitewater activities, fishing, or use of natural hot springs.
Non-Contact Water Recreation (REC-2)	Uses of water for recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beach-combing, camping, boating, tide-pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

6.2 Nutrients and food web productivity

The narrative water quality objective for nutrients and other biostimulatory substances limits levels of these substances to below those that "promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses" (CVRWQCB 2011, p. III-3.00)). Nutrients found in receiving waters include nitrogen (e.g., ammonia, nitrate, and nitrite) and phosphorus (orthophosphate) compounds which arrive in storm water runoff as well as discharges from waste water treatment plants and livestock facilities. Organic and particulate forms of nitrogen and phosphorus also become bioavailable through a range of mechanisms. Aquatic nutrient cycling within the Delta is governed by a set of complex reactions and feedback mechanisms that in turn affect primary productivity and the aquatic food web. Aquatic beneficial uses of water related to fish habitat (MIGR, SPAWN, COLD, WARM) may be adversely affected by excess nutrients (i.e., "eutrophication" or "biostimulation") fueling algae blooms and excess aquatic plant growth that can result in anaerobic conditions, changes in food-web structure, and toxicity from algal waste products. In addition, impacts to human-activity uses (MUN, IND, PROC, REC-1, REC-2) may occur.

Past conversion of wetlands to grazing and agricultural lands has eliminated natural nitrogen storage and cycling functions characteristic of wetlands while simultaneously increasing discharges of excess nitrogen. Up until the 1800s, farmers primarily used poultry and livestock manure to fertilize crops. But following World War II, industrially-produced ammonia-containing fertilizers largely replaced the use of manure. Volumes of nitrogen-based fertilizer application increased rapidly between the 1950s and 1980s (Mueller and Helsel 1996), and today pose a continuing chronic threat to water quality nationwide.

Recent concerns regarding changes in algal species composition (Baxter et al. 2010), as well as production of harmful algal blooms of *Microcystis* (Lehman et al. 2005), have highlighted the importance of nutrients in controlling algal species dynamics. Wetland restoration may reduce overall nutrient concentrations by removing lands from agricultural production (and thereby diminishing the discharge of fertilizers), restoring historical functions such as sedimentation, increasing uptake and storage of nutrients by plants, and boosting microbial processes such as denitrification.

6.3 Dissolved organic carbon

While there are no specific Basin Plan objectives for dissolved organic carbon (DOC), high DOC concentrations in potable water supplies (MUN) may lead to the formation of disinfection byproducts (DBPs) such as trihalomethanes (Rook 1974), haloacetic acids, and other carcinogenic compounds formed during chlorine or ozone disinfection. DOC is ubiquitous in the natural environment as a component of and breakdown product from natural organic matter. A local over-abundance may persist as a result of algal productivity, peat soil drainage, or agricultural runoff.

In-Delta organic carbon loading is generally less than tributary loads from the Sacramento and San Joaquin River watershed, and represents a lower percentage of total source loading of organic carbon in wet years than in dry years (CVRWQCB 2012).

In the CSC, the primary current source of DOC is runoff from areas supporting livestock grazing into the surrounding watershed (Archibald Consulting et al. 2007). Elevated DOC levels at the Barker Slough Pumping Plant (BSPP) have been an ongoing water quality problem related to disinfection byproducts (DBP) formation in treated water from the State Water Project's North Bay Aqueduct (DWR 2002). Proposed wetland restoration may contribute to DOC related water quality problems at the BSPP, both directly through the accumulation of litter and peat soils (Kraus et al. 2008), as well as through changes in algal productivity of surrounding waterways.

6.4 Dissolved oxygen

The Basin Plan Dissolved oxygen (DO) objective applicable to the CSC is 5 mg/L, while the DO objective for non-Delta waterbodies designated with the Fish Spawning beneficial use is 7 mg/L. DO concentrations in water depend on several factors, including temperature, flow and water aeration, salinity, and abundance of aerobic bacteria, algae, plants, as well as aquatic organisms. Low DO concentrations may adversely affect beneficial uses for aquatic species (COLD, WARM, MIGR, SPAWN), and habitat restoration efforts may require consideration of adequate depths, temperatures and flows, to maintain DO concentrations for fish and other aquatic organisms.

The extent to which DO is affected by the inflow of water with low DO concentrations depends on hydrodynamic exchanges of surface and bottom waters. Large tidal sloughs exchange water rapidly and thus are not as subject to low DO problems. Small and especially dead-end sloughs exhibit less exchange and thus longer residence times and consequently are particularly susceptible to low DO. Other potential causes of low DO levels in the Cache Slough include areas with a significant amount of floating or submerged aquatic vegetation, and return water from agricultural fields and managed wetlands.

6.5 Salinity

Under the Basin Plan and water rights decision D-1641, salinity in the Delta is managed for the protection of at-risk fish species (e.g., Delta Smelt) as well as agricultural, industrial, and municipal water supplies (Table 2-2 and Table 6-3). Salinity in the Delta is managed primarily through freshwater releases from upstream reservoirs, and is also affected by physical barrier manipulation at several sites throughout the Delta (e.g., Cross-Channel Gates, South Delta Temporary Barriers), and variation in volume of water diverted/exported. Collectively, these mechanisms are operated so as to prevent the location of the saltwater-freshwater interface from reaching inland export facilities, which is particularly important during drought periods.

Table 6-2. Electrical Conductivity Water Quality Objectives—Fish and Wildlife and Agriculture (SWRCB 2006)

Station	Water Year Type[1]	Fish and Wildlife		Agriculture			
		Value[2]	Time Period	Value[2]	Time Period	Value[2]	Time Period
Sacramento at Emmaton	Wet	not applicable		0.45	Apr 1 - Aug 15	not applicable	
	Above Normal			0.45	Apr 1 - Jun 30	0.63	Jul 1 - Aug 15
	Below Normal			0.45	Apr 1 - Jun 19	1.14	Jun 20 - Aug 15
	Dry			0.45	April 1 - June 14	1.67	Jun 15 - Aug 15
	Critical			2.78	Apr 1 - Aug 15	not applicable	
San Joaquin at Jersey Point	Wet	0.44	Apr 1 - May 31	0.45	Apr 1 - Aug 15	not applicable	
	Above Normal	0.44	Apr 1 - May 31	0.45	Apr 1 - Aug 15	not applicable	
	Below Normal	0.44	Apr 1 - May 31	0.45	Apr 1 - Jun 19	0.74	Jun 20 - Aug 15
	Dry	0.44	Apr 1 - May 31	0.45	April 1 - June 14	1.35	Jun 15 - Aug 15
	Critical	not applicable		2.20	Apr 1 - Aug 15	not applicable	
San Joaquin at Prisoners Point	Wet, Above Normal, Below Normal, Dry	0.44	Apr 1 - May 31	not applicable			

Notes
1. Sacramento Valley Water Year Hydrologic Classification
2. Maximum 14-day running average of mean daily EC (mmhos/cm)

Table 6-3. Chloride Water Quality Objectives—Municipal and Industrial (SWRCB 2006)

Station	Water Year Type[1]	Municipal and Industrial	
		(Cl^-) Value[2]	Days of the Calendar Year
Contra Costa Canal at Pumping Plant 1	Wet	less than or equal to 150	240
	Above Normal		190
	Below Normal		175
	Dry		165
	Critical		155
Contra Costa Canal at Pumping Plant 1	All	250	365
West Canal at mouth of Clifton Court Forebay			
Delta-Mendota Canal at Tracy Pumping Plant			
Barker Slough NBA intake			
Cache Slough at City of Vallejo Intake			

1. Sacramento Valley Water Year Hydrologic Classification
2. Maximum mean daily value in mg/L

Prior to European settlement, Delta waters were influenced primarily by seasonal and annual variations in precipitation and thus river discharge, likely resulting in variable seasonal and annual salinity gradients (declining from west to east). Development activities—including wetland reclamation, channelization, and upstream dams and diversions—have reduced seasonal and between-year variation in salinity (CCWD 2010), which has affected species diversity and abundance (e.g., Kimmerer 2002) and promoted conditions that favor non-native fish species (Moyle 2002).

The CSC is characterized as fresh water with low levels of salinity, typically well under 1 mS/cm, even during dry periods. Salinity can increase due to high rates of evaporation over extended periods—often following extensive periods of dry, hot weather—in relatively shallow, slow-flowing waterbodies without shade, with large surface-to-volume ratios, or lacking adequate outflow. Such conditions can be characteristic of habitats and land forms found within the CSC at certain times of the year.

6.6 Suspended Sediments and Turbidity

The Basin Plan contains narrative water quality objectives for turbidity such that water must be “free of changes in turbidity that cause nuisance or adversely affect beneficial uses.” Numeric water quality objectives for the Cache Slough area (CVRWQCB 2011p. III-9.00) which limit turbidity in the Cache Slough area is not to exceed 150 nephelometric turbidity units (NTUs), except during periods of storm runoff, and special circumstances, such as dredging. More broadly, the Central Valley numeric turbidity objectives vary with natural ambient conditions (e.g., if natural turbidity exceeds 100 NTU, controllable factors must not cause a 10% or higher increase).

Most suspended sediment contributing to turbidity is supplied to the Delta during high flow events (Schoellhamer et al. 2012). The CSC exhibits some of the highest turbidity in the Delta (Nobriga et al. 2005, Lehman et al. 2010a, Morgan-King and Schoellhamer 2013, Schoellhamer et al. 2013). During 2009 and 2010, average turbidity in the CSC was 27 NTU, twice as high as elsewhere in the Delta (Morgan-King and Schoellhamer 2013, Schoellhamer et al. 2013). The CSC receives the bulk of its sediment load from the Yolo Bypass, which supplied an average annual suspended sediment load of 310 +/- 130 thousand metric tons estimated during 1999–2002 (Wright and Schoellhamer 2005). Local runoff also carries turbidity from tributaries to the CSC, including Cache Slough, Lindsey Slough, and Ulatis Creek. An estuarine turbidity maximum (ETM) is generally associated with the freshwater/saltwater interface. However, other factors (e.g., morphology, wind-waves) can create and maintain an ETM. Within the freshwater CSC, a second ETM is created by tidal asymmetry with flood dominant velocities, channels with limited tidal excursion, and wind-wave resuspension (Morgan-King and Schoellhamer 2013, Schoellhamer et al. 2013). During predominant low flow conditions (spring to early fall), these processes contribute to net landward sediment flux and efficiently trap sediment within Liberty Island and shallow dead end sloughs of the CSC (Morgan-King and Schoellhamer 2013, Schoellhamer et al. 2013).

Turbidity in the Delta and other estuaries is largely determined by the amounts of suspended sediments with effects upon primary productivity (Cloern 1987). While higher turbidity levels are beneficial to native fish such as Delta Smelt (Sommer and Mejia 2013), the presence of suspended solids in water supplies (e.g., associated with the IND, MUN, PROC beneficial use categories) may clog filtration and affect other industrial processes, as well as reduce the efficiency of various disinfection systems. For example, water diverted for industrial and municipal uses from the Barker Slough Pumping Plant must be tested and pre-treated (e.g., by application of a flocculating agent) for suspended solids prior to disinfection.

6.7 Temperature

Water temperature affects many biochemical and physiological processes in aquatic organisms, including energy demands due to shifts in metabolic rates and chemical (e.g., contaminant) transformation and excretion rates (Werner et al. 2008). Applicable water quality objectives for aquatic beneficial uses related to water temperature (MIGR, SPAWN, COLD, WARM) may be found in the Basin Plan (CVRWQCB 2011), with prohibitions on discharges or other activities that increase water temperatures by more than five degrees Fahrenheit.

Water temperatures within Delta waterways are influenced by seasonal variations in the amount of daytime solar heating as well as radiative cooling at night. To a lesser degree, water temperatures are also affected by seasonal and longer term changes in weather and climate (e.g., climate change) and Delta inflows. As water flows to the Delta, its temperature rapidly reaches equilibrium with ambient air temperatures, generally increasing in summer and cooling in winter. Delta water temperatures reflect differences in heat exchange rates of various waterbodies due to multiple influences (e.g., advective transport, shading, wind-wave mixing, evaporative cooling), the mixing of river and tidal waters with different temperatures, as well as mixing between regions with different heat exchange rates with the atmosphere (Stacey and Monismith 2008).

Tidal wetlands affect local water temperatures, the magnitude of which depends on the interaction of air temperature and wind speed with vegetation effects on shading and evapotranspiration (Kadlec and Wallace 2009). Shading by emergent and riparian vegetation can reduce summertime high water temperatures by directly blocking incoming solar radiation (Crepeau and Miller 2014). As compared to adjacent sloughs, shallower water on the marsh plain loses and gains heat more readily through conductive heating and cooling processes on a diurnal timescale. Nighttime cooling of water on the marsh plain has the potential to provide temperature refugia for fish as water cools more rapidly at night and drains into adjoining open water habitats (Enright et al. 2013a). Diked sloughs do not show the same variations in water temperature because they have relatively few shallow areas (CALFED 2009). In these sloughs, water temperature is highly correlated with average air temperature (CALFED 2009).

6.8 Toxic Chemical Pollutants

The Basin Plan requires that waters be free of toxic pollutants at concentrations detrimental to human, plant, and animal life. Numeric water quality objectives have been established for particular aquatic contaminants such as organic compounds and trace metals. Where water bodies do not meet water quality objectives, they are listed as impaired under section 303(d) of the Basin Plan. There is little or no information on historical baseline levels of contaminants in the Delta prior to European settlement; however, it is fair to assume that land-use changes and accompanying proliferation of agricultural, industrial, and domestic chemicals have detrimentally impacted ambient water quality over time. Fox and Archibald (1997) found that water sampled from the Delta occasionally caused mortality in standardized EPA aquatic toxicity tests (e.g. using larval Fathead Minnow, Striped Bass, *Ceriodaphnia,* Neomysid shrimp). Several events causing mortality of aquatic organisms have been documented in the CSC in recent years (DWR 2007b, Werner et al. 2010, Weston et al. 2014) and North and Northwestern Delta waterways are currently listed on the 303(d) list as impaired for toxicity due to unknown causes, and multiple other stressors (Table 6-4).

Table 6-4. Clean Water Act Section 303(d) List, Affected Beneficial Uses, and Potential Sources for Northern and Northwestern Delta Waterways (SWRCB 2013).

Pollutant category	Potential sources
Chlordane	Agriculture
Chlorpyrifos	Agriculture
Chlorpyrifos	Urban Runoff/Storm Sewers
DDT (Dichlorodiphenyltrichloroethane)	Agriculture
Diazinon	Urban Runoff/Storm Sewers
Diazinon	Agriculture
Dieldrin	Agriculture
Group A Pesticides	Agriculture
Invasive Species	Source Unknown
Mercury	Resource Extraction
PCBs (Polychlorinated biphenyls)	Industrial Waste/Dumping
Unknown Toxicity	Source Unknown
Electrical Conductivity	Agriculture

The following sections briefly discuss the contaminants listed above, as well as other selected aquatic contaminants of potential concern in the Cache Slough area.

6.8.1 Ammonia

Un-ionized ammonia can be acutely toxic to aquatic organisms at relatively low concentrations (typically >0.2 mg/L), and can potentially impact biologically-based beneficial uses of water (COLD, MIGR, SPAWN, WARM). The NH_3 fraction of total ammonia is positively correlated with pH and temperature, such that higher (more basic) pH levels and warmer water temperatures result in a greater fraction of NH_3. At pH and temperature values typical of Delta water (e.g., pH 7–8 and 15–25 ºC), the proportion in water of NH_3 is usually relatively low compared to that of NH_4^+.

Total ammonia concentrations in the Delta and its tributaries are relatively high due to wastewater discharge effluent, agricultural runoff (e.g., fertilizers and manure originating from the Barker Slough watershed), and atmospheric deposition (Archibald Consulting et al. 2007). The Sacramento Regional Wastewater Treatment Plant (SRWTP), the largest point-source discharger of ammonia compounds in the Delta, accounts for 90% of the ammonium load in the Sacramento River at Hood (RM 38;Jassby 2008). Due to tidal action, the Sacramento River contributes to ammonia loads in the upstream CSC. In addition, Vacaville's Easterly Waste Water Treatment Plant discharges effluent to Old Alamo Creek, a tributary to New Alamo Creek, Ulatis Creek, and Cache Slough.

Historically common blooms of beneficial phytoplankton are now rare in the SF Bay-Delta, and are believed to occur within a specific range of nutrient concentrations (i.e., low NH_4^+) coupled with longer residence times (Glibert et al. 2014). High nutrient loads, including ammonium, have been identified as a potential water quality issue in Barker Slough (CNRA 2009) and other areas of the CSC, and such loads have been shown to alter the community composition of phytoplankton in the SF Bay-Delta (Dugdale et al. 2007) (Parker et al. 2012).

Although ionized ammonium can also be toxic to phytoplankton and invertebrate species in the Delta, total ammonia concentrations in Delta water bodies have not been observed to directly cause mortality in pelagic fish species (Werner et al. 2009). Nevertheless, sublethal effects may be present (Eddy 2005) and lethal affects in invertebrate species due to ammonia or mixtures of ammonia with other contaminants have been demonstrated (Werner et al. 2010).To address potential toxicity associated with elevated total ammonia downstream of the Sacramento Regional Wastewater Treatment Plant, a range of toxicity studies have been conducted by researchers at the University of California at Davis. Although total ammonia concentrations were not found to cause acute toxicity, Werner et al. (2009) concluded that concentrations downstream of the plant may be causing chronic toxicity to Delta Smelt. Toxicity testing (96-h) of ambient surface waters from several locations in the north Delta in April-May 2008, including the Cache Slough area resulted in significant mortality of the copepod *Eurytemora affinis* (Teh et al. 2009). Reduced survival of *E. affinis* and other copepods was attributed to the presence of ammonia, copper, and, to a lesser extent, pyrethroid pesticides (Section 6.8.4) in the water column.

6.8.2 Methylmercury

The presence of mercury in the Delta is due primarily to historical gold mining activities in the Sierra Nevada. Abandoned gold mines, sluices, pits, and streamside piles of tailings continue to discharge mercury to waterbodies upstream of the Delta, which then transport mercury downstream in association with suspended particles. Mercury also enters Delta waters via atmospheric deposition, which can originate from distant sources (e.g., unregulated power plants and industrial activities).

Methylmercury (CH_3Hg^+) is the organic form of mercury most commonly found in the environment. Methylation of inorganic mercury occurs in the aquatic environment under low oxygen conditions, facilitated by naturally occurring sulfur- and iron-reducing bacteria (Gilmour et al. 1992, Benoit et al. 2003, Kerin et al. 2006). At sufficient concentrations, methylmercury is a neurotoxin and teratogen (USEPA 2007). Concerns regarding the bioaccumulation of methylmercury within the food chain are based on fears of potential impacts to human health, to human activity, and to other the beneficial uses of water bodies (e.g., commercial and sport fishing, fish spawning, etc.). The primary route of exposure to higher trophic-level organisms, including humans, is through consumption of mercury-contaminated fish. Waterways of the CSC are listed as impaired due to elevated methylmercury in resident fish under the Clean Water Act Section 303(d) (SWRCB 2013). In addition, state health advisories have been issued for the San Francisco Bay Estuary and several of its tributaries, cautioning people to limit consumption of certain fish species that tend to carry mercury burdens.

The overall net production in, and release of methylmercury from, tidal wetlands is dependent upon many factors, such as topography and geology, quantities and sources of inorganic mercury, daily tidal regime and overall hydrology, meteorological conditions, and soil biogeochemistry (Bergamaschi et al. 2011). Hydroperiod is the dominant factor in determining the types of wetland habitats that produce the most methylmercury (Alpers et al. 2008). Wetlands with long duration wetting and drying periods, such as seasonal floodplains, seasonal wetlands, and high elevation tidal marsh that are infrequently flooded and retain waters when flooded, tend to have relatively high water and sediment methylmercury content (Snodgrass et al. 2000, Windham-Myers et al. 2010, Windham-Myers et al. 2011). Perennially flooded habitats, such as open-water zones and areas with emergent or submerged aquatic vegetation, tend to have lower concentrations of methylmercury in water and sediment than seasonally or regularly flooded habitats (Alpers et al. 2008, Nonpoint Sources Workgroup 2012).

Methylmercury TMDL

To address mercury contamination in the Delta and Yolo Bypass, the Central Valley Regional Water Quality Control Board (Regional Board) adopted the Methylmercury Total Maximum Daily Load and Basin Plan Amendment that established a Delta Mercury Control Program (DMCP; Wood et al. 2010a, Wood et al. 2010b). Under the DMCP, fish-tissue objectives for methylmercury for the Sacramento River and San Joaquin River basins (Wood et al. 2010b) are as recommended in the following:

> "The recommended alternative would establish Delta-specific methylmercury fish tissue objectives of 0.08 and 0.24 mg/kg, wet weight, in fish tissue for large trophic level 3 and 4 fish (150-500 mm total length) and 0.03 mg/kg, wet weight, for small trophic level 2 and 3 fish (less than 50 mm)."

To achieve these new objectives, the TMDL establishes point and non-point source MeHg load reduction targets for eight geographic regions within the Delta. The Yolo Bypass, for example, has a target load reduction of approximately 80% to meet the methylmercury fish tissue objectives by 2030 (Wood et al. 2010a, 2010b). The Regional Board is currently working with DWR and CDFW to plan and eventually implement methylmercury studies, intended to (a) investigate methylmercury production in and export from tidal wetlands, and (b) develop effective methods to reduce potential methylmercury impacts, if impacts are likely, from restoration projects. The proposed California WaterFix also requires monitoring, research, and reporting on methylmercury production in and export from restored wetland areas as mitigation for California WaterFix project activities.

Although several recent studies have suggested that methylmercury water column concentrations in tidal wetlands can be elevated (e.g., Mitchell and Gilmour 2008, Windham-Myers et al. 2009, Bergamaschi et al. 2011, Bergamaschi et al. 2012), these studies are based predominantly on data from salt marshes, with limited consideration of non-tidal freshwater wetlands and agricultural wetlands (e.g., rice fields) and no instances of freshwater tidal wetlands. Further, a recent study in Chesapeake Bay indicates that tidal marshes may not be large contributors when considered on the basis of mercury loading rather than water column concentrations (Mitchell et al. 2012). The DWR and

CDFW compliance control studies would contribute to knowledge that can be used to better understand the potential contributions of freshwater tidal wetlands, like those in the CSC, to Delta methylmercury loading and to inform future restoration project planning efforts. Updates to the Regional Board regarding these activities are currently anticipated in 2015 and 2018.

6.8.3 Copper and other trace metals

The Basin Plan contains narrative objectives for chemical constituents such as trace metals such that "Waters shall not contain chemical constituents in concentrations that adversely affect beneficial uses." Various metals (e.g., arsenic, chromium, copper, lead, mercury, nickel, etc.) may be found in aquatic environments and the food web. In high concentrations in water and tissue these metals are potentially toxic to aquatic organisms, wildlife, and human consumers of fish and wildlife. Sources of metals can be anthropogenic or natural and discharges can exceed regulatory criteria.

Copper is used in a wide range of industrial, plumbing, electrical, agricultural, marine, and domestic applications. It forms the basis for various products widely used in Central Valley ponds and channels as fungicides, herbicides, and pesticides. Copper is also released into the aquatic environment from other sources, including vehicle brake pads, leaching from architectural structures, and anti-fouling boat and dock paints (CVRWQCB 2011). Tailings and acid mine drainage from past mining operations in the Sierra Nevada and Cascade mountain ranges persist as sources of copper and other trace metals that are transported to Central Valley waterways (CVRWQCB 2011).

Copper is both an essential trace nutrient (at very low concentrations) and a chronic and acutely toxic contaminant (at high concentrations). Low concentrations of dissolved copper result in acute toxicity to the calanoid copepod *Eurytemora affinis* at sites in the Cache Slough area (Teh et al. 2009) and may interact with ammonia or pesticides to cause synergistic effects (Oros and Werner 2005).Copper desorption (release from a surface or interface) in aquatic environments varies with changes in pH, increasing as water becomes more acidic. Therefore, the release of CO_2 to the water column during (nighttime) algal respiration is a potential concern due to resulting water column acidification (USBR 2011).

Other mineral and metal contaminants of concern include arsenic, cadmium, chromium, lead, nickel, selenium, and zinc—each with specific environmental and biological chemistry and potentially complex environmental cycles of transformation and equilibrium, and each associated with varying levels of acute or chronic toxicity dependent on concentrations in sediment, water, and living tissue. Arsenic and selenium are found at high concentrations in some areas due to natural or artificial sources in Central Valley soils, groundwater, and agricultural runoff. Lead, like copper and mercury, has been and continues to be released to the environment via atmospheric deposition and discharges to waterways from nonpoint sources and industrial runoff. Levels of these trace metals in CSC soils and water are presently unknown.

6.8.4 Pesticides

The narrative objective for pesticides in the Basin Plan states that "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses." Although many persistent bioaccumulative pesticides (e.g., DDT, toxaphene, endosulfan, chlordane) have been phased out of the American marketplace, new classes of chemicals have taken their place. Despite having generally shorter environmental half-lives, some or most of these pesticides may still be acutely toxic and therefore deleterious to the environment. Organophosphate pesticides, including diazinon and chlorpyrifos, have been recognized by the EPA as acutely toxic to aquatic and terrestrial organisms, including humans, thus leading to restrictions on urban and agricultural use. As a replacement, pyrethroid pesticides have increased in use over the past 20 years. Though pyrethroids have very low toxicity to humans, they are highly toxic to aquatic invertebrates, and lethal effects can occur at trace concentrations. Sources of pesticides are generally attributed to urban and agricultural runoff (Table 6-2). Multiple pesticides in CSC have been associated with toxicity to aquatic copepods and *Hyalella azteca* (Teh et al. 2009) (Weston et al. 2014). Currently, North and Northwest Delta waterways are listed as impaired for pesticides, including chlordane, chlorpyrifos, DDT, diazinon, dieldrin, and Group A Pesticides (human carcinogens). TMDLs have been completed for chlorpyrifos and diazinon (McClure et al. 2006), and are in progress for pyrethroid pesticides.

6.8.5 Contaminants of emerging concern

Increased attention is also being paid to contaminants of emerging concern (CECs), which are largely unregulated and unmonitored chemicals due to the fact that their environmental presence and effects are not well established. Current CECs in the SF Bay Delta include new pesticides (e.g. pyrethroids and fipronil), pharmaceuticals and personal care products, industrial chemicals (e.g. perflourooctane sulfonate), chemical surfactancts and additives, alternative flame retardants, and microplastics among others(San Francisco Estuary Institute (SFEI) 2013).POTW effluent is found to harbor surprisingly high concentrations of contaminants including CECs. Contaminants originating in SRWWTP and the

Vacaville Easterly WWTP effluent may enter the CSC during periods of high flow via the Yolo Bypass.

7 LAND USE

Land ownership is largely private in the CSC, with some lands in state agency ownership, federal agency ownership, and local government district ownership (see Section 2.3 and Figure 2-8). Restoration efforts would for the most part take place first on publicly owned lands that are suitable for restoration. All such lands with restoration potential are already being planned for restoration—Calhoun Cut (CDFW), Prospect Island (DWR), Yolo Ranch (SFCWA). Consequently, any future restoration efforts would by necessity need to occur through acquisition of private lands or some form of public-private partnerships on these lands.

Land use in the CSC is predominately agricultural, but also includes recreational uses and habitat restoration (see Section 2.4 for description of habitat restoration efforts). Agricultural uses are primarily field crops, livestock grazing, and hay production (Figure 7-1). Agricultural practices play a vital role in the CSC, providing a major source of income for residents and landowners. Some of the agricultural land in the CSC occurs where elevations are suitable for restoration. This overlap could translate into some agricultural lands being purchased and taken out of production for restoration to occur.

7.1 Agricultural Uses and Zoning

Most of the CSC and the southern Yolo Bypass is within Solano County. Agricultural lands are distributed throughout most of the CSC. Natural lands managed by private and public entities may use livestock grazing or other agricultural practices as a means of vegetation management.

7.1.1 Department of Conservation Farmland Types

The California Department of Conservation, Division of Land Resource Protection, Farmland Mapping and Monitoring Program (FMMP) has developed a statewide classification system for designating farmland type to reflect agricultural productivity (Figure 7-2). FMMP derives these designations based on soil types and current land uses. The top three classifications relative to productivity are Prime Farmland, Farmland of Statewide Importance, and Unique Farmland.

Under the FMMP classifications, the CSC contains approximately 13,721 ac of Prime Farmland, 3,730 ac of Farmland of Statewide Importance, and 2,113 ac of

Unique Farmland. In addition, 15,852 ac of Grazing Landand 3,075 ac of Other Land are included in the CSC (Table 7-1, Figure 7-2).

Table 7-1. California Department of Conservation Farmland Classification System

Classification	Definition
Prime Farmland	Farmland with the best combination of physical and chemical features able to sustain long term agricultural production. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields. Land must have been used for irrigated agricultural production at some time during the four years prior to the mapping date.
Farmland of Statewide Importance	Farmland similar to Prime Farmland but with minor shortcomings, such as greater slopes or less ability to store soil moisture. Land must have been used for irrigated agricultural production at some time during the four years prior to the mapping date.
Unique Farmland	Farmland of lesser quality soils used for the production of the state's leading agricultural crops. This land is usually irrigated, but may include nonirrigated orchards or vineyards as found in some climatic zones in California. Land must have been cropped at some time during the four years prior to the mapping date.
Farmland of Local Importance	Land of importance to the local agricultural economy as determined by each county's board of supervisors and a local advisory committee.
Grazing Land	Land on which the existing vegetation is suited to the grazing of livestock.
Urban and Built-up Land	Land occupied by structures with a building density of at least 1 unit to 1.5 acres, or approximately 6 structures to a 10-acre parcel. This land is used for residential, industrial, commercial, construction, institutional, public administration, railroad and other transportation yards, cemeteries, airports, golf courses, sanitary landfills, sewage treatment, water control structures, and other developed purposes.
Other Land	Land not included in any other mapping category. Common examples include low density rural developments; brush, timber, wetland, and riparian areas not suitable for livestock grazing; confined livestock, poultry or aquaculture facilities; strip mines, borrow pits; and waterbodies smaller than forty acres. Vacant and nonagricultural land surrounded on all sides by urban development and greater than 40.
Water	Perennial waterbodies with an extent of at least 40 acres.

Source: California: Farmland Mapping and Monitoring Program (2010)

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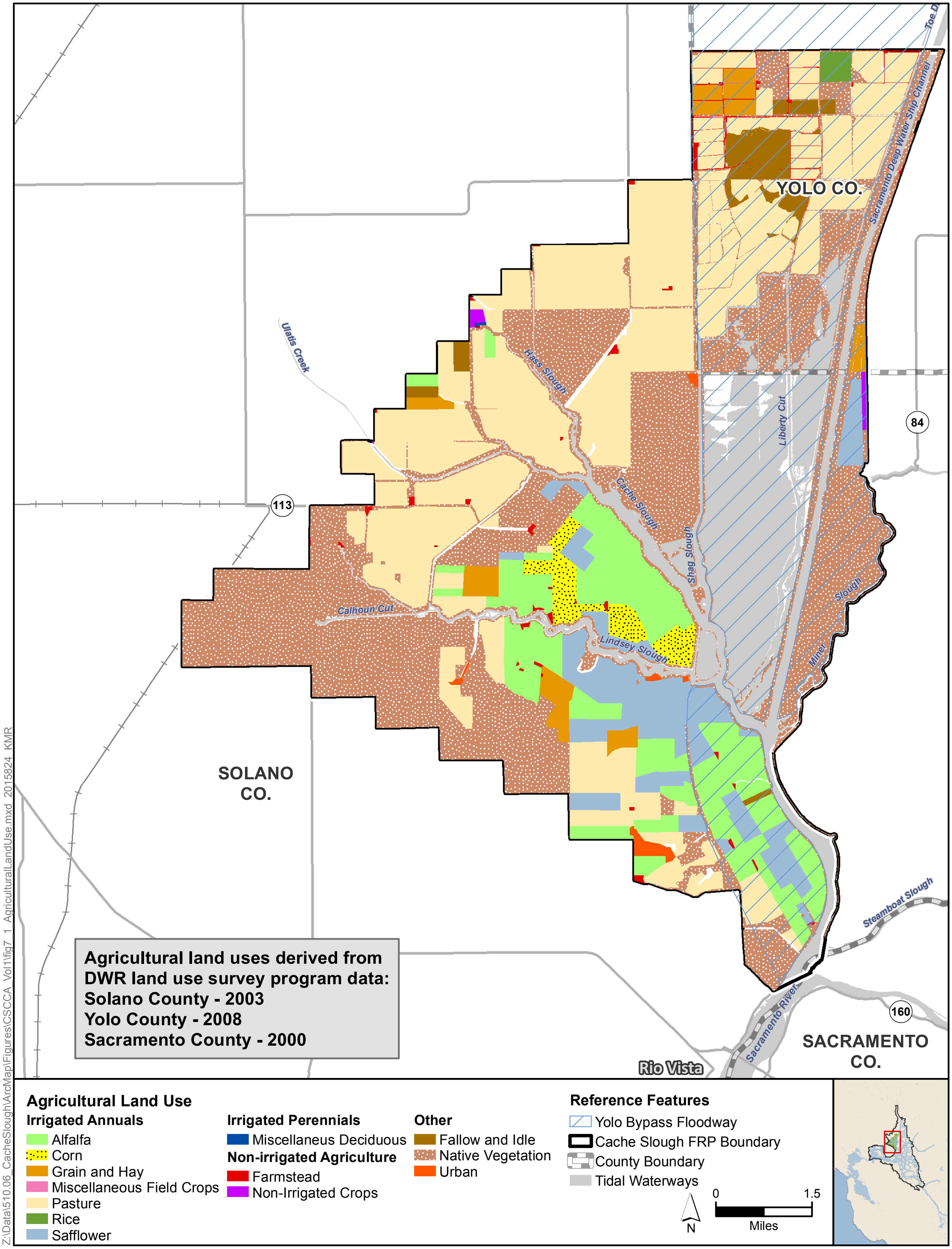
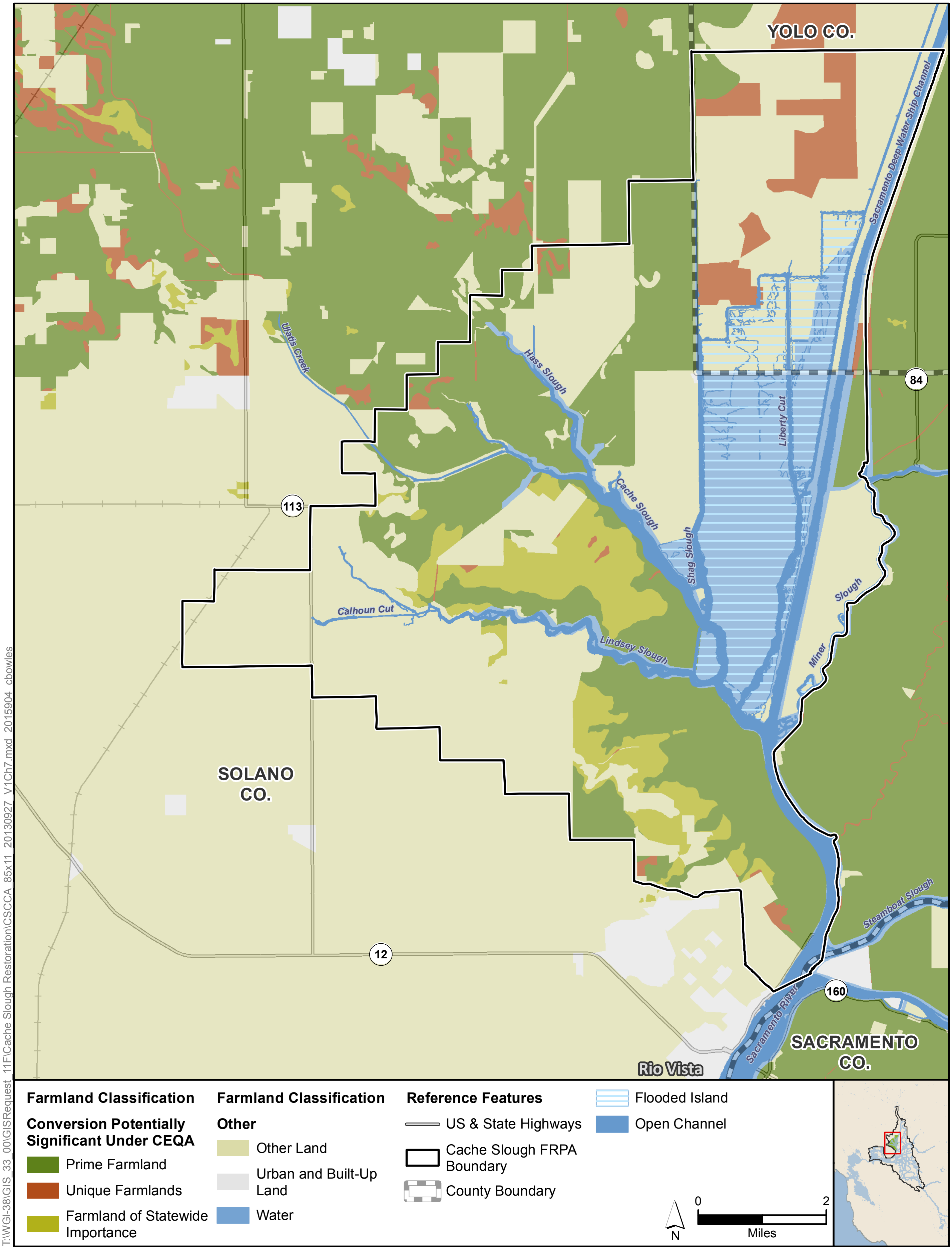


Sources: Land Use/Crop Type (DWR, 2000, 2003, & 2008);
Tidal Waterways (CDFW, 2005 and BDCP, 2012 - WWR mod. 2013);
Cache Slough Planning Boundary (WWR, 2013-0708)

Figure 7-1: Agricultural Land Uses
Cache Slough Complex Conservation Assessment



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Sources: Cache Slough Complex Planning Boundary (WWR, 20130708); Important Farmland (DOC, 2010); Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 7-2: Farmland Types by Department of Conservation Classifications
Cache Slough Complex Conservation Assessment

7.1.2 Solano County

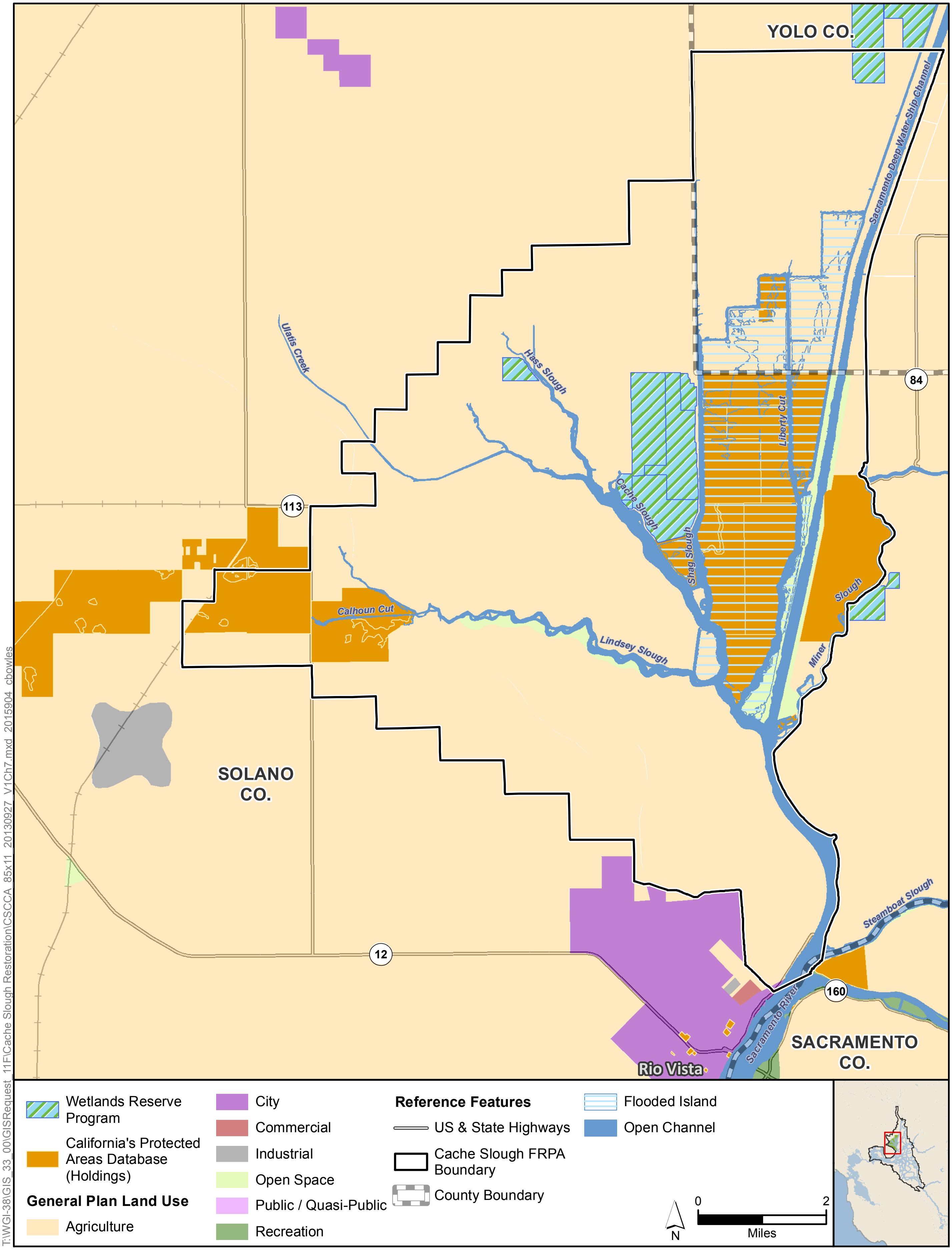
In the Solano County portion of the CSC, 93% (38,975 ac) of land is zoned for agriculture under Solano County's General Plan (Figure 7-3), which was adopted in 2008 and is intended to guide development and conservation within the unincorporated county through 2030. The agricultural land use designation reserves areas for agriculture as the primary use, including areas that contribute significantly to the local agricultural economy, and allows for secondary uses that support the economic viability of agriculture. Open Space occupies 13,057 ac (8%) of the Solano County portion of the CSC (depicted as holdings or parcels protected as open space in the California Protected Areas database) and the balance, 9 ac, is designated for public, industrial, or city land uses.

7.1.3 Yolo County

In the Yolo County portion of the CSC, 100% of the 9,972 ac are zoned for agriculture under Yolo County's 2030 General Plan (Figure 7-3) (Yolo County 2009). The portion of the county included in the CSC is in the Yolo Bypass agricultural region, which has wildlife habitat and pasture as the primary land uses. Most (92%) of the county is off-limits to residential, commercial, and industrial development that is inconsistent with parcel designation as agricultural land intended to be set aside for farming, grazing, and open space.

In Yolo County, the agricultural designation covers a wide variety of uses, such as row crops, orchards, vineyards, dryland farming, livestock grazing, forest products, horticulture, floriculture, apiaries, confined animal feedlot operations, and equestrian facilities. It also includes related industrial uses, such as agricultural research; crop processing and storage; supply sales and servicing; crop dusting; agricultural chemical and equipment sales; surface mining; and commercial uses serving rural areas (e.g., roadside stands, wineries, farm-based tourism, horse shows, rodeos, crop-themed or seasonal events, ancillary restaurants and stores). Agriculture also includes farmworker housing and incidental wildlife habitat.

Yolo County's agricultural production grossed $549,249,669 in 2011. The 2011 crop report shows that processing tomatoes are the County's top commodity, followed by rice, wine grapes, hay and walnuts. Organic production has grown considerably in recent years (Economics 2011, Yolo County 2011).



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Sources: Cache Slough Complex Planning Boundary (WWR, 20130708); California's Protected Areas Database (GreenInfo Network, 2013); Wetlands Reserve Program (NRCS, 2012) Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 7-3: General Plan Designations and Protected Areas
Cache Slough Complex Conservation Assessment

7.2 Williamson Act Lands

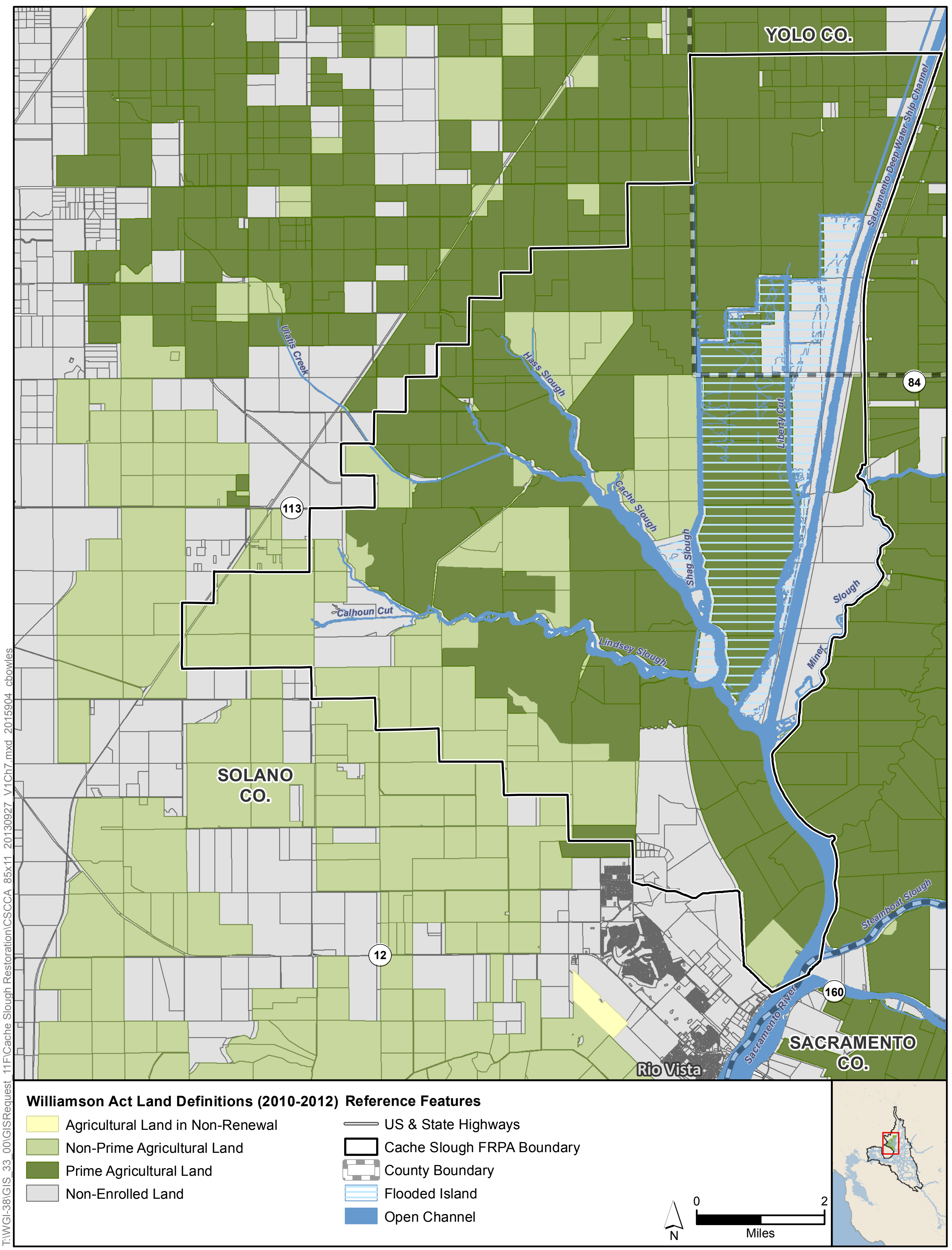
The Williamson Act, also known as the California Land Act of 1965, allows local governments, such as Solano and Yolo counties, to contract with private landowners for the purpose of conserving agricultural land. Williamson Act contracts are designed to discourage the conversion of open space and agricultural land by restricting specific parcels from land use conversion. In return, landowners receive reduced property tax assessments (20–70% less) since their property values, while under contract, are based upon farming and open space uses rather than full market value. Williamson Act contracts utilize a rolling ten-year term, which automatically renews each year unless either party files a “notice of nonrenewal”. Once a “notice of nonrenewal” has been filed, the nine-year period of nonrenewal begins during which, the property tax assessment gradually increases. At the end of the nine-year nonrenewal period, the contract is terminated. The Williamson Act includes provisions for 20-year contracts under the Farmland Security Zone, sometimes known as “Super Williamson Act Contracts”, that offer increased property tax savings to the landowner in exchange for longer commitments. For many years, the State of California reimbursed participating counties for their lost property tax revenue. Those payments, known as subventions, have essentially been defunded in State budgets since 2009.

7.2.1 Solano County

Solano County has approximately 62% or 215,000 ac of its agricultural lands held in Williamson Act contracts (Figure 7-4). Within the CSC, 33,537 ac are under Williamson Act contracts, which include 19,145 ac of prime farmland, 9,811 ac of non-prime farmland, and 4,581 ac of mixed prime and non-prime farmland.

7.2.2 Yolo County

Of Yolo County’s 653,549 ac of total land area, 64% is covered under Williamson Act contracts (Figure 7-4). In the Yolo County portion of CSC, which encompasses 10,005 ac, 7,176 ac or 72% are in Williamson Act contracts and all lands under contract are classified as Prime Farmland (see Section 7.1.1). In 2005, Yolo County received the Williamson Act Stewardship Award from the California Department of Conservation for Yolo County’s “commitment to creating an environment in which farming and ranching can thrive.”



Sources: Cache Slough Complex Planning Boundary (WWR, 20130708); Williamson Act Contract Lands (Sacramento, Solano, and Yolo Counties, 2010-2012); Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 7-4: Williamson Act Contract Lands
Cache Slough Complex Conservation Assessment

7.3 Delta Protection Commission's Land Use and Resource Management Plan

The Delta Protection Act of 1992 established the Delta Protection Commission with the goal of developing regional policies for the Delta to protect and enhance the existing land uses in the Primary Zone, which includes the CSC: agriculture, wildlife habitat, and recreation. The Delta Protection Commission's Land Use and Resource Management Plan (LURMP) was prepared and adopted by the Delta Protection Commission in 1995 and revised in 2002 and 2010. The LURMP outlines the long-term land use requirements and includes the following policies and recommendations applicable to the land use:

- **Land Use Policy P-2:** Local government General Plans and zoning codes shall continue to strongly promote agriculture as the primary land use in the Primary Zone; recreation land uses shall be supported in appropriate locations and where the recreation uses do not conflict with agricultural land uses or other beneficial uses, such as waterside habitat.
- **Land Use Recommendation R-2:** Public agencies and non-profit groups have or propose to purchase thousands of acres of agricultural lands to restore to wildlife habitat. The amount, type, and location of land identified to be enhanced for wildlife habitat should be studied by wildlife experts to determine goals for future acquisition and restoration. Lands acquired for wildlife habitat should also be evaluated for recreation, access, research and other needed uses in the Delta. Habitat restoration projects should not adversely impact surrounding agricultural practices. Public-private partnerships in management of public lands should be encouraged. Public agencies shall provide funds to replace lost tax base when land is removed from private ownership.
- **Land Use Recommendation R-3:** Multiple use of agricultural lands for commercial agriculture, wildlife habitat, and, if appropriate, recreational use, should be supported, and funding to offset management costs pursued from all possible sources. Public agencies shall provide funds to replace lost tax base when land is removed from private ownership.

7.4 Delta Plan

The Delta Plan is a comprehensive, long-term management plan for the Delta. Required by the 2009 Delta Reform Act, it creates new rules and recommendations to further the state's co-equal goals for the Delta: Improve statewide water supply reliability, and protect and restore a vibrant and healthy Delta ecosystem, all in a manner that preserves, protects, and enhances the unique agricultural, cultural, and recreational characteristics of the Delta. The Delta Plan contains a set of regulatory policies that would be enforced by the Council's appellate authority and oversight. The Delta Plan designates much of the CSC as being in a Priority Habitat Restoration Area. Relevant Delta Plan policies include the following "recommended policies":

- **ER R2. Prioritize and Implement Projects that Restore Delta Habitat.** Bay Delta Conservation Plan implementers, California Department of Fish and Wildlife, California Department of Water Resources, and the Delta Conservancy should prioritize and implement habitat restoration projects in the areas shown on Figure 4-8 of the Delta Plan (Delta Stewardship Council 2013). Habitat restoration projects should ensure connections between areas being restored and existing habitat areas and other elements of the landscape needed for the full life cycle of the species that would benefit from the restoration project. Where possible, restoration projects should also emphasize the potential for improving water quality.
- **DP R10. Encourage Wildlife-friendly Farming.** CDFW, the Delta Conservancy, and other ecosystem restoration agencies should encourage habitat enhancement and wildlife-friendly farming systems on agricultural lands to benefit both the environment and agriculture.

7.5 Physical Setting as it Affects Agricultural Suitability

Agriculture in the CSC region is dependent upon two primary physical factors: flood protection from the tides and floods from the Yolo Bypass, Sacramento River, and the local watershed and soils suitability to support a range of agricultural land uses. The California Department of Conservation uses these and other factors to establish the FMMP and to designate lands into each of its type categories (Section 7.1.1).

CSC levees and the RDs that maintain them provide flood protection for the agricultural operations in the region. Chapter 3 contains detailed information about the configurations, design standards, and conditions of levees and about the RDs within the CSC.

Section 5.2 contains detailed information about the soils found within the CSC and their characteristics. Figure 5-2 provides a visual representation of the soils types in the CSC region. Soils in the CSC, categorized by the USDA Soil

Conservation Service into 17 soil associations (NRCS 1977), vary depending on slope, drainage class, and the physiographic positions of the soils on the landscapes. Agricultural land use is largely dependent on soil characteristics. Some soil associations are ideal for irrigated orchards and row and field crops, while others are more appropriate for irrigated or dryland pasture and small grains.

7.6 Recreation in the CSC

The 2011 California State Parks Recreation Proposal for the Sacramento-San Joaquin Delta, published in response to requirements included in the 2009 Delta Reform Act, contains 13 regional recommendations for future recreation planning and development in the Delta and surrounding areas. The State Parks proposal recommends exploring the recreation potential of the CSC recognizing that there is potential in this area for environmental restoration coupled with outdoor recreation (wildlife observation, boating, fishing access and hunting). The proposal also contains a list of “Potential Future State Parks in the Delta-Suisun Marsh Region” and includes Barker Slough as a possible location for a new State Park. Habitat restoration would be conducted along with the development of recreational facilities such as picnic sites, trails, facilities for kayaks, canoes and other small paddle-craft, and interpretive services.

The Great California Delta Trail proposal was created by 2006 legislation aimed at increasing opportunities for outdoor recreation in an effort to address childhood obesity. The vision for the trail is to link the San Francisco Bay Trails system and planned Sacramento River trails in Yolo and Sacramento counties to current and future trails in the Delta. The Delta Protection Commission would facilitate the planning process of the Great California Delta Trail. Recent maps show the trail skirting the eastern edge of the CSC.

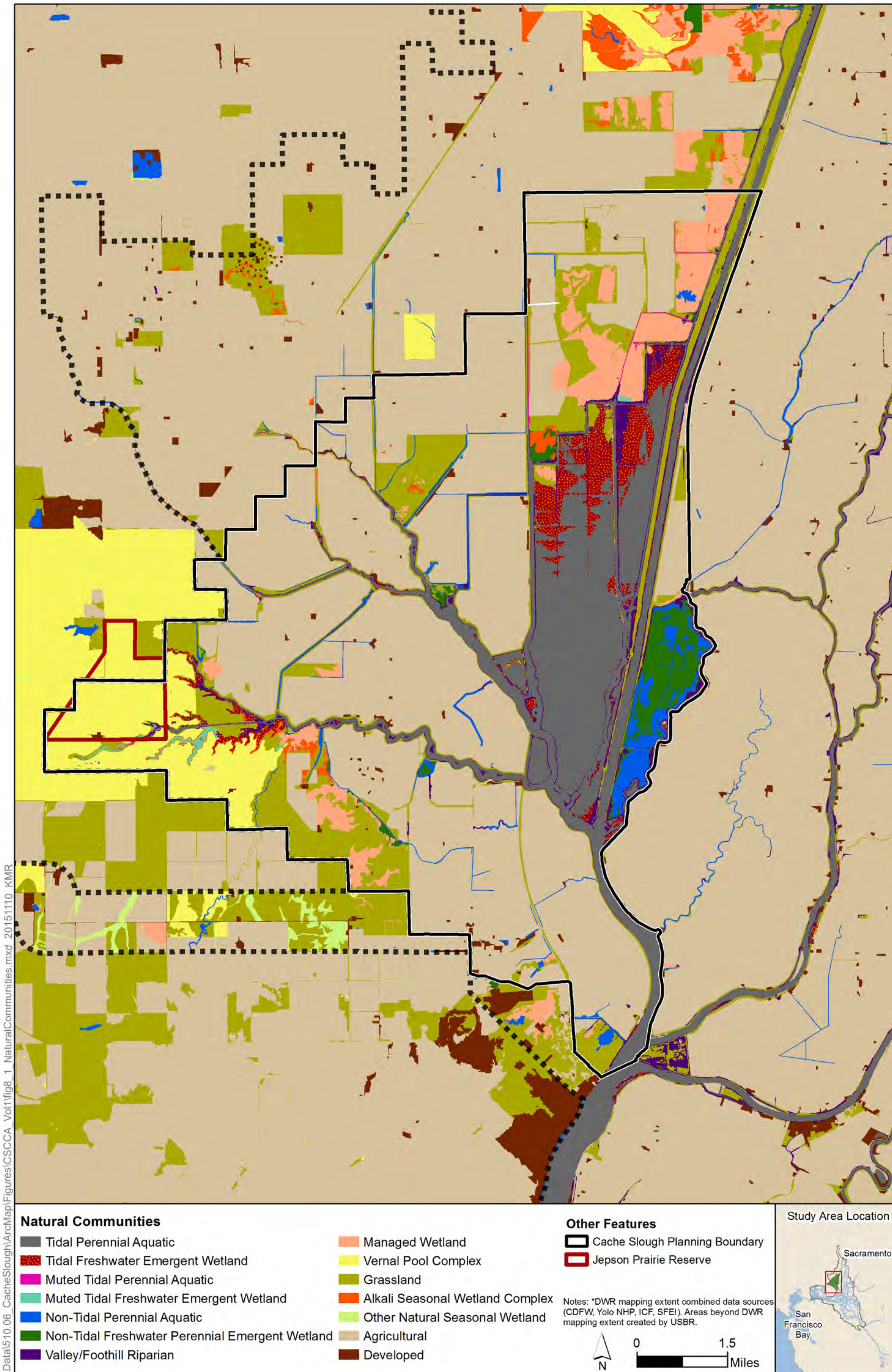
Currently, there are several recreation areas in the CSC. Many of these are private facilities set up for hunting waterfowl and other game birds; however, there are public areas such as the Miner Slough Wildlife Area and Liberty Island Ecological Reserve that also allow hunting and fishing. There are also opportunities for fishing camping, boating and hiking.

8 VEGETATION AND NATURAL COMMUNITIES

The community composition of vegetation is a primary driver of habitats and ecosystem functioning in the Delta. The CSC contains a wide variety of natural communities and many special status plant species. Non-native invasive plants are also present and may have implications for restoration planning. This chapter describes the natural communities and the plant and wildlife species they support. Special-status plant species known to be present in the CSC are identified and non-native invasive plant species are listed.

8.1 Natural Communities Classification

The descriptions of natural communities below are based on those described in Chapter 2 Existing Conditions of the BDCP Public Draft (DWR 2013a), the CALFED Bay-Delta Program Multi-Species Conservation Strategy Programmatic EIS/EIR (CALFED Bay-Delta Program 2000), and the *Vegetation and Land Use Classification and Map of the Sacramento-San Joaquin River Delta* (Hickson and Keeler-Wolf 2007). The distribution of natural communities is shown in Figure 8-1. A "crosswalk" showing correspondence between the natural communities described below and those described in the Vegetation and Land Use Classification of the Sacramento-San Joaquin River Delta (Hickson and Keeler-Wolf 2007) as well as total coverage of each community by geomorphic position (e.g., channel margin, flooded island) follows in Table 8-1. Detailed descriptions of special status and invasive plant species associated with these natural communities are presented in Appendix B.



Sources: Natural Communities (BDCP, 2012 and USBR, 2005, WWR mod, 2013);
Cache Slough Planning Boundary (WWR 2013-0708); Legal Delta Boundary (DWR 2002);
Tidal Waterways (CDFG, 2005 and CDFG, 2008 - WWR mod, 2013)
Jepson Prarie Boundary (WWR, 2013)

Figure 8-1: Natural Communities
Cache Slough Complex Conservation Assessment

Table 8-1. Natural Communities and Vegetation Types Crosswalk by Geomorphic Position.

Natural communities	DFG vegetation types[1]	Channel margin		Diked or upland		Flooded island		In channel		Remnant levee		Open channel		Total	
		Ac	%[2]	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%[3]
Agricultural	Agriculture Sparsely or unvegetated areas; abandoned orchards Grain / hay crops Non-native vegetation stands Eucalyptus	73	0.3	26,557	99.7	0	0	0	0	5	0.02	0	0	26,635	50.4
Alkali Seasonal Wetland Complex	Salt grass (*Distichlis spicata*) *Distichlis spicata* – Annual grasses *Distichlis spicata* – Juncus balticus Salt scalds and associated sparse vegetation	0	0	268	99.6	1	0.4	0	0	0	0	0	0	269	0.5
Developed	Levee rock riprap Urban developed – Built up	38	12.9	253	86.1	0	0	2	0.7	1	0.3	0	0	294	0.6
Grassland	California annual grasslands – Herbaceous Italian rye-grass (*Lolium multiflorum*) *Lolium multiflorum – Convolvulus arvensis* Ruderal herbaceous grasses & forbs Seasonally flooded grasslands	1,012	15.4	5,392	82.1	129	2.0	1	0.02	33	0.5	0	0	6,567	12.4

Natural communities	DFG vegetation types[1]	Channel margin		Diked or upland		Flooded island		In channel		Remnant levee		Open channel		Total	
		Ac	%[2]	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%[3]
Managed Wetland	Intermittently or temporarily flooded undifferentiated annual grasses and forbs *Lepidium latifolium – Salicornia virginica – Distichlis spicata* Managed alkali wetland (*Crypsis*) Perennial pepperweed (*Lepidium latifolium*) Poison hemlock (*Conium maculatum*) *Polygonum amphibium* Rabbitfoot grass (*Polypogon maritimus*) *Scirpus* spp. in managed wetlands Seasonally flooded undifferentiated annual grasses and forbs Shallow flooding with minimal vegetation at time of photography Smartweed *Polygonum* spp. – Mixed forbs	3	0.1	2,515	98.1	47	1.8	0	0	0	0	0	0	2,565	4.9
Muted Tidal Freshwater Emergent Wetland	*Scirpus acutus* pure *Scirpus acutus – Typha latifolia* Mixed *Scirpus* / Floating aquatics (*Hydrocotyle – Eichhornia*) complex Mixed *Scirpus* mapping unit Salt grass (*Distichlis spicata*)	0	0	99	100	0	0	0	0	0	0	0	0	99	0.2
Muted Tidal Perennial Aquatic	Water	0	0	33	53.2	0	0	0	0	0	0	29	46.8	62	0.1
Non-Tidal Freshwater Perennial Emergent Wetland	Broad-leaf cattail (*Typha latifolia*) Hard-stem bulrush (*Scirpus acutus*) *Scirpus acutus* pure *Scirpus acutus – Typha latifolia*	0	0	1,070	99.8	2	0.2	0	0	0	0	0	0	1,072	2.0

Natural communities	DFG vegetation types[1]	Channel margin		Diked or upland		Flooded island		In channel		Remnant levee		Open channel		Total	
		Ac	%[2]	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%[3]
Non-Tidal Perennial Aquatic	Brazilian waterweed (*Egeria – Myriophyllum*) submerged Floating primrose (*Ludwigia peploides*) Generic floating aquatics Water	5	0.5	1,013	99.5	0	0	0	0	0	0	0	0	1,018	1.9
Tidal Freshwater Emergent Wetland	California bulrush (*Scirpus californicus*) Common reed (*Phragmites australis*) Hard-stem bulrush (*Scirpus acutus*) Mixed *Scirpus* / Floating aquatics (*Hydrocotyle – Eichhornia*) complex Mixed *Scirpus*/Submerged aquatics (*Egeria – Cabomba – Myriophyllum* spp.) complex Mixed *Scirpus* mapping unit *Scirpus acutus* – (*Typha latifolia*) – *Phragmites australis* *Scirpus acutus* pure *Scirpus acutus – Typha latifolia* *Scirpus californicus - Scirpus acutus*	67	4.3	168	10.7	1,303	82.8	30	1.9	5	0.3	0	0	1,573	3.0
Tidal Perennial Aquatic	Brazilian waterweed (*Egeria – Myriophyllum*) submerged Floating primrose (*Ludwigia peploides*) Generic floating aquatics Milfoil – Waterweed (generic submerged aquatics Water	0	0	0	0	4,772	57.9	0	0	0	0	3,466	42.1	8,238	15.6

Natural communities	DFG vegetation types[1]	Channel margin		Diked or upland		Flooded island		In channel		Remnant levee		Open channel		Total	
		Ac	%[2]	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%[3]
Valley/Foothill Riparian	*Acacia – Robinia* *Alnus rhombifolia* / *Cornus sericea* *Alnus rhombifolia* / *Salix exigua* (*Rosa californica*) Arroyo willow (*Salix lasiolepis*) Black willow (*Salix gooddingii*) Blackberry (*Rubus discolor*) Box elder (*Acer negundo*) California dogwood (*Cornus sericea*) California wild rose (*Rosa californica*) Coast live oak (*Quercus agrifolia*) *Cornus sericea – Salix exigua* *Cornus sericea – Salix lasiolepis* / (*Phragmites australis*) Fremont cottonwood (*Populus fremontii*) Giant cane (*Arundo donax*) Intermittently or temporarily flooded deciduous shrublands Narrow-leaf willow (*Salix exigua*) *Quercus lobata – Alnus rhombifolia* (*Salix lasiolepis – Populus fremontii – Quercus agrifolia*) *Quercus lobata* / *Rosa californica* (*Rubus discolor – Salix lasiolepis* / *Carex* spp.) *Salix exigua* – (*Salix lasiolepis – Rubus discolor – Rosa californica*) *Salix gooddingii – Populus fremontii* – (*Quercus lobata – Salix exigua – Rubus discolor*) *Salix gooddingii* / Wetland herbs *Salix lasiolepis* – (*Cornus sericea*) / *Scirpus* spp.– (*Phragmites australis – Typha* spp.) complex unit *Salix lasiolepis* – Mixed brambles (*Rosa californica – Vitis californica – Rubus discolor*) Temporarily or seasonally flooded – Deciduous forests Valley oak (*Quercus lobata*) White alder (*Alnus rhombifolia*)	428	31.6	393	29.0	230	17.0	64	4.7	240	17.7	0	0	1,355	2.6

Natural communities	DFG vegetation types[1]	Channel margin		Diked or upland		Flooded island		In channel		Remnant levee		Open channel		Total	
		Ac	%[2]	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%	Ac	%[3]
Vernal Pool Complex	California annual grasslands – Herbaceous *Distichlis spicata* – Annual grasslands Salt scalds and associated sparse vegetation Salt grass (*Distichlis spicata*) Seasonally flooded grasslands Vernal pools	0	0	3,114	100	0	0	0	0	0	0	0	0	3,114	5.9
Total Ac		**1,626**		**40,875**		**6,484**		**97**		**284**		**3,495**		**52,861**	

1 Vegetation types listed are those described in the Vegetation and Land Use Classification of the Sacramento-San Joaquin River Delta (Hickson and Keeler-Wolf 2007).
2 Values provided are the percent of the natural community falling within each geomorphic position (e.g., 0.3% of the agricultural lands are found along channel margins).
3 Total percentages provided are the percent of the CSC that is a particular natural community (e.g., 50.4% of the CSC is agricultural).

8.1.1 Tidal and muted tidal perennial aquatic

Approximately 15% of the CSC is mapped as tidal perennial aquatic and less than one percent (0.1%) is mapped as muted tidal perennial aquatic, which maintains some tidal influence, but is hydrologically muted (Table 8-1). Tidal perennial aquatic and muted tidal perennial aquatic natural communities include deep-subtidal aquatic (greater than 10 ft deep from mean lower low water), mid-subtidal aquatic (less than or equal to 10 ft deep from mean lower low water), and shallow subtidal (mean lower low water to 2 ft below mean lower low water). These communities are freshwater habitats under current conditions, with vegetation consisting of floating and submerged aquatic vegetation. Over half (57.9%) of the tidal perennial aquatic habitat is located within flooded islands; the remaining (42.1%) is within open channels (Table 8-1). The small amount of muted tidal perennial aquatic habitat is split between lands enclosed by dikes (53.2%) and open channels or sloughs (46.8%; Table 8-1). Distribution of vegetation within this community is dynamic, influenced by physical factors such as depth, turbidity, water velocity, wind, substrate, and nutrient availability.

Floating aquatic vegetation can be floating on the water surface or rooted in banks and extending into open water. These species are most often found in low-velocity water rich in nutrients, and include native species such as duckweed (*Lemna* spp.) and mosquito fern (*Azolla filiculoides*), as well as highly invasive non-native plants such as water primrose (*Ludwigia peploides*) and water hyacinth (*Eichhornia crassipes*). Floating aquatic vegetation can accumulate in such large quantities that its decay creates anoxic conditions.

Submerged aquatic plants are those submerged for all or nearly all of their life-cycle, with root systems anchoring them to the bottom. Submerged aquatic vegetation may be in the form of patches or as extensive uninterrupted “canopy” cover over the substrate. Native species, such as native pondweeds (*Potamogeton* spp.) and musk weeds (*Chara* spp.) for example, are important as food for waterfowl and as nursery habitat for aquatic invertebrates and fish. Brazilian waterweed (*Egeria densa*) is invasive, extremely competitive with native species, and capable of surviving at great depths. It can also act as cover and shelter for non-native predatory fish in tidal wetlands.

8.1.2 Tidal Mudflat

The tidal mudflat natural community typically occurs as sediments in the intertidal zone between mean high water and the mean lower low water. This natural community is exposed above water at low tide and is typically associated with tidal freshwater emergent wetland at its upper edge. Because tidal mudflat has been mapped as part of the tidal perennial aquatic and tidal freshwater emergent wetland communities, it is not shown on Figure 8-1 or listed in Table 8-1.

Tidal mudflat is important habitat for several special-status plant species: Mason's lilaeopsis (*Lilaeopsis masonii*), Delta mudwort (*Limosella subulata*), and Suisun marsh aster (*Symphyotrichum lentum*). A great abundance and diversity of invertebrates are found at varying depths in the substrate, and they support a variety of foraging shorebirds, wading birds, and dabbling ducks, such as western sandpiper (*Calidris mauri*), dunlin (*Calidris alpine*), long- and short-billed dowitchers (*Limnodromus scolopaceus* and *griseus*), whimbrel (*Numenius phaeopus*), long-billed curlew (*Numenius americanus*), great egret (*Ardea alba*), black-crowned night heron (*Nycticorax nycticorax*), cinnamon and green-winged teal (*Anas cyanoptera* and *carolinensis*), and mallard (*Anas platyrhynchos*).

8.1.3 Tidal and muted tidal freshwater emergent wetland

Only 3% of the CSC is mapped as tidal freshwater emergent wetland and less than one percent (0.2%) is mapped as muted tidal freshwater emergent wetland, which has hydrologically muted waters, but maintains some tidal influence. Tidal and muted tidal freshwater emergent wetlands are transitional communities between tidal/muted tidal perennial aquatic and valley/foothill riparian or terrestrial upland communities across a range of hydrologic and soil conditions; tidal and muted tidal freshwater emergent wetland communities are often at shallow, slow-moving, or stagnant edges of freshwater sloughs in the intertidal zone and are subject to frequent flooding of varying duration and depth. These communities are often narrow transition zones adjacent to agricultural land, managed wetlands, or levees and other artificial features. Most tidal freshwater emergent wetlands are found within flooded islands (82.8%); the remaining acreage is distributed across diked lands (10.7%), along channel margins (4.3%), in channel (1.9%), and remnant levees (0.3%). The small amounts of muted tidal freshwater emergent wetlands fall entirely within diked lands.

Low-elevation tidal freshwater emergent wetland (from mean lower low water [MLLW] to mean tide level [MTL)]) is typically dominated by tules and occasionally cattails. They are highly productive but support few species other than tules, which tolerate deep, prolonged tidal flooding.

Middle-elevation tidal freshwater emergent wetland (from MTL to mean higher high water (MHHW)) has a more diverse plant community, including such plants as bur-reed (*Sparganium* spp.), arrowhead (*Sagittaria* spp.), and water smartweed (*Persicaria amphibia*), although this community can also be dominated by tules. It typically represents a more mature marsh condition created by long periods of peat accumulation or sediment deposition.

High-elevation tidal freshwater emergent wetland (above MHHW) can be dominated by grass and grass-like species, such as Baltic rush (*Juncus balticus* subsp. *ater*), creeping wild rye (*Elymus triticoides*), and salt grass (*Distichlis spicata*). It typically includes large patches of yerba mansa (*Anemopsis californica*) and wild heliotrope (*Helitropium* spp.). Special-status plant species commonly found in this plant community include Suisun Marsh aster (*Symphyotrichum lentum*) and woolly rose-mallow (*Hibiscus lasiocarpos* var. *occidentalis*). Large thickets of non-native Himalayan blackberry (*Rubus armeniacus*) can encroach upon high-elevation freshwater tidal marsh, converting it to riparian scrub. High-elevation freshwater tidal marsh may naturally grade into low-elevation grasslands, seasonal wetland, or end abruptly at the edges of steep levees or eroded riverbanks.

8.1.4 Non-tidal freshwater perennial emergent wetland

Non-tidal freshwater perennial emergent wetlands make up about 2% of the CSC; these are permanently saturated meadows and wetlands less than 3 ft deep dominated by freshwater emergent plants such as dense stands of tules and cattails. Within the CSC, this community is primarily represented by small patches of wetlands within diked lands (99.8%), with the remaining 0.2% within flooded islands. Cattails dominate in disturbed areas such as irrigation ditches. Grass-like species include needle spikerush (*Eleocharis acicularis*), rabbitfoot grass (*Polypogon monspeliensis*), and dallis grass (*Paspalum dilatatum*). Associated forbs include cocklebur (*Xanthium strumarium*), curly dock (*Rumex crispus*), and knotweed (*Polygonum* spp.).

This community provides important foraging and reproductive habitat for waterfowl and other wildlife; dense vegetation provides cover from predators and weather. Reptiles, amphibians, and birds associated with this habitat include the highly aquatic giant garter snake (*Thamnophis gigas*, a federally and state-threatened species), Pacific chorus frog (*Pseudacris regilla)*, non-native bullfrogs, wading birds (egrets and herons), waterfowl (ducks, geese, swans), shorebirds (rails, plovers, sandpipers), and perching birds (red-winged blackbird, marsh wren, common yellowthroat). All use non-tidal marsh habitat for forage, cover, and/or nesting. Beaver and muskrat also exploit this community for forage, cover, and den material.

8.1.5 Non-tidal perennial aquatic

Non-tidal perennial aquatic communities make up about 2% of the CSC, ranging in size from small ponds and channels in uplands to large ponded areas within Prospect Island. They are found in association with terrestrial habitat and can transition into non-tidal freshwater perennial emergent wetland and valley/foothill riparian communities. Physical separation from tidally influenced waterbodies distinguishes it from the tidal perennial aquatic community. Most (99.5%) non-tidal perennial aquatic habitat is within diked lands; the remaining 0.5% is along channel margins.

Vegetation in this community is similar to that in the tidal perennial aquatic community described above, including floating and submerged aquatic plants such as water primrose, water hyacinth, and Brazilian waterweed. Foraging and winter loafing and roosting habitat is provided for waterfowl that nest in other habitats (e.g., pied-billed grebe, western grebe, ruddy duck, canvasback, bufflehead) as well as habitat for beaver and river otter.

8.1.6 Vernal pool complex

Approximately 6% of the CSC is mapped as vernal pool complex. The vernal pool complex community is made up of interconnected and isolated vernal pool wetlands and seasonal swales in the matrix of the grassland natural community (described below). These habitats are rare in the CSC, generally found along its eastern edge near the Jepson Prairie. All of the vernal pool complexes are found within diked lands or uplands.

Vernal pools and vernal pool grasslands are considered special-status natural communities because they provide critical habitat for many rare, threatened, or endangered plants and animals. They are often special-status natural communities as designated by CDFW, and when they meet specific criteria established by USACE, they are considered jurisdictional wetlands under Section 404 of the CWA.

During winter and spring, when vernal pools or seasonal wetlands are filled with water, plants, and aquatic life, they act as an important foraging habitat for a variety of native wildlife species, including bees and other pollinators, Pacific chorus frogs, snakes, great blue herons, great egrets, and dabbling ducks. During this time, California tiger salamanders (*Ambystoma californiense*; a state- and federally threatened species) use vernal pools for breeding. During the dry summer months, they contain the dormant cysts of fairy and tadpole shrimp that hatch once the pools become inundated again.

8.1.7 Alkali seasonal wetland complex

There are very few alkali seasonal wetlands within the CSC; only 0.5% of the CSC is mapped as alkali seasonal wetland complex. This natural community occurs on alkaline soils with prolonged ponded or saturated soil conditions during the growing season, vegetated with salt-tolerant wetland plants. Habitats include seasonally ponded and saturated wetlands and surrounding grassland. Alkali seasonal wetlands are found only along the CSC's western edge near Olcott Lake and at other small ponds. Most (99.6%) of the coverage is found within diked lands; the remaining 0.4% is within flooded islands.

The composition of alkaline seasonal wetlands can be highly variable from site to site, and these wetlands may include species typically associated with the Holland communities of alkali grassland, alkali sink, chenopod scrub, brackish marsh, valley sink scrub, and alkaline vernal pools (Holland 1986). Alkaline seasonal wetlands often support a diverse flora, including a number of special-status plant species. Dominant grasses include salt grass and hare barley (*Hordeum murinum* subsp. *leporinum*). The associated herb cover consists of salt-tolerant species, including saltbush (*Atriplex* spp.), alkali heath (*Frankenia salina*), alkali weed (*Cressa truxillensis*), alkali-mallow (*Malvella leprosa*), and common spikeweed (*Centromadia pungens* supsp. *pungens*).

Alkaline seasonal wetlands are considered special-status communities because many special-status plants and animals are associated with them; in many cases they are considered jurisdictional wetlands regulated by USACE under Section 404 of the CWA. Wildlife species associated with alkaline seasonal wetlands are discussed in the vernal pools section.

8.1.8 Managed wetland

Managed wetlands cover approximately 5% of land in the CSC, consisting of areas intentionally flooded and managed during specific seasons to enhance habitat for waterfowl and provide waterfowl hunting opportunities. Ditches and drains used to manage flows are included in this community. Managed wetlands are distributed throughout the CSC, with most found in the southern Yolo Bypass, where they are managed as duck clubs, mitigation banks, and other purposes. The typical hydrologic management regime includes flooding upon winter arrival of migratory waterfowl, followed by slow drawdown to encourage plant seed production and reduce mosquito populations. Most of the managed wetlands are found within diked lands (98.1%); the remaining acreage is split between flooded islands (1.8%) and channel margins (0.1%).

Managed wetlands are dominated by dense stands of perennial emergent vegetation and moist soils dominated by annual grasses and forbs (Hickson and Keeler-Wolf 2007). Plants important to waterfowl include alkali bulrush (*Bolboschoenus maritimus* subsp. *paludosus*), grand redstem (*Ammannia robusta*), brass-buttons (*Cotula coronopifolia*), knotweed, barnyard grass (*Echinochloa crus-galli*), burhead (*Echinodorus berteroi*), and swamp prickle grass (*Crypsis schoenoides*). During drawdown, a wide variety of annual grasses and forbs germinate and grow in and around emergent plants such as cattails and tules.

Management of water levels in these wetlands is designed to provide overwintering habitat for waterfowl, including northern pintails (*Anas acuta)*, mallards, American wigeons, green-winged teals, northern shovelers (*Anas clypeata*), gadwalls, cinnamon teals, ruddy ducks (*Oxyura jamaicensis*), canvasbacks (*Aythya valisineria*), snow and Ross's geese (*Chen caerulescens* and *rossii*), white-fronted geese (*Anser albifrons),* Canada geese (Branta canadensis), and tundra swans (*Cygnus columbianus*). Some wetlands are also managed as breeding habitat for species such as mallard, or as habitat for migratory waders and shorebirds, which include western and least sandpipers, long- and short-billed dowitchers, dunlin, greater and lesser yellowlegs, whimbrels, long-billed curlews, and Wilson's phalaropes (*Phalaropus tricolor*). Other wildlife found in managed wetlands include species discussed in the tidal and non-tidal freshwater emergent wetlands sections.

8.1.9 Other natural seasonal wetland

The other natural seasonal wetland natural community encompasses all the remaining natural (not managed) seasonal wetland communities other than vernal pools and alkali seasonal wetlands. These areas mapped by CDFW (Hickson and Keeler-Wolf 2007) consist of seasonally ponded, flooded, or saturated soils dominated by grasses, sedges, or rushes. Because other natural seasonal wetlands have been mapped as part of other communities, it is not shown on Figure 8-1 or listed in Table 8-1.

Other natural seasonal wetlands are freshwater wetlands characterized by ponded or saturated soil conditions during winter and spring and by dry soil conditions throughout summer and fall until the first substantial rainfall. In the Yolo Bypass floodway, seasonal wetland can be characterized by periods of inundation ranging from days to weeks or months. The vegetation of seasonal wetlands is typically composed of wetland generalist species such as hyssop loosestrife, cocklebur, dallis grass, Bermuda grass, barnyard grass, and Italian ryegrass, which typically occur in frequently disturbed sites. Some of the dominant plant species in other natural seasonal wetland are the same as those found in the managed wetland community. Species dominance varies according to flooding regime. Other natural seasonal wetlands are considered special-status natural communities because they typically qualify as jurisdictional wetlands subject to USACE jurisdiction under Section 404 of the CWA, and wetlands subject to regulation under the Porter-Cologne Act.

8.1.10 Valley/foothill riparian

Only 2.6% of the CSC is mapped as valley/foothill riparian. Broadly defined, the valley/foothill riparian community is a transition zone between aquatic and upland terrestrial habitat and is found in a wide range of geologic, soil, and other environmental conditions within the CSC, most often as long, linear patches. This natural community is further defined by its subcategories: riparian scrub and riparian forest and woodland. Valley/foothill riparian occurs along channel margins (31.6%), diked or uplands (29.0%), remnant levees (17.7%), flooded islands (17.0%), and in channel (4.7%).

Riparian habitat supports a wide variety of wildlife. Riparian trees are used for nesting, foraging, and as protective cover by many birds, including black-headed grosbeaks, warblers, and accipiters, and cavity-nesters such as tree swallows, wood ducks, and kestrels. Riparian canopies provide nesting and foraging habitat for western gray squirrel (*Sciurus griseus*). Understory shrubs provide cover for desert cottontail and ground-nesting birds such as spotted towhees (*Pipilo maculatus*) that forage among the vegetation and leaf litter. Raccoons and opossums may forage on berries, invertebrates, small mammals, and bird eggs for food.

Riparian scrub: Riparian scrub consists of woody riparian shrubs forming dense thickets. Typical species include willows (*Salix* spp.), blackberries (*Rubus* spp.), California button willow (*Cephalanthus occidentalis*), mule fat (*Baccharis salicifolia* subsp. *salicifolia*), and other shrub species associated with higher, sloping, well-drained edges of marshes, or topographic high areas, such as levee remnants and elevated flood deposits. They may occur along shorelines of ponds or banks of channels in tidal or non-tidal freshwater habitats. During extreme floods, dense and tall riparian willow thicket canopies may remain partially above water levels, trap debris and sediment, and act as permeable barriers to wave energy traveling across open water. Non-native Himalayan blackberry thickets are the most-common vegetation type within riparian scrub communities along levees and within leveed pastures.

Riparian forest and woodland: Riparian forest and woodland communities are a mix of Fremont cottonwood (*Populus fremontii* subsp. *fremontii*), valley oak (*Quercus lobata*), northern California black walnut (*Juglans hindsii*), western sycamore (*Platanus racemosa*), and willow, mixed with big-leaf maple (*Acer macrophyllum*), Oregon ash (*Fraxinus latifolia*), and box elder (*Acer negundo*). Canopy cover ranges from relatively open to very dense and can be up to 60 feet in height. Riparian woodland often has a shrubby understory that includes species found in riparian scrub. Willow thickets and dead branches or trees (snags) in riparian woodland provide important habitat for a wide range of wildlife species. This community is mostly limited to narrow bands along sloughs, channels, rivers, and remnant levees throughout the CSC. Riparian forest and woodlands are considered a sensitive community because they have sustained considerable losses throughout the State.

8.1.11 Grassland

Approximately 12% of the CSC is mapped as grassland. The grassland community is a spectrum ranging from natural to intensively managed vegetation dominated by grasses. At the more natural end of the spectrum, it is composed of non-native or native annual and perennial grasses and forbs. At the intensively managed end of the spectrum, it includes irrigated and non-irrigated pasturelands. Grasslands are often found adjacent to wetland and riparian habitats and are the dominant community on managed levees in the Delta. Most of the grassland occurs within diked lands or uplands (82.1%); the remaining acreage is split between channel margins (15.4%), flooded islands (2.0%), remnant levees (0.5%), and in channel (0.02%).

Grassland communities are generally dominated by non-native species, such as wild oat (*Avena fatua*), various bromes (*Bromus* spp.) and barleys (*Hordeum* spp.), rye grass (*Festuca perennis*), filarees (*Erodium* spp.), mustards (*Brassica* spp.), radish (*Raphanus sativus*), mallows (*Malva* spp.), vetches (*Vicia* spp.), and starthistles (*Centaurea* spp.). They may also support infrequent native annual and perennial grasses and forbs. In some areas of the CSC, the grassland community is interspersed with vernal pool complex, alkali seasonal wetland complex, and other seasonal wetland community types. In addition, alkali milkvetch (*Astragalus tener* var. *tener*), Heckard's pepper-grass (*Lepidium latipes* var. *heckardii*), and San Joaquin spearscale (*Extriplex joaquinana*) can sometimes be found in the grassland community.

8.1.12 Agricultural

Approximately 50% of the CSC is mapped as agricultural. Major crops and cover types in agricultural production include tomatoes, alfalfa, rice, wine grapes, hay, and walnuts. The distribution of seasonal crops varies annually, depending on crop-rotation patterns and market forces. Generally crop practices result in monotypic stands of vegetation for the growing season and bare ground in fall and winter. Regular maintenance of fallow fields, roads, ditches, and levee slopes, can reduce the establishment of ruderal vegetation or native plant communities. Most of the agricultural lands occur within diked or uplands (99.7%); the remaining acreage is split between channel margins (0.3%) and remnant levees (0.02%).

Cultivated crops such as alfalfa, rice, and other grain crops can provide habitat for wildlife. Alfalfa is an irrigated, intensively mowed, leguminous crop that constitutes a dynamic habitat. It is a very productive crop that does not require frequent tilling, so it can support large populations of small mammals (e.g., voles) and invertebrate species. As a result, it provides high-quality foraging habitat for wildlife, including wading birds, shorebirds, sparrows, and hawks. Alfalfa is particularly important as foraging habitat for Swainson's hawks (*Buteo swainsoni*), white-tailed kites (*Elanus leucurus*), and other raptors.

Rice is an annual grass and flood-irrigated crop that is maintained in a flooded state until near maturation. Many wetland wildlife species use rice fields, especially waterfowl and shorebirds. Other wildlife species that use rice fields include giant garter snake, bullfrog, wading birds that forage on aquatic invertebrates, and small vertebrates. Rice fields provide habitat for overwintering waterfowl, waders, and shorebirds in the Yolo Bypass including pintail, wigeon, mallards, shovelers, snow and Ross's geese, white-fronted geese, tundra swans, dunlin, long-billed dowitchers, sandhill cranes (*Grus canadensis*), white-faced ibis, and egrets.

Other cultivated crops include grain and seed crops, as well as row crops and silage. Grain and seed crops are annual grasses that are grown in dense stands. Most of the wildlife values are derived during the early growing period and following the harvest, when waste grain is accessible. In some areas of the Delta, grain fields support a substantial proportion of the sandhill crane population that winters in California. Although generally of lesser value to wildlife than native habitats, row crops and silage fields often support abundant populations of small mammals, such as western harvest mouse (*Reithrodontomys megalotis*) and California vole (*Microtus californicus*). These species in turn attract predators such as gopher snake (*Pituophis catenifer*), western yellow-bellied racer (*Coluber constrictor mormon*), American kestrel (*Falco sparverius*), and red-tailed hawk (*Buteo jamaicensis*).

Orchards and vineyards provide limited habitat to wildlife. Orchard habitats are used by several common woodland species such as western gray squirrel, American robin (*Turdus migratorius*), red-tailed hawk, bats, and the non-native black rat (*Rattus rattus*). Except for some common species – such as mourning dove and raptors that use perches and nest boxes installed to attract raptors to control pest species – vineyards provide less wildlife habitat value relative to other crops.

Pastures and ruderal lands provide varying habitat values to wildlife. Pastures provide breeding opportunities for ground-nesting birds and burrowing animals, such as burrowing owl (*Athene cunicularia*), northern harrier (*Circus cyaneus*), western meadowlark (*Sturnella neglecta*), California ground squirrel (*Otospermophilus beecheyi*), and Botta's pocket gopher (*Thomomys bottae*). The open structure of pastures provides foraging habitat for grassland wildlife, such as red-tailed hawk, American kestrel, and coyote (*Canis latrans*). Fallow and disturbed fields (ruderal lands) often are dense, monotypic stands of weedy invasive plants that provide limited wildlife value.

Wildlife communities in fallow and ruderal fields are often similar to those in cultivated row crop or silage fields. The absence of active cultivation increases the potential for successful bird nesting; however, these habitats provide limited breeding habitat for grassland-associated wildlife, such as western meadowlark, American goldfinch (*Carduelis tristis*), northern harrier, and California vole.

8.1.13 Developed

Very little land has been developed in the CSC (0.6%). The category includes residential, recreational, and industrial agriculture operation areas, as well as landscaped areas, riprap, roads, and other transportation-associated features. Developed land supports some plant and wildlife species, with abundance and species richness tending to vary with intensity of development and human disturbance. Developed areas with mature trees can approximate a natural environment but typically support more non-native species. House sparrows, European starlings (*Sturnus vulgaris*), rock dove (*Columba livia*), native house finches (*Carpodacus mexicanus*), and western scrub-jays (*Aphelocoma californica*) are more prevalent in developed areas. Native species including wrentit (*Chamaea fasciata*), bushtit (*Psaltriparus minimus*), white-tailed kite, red-tailed hawk, red-shouldered hawk (*Buteo lineatus*), Cooper's hawk (*Accipiter cooperii*), and California quail (*Callipepla californica*) are more common where developed areas transition to rural areas. Most of the developed land occurs within diked land and uplands (86.1%); the remaining acreage is split between channel margins (12.9%), in channel (0.7%), and remnant levees (0.3%).

8.2 Special-Status Plant Species

Many special-status plant species are found in the CSC, including two federally listed species. Details of these species and their distribution are elaborated below in Table 8-2 and in Appendix B.

The purpose of the species utilization table (Table 8-2) is to establish the relationships between species of interest (species that may benefit from or be impacted by tidal wetland restoration) and the natural communities present or to be restored within the CSC.

Table 8-2. Species Utilization of Natural Communities in the Cache Slough Complex: Special-Status Plants.

Species		Listing status			Tidal freshwater emergent wetland				Non tidal freshwater emergent wetland	Managed wetlands	Valley foothill riparian	Seasonal wetlands	Vernal pool complexes	Grasslands	Agricultural lands	Seasonal wetland
Common name	Species name	Federal	State	CRPR	Low marsh (<MLW)	Mid marsh (MLW-MHW)	High marsh (>MHW)	Upland transition								
alkali milk-vetch	*Astragalus tener* var. *tener*			1B.2						X		X	X	X		
heartscale	*Atriplex cordulata* var. *cordulata*			1B.2						X		X	X	X		
brittlescale	*Atriplex depressa*			1B.2						X		X	X	X		
vernal pool smallscale	*Atriplex persistens*			1B.2									X			
Bolander's water-hemlock	*Cicuta maculata* var. *bolanderi*			2B.1			X		X	X						
dwarf downingia	*Downingia pusilla*			2B.2									X			
San Joaquin spearscale	*Extriplex joaquinana*			1B.2								X		X		X
fragrant fritillary	*Fritillaria liliacea*			1B.2										X		
Boggs Lake hedge-hyssop	*Gratiola heterosepala*		E	1B.2					X	X			X			

Species		Listing status			Tidal freshwater emergent wetland				Non tidal freshwater emergent wetland	Managed wetlands	Valley foothill riparian	Seasonal wetlands	Vernal pool complexes	Grasslands	Agricultural lands	Seasonal wetland
Common name	**Species name**	**Federal**	**State**	**CRPR**	**Low marsh (<MLW)**	**Mid marsh (MLW-MHW)**	**High marsh (>MHW)**	**Upland transition**								
woolly rose-mallow	*Hibiscus lasiocarpos* var. *occidentalis*			1B.2			X		X							
Carquinez goldenbush	*Isocoma arguta*			1B.1										X		
Delta tule pea	*Lathyrus jepsonii* var. *jepsonii*			1B.2			X	X	X	X	X					
legenere	*Legenere limosa*			1B.1									X			
Heckard's pepper-grass	*Lepidium latipes* var. *heckardii*			1B.2									X			
Mason's lilaeopsis	*Lilaeopsis masonii*		R	1B.1		X					X					
Delta mudwort	*Limosella australis*			2B.1		X					X					
Colusa grass	*Neostapfia colusana*	T	E	1B.1									X			
bearded popcornflower	*Plagiobothrys hystriculus*			1B.1									X	X		
Sanford's arrowhead	*Sagittaria sanfordii*			1B.2					X	X						

Species		Listing status			Tidal freshwater emergent wetland				Non tidal freshwater emergent wetland	Managed wetlands	Valley foothill riparian	Seasonal wetlands	Vernal pool complexes	Grasslands	Agricultural lands	Seasonal wetland
Common name	Species name	Federal	State	CRPR	Low marsh (<MLW)	Mid marsh (MLW-MHW)	High marsh (>MHW)	Upland transition								
Suisun Marsh aster	*Symphyotrichum lentum*			1B.2			X		X		X					
Crampton's tuctoria or Solano grass	*Tuctoria mucronata*	E	E	1B.1								X				

Listing Status
Federal and State:
(E) Listed as Endangered under Endangered Species Act
(T) Listed as Threatened under Endangered Species Act
(R) Listed as Rare under California Endangered Species Act
(SC) Species of Special Concern

California Native Plant Society (California Rare Plant Rank [CRPR]):
1B Rare, threatened, or endangered in California and elsewhere
2B Rare, threatened, or endangered in California, but more common elsewhere
.1 Seriously threatened in California
.2 Fairly threatened in California

8.3 Non-Native Invasive Plant Species

Many non-native invasive plant species of concern, both aquatic and terrestrial, are known to occur in the CSC and throughout the Delta. Invasive plants have the potential to adversely impact the ecosystem processes, native species, and communities that are goals of restoration efforts.

For restoration projects within the CSC, incorporation of appropriate design elements and proper site management will be vital in controlling invasive plant populations and maintaining desired habitat goals. Invasive aquatic vegetation includes both submerged aquatic vegetation and floating aquatic vegetation. Invasive aquatic vegetation can impact fish habitat by reducing water flow and decreasing turbidity, providing habitat for predatory fish that prey on the protected fish species, restricting access and displacing native fish from shallow-water habitats, and altering physical and chemical habitat attributes such as light penetration, DO, pH, and nutrient concentrations (see section 9.4.4.1). Invasive aquatic vegetation can also displace native plants.

Upland habitats support some native plant species within the valley/foothill riparian and grassland habitat types. However, these upland areas predominantly support ruderal, non-native, and some highly invasive plant species. Invasive terrestrial vegetation may not have a direct impact on tidal wetlands. However, when sea level rise accommodation is taken into account, upland areas should be maintained in a state that allows for migration of native habitats to support the protected fish species.

Invasive plants that have been documented either within the CSC or that are broadly distributed throughout the Delta and listed by the California Invasive Plant Council (CalIPC 2013) as species of concern in California are presented in Table 8-3. A detailed description for each plant is provided in Appendix B.

Table 8-3. Non-native invasive Plant Species in the Cache Slough Complex.

Common name	Latin name	Cal-IPC Rating[1]	CDFA Rating[2]
AQUATIC PLANT SPECIES			
alligator weed	*Alternanthera philoxeroides*	High/Alert	A
Brazilian waterweed	*Egeria densa*	High	C
water hyacinth	*Eichhornia crassipes*	High	C
yellowflag iris	*Iris pseudacorus*	Limited	None
South American spongeplant	*Limnobium laevigatum*	High	Q
Uruguayan primrose-willow	*Ludwigia hexapetala*	High/Alert	None
water primrose	*Ludwigia peploides*	High	None
Eurasian water-milfoil	*Myriophyllum spicatum*	High	C
parrot's feather	*Myriophyllum aquaticum*	High	None
smartweed	*Persicaria* spp.	None	B and C
curlyleaf pondweed	*Potamogeton crispus*	Moderate	None
TERRESTRIAL PLANT SPECIES			
Russian knapweed	*Acroptilon repens*	Moderate	A
barbed goat grass	*Aegilops triuncialis*	High	B
tree-of-heaven	*Ailanthus altissima*	Moderate	C
giant reed	*Arundo donax*	High	B
red brome	*Bromus madritensis* subsp. *rubens*	High	None
Italian thistle	*Carduus pycnocephalus*	Moderate	C
yellow starthistle	*Centaurea solstitialis*	High	C
poison-hemlock	*Conium maculatum*	Moderate	None
jubata grass	*Cortaderia jubata*	High	None
pampas grass	*Cortaderia selloana*	High	None
medusa head	*Elymus caput-medusae*	High	None
fig	*Ficus carica*	Moderate	None
fennel	*Foeniculum vulgare*	High	None
French broom	*Genista monspessulana*	High	C
perennial pepperweed	*Lepidium latifolium*	High	None
purple loosestrife	*Lythrum salicaria*	High	None
Himalayan blackberry	*Rubus armeniacus*	High	None
red sesbania	*Sesbania punicea*	High	B
smallflower tamarisk	*Tamarix parviflora*	High	B
saltcedar	*Tamarix ramosissima*	High	B

1 California Invasive Plant Council:
- High = Severe ecological impacts, moderate to high rates of dispersal and establishment, widely distributed.
- Moderate (Mod) = Substantial and apparent ecological impacts, moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance.
- Limited (Lim) = Invasive, but ecological impacts are minor, moderate rates of invasion, distribution generally limited.
- Red Alert = Pest plants with significant potential to spread into new ecosystems.

2 California Department of Food and Agriculture Lists:

A = The agency mandates that these species be targeted for eradication or containment.
B = These species are more widespread and, therefore, difficult to contain and the agency allows County Agricultural Commissioners to decide whether to target them for eradication or containment in their jurisdictions.
C = These weeds are so widespread that the agency does not endorse state- or county-funded eradication or containment efforts except in nurseries or seed lots.

9 FISH AND AQUATIC FOOD WEB

Fish declines in the Delta have been driven by a multitude of stressors which include habitat loss, declining water quality, altered flow regime, entrainment in water diversions, and the establishment of invasive species leading to reduced prey availability and increased predation by non-native piscivores (Sommer et al. 2007, Kimmerer 2008, Baxter et al. 2010). This suite of stressors culminated in the Pelagic Organism Decline (POD) of the early 2000s, when abundance indices for key pelagic fish species in the Delta hit several consecutive years of record low numbers (Feyrer et al. 2007, Sommer et al. 2007).

Despite declining native fish populations throughout the Delta, the CSC is a region where key species of concern have been consistently detected. Several monitoring programs and special studies have documented native fish in the region year-round (Table 9-2). While non-native species are still numerically dominant in the Cache Slough region native species of concern are present at higher proportions compared with other Delta regions. Most notably, the CSC at times provides spawning and rearing habitat for species listed as threatened or endangered under the federal ESA and CESA (Table 9-1). Due to its unique combination of tidal and flood flow regimes, nutrient input from various sources, and habitat quality the CSC is an important area for restoration and native fish species alike.

Table 9-1. Special-status Fish Species with the Potential to Occur in the CSC.

Common name *Scientific name*	Status[a] Federal/ State	Habitat associations
Pacific Lamprey *Entosphenus tridentatus*	FSC/–	Adults spawn on sand and gravel in streams (lotic environments), but have been observed spawning in stagnant and muddy (lentic) environments; larvae (ammocoetes) bury themselves and feed in silty or sandy backwaters or stream edges with temperatures below 20°C
River Lamprey *Lampetra ayresi*	FSC/SSC	Spawning adults need riffle habitat with clean gravels in permanent streams; larvae (ammocoetes) bury themselves and feed in silty or sandy backwaters or stream edges with temperatures below 25°C
North American Green Sturgeon: southern DPS *Acipenser medirostris*	FT/SSC	Spawn in pools of large freshwater rivers with cool water and cobble, clean sand, or bedrock; in San Francisco Bay adults swim near the surface or forage along the bottom in water less than 33 ft deep; juveniles may rear in Delta for two years or more but Delta rearing habitat has not been documented
Sacramento Splittail *Pogonichthys macrolepidotus*	–/SSC	Low-elevation rivers and estuaries with low to moderate salinity (0–18 ppt); shallow, flooded vegetated habitat for spawning and foraging
Delta Smelt *Hypomesus transpacificus*	FT/SE	Estuarine or brackish waters up to 18 ppt; spawn in shallow brackish water upstream of the mixing zone (zone of saltwater-freshwater interface) where salinity is around 2 ppt
Longfin Smelt *Spirnichus thaleichthys*	FPT/ST	Adults in large bays, estuaries, and nearshore coastal areas; migrate into freshwater rivers to spawn; salinities of 15–30 ppt
Chinook Salmon, Sacramento River winter-run ESU *Oncorhynchus tshawytscha*	FE/SE	Mainstem river reaches with cool water and available spawning gravel; rear five to ten months in the river and estuary (potentially including Yolo bypass and similar habitats); migrate to the ocean to feed and grow until sexually mature
Chinook Salmon, central Valley spring-run ESU *O. tshawytscha*	FT/ST	Low- to mid-elevation rivers and streams with cold water, clean gravel of appropriate size for spawning and adequate rearing habitat; typically rear in freshwater for one or more years before migrating to the ocean; species documented to rear in Yolo bypass and other Delta habitats
Steelhead, Central Valley DPS *Oncorhynchus mykiss*	FT/–	Rivers and streams with cold water, clean gravel of appropriate size for spawning, and suitable rearing habitat; typically rear in freshwater for one or more years before migrating to the ocean; prevalence of Delta rearing largely unknown

a. Federal Status
FE = Listed as endangered under the federal Endangered Species Act
FT = Listed as threatened under the federal Endangered Species Act
FPT = Federally proposed as threatened
FSC = Federal Species of Concern

State Status
SE = Listed as Endangered under the California Endangered Species Act
ST = Listed as Threatened under the California Endangered Species Act
SSC = California Species of Special Concern

9.1 Important Habitat and Natural Communities

Key habitats important to target fish species include tidally influenced channels and sloughs, shallow open water, emergent marsh, and seasonal floodplain. Large tidal channels (e.g., Sacramento Deep Water Ship Channel [DWSC]) and sloughs (e.g., Cache Slough) provide habitat for pelagic fish and transport food resources from adjacent shallow water and emergent marsh habitats. Several smaller dead-end sloughs (e.g., Lindsey Slough) drain upland areas and provide freshwater flow to the region during runoff events but revert to a tidal channel during drier summer and fall months.

Shallow shoals of the DWSC now comprise as much as 2/3 of the channel width (T. Morgan, USGS, unpubl. data). Delta Smelt are believed to spawn on these shallow open shoals (Bennett 2005, Sommer and Mejia 2013). Additionally, Liberty Island and Little Holland Tract have large expanses of intertidal and shallow open water habitats. Some remnant emergent marsh still exists in the region. Reestablishment of emergent marsh vegetation has occurred to a limited extent in restored wetland areas such as Liberty Island and Little Holland Tract and in shallow channel margin habitat.

The CSC includes the transition between tidal waters of the Delta and seasonally aquatic habitat in the Yolo Bypass, the largest floodplain on the Sacramento River. Although its primary purpose is conveyance of floodwater from the Sacramento River, the Yolo Bypass floodplain is key spawning and rearing habitat for native fish, and is a key migration corridor for several listed and sportfish species (Sommer et al. 2001a). Additionally, the floodplain is a source of algal productivity to the food web of the CSC and other Estuary regions (Schemel et al. 2004).

9.2 Special-Status Fish Species

9.2.1 Delta Smelt

Status and range: Delta Smelt are listed as endangered under CESA and threatened under the ESA. In 2010, the USFWS determined that reclassification of Delta Smelt to endangered was warranted, but the status change was precluded by higher listing priorities. Federally designated critical habitat for Delta Smelt includes Suisun Marsh and the contiguous waters of the Delta, which includes the CSC.

Delta Smelt are endemic to the upper San Francisco estuary and were once one of the most common fish species in the Delta (Moyle 2002); however, in recent decades the Delta Smelt, along with other pelagic fish species, have experienced a substantial decline in population (Baxter et al. 2010).

The southern end of the Yolo Bypass, including Liberty Island (Table 9-2), Cache Slough, and the DWSC are known to support Delta Smelt spawning and rearing (Bennett 2005) (Grimaldo et al. 2004). The USFWS found Delta Smelt in shallow water habitats within Liberty Island using a variety of fish sampling techniques (Figure 9-1). Delta Smelt catch and gonadal staging from fish collected from the Spring Kodiak Trawl (SKT) surveys also indicate that the DWSC is an important spawning location in the Delta (Figure 9-2). Additionally, a non-migratory contingent has been recently observed to remain in freshwater and carry out their entire lifecycle in the tidal freshwater region of the CSC, which offers cool, turbid habitat and abundant prey (Sommer et al. 2011).

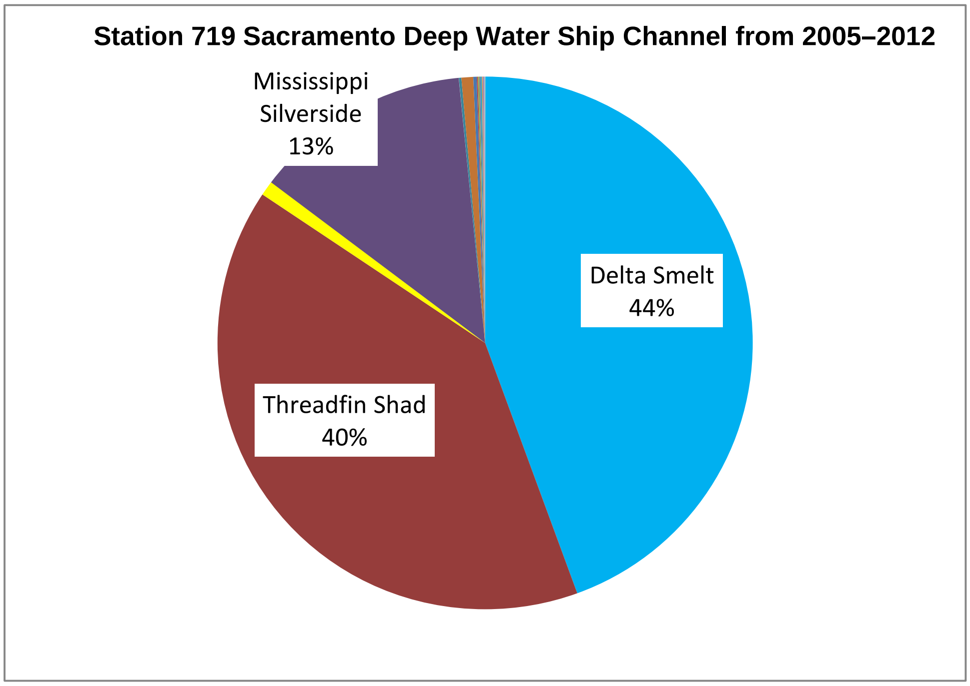
Habitat requirements: Delta Smelt are a relatively small fish (2.3–2.7 inches [in]), and spend their entire one- to two-year lifespan within brackish to freshwater portions of the San Francisco-Bay Delta (Moyle 2002). They are a pelagic species, inhabiting open waters, away from the bottom and shore-associated structural features (Nobriga and Herbold 2009). Distribution is concentrated around the low salinity zone (≤ 6 PSU), where incoming salt water and out flowing freshwater mix, creating a turbid zone of high primary and secondary productivity (Jassby et al. 1995). Delta Smelt feed primarily on zooplankton, mysid shrimp, and amphipods. Low water clarity has shown to be an important habitat component for Delta Smelt (Nobriga and Herbold 2009, Slater 2012). As an annual species, the majority of Delta Smelt complete their life cycle in a single year. Only a small percentage lives to two years and these fish are believed to spawn in both years (Bennett 2005). Spawning migration upstream to tidal freshwaters appears to be triggered by the first flow pulses of the year, typically from December-March (Grimaldo et al. 2009, Sommer et al. 2011). After hatching, young may return downstream to brackish regions to rear (Dege and Brown 2004). Larval and juvenile Delta Smelt need turbid, food-rich nursery habitat for survival (Sommer and Mejia 2013).

Threats and stressors: Threats to Delta Smelt may include low abundance (stock-recruitment effects), water diversions and exports, predation, decline in quality and quantity of food resources, invasive species, contaminants, and other water quality factors such as a decrease in turbidity (Sommer et al. 2007, Kimmerer 2008, Nobriga et al. 2008, Miller et al. 2012).

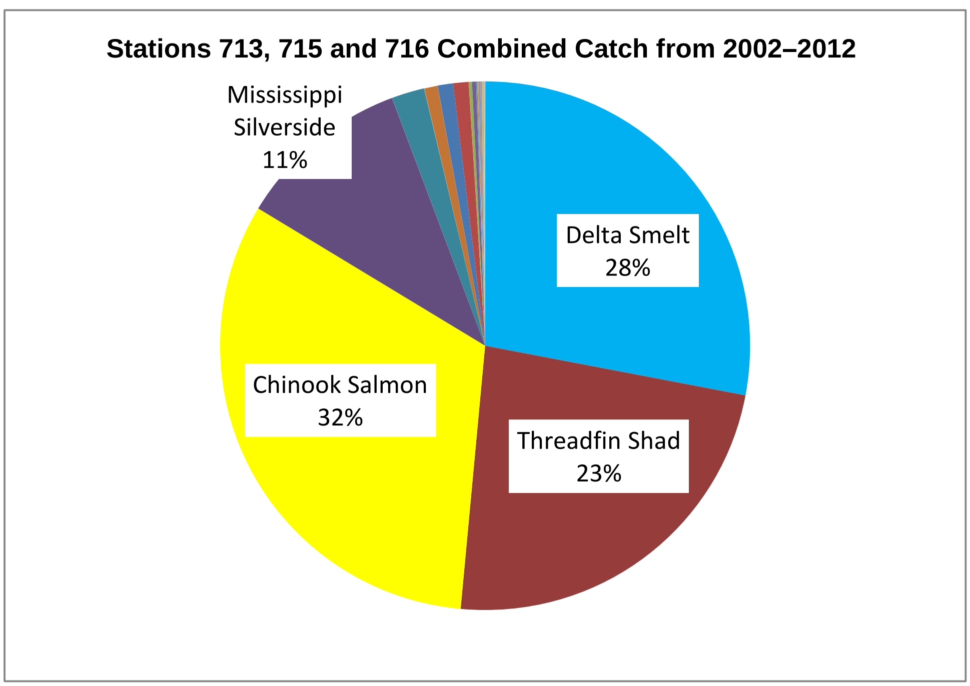
Table 9-2. Species Composition and Percentage of Overall Catch (raw data) at Liberty Island by Sampling Gear Type. Data source: USFWS unpubl. data.

Species	Kodiak trawl (2003–04)	Gillnet (2003–05)	Light trap (2003–04)	Larval trawl		Beach seine	
				2004–05	2010–12	2002–04	2010–12
NON-NATIVE							
Striped Bass	15%	22%	3%	8%	6%	<1%	3%
Miss. Silverside	10%	0%	36%	11%	39%	54%	78%
Threadfin Shad	26%	4%	4%	41%	11%	11%	2%
American Shad	42%	2%	<1%	2%	1%	1%	5%
Common Carp	<1%	18%	3%	4%	<1%	<1%	<1%
White Catfish	1%	32%	0%	<1%	<1%	<1%	<1%
All other spp.	1%	11%	8%	3%	2%	11%	3%
Subtotal	95%	89%	54%	69%	59%	77%	91%
NATIVE							
Delta Smelt	3%	0%	3%	<1%	3%	<1%	<1%
Longfin Smelt	<1%	<1%	2%	<1%	1%	0%	0%
Chinook Salmon	1%	<1%	<1%	<1%	0%	5%	<1%
Sacramento Splittail	1%	5%	<1%	1%	2%	16%	7%
Prickly Sculpin	0%	0%	40%	28%	36%	<1%	<1%
All other spp.	<1	5%	<1%	<1%	<1%	1%	1%
Subtotal	5%	11%	45%	30%	41%	23%	9%
Total (total catch)	**100% (9,666)**	**100% (2,092)**	**100% (9,820)**	**100% (14,550)**	**100% (14,614)**	**100% (18,602)**	**100% (52,782)**

Figure 9-1. Most Abundant Juvenile and Adult Fish Caught in the Spring Kodiak Trawls in the Cache Slough Complex from 2002-2012.

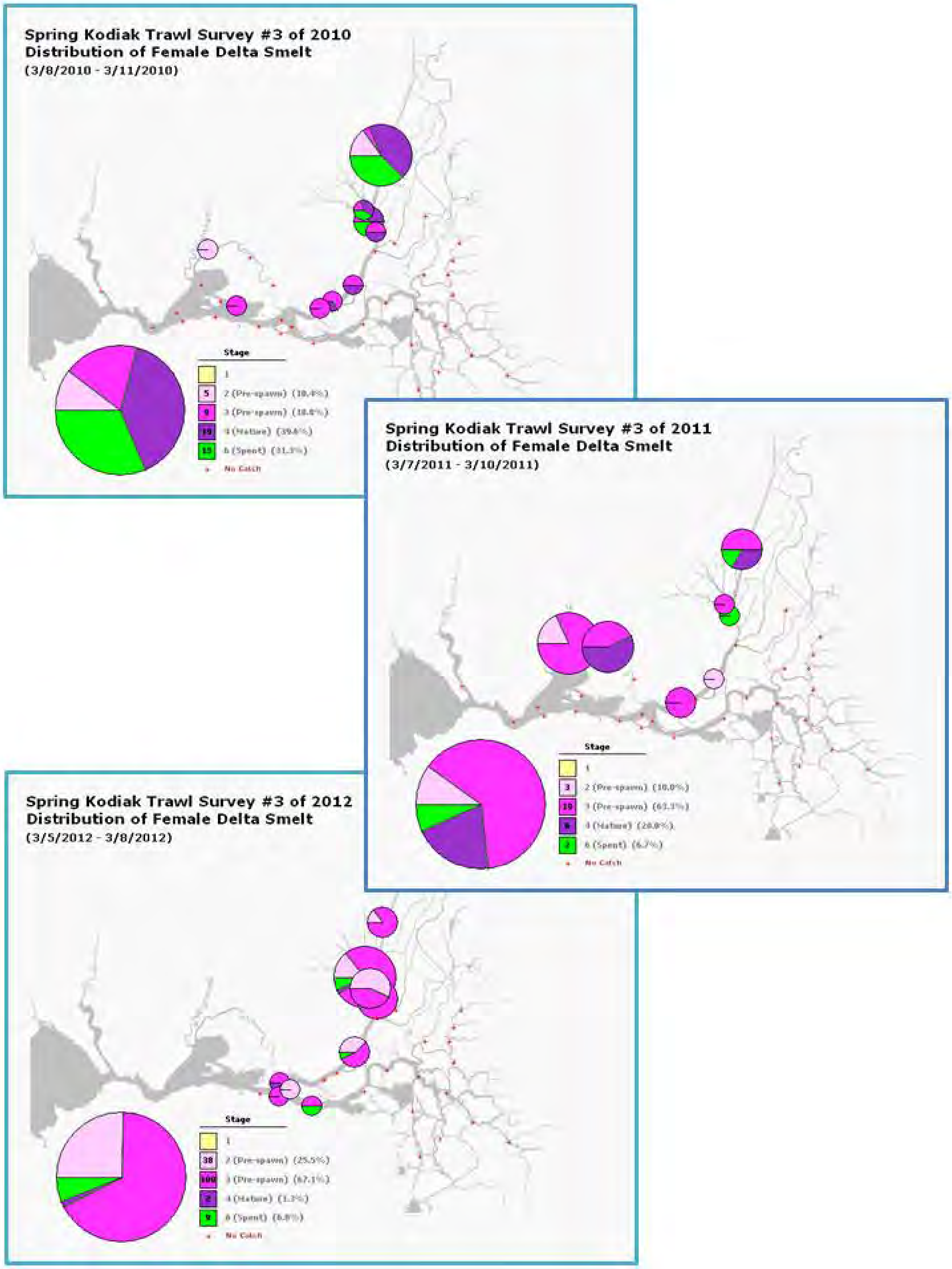


Source: CDFW unpubl. data.



Source: CDFW unpubl. data.

Figure 9-2. Female Delta Smelt Geographical Distribution and Gonadal Stages for March Spring Kodiak Trawl Surveys in 2010, 2011, and 2012



Data source: CDFW Spring Kodiak Trawl webpage (http://www.delta.dfg.ca.gov/data/projects/?ProjectID=SKT).

9.2.2 Longfin Smelt

Status and range: Longfin Smelt is listed as a threatened species under the CESA. In 2012, the USFWS found that listing the Bay-Delta distinct population segment (DPS) of Longfin Smelt is warranted, however, listing was precluded by higher priority actions. The Bay-Delta DPS of Longfin Smelt is on the USFWS candidate species list. Longfin Smelt is one of the four POD species having experienced substantial population declines in recent decades (Baxter et al. 2010). In the San Francisco Estuary, Longfin Smelt populations are primarily concentrated in Suisun, San Pablo, and North San Francisco bays (Baxter 2000).

Habitat requirements: Similar to Delta Smelt, Longfin Smelt are relatively small fish (3–4 in) with a short lifespan of 2–3 years. In contrast to Delta Smelt, Longfin Smelt juveniles and adults are broadly distributed and inhabit the more saline regions of the Bay-Delta and nearshore coastal waters. Mature Longfin Smelt migrate upstream to freshwater to spawn (December through March), where it is thought they select benthic, sandy substrates to lay their adhesive eggs (Moyle 2002, Hobbs et al. 2010). Longfin Smelt larvae are regularly collected in the Cache Slough region by the Smelt Larva Survey (http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SLS), although they primarily migrate back to the low salinity zone to rear (Hobbs et al. 2010). Longfin Smelt feed primarily on mysid shrimp and zooplankton (MacNally et al. 2010).

Threats and stressors: Threats to Longfin Smelt may include water diversions and export, reduced outflows, climatic variation, invasive species, decline in quality and quantity of food resources, predation, and toxic substances (Kimmerer 2002, Moyle 2002, MacNally et al. 2010).

9.2.3 Chinook Salmon

Status and range: Two runs of Chinook Salmon are listed under the federal and state endangered species acts. Sacramento River winter-run Chinook Salmon Evolutionarily Significant Unit (ESU) is listed as endangered, and Central Valley spring-run Chinook Salmon is listed as threatened under both the ESA and CESA. Central Valley fall- and late fall- run Chinook Salmon is a Species of Concern under the ESA.

Chinook Salmon utilize the Delta as a rearing and migratory corridor as they move between spawning locations upstream and the ocean. Spawning runs of anadromous Chinook Salmon in California occur in rivers of the north and central coast and rivers draining the Central Valley.

Winter-run migrants enter the estuary as early as December; with peak migration from January through March. Spawning habitat is restricted to the Sacramento River below Shasta Reservoir. Juveniles spend 5 to 10 months in streams followed by an intermediate period in the San Francisco estuary, including the Delta (Moyle 2002). Juvenile winter-run Chinook Salmon may be in the Delta from September through May. Based on their size prior to entering the ocean, it is estimated that winter-run juveniles inhabit fresh and estuarine waters for 5–9 months, until they reach about 4.6 in (Fisher 1994, Myers et al. 1998).

Spring-run Chinook Salmon enter the San Francisco Bay as adults in spring or early summer and migrate to tributaries of the Sacramento River, where they hold in deep, cold pools for several months prior to spawning in early fall (Fisher 1994, Moyle et al. 1995). Spring-run migrants enter the estuary as early as March; however the peak migration occurs from May through June (Yoshiyama et al. 2001). Juveniles typically rear in streams for 3 to 15 months before moving downstream, primarily as smolts that move rapidly through the Delta (Fisher 1994, Moyle et al. 1995).

The fall run is the most abundant Chinook Salmon run in the Central Valley (Azat 2014), although the population is supplemented by hatcheries on Battle Creek and the Feather, American, Mokelumne, and Merced rivers. Fall-run Chinook Salmon migrate from the ocean in late summer and early fall as adults. Spawning generally occurs within days or weeks upon reaching spawning grounds. Fall migrants enter the estuary as early as June; however peak migration occurs from September through October (Yoshiyama 1998). Juveniles emerge in spring and move downstream within a few months to rear in mainstem rivers or estuaries (Moyle 2002). Late fall-run Chinook Salmon typically migrate upstream from the ocean from October through February and hold for 1–3 months prior to spawning in January through March (Moyle et al. 1995). Juveniles spend 7–13 months in freshwater prior to outmigration. All runs of Chinook Salmon may use the Cache Slough region as a migratory corridor and as rearing habitat. For example, Chinook Salmon use Miner Slough as a migration corridor to and from the Sacramento River (Vogel 2008). Additionally, Spring Kodiak Trawl sampling found that juvenile Chinook Salmon were more prevalent in the channel stations near and below the confluence of Cache and Miner sloughs than upstream in the DWSC (Figure 9-2).

Habitat requirements: Juvenile Chinook Salmon feed on zooplankton, larger crustaceans and aquatic insects. Ephemeral habitats such as the Yolo Bypass are very important to rearing Chinook Salmon due to high densities of prey resources, primarily chironomid larvae (Sommer et al. 2001b). In the Cache Slough region, intertidal mudflats and tule marshes become important habitat for juveniles during high tides. High abundance of invertebrate prey resources for juvenile Chinook Salmon can be associated with emergent marsh edge habitat. Chinook Salmon fry tend to remain close to channel banks and vegetation, near protective cover, and in dead-end tidal channels (Moyle et al. 1986).

Threats and stressors: Threats to Chinook Salmon may include water diversions and exports, predation, fishing, loss of suitable spawning and rearing habitats, impacts due to hatchery programs, migration barriers, contaminants, diseases, and increased water temperatures (Yoshiyama et al. 2001, Moyle 2002, NMFS 2009a).

9.2.4 Central Valley Steelhead

Status and range: The Central Valley Steelhead (*Onorhynchus mykiss*) DPS is listed as threatened under the ESA.

Steelhead in the Central Valley DPS spawn in streams and rivers of the Sacramento and San Joaquin basins and travel through the Delta during their upstream and downstream migrations. Central Valley Steelhead enter freshwater in August with migration peaking in late September through October and hold until flows are adequate to allow them to move to spawning grounds (Gerstung, E., personal communication 1999;McEwan 2001).

Central Valley Steelhead have been documented in the CSC by DWR Yolo Bypass Fish Monitoring and USFWS Juvenile Fish Monitoring Programs. The presence of juvenile Steelhead in the Yolo Bypass suggests that the CSC is a migration corridor and may be used as rearing habitat for the species, although the extent to which they use the region is unknown.

Habitat requirements: Steelhead have a similar life history to Chinook Salmon, where they spawn in freshwater, rear in fresh and estuarine habitats, migrate to the ocean to mature, then return to upstream freshwater riverine habitat to spawn as adults; however, Steelhead are iteroparous, and can return to freshwater several times as adults to spawn. While Steelhead benefit from seasonal floodplain habitat and juveniles have been found rearing in the Yolo Bypass (Sommer et al. 2001a), their use of tidal wetland habitat is poorly understood (Brown 2003).

Threats and stressors: Threats to Steelhead may include water diversions and exports, predation, fishing, hatchery fish, loss of suitable spawning and rearing habitats, migration barriers, contaminants, diseases, and increased water temperatures (NMFS 1996, Moyle 2002, NMFS 2009b).

9.2.5 Green Sturgeon

Status and range: Green Sturgeon (*Acipenser medirostris*) are divided into two distinct population segments: the northern and southern DPS. The Northern DPS includes populations that spawn within Eel River and coastal watersheds northward. The Southern DPS consists of populations that spawn south of the Eel River (Klimley et al. 2007). The southern distinct population segment is listed as threatened under the ESA and is a state species of special concern. The Southern DPS is known to spawn in the Sacramento River and tributaries; spawning was documented for the first time in the Feather River in 2011(Seesholtz et al. 2015). Spawning migrations take place from February through July, with a peak spawning period of mid-April to mid-June (Moyle 2002). Juvenile Green Sturgeon have been captured in the Delta during all months of the year, as indicated by CVP and SWP salvage data (data available at: http://www.dfg.ca.gov/delta/apps/salvage/Default.aspx). Green Sturgeon have been documented in the Yolo Bypass (M. Marshall, pers. comm., as cited in BDCP 2012) and the DWSC (Gleason et al. 2008) which suggests that the CSC is a migration corridor and rearing habitat for the species.

Habitat requirements: Green Sturgeon are large (3 ft or larger) and long-lived (up to 60–70 years), reaching sexual maturity around 15 years and have an average lifespan of several decades (Moyle 2002). Due to their anadromous nature juvenile and adult Green Sturgeon will utilize both estuarine and oceanic waters during their life cycle, but will return to freshwater as sexually mature adults to spawn. Optimal spawning habitat consists of deep, swiftly flowing water that is characterized by large cobble or gravel substrate (Emmett et al. 1991). Juveniles spend 1 to 4 years in fresh water and estuaries before entering the ocean (Beamesderfer and Webb 2002).They generally begin their downstream migration in summer (Adams et al. 2002).

Threats and stressors: Threats to Green Sturgeon may include reduced spawning habitat, water diversions and exports, poaching, contaminants, low abundance, invasive species, migration barriers, and increased water temperatures (NOAA Fisheries 2014).

9.2.6 Sacramento Splittail

Status and range: Sacramento Splittail (*Pogonichthys macrolepitodus*) is a minnow endemic to California's Central Valley. Splittail were previously listed under the ESA as a threatened species, but were reclassified to a Species of Concern in 2003. Sacramento Splittail are caught throughout the Delta in various IEP monitoring programs (Table 9-2).

Habitat requirements: Sacramento Splittail feed on benthic detritus and epibenthic invertebrates (Moyle 2002). Spawning occurs on inundated channel margin and floodplain vegetation during springtime high water events. Splittail abundance is highly correlated with recruitment success related to Yolo Bypass inundation (Sommer et al. 1997). Emergent marsh may provide spawning habitat in dry years when fish do not have access to inundated floodplain habitat. Additionally, floodplain and tidal wetland habitats of the Cache Slough region provide rearing habitat for larvae and young (Sommer et al. 1997).

Threats and stressors: Threats to Sacramento Splittail include loss of valley floor floodplain habitats, including spawning habitats, changes in Delta hydrology, climatic variation, contaminants, harvest, and introduced species (Moyle 2002).

9.2.7 Lampreys

Status and range: Two lamprey species are found in the Delta: River Lamprey (*Lampetra ayresi*) which is a federal Species of Concern and a state Species of Special Concern, and the Pacific Lamprey (*Lampetra tridentate*) which is a federal Species of Concern.

River Lamprey distribution extends from Juneau, Alaska to San Francisco, California, though their distribution and abundance trends in the Delta and CSC are not well known. Pacific Lamprey has an even wider distribution stretching from Japan to Mexico. They have been associated with large rivers such as the Sacramento and Eel River. Beamish (1980) found that river lamprey concentrate only in particular rivers, where they inhabit only the lower reaches. Lampreys of both species use Delta waterways as migration corridors to upstream spawning habitats and downstream migration back to the ocean.

Habitat requirements: Lampreys are an anadromous, parasitic species found in coastal streams, the upper reaches of the San Francisco Estuary, and Central Valley rivers and tributary streams. They migrate upriver in the spring to spawn in gravelly streams; riffles and side channels are essential for both spawning and rearing stages (USFWS 2004). The juvenile ammocoetes will remain in sandy or muddy areas of the stream for 3–5 years for River Lampreys and 3–7 years for Pacific Lampreys (Moyle 2002). Due to their immobility as ammocoetes, water quality must be maintained in good condition and low water velocities are preferred (USFWS 2004). After they transform from detritus-feeding to active predation, most return to the ocean: briefly for River Lampreys and for several years for Pacific Lampreys (Wang 1986) (Moyle 2002). Specific lamprey habitats in the Delta are unknown.

Threats and stressors: Threats to lampreys are not well understood, but probably are mostly human related and likely include migration barriers caused by land and water development, and loss of suitable spawning and rearing stream habitats.

9.3 Non-native Fish Species

Native Delta fish species have evolved under highly variable flow and water quality conditions. Water management practices within and upstream of the Delta, reductions in sediment supply, and conversion of historical waterways into conveyance canals have substantially reduced this natural variability and created highly altered conditions (Whipple et al. 2012). Natural seasonal variations and seaward gradients in temperature, turbidity, salinity, and flow have been altered and reduced. Water conditions of the modern Delta and CSC are more warm, clear, and uniform than they were historically (Cloern and Jassby 2012). These altered conditions favor a narrower group of non-native fish species that are more commonly associated with temperate freshwater lakes, as they prefer stable, low flow conditions (Sommer et al. 2007, Moyle et al. 2012).

Invasive fish species, such as Striped Bass, Largemouth Bass, and sunfish are known to occur throughout the Delta, and have been shown to prey on juvenile native fish, including Chinook Salmon, in the Delta (Lindley and Mohr 2003, Moyle and Marchetti 2006, Crain and Moyle 2011). These non-native species are well suited to the highly altered conditions of the modern Delta and, therefore, occur in large numbers (Feyrer 2003). The piscivorous Largemouth Bass is a generalist predator that is also likely to have a high impact on shallow water fisheries (Nobriga and Feyrer 2007). Largemouth Bass and Inland Silverside have been identified as predators of larval Delta Smelt, with Inland Silverside believed to be the primary consumer of Delta Smelt in the San Francisco Estuary (Bennett and Moyle 1996, Bennett 2005, Baerwald et al. 2012). Populations of Largemouth Bass and Inland Silversides in the Delta are currently expanding (Bennett and Moyle 1996, Brown and Michniuk 2007, Thomson et al. 2010). However, there is little evidence indicating predation by introduced species is a major factor in the decline of Delta Smelt (IEP MAST 2015).

Table **9-3** lists other native and non-native fish that occur within the CSC. The section below describes a few of the non-native fish species that impact the Delta dramatically. Although these alien species are dominant throughout the Delta, the CSC has a diverse fish community including relatively robust densities of some native fish species (Brown and Michniuk 2007).

Table 9-3. Other Native and Non-Native Fish Species to Occur in the CSC.

Common Name ***Scientific Name***	**Native/ Introduced**	**Habitat Requirements**	**Spawning Requirements**
White Sturgeon *Acipenser transmontanus*	Native	In estuaries adults tend to concentrate in deep areas with soft bottoms, although they may move into intertidal areas to feed at high tides.	Spawning takes place when water temperatures range from 8 to 19˚C, triggered by a pulse of high flow. They spawn in rivers upstream of the Delta, either over deep gravel riffles or in deep holes with swift currents and rock bottoms.
Tule Perch *Hysterocarpus traskii*	Native	In rivers typically associated with beds of emergent aquatic plants, deep pools, and banks with complex cover, such as overhanging bushes, fallen trees, and undercutting. Can also be common in riprap. Generally require cool, well-oxygenated water.	Males actively court females in late summer when they defend small territories under overhanging branches or plants close to shore. Although, courtship and mating can also occur away from territories.
Prickly Sculpin *Cottus asper*	Native	Spend most of their time lying on the bottom. During the day they hide underneath or in submerged objects such as rocks, logs, and pieces of trash.	Sculpins move into freshwater or intertidal areas that contain large flat rocks and moderate current, so that males can select nest sites underneath rocks. Spawning in streams usually requires temperatures of 8-13˚C.
Sacramento Blackfish *Orthodon microlepidotus*	Native	Most abundant in warm, usually turbid, waters of the Central Valley floor, often occurring in highly modified habitats (pH 9-10, salinities of 7-9 ppt) otherwise dominated by nonnative fishes. Can survive in extreme environments.	Spawning occurs at water temperatures of 12-24˚C in shallow areas with heavy growths of aquatic plants.
Sacramento Pikeminnow *Ptychocheilus grandis*	Native	Associated with low- to mid-elevation streams with deep pools, slow runs, undercut banks, and overhanging vegetation. Most abundant in lightly disturbed, tree-lined reaches that also contain other native fishes. Generally live in 18-28˚C water temperatures.	Spawning areas include gravel riffles or shallow flowing areas at the base of pools when water temperatures rise to 15-20˚C.
Threadfin Shad *Dorosoma petenense*	Introduced	Prefer well-lighted surface waters and are seldom found below depths of 18 m. Best growth and survival occur in waters in which summer	Spawning peaks when water temperatures exceed 20˚C, but has been observed at 14-18˚C. Centers around floating

		temperatures exceed 22-24˚C and do not become colder than 7-9˚C.	or partially submerged objects, such as logs, brush, aquatic plants, and gill nets.
American Shad *Alosa sapidissima*	Introduced	Found in fresh water only when adults move up into rivers to spawn and when juveniles use rivers as nursery areas for the first year or two of life.	Peak runs and spawning usually occur at higher temperatures, 17-24˚C in the Sacramento River. Spawning takes place mostly in main channels of rivers over a wide variety of substrates, although sand and gravel are most typical. Depth usually less than 3 m, currents typically 31-91 cm/sec, and DO levels must be above 5 mg/L.
Channel Catfish *Ictalurus punctatus*	Introduced	In rivers adults typically spend days in pools or beneath logjams or undercut banks, moving into faster water to feed at night. YOY will live full time in riffles. Optimal habitat is clear warm water streams with sand, gravel, or rubble bottoms.	Require cavelike sites for nests, preferring old muskrat burrows, undercut banks, logjams or riprap made up of large rocks.
White Catfish *Ameiurus catus*	Introduced	More abundant in deeper, swifter channels. Avoid heavy beds of aquatic plants and water less than 2 m deep during the day, but move into shallower water at night. Can live in high salinities (11-14.5 ppt). Bulk of population is located below 10 m.	Spawning occurs when water temperatures exceed 21 ˚C. Males build a nest on sand or gravel, near cover, or in cavelike situations among rocks.
Common Carp *Cyrpinus carpio*	Introduced	Most abundant in eutrophic lakes, reservoirs, and sloughs with silty bottoms and growths of submerged and emergent aquatic vegetation. In streams they are associated with turbid water; deep, permanent pools; high alkalinity; and soft bottoms. Cover becomes more important as water becomes clearer.	Spawning takes place when water temperatures start to exceed 15˚C. Swim into open water near beds of aquatic plants, usually close to shore in large shoals then move into shallow, weedy areas, preferably recently flooded to spawn.
Wakasagi *Hypomesus nipponensis*	Introduced	Tolerate wide range of salinities (0-29 ppt) and temperatures, although 14-21˚C is optimal for growth and reproduction.	Wakasagi move up rivers a short distance to deposit fertilized eggs in shallow areas of gravel or sand.

9.3.1 Striped Bass

Status and range: Striped Bass (*Morone saxatilis*) are an important predatory anadromous sportfish that were first introduced to the Sacramento-San Joaquin Delta in 1879 (Scofield and Bryant 1926). IEP long-term monitoring programs indicate that all life stages of Striped Bass are present in the CSC. Larval Striped Bass are regularly caught in Cache, Lindsey and Miner sloughs, and in the DWSC (data available at http://www.dfg.ca.gov/delta/projects.asp?ProjectID=20mm). Recent monitoring from the Summer Townet and Fall Midwater Trawl surveys indicates age-0 Striped Bass are present in Cache Slough and the DWSC (Contreras et al. 2012). Adult Striped Bass also pass through and feed in the area. As referenced in Skinner (1962), Cache Slough and its tributaries were a noted Striped Bass fishing spot as far back as the early 1900s.

Threats to native fishes: Adults are opportunistic feeders and may feed on a range of pelagic organisms, including shad, herring, anchovies, salmon and their own young (Moyle 2002). Once they become piscivorous, predation pressure by young and adult Striped Bass on pelagic fish in the Delta can be significant (Loboschefsky et al. 2012).

9.3.2 Largemouth Bass, sunfish, and crappie

Status and range: Largemouth Bass (*Micropterus salmoides*) are an important sportfish that were introduced into California in 1891 (Dill and Cordone 1997). Similarly, during the early 20th Century, various sunfish and crappie species were introduced into the Central Valley (Moyle 2002).

Although relatively few Largemouth Bass, sunfish, and crappie are caught in IEP long-term monitoring programs, these species likely occur in vegetated, shallow water habitats, along vegetated levees, and near levee breaches in the CSC; all of which are not typically sampled by IEP collaborators. The monitoring that has occurred suggests that Largemouth Bass abundance is likely lower in the CSC than in other regions of the Delta. The north Delta has less submerged aquatic vegetation along the nearshore habitats and a lower percentage of non-native fishes (Brown and Michniuk 2007), in particular fewer centrarchids, e.g., bass, sunfish, and crappie (Michniuk 2003). McLain and Castillo (2009) indicated that Largemouth Bass abundance was low in their nearshore sample sites in the Liberty Island-Prospect Island complex.

Threats to native fishes: Largemouth Bass are usually solitary, opportunistic ambush predators that can reside in a relatively small area or roam widely (Moyle 2002) and they can have a high per capita predatory impact on native fishes in vegetated shallow water habitats in the Delta (Nobriga and Feyrer 2007). Because of their prolific nature, aggressiveness, wide distribution, and diverse feeding ability, sunfish and crappie may directly and indirectly compete with native fishes and limit their populations (Moyle 2002).

9.3.3 Inland silverside

Status and range: Although Inland Silversides (*Menidia beryllina*) are only occasionally caught by open-water sampling in the Delta (http://www.dfg.ca.gov/delta/data/), they are often one of the most abundant species caught with beach seines in the nearshore habitats of the Delta (Marshall 2005, Brown and May 2006). In the CSC, Inland Silversides are found from the floodplain habitats of the Yolo Bypass (Sommer et al. 2004) downstream through the confluence of Miner Slough, Cache Slough, and the DWSC (http://www.dfg.ca.gov/delta/data/). They were the most abundant species captured by McLain and Castillo (2009) during beach seine surveys in the northwestern Delta, which included the Prospect Island-Liberty Island complex and lower Miner Slough.

Threats to native fishes: Because Inland Silversides are so prolific and can become very abundant they may impact local shallow water food resources which then could affect growth and survival rates of rearing native fishes (Moyle 2002). Bennett and Moyle (1996) suggest that silversides might have played a role in the decline of Delta Smelt and recent research in the north Delta has found that Inland Silversides prey on larval Delta Smelt (Baerwald et al. 2012)

9.4 Aquatic Food Web

9.4.1 Food web overview

Two distinct food web pathways drive productivity in tidal freshwater regions of the Delta: pelagic phytoplankton productivity (Sobczak et al. 2002, Sobczak et al. 2005) and tidal marsh subsidies (Howe and Simenstad 2011). In Cache Slough, winter-spring productivity is also driven by large seasonal inputs of productive Yolo Bypass floodwater (Schemel et al. 2004). Diverse and dynamic habitat types and hydrodynamic processes linking phytoplankton, marsh, and floodplain subsidies to the pelagic food web in the CSC enhance overall prey availability and native fish abundance, and may limit the impact of invasive species on food web processes in the region (Moyle et al. 2010).

9.4.2 Pelagic productivity

The importance of phytoplankton as a high quality food source to the pelagic food web of the Delta has been well documented (Muller-Solger et al. 2002, Sobczak et al. 2002, Sobczak et al. 2005). The strength of the pelagic food web in CSC is likely driven by diverse habitat structure, including shallow open water and dendritic channels, with variable residence times that generate high phytoplankton levels (Lehman et al. 2010a). The diatom-rich phytoplankton community supports zooplankton prey availability for an abundance of pelagic fish (Bennett and Moyle 1996, Winder and Jassby 2011, respectively). In turbid Delta water, phytoplankton growth is primarily limited by light availability (Jassby 2008). Shallow open water habitat where light penetration is maximized (i.e., the photic zone) can exhibit high phytoplankton production (Cloern 2007). Tidal transport of phytoplankton from productive habitat can support zooplankton growth in less productive channel habitat (Lucas et al. 2002, Lopez et al. 2006).

Recent monitoring indicates that abundance of high quality zooplankton prey, including calanoid copepods, cladocerans, and mysid shrimp, remains relatively high in CSC (Hennessy 2012). Fish diet data from the region confirm that these prey resources are being consumed (Slater 2012, Whitley and Bollens 2013).

9.4.3 Tidal marsh subsidies

Emergent marsh provides a large amount of organic matter (detritus) to tidal waterways. Despite its abundance, detritus is a less bioavailable food source than phytoplankton carbon, as microbial loop decomposition is a relatively inefficient food web pathway and there is little evidence that this carbon source supports pelagic food webs in the freshwater Delta (Muller-Solger et al. 2002, Sobczak et al. 2002, Sobczak et al. 2005). However, the long-term decline in pelagic productivity may increase the importance of other food web pathways in the Delta (Grimaldo et al. 2009). The contribution of marsh detritus to fish and invertebrates in shallow water habitats has been documented in salt and brackish marshes of the Estuary, and it is likely that similar processes are associated with freshwater marsh (Howe and Simenstad 2011).

Organic matter sources associated with tidal wetlands, including detritus, benthic diatoms, and filamentous algae, are used by invertebrates such as aquatic insects and amphipods. Where these invertebrate prey types are available to pelagic consumers, they can be an important component of the pelagic food web (Grimaldo et al. 2009). Both amphipods and chironomid larvae have been found in open water and channel habitat in Liberty Island (Kramer-Wilt 2010), indicating that they are present in habitat types also used by fish. Fish diets from the region confirm that they are eaten by pelagic fish (Slater 2012, Whitley and Bollens 2013). Current research on Liberty Island includes stable isotope analysis to determine if marsh productivity is assimilated into fish tissue (Howe and Simenstad 2011).

9.4.4 Invasive invertebrate, plant, and phytoplankton species

Aquatic communities in the Delta have been shaped by a long history of non-native species introductions (Cohen and Carlton 1998). Simplification of habitat structure and altered flow patterns have facilitated non-native species establishment throughout the Delta. Some invasions have significantly altered habitat conditions and food web processes, as highlighted below.

9.4.4.1 Aquatic vegetation

The establishment of submerged aquatic vegetation (SAV) alters the structure and function of shallow water habitat (Brown 2003). Brazilian waterweed readily colonizes relatively clear low-velocity shallow habitat, and provides habitat for invasive centrarchid fish species (Brown 2003, Brown and Michniuk 2007). Where established, Brazilian waterweed reduces tidal velocity and decreases turbidity, which can facilitate further spread of SAV and increase centrarchid abundance (Brown 2003, Brown and Michniuk 2007, Ferrari et al. 2014). Currently, Brazilian waterweed remains relatively uncommon in the CSC compared to other regions of the Delta (Brown and Michniuk 2007), but this will likely change in the future.

One invasive aquatic plant that is becoming increasingly prevalent in the north Delta is *Ludwigia* sp., a floating aquatic weed that has been observed clogging entire channels in the western freshwater Delta (Callaway et al. 2011). There is no documentation of the habitat effects or food web impacts associated with this species in the region. Water hyacinth, a type of invasive floating aquatic vegetation (FAV), has recently become abundant in parts of the CSC. FAV has been found to decrease habitat quality, provide structural habitat for non-native fish, and support an invertebrate community that is not prevalent in fish diets (Toft 2003). These and other invasive aquatic plant species that currently occur in the Delta could potentially colonize restoration sites in the CSC.

9.4.4.2 Invasive invertebrates

Numerous invasive invertebrate species currently occur in the Delta, and could potentially colonize the benthic zones of restoration sites in the CSC. Many of the invasive invertebrate species that occur in the Delta are not well studied, and therefore their potential effects on the ecosystem are not yet known.

Corbicula fluminea (Corbicula) is a freshwater bivalve that was introduced into the Delta in the 1940s, and quickly became the dominant benthic grazer in freshwater parts of the Delta (Hymanson et al. 1994). Where abundant, *Corbicula* can consume large quantities of phytoplankton biomass (Lucas et al. 2002, Lopez et al. 2006). The impact of grazing by introduced clams is seen at multiple trophic levels (Jassby 2008, Winder and Jassby 2011). In addition to reducing phytoplankton supply, clam grazing can also directly remove organic matter and small life stages of zooplankton from the water column (Kimmerer et al. 1994, Winder and Jassby 2011). Distribution of *Corbicula* is unpredictably patchy in the freshwater Delta (Lopez et al. 2006). Where clams are established, shallow water habitat becomes a net sink of phytoplankton productivity due to grazing (Lucas et al. 2002, Lopez et al. 2006).

Corbicula is present in the CSC; however, this region is not well sampled compared with other freshwater Delta regions. In a pilot study in the fall of 2014, benthic grabs were collected at 93 stations in the CSC. *Corbicula* was found at 72 of these stations. Clam biomass varied greatly but was high in certain areas of the complex, particularly at the mouths of Cache and Lindsey Sloughs and in the southern section of the Deepwater Ship Channel (J. Thompson and J. Frantzich, personal communication, December 11, 2014). Kramer-Wilt (2010) found juvenile clams were associated with emergent marsh vegetation in Liberty Island, with highest densities at the edges of vegetation patches. Adult clams were present primarily in channel habitat, and Kramer-Wilt hypothesized that lack of soft substrate may limit presence of adults on the marsh plain.

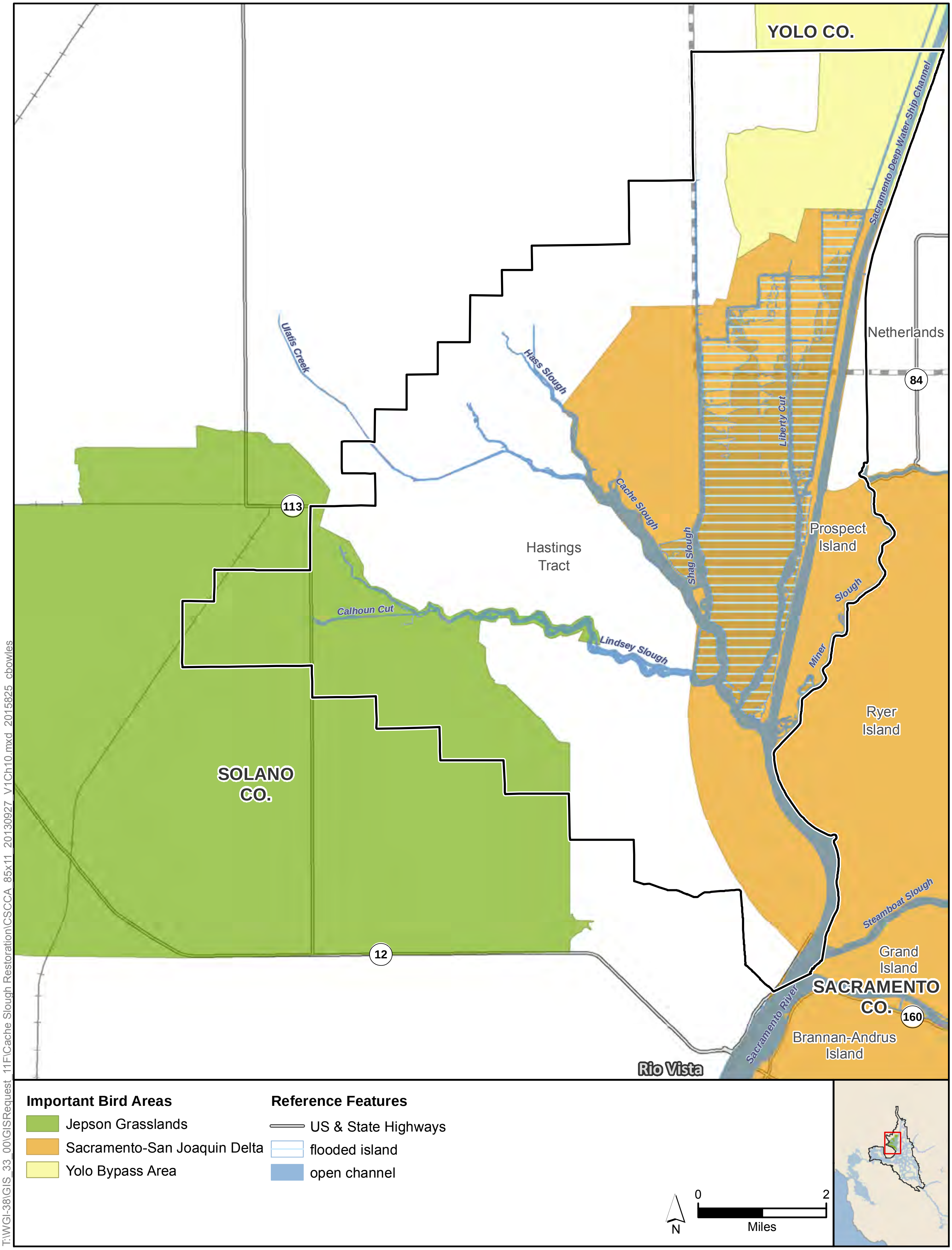
9.4.4.3 Toxic algal blooms

Blooms of the toxic cyanobacteria *Microcystis aeruginosa* have been increasing in frequency in the Delta since the early 2000s (Lehman et al. 2008). These harmful algae blooms generally occur in summer and fall, and are associated with clear, warm, slow moving freshwater (Lehman et al. 2008). Blooms result in high levels of microcystin toxin, which can reduce growth and survival of zooplankton (Ger et al. 2009, Herrera et al. 2015), and promote tumors in fish exposed to the toxin (Lehman et al. 2010). Even though *M. aeruginosa* is rarely detected in CSC, and does not form dense blooms as it does in other freshwater regions (CDFW unpubl. data), microcystin toxin was detected in both zooplankton and fish tissue collected from the region, suggesting the potential for acute toxicity impacts to the food web (Lehman et al. 2010b).

10 WILDLIFE

The terrestrial and aquatic habitats of the CSC provide important habitat for many wildlife species throughout the year. Despite dramatic changes to the Sacramento-San Joaquin Delta landscape over the last 150 years, the CSC continues to provide quality habitat for wildlife species. The area's mosaic of habitat types supports a diverse assemblage of species, from vernal pool shrimp to waterfowl. The CSC's diversity of habitats, and proximity and potential connectivity to surrounding protected areas such as Yolo Bypass, Cosumnes River Preserve, Stone Lakes National Wildlife Refuge, and Jepson Prairie Preserve, give the region tremendous biological importance. This region is of special importance to bird species and consists of several National Audubon Society Important Bird Areas (Figure 10-1).

There are 28 special-status wildlife species found in the CSC; this section gives information on several of these species that are more likely than others to be affected by tidal restoration projects. Life histories of the rest of the special-status wildlife in the region, as well as discussion on other native and non-native wildlife species, can be found in Appendix C.



Sources: Cache Slough Complex Planning Boundary (WWR, 20130708)
Important Bird Areas (CA Audobon, 2008)
Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 10-1: Important Bird Areas
Cache Slough Complex Conservation Assessment

10.1 Swainson's hawk

Status and range: Swainson's hawk (*Buteo swainsoni*) is listed as threatened under CESA. In California, Swainson's hawks breed in the Central Valley, northeastern California, and the Great Basin, and migrate south during winter. The Sacramento-San Joaquin Delta is one of the few places in North America where Swainson's hawks have been occasionally found during winter (Herzog 1996).

Swainson's hawk is mainly found in the region from early March through mid-September and tends to nest in large trees, typically along riparian wooded vegetation, but also in roadside trees, rows or isolated trees in fields, or along field borders, small groves, farmyards, and residential rural areas (Estep 2008, 2009). Much of the CSC consists of cultivated land and is considered to have some value as foraging habitat for Swainson's hawk; however, the habitat value of crop types differs widely because of their growth, structure, and management, which influences accessibility for foraging hawks and prey abundance.

Habitat requirements: In the Central Valley, Swainson's hawks typically nest in large native trees that provide a stable nesting platform, such as cottonwood, valley oak, walnut, and black willow. These trees (and thus most nest sites) are most often found along riparian forest (Schlorff and Bloom 1984, England et al. 1995); however, Swainson's hawks also nest in a variety of other native (e.g., Oregon ash, box elder, white alder) and non-native trees (e.g., eucalyptus) and habitats such as roadside trees, windbreaks, oak groves, isolated trees, and trees around rural residences. Foraging takes place over open country, historically grassland, but today Swainson's hawk forages mostly within irrigated cropland and pastureland. The Swainson's hawk is closely associated with cultivated lands, especially alfalfa. Prey is dominated by rodents, primarily voles, gophers, and deer mice, but the species also forages opportunistically for reptiles, birds, and insects (CDFG 1994).

Threats and stressors: Threats to Swainson's hawk include loss of habitat in both breeding and wintering grounds (Battistone) as well as pesticides.

10.2 Giant garter snake

Status and range: The State of California listed giant garter snakes (*Thamnophis gigas*) as threatened in 1971 and the USFWS listed them as federally threatened in 1993 (USFWS 1993). The Draft Recovery Plan for the giant garter snake was completed in 1999 (USFWS 1999). Critical habitat has not yet been designated for this species.

Giant garter snakes are endemic to wetlands in California's Central Valley and were historically distributed throughout the San Joaquin Valley (Hansen and Brode 1980). Their current distribution extends from near Chico in Butte County south to the Mendota Wildlife Area in Fresno County. Records indicate that giant garter snakes are currently distributed in 13 unique population clusters coinciding with historical flood basins, marshes, wetlands, and tributary streams of the Central Valley (Hansen and Brode 1980, Brode and Hansen 1992, USFWS 1999). These populations are isolated, lack protected dispersal corridors to adjacent populations, and are threatened by land use practices and other human activities, including development of wetland and suitable agricultural habitats.

There are two CNDDB records of giant garter snake documented in the CSC (1987, 1994), as well as an occurrence north in the wetlands and pasturelands of the Yolo Basin (2008). The recent occurrences demonstrate that the giant garter snake appears extant in portions of the Yolo Basin (Wylie et al. 2003, Wylie et al. 2004, Wylie and Amarello 2006, Hansen 2007, Hansen personal communication, 2009, CDFW 2014a).

Habitat requirements: Giant garter snakes reside in marshes, ponds, sloughs, small lakes, low-gradient streams, and other water bodies, as well as agricultural wetlands, irrigation and drainage canals, rice fields, and adjacent uplands. The species requires the following habitat elements:

- Adequate water during the snake's active season (early spring through mid-fall) to provide food and cover.
- Emergent, herbaceous wetland vegetation, such as cattails (*Typha* spp.) and bulrushes (*Schoenoplectus*, formerly *Scirpus*), accompanied by vegetated banks for escape cover and foraging habitat during the active season.
- Basking habitat of grassy banks and openings in waterside vegetation.
- Higher-elevation uplands for cover and refuge from floodwaters during the snake's dormant season in the winter (Hansen and Brode 1980, Hansen 1998, USFWS 2006b).

In some rice-growing areas, giant garter snakes have adapted well to vegetated artificial waterways and rice fields (Hansen and Brode 1993). The giant garter snake resides in small mammal burrows and soil crevices located above prevailing flood elevations throughout its winter dormancy period (USFWS 2006a). Burrows are typically located in sunny exposures along south- and west-facing slopes.

Threats and stressors: Loss of habitat to urbanization and conversion of rice fields remains the greatest threat to the survival of the giant garter snake; however, additional activities that may degrade habitat, increase mortality, or reduce the species' prey base include:

- changes to water management that reduce summer water and result in elimination of prey;
- use of agricultural runoff on wetlands and discharge into waterways;
- lack of flood control resulting in displacement, drowning, or exposure to predators;
- mechanical methods of weed abatement (e.g., discing, mowing, prescribed burning);
- maintenance of irrigation ditches and channels;
- rodent control;
- herbicide application to eradicate water hyacinth and other aquatic plants;
- agricultural runoff on wetlands and discharge into waterways;
- livestock grazing in wetlands or streamside habitats;
- predation by bullfrogs, domestic cats, and other non-native species;
- natural gas exploration on National Wildlife Refuges in the Sacramento and San Joaquin valleys and private lands (USFWS 1999, 2006a).
- changes in agricultural and land management

10.3 Western pond turtle

Status and range: Western pond turtle (*Actinemys marmorata*) is a California Species of Special Concern.

In California, western pond turtles historically occurred in most Pacific slope drainages between the Oregon and Mexican borders. They are currently uncommon to common in suitable aquatic habitat throughout California west of the Sierra Nevada-Cascade crest and are distributed at elevations from near sea level to 1,429 m (4,690 ft) (Jennings and Hayes 1994).

There are relatively few CNDDB records for western pond turtles in the Delta; however, it is likely that this species is underreported. The species has the potential to occur in most slower-moving natural and artificial channels and stillwater habitats in the CSC where essential habitat elements (streamside cover, basking sites, and adjacent upland habitats) are present.

Habitat requirements: Western pond turtles, although primarily found in natural habitats, also inhabit reservoirs, irrigation ditches, and other artificial water bodies (Ernst et al. 1994). They prefer stagnant or slow-moving freshwater streams, but brackish habitats may also be used (Ernst et al. 1994). They are uncommon in high-gradient streams, most likely due to low water temperatures, high current velocity, and areas lacking sufficient food, which may influence distribution at the local scale (Jennings and Hayes 1994).

Pond turtles are usually found in aquatic habitats with muddy or rocky substrates and some submergent or short emergent vegetation (Ernst et al. 1994). Habitat value seems to increase with basking site availability (Jennings and Hayes 1994). Habitat components used as cover include undercut banks, aquatic vegetation, rocks, wood, and mud; pond turtles appear to avoid open water where cover is not available. They bask on rocks, wood, submergent vegetation, islands, as well as manmade structures and debris (Holland 1994).

Upland habitat is important for nesting, overwintering, and dispersing (Holland 1994). Turtles may nest 396 m (1,300 ft) or more from water, although usually closer, around 91 m (300 ft) (Jennings and Hayes 1994; Slavens 1995). Nesting sites typically have a southern or western aspect, on slopes of 0–46% in compacted, dry soil (Holland 1994; Bury et al. 2001). Turtles that overwinter in upland habitats typically leave aquatic habitats in late fall, moving as far as 499 m (1,640 ft) from water (Holland 1994). There they burrow into duff (leaf litter), soil, or both, where they remain over the winter (Holland 1994). For reasons not entirely clear, western pond turtles can be found in upland habitats at other times of the year, burrowed into duff or resting under shrubs (Rathbun et al. 1993; Yolo County 2009).

Threats and stressors: Western pond turtle population declines have been mostly attributed to habitat loss and fragmentation, flooding and irrigation management, as well as competition from, and predation by, native and non-native species (e.g., bullfrogs, bass, carp, and non-native turtles).

10.4 Valley elderberry longhorn beetle

Status and range: Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) is listed as threatened under the federal ESA. The valley elderberry longhorn beetle has no state regulatory status.

Little is known about the historical abundance of valley elderberry longhorn beetle; it is presumed to have occurred throughout the Central Valley. The extensive destruction of its habitat suggests that the beetle's range has been largely reduced and fragmented (USFWS 1984).

Riparian habitat for the valley elderberry longhorn beetle is found throughout the CSC, including along the Sacramento River Deep Water Ship Channel, Calhoun Cut, Hasting Cut, Shag Slough, Lindsey Slough, Miner Slough, and other waterways throughout the CSC.

Habitat requirements: Valley elderberry longhorn beetle is closely associated with a few species of elderberry, mainly blue elderberry (*Sambucus nigra* subsp. *caerulea*, formerly *S. mexicana*) and red elderberry (*S. racemosa*). These plants are an obligate host plant for larvae and are necessary for the completion of the species' life cycle (Linsley and Chemsak 1972, Eng 1984, Barr 1991, Collinge et al. 2001). Elderberry shrub is a component of riparian habitats throughout the Central Valley. Although this shrub occasionally occurs outside riparian areas, shrubs supporting the greatest beetle densities are located in areas where the shrubs are abundant and interspersed in significant riparian zones (Talley et al. 2006).

Threats and stressors: The greatest historical threat to the valley elderberry longhorn beetle has been the elimination, loss, or modification of its habitat by urban, agricultural, or industrial development and other activities that reduce or eliminate its host plants (Talley et al. 2006). Non-native invasive plant species such as black locust (*Robinia pseudoacacia*), giant reed (*Arundo donax*), red sesbania (*Sesbania punicea*), Himalayan blackberry (*Rubus armeniacus*), tree of heaven (*Ailanthus altissima*), Spanish broom (*Spartium junceum*), Russian olive (*Eleagnus angustifolia*), edible fig (*Ficus carica*), and Chinese tallowtree (*Sapium sebiferum*) may have significant indirect impacts on valley elderberry longhorn beetle by impacting elderberry shrub vigor and recruitment (Talley et al. 2006).

11 CULTURAL RESOURCES

Cultural resources may include buildings, structures, sites, or objects, each of which may reflect many kinds of significance in history, architecture, archaeology, engineering, science, or culture. According to guidance published by the Office of Historic Preservation (OHP) (1995:2), any "physical evidence of human activities over 45 years old may be recorded for purposes of inclusion in [OHP's] filing system". The term "cultural resource" is also applied to Sacred Sites, also called Traditional Cultural Properties (TCPs). These are cultural properties that may or may not have any physical features such as buildings, structures, or sites, but that "play an important part in a community's historically rooted beliefs, customs, and practices" (NPS 1998: 1).

11.1 Documented Cultural Resources

Records searches were conducted by Sikes and Arrington at the Northwest Information Center (NWIC) of the California Historic Information System (CHRIS) on March 20, 2012 (NWIC File No. 11-1006) (Sikes and Arrington 2012) and by Wendy Pierce of DWR on January 11, 2013 (NWIC File No. 12-0490). The NWIC maintains the CHRIS's official records of previous cultural resource studies and known cultural resources for a 16-county area that includes both Solano and Yolo counties. The record searches covered the entire CSC and consisted of a review of historic maps, previous cultural resource studies, and recorded resources. The cultural resource library and files at the DWR Division of Environmental Services were also searched for relevant studies in the CSC.

The records searches and literature review indicate that approximately 22% of the CSC has been surveyed for the presence of cultural resources. Three types of surveys have been conducted within the area: spot clearance surveys (small areas surveyed for a single project each), linear surveys (e.g., along levees or pipeline corridors), and parcel surveys (large areas sampled by linear transects). The majority of the area that has been surveyed occurs in the Yolo County portion of the CSC, and was covered by large parcel surveys. The rest of the CSC has been dotted and crossed by smaller linear and spot surveys. In addition, an underwater side-scan sonar survey was conducted adjacent to the southern CSC boundary in the Sacramento River (Panamerican Consultants Inc 2010) for submerged resources, such as shipwrecks.

11.1.1 Summary of results

The records searches conducted by DWR and Parus Consulting, Inc. identified twelve recorded cultural resource sites within the CSC. Of these, eight are prehistoric archaeological sites and four are historic-era resources. There are also submerged resources recorded in the waterways in the CSC. One such resource may be the historic schooner Bianca, which sunk at the mouth of Cache Slough in 1854 on its way to Sacramento, but the wreck has not been located (Commission 1988).

11.1.2 Prehistoric archaeological sites

Eight prehistoric archaeological sites have been recorded inside the CSC boundary (Table 10-1). Of these, four are Native American occupation sites known to have contained human burials; two sites are occupations where the presence of human remains is unknown. One site is an extensive artifact scatter that may represent a temporary camp or seasonal occupation. The remaining site has no description, but is in close proximity to other mound sites and may be similar in nature.

One of the above sites, in addition to having a surface manifestation, was also observed to have a buried component visible in a cut bank. This site highlights the potential for the presence of buried archaeological sites within the CSC.

Table 10-1. Previously Recorded Prehistoric Cultural Resources in the Cache Slough Complex.

Resource Designation	Description	Environmental Context	Project Region	Significance
CA-SOL-1	Occupation and burial site	Near stream	West of Hastings Tract	Unevaluated; Recommended eligible (NRHP/CRHR)
CA-SOL-2	Occupation and burial site	Near stream	West of Hastings Tract	Unevaluated; Recommended eligible (NRHP/CRHR)
CA-SOL-3	Occupation and burial site	Near stream	West of Hastings Tract	Unevaluated; May be destroyed

Resource Designation	Description	Environmental Context	Project Region	Significance
CA-SOL-4	No information	Near stream	West of Hastings Tract	Unevaluated; Recommended eligible (NRHP/CRHR)
CA-SOL-5	Occupation site	Near stream	West of Hastings Tract	Unevaluated; Recommended eligible (NRHP/CRHR)
CA-SOL-276	Occupation and burial site	Near the River	Southeastern Egbert Tract	Unevaluated; Recommended eligible (NRHP/CRHR)
CA-SOL-347	Occupation site	Near stream (also has buried component- noted in cut bank)	West of Hastings Tract	Unevaluated; Recommended eligible (NRHP/CRHR)
CA-SOL-348	Extensive artifact scatter	Near vernal pools	West of Hastings Tract	Recommended Eligible for (NRHP/CRHR) listing

11.1.3 Historic-era archaeological resources

Four historic cultural resources occur within the CSC (Table 10-2). Two of these are levee systems around islands or portions of islands, one consists of abandoned farm equipment, and one is a cluster of historic-era structures. Two of these resources, both located on Prospect Island, have been evaluated for NRHP and CRHR status and have been found ineligible. The remaining two are recommended ineligible.

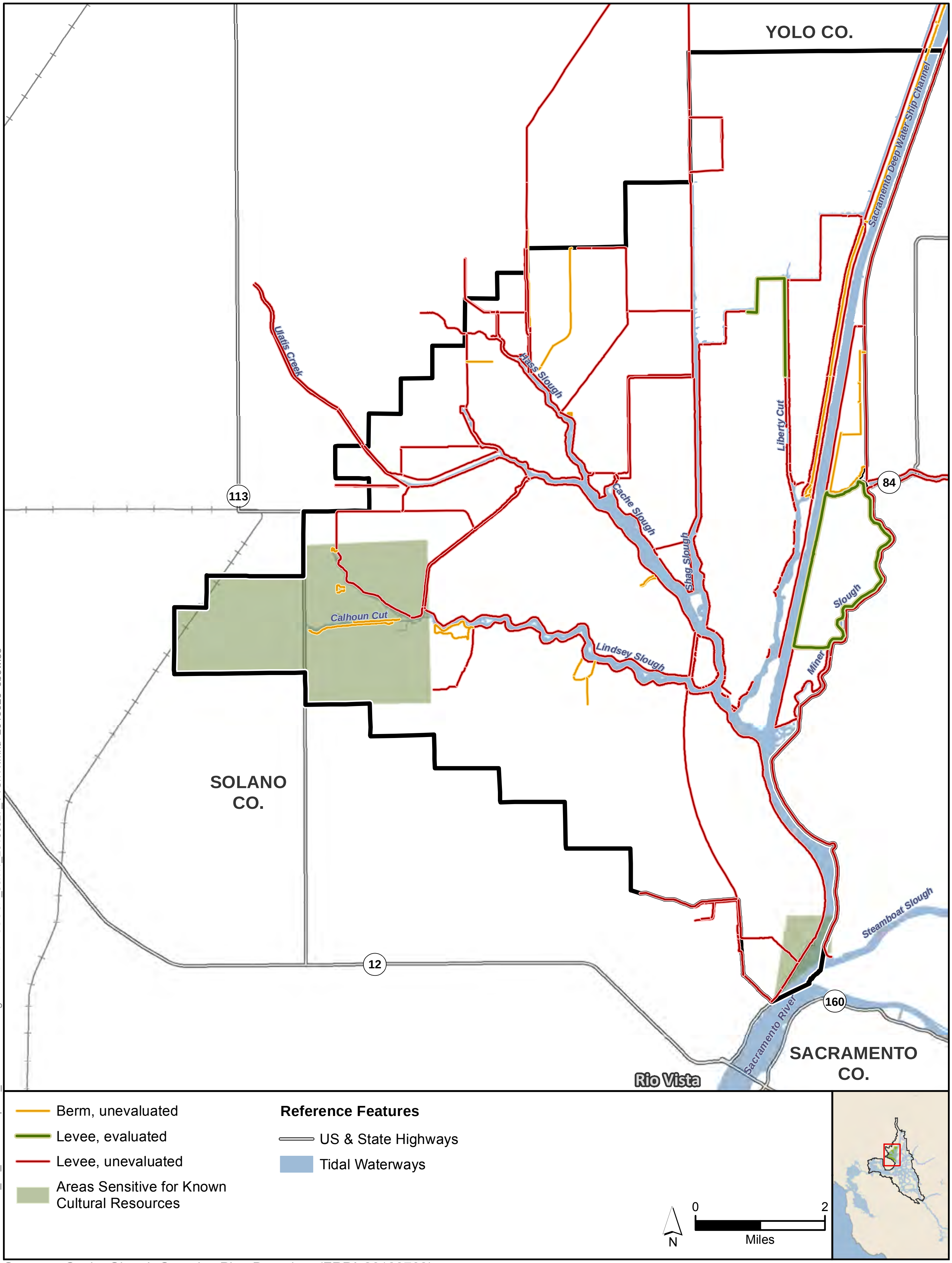
Table 10-2. Previously Recorded Historic Resources in the Cache Slough Complex.

Resource designation	Description	Environmental context	Project region	Significance
P-57-587	Farm equipment	Reclaimed agricultural land	Liberty Island	Recommended ineligible
P-57-588	Liberty Island levee	Reclaimed agricultural land	Liberty Island	Recommended ineligible
P-48-000417	Prospect Island structures	Reclaimed agricultural land	Prospect Island	Determined Ineligible for NRHP/CRHR

P-48-000787	Prospect Island Levee System, circa 1910-1920	Reclaimed agricultural land	Prospect Island	Determined Ineligible for NRHP/CRHR

11.1.4 Distribution of recorded and known cultural resources

The spatial distribution of recorded cultural resources cluster into three distinct areas, one area is located to the west of Hastings tract (highly sensitive), one is on the northern end of Liberty Island, and the other is in southern Egbert Tract. In addition to the sites identified in the records searches, there are cultural resources submerged in the Sacramento River adjacent to southern Egbert Tract (Panamerican Consultants Inc 2010). These are technically outside the CSC, but are directly adjacent, and therefore mentioned in this discussion and included in the map of Areas Sensitive for Known Cultural Resources (Figure 11-1). In addition to the cultural resources recorded and on file with the CHRIS, the area contains numerous levees, many of which are older than 50 years. All levees in the Delta are documented in the California Levee Database v3.0 r1 (DWR 2011). These levees are cultural resources of the structural type. Levees that are part of the USACE Sacramento River Flood Control Project are likely to be considered historically significant (Polson, N., USACE, personal communication, 2014).



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Sources: Cache Slough Complex Plan Boundary (FRPA 20130708);
CA Levee Database (CLD v3.0 r1, 201112; WWR modified, 2013);
Known Cultural Resources and Evaluated Levees (DWR 2013)
Tidal Waterways (CDFW, 2005 and BDCP, 2012-WWR modified, 2013)

Figure 11-1: Sensitivity for Known Cultural Resources
Cache Slough Complex Conservation Assessment

11.2 The Potential to Encounter Undocumented Cultural Resources in the Cache Slough Complex Characterization Report Area

Approximately 22% of the CSC has been covered by pedestrian archaeological survey. There remains a significant potential for undocumented cultural resources to exist within the CSC.

Undocumented cultural resources fall into two categories: resources that have visible manifestations on the ground surface but have not yet been located by pedestrian survey, and buried archaeological deposits that have no surface indications. Structures and historic sites generally have visible surface indications and pedestrian survey is an adequate method for locating those sites. The locations of prehistoric archaeological sites, however, are more complicated to predict and locate. Two natural processes that affect the archaeological record are erosion (destructive) and deposition (protective). Archaeological sites in the Delta can potentially be affected in both ways. Sites can be capped by deposition and conversely eroded by adjacent watercourses or tidal fluctuation.

The locations of prehistoric Native American occupation sites can be predicted by a number of factors, including distance to reliable water sources and proximity to important resource tracts. However, even occupation sites in predictable locations may be undetectable during pedestrian surveys because they have been obscured by the growth of thick vegetation, by geologic depositional processes, or otherwise damaged or obscured. Because buried sites lack visible features or surface artifacts indicating their presence to the field observer, they are often not identified in surface surveys. This is especially true of archaeological sites that are located on older landforms that have been buried, sometimes deeply, by Holocene alluviation.

The four archaeological deposits that have been studied in the CSC demonstrate this phenomenon. All are late Augustine Pattern deposits that had cultural material visible on the surface or eroding out of an embankment. Even though the two mound sites studied are of late Holocene age, their visibility was obscured by recent alluviation according to Cook and Treganza (1947) and Treganza and Cook (1948). They note, “The site has been protected by a sterile cap of clay deposited by overflow of the Sacramento River, a feature resulting from levee building and hydraulic placer mining subsequent to 1850”(Cook and Treganza 1947: 135). No archaeological deposits predating the Augustine Pattern have been identified in the CSC, but this does not rule out the presence of such resources. They are likely present, but buried.

11.2.1 Ethnographic Setting - Plains Miwok

The CSC falls mainly within the traditional Plains Miwok territory (Levy 1978), but may overlap on its western extent into traditional Patwin territory (Johnson 1978). The eastern Miwok, and more specifically the Plains Miwok, inhabited the lower reaches of the Mokelumne and Cosumnes Rivers, and the banks of the Sacramento River from Rio Vista to Freeport (Levy 1978).

Plains Miwok were organized politically into tribelets. The tribelet represented an independent, sovereign nation that defined and defended a territory. One of these tribelets, known as Anizumne, is a Plains Miwok ethnographic village mentioned in early mission records and other sources. It was reportedly located on the western side of the Sacramento River just north of Rio Vista (Levy 1978). The archaeological site present in the southeastern Egbert Tract portion of the CSC is likely the Anizumne village site (Levy 1978, Parkman and Fylnn 1980, Bennyhoff 1982).

11.2.2 Geomorphology and archaeological site sensitivity in the Cache Slough Complex Area

Of the eight recorded prehistoric archaeological sites within the CSC, seven are found on exposed Pleistocene deposits (Qpf, Qoa) or in the fine-grained alluvial fan deposits (Qhff) that Atwater dated to the older Holocene/Upper-Pleistocene, and one is located in Holocene stream channel deposits (Qhc) (Table 10-3). In light of geologic processes, the results of pedestrian surveys lead to the conclusion that archaeological sites tend to be found on exposed older surfaces that have not been buried under sedimentation and areas where no archaeological deposits were found may be highly sensitive for buried sites. In fact, one site record notes the existence of a buried site deposit, only visible in a cut bank.

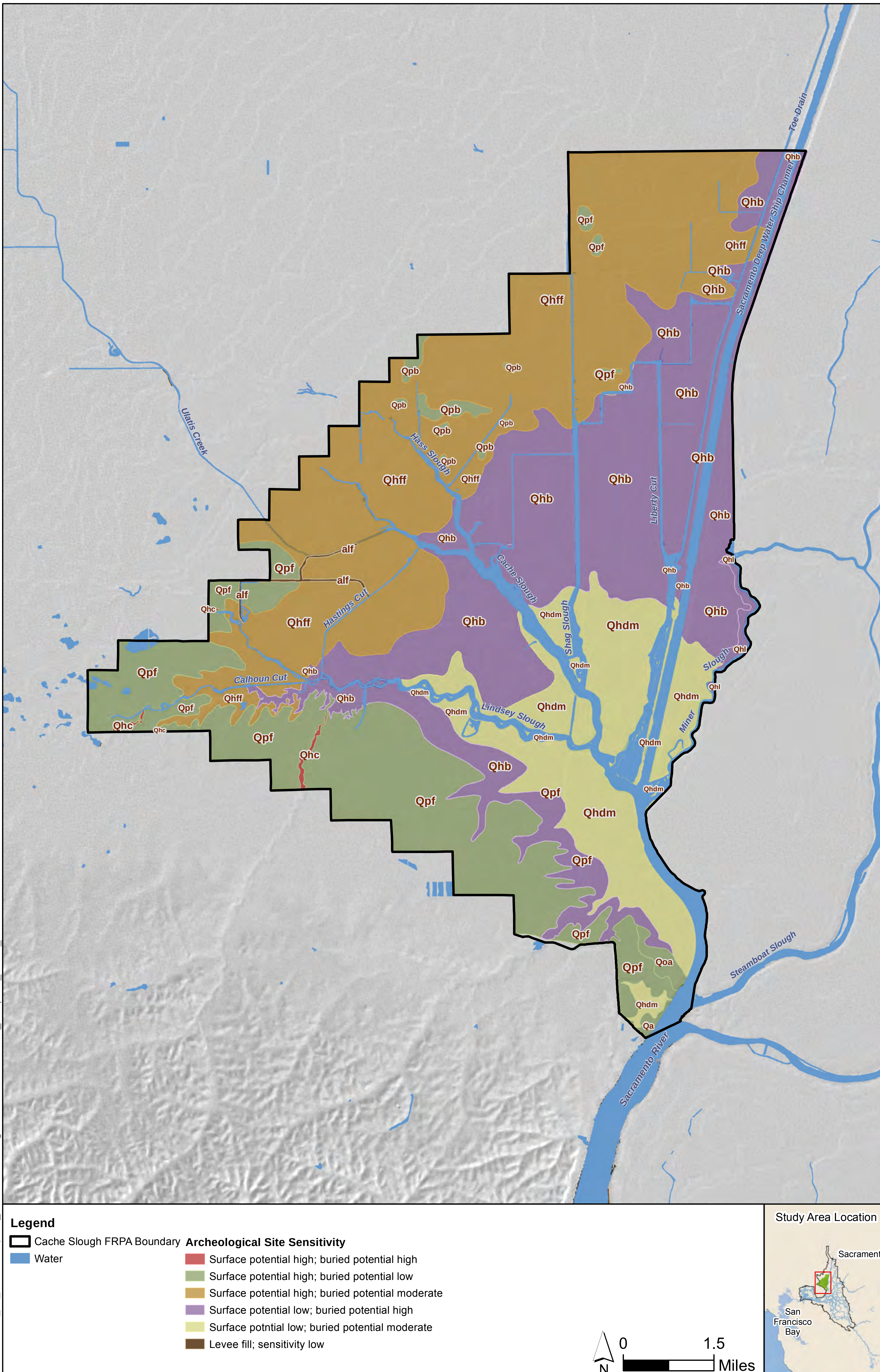
Table 10-3. Prehistoric Archaeological Sensitivity for Surface and Buried Sites Based on Geomorphological Types (Dawson 2009).

Description	Age	Type	Surface site potential	Buried site potential
Alluvial deposits and basin deposits	Pleistocene	Qpf, Qpb, Qoa, Qa	High	Low
Alluvial Fan Deposits, fine-grained	Older Holocene	Qhff	High	Moderate

Flood basin and fan levee deposits	Holocene	Qhb, Qhl	Low	High
Holocene delta mud	Holocene	Qhdm	Low	Moderate
Holocene stream channel deposits	Holocene	Qhc	High	High
Levee fill	Modern	alf	None	Low

Buried sites are predicted to be situated with increasing depth toward and below sea level. Buried sites may or may not have the potential to be impacted by restoration actions and potential impacts may depend on both the depth of any grading and excavation to take place and the age and depth of the subject landform. For example, buried sites could easily be encountered during shallow grading in the fine-grained alluvium (Qhff), but may not be encountered unless excavations penetrate deeper into flood basin deposits (Qhb). Delta mud (Qhdm) may have few archaeological materials on the surface, but can overlay significantly older landforms that may have been suitable for habitation before the rapid rise in sea level during the Pleistocene. The potential for buried deposits in the Delta mud is categorized as “Moderate”.

Buried sites as well as surface sites are more common along or near natural permanent or seasonal sources of water (rivers, streams, ponds, vernal pools etc.). This should be taken into account along with the geologic data when predicting potential for encountering buried sites.



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Sources: Cache Slough Complex Plan Boundary (FRPA 20130708);
Archaeological Site Sensitivity (Lodi Quadrangle, CA Geologic Society 2009)

Figure 11 - 2: Prehistoric Archaeological Sensitivity
Cache Slough Complex Conservation Assessment

11.2.3 Potential cultural resource categories that may occur in the CSC

This section describes the types of cultural resources that may be present. These resource types have been broadly categorized into groups, based on their cultural and temporal associations. Some of these resource types, such as prehistoric archaeological sites and historic structures, are known to occur in the CSC and others are likely to occur.

11.2.3.1 Prehistoric archaeological sites

The kinds of archaeological sites identified in the record searches conducted for this report give a good indication of the kinds of prehistoric archaeological sites that may be found. Archaeological resources resulting from Native American land uses comprise a continuum from isolated artifacts to year-round occupation sites with high densities of artifacts and features. Prehistoric sites and features that may be encountered in the CSC are broken into groups characterized mainly by diversity and density of artifacts, ecofacts, and feature types and are described in greater detail below.

Long-term occupation sites

Long-term occupation sites in the Delta are often located on high spots that would stay dry during the rainy season and spring snow melt. These areas are often characterized by a high density of artifacts, dietary remains, including shellfish, faunal remains, charred plant materials (ecofacts), features such as house pit depressions, rock rings, fire hearths, and human burials. The accumulation of debris and charcoal from many campfires combine overtime to form what looks like a dark soil layer called a midden. A midden is an anthropogenic deposit containing charcoal, shells, animal bones, and other cultural refuse that indicates the site of a relatively permanent human settlement.

Cemeteries

When long-term occupation sites were near a river or stream, cemeteries were often located on nearby high places that would not be inundated, reducing the possibility of the dead becoming uncovered by flood waters. Older cemeteries often became the sites of newer occupation camps. Thus, sites that appear to be occupations on the surface may be located over older cemetery sites. This situation is commonly encountered near waterways where human use areas were limited the adjacent areas of higher ground. Ancient human remains are sometimes exposed in cut banks, erosional or disturbed contexts, or in rodent burrow back-dirt piles.

Temporary camps

Temporary camps are similar to occupation sites, but they were occupied for shorter periods of time, perhaps on a seasonal basis, often to exploit locally occurring resources. These sites may contain artifacts and feature classes similar to those at long-term occupation sites, but the densities and diversity of artifacts and ecofacts encountered at these sites is generally lower, and midden accumulations may or may not be present.

Artifact scatters and lithic scatters

Artifact scatters may result from the ephemeral use of a locality. The activities at this type of site did not occur over a long enough time to leave many traces, and these sites may only consist of several artifact classes. Lithic scatters consist of only flaked stone artifact types, and often represent a single event of tool maintenance or a hunting camp.

Isolated artifacts, features, and burials

Artifacts, features, and burials may occur in isolated contexts, apart from any other archaeological traces. Even though these don’t constitute archaeological “sites”, they are cultural resources and need to be treated accordingly.

11.2.3.2 Historic archaeological sites

Historic archaeological sites and features that could potentially occur in the CSC may consist of the ruins of any of the historic structure types such as building foundations, wells, privy pits; transportation related features such as railroads, roads, and landings; water conveyance systems, orchards, or landscape features that were associated with a historic structure; and historic-era refuse scatters.

Structures

Flood control and irrigation played an important role in the development of the Delta. Structures related to these contexts include levees, weirs, slips, canals/ditches, pumping stations, water towers, and related water conveyance systems. Other resource types within this category may include roads, railroads, and bridges.

Buildings

Buildings can include residential, commercial, agricultural, civic, or social buildings. Residential buildings and agricultural buildings would be most common in the CSC. Residential buildings include both single and multifamily residences. Agricultural buildings include ranch complexes, sheds, barns, and associated outbuildings.

Historic landscapes
Within the CSC, there may be historic vernacular landscapes or rural landscapes. Resource types that contribute to a historic landscape may include ranch complexes with a farmhouse, associated outbuildings, and circulation paths. Under the context of flood control and irrigation, it is also possible to have a historic landscape that includes levees, weirs, canals, levee roads, bridges, and agricultural fields/orchards.

11.2.3.3 Submerged resources

Previous studies in the vicinity of the CSC provide reasonable expectations of the range of submerged resource types. These resources are typically associated with historic-era activities, although there is a small possibility for submerged prehistoric resources. Previous cultural resources studies in the Sacramento River directly adjacent to the CSC have identified several submerged resources (Panamerican Consultants Inc 2010). Submerged resource types include the remains of landings, pilings, ferries and ferry crossings, and modern and historic vessels. Each resource type is described below.

Landings and pilings
Landings are usually wooden structures used for docking vessels for loading and unloading people, livestock, and materials. Pilings are generally associated with landings or structures built along the riverfront. Pilings are wood or concrete poles driven into the river bottom to provide support to the associated structure, but they were also sometimes used individually for the mooring of vessels. Landings in the CSC would probably have been associated with private properties and would have been used for loading and unloading materials associated with agricultural endeavors. As overland transportation became more common, use of the waterways declined and landings and pilings fell into disrepair, often resulting in their collapse into the water.

Vessels
A wide range of submerged vessels dating from the 1840s to the present can be found in the Sacramento River. The earliest vessel types were typically wooden hulls with metal hardware and included small and large sailing vessels and barges. These vessels were usually associated with commercial endeavors because recreational boating was not common until the 1930s. Steel hulls became more prominent after the 1860s and are typical of steamboats, barges, fishing vessels, or military vessels. Modern vessels are most often recreational and are made of fiberglass and wood or steel composite.

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Appendices

Appendix A

Geomorphology and Geology

Table A1-1. NRCS-mapped Soil Types Present within the Cache Slough Complex Area.

Soil type		Soil properties				
Symbol	**Name**	**Texture(s) A**	**Hydrologic soil group B**	**Infiltration rate, Ksat (mm/hr) C**	**Salinity, EC (mmhos/cm) D**	**Shrink-swell potential, LEP (%) E**
SACRAMENTO-RYDE-EGBERT GROUP						
Cm	Columbia fine sandy loam	Fine sandy loam, silty clay loam	C	Moderately low to very high, 3.3–101	Non-saline, 0–1	Low to high, 1.5–7.5
DaC	Diablo-Ayar clays, 2 to 9 percent slopes	Clay, silty clay, weathered bedrock	D	Moderately low, 3.3	Non-saline, 1	High, 7.5
Eb	Egbert silty clay loam	Silty clay loam	C	Moderately low to moderately high, 3.3–9.7	Non-saline, 1	Moderate to high, 4.5–7.5
Ec	Egbert silty clay loam, occasionally flooded	Silty clay loam	C	Moderately low to moderately high, 3.3–9.7	Non-saline, 1	Moderate to high, 4.5–7.5
Ry	Ryde clay loam	Clay loam, muck, silty clay loam	C	Moderately high, 9.7–32	Slightly, 4	Moderate, 4.5
Sa	Sacramento silty clay loam	Silty clay loam, clay	D	Moderately low to moderately high, 3.3–9.7	Non-saline, 1	Moderate to high, 4.5–7.5
Sc	Sacramento silty clay loam, occasionally flooded	Silty clay loam, clay	D	Moderately low, 3.3	Non-saline, 0–1	High, 7.5
Sd	Sacramento clay	Clay	D	Moderately low, 3.3	Non-saline, 1	High, 7.5
Sc	Sacramento silty clay loam, occasionally flooded	Silty clay loam, clay	D	Moderately low, 3.3	Non-saline, 0–1	High, 7.5
Sg	Sacramento soils, flooded	Silty clay loam, clay	D	Very low to moderately high, 0.8–9.7	Non-saline, 0–1	Moderate to high, 4.5–7.5
Su	Sycamore complex, occasionally flooded	Silty clay loam	C	Moderately low to moderately high, 3.3–32	Non-saline to moderately, 0–12	Moderate, 4.5
Sw	Sycamore complex, flooded	Silty clay loam, silty clay	C	Moderately high to high, 9.8–32	Non-saline, 0–1	Moderate, 4.5
Td	Tidal marsh	Variable	D	--	Moderately, 12	--
Tu	Tujunga fine sand	Fine sand, sand	A	Very high, 331	Non-saline, 0	Low, 1.5
Va	Valdez silt loam drained	Silt loam	C	Moderately high to high, 9.8–32	Non-saline, 0–1	Low, 1.5

Soil type		Soil properties				
Symbol	Name	Texture(s) A	Hydrologic soil group B	Infiltration rate, Ksat (mm/hr) C	Salinity, EC (mmhos/cm) D	Shrink-swell potential, LEP (%) E
STOCKTON-CLEAR LAKE-CAPAY GROUP						
Ca	Capay silty clay loam	Silty clay loam, clay, clay loam	D	Moderately low, 3.3	Non-saline, 1	High, 7.5
Cc	Capay soils, flooded	Clay, clay loam	D	Moderately low, 3.3	Non-saline, 1	High, 7.5
CeA	Clear Lake clay, 0 to 2 percent slopes	Clay	D	Moderately low, 3.3	Non-saline to very slightly saline, 1–2	High, 7.5
Cn	Clear Lake soils, flooded	Clay loam, clay	D	Moderately low to moderately high, 3.3–9.7	Very slightly to slightly, 2–4	High, 7.5
Co	Conejo gravelly loam	Gravelly loam	B	Moderately high 9.8–32	Non-saline, 0	Low to moderate, 1.5–4.5
On	Omni silty clay	Silty clay	D	Moderately low, 3.3	Non-saline, 1	High, 7.5
Rk	Riz loam	Loam, Clay	D	Very low to moderately high, 0.8–9.7	Moderately, 10	Low to high, 1.5–7.5
Rn	Riz loam, flooded	Loam, clay loam	D	Very low to moderately high, 0.8–9.7	Moderately, 10	Low to high, 1.5–7.5
WILLOWS-SOLANO-PESCADERO GROUP						
Pc	Pescadero clay loam	Clay loam, clay	D	Very low to moderately high 0.8–32.4	Slightly saline to moderately saline, 6–12	Low to high, 1.5–7.5
Pe	Pescadero clay	Clay, clay loam	D	Very low to moderately low, 0.8–3.3	Very slightly to moderately, 2–10	Moderate to high, 4.5–7.5
Sh	Solano loam	Loam, silty clay loam	D	Very low to moderately high, 0.8–9.7	Non-saline to slightly, 1–4	Low to high, 1.5–7.5
Sk	Solano-Pescadero complex	Loam, clay loam	D	Very low to moderately high, 0.8–9.7	Non-saline to very high, 1–10	Low to high, 1.5–7.5
Wc	Willows clay	Clay	D	Moderately low, 3.3	Slightly, 5–6	High, 7.5

Soil type		Soil properties				
Symbol	**Name**	**Texture(s) A**	**Hydrologic soil group B**	**Infiltration rate, Ksat (mm/hr) C**	**Salinity, EC (mmhos/cm) D**	**Shrink-swell potential, LEP (%) E**
SAN YSIDRO-ANTIOCH GROUP						
AoA	Antioch-San Ysidro complex, 0 to 2 percent slopes	Loam, clay	D	Very low to moderately high, 0.8–32	Non-saline to very slightly, 0–2	Low to high, 1.5–7.5
AoC	Antioch-San Ysidro complex, 2 to 9 percent slopes	Loam, clay	D	Very low to moderately high, 0.8–32	Non-saline, 0–1	Low to high, 1.5–7.5
AsA	Antioch-San Ysidro complex, thick surface, 0 to 2 percent slopes	Loam, clay	D	Very low to moderately high, 0.8–32	Non-saline to very slightly, 0–2	Low to high, 1.5–7.5
SeA	San Ysidro sandy loam, 0 to 2 percent slopes	Sandy loam, clay loam, sandy clay loam	D	Very low to moderately high, 0.8–32	Non-saline to very slightly, 0–2	Low to high, 1.5–7.5
SeB	San Ysidro sandy loam, 2 to 5 percent slopes	Sandy loam, clay loam, sandy clay loam	D	Very low to Moderately high, 0.8–9.8	Non-saline to very slightly, 0–2	Low to high, 1.5–7.5
SfA	San Ysidro sandy loam, thick surface, 0 to 2 percent slopes	Sandy loam, clay loam, sandy clay loam	D	Very low to moderately high, 0.8–32	Non-saline to very slightly, 0–2	Low to high, 1.5–7.5
OTHER MAPPED UNITS						
Ma	Made land	Artificial fill	--	--	--	--
W	Water	--	--	--	--	--

Definitions from NRCS's Soil Survey Geographic (SSURGO) database (2007):

[A] Material textures within the profile:

[1] Clay: As a soil separate, the mineral soil particles less than 0.002 millimeter (mm) in diameter. As a soil textural class, soil material that is 40% or more clay, less than 45% sand, and less than 40% silt.

[2] Loam: Soil material that is 7–27% clay particles, 28–50% silt particles, and <52% sand particles.

[3] Sand: As a soil separate, individual rock or mineral fragments from 0.05–2.0 mm in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85% or more sand and not more than 10% clay.

[4] Silt: As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 mm) to the lower limit of very fine sand (0.05 mm). As a soil textural class, soil that is 80% or more silt and less than 12% clay.

[B] Hydrologic soil groups refers to soils grouped according to their runoff potential (see also NRCS 2012). The soil properties that influence this potential are those that affect the minimum rate of water infiltration on a bare soil during periods after prolonged wetting when the soil is not frozen. These properties include depth to a seasonal high water table, the infiltration rate, and depth to a layer that significantly restricts the downward movement of water. The slope and the kind of plant cover are not considered but are separate factors in predicting runoff.

[1] Group A (low runoff potential): The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels. They have a high rate of water transmission.
[2] Group B: The soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep to deep, moderately well drained to well drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission.
[3] Group C: The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water of have moderately fine to fine texture. They have a slow rate of water transmission.
[4] Group D (high runoff potential): The soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. The have a very slow rate of water transmission.

[C] Infiltration rate is the rate at which water penetrates the surface of the soil at any given instant, usually expressed in millimeters per hour (mm/hr). The rate can be limited by the infiltration capacity of the soil or the rate at which water is applied at the surface. *Also*, saturated hydraulic conductivity, or *Ksat*, is the ease with which pores of a saturated soil transmit water. Formally, the proportionality coefficient that expresses the relationship of the rate of water movement to hydraulic gradient in Darcy's Law, a law that describes the rate of water movement through porous media.

[1] Very low or moderately low: *Ksat* is <1.1 mm/hr
[2] Moderately low: *Ksat* is 1.1–4.3 mm/hr
[3] Moderately high: *Ksat* is 4.3–17.3 mm/hr
[4] Moderately high or high: *Ksat* is 17.3–54 mm/hr
[5] High: *Ksat* is 54–108 mm/hr
[6] High or very high: *Ksat* is ≥108 mm/hr

[D] Salinity within a soil is represented by the Electrical Conductivity (EC), usually expressed in millimhos per centimeter (mmhos/cm). EC is a measure of the concentration of water-soluble salts in a soil. High concentrations of salts can interfere with the absorption of water by plants.

[1] Non-saline: EC is <2 mmhos/cm
[2] Very slightly saline: EC is 2–3.9 mmhos/cm
[3] Slightly saline: EC is 4–7.9 mmhos/cm
[4] Moderately saline: EC is 8–15.9 mmhos/cm
[5] Strongly saline: EC is ≥16 mmhos/cm

[E] The potential for a soil to exhibit shrinking or swelling under varying degrees of moisture is represented by the Linear Extensibility Percent (LEP). LEP is measured directly as the change in soil sample dimension from moist to dry conditions, and is expressed as a percentage of the volume change to the dry length. Soils with high or very high shrink-swell potential can damage structures and plant roots.

[1] Low shrink-swell class: LEP is <3.0
[2] Moderate shrink-swell class: LEP is 3–5.9
[3] High shrink-swell class: LEP is 6.0–8.9
[4] Very high shrink-swell class: LEP is ≥9.0

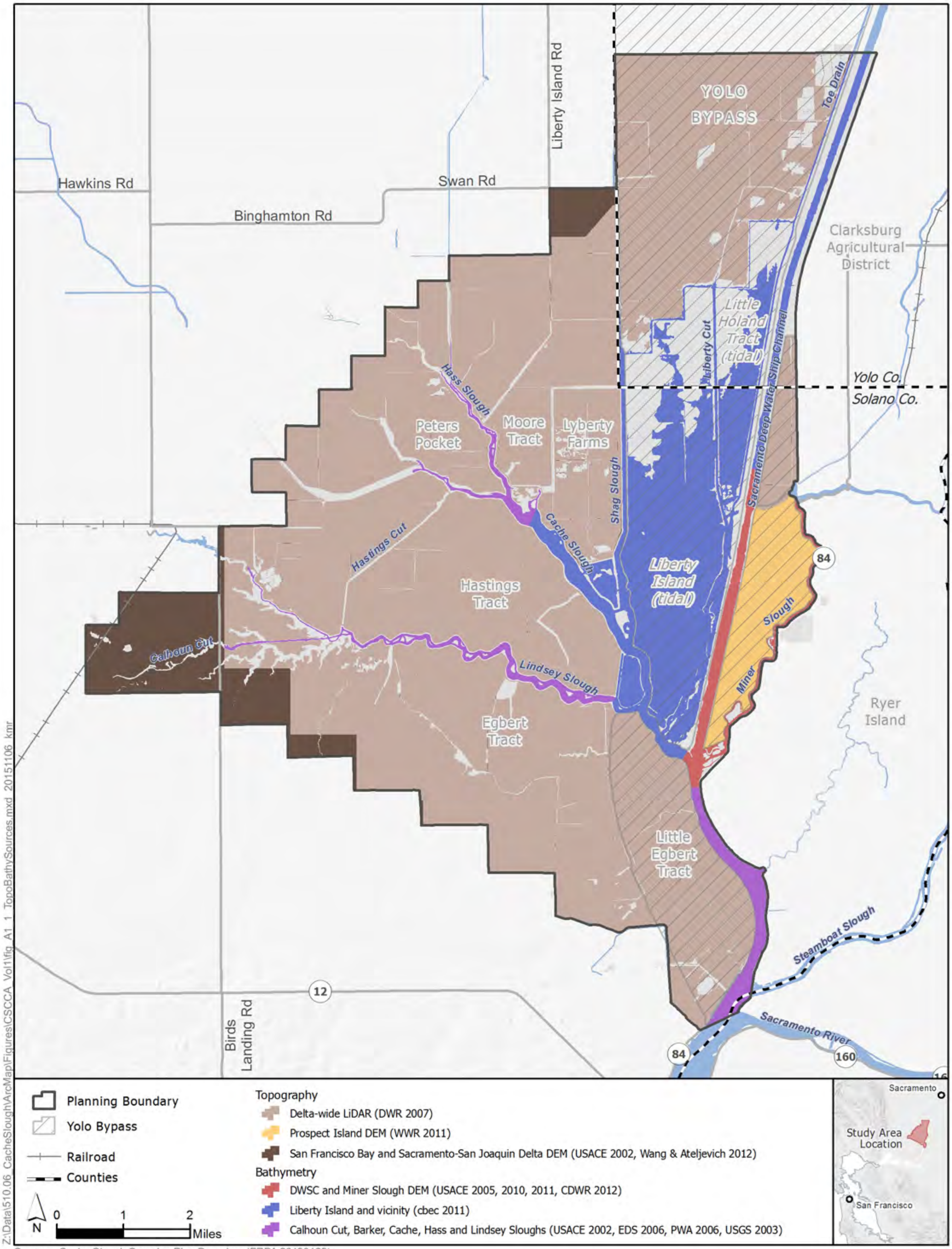
Topography and Bathymetry

Sources of contemporary topographic and bathymetric data collected within and around the Cache Slough Complex are outlined in Table A-1-1. For the purposes of this report, a composite elevational surface was created by merging the data sources as shown in Figure A1-1.

Table A-12. Bathymetric and Topographic Data for Cache Slough Complex Area.

Data type	Resolution/Accuracy	Year	Coverage within planning area	Source
Topography & Bathymetry	3 ft horizontal and +1 ft vertical to produce 2 ft contours; transects reported at 50–250 ft apart	1997	Entire	(USACE 2002)
Bathymetry	USACE Class 1 hydrographic survey; transects spaced at 400 ft apart	2005, 2010, 2011	DWSC and lower Cache Slough	(USACE 2005, 2010, 2011)
Topography & Bathymetry	2-ft	2010, 2011	Prospect Island	(DWR 2011, WWR 2011)
Bathymetry	USACE Class 1 hydrographic survey; transects spaced at 300–500 ft apart	2006	Lindsey and Barker sloughs	(PWA 2006), Lindsey and Barker sloughs bathymetric data collected to support 2D modeling for SCWA
Bathymetry	Not stated; marsh transects spaced at 500–1500 ft apart	2006	Old Lindsey Slough, with some adjacent topography	PWA (2006), Old Lindsey Slough hydrographic data collected to support 2D modeling for SCWA
Topography	LiDAR: 1-ft horizontal and +0.6 ft vertical at 95%	2007	90% of planning area, missing western edge	DWR (2007)(DWR 2007a), LiDAR data for the Delta
Bathymetry	10-m	2007	Main sloughs, Yolo toe drain, and ship channel; missing western-most areas	CDWR and USGS http://sfbay.wr.usgs.gov/sediment/delta/
Bathymetry	USACE Class 1 hydrographic survey; transects	2009	Liberty Island and vicinity	(cbec 2011)

Data type	Resolution/Accuracy	Year	Coverage within planning area	Source
	spaced 300 ft to 1,000 ft apart			
Bathymetry	3 ft multibeam survey supplemented by single beam data in shallow areas	2012	Miner Slough	(DWR 2012c)
Bathymetry	Multibeam bathymetry: 1 ft horizontal and +0.5 ft vertical at 95%; data filtered to 3 ft posting on average	2007/2008	None; Sacramento River RMs 36–64	CVFED ULEP (CDWR 2008), Multibeam bathymetric data collected to support urban levee evaluation
Bathymetry	Single-beam bathymetry: USACE Class 1 hydrographic survey; transects spaced 300–1,000 ft apart	2009	Liberty Island, lower Yolo Bypass and toe drain, and lower Haas Slough	EDS/cbec (EDS and cbec 2009), single-beam bathymetric data collected to support 2D hydrodynamic modeling for SCWA
Bathymetry	Single-beam bathymetry: 6 ft horizontal and +0.5 ft vertical at 95% for depths <15 ft; 12 ft horizontal and +1 ft vertical at 95% for depths >15 ft; transects spaced 900–1800 ft apart	2010	Lindsey, Haas, upper Cache, lower Cache, Miner, Sutter, Steamboat, Elk, Threemile, and Georgiana sloughs; Sacramento River (RMs 1–26); and Horseshoe Bend	CVFED TO18 (CDWR 2011), single-beam bathymetric data collected to support hydraulic modeling
Bathymetry	Multibeam bathymetry: 3 ft horizontal and +0.5 ft vertical at 95%; data filtered to 3 ft posting on average	2010	None; Sacramento River RMs 26–36	CVFED TO202 (CDWR 2010), multibeam bathymetric data collected to support hydraulic modeling
Topography & Bathymetry	2 ft field survey DEM	2011	Prospect Island	WWR and EDS (2011), Prospect Island hydrographic data
Topography & Bathymetry	32 ft and 6 ft integrated DEM	2012	Entire	Wang, R. & Ateljevich, E. (2012).



Sources: Cache Slough Complex Plan Boundary (FRPA 20130129);

Figure A1-1 : Topography and Bathymetry surface data sources
Cache Slough Complex Conservation Assessment

Appendix B

Vegetation and Natural Communities

Special-Status Native Plants

*Astragalus tener var. tener (*alkali milk-vetch*)*

Status, range and presence: Alkali milk-vetch is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, alkali milk-vetch has been documented in Alameda, Contra Costa, Merced, Monterey, Napa, San Benito, Santa Clara, San Francisco, San Joaquin, Solano, Sonoma, Stanislaus, and Yolo counties (CNPS 2014). Alkali milk-vetch is known to occur in the vernal pools on the western side of the Cache Slough Complex (CSC) including in the Calhoun Cut Ecological Reserve and the Jepson Prairie Reserve (CDFW 2014b).

Habitat requirements: Alkali milk-vetch grows in alkali grassland and alkali vernal pools and playas (CDFW 2014b). Grassland, alkali seasonal wetland complex, vernal pool complex, and managed wetland are the natural community types in the CSC that may provide habitat for alkali milk-vetch. Common species associations are dwarf peppergrass (*Lepidium latipes* var. *latipes*), Fremont's goldfields (*Lasthenia fremontii*), and salt grass (USFWS 2005).

Threats and stressors: The threats to alkali milk-vetch are development, competition from non-native plants, trampling, energy transmission line construction, and habitat destruction, particularly from the conversion of habitat to agriculture (CNPS 2014).

Viability assessment: A comprehensive population status assessment of alkali milk-vetch within the CSC has not been performed or updated recently. Restoration of habitat associated with this species would increase the amount of contiguous habitat in this area, as well as increase the value of the conserved areas for vernal pool invertebrates including the longhorn fairy shrimp. This specie would benefit from the restoration or protection of its associated habitats.

*Atriplex cordulata var. cordulata (*heartscale*)*

Status range and presence: Heartscale is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, heartscale has been documented in Alameda, Butte, Contra Costa, Colusa, Fresno, Glenn, Kern, Madera, Merced, San Joaquin, Solano, Stanislaus, Tulare, and Yolo counties (CNPS 2014). Heartscale is known to occur in the vernal pools on the western side of the CSC including in the Calhoun Cut Ecological Reserve and the Jepson Prairie Reserve (CDFW 2014b).

Habitat requirements: Heartscale is typically found in alkali grassland, alkali meadow, or iodinebush scrub with alkaline soils, usually near or on the margins of scalds, slickspots, and vernal pools (CDFW 2014b). Grassland, alkali seasonal wetland complex, vernal pool complex, and managed wetland are the natural community types in the CSC that may provide habitat for heartscale. Heartscale is commonly associated with salt grass, low barley (*Hordeum depressum*), common spikeweed, alkali heath (*Frankenia salina*), alkali weed, and bush seepweed (*Suaeda nigra*) (CDFW 2014b, CNPS 2014). It often co-occurs with other annual saltbush species.

Threats and stressors: Reported threats to heartscale include agriculture intensification, development, non-native plants, overgrazing, and trampling (CDFW 2014b, CNPS 2014).

Viability assessment: A comprehensive population status assessment of heartscale within the CSC has not been performed or updated recently. This specie would benefit from the restoration or protection of its associated habitats.

*Atriplex depressa (*brittlescale*)*

Status range and presence: Brittlescale is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, brittlescale has been documented in Alameda, Contra Costa, Colusa, Fresno, Glenn, Kern, Merced, Solano, Stanislaus, Tulare, and Yolo counties (CNPS 2014). Brittlescale is known to occur in the vernal pools in the Jepson Prairie Reserve on the western side of the CSC (CDFW 2014b).

Habitat requirements: Brittlescale is found in alkali meadows and on the margins of scalds, slickspots and vernal pools with alkaline clay soils (CNPS 2013). Grassland, alkali seasonal wetland complex, vernal pool complex, and managed wetland are the natural community types in the CSC that may provide habitat for brittlescale. Species associated with brittlescale can include common spikeweed, salt grass, alkali heath, low barley, Mediterranean barley (*Hordeum marinum* subsp. *gussoneanum*), boraxweed (*Nitrophila occidentalis*), Parish's glasswort (*Arthrocnemum subterminale*), bush seepweed, heartscale, and San Joaquin spearscale (CDFW 2014b, CNPS 2014).

Threats and stressors: The primary threat to brittlescale is the loss of suitable habitat within the range of the species (CDFW 2014b). Other threats include livestock grazing and trampling, flooding of alkali grassland to create waterfowl habitat, and urban development (CDFW 2014b).

Viability assessment: A comprehensive population status assessment of brittlescale within the CSC has not been performed or updated recently.

Extriplex joaquinana (San Joaquin spearscale)

Status range and presence: San Joaquin spearscale is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, San Joaquin spearscale has been documented in Alameda, Contra Costa, Colusa, Fresno, Glenn, Merced, Monterey, Napa, San Benito, Santa Clara, San Joaquin, San Luis Obispo, Solano, Tulare, and Yolo counties (CNPS 2014). The only known occurrence for this species in the CSC is from 1891 Jepson collections in CNDDB (CDFW 2014b), re-surveying efforts are needed to identify if San Joaquin spearscale still occurs in the area.

Habitat requirements: San Joaquin spearscale occurs in alkali grassland and meadows, and other seasonal wetlands with alkaline soils (California Department of Fish and Game 2012b). (CDFW 2013). The habitat types within the CSC that could support San Joaquin spearscale include grasslands and alkali seasonal wetland complex. San Joaquin spearscale is generally found associated with other salt- or alkali-tolerant species, including salt grass, alkali heath, bush seepweed, alkali weed, common spikeweed, low barley, and iodinebush (*Allenrolfea occidentalis*) (CDFW 2014b).

Threats and stressors: The current threats to San Joaquin spearscale include grazing, agriculture, and development (CNPS 2014).

Viability assessment: A comprehensive population status assessment of San Joaquin spearscale within the CSC has not been performed or updated recently.

Atriplex persistens (vernal pool smallscale)

Status range and presence: Vernal pool smallscale is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, vernal pool smallscale has been documented in Colusa, Glenn, Madera, Merced, Solano, Stanislaus, and Tulare counties (CNPS 2014). Vernal pool smallscale is known to occur in the vernal pools in the Jepson Prairie Reserve on the western side of the CSC (CDFW 2014b).

Habitat requirements: It grows in alkali vernal pools (CNPS 2014). The natural community type in the CSC that may provide habitat for vernal pool smallscale is vernal pool complex. Vernal pool smallscale co-occurs with many plants including, alkali weed, fivehorn smotherweed (*Bassia hyssopifolia*), alkali heath, gumplant (*Grindelia camporum*), common spikeweed, and salt grass (CDFW 2014b).

Threats and stressors: Possible threats to vernal pool smallscale are flood-management activities and agriculture (CNPS 2014).

Viability assessment: A comprehensive population status assessment of vernal pool smallscale within the CSC has not been performed or updated recently.

*Cicuta maculata var. bolanderi (*Bolander's water-hemlock*)*

Status range and presence: Hemlock is on the CNPS List 2B.1 (rare, threatened, or endangered in California, but more common elsewhere). Bolander's water-hemlock has been documented in Contra Costa, Los Angeles, Marin, Sacramento, Santa Barbara, San Luis Obispo, and Solano counties, as well as in Arizona, New Mexico, and Washington State (CNPS 2014). The only known location in the CSC is in the western portion of the area, possibly as part of the Jepson Prairie Reserve; further field studies should be done to identify extent of Bolander's water-hemlock within the CSC (CDFW 2013).

Habitat requirements: Bolander's water-hemlock occurs in marshes and swamps in coastal, fresh or brackish water (CDFW 2013). Tidal freshwater emergent wetland is the natural community type in the CSC that may provide habitat for Bolander's water-hemlock.

Threats and stressors: Threats to Bolander's water-hemlock are development, competition from non-native plants, and hydrological alterations (CNPS 2013).

Viability assessment: A comprehensive population status assessment of Bolander's water-hemlock within the CSC has not been performed or updated recently.

*Downingia pusilla (*dwarf downingia*)*

Status range and presence: Dwarf downingia is on the CNPS List 2B.2 (rare, threatened, or endangered in California, but more common elsewhere). Dwarf downingia has been documented in Amador, Fresno, Merced, Napa, Placer, Sacramento, San Joaquin, Solano, Sonoma, Stanislaus, Tehama, and Yuba counties, as well as in South America (CNPS 2013). Dwarf downingia is known to occur in the vernal pools on the western side of the CSC including in the Calhoun Cut Ecological Reserve and the Jepson Prairie Reserve (CDFW 2013).

Habitat requirements: Throughout its distribution, dwarf downingia occurs in vernal pools, vernal swales, pools in seasonal streambeds, vernal marshes, tire ruts, hydrologically altered sloughs, and irrigation ponds (CDFW 2013). The natural community type in the CSC that may provide habitat for dwarf downingia is vernal pool complex. On the clay soils of the greater Jepson Prairie area it is found across a range of microtopographic positions in vernal pools within grassland vegetation that typically has a high cover of rye grass, a non-native grass (Witham 2006, Barbour et al. 2007).

Threats and stressors: The threats to dwarf downingia are competition from non-native plants, urbanization, development, agriculture, grazing, vehicles, and industrial forestry (CNPS 2013).

Viability assessment: A comprehensive population status assessment of dwarf downingia within the CSC has not been performed or updated recently.

*Fritillaria liliacea (*fragrant fritillary*)*

Status range and presence: Fragrant fritillary is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, fragrant fritillary has been documented in Alameda, Contra Costa, Marin, Monterey, Napa, San Benito, Santa Clara, San Francisco, San Mateo, Solano, and Sonoma counties (CNPS 2013). Fragrant fritillary is found on the western portion of the CSC in the Jepson Prairie Reserve (CDFW 2013).

Habitat requirements: It occurs in grasslands, coastal prairie, and open, grassy areas in coastal scrub and oak woodlands, often on serpentine soils (CDFW 2013). The natural community type in the CSC that provides habitat for fragrant fritillary is grassland. Some species commonly associated with fragrant fritillary are purple needle grass (*Stipa pulchra*), blue dicks (*Dichelostemma capitatum*), wavyleaf soap plant (*Chlorogalum pomeridianum*), goldeneggs (*Taraxia ovata*), winecup clarkia (*Clarkia purpurea*), and coyote brush (*Baccharis pilularis*) (CDFW 2013).

Threats and stressors: Threats to fragrant fritillary are grazing, agriculture, urbanization, competition from non-native plants, and possibly recreational activities (CNPS 2013).

Viability assessment: A comprehensive population status assessment of fragrant fritillary within the CSC has not been performed or updated recently.

Gratiola heterosepala (Boggs Lake hedge-hyssop)

Status range and presence: Boggs Lake hedge-hyssop is state-listed endangered and on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). Boggs Lake hedge-hyssop has been documented in Fresno, Lake, Lassen, Madera, Merced, Modoc, Placer, Sacramento, Shasta, Siskiyou, San Joaquin, Solano, Sonoma, and Tehama counties, as well as in Oregon (CNPS 2013). The only known occurrence of this plant in the CSC is at the Jepson Prairie Reserve (CDFW 2013).

Habitat requirements: Boggs Lake hedge-hyssop occurs in vernal pools and in marshy areas on the margins of reservoirs and lakes, as well as in man-made habitats such as borrow pits and cattle ponds (CDFW 2013). The natural community type in the CSC that may provide habitat for Boggs Lake hedge-hyssop is vernal pool complex. The most frequent associates of this species include bractless hedge-hyssop (*Gratiola ebracteata*), Great Valley popcornflower (*Plagiobothrys stipitatus*), doublehorn calicoflower (*Downingia bicornuta*), slender Orcutt grass (*Orcuttia tenuis*), and pale spikerush (*Eleocharis macrostachya)* (USFWS 2005).

Threats and stressors: Threats to Boggs Lake hedge-hyssop mainly are due to habitat loss, alteration, and degradation. Habitat loss generally is a result of urbanization, agricultural conversion, changes to natural hydrology, invasive species, incompatible grazing regimes, infrastructure projects, recreational activities, erosion, climatic and environmental change, and contamination (USFWS 2005).

Viability assessment: A comprehensive population status assessment of Boggs Lake hedge-hyssop within the CSC has not been performed or updated recently.

Hibiscus lasiocarpos var. *occidentalis* (woolly rose-mallow)

Status range and presence: Woolly rose-mallow is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, woolly rose-mallow has been documented in Butte, Contra Costa, Colusa, Glenn, Sacramento, San Joaquin, Solano, Sutter, and Yolo counties (CNPS 2013). There are two mapped CNDDB occurrences of woolly rose-mallow in the CSC, one in Calhoun Cut and the other on Hass Slough (CDFW 2013).

Habitat requirements: It grows in freshwater marsh along river banks and sloughs (CDFW 2013). Freshwater perennial emergent wetland and valley/foothill riparian are the natural community types in the CSC that provide habitat for woolly rose-mallow. Associated species include dotted smartweed

(*Persicaria punctata),* tules*,* iris-leaved rush *(Juncus xiphioides*)*,* field mint (*Mentha arvensis*), California rose (*Rosa californica*)*,* white alder (*Alnus rhombifolia*)*,* American dogwood (*Cornus sericea*)*,* ragweed (*Ambrosia* spp.)*,* hedge bindweed (*Calystegia sepium*)*,* Italian thistle (*Carduus pycnocephalus*)*,* and bull thistle (*Cirsium vulgare*) (CDFW 2013)*.*

Threats and stressors: Threats to woolly rose-mallow are habitat disturbance, development, agriculture, recreational activities, weed control measures, erosion, and channelization of the Sacramento River and its tributaries (CNPS 2013).

Viability assessment: A comprehensive population status assessment of woolly rose-mallow within the CSC has not been performed or updated recently.

Isocoma arguta (Carquinez goldenbush)

Status range and presence: Carquinez goldenbush is on the CNPS List 1B.1 (rare, threatened, or endangered in California and elsewhere, seriously endangered in California). A California endemic, Carquinez goldenbush has been documented in Solano County (CNPS 2013). The only known occurrence of this plant in the CSC is at the Jepson Prairie Reserve (CDFW 2013).

Habitat requirements: It occurs in grasslands with alkali soils (CDFW 2013). The natural community type in the CSC that provides habitat for Carquinez goldenbush is grassland. Associated species include rye grass, soft chess (*Bromus hordeaceus*), low barley, brodiaea (*Brodiaea* spp.), and sticky sand-spurry (*Spergularia macrotheca*).

Threats and stressors: Potential threats to Carquinez goldenbush include loss of habitat due to development and agriculture (CNPS 2013).

Viability assessment: A comprehensive population status assessment of Carquinez goldenbush within the CSC has not been performed or updated recently.

Lathyrus jepsonii var. *jepsonii* (Delta tule pea)

Status range and presence: Delta tule pea is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, Delta tule pea has been documented in Contra Costa, Napa, Sacramento, San Joaquin, Solano, Sonoma, and Yolo counties (CNPS 2013). Within the CSC there are occurrences of Delta tule pea at and immediately above the tidal zone in marshes and along rivers and streams on Barker Slough, Calhoun Cut, Lindsay Slough, Hass Slough, Cache Slough, and Miner Slough (CDFW 2013).

Habitat requirements: Delta tule pea occurs on the borders of fresh and brackish marshes (CNPS 2013). Tidal freshwater emergent wetland and valley/foothill riparian habitat are the natural community types in the CSC that may provide habitat for Delta tule pea. Associated plant species with Delta tule pea include: salt grass, pickleweed (*Salicornia pacifica*), cattails, California rose, coyote brush, Himalayan blackberry, common reed (*Phragmites australis*), Mason's lilaeopsis (*Lilaeopsis masonii*), tules, marsh pennywort (*Hydrocotyle verticillata*), and marsh jaumea (*Jaumea carnosa*) (CDFW 2013).

Threats and stressors: The primary threat to Delta tule pea is the loss of marsh and floodplain habitat within the range of the species through agriculture, water diversions, and erosion (CNPS 2013).

Viability assessment: A comprehensive population status assessment of Delta tule pea within the CSC has not been performed or updated recently. This species was discontinued as a species of concern in the draft recovery plan for tidal marshes of central California (USFWS 2010).

Legenere limosa (legenere)

Status range and presence: Legenere is on the CNPS List 1B.1 (rare, threatened, or endangered in California and elsewhere, seriously endangered in California). A California endemic, legenere has been documented in Alameda, Lake, Monterey, Napa, Placer, Sacramento, Santa Clara, Shasta, San Joaquin, San Mateo, Solano, Sonoma, Stanislaus, Tehama, and Yuba counties (CNPS 2013). Legenere is found in the western portion of CSC both in the Calhoun Cut Ecological Reserve and Jepson Prairie Reserve (CDFW 2013).

Habitat requirements: It occurs in vernal pools and other seasonal wetlands (CDFW 2013). The natural community type in the CSC that provides habitat for legenere consists of vernal pool complex. Plant species most commonly associated with legenere are smooth goldfields (*Lasthenia glaberrima*) and pale spikerush, and to a lesser extent other rare plants such as Bogg's Lake hedge-hyssop and dwarf downingia (USFWS 2005).

Threats and stressors: The vernal pool habitat of legenere is primarily threatened by grazing, development, non-native plants, and road widening (CNPS 2013).

Viability assessment: A comprehensive population status assessment of legenere within the CSC has not been performed or updated recently.

Lepidium latipes var. *heckardii* (Heckard's pepper-grass)

Status range and presence: Heckard's pepper-grass is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, Heckard's pepper-grass has been documented in Glenn, Merced, Sacramento, Solano, and Yolo counties (CNPS 2013). The CNDDB occurrence for this species within the CSC is along Hass Slough (CDFW 2013).

Habitat requirements: Heckard's pepper-grass generally occurs in alkaline flats and alkaline grasslands along the edges of vernal pools (CDFW 2013). The habitat type in the CSC most likely to support Heckard's pepper-grass is the vernal pool complex. Common species associations in the Solano-Colusa Vernal Pool Region are peppergrass (*Lepidium latipes*), Fremont's goldfields, salt grass, miniature lupine (*Lupinus bicolor*), and California eryngo (*Eryngium aristulatum*) (USFWS 2005).

Threats and stressors: Primary threats to Heckard's pepper-grass include development, waterfowl management, agricultural conversion, urban development, and competition with non-native plant species (CDFW 2013).

Viability assessment: A comprehensive population status assessment of Heckard's pepper-grass within the CSC has not been performed or updated recently.

Lilaeopsis masonii (Mason's lilaeopsis)

Status range and presence: Mason's lilaeopsis is state-listed as rare and on the CNPS List 1B.1 (rare, threatened, or endangered in California and elsewhere, seriously endangered in California). A California endemic, Mason's lilaeopsis has been documented in Alameda, Contra Costa, Marin, Napa, Sacramento, San Joaquin, Solano, and Yolo counties (CNPS 2013). Mason's lilaeopsis is found along the edges of many of the sloughs within the CSC as well as along the DWSC.

Habitat requirements: It grows on the bare soil of mudflats and river banks and on pilings, riprap, and other exposed substrates (CDFW 2013). Natural community types in the CSC that may provide habitat for Mason's lilaeopsis are tidal freshwater emergent wetland and valley/foothill riparian. Some of the species commonly associated with Mason's lilaeopsis include southern bulrush (*Schoenoplectus californicus*), marsh pennywort, and low bulrush (*Isolepis cernua*) (Golden and Fiedler 1991).

Threats and stressors: Threats to Mason's lilaeopsis are erosion, channel stabilization, development, flood-management projects, recreation, agriculture, shading resulting from marsh succession, and competition with invasive water hyacinth (CNPS 2013).

Viability assessment: A comprehensive population status assessment of Mason's lilaeopsis within the CSC has not been performed or updated recently. Detection of Mason's lilaeopsis is difficult and its habitat is inherently unstable, thus its distribution and abundance may be both highly variable and underestimated (WWR et al. 2010a). Field and genetic studies have suggested that this species may not be distinct from the more common coastal species *Lilaeopsis occidentalis* (USFWS 2010).

Limosella australis (Delta mudwort)

Status range and presence: Delta mudwort (formerly *Limosella subulata*) is on the CNPS List 2B.1 (rare, threatened, or endangered in California, but more common elsewhere). Delta mudwort has been documented in Contra Costa, Sacramento, San Joaquin, and Solano Yolo counties, as well as in Washington State (CNPS 2013). Delta mudwort occurrences have been reported in the Calhoun Cut Ecological Reserve as well as the Miner Slough Wildlife Area.

Habitat requirements: It grows on the bare soil of mudflats and river banks and on pilings, riprap, and other exposed substrates (CDFW 2013). Tidal freshwater emergent wetland and valley/foothill riparian are the natural community types in the CSC that may provide habitat for Delta mudwort. Some of the species commonly associated with Delta mudwort include southern bulrush, marsh pennywort, and low bulrush (Golden and Fiedler 1991).

Threats and stressors: Threats to Delta mudwort in California are erosion, recreation, trampling, flotsam deposition, riprap, possible tidal gate installation, grazing on adjacent land, fishing access, streambank alteration for wetlands restoration, trash, levee maintenance/upgrades, rising sea levels, and increased salinity (CDFW 2013).

Viability assessment: A comprehensive population status assessment of Delta mudwort within the CSC has not been performed or updated recently.

Neostapfia colusana (Colusa grass)

Status range and presence: Colusa grass is federally-listed as threatened, state-listed as endangered, and is on the CNPS List 1B.1 (rare, threatened, or endangered in California and elsewhere, seriously endangered in California). A California endemic, Colusa grass has been documented in Colusa, Glenn, Merced, Solano, Stanislaus, and Yolo counties (CNPS 2013). Colusa grass is found within the CSC boundary in the Jepson Prairie Preserve.

Habitat requirements: Colusa grass occurs in the bottoms of large, deep vernal pools (CDFW 2013). The natural community type in the CSC that provides habitat for Colusa grass is vernal pool complex. Colusa grass usually grows in single-species stands, rather than intermixed with other plants. Thus, associated species in this case are plants that occur in different zones of the same pools, but are generally present in the same season (USFWS 2005). In saline-alkaline sites, common associates of Colusa grass include alkali heath and salt grass, whereas on acidic sites associates include eryngo species (*Eryngium* spp.), turkey-mullein (*Croton setiger*), and Great Valley popcornflower (Natureserve 2013).

Threats and stressors: Threats to Colusa grass are competition with non-native plants, agriculture, development, overgrazing, and flood management actions (CNPS 2013).

Viability assessment: A comprehensive population status assessment of Colusa grass within the CSC has not been performed or updated recently.

Plagiobothrys hystriculus (bearded popcornflower)

Status range and presence: Bearded popcornflower is on the CNPS List 1B.1 (rare, threatened, or endangered in California and elsewhere, seriously endangered in California). A California endemic, bearded popcornflower has been documented in Napa, Solano, and Yolo counties (CNPS 2013). Bearded popcornflower is known to occur within the western portion of the CSC including the Jepson Prairie Reserve.

Habitat requirements: Bearded popcornflower was presumed extinct until rediscovered in 2005 (CNPS 2013). It occurs in vernal pools and vernal swales and also in other vernally moist areas in grasslands (Preston et al. 2010). Natural community types in the CSC that provide habitat for bearded popcornflower are vernal pool complex and grassland. Commonly associated species include rye grass, Jepson's button-celery, blow-wives (*Achyrachaena mollis*), spinyfruit buttercup (*Ranunculus muricatus*), Mediterranean barley, and the rare pappose tarplant (*Centromadia parryi* subsp. *parryi*) (CDFW 2013).

Threats and stressors: Threats to bearded popcornflower are disking, development, and competition with non-native plants (CNPS 2013).

Viability assessment: A comprehensive population status assessment of bearded popcorn-flower within the CSC has not been performed or updated recently.

Sagittaria sanfordii (Sanford's arrowhead)

Status range and presence: Sanford's arrowhead is on the CNPS List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, Sanford's arrowhead has been documented in Butte, Del Norte, El Dorado, Fresno, Merced, Mariposa, Orange, Placer, Sacramento, San Bernardino, Shasta, San Joaquin, Solano, Tehama, Ventura, and Yuba counties (CNPS 2013). Sanford's arrowhead has only been found within the CSC boundary along Miner Slough and near the CDFW Miner Slough Wildlife Area.

Habitat requirements: It occurs in freshwater ponds, marshes, streams and ditches with standing or slow-moving water (CDFW 2013). Natural community types in the CSC that provide potential habitat for Sanford's arrowhead are non-tidal perennial aquatic and non-tidal freshwater perennial emergent wetland.

Threats and stressors: Threats to Sanford's arrowhead include grazing, development, recreational activities, competition with non-native plants, road widening, and channel alteration (CNPS 2013, BDCP 2013).

Viability assessment: A comprehensive population status assessment of Sanford's arrowhead within the CSC has not been performed or updated recently.

Symphyotrichum lentum (Suisun Marsh aster)

Status range and presence: Suisun Marsh aster is on the CNPS 2013 List 1B.2 (rare, threatened, or endangered in California and elsewhere). A California endemic, Suisun Marsh aster has been documented in Contra Costa, Napa, Sacramento, San Joaquin, Solano, and Yolo counties (CNPS 2013). Suisun Marsh aster is mapped along many of the sloughs as well as the DWSC within the boundary of the CSC.

Habitat requirements: Suisun Marsh aster grows on the upper margins of brackish and freshwater marshes in the ecotone with terrestrial habitats (Goals Project 2000) and above erosional cuts and along the banks of sloughs and watercourses, often occurring with common reed, cattails, tules, and blackberries (CDFW 2013). Freshwater emergent wetland and valley/foothill riparian are the natural community types in the CSC that provide habitat for Suisun Marsh aster.

Threats and stressors: Current threats to Suisun Marsh aster include invasive plants, erosion, creek channelizing, levee maintenance and construction, and possibly herbicide applications (CDFW 2013, CNPS 2013).

Viability assessment: Suisun Marsh aster is an obligate outcrossing species which is believed to cross-pollinate with the more common species (Pacific aster [*Symphyotrichum chilense*]). A comprehensive population status assessment of Suisun Marsh aster within the CSC has not been performed or updated recently.

Tuctoria mucronata (Crampton's tuctoria or Solano grass)

Status range and presence: Solano grass is federally and state-listed as endangered and is on the CNPS List 1B.1 (rare, threatened, or endangered in California and elsewhere, seriously endangered in California). A California endemic, Solano grass has been documented in Solano and Yolo counties (CNPS 2013). One CNDDB record of Solano grass is found within the CSC boundary at the Jepson Prairie Preserve, however it is believed to be extirpated (CDFW 2013).

Habitat requirements: Solano grass is known from only three occurrences in the southwestern Sacramento Valley in Solano and Yolo counties, where it grows in vernal pools (CDFW 2013). The natural community type in the CSC that provides habitat for Solano grass is vernal pool complex.

Threats and stressors: Competition from non-native plants is a threat to Solano grass (CNPS 2013).

Viability assessment: A comprehensive population status assessment of Solano grass within the CSC has not been performed or updated recently.

Invasive Aquatic Vegetation

Alternanthera philoxeroides (alligator weed)

Cal-IPC: High/Alert; CDFA: A

Alligator weed is a noxious herbaceous aquatic perennial that forms dense floating mats. It invades lakes, streams, canals, ponds and irrigation ditches. It was previously used in the aquarium trade (CalIPC 2013). Typically plants grow rooted in soil in shallow water and form dense, interwoven floating mats that extend over the surface of deeper water (DiTomaso and Healy 2003). Mats disrupt the natural ecology of a site by reducing light penetration and crowding out native species. Biological control agents do exist but are not yet established in California. Alligator weed could have potential negative impacts to restoration of tidal habitats by crowding out native species and providing potential habitat for non-native fish species.

Egeria densa (Brazilian waterweed)

Cal-IPC: High; CDFA: C

Brazilian waterweed 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. Its underwater growth significantly retards water flow and reduces the abundance and diversity of native plant seeds in lake bottoms (Cal-IPC 2013). The plant aggressively invades new aquatic environments, displacing native aquatic vegetation and altering the dynamic of aquatic ecosystems (DiTomaso & Healy 2003). Heavy infestations can impact water flow impediment, which could have potential to impact restoration of tidal habitats by crowding out native species and providing potential habitat for non-native fish species. Brazilian waterweed is thought to reduce turbidity through a reduction in water velocity, resulting in higher local particle sediment rates. In addition, the thick cover of these two invasive plants provides excellent habitat for non-native ambush predators, such as bass and sunfish, which prey on native fish species (Brown and Michniuk 2007).

Eichhornia crassipes (water hyacinth)

Cal-IPC: High; CDFA: C

Water hyacinth is a floating freshwater perennial that jams rivers and lakes with tons of floating plant matter. Floating mats of this plant can weigh up to 200 tons per acre. In California, water hyacinth typically is found below 660 ft elevation in the Central Valley, San Francisco Bay Area, and south coast. Water hyacinth can quickly dominate a waterway or aquatic system because of rapid leaf production, fragmentation of daughter plants, and copious seed production and germination. It degrades habitat for waterfowl by reducing areas of open water used for resting, and when decomposing it makes water unfit for drinking. It displaces native aquatic plants used for food or shelter by other wildlife species. Once it proliferates in a waterbody, water hyacinth dramatically alters the ecosystem and often results in environmental degradation and a reduction in bio-diversity (CABI 2013). Water hyacinth can completely exclude native floating and submerged vegetation, shade habitat, change water temperature and deplete DO (SFEI 2003). This affects the health of fish, while decaying plants make water unfit for drinking by humans, livestock, and wildlife (Godfrey 2000).

Iris pseudacorus (yellowflag iris)

Cal-IPC: Limited; CDFA: none

Yellowflag iris is a non-native plant patchily distributed throughout the Delta. It reproduces by seed and through rhizomes and bulbs (corms), and is a fast-growing plant that can spread rapidly. Able to outcompete wetland plants, it forms monospecific stands (Cal-IPC 2013).

Limnobium laevigatum (South American spongeplant)

Cal-IPC: High; CDFA: Q

This invasive non-native plant was first found in the San Joaquin River and the Delta in 2007, and has been reported in small patches near Brannan Island (South of Rio Vista). In the fall of 2012, South American spongeplant was observed behind marinas in Franks Tract (L. Anderson, personal observation). This plant reproduces by seed and seedlings which are very small (often confused with duckweeds), buoyant, and easily dispersed and carried by boats, waterfowl, wind, and water currents. This species can form dense mats, like water hyacinth, through clonal growth during the spring through late fall.

Ludwigia hexapetala (Uruguayan primrose-willow)

Cal-IPC: High/Alert; CDFA: none

Uruguayan primrose-willow is an aquatic plant that forms dense mats in waterways, reaching above and below the water surface. This dense growth impedes water movement, blocks the growth of native plants, and reduces available habitat for waterfowl and fish. Although this species has been naturalized in California for at least 25 years, it has grown exponentially in the past several years, leading to increased concern over its impacts on waterways. Pieces of Uruguayan primrose-willow mats can catch on boat and other watercraft that then spread plants to new areas. (Cal-IPC 2013)

Ludwigia peploides (water primrose)

Cal-IPC: High; CDFA: none

Water primrose is a perennial aquatic plant that forms very dense, virtually impenetrable mats which restrict fishing and boat access. It also out-competes native aquatic plants. Water primrose can be found throughout California in rice fields, ditches, ponds, slow moving streams, and along edges of lakes and reservoirs. There is some confusion as to which non-native species occur in California and more than one species may be invasive. This species has an allelopathic effect that impacts water quality throughout the year (CABI 2013)

Myriophyllum spicatum (Eurasian water-milfoil)

Cal-IPC: High; CDFA: C

Eurasian water-milfoil is a common submersed aquatic perennial. Eurasian water-milfoil can be found in freshwater lakes, ponds, and canals with slow moving waters in northern and central California, particularly in the San Francisco Bay and San Joaquin Valley regions and Lake Tahoe. This plant grows and spreads rapidly, creating dense mats on the water surface (Cal-IPC 2013). These mats impede water flow, interfere with boat traffic and recreational activities, and create mosquito habitat (DiTomaso and Healy 2003). These monotypic mats may alter aquatic ecosystems by out-competing native aquatic plants, thus decreasing native plant and animal diversity and abundance, these plants also have the ability to affect the predator prey relationships of fish among littoral plants (Gettys et al. 2009).

Myriophyllum aquaticum (parrot's feather)

Cal-IPC: High; CDFA: none

Parrot's feather is a stout aquatic perennial that forms dense mats of intertwined brownish stems (rhizomes) that can entirely cover the surface of the water in shallow lakes and other waterways. These mats clog waterways, making them unusable for navigation or recreation and causing flooding out of the channel. This invasive plant may compete with native aquatic plants, eliminating them or reducing their numbers in infested sites. The species does not produce viable seed and its distribution is limited to vegetative dispersal mechanisms. (Cal-IPC 2013) While parrot's feather may provide cover for some aquatic organisms, it can significantly alter the physical and chemical characteristics of lakes and streams. Infestations can alter aquatic ecosystems by shading out algae in the water column that serve as the basis of the aquatic food web. It also alters habitats for aquatic organisms, waterfowl, and other wildlife (Godfrey 2000).

Persicaria spp. (smartweed)

Cal-IPC: None; CDFA: B and C

Smartweed is a rhizomed perennial herb that forms dense stands, typically at water depths of 3–16 feet deep. Stands can dominate edges of ponds, shallow lakes, marshes, irrigation ditches, rice fields, and other areas subject to seasonal flooding. Water smartweed produces both vegetatively (from rhizomes and fragmented stems) and from seed; both stems and seeds can disperse large distances along watercourses (CDFA 2013). This invasive plant may compete with native aquatic plants, eliminating them or reducing their numbers in infested sites, and can impede water flow.

Potamogeton crispus (curlyleaf pondweed)

Cal-IPC: Moderate; CDFA: none

Curlyleaf pondweed is a perennial, herbaceous, submerged aquatic plant commonly found in the Delta, where it creates dense stands and canopies near the water surface. It is native to Europe and has no known natural pathogens or herbivores in the U.S. Curlyleaf pondweed is rapidly becoming a species of high concern due to expansion in U.S. lakes, streams, and ponds. Curlyleaf pondweed produces widespread and dense canopies in early- to mid-summer, which block light and space for native aquatic plants. Its long shoots (often greater than 0.6–0.9 ft) often interfere with commercial and recreational boating, angling, swimming, and waterfowl access to benthic food sources. The tall canopy also alters water flows, increasing accretion of silt and sediments, and changes temperature profiles in the water column, creating warmer layers near the water surface. Photosynthesis within the dense mats can also create steep gradients and diurnal changes in pH (James et al. 2001, Mi et al. 2008, ANSTF 2012).

Invasive terrestrial plant species

Ailanthus altissima (tree-of-heaven)

Cal-IPC: Moderate; CDFA: C

Tree-of-heaven is a fast-growing deciduous tree to 20 m tall, with creeping roots that sucker sprout freely. One tree can rapidly produce a clonal thicket and displace native vegetation and wildlife. It grows in disturbed places in riparian areas, grassland, and woodland (DiTomaso and Healy 2007).

Aegilops triuncialis (barbed goat grass)

Cal-IPC: High; CDFA: B

Barbed goat grass is an annual grass that grows in rangelands, grasslands, and oak woodlands. It is becoming a dominant grass in foothill grasslands of central California (Cal-IPC 2013). Barbed goat grass reduces the abundance of native grasses and forbs by forming monospecific stands, reducing forage for wildlife, and using high amounts of soil moisture. Its impact may be most felt in upland restoration sites, especially vernal pool habitat.

Arundo donax (giant reed)

Cal-IPC: High; CDFA: B

Giant reed is a tall perennial grass that typically forms dense stands on disturbed sites, sand dunes, riparian areas, and wetlands. *Arundo donax* is threatening California's riparian ecosystems by outcompeting native species, such as willows, for water. Giant reed displaces native plants and associated wildlife species by monopolization of soil moisture and by shading. It also leads to increased water temperatures by providing little shading to in-stream habitat, thus reducing habitat quality for aquatic wildlife (Dudley 2000). Giant reed also causes substantial alterations to water flow during storm events leading to increased erosion. In addition, its stems and rhizomes break off in the flood currents and flow with the flood. These rhizomes and stems deposit themselves and quickly re-establish in these new locations. This is why control in and around restoration sites is important (CABI 2013).

Bromus madritensis subsp. rubens **(=B. rubens) (red brome)**

Cal-IPC: High; CDFA: none

Red brome is a cool-season annual grass found throughout California, especially in the southern part of the state. Red brome invades disturbed areas, roadsides, agricultural fields, rangelands, and logging sites, in addition to native communities. It is found throughout the CSC (Cal-IPC 2013). Red brome can lead to altered patterns of wildfire, microhabitat characteristics, and nutrient cycling. It also competes with native species for soil nutrients and light which can affect native annual plant populations (D'Antonio and Vitousek 1992) (Brooks 2000).

Carduus pycnocephalus **(Italian thistle)**

Cal-IPC: Moderate; CDFA: C

Italian thistle is a winter annual, sometimes biennial, and grows to 2 m tall. It typically colonizes disturbed open sites, roadsides, pastures, and annual grasslands, preferring sandy to clasy soils. It’s widely distributed throughout California (DiTomaso 2007).

Centaurea solstitialis **(yellow starthistle)**

Cal-IPC: High; CDFA: C

Yellow starthistle is a bushy winter annual that invades 12 million ac in California. Yellow starthistle inhabits open hills, grasslands, open woodlands, fields, roadsides, and rangelands, and it is considered one of the most serious rangeland weeds in the state. It propagates rapidly by seed, and a large plant can produce nearly 75,000 seeds. Several insects from the Mediterranean region, including weevils and flies, have been employed as biocontrol agents for yellow starthistle with minor success (Cal-IPC 2013). CalWeedMapper shows yellow starthistle throughout the CSC and says it is being managed and decreasing in abundance (CalWeedMapper 2013). Dense infestations of yellow starthistle displace native plants and animals, threatening natural ecosystems and nature reserves (Gerlach and DiTomaso 2000). Dense infestations of this species within newly restored habitats, mainly in the upland transition zone, would be problematic due to displacement of native species, habitat fragmentation, and loss of species diversity. Yellow starthistle seed is transported by human activities and animals. This species has a deep taproot (one meter or more) that grows quickly and can access and deplete deep soil moisture reserves in grasslands. It can outcompete many other species in both stressed conditions and disturbed conditions (DiTomaso et al. 2006). Heavy infestations have been reported to use as much as 50% of annual stored soil moisture in loamy soils, and significantly reduce soil moisture reserves more than six feet deep (DiTomaso 2001). Grazing and fire can both influence the distribution and density of yellow starthistle either positively or negatively depending on the timing and intensity of the regimes (D'Antonio et al. 2007).

Conium maculatum (poison-hemlock)

Cal-IPC: Moderate; CDFA: none

Poison-hemlock is typically a biennial growing to 3 m tall. It contains piperidine alkaloids, and all plant parts are highly toxic to humans and animals when ingested. It grows on roadsides, pastures, fields, ditches, riparian areas, and other disturbed, often moist sites. It's found throughout California (DiTomaso 2007).

Cortaderia jubata (jubata grass)

Cal-IPC: High; CDFA: none

Jubata grass is a large perennial grass which favors dunes, bluffs, and disturbed areas, including inland areas where temperatures are moderated by fog. It was introduced as an ornamental plant and for erosion control. Each plume produces up to 100,000 seeds that are widely dispersed by wind and develop without fertilization. Jubata grass quickly colonizes bare ground, but establishment is generally poor where the seedlings must compete with other grasses or sedges (Cal-IPC 2013). Large infestations threaten California's native coastal ecosystems by crowding out native plants. In addition to its effect on native plant diversity, jubata grass can reduce the aesthetic and recreational value of natural areas. Dense colonies can be fire hazards (DiTomaso 2000a).

Cortaderia selloana (pampas grass)

Cal-IPC: High; CDFA: none

Pampas grass is a large perennial grass found along the coast of California, and in the Coast Ranges, Central Valley, Western Transverse Ranges, and Mojave Desert. Pampas grass favors dunes, bluffs, coastal shrublands and marshes, inland riparian areas, and disturbed areas. It was introduced as an ornamental plant and for erosion control. Each plume produces up to 100,000 seeds that are widely dispersed by wind and develop without fertilization. Pampas grass quickly colonizes bare ground, but establishment is generally poor where the seedlings must compete with other grasses or sedges (Cal-IPC 2013). In the CSC, pampas grass competes with native vegetation, reduces the aesthetic and recreational value of these areas, and also increases the fire potential (DiTomaso 2000b).

Elymus caput-medusae (medusa head)

Cal-IPC: High; CDFA: none

Medusa head is a winter annual that typically invades disturbed sites, grasslands, openings in chaparral and oak woodlands (Cal-IPC 2013). Medusa head out-competes native grasses and forbs, and, once established, can reach densities of 1,000 to 2,000 plants per square meter. After seed set, the silica-rich plants persist as a dense litter layer that prevents germination and survival of native species, ties up nutrients, and contributes to fire danger in summer. Because of its high silica content, medusa head is unpalatable to livestock and native wildlife except early in the growing season (Pollack and Kan 2000).

Foeniculum vulgare (fennel)

Cal-IPC: High; CDFA: none

Fennel is an erect perennial herb. Fennel will invade areas where the soil has been disturbed and can exclude or prevent reestablishment of native plant species. It can drastically alter the composition and structure of many plant communities, including grasslands, coastal scrub, riparian, and wetland communities (Cal-IPC 2013). Once established, fennel is tenacious and difficult to control. Because of its prolific seed production and seed viability, a long-lived seedbank can build up rapidly.

Ficus carica (fig)

Cal-IPC: Moderate; CDFA: none

Fig is a deciduous tree growing up to 10 m tall. Fig is widely cultivated as an ornamental and for its edible fruits, but it has escaped cultivation in some regions of California. On sites where fig thrives, trees frequently form dense clonal thickets that exclude native vegetation. Fig grows in riparian areas, canal banks, and disturbed places typically where soil moisture is available throughout the year. It reproduces by seed and vegetatively from roots and stem fragments (DiTomaso 2007).

Genista monspessulana (French broom)

Cal-IPC: High; CDFA: C

French broom is a perennial shrub that is an aggressive invader, forming dense stands that exclude native plants and wildlife. These leguminous plants produce copious amounts of seed, and may re-sprout from the root crown if cut or grazed (Cal-IPC 2013). It is a strong competitor and can dominate a plant community and make reforestation difficult (IPCW Carla D'Antonio). Broom tends to form monospecific stands that degrade the quality of habitat for wildlife by shading out native plant and forage species as well as changing microclimate conditions at soil levels. Maybe important to control French broom on uplands of restoration sites.

Lepidium latifolium (perennial pepperweed)

Cal-IPC: High; CDFA: none

Perennial pepperweed is a perennial herb found in moist or seasonally wet sites throughout California. Perennial pepperweed grows very aggressively, forming dense colonies that exclude native species. It reproduces both by seed and vegetatively from its roots and small root fragments. Seeds and root fragments are spread easily by flooding and soil movement and seeds stick to tires, shoes, and animals, making continued dispersion difficult to avoid. Perennial pepperweed is a state-listed noxious weed in California and many other western states. It is found throughout the CSC (Cal-IPC 2013). Also has potential to alter habitat for native wildlife. Perennial pepperweed is especially invasive on physically disturbed soils and where vegetation cover has been reduced, forming a continuous leaf canopy, eliminating the vegetation gaps that may be essential for seedling establishment of native plants and special-status species (CABI 2013).

Lythrum salicaria (purple loosestrife)

Cal-IPC: High; CDFA: none

Purple loosestrife is a wetland herb that invades scattered freshwater wetlands of northern and central California (Cal-IPC 2013). Purple loosestrife invades many types of wetlands, tidal and non-tidal marshes, river, and stream banks. It can form dense monotypic stands that suppress native plant species, decrease biodiversity and lead to a change in wetland community structure and hydrologic function. Purple loosestrife can eliminate open water habitat and can also vary the timing of nutrient release due to decomposition in the fall, which can alter the structure of the food web (Gettys et al. 2009). The impacts of purple loosestrife on tidal restoration include the potential to outcompete cattails and other native marsh plants as well as degradation of habitat for waterfowl and other wildlife (SFEI 2003).

Rubus armeniacus (Himalayan blackberry)

Cal-IPC: High; CDFA: none

Himalayan blackberry is a sprawling, essentially evergreen, glandless, robust shrub. Himalayan blackberry is a strong competitor, and it rapidly displaces native plant species. Blackberries are highly competitive plants. Thickets form such a dense canopy that the lack of light severely limits the growth of other plants. In wet areas blackberries may hinder medium-sized to large mammals from gaining access to water (IPCW Marc C. Hoshovsky).

Sesbania punicea (red sesbania)

Cal-IPC: High; CDFA: B

Red sesbania is a deciduous shrub or small tree that grows up to 13 ft tall. Red sesbania is mostly found in riparian areas in the Central Valley, forming clusters so thick that access to the river becomes difficult to impossible. It displaces native plants used by wildlife and contributes to bank erosion and flooding (Cal-IPC 2013).

Tamarix parviflora (smallflower tamarisk)

Cal-IPC: High; CDFA: B

Smallflower tamarisk is a shrub or a tree and can be found along streams and lake shores, throughout California. Tamarix species are associated with dramatic changes in geomorphology, groundwater availability, soil chemistry, fire frequency, plant community composition, and native wildlife diversity. It is being managed and is decreasing in abundance within the CSC (CalWeedMapper 2013).

Tamarix ramosissima (saltcedar, tamarisk)

Cal-IPC: High; CDFA: B

Saltcedar is a shrub or a tree and can be found along streams and lake shores, throughout California. Saltcedar is associated with dramatic changes in geomorphology, groundwater availability, soil chemistry, fire frequency, plant community composition, and native wildlife diversity. Saltcedar is found in a large portion of the CSC (Calfora 2013). Saltcedar excludes other plants from growing underneath, due to salt deposited from leaves and has an aggressive root system depletes ground water needed by native species (SFEI 2003).

Appendix C

Wildlife

Special-status Invertebrates

Conservancy fairy shrimp

Status: Conservancy fairy shrimp (*Branchinecta conservatio*) was listed as endangered throughout its range under the federal ESA on September 19, 1994. Revised critical habitat for vernal pool crustaceans was designated on August 11, 2005. This species is included in the December 15, 2005, *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (USFWS 2005). The conservancy fairy shrimp has no state regulatory status.

There are two recent (2012) CNDDB occurrences of conservancy fairy shrimp that occur within the CSC. There are also several occurrences that were recorded within approximately 5.6 km (3.5 mi) to the west of the CSC. Critical habitat for conservancy fairy shrimp does not occur within the CSC, but there is critical habitat for the conservancy fairy shrimp found in the northern portion of Suisun Marsh, located west of the CSC.

Habitat requirements: Habitats for conservancy fairy shrimp in California are typically large, playa-type vernal pools or smaller vernal pools that are turbid and have a relatively long inundation period compared with most vernal pools (Eng et al. 1990, USFWS 2007). This species is entirely dependent on the aquatic environment provided by the temporary waters of natural vernal pool and playa pool ecosystems as well as the artificial environments of ditches and tire ruts (King et al. 1996, Helm 1998, Eriksen and Belk 1999). The temporary waters that conservancy fairy shrimp inhabits fill in the fall and winter during the beginning of the wet season, dry in late spring at the beginning of the dry season, and remain desiccated throughout the summer (Eriksen and Belk 1999).

Threats and stressors: The primary threats to vernal pool habitat used by conservancy fairy shrimp as identified in the *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (USFWS 2005) include: habitat loss and fragmentation, which were identified as the largest threat to the survival and recovery of vernal pool species; invasive species; altered hydrology; climate change; and inappropriate grazing practices.

Longhorn fairy shrimp

Status: Longhorn fairy shrimp (*Branchinecta longiantenna*) was federally listed as endangered by the USFWS on September 19, 1994. Revised critical habitat for vernal pool crustaceans was designated on August 11, 2005 and critical habitat unit designations were published on February 10, 2006. This species is covered by the December 15, 2005, *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (USFWS 2005). The longhorn fairy shrimp has no state regulatory status.

Vernal pools that may support the species occur in Jepson Prairie Preserve and within the CSC, as well as in the CDFG Tule Ranch Unit of the Yolo Bypass Wildlife area north of the CSC.

Habitat requirements: Although the longhorn fairy shrimp is only known from a few locations, these sites contain very different types of vernal pool habitats (USFWS 2005). Longhorn fairy shrimp in Contra Costa and Alameda Counties are primarily reported from small (sometimes no larger than 1 meter diameter), clear, sandstone outcrop pools with a near-neutral pH, and very low alkalinity and conductivity. The longhorn fairy shrimp is capable of living in vernal pools of relatively short ponding duration (6–7 weeks in winter and 3 weeks in spring) (Eriksen and Belk 1999).

Threats and stressors: In general, the primary threats to vernal pool habitat used by longhorn fairy shrimp as identified in the Vernal Pool Recovery Plan (USFWS 2005) include: habitat loss and fragmentation, which were identified as the largest threat to the survival and recovery of vernal pool species; invasive species; altered hydrology; climate change; and inappropriate grazing practices.

Vernal pool fairy shrimp

Status and range: Vernal pool fairy shrimp (*Branchinecta lynchi*) is listed as threatened under the federal ESA throughout its range. This species is covered by the December 15, 2005, *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (USFWS 2005). The vernal pool fairy shrimp has no state regulatory status.

While there aren't any CNDDB occurrences of vernal pool fairy shrimp that occur within the CSC, there is vernal pool habitat present that could support the species. There are also several occurrences that were recorded within approximately 4.5 miles of the CSC.

Habitat requirements: This species is entirely dependent on the aquatic environment provided by the temporary waters of natural vernal pool and playa pool ecosystems as well as the artificial environments of ditches and tire ruts (King et al. 1996, Helm 1998, Eriksen and Belk 1999). The temporary waters that vernal pool fairy shrimp inhabits fill in the fall and winter during the beginning of the wet season, dry in late spring at the beginning of the dry season, and remain desiccated throughout the summer (Eriksen and Belk 1999). The temporary waters fill directly from precipitation as well as from surface runoff and perched groundwater from their watersheds (Williamson et al. 2005, Rains et al. 2006, O'Geen et al. 2008, Rains et al. 2008).

Vernal pool fairy shrimp have also occasionally been found in degraded vernal pool habitats and artificially created seasonal pools (Helm 1998). Vernal pool fairy shrimp commonly co-occur with other fairy shrimp and vernal pool tadpole shrimp (USFWS 2005).

Threats and stressors: In general, the primary threats to vernal pool habitat used by vernal pool fairy shrimp as identified in the *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (USFWS 2005) include: random, naturally occurring events; habitat loss and fragmentation, which were identified as the largest threat to the survival and recovery of vernal pool species; invasive species; altered hydrology; climate change; and inappropriate grazing practices or lack of grazing.

Vernal pool tadpole shrimp

Status and range: Vernal pool tadpole shrimp (*Lepidurus packardi*) was listed as endangered throughout its range under the federal ESA on September 19, 1994. Revised critical habitat for vernal pool crustaceans was designated on August 11, 2005 and critical habitat unit designations were published on February 10, 2006. This species is included in the December 15, 2005, *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (USFWS 2005)*. Vernal pool tadpole shrimp has no state regulatory status.

Vernal pool tadpole shrimp is distributed across the Central Valley of California and in the San Francisco Bay area, and are uncommon even where vernal pool habitats occur (USFWS 2005). Historically, vernal pool tadpole shrimp was probably distributed over most of the vernal pool habitat that existed in the Central Valley during pre-agricultural times; however, surveys in southern portions of California have never revealed vernal pool tadpole shrimp populations, and the species probably did not occur historically outside of the Central Valley and Central Coast regions.

There are two recent (2012) CNDDB occurrences of vernal pool tadpole shrimp that occur within the CSC. There are also several occurrences that were recorded within approximately 4.5 miles to the west and northwest of the CSC, as well a critical habitat to the west of the CSC in the northern part of Suisun Marsh.

Habitat requirements: Vernal pool tadpole shrimp occur in a wide variety of ephemeral wetland habitats (Helm 1998). Determining the vernal pool tadpole shrimp's habitat requirements is not possible based on anecdotal evidence, and the tolerances of this species to specific environmental conditions have yet to be determined (USFWS 2005).

Threats and stressors: In general, the primary threats to vernal pool habitat used by vernal pool tadpole shrimp as identified in the *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon* (USFWS 2005) include: habitat loss and fragmentation, which were identified as the largest threat to the survival and recovery of vernal pool species; invasive species; altered hydrology; climate change; and inappropriate grazing practices or lack of grazing.

Delta green ground beetle

Status and range: Delta green ground beetle was federally listed as threatened on August 8, 1980 (USFWS 1985). At the same time, two areas in south-central Solano County, separated by 0.8 km (0.5 mi) and totaling 388 ha (960 ac), were designated as critical habitat (USFWS 1980). In 1985, USFWS prepared a recovery plan for the Delta green ground beetle (USFWS 1985). This species was also included in USFWS's 2005 *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon*.

To date, Delta green ground beetle has only been found in the greater Jepson Prairie area in south-central Solano County, California (USFWS 2005).

Several Delta green ground beetles have been observed in vernal pool habitat within the CSC (CDFW 2014b). There are also several occurrences to the west of the CSC within the Jepson Prairie Preserve. Of the 388 ha (960 ac) designated as critical habitat for the Delta green ground beetle in south-central Solano County, approximately 131 ha (325 ac) fall within the CSC.

Habitat requirements: Delta green ground beetle lives in areas of grassland interspersed with vernal pools including several larger vernal pools (sometimes called playa pools or vernal lakes), such as Olcott Lake found in the Jepson Prairie Preserve. Such playa pools typically hold water for longer durations than smaller vernal pools, from the onset of the rainy season through mid-summer (USFWS 2005).

Threats and stressors: The primary threats to vernal pool habitat, including habitat used by the Delta green ground beetle, as identified in the *Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon*, include: impacts to its habitat, especially due to the beetle's extremely limited distribution and population; changes in vegetation management, specifically the temporary removal or absence of managed grazing; and the maintenance and monitoring of fuel pipelines and electricity transmission lines.

Special-status Amphibians

California tiger salamander

Status and range: California tiger salamander (*Ambystoma californiense*) is listed as federally threatened throughout most of its range, but receives the more critical designation of endangered in Sonoma and Santa Barbara counties. The distinct population segment (DPS) in the Central Valley was state-listed as threatened in 2010. In 2005, the USFWS designated approximately 80,576 ha (199,109 ac) of critical habitat for the Central Valley DPS throughout 19 California counties. Populations are known in the Central Valley and Sierra Nevada foothills from Yolo to Kern counties (up to elevations of 610 m [2,000 ft]).

Habitat requirements: California tiger salamanders are found in annual grassland and open woodland communities in lowland and foothill regions of central California where aquatic sites are available for breeding (USFWS 2003). Vernal pools are the primary breeding habitat, but it is also known to successfully reproduce in natural and man-made ponds, including stock ponds (Barry and Shaffer 1994).

Adults are terrestrial, found most of the year (6–9 months) in grassland and open woodland habitats where small mammal burrows provide shelter. Trenham (Trenham) found a preference for open grassland; salamanders in contiguous woody vegetation were never found more than 10 ft from open grassland, presumably because that is where cover, in the form of ground squirrel burrows, was more readily available (Jameson and Peeters 1988, Trenham 2001).

Approximately 131 ha (325 ac) of the CSC overlaps the Jepson Prairie Preserve, a 1,566-acre conservation area owned by the Solano Land Trust where California tiger salamanders have been documented (west of Highway 113 and east of Travis Air Force Base). Much of this area has been designated as critical habitat, approximately 477 ha (1,180 ac) of which is within, and 2,399 ha (5,930 ac) adjacent to, the CSC.

Threats and stressors: California tiger salamander populations are believed to be declining as a result of habitat loss (Shaffer et al. 1993, Barry and Shaffer 1994, Holland 1998). An estimated 80% of the species' historical aquatic habitat has been lost (Holland 1998), and the species has been eliminated from 55% to 58% of historical breeding sites (Barry and Shaffer 1994). Another primary cause of decline is habitat fragmentation resulting from urban and agricultural development. Non-native aquatic species in perennial ponds such as bullfrog, mosquitofish (*Gambusia affinis*), sunfish (*Lepomis* spp.), black bass (*Micropterus* spp.), catfish, fathead minnows, etc. may prey on larval salamanders (Anderson 1968, Morey and Guinn 1992, Graf and Allen-Diaz 1993, Shaffer et al. 1993, Seymour and Westphal 1994, Fisher and Shaffer 1996, Lawler et al. 1999, Laabs et al. 2001, Leyse 2005).

Contamination of surface water by pesticides, fertilizers, and other pollutants may reduce larval survival, while rodenticides and poison gases used to control rodents (e.g., chlorophacinone, diphacinone, strychnine, aluminum phosphide, carbon monoxide, and methyl bromide) are also toxic to adult salamanders (Salmon and Schmidt 1984). Removal of California ground squirrels and pocket gophers may also reduce the availability of upland burrows used by adult salamanders (Loredo-Prendeville et al. 1994).

Special-status Birds

Watch List Species

Several species of birds are on the State of California Watch List. These species will not be discussed here as they are not expected to be negatively impacted by restoration activities. Species found in the CSC on the Watch List include: white-faced ibis, double-crested cormorant, golden eagle, ferruginous hawk, Cooper's hawk, osprey, and horned lark.

Redhead

Status and range: Redheads, a type of diving duck, are a California Species of Special Concern. The year-round range of redhead includes the Central Valley, northeastern California and southern California.

Small numbers of redhead are known to nest in private duck clubs and public refuges where summer water levels are greater than 1 meter deep(Shuford and Gardali 2008). Breeding has been documented in the Yolo Bypass where deep permanent wetlands are maintained. There are no recent records of redheads breeding in the CSC.

Habitat requirements: Suitable nesting habitat for redhead in the CSC is in managed wetlands, inland marshes, and non-tidal freshwater emergent wetlands where it feeds on vegetative parts and tubers of submerged aquatic plants.

Threats and stressors: Threats to redhead nesting habitat in California includes loss of suitable wetland habitat as well as pesticides and other contaminants (Shuford and Gardali 2008).

Least bittern

Status and range: Least bittern is a California Species of Special Concern and a USFWS bird of conservation concern.

There are recent breeding records of least bitterns near Freeport and in the Yolo Bypass (Shuford and Gardali 2005). Because of the species secretive nature, the exact range of breeding in the CSC is unknown.

Habitat requirements: Least bitterns are found in brackish and freshwater marshes. For nesting, bitterns require extensive, tall, dense emergent marshes. They may also use dense woody vegetation over deep water. Least bitterns nest in places where they are able to create a platform of vegetation over the high water line.

Threats and stressors: The primary threat to this species is the loss of dense wetland vegetation and wetland habitat in general, especially in the Salton Sea (Shuford and Gardali 2008). To a lesser extent, invasive species and water contamination also threaten the species.

White-tailed kite

Status and range: White-tailed kite is a CDFW fully protected species. White-tailed kites are a year round resident of California.In California, white-tailed kites are closely associated with cultivated fields of the coastal areas and lowland valleys (Zeiner et al. 1990a).

Habitat requirements: White-tailed kite inhabits low-elevation open grasslands, savannah-like habitats, agricultural areas, wetlands, and oak woodlands (Dunk 1995). Most white-tailed kites nesting in the Sacramento Valley are found in oak and cottonwood riparian forests, valley oak woodlands, or other groups of trees and are usually associated with compatible foraging habitat consisting of low-growing, herbaceous vegetation in patches of more than 1,500 m^2 (4,921 ft^2) (Erichsen et al. 1996). Pasture and hay crops, compatible row and grain crops, and natural vegetation such as seasonal wetlands and annual grasslands provide foraging habitat for this species (Erichsen et al. 1996). The white-tailed kite is excluded from narrow bands of riparian vegetation by Swainson's hawks, and therefore requires wide patches of nesting habitat where its range overlaps with the Swainson's hawk (Hansen, pers. comm.). Foraging habitat types noted above are considered available year-round; however, flooded seasonal wetlands receive less use during periods of inundation. During the breeding season, kites generally restrict their foraging territories to an approximately 1.6-km^2 (1-mi^2) area around the nest (Warner and Rudd 1975). During the non-breeding season, kites are not confined to the limits of breeding territories and can be found throughout the CSC. Grassland and seasonal wetland cover types generally provide more stable food resources over the long term; however, irrigated croplands and pasturelands are also widely used. Agricultural cover types that appear to be preferred include alfalfa and other hay crops, irrigated pastures, and some cultivated habitats, particularly sugar beets and tomatoes, both of which can support relatively large populations of voles and which have been highly correlated with kite nest site densities (Erichsen et al. 1996). Kites also forage in pastures, rice stubble fields, and occasionally in orchards (Erichsen et al. 1996).

Threats and stressors: White-tailed kite populations are increasing. In localities where populations are decreasing it is due to loss of habitat, especially trees appropriate for nesting.

Short-eared owl and northern harrier

Status and range: Short-eared owl and northern harrier are marsh-associated ground nesting birds and are California Species of Special Concern.

Northern harriers are common year-round residents of California, where they breed at lower elevations statewide.

Short-eared owls breed and winter over most of the United States. In California, breeding primarily occurs in northeastern portion of the State and Suisun Marsh.

On occasion, short-eared owls are found breeding in the Delta and the San Joaquin Valley.

Both raptors are found within the Delta year-round and the breeding range of short-eared owl and northern harrier includes the CSC. Both species have been observed in the area may nest and forage throughout the CSC.

Habitat requirements: Habitats for short-eared owl and northern harrier include tidal brackish and freshwater emergent wetland, non-tidal freshwater perennial emergent wetland, other natural seasonal wetland, grassland, and selected cultivated lands. Both species require uplands with cover and sufficient prey base for breeding.

Threats and stressors: Breeding habitat loss and degradation is the primary threat to these species. Habitat degradation may be caused by grazing, invasive weeds, and water management (Shuford and Gardali 2008).

Golden eagle and ferruginous hawk

Status and range: Golden eagle is a USFWS bird of conservation concern and is fully protected by CDFW. Though the golden eagle is a permanent resident throughout much of California, it only winters in the Central Valley and the CSC.

Ferruginous hawk is a USFWS bird of conservation concern. Ferruginous hawks overwinter in the CSC but do not breed there.

Habitat requirements: As both raptors only overwinter in the CSC, the primary use of habitat in the CSC is for foraging. The golden eagle and ferruginous hawk use open lands such as grasslands for foraging.

Threats and stressors: Both golden eagles and ferruginous hawk populations are stressed by habitat loss and habitat disturbance.

California black rail

Status and range: California black rail (*Laterallus jamaicensis coturniculus*) is a threatened species under the CESA, a USFWS bird of conservation concern, and is fully protected by CDFW.

Black rail inhabits high elevation areas of tidal saltwater and brackish marshes and freshwater marshes in several areas of California (Eddlemen 1994).

Approximately 80% of the California black rail subspecies resides in the San Francisco Bay (Evens et al. 1991), though some smaller populations occur along the outer coast of Marin County and the freshwater marshes of the Sierra Nevada foothills and the Colorado River Area (Spautz et al. 2006). Of the black rail populations occurring in the Estuary, many are currently found in the historical marshes of San Pablo Bay, Suisun Bay, and the Carquinez Strait (Evens et al. 1991). Black rails have been heard calling in the CSC, along Lindsey and Barker Sloughs (Pers. Communication Danika Tsao, DWR, September 2015).

Habitat requirements: The highest concentrations are in marshes associated with large rivers and sloughs (Petaluma River Marsh, Black John Slough, Coon Island, Fagan Slough, Napa River) (Evens et al. 1991, Spautz and Nur 2004); thus freshwater input to tidal marshes appears to correlate positively with black rail abundance. Manolis (1978) found black rails only in the upper elevations of marshes, near the limit of tidal inundation. Black rails prefer saturated substrates; therefore, marshes with muted tidal influence are more likely to provide habitat in years when there is above-average precipitation.

A study of black rail habitat use within the Delta showed that the probability of presence within a habitat is most strongly and positively influenced by red-stem dogwood (*Cornus sericea*), arroyo willow (Salix *lasiolepis*), bulrush (*Schoenoplectus* spp.), and broad-leaf cattail (*Typha latifolia*) with agriculture negatively influencing the probability of presence (Tsao, et al., unpublished). These habitats differ from those used in San Francisco Bay, where black rails are found in high tidal marshes dominated by pickleweed (*Salicornia pacifica*), and from foothill black rails, which use emergent wetland vegetation associated with irrigated lands.

Primary (breeding) habitat for this species within the Delta includes all bulrush- (*Schoenoplectus*) and cattail- (*Typha*) dominated tidal and non-tidal freshwater emergent wetland in patches greater than 1.22 ha (0.55 ac). Upland transitional zones, providing refugia during high tides, within 45 m (150 ft) of the tidal wetland edge are used as secondary habitat. Secondary habitats generally provide only a few ecological functions such as foraging (low marsh and managed wetlands) or extreme high tide refuge (upland transition zones), while primary habitats provide multiple functions, including breeding, effective predator cover, and quality foraging opportunities. Natural communities in the CSC containing suitable California black rail habitat are tidal brackish emergent wetland, tidal freshwater emergent wetland, alkali seasonal wetland complex, and managed wetland.

Threats and stressors: Black rail populations are threatened by habitat loss, degradation of remaining habitat, predation by domestic cats and herons, as well as disturbance around breeding populations.

Greater and lesser sandhill crane

Status and range: Greater sandhill cranes (*Grus canadensis tabida*) are fully protected by CDFW and listed as threatened under CESA. Lesser sandhill cranes are a CDFW Species of Special Concern.

Sandhill cranes are winter residents in the Delta, arriving early September, reaching maximum densities during December and January, and departing during early March. The Sacramento-San Joaquin Delta is one of the most important wintering areas for sandhill crane (Littlefield and Ivey 2000).

Although surveys for greater sandhill cranes have not been conducted within the CSC, they are known to overwinter (October to February) by the thousands in nearby Cosumnes River Preserve, Stone Lakes National Wildlife Refuge and Woodbridge Ecological Preserve south of the CSC.

Habitat requirements: Cranes roost in shallowly flooding seasonal wetlands and forage primarily in harvested corn fields, winter wheat fields, alfalfa fields, seasonal wetlands, irrigated pastures, and grasslands (Pogson and Lindstedt 1988, Littlefield and Ivey 2000). Wintering sandhill cranes generally use agricultural grain fields (i.e., corn, wheat, barley, rice, rye, and oats) for foraging and wetlands for roosting. In addition to grain crops, sandhill cranes use alfalfa, grasslands, and pasture to obtain calcium, other minerals, and protein (Littlefield and Ivey 2000).

Throughout their wintering range in the Delta, suitable foraging habitat is likely also a function of patch size; however, because there are insufficient data on winter habitat patch size and because, in general, field sizes within the Delta winter range are probably sufficiently large to support foraging cranes, all suitable cover types are considered suitable habitat irrespective of patch size. Mid-day loafing typically occurs in wetlands and flooded fields along agricultural field borders, levees, rice checks, and ditches, and in alfalfa fields or pastures. Night-roosting is in shallowly flooded open fields and open wetlands interspersed with uplands. Portions of the CSC may be used regularly by large numbers of greater sandhill cranes. Sandhill cranes primarily forage in harvested row crops (primarily grains such as corn) and tend to congregate in small to large flocks. Corn, rice, and alfalfa as well as wetland, grassland, and pasture habitats can be found within the CSC.

Threats and stressors: Loss and degradation of riverine and wetland ecosystems as well as agricultural lands for foraging are the most important threats to sandhill crane populations. For the migratory populations, this is of greatest concern in staging and wintering areas.

Mountain plover

Status and range: Mountain plover is a California Species of Special Concern, a USFWS bird of conservation concern, and is proposed threatened under the ESA. Mountain plovers have been documented wintering in Solano and Yolo counties.

Habitat requirements: Suitable habitat includes heavily grazed grassland, short hay crops such as alfalfa, and freshly tilled fields (Hunting and Edson 2008).

Threats and stressors: Habitat loss and degradation both in the breeding and wintering areas is the primary threat to the species.

California least tern

Status and range: California least tern (*Sterna antillarum browni*) is listed as endangered under ESA and CESA.

Nesting today is limited to colonies in San Francisco Bay, Sacramento River Delta, and areas along the coast from San Luis Obispo County to San Diego County. The largest colony is located at Alameda Point in San Francisco Bay on the runway complex of the former Naval Air Station, Alameda. Smaller colonies can be found at Napa–Sonoma Marshes Wildlife Area, Montezuma Wetlands, and Hayward Regional Shoreline.

California least terns have been observed breeding within close proximity to CSC, at the Sacramento Regional Wastewater Treatment Plant, between Sacramento and Elk Grove (Conard 2009).

Habitat requirements: Least terns feed on smelt, anchovies, silversides, and other small fish in shallow estuaries or lagoons where fish are abundant. California least terns breed in loose colonies from April through September. After mating, females lay their eggs in shallow depressions on barren to sparsely vegetated sites near water, usually on sandy or gravelly substrate. Barren or sparsely vegetated sites with sandy or gravelly substrate near water could provide primary nesting habitat within CSC for California least terns.

Threats and stressors: The primary threat to California least terns is habitat degradation and disturbance in nesting areas.

Yellow-billed cuckoo

Status and range: Yellow-billed cuckoo (*Coccycus americanus*) is a candidate for listing under ESA, a USFWS bird of conservation concern, and is listed as endangered under CESA.

The historical distribution of western yellow-billed cuckoo extended throughout the Central Valley, but the species is now widely extirpated, with less than 1% of suitable habitat remaining in the Sacramento Valley. The remaining habitat lies between Colusa and Red Bluff, with known populations at Butte Sink National Wildlife Refuge (NWR), Sacramento River NWR, and Sutter NWR.

Western yellow-billed cuckoo is uncommon in the area at present. Several migrating western yellow-billed cuckoos have been spotted within the CSC, but most of the suitable riparian habitat occurs in patches too small to support breeding pairs, and no confirmed recent breeding records exist.

Habitat requirements: The Western Distinct Population Segment (DPS) of the yellow-billed cuckoo is a riparian-obligate species whose habitat within the CSC is restricted to valley/foothill riparian natural communities. Its primary habitat association is willow-cottonwood riparian forest, but other species such as alder (*Alnus rhombifolia*) and box elder (*Acer negundo*) may be an important habitat element in some areas, including occupied sites along the Sacramento River (Laymon 1998). Dense canopy cover (averaging 96.8% at the nest) and large patch sizes (generally greater than 20 ha [50 ac]) are typically required. The Riparian Bird Conservation Plan (RHJV 2004) suggests that minimum patch size to benefit the species should be aproximately 20–40 ha (50–100 ac), with a minimum width of 100 m (328 ft).

Threats and stressors: Yellow-billed cuckoos are threatened by loss of large patches of riparian habitat. Remaining climax riparian habitats are in such fragmented, small patches that they are not suitable for the cuckoo.

Western burrowing owl

Status and range: Western burrowing owl is a California Species of Special Concern and a year-round resident of the Central Valley and other portions of central California. It is found mainly in grasslands and pasturelands west of the Sacramento River Deep Water Ship Channel in Yolo and Solano counties.

Habitat requirements: Areas with greater densities of burrowing owls are mostly uncultivated, are less exposed to ground disturbances, and harbor larger and more stable populations of California ground squirrels. In Northern California, most nest sites occur in ground squirrel burrows; however, other mammal burrows and various artificial sites, such as culverts, pipes, and rock piles are also used (Haug and Didiuk 1993). Optimal nesting locations are within an open landscape with level to gently sloping topography, sparse or low grassland or pasture cover, and a high density of burrows; however, nest locations also include disturbed habitats within this landscape, including roadside berms, levee slopes, and debris piles. Western burrowing owls occur primarily in open grassland habitats where vegetation is low to maximize visibility and access. Thus, open grassland habitats are ranked as high value for burrowing owls. Moderate-value foraging and nesting habitat includes native and irrigated pasture types that maintain a relatively constant vegetation structure; and berms, road edges, and fence rows around the perimeter of fields; and levee slopes in managed and natural seasonal wetland types. Low-value nesting and foraging habitat includes seasonal wetland types that are dry during the breeding season and types (e.g., irrigated crops) that exhibit periodic or seasonal foraging value due to management activities and changes in vegetation structure. A variety of irrigated crop types may be used; however, use is generally associated with low vegetation structure and thus occurs primarily during pre-planting or post-harvesting seasons.

Threats and stressors: The primary threats to burrowing owl populations are rodent control resulting in the loss of burrows and the loss of habitat due to urbanization and farming.

Loggerhead shrike

Status and range: Loggerhead shrike is a California Species of Special Concern and a USFWS bird of conservation concern for nesting birds. In California, the loggerhead shrike breeds in lower elevation areas as well as the northeast section of the State. The loggerhead shrike is expected to breed in the CSC.

Habitat requirements: In the Central Valley, loggerhead shrikes show a positive association with grasslands, irrigated pasture, and grain and hay crops

(Pandolfino and Smith 2012). Loggerhead shrikes in the Central Valley were shown to have neither a positive or negative association with row crops (Pandolfino and Smith 2012).

Threats and stressors: Habitat loss is thought to be a major threat to the species but reasons for the species decline are poorly understood (Shuford and Gardali 2008).

Grasshopper sparrow

Status and range: Grasshopper sparrow is a California Species of Special Concern. In California, includes most of the low elevation areas of the state.

The species has been observed in the CSC.

Habitat requirements: Suitable habitat for the grasshopper sparrow includes open grasslands and prairies with bare patches of ground.

Threats and stressors: The primary threat to grasshopper sparrows is the loss of habitat due to the expansion of urban areas and agricultural cultivation.

Yellow-breasted chat

Status and range: Yellow-breasted chat is a USFWS bird of conservation concern and a California Species of Special Concern. The subspecies *Icteria virens auricollis* nests in the western U.S. and southern Canada. In the Central Valley, they are typically only found in the Sierra Nevada foothills.

The National Audubon Society (2008) noted pairs of yellow-breasted chat at Liberty Island, Sherman Island, and Piper Slough in the central Delta.

Habitat requirements: Yellow-breasted chats nest and forage in dense riparian thickets of willows, vines, and brush associated with streams and other wetland habitats (Small 1994). Population density is directly related to shrub density (Crawford et al. 1981), with a preference for blackberry noted in several studies (Kroodsma 1982, Burnett and DeStaebler 2003), although a variety of other shrubs and thickets are considered suitable, including wild grape, willows, and California wild rose (Mehlhop and Lynch 1986, Annand and Thompson III 1997, Ricketts and Kus 2000). Some taller overstory trees are also required for song perches (Dunn and Garrett 1997), but the mature and dense overstory canopies are apparently avoided (Kroodsma 1982, Mehlhop and Lynch 1986, Annand and Thompson III 1997).

Zeiner et al. (1990a) reported chat territory sizes from 0.1 to 1.3 ha (0.3 to 3.2 ac). Note however, that Gaines (1974) reported a breeding density from the Sacramento Valley of one chat per 4 ha (10 ac).

Threats and stressors: Riparian width may be an important factor related to yellow-breasted chat occurrence. Narrow widths may make chats more susceptible to brown-headed cowbird parasitism (Gaines 1974, Ricketts and Kus 2000) and predation.

Song sparrow "Modesto" population

Status and range: Song sparrow "Modesto" population (hereafter referred to as Modesto song sparrow), is ubiquitous in the Delta. Modesto song sparrow, a state Species of Special Concern, was a valid subspecies until 2001 and may be again after additional taxonomic analysis (Shuford and Gardali 2008). The population is endemic to the north-central portion of the Central Valley and the Bay-Delta is one of two areas with the highest population densities.

Habitat requirements: Modesto song sparrow occupies wetland, riparian, and scrub habitats, as well as agricultural habitats near drains. Emergent marsh and riparian scrub provide primary nesting habitat.

Threats and stressors: Habitat loss and degradation are believed to be the primary threat to this species. Habitat degradation may be leading to an increase in predator populations leading to greater nest predation (Shuford and Gardali 2008).

Tricolored blackbird

Status and range: Tricolored blackbirds are a California Species of Special Concern. Tricolored blackbird is primarily a California species with small populations found in surrounding states. A majority of tricolored blackbirds are found in the Central Valley through to the coast. They are also found in southern California coastal areas. The Delta is recognized as a major wintering area for tricolored blackbird (Beedy and Hamilton 1997, Hamilton 2004).

Although nesting colonies have been documented in the Yolo Bypass and along the western perimeter of the CSC, breeding colonies are uncommon in the CSC.

Habitat requirements: Tricolored blackbirds nest colonially in large dense stands of freshwater marsh, riparian scrub, and other shrubs and herbs. Foraging habitat consists of grassland, managed wetlands, natural seasonal wetlands and diverse cultivated land cover types.

Outside of the breeding season, tricolored blackbirds are primarily granivores that forage opportunistically in grasslands, pasturelands, croplands, dairies, and livestock feed lots.

Threats and stressors: The primary threat to tricolored blackbird populations is the loss and degradation of habitat. Much of the habitat in their range has been lost to urbanization and incompatible agricultural crops.

Yellow-headed blackbird

Status and range: Yellow-headed blackbird is a California Species of Special Concern. It occurs in the Central Valley.

Habitat requirements: Within the CSC, suitable yellow-headed blackbird nesting habitat includes freshwater emergent wetlands, while associated foraging habitat includes irrigated pastures and alfalfa fields.

Threats and stressors: The primary threat to the yellow-headed blackbird is habitat loss and degradation. As the species is sensitive to water depth in breeding marshes, even drawing down of managed wetlands can degrade the marsh habitat enough to impact the species.

Special-status Mammals

Western red bat

Status and range: Western red bats are a CDFW Species of Special Concern and a Western Bat Working Group High Priority Species.

In California, western red bat has been observed along the Pacific Coast, in the Central Valley, and in the Sierra Nevada Range and foothills.

Western red bats likely use well-established riparian habitats with large trees in the CSC.

Habitat requirements: Western red bats roost in the foliage of large trees and are strongly associated with riparian habitats, particularly mature stands of cottonwood and sycamore. Studies by Pierson et al. (Pierson et al. 2006) show that roosting habits of tree-dwelling bats demonstrate a preference for larger, older trees, most commonly found in mature forest stands, which have become uncommon in the Delta. With the loss of riparian habitat in the Central Valley, orchards serve as an alternative habitat, though the deleterious effects of pesticides used in orchards on bats are unknown (Pierson et al. 2006).

Threats and stressors: There are three significant threats to the western red bat. The main management consideration for this species is maintaining large, wide riparian zones with mature stands of cottonwood trees (Pierson et al. 2006). Pesticide use in orchards and other agricultural land along the Sacramento River may be harmful to red bats through reducing invertebrate prey or bioaccumulation. Finally, bat mortality attributed to wind energy facilities is very high and is something that should be considered in regional planning (Cryan 2011).

Other Native Wildlife Species

Invertebrates

Other native aquatic invertebrate species that may be present in the CSC include Midvalley fairy shrimp and California linderiella.

Amphibians

Other native amphibian species that may be present in the CSC include western spadefoot (*Spea hammondii*; a California Species of Special Concern), western toad (*Bufo boreas*), and Pacific chorus frog (*Pseudacris regilla*).

Reptiles

Other native reptile species that may be present in the CSC include western fence lizard (*Sceloporus occidentalis*), western yellow-bellied racer (*Coluber constrictor*), gopher snake (*Pituophis catenifer*), common kingsnake (*Lampropeltis getula*) and valley garter snake (*Thamnophis sirtalis fitchi*).

Birds

Habitat Associations and Use by Bird Group: Several natural community types are found within the CSC (Figure 8-1) including tidal and non-tidal perennial aquatic; managed, seasonal, and emergent wetlands; grassland and vernal pool complex; valley foothill riparian; and ruderal and cultivated agricultural lands. These community types provide habitat for various birds depending on their size, quality, and connection to other community types within the surrounding area. The paragraphs below provide information on major birds groups and their usage of various natural communities.

Wading Birds

Wading birds found within the Delta include the great blue heron (*Ardea herodias*), black-crowned night heron (*Nycticoras nycticoras*), green heron (*Butorides virescens*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), white-faced Ibis (*Plegadis chihi*) and least bittern (*Ixobrychus exilis*), a Species of Special Concern, and American bittern (*Botaurus lentiginosus*).

Most herons and egrets nest colonially in rookeries, depending on large trees, dense types of vegetation, and man-made structures. Rookeries (centralized nesting colonies) for species such as the great egret (*Ardea alba*) and great blue heron (*Ardea herodias*) are located in riparian and other woodland trees as well as emergent marshes. These species are large wading birds that feed on fish and other aquatic organisms in shallow, open-water areas and along the edges of channels in diked and tidal marshes. Managed wetlands typically provide high quality foraging habitat for these species. Large rookeries are located nearby at Cosumnes River Preserve, Stone Lakes NWR, and the Sacramento Regional County Sanitation District's Bufferlands.

Waterfowl

Habitats, such as subtidal areas like bays and sloughs, tidal marsh, and managed wetlands with adjacent upland areas provide important foraging habitat for certain duck species. Diving ducks found in the Delta include redhead (*Aythya americana*), a California species of special concern; greater and lesser scaup (*Aythya marila* and *A. affinis*); common, red-breasted, and hooded mergansers (*Mergus merganser, M. Serrator,* and *Lophodytes cucullatus*); ruddy duck (*Oxyura jamaicensis*); and canvasback (*Aythya valisineria*).

Dabbling ducks found in the Delta include American wigeon (*Anas americana*); cinnamon, green-winged, and blue-Winged teal *(Anas cyanoptera, Anas crecca,* and *Anas discors*); northern shoveler (*Anas clypeata*); mallard (*Anas platyrhynchos*); gadwall (*Anas strepera*); and northern pintail (*Anas acuta*).

Geese and swans found in the Delta include Canada goose (*Branta canadensis*), Snow Goose (*Chen caerulescens*), tule greater white-fronted goose (*Anser albifrons*) a Species of Special Concern, and tundra swan (*Cygnus columbianus*).

Diurnal Raptors

A broad suite of raptor species, many of which are special-status, utilizes habitats, including riparian, grassland, and marsh, within and around the Delta for foraging, nesting, and roosting. There are many raptors found within the Delta, including northern harrier (C*ircus cyaneus*), Species of Special Concern; Swainson's hawk (*Buteo swainsoni*), stated listed threatened; golden eagle (*Aquila chrysaetos*), Fully Protected Species; ferruginous hawk (*Buteo regalis*), USFWS bird of conservation concern; white-tailed kite (*Elanus leucurus*), Fully Protected Species; Cooper's hawk (*Accipiter cooperii*); and osprey (*Pandion haliaetus*). Many raptors typically hunt in upland grasslands and nest in large trees near wetlands, grasslands, and along the edges of ephemeral creeks. All of these species take advantage of an ample prey base of small mammals, reptiles, and amphibians. Due to the high development pressure in habitats within and surrounding the Delta, and the unique adjacency between different habitat types proposed for restoration, it is a regionally important area for raptor conservation.

Rails and Cranes

Rails generally nest in dense emergent vegetation of salt marshes, shallow freshwater marshes, wet meadows, and flooded grassy vegetation. They forage mostly on crustaceans, but will also take small fish, insects, seeds, bird eggs, and slugs. There are two species of rail found in the Delta: California clapper rail (*Rallus longirostris obsoletus*), federally and state-listed as endangered; and the California Black Rail (*Laterallus jamaicensis coturniculus*), threatened under CESA, a USFWS bird of conservation concern, and a fully protected species by CDFW. Two other species are known to occur in the CSC, but are not listed species: Virginia rail (*Rallus limicola*) and sora (*Porzana Carolina*). Greater sandhill cranes (*Grus canadensis tabida*) are a fully protected species by CDFW and state-listed as threatened.

Rails and sora nest in tidal and freshwater marshes and shallow wetlands (Eddleman et al. 1994). Sandhill cranes are found throughout the Delta, but are occasional winter residents in the CSC, arriving early September, reaching maximum densities during December and January, and departing during early March.

Shorebirds

Shorebirds can be found on a variety of habitats, including estuaries, marshes, tidal and mudflats, beaches, river and stream banks, lake shores, and ponds. Managed wetlands provide important habitat for numerous species of shorebirds, particularly migrating and overwintering species. Some examples of species using managed wetlands for foraging include black-necked stilt (*Himantopus* *mexicanus),* greater yellowlegs (*Tringa melanoleuca*), dunlin (*Calidris alpina*), and long-billed dowitcher (*Limnodromus scolopaceus*). Managed wetlands also provide nesting habitat for black-necked stilt and American avocet (*Recurvirostra americana*) (Hickey et al. 2003). Upland areas may be useful refugia habitat for shorebirds, but generally they only use upland areas around ponds for nesting.

Terns

Terns are found along the coast, salt marshes, beaches, bay, estuaries, lakes and rivers and usually breed on sandy or gravelly beaches. Terns are mostly coastal migrants to California, except for the California black tern (*Chlidonias niger*) which nest in the Sacramento Valley in rice fields. The California least tern, a Fully Protected Species, occurs along the Pacific Coast, though has recently been documented in Sacramento and Solano counties. Also, Forster's and Caspian Terns breed in San Francisco Bay and are often observed foraging in the Delta. Most terns eat fish.

Owls

Most owls forage mainly by perching and watching for prey, which consists of insects for smaller owl species and rodents and other small mammals for larger owl species. Western burrowing owls and short-eared owls (*Asio flammeus*), two Species of Special Concern, are found throughout the Delta. Most species nest in cavities, except for burrowing owls, which occupy burrows excavated by ground squirrels.

Passerines and others

Suitable foraging and nesting habitat for passerines include open grasslands and prairies with bare patches of ground, well-developed middle marsh habitat, emergent marsh, tidal marshes, freshwater marshes, managed wetlands, natural seasonal wetlands, marshy coastal forb vegetation, riparian, riparian scrub and riparian thickets, valley/foothill riparian scrub and woodland, shrub-steppe, open savannah, irrigated pastures, alfalfa fields, and diverse cultivated land cover types. Bank swallows are unique in that they nest in colonies along rivers, streams, or other water and require fine-textured sandy soils in vertical banks for burrowing.

Mammals

American beaver

American beavers are widespread throughout the Sacramento-San Joaquin Delta, including the CSC. They use sloughs as corridors, cover, and reproductive habitat, and feed on aquatic vegetation such as tules and cattails (Zeiner et al. 1990b). Beavers are often considered a “keystone” species, because their tree-felling and lodge- and dam-building activities can significantly alter local hydrology, surrounding habitats, and populations of other species.

Beavers are considered by some to be a pest in the Delta due to the damage they cause to levees and docks. Occasionally, beavers build dens in levees that lead to increased levee maintenance costs, levee failure, property loss, or all of the above. Beavers are a huntable species in California and may also be taken by depredation permit if causing damage. Currently, no data are collected on beaver populations other than depredation permit numbers; however, the Delta population appears to be stable (CDFW, personal communication, August 2013).

River otter

River otters frequent the sloughs, riparian areas, and flooded islands throughout the CSC. They also use sub-tidal habitats where there is sufficient bank cover (Goals Project 2000). River otters were once widely distributed throughout California and North America but populations showed significant declines due to fur trapping, which became illegal in 1961.

Non-native Wildlife Species

The introduction and spread of bullfrogs (*Rana catesbeiana*) in California during the early- to mid-1900s has posed a threat to numerous species, particularly native amphibians and reptiles (Witmer and Lewis 2001, Boersma et al. 2006, Snow and Witmer 2010). Both tadpoles and adults are voracious feeders, consuming the eggs and offspring of many native invertebrates and (as adults) vertebrates including fish, reptiles, amphibians, waterfowl, and even small mammals (including bats). The introduction of bullfrogs and concurrent declines in certain native species suggest that bullfrogs may compete with such species for limited food resources or prey directly on them (Adams and Pearl 2007, Snow and Witmer 2010).

The red-eared slider (*Trachemys scripta elegans*), a turtle native to the Midwest, has been introduced into California primarily by people releasing pets into the wild. Adaptable and omnivorous, it competes directly with native western pond turtles for food and basking sites (Frank and McCoy 1995, Williams 1999, Salzberg 2000).

Non-native birds have impacted agriculture and native bird populations. Most notable are the European starling and house sparrow.

Non-native mammal species include Virginia opossum, black and Norway rats, feral cats, and red fox.