VEGETATION AND LAND USE CLASSIFICATION AND MAP UPDATE OF THE SACRAMENTO-SAN JOAQUIN RIVER DELTA

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ABSTRACT

The following report describes the vegetation classification and mapping of the Legal Delta portion of the Sacramento-San Joaquin River Delta based on 2016 imagery, for use in conjunction with the Delta Regional Ecosystem Restoration Implementation Plan. The Legal Delta covers approximately 737,621 acres, of which approximately 137,230 acres (18.6%) are natural vegetation, 448,565 acres (60.8%) agriculture, 85,802 acres (11.6%) urban development, and 65,747 acres (8.9%) are open water or inundated lands. In 2005-06 vegetation sampling by means of the California Native Plant Society (CNPS) Rapid Assessment Protocol was used to obtain a total of 377 Rapid Assessments, which were used to develop a quantitative classification based on cluster analysis. A total of 52 vegetation alliances were identified, which included an additional 45 defined plant associations. In combination, 95 fine-scale floristic classification units emerged from the analysis. These classification units were either directly or indirectly used to develop a combination of 129 fine-scale to mid-scale vegetation mapping units. A crosswalk was created by the Department of Fish and Wildlife to compensate for any categorical changes that have been made since the original mapping effort in 2007. Mapping was completed via heads-up digitizing, and each delineated polygon was coded with a vegetation type. Base imagery used was 1-meter resolution National Agriculture Imagery Program (NAIP) aerial photography from 2016. Land use was filled in using Land IQ data with a date of July 2014.

PROJECT STAFF

This classification and mapping project was completed by a team of agency biologists and contracting field staff, aerial photo interpreters, and GIS analysts. The following lists the basic roles and the staff involved in each.

2005 field data collection and coordination and plant identification: Jeff Kennedy, Kristi Lazar, Jeanne Taylor, and Jahalel L. Tuil [University of California Davis Information Center for the Environment (ICE)]; Brad Burkholder, Daniel Burmester, Curtis Hagen, Diana Hickson, and Todd Keeler-Wolf [Department of Fish and Wildlife (DFW)].

Vegetation classification, description, and key development: Diana Hickson and Todd Keeler-Wolf.

Vegetation mapping, geodatabase development, data management (entry, quality control): Brian Kreb, Laura Askim, Kristin Quigley, Lucy Haworth, and Patrick Spielman (Geographical Information Center).

Report: Brian Kreb, Erik Fintel updated the 2007 report by Diana Hickson and Todd Keeler-Wolf.

2007 original vegetation mapping and geodatabase development used for change detection: John Menke and Carmelita Gutierrez (natural and semi-natural vegetation), Debbie Johnson and Janet Reyes (human land use) (Aerial Information Systems).

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Department of Water Resources boat operators and facilitators including: James Eckman, Ibraheem Alsufi, Babak Jafarnejad, and David Carrothers.

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Department of Fish and Wildlife for key development and crosswalking data to state and national classification systems: Todd Keeler-Wolf, Diana Hickson, and Rosie Yacoub.

Delta Stewardship Council for funding the Delta remapping project.

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Field Descriptions

OBJECTID
Sequential unique whole numbers that are automatically generated.

Shape
Feature geometry.

HT_CODE_
The average height of the stand. This is a mean/modal value, or the average of the most commonly occurring species in the strata of the group/alliance. Outliers are removed from the average.

1	<1 meter
2	1-5 meters
3	5-20 meters
4	20-50 meters
5	>50 meters

SIZE_CATEGORY
The average diameter at breast height. This is a mean/modal value, or the average of the most commonly occurring species in the strata of the group/alliance. Outliers are removed from the average.

<1”	Less than one inch
1-6”	One to six inches
6-11”	Six to eleven inches
11-24”	Eleven to twenty-four inches
>24”	Greater than twenty-four inches

PER_HARWO
Percentage of hardwoods is entered as a whole number and is the absolute cover which includes porosity of the canopy. A value of .2 was entered when there was <1% hardwood cover.

PER_CONIFE
Percentage of conifers is entered as a whole number and is the absolute cover which includes porosity of the canopy. A value of .2 was entered when there was <1% conifer cover.

PER_TREE
Percentage tree is the sum of percent hardwood and percent conifer. A value of .2 was entered when there was <1% tree cover.

ISOLATED_TREE
Isolated tree was selected when tree cover was present but was <5%.

RESTORATION
Restoration was selected when it was clear to the photo interpreter that the land had been restored within the past five years. Older restoration areas become more challenging to differentiate from natural vegetation stands.

CLEARING_DISTURBANCE
Man-made disturbance including roads, trails, disking, and scrapes.

1 No disturbance = <5%
2 Minimal disturbance = 5-25%
3 Moderate disturbance = 25-50%
4 High disturbance = >50%

INVASIVE_PLANT
Relative percentage of invasive species present. Many species that are invasive are not visible via aerial imagery and are most likely underreported in this dataset. Larger species such as *Arundo donax* and *Cortaderia jubata* will have a higher degree of accuracy.

1 No Invasive = <5%
2 Low Invasive = 5-25%
3 Moderate Invasive = 25-50%
4 High Invasive = >50%

Acres
Number of acres represented by each polygon.

Comments_Final
These are comments from the photo interpreter. They typically address other species present in the polygon including invasive species and other codominant or sub-dominant species. Other significant information has been provided here, such as the presence of a bird rookery (mating site).

Ortho_NAIP_Year
Year of base imagery used for linework. National Agricultural Inventory Program 2016 imagery was used for this current mapping effort.

Shape_Leng
Automatically generated number defining length.

Crop2014
The 2014 Land IQ data was chosen over the 2016 due to its better coverage and completeness. Crop types that were registered or planted as of 2014 (updated by Zhongwu Wang 5/7/2017). Land Use IQ 2014 dataset was overlaid with the vegetation dataset to populate agriculture land with crop type. The slivers (very small polygons) that reside in this dataset are where there was no vegetation data and no LandIQ data. Often these were small agricultural roads where the photo interpreter classified them as agriculture (because they were not natural vegetation and more like agriculture than natural vegetation) and the LandIQ classified them as non-agriculture.

2014 Land IQ dataset can be found here: https://map.dfg.ca.gov/metadata/ds2677.html

County
County in which the majority of the polygon resides. Note: For Land IQ data only.

Source
Originator of data for each polygon attributed. There were two sources for this dataset: Geographical Information Center (GIC) at Chico State Research Foundation and Land IQ, LLC.

Modified_B
Name responsible for the LandIQ dataset update.

Date_Data_
LandIQ dataset date.

Last_Modif
Date of the last update to the 2014 LandIQ dataset.

DWR_Standa
Department of Water Resources version of crop type.

Veg_Classification_Name
Original units mapped by the Geographical Information Center before being crosswalked to other classification systems. These values were agreed upon by the Department of Fish and Wildlife and the Geographical Information Center and were the most current at the time the mapping started. Rosie Yacoub at the Department of Fish and Wildlife's VegCAMP program performed the crosswalk of these values to the National Vegetation Classification System's names, NVCS levels, NVCS Group, NVCS Macrogroup, global and state ranking, rarity ranking, Cal Veg Code, Cal Veg Name, CWHR Code, and CWHR Type.

MapClass
Basically the same as the Veg_Classification_Name where group-level vegetation types, agriculture, urban, water, and mining have acronyms and full names.

NVCS_Name
The standardized name of the vegetation description used in the National Classification System.

NVCS_Level
The level of the National Vegetation Classification System hierarchy that the vegetation type corresponds to.

CaCode
California Natural Community Codes - unique code assigned to alliances.

Alliance_Name
Latin name(s) of species characteristic or diagnostic to define the alliance. Polygons were mapped to the alliance level following the membership rules defined in A Manual of California Vegetation (Sawyer et al. 2009) and Vegetation Alliances and Associations of the Great Valley Ecoregion, California (Buck-Diaz et al. 2012). An alliance is a characteristic range of species composition, including some species from the dominant layer of vegetation, which has a moderately similar composition that reflects regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes.

NVCS_Group
The NVCS group level of the map class, which is the classification level between macrogroup and alliance. It is coarser than alliance and finer than macrogroup. It is typically a description of the environment a certain alliance would be found in. Groups include combinations of relatively narrow sets of diagnostic plant species, including dominants and codominants, with broadly similar composition and diagnostic growth forms.

NVCS_MG
The standardized name for the macrogroup within the National Vegetation Classification System that the vegetation type corresponds to.

GlobalRank

The global rarity ranking of the plant community mapped (only for alliances). G1: Fewer than 6 viable occurrences worldwide and/or 2,000 acres; G2: 6-20 viable occurrences worldwide and/or 2,000-10,000 acres; G3: 21-100 viable occurrences worldwide and/or 10,000-50,000 acres; G4: Greater than 100 viable occurrences worldwide and/or greater than 50,000; G5: Community demonstrably secure due to security worldwide.

StateRank
The state rarity ranking of the plant community mapped (only for alliances). S1: Fewer than 6 viable occurrences statewide and/or 2,000 acres; S2: 6-20 viable occurrences statewide and/or 2,000-10,000 acres; S3: 21-100 viable occurrences statewide and/or 10,000-50,000 acres; S4: Greater than 100 viable occurrences statewide and/or greater than 50,000; S5: Community demonstrably secure due to security statewide.

Rare
Rarity of the vegetation type. Alliances with state ranks of S1-S3 are considered rare. Y=Rare, N=Not Rare, U=Unknown

CalVegCode
Code used for a crosswalk to the CalVeg vegetation system.

CalVegName
A crosswalk to the CalVeg vegetation system.

CWHRCODE
Code assigned to the California Wildlife Habitat Relationships type.

CWHRType
Crosswalk to the California Wildlife Habitat Relationships system.

Shape_Length
Positive real numbers that are automatically generated describing length.

Shape_Area
Positive real numbers that are automatically generated describing area in units squared.

Introduction

The Sacramento-San Joaquin Delta Reform Act of 2009 established the Delta Stewardship Council (DSC) to achieve more effective governance while providing for the sustainable management of the Delta ecosystem and a more reliable water supply, using an adaptive management framework. “Adaptive management” means a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management, planning, and implementation of a project to achieve specified objectives. The DSC employed the Geographical Information Center to produce a vegetation and land-use map of the legal Delta. The vegetation and land-use map described in this report directly supports the following sub-goals (as well as other goals) of the DSC:

(1) Restore large areas of interconnected habitats within the Delta and its watershed by 2100. (2) Establish migratory corridors for fish, birds, and other animals along selected Delta river channels. (3) Promote self-sustaining, diverse populations of native and valued species by reducing the risk of take and harm from invasive species. (4) Restore Delta flows and channels to support a healthy estuary and other ecosystems. (5) Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals. (6) Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds.

This integrated vegetation classification and mapping of the Legal Delta (Figure 1) is meant to provide an accurate, biologically driven base map to assist in habitat restoration planning. For this reason, natural vegetation is mapped at a finer scale than agriculture and other land cover. However, both levels of classification and mapping comply with the draft mapping standards of the interagency Vegetation MOU Group (see https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=114778), and the finer scale complies with the Manual of California Vegetation (Sawyer et al. 2009) and the National Vegetation Classification Standard (NVCS) as defined in the April 2003 Federal Geographic Data Committee draft standards (see https://www.fgdc.gov/standards/projects/vegetation/NVCS_V2_FINAL_2008-02.pdf. Along with the map provided in ArcGIS shapefile format and the classification, we provide keys to and descriptions of the vegetation types, as well as a crosswalk to the California Wildlife Habitat Relationships (CWHR) classification. Other products include databases of the field data and ground photos taken at sampling points, which are useful as baseline or reference site data.

Background

The Sacramento-San Joaquin River Delta, located at the confluence of the Sacramento and San Joaquin Rivers, was once a great tidal brackish-to-freshwater marsh interspersed with riparian scrub and forest underlain by peat and peaty alluvium. The Delta receives runoff from about 40 percent of the land area of California and about 50 percent of California’s total streamflow. Natural levees were formed by sediments deposited during spring floods and stabilized by woody riparian vegetation. Natural islands built up over thousands of years from deposition of peat originating from non-decomposed dead stems of tules (*Schoenoplectus acutus* and *S. californicus*, primarily) and other emergent wetland plant species. Beginning in the late 1800s, levees were reinforced and built up along the stream channels, and the protected land was drained, cleared, and planted. By around 1930 the system of modified levees and drainage systems was largely complete and the Delta had taken on its current appearance, with most of its 1,150-square-mile area reclaimed for agricultural use (Thompson 1957).

Although the Delta is now an exceptionally rich agricultural area, it is also a source of freshwater for much of the rest of the state. It is the core of a massive southward-bound water-delivery system. State and federal water projects export approximately 3 million acre-feet in dry years and up to around 6.5 million acre-feet in wet years from two huge pumping stations in the southern Delta near the Clifton Court Forebay (Delta Plan amended 4/26/18). About 83 percent of this water is used for agriculture, with the remainder used for various urban uses in central and Southern California. The nearly 60 individual leveed tracts and islands help to protect water-export facilities in the southern Delta from saltwater intrusion by displacing water and maintaining favorable freshwater gradients. However, ongoing subsidence behind the levees

reduces levee stability and, thus, threatens to degrade water quality in the water-transfer system. Vegetation mapping is critical to identify vegetation prescence/absence on levees, native communities, invasive species, and also to define migration corridors which allow for the migration of both flora and fauna throughout the Delta. More detailed information on the Delta and the effects of the State and Central Valley Water Projects can be found in The Delta Plan and the 2019 Biological Opinion links below:

Delta Plan
https://deltacouncil.ca.gov/delta-plan/

2019 Fish and Wildlife Service Biological Opinion
https://www.fws.gov/sfbaydelta/cvp-swp/documents/10182019_ROC_BO_final.pdf

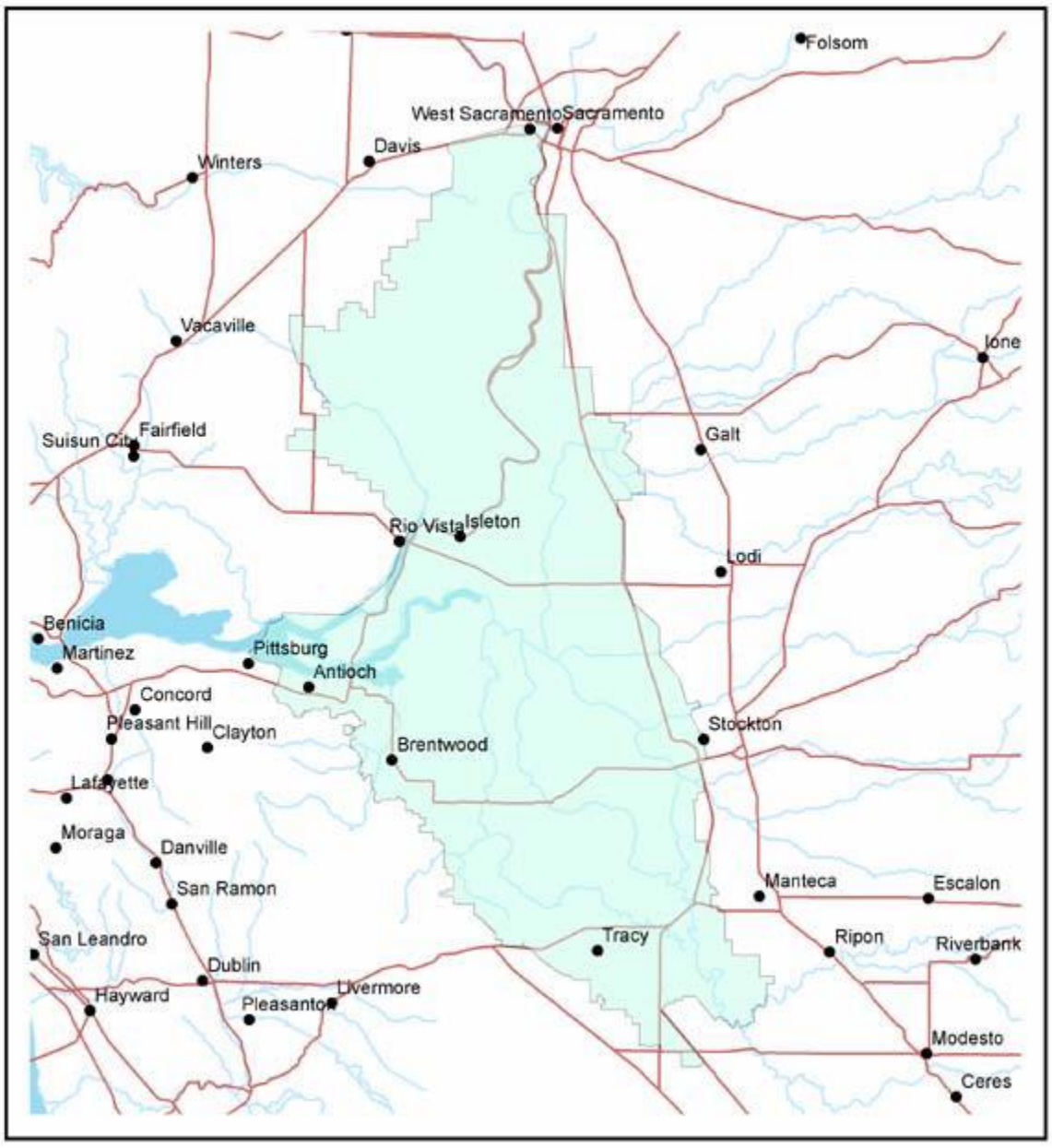

Figure 1. Study area location.
The Legal Delta is shown in green.

Levee failures have been common in the Sacramento-San Joaquin Delta since reclamation began in the 1850s. Each of the islands and tracts in the Delta has flooded at least once, with several flooding repeatedly. About 100 levee failures have occurred since the early 1890s. Initially, most of the failures were caused by overtopping during periods of spring flooding. Though construction of upstream reservoirs since the 1940s has reduced the threat of overtopping, it has not reduced the incidence of levee failure.

The dominant cause of land subsidence in the Delta is decomposition of organic carbon in the peat soils. Prior to agricultural development, the soil was water-logged and anaerobic. Thus, organic carbon accumulated faster than it could decompose. Drainage for agriculture led to aerobic conditions that favor rapid microbial oxidation of the carbon in the peat soil.

The waterways of the Delta are subject to tidal action. Ocean tides moving into San Francisco Bay are observed 5–6 hours later along the Cosumnes River in the eastern Delta. The position

of the interface between the saline waters of the Bay and the fresh waters of the Delta depends upon the tidal cycle and the flow of freshwater through the Delta. Before major dams were built on rivers in the Delta watershed, the salinity interface migrated far upstream (see Figure 2) along the Sacramento River (DWR 1993). Today, releases of freshwater from dams help reduce the maximum landward migration of the salinity interface during the late summer. However, in the spring, the filling of these reservoirs and the export of Delta water consistently interact to move the salinity interface further inland, well beyond that expected under natural unimpaired flows in this season (Knowles 2000). Water quality (especially salinity) becomes a critical issue as brackish water moves into the vicinity of the south Delta pumping stations. Thus, there is now a powerful human-induced tension between providing good quality drinking and agricultural water, and maintaining the natural ecosystems that support the Delta's unique fauna and flora.

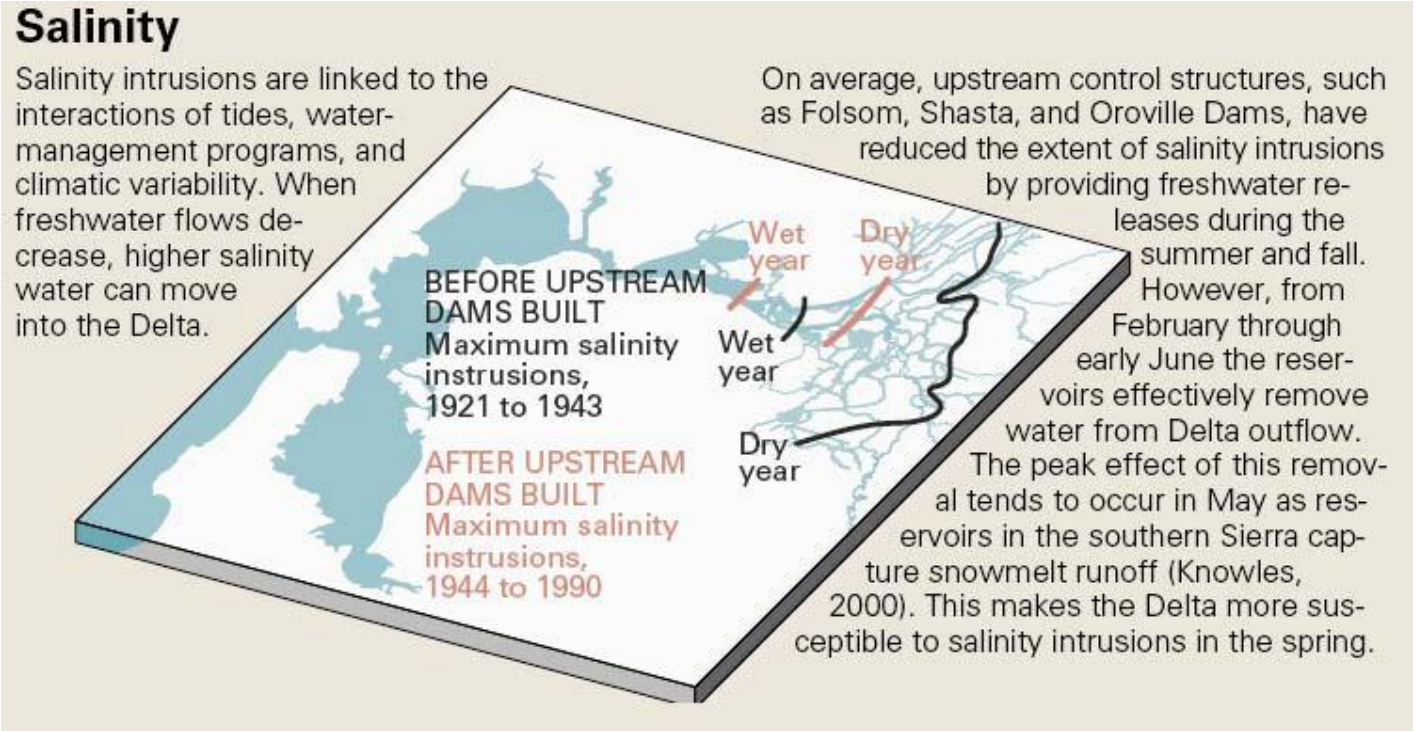

Figure 2. Schematic of salinity issues for the Delta
(Excerpted from S.E. Ingebritsen, Marti E. Ikehara, Devin L. Galloway, and David R. Jones, Delta Subsidence in California: The sinking heart of the State. USGS Factsheet FS-005-00 April 2000).

Historically, the Delta probably became brackish in dry summers. Its native fishes and other aquatic species evolved in a highly variable system. Eventually, saltwater may again penetrate into the Delta as a result of: (1) a drought strong and long enough to deplete reservoirs; (2) levee failures on subsided Delta islands; (3) changes in the way freshwater is routed south, eliminating the need for constantly fresh conditions in the Delta; or (4) an adaptive management-based manipulation to control introduced species or to study the consequences of unavoidable increases in salinity.

Vegetation of the Delta was once composed of extensive freshwater and brackish marshes with tules (*Schoenoplectus acutus* and *S. californicus*) and cattails (*Typha* spp.), broad riparian thickets of scrub willows (*Salix* spp.), buttonwillow (*Cephalanthus occidentalis*), and native brambles (*Rubus ursinus, Rosa californica*), and extensive riparian forests of Fremont cottonwood (*Populus fremontii*), valley oak (*Quercus lobata*), Oregon ash (*Fraxinus latifolia*), box elder (*Acer negundo*), white alder (*Alnus rhombifolia*), and black willow (*Salix gooddingii*). Upland, non-riparian stands of valley oak and coast live oak (*Quercus agrifolia*) occurred in a mosaic with seasonally flooded herbaceous vegetation including vernal pools and alkali

wetlands. Currently, much of the land has been taken over by agriculture, urban and suburban development, and pasture land. The remaining natural vegetation is largely restricted to the edges of waterways, flooded islands, and small protected areas such as parks, wildlife areas, and nature reserves (Figure 3).

For more information on ecosystem processes and restoration efforts, see Chapter 4 of The Delta Plan, titled Protect, Restore, and Enhance the Delta Ecosystem. This chapter describes the Sacramento-San Joaquin Delta (Delta) ecosystem and the factors that affect and too often degrade it. It proposes policies and recommendations for restoring the Delta ecosystem organized into five core strategies to achieve the coequal goals of the Delta Reform Act: create more natural functional flows, restore habitat, improve water quality to protect the ecosystem, prevent introduction of and manage nonnative species impacts, improve hatcheries and harvest management.

Previous Vegetation and Habitat Mapping Projects in Relation to the Current Effort

There have been several previous vegetation and habitat mapping projects in the Delta, described below, based on data provided by Ken Devore of the Department of Fish and Wildlife (DFW).

Older mapping efforts

Preliminary Sacramento-San Joaquin Delta Atlas (DWR 1993). Fine-scale delineation of habitat and natural community information for the entire Delta based on 1:24,000 scale orthophoto quadrangle maps. This was first produced as a book in 1987 and was never completely digitized, but could serve as a baseline of the existing extent of habitat in the late 80's or early 90's.

GAP analysis vegetation layer (Davis et al. 1998). This statewide map, produced from 1990 information and completed in 1995, is a very coarse view of terrestrial vegetation and natural communities. Although it covers the Delta area, the minimum mapping unit was 250 acres (100 ha), so fine-scale patches of vegetation and habitat were largely missed and poorly estimated.

The Central Valley Wetlands and Riparian Areas GIS database (CDFG 1997). This map was developed to inventory wetlands, riparian woody areas, and surrounding land cover in the Sacramento Valley, San Francisco Bay/Delta, and San Joaquin Valley to support cooperative conservation planning and wetland resource protection efforts of state, federal, and local agencies and private organizations. For the three regions, Landsat Thematic Mapper satellite imagery was processed to map land cover classes from three broad categories: wetlands, agriculture, and uplands. A cooperative grant from DFW (using funds from the U.S. Environmental Protection Agency), the Wildlife Conservation Board (WCB), the Resources Agency of California, and the U.S. Bureau of Reclamation (BOR), funded the development of this GIS database by Ducks Unlimited, Inc. and their subcontractor Pacific Meridian Resources, in cooperation with DFW, WCB, and BOR staff.

2007 Aerial Information Systems Delta map

In 2007, Aerial Information Systems mapped 725,888 acres of the Delta for the California Department of Fish and Wildlife's VegCAMP program. Vegetation sampling by means of the CNPS Rapid Assessment Protocol was used to obtain a total of 377 Rapid Assessments, which were used to develop a quantitative classification based on cluster analysis. A total of 52 vegetation alliances were identified, which included an additional 45 defined plant associations. In combination, 95 fine-scale floristic classification units emerged from the analysis. These classification units were either directly or indirectly used to develop a combination of 129 fine-scale to mid-scale vegetation mapping units. Mapping was completed via heads-up digitizing,

and each delineated polygon was coded with both a vegetation type and one of 25 land use types. Base imagery was true color 1-foot resolution aerial photography from spring 2002 with additional marginal areas of the study area supplemented by true color 1-meter resolution photography from summer 2005. This type of mapping approach was then compared with a more traditional fine-scale vegetation mapping product of Suisun Marsh to provide measures of efficiency and accuracy for future mapping efforts in the Bay-Delta Region.

2019 Geographical Information Center (current effort)

The current effort produced a digital map covering 737,621 acres considered to be the Legal Delta Area. 2016 National Agricultural Imagery Program (NAIP) 1-meter resolution imagery was used to delineate line work and attribute polygons. The 2019 map is a re-map of the 2007 effort. This map retained the line work and attributes of the 2007 mapping when static and was amended in areas where change occurred. Change detection was done comparing 723,426 acres, which were identical in the 2007 (2005 base imagery) and 2019 (2016 base imagery) efforts. Details on change detection can be found later in this report. The GIC utilized the key produced for the 2007 mapping effort, in conjunction with the 2009 Central Valley key, as well as the CNPS membership rules online to determine classification levels and vegetation communities.

Study Area

The Legal Delta portion of the Sacramento-San Joaquin River Delta stretches from Sacramento in the north to just south of Tracy in the south and from Antioch in the west to Stockton in the east. It includes parts of Alameda, Contra Costa, Solano, Sacramento, San Joaquin, and Yolo counties. Elevations are low, ranging from below sea level on many of the leveed Delta islands to about 300 ft. in the Montezuma Hills. Ecologically, the area is an inland delta where the waters of the two major rivers mingle with the seawater of the Pacific Ocean as it passes through the estuaries of the San Francisco Bay and the adjacent Suisun Bay areas. Tidal influence occurs throughout most of the area's interconnected waterways and salinity values vary from 1-2 ppt. to completely fresh on a gradient from west to east throughout the area. Most of the Delta is now maintained as a freshwater system with brackish waters prevailing only in the extreme western portion. However, as shown in Figure 2, historically this varied substantially from season to season and from year to year.

Based on this study, approximately 18.6% of the area is considered to be covered by natural vegetation, while 60.8% is agriculture and pasture, 11.6% is urban/mining, and 8.9% is open water.

Field Data Collection for Classification 2005-2007

The primary goal of sampling was to collect replicate samples of all significant vegetation types present in the study area. To aid field crews in identifying types that should be sampled, a preliminary list of vegetation types for the study area was developed in April 2005 from an existing California vegetation classification (Sawyer and Keeler-Wolf 1995), with augmentation from the most recent California Natural Communities List compiled by DFW's Vegetation Classification and Mapping Program. It was later updated with information from initial reconnaissance of the study area conducted in June of 2005. This list was recognized as preliminary and was used for project management purposes to target stands for sampling. This initial inventory included around 50 alliances and suggested about 100 associations or phases (an informal subdivision of an association) in the mapping area.

Figure 3. A high-quality, natural, tidally-influenced marsh with high native floristic diversity and evidence of otter activity (Brown's Island)

Access to the maze of natural channels, artificial "cuts," canals, and privately owned islands was recognized initially as one of the great challenges to attaining an adequate and representative field sample of the full array of natural and semi-natural vegetation. This problem was simplified significantly by the generous assistance of boat operators from the staff of the DFW Bay-Delta Branch, Curtis Hagen and Brad Burkholder. Access by water was essential for all field components of this project, from initial reconnaissance to vegetation sampling, and finally to verification and accuracy assessment data collection. A total of 25 individual "boat days" were used to gather data for the 2005-2007 classification.

In addition to boat access, the field crew visited publicly accessible portions of the Delta including the Department of Fish and Wildlife's Yolo Bypass Wildlife Area and Calhoun Cut Ecological Reserve; California Department of Parks and Recreation's Delta Meadows and Caswell Memorial State Park: US Fish and Wildlife Service's Antioch Dunes and Stone Lakes National Wildlife Refuges; and The Nature Conservancy's Cosumnes River Preserve.

Survey sites were selected by subjectively identifying stands of vegetation. A *stand* is defined as a homogeneous patch of vegetation that has a characteristic combination of plant species that is similar in age, size, and disturbance history, and that repeats across a landscape. A stand may be a small seep measuring several square meters in size or a brush stand measuring many acres in size.

Over the course of the field season, the CNPS Rapid Assessment method was used to collect samples of stands of vegetation (see www.cnps.org for the protocol descriptions). The focus of the field data collection was to collect as many Rapid Assessments as could be completed in

the accessible portions of the study area. The majority of field data was collected between June 29 and September 25, 2005. In April 2006, a final group of Rapid Assessment samples was collected from the Byron area in eastern Contra Costa County.

The Rapid Assessment protocol is a concise method for collecting environmental variables, species composition, and wildlife habitat information across an entire stand of vegetation. Each assessment takes about 30-45 minutes to complete. Survey time depends on the size and accessibility of the stand.

For each stand identified, a list of the major tree, shrub, and/or herb species was recorded (each Rapid Assessment list could contain up to 12 native species and additional non-native species). Each species was designated with a height stratum (low=<0.5 m, medium=>0.5 to 5 m, and tall=>5 m), and the abundance or percent cover of each species was assessed by estimating the percentage of ground area covered by living parts. Sometimes, species were identified in more than one stratum (*e.g.*, *Quercus lobata* could be found in the low, medium and tall layers). In these instances, percent cover was estimated separately for each stratum in which the species occurred. Additional variables recorded included total vegetative cover, total tree, shrub, and herb cover, and the aspect and degree of slope when applicable. Elevation as indicated by a GPS unit was recorded, but was generally not reliable.

Additional sampling was done using Reconnaissance surveys to provide the photo interpreters with a maximum number of on-the-ground data points to create an accurate vegetation map. This shortened version of the Rapid Assessment method provided supplementary ground points indicating the dominant species in a stand. Note that the data collected from Reconnaissance surveys were not used in the data analysis phase of classification.

2005-2007 Rapid Assessment and Reconnaissance data were collected over 51 individual field days, (149 person-days). Accuracy Assessment data were collected over 14 individual days (18 person- days). (Days in which both Rapid Assessment and Accuracy Assessment data were collected were attributed to the former, which consumes more time.) Data entry, quality checking, and photo archiving took a total of 168 hours.

This project has attempted to describe all the vegetation types in the study area. However, we limited sampling to areas that were accessible by boat or car, and did not seek permission to collect data from private lands. It is possible that additional alliances and associations could be identified with further research. Additionally, detailed sampling using the CNPS Relevé protocol (see www.cnps.org) and classification could be allocated to vegetation with an abundant herbaceous cover, which is not addressed well in the Rapid Assessment protocol.

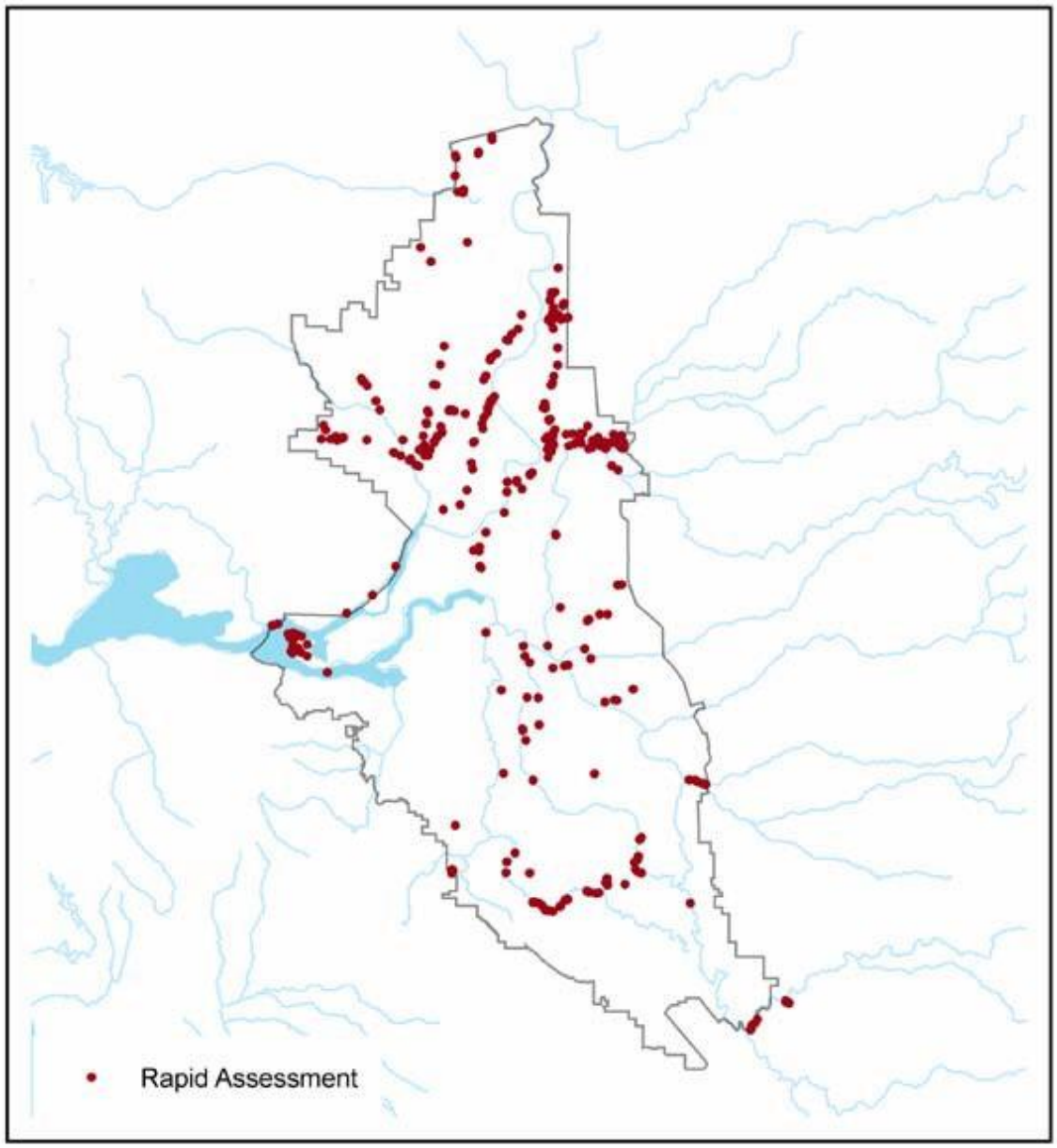

Figure 4. Location of Rapid Assessment samples used for classification 2005-2007

Classification Analysis for Development of Classification Key (2005-2007)

For quantitative analysis of the collected field data, scientific names of the taxa were converted to alpha-numeric codes. Codes for taxa occurring in multiple strata were initially given a modifier indicating the layers in which they occurred (-t for tall layer, -m for middle layer, and –l for low layer). For example, *Quercus lobata* sampled in both the tall and low strata were coded "QULO-t" and "QULO-l," respectively. Based on the assessment of the frequency of distribution of these "pseudo-taxa," in the case of the shrubby willows (*Salix exigua, S. lasiolepis, S. lucida*), the tall and middle strata were lumped into the middle stratum. For example, in most cases *Salix lasiolepis* tends to be 1-5 meters tall (thus technically middle layer); however, some individuals attain heights of slightly greater than 5 meters (technically tall layer). However, for classification, the covers of these two layers were merged into a single middle layer category.

Following the 2005 sampling effort by the field staff, 372 Rapid Assessment surveys were statistically analyzed. With the addition of seven samples in April 2006 the analyses were rerun to include these. The analysis of sample data was undertaken using the PC-ORD software suite of classification and ordination tools (McCune and Mefford 1997). PC-ORD performs multivariate analyses to generate order out of complex biological patterns. It can be used to objectively define groups of samples into a formalized classification of community types. Using cluster analysis (McCune and Mefford 1997), groups are defined by similarities in species composition and abundance.

Since plant community datasets are inherently complex and more than one environmental axis determines the heterogeneity in plant patterns, hierarchical agglomerative cluster analysis techniques were used to define the most reasonable interpretation of the arrangement of plot and species data. Several exploratory analyses were conducted before a final analysis technique was settled upon. These included using Ward's Euclidian distance measures and relative Euclidian distance in conjunction with varying the cover classes from 6 to 7. The final analysis used the Sorensen distance and flexible beta linkage method at -0.25 (McCune and Grace 2002). This cluster analysis technique was based on abundance (cover) values converted to seven different classes using the following modified Braun-Blanquet (1932) cover categories: 1=<1%, 2=1-5%, 3=>5-15%, 4=>15-25%, 5=>25-50%, 6=>50-75%, 7=>75%. The majority of the species' values fell within the first four cover classes.

Prior to these analyses, data were screened for outliers (extreme values of sample units or species) using outlier analysis in PC-ORD. In this data analysis process, outlier samples and species may be removed to reduce heterogeneity and increase normality in the dataset. In this analysis, however, no major outliers existed, so no samples or species were removed. However, two samples were dominated by species that were believed to be misidentified in the field, and so these two samples were discarded after the analysis. A dendrogram was generated in the first-order cluster analysis run. This resulted in five main clusters. This dendrogram was interpreted at group levels 6, 55, and 150 to display the main ecological groupings: the generic alliance levels, and the finest association and phase levels, respectively.

After the main cluster analysis run, indicator species analysis (ISA) was employed to decide objectively at what group level to "cut" the dendrogram and explicitly interpret the groups. ISA was also used to designate the key diagnostic species for each of the different groups. ISA produced indicator values for each species in each of the groups within the dendrogram, and these species were tested for statistical significance using a Monte Carlo technique (Dufrêne and Legendre 1997). ISA was repeated at group levels for the 5 main groups of the dendrogram at 55 and 150 groups. At the 55 and 150 group levels, the analysis was evaluated to obtain the total number of significant indicator species (p-value < 0.05) within each group level and the

mean p-value for all species. A total of 108 species or “pseudo-species” out of the 357 used (33.9%) in the main analysis had some value as indicators ($p < 0.05$). These species were commonly used as part of either the alliance or association-level names developed for the formal classification.

Each sample was revisited within the context of the cluster to which it had been assigned to quantitatively define membership rules for each association. The membership rules were defined by species constancy, indicator species, and species cover values. Upon revisiting each sample, samples misclassified in earlier iterations of the cluster analysis were reclassified based on the membership rules.

The set of data collected throughout the study area was used as the principal means for defining the association composition and membership rules; however, pre-existing classifications and floras were consulted to locate analogous/similar classifications or descriptions of vegetation types.

Naming conventions followed the National Vegetation Classification System (Grossman et al. 1998) and the California Native Plant Society (Sawyer and Keeler-Wolf 1995). An association is defined by a group of samples that have similar dominant and characteristic species in the overstory and other important or indicator species, whereby these species are distinctive for a particular environmental setting. Significant indicator species were drawn from the analysis and applied to the associations. A set of similar associations is grouped hierarchically to the next higher level in the classification, the alliance-level. For example, different types of valley oak (*Quercus lobata*) riparian forests are classified to the association level depending on the characteristic overstory and understory species (*e.g.*, *Quercus lobata/Rubus discolor* as compared to *Quercus lobata-Acer negundo*), while the overarching *Quercus lobata* Alliance is based on the characteristic presence of this tree in the overstory. Associations are usually differentiated by environmental factors as well as floristic characteristics.

Samples were classified first to the generic alliance-level then defined to the more specific association-level when at least two samples of similar species composition and cover were present. Samples were defined only at the alliance-level when less than five samples occurred in the study area. These alliances were described elsewhere in the nation or state, but we had insufficient data to either assign them to an existing association, or the data did not support even defining a preliminary association. With a few more samples, some types would probably have become associations, including types represented by *Salix gooddingii* and *Salix lucida* sampled stands.

Sue Bainbridge provided Relevé data from the Antioch Dunes portion of the Delta. They were not analyzed with the Rapid Assessment data, but her data were used to define several associations unique to the Antioch Dunes. Likewise, Carol Witham provided data from the Tule Ranch (Witham 2003 and personal communication), and her defined associations are included in our final classification.

All associations described based on fewer than 10 samples are designated as provisional associations.

Key to the Alliances and Associations

A key was provided to identify all vegetation types classified based on previous fieldwork and mapping efforts. The key provides general choices and information on the physiognomy of the vegetation and in some cases the different environments of the vegetation. This approach in the key was chosen: (1) to reduce the length and redundancy that is common in dichotomous keys, and (2) to be a guide that can be easily used by non-botanists/plant ecologists. The vegetation key can be used as a stand-alone product, allowing anyone with some basic

ecology background and knowledge of the main characteristic plant species to identify the vegetation. It is written from two perspectives: (1) a field team attempting to identify vegetation and (2) an office team attempting to place field samples into the proper category. Thus, heavy reliance is placed on correct identification of characteristic plant species and estimation of cover of these species.

Description Writing, Standards, and Definitions

Following previous classification analysis of field data, brief association-level descriptions were written based on field data and available literature. Alliances or habitats defined without any associations also have brief descriptions in a slightly different format from the association descriptions. In these descriptions, scientific names of plants follow Hickman (1993) and Jepson Online Interchange (2006). Common names follow these sources and NRCS (2006). When writing the descriptions, the following standards and definitions were used:

Dominant or codominant species: Must be in at least 80 percent of the samples, with at least 30 percent relative cover in all samples.

Consistent/Characteristic/Diagnostic species: Must be in at least 80 percent of the samples, with no restriction on cover.

Abundant species: Must be in at least 50 percent of the samples, with an average of at least 30 percent relative cover in all samples.

Frequently/often/usually occurring species: Must be in at least 50 percent of the samples, with no restriction on cover.

Infrequently occurring: Present in less than 25 percent of the samples.

Minimum sample size for classification and description: n = 2. Descriptions of associations with fewer than ten samples were attempted if (a) the association was sampled and described by previous authors or (b) the vegetation was confirmed as distinctive and repeatedly encountered based on field reconnaissance or by photo-interpretation signature.

Open: Used to describe individual layers of vegetation (tree, shrub, or herb) where the cover is generally less than 33 percent absolute cover.

Intermittent: Used to describe individual layers of vegetation (tree, shrub, or herb) where there is 33-66 percent absolute cover.

Continuous: Used to describe individual layers of vegetation (tree, shrub, or herb) where there is greater than 66 percent absolute cover.

Relative cover: Refers to the amount of the surface of the stand sampled that is covered by one species (or physiognomic group) as compared to (relative to) the amount of surface of the stand covered by all species (in that group). Thus, 50 percent relative cover means that half of the total cover of all species or physiognomic groups is composed of the single species or group in question. Relative cover values are proportional numbers and, if added, total 100 percent for each stand (sample).

Absolute cover: Refers to the actual percentage of the ground (surface of the stand) that is covered by a species or group of species. For example, *Populus fremontii* covers between 5 percent and 10 percent of the stand. Absolute cover of all species or groups if added in a stand may total greater or less than 100 percent because it is not a proportional number. Unless stated otherwise, cover refers to absolute cover.

Stand: Refers to the basic physical unit of vegetation in a landscape. It has no set size. Some vegetation stands are very small, such as wetland seeps, and some may be several square kilometers in size, such as desert or forest types. A stand is defined by two main unifying characteristics:

A. It has *compositional* integrity. Throughout the site, the combination of species is similar. The stand is differentiated from adjacent stands by a discernable boundary that may be abrupt or gradual.

B. It has *structural* integrity. It has a similar history or environmental setting, affording relatively similar horizontal and vertical spacing of plant species. For example, a riparian forest formerly dominated by the same species, but that has burned in one part but not in the other, is divided into two stands. Likewise, a sparse woodland occupying a more recent terrace is considered a different stand from an adjacent older terrace with a denser woodland/forest of the same species.

Woody plant: Refers to any species of plant that has noticeably woody stems. It does not include herbaceous species with woody underground portions such as tubers, roots, or rhizomes.

Tree: Refers to a one-stemmed woody plant that normally grows to be greater than 5 meters tall.

Shrub: Refers to what is normally a multi-stemmed woody plant that is usually between 0.2 meters and 5 meters tall. Definitions are blurred at the low and the high ends of the height scales. At the tall end, shrubs may approach trees based on disturbance frequencies (*e.g.*, *Salix exigua* may frequently attain “tree size”). At the short end, woody perennial herbs or sub-shrubs of various species are often difficult to categorize into a consistent life form.

Herbaceous plant: Refers to any species of plant that has no main woody stem development, and includes grasses, forbs, and perennial species that die back seasonally.

Forest: In the National Vegetation Classification, a forest is defined as a tree-dominated stand of vegetation with 60 percent or greater relative cover of trees.

Woodland: In the National Vegetation Classification, a woodland is defined as a tree-dominated stand of vegetation with between 25 percent and 60 percent relative cover of trees.

Emergent: A vegetation stratum is considered emergent if it includes a sparse cover of species, which rise above the predominant vegetation layer and would be considered members of the next tallest layer, but has an absolute cover of <10%. For example, individual *Salix gooddingii* trees may comprise an emergent tree layer over a denser layer of *Salix exigua* shrubs, but the stand would be considered a member of the *Salix exigua* shrub alliance because the total tree cover is less than 10%. In this report tall shrubs are not considered emergent over shorter shrubs, but short trees are considered emergent over tall shrubs.

Rare and endangered plants: Listed as per CNPS (2016) Online Inventory of Rare and Endangered Plants.

Conservation rank: Listed by the state Nature Conservancy Heritage Programs. All communities were ranked, though ones without much information were ranked with a “?” after the rank to denote that this rank may change with more information, but that the best knowledge to date (sometimes personal) was used in these situations. Otherwise, hard references were used to place rank. These ranks are the “Global” and “State” ranks as seen below:

G1 and S1: Fewer than 6 viable occurrences worldwide/statewide and/or 2,000acres
G2 and S2: 6-20 viable occurrences worldwide/statewide and/or 2,000-10,000 acres
G3 and S3: 21-100 viable occurrences worldwide/statewide and/or 10,000-50,000 acres

G4 and S4: Greater than 100 viable occurrences worldwide/statewide and/or greater than 50,000 acres
G5 and S5: Community demonstrably secure due to security worldwide/statewide

Sample(s): Listed by their survey numbers from the vegetation databases, and indicated using the alpha-code SSJD (an abbreviation for Sacramento-San Joaquin Delta). Successive numeric codes follow each of the alpha-prefixes.

Con, Avg, Min, Max: A species table is provided at the end of each alliance description. The Con column provides the overall constancy value for each species within all Rapid Assessments classified as that alliance. The constancy values are between 0 and 100. Trees, shrubs, and herbs that occurred with at least 10% constancy are listed in the table. The Avg column provides the average cover value for each species, as calculated across all samples in that alliance. The Min and Max values denote the minimum and maximum cover values of species listed in the table.

Mapping (2016-19)

Numerous techniques are available for fine-scale mapping. Among the most promising are those relying on delineation and attribution using expert interpretation of digital geo-referenced aerial photography. This method was employed by the photo interpretation team at the Geographical Information Center (GIC).

GIC used true color and infrared orthorectified base imagery to produce the alliance-level vegetation map. 2016 National Agricultural Imagery Program (NAIP) imagery flown at a one meter resolution and rectified to the national standards at a 1:24,000 scale was used for all mapping.

GIC coded each mapped polygon with a 2014 Land Use code and a Vegetation code. Delineation and attribution of land use was completed using the Anderson Level II classification. For natural vegetation, the photo interpreters and DFW staff met to agree upon a mapping classification derived from the vegetation classification, ultimately based off of A Manual of California Vegetation (Sawyer et al. 2009) and the National Vegetation Classification System. A crosswalk was developed to compare all mapping categories that were utilized in the 2007 effort to match the categories that were used in the 2016 effort. All vegetation types were attempted to be mapped at the alliance level; in some cases vegetation was only interpretable at the group level, meaning there was some degree of aggregation or combination of alliances.

In addition to the vegetation alliance/group, photo interpreters attributed each natural vegetation polygon with a height code, size code (average diameter at breast height, only for tree types), tree/shrub/herb strata covers (densities), isolated tree code (0.2-5% tree), and restoration code for stands that had been restored within 5 years of the NAIP imagery (2011 or later).

The GIC produced a map utilizing 17 groups and 36 alliances. The map contains 32,700 polygons and covers 737,621.24 acres, which is the surface area of the Legal Delta.

For complete details on mapping methodology, including attribute category descriptions and criteria such as minimum widths for linear features, see Appendix A.

Note: The 2007 mapping was done to the association level when possible, whereas the 2019 mapping was done to the alliance level.

Vegetation and Land Use Overlay

The vegetation map based on 2016 NAIP imagery was overlaid with the Land IQ land use map based on 2014 imagery to populate agricultural polygons with more specific crop type information. The following steps were taken to complete this overlay.

File Preparation

2016 Delta Vegetation

- The 2016 Delta vegetation map was prepared for processing by removing all polygons that were attributed with the Agriculture group. This prepared the file for the addition of Land IQ detailed agriculture polygons.

2014 Land IQ

- The 2014 Land IQ land use map was prepared for processing by removing all polygons that were attributed with an alliance/group that was not agriculture. This created a file that only had the agriculture polygons that were to be added to the 2016 Delta vegetation map.

File Processing

1. The prepared Land IQ and the prepared Delta vegetation map described above were then merged. This resulted in a 2016 Delta vegetation map that had the detailed agriculture classes from the Land IQ map.
2. The 2016 unprocessed Delta vegetation map was then 'erased' using the result of the previous merge. This created a file of infill areas that could be used to fill in any gaps in the data that may have arisen from alignment issues that resulted from using imagery from different years and the accuracy of the imagery.
3. The infill polygons were then merged with the result of the 2014 Land IQ and 2016 Delta vegetation merge to create a complete map covering any gaps that occurred between the two original processed maps.
4. Further cleanup was performed to merge any slivers that were less than .05 acres with adjacent polygons. All merging was completed using heads-up digitizing by photo interpreters. Remaining slivers were areas where the GIC had called the land agriculture but there was no Land IQ data available for these areas. For example, when the GIC mapped a small agricultural road as Agriculture and Land IQ did not consider the road to be an agricultural type.

The final Vegetation and Land Use map for the 2016 Delta is available as a shapefile with detailed metadata including attribute values and mapping criteria and can be found here:
ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets/2800_2899/ds2855.zip (Vegetation Map)
https://map.dfg.ca.gov/metadata/ds2677.html (statewide land use dataset)

Crosswalk

The term "crosswalk" is commonly used in classification and mapping, referring to the development of relationships between different classification systems. The need for crosswalks arises when there is more than one classification system in use for a given area. It is important to note that crosswalks are never exactly precise.

Assuming that classifications arise independently, the meaning of one classification unit may not always completely encompass or be nested within the other classification unit(s) to

which it is being related. Choices need to be made about those classification units that are partially included within two or more types of another classification system. For example, CWHR's classification type of "Fresh Emergent Wetland" includes many associations and alliances of herbaceous vegetation in the National Vegetation Classification. The complexity and uncertainty of such relationships arise not only from independent evolution of classifications, but also from their imprecise definitions, without quantitative rules for proper interpretation. The best crosswalks are those that have been developed with a good understanding of the meaning and definitions of each classification system.

A crosswalk was developed by the GIC to compare the 2007 Delta map to the current 2019 Delta vegetation map. Since the 2007 mapping effort a few alliances have been moved to different groups and some alliances have been combined. This crosswalk is the GIC's best attempt to compare "apples to apples" in order to see what has changed on the ground from 2005 to 2016 (base imagery years). The crosswalk can be found in Table 1.

Table 1: Crosswalk for 2007 to 2019 mapping classes (use zoom tool to view table)

GRP	Alliance	2016 Alliance Desc.	2016 Alliance X Walk	2007 Grp	2007 Alliance	2007 Alliance X Walk
2	5	IMF - Ailanthus altissima - provisional	IMF - Ailanthus altissima - provisional	IMF	Tree-of-Heaven (Ailanthus altissima)	IMF - Ailanthus altissima - provisional
2	6	IMF - Eucalyptus (globulus, camaldulensis)	IMF - Eucalyptus (globulus, camaldulensis)	IMF	Eucalyptus	IMF - Eucalyptus (globulus, camaldulensis)
2	7	IMF - Ornamental trees	IMF - Ornamental trees			
2	9	IMF - Robinia pseudoacacia	IMF - Robinia pseudoacacia	IMF	Acacia - Robinia	IMF - Robinia pseudoacacia
2	11	IMF - IMF	IMF - IMF			
				IMF	Tobacco brush (Nicotiana glauca) mapping unit	IMF - Nicotiana glauca
3	12	RWF - Acer negundo	RWF - Acer negundo	RWF	Box Elder (Acer negundo)	RWF - Acer negundo
3	13	RWF - Juglans hindsii and hybrids	RWF - Juglans hindsii and hybrids	RWF	Hinds walnut (Juglans hindsii)	RWF - Juglans hindsii and hybrids
3	14	RWF - Platanus racemosa	RWF - Platanus racemosa			
3	15	RWF - Populus fremontii	RWF - Populus fremontii	RWF	Fremont Cottonwood (Populus fremontii)	RWF - Populus fremontii
3	16	RWF - Quercus lobata	RWF - Quercus lobata	RWF	Quercus lobata / Rosa californica (Rubus discolor - Salix lasiolepis / Carex spp.)	RWF - Quercus lobata
		RWF - Quercus lobata		RWF	Quercus lobata - Acer negundo	RWF - Quercus lobata
		RWF - Quercus lobata		RWF	Quercus lobata - Alnus rhombifolia (Salix lasiolepis - Populus fremontii - Quercus agrifolia)	RWF - Quercus lobata
3	17	RWF - Salix gooddingii	RWF - Salix gooddingii	RWF	Black Willow (Salix gooddingii)	RWF - Salix gooddingii
				RWF	Acer negundo- Salix gooddingii	RWF - Acer negundo
				RWF	Black Willow (Salix gooddingii) - Valley Oak (Quercus lobata) restoration	RWF - Salix gooddingii
				RWF	Salix gooddingii - Populus fremontii - (Quercus lobata-Salix exigua-Rubus discolor)	RWF - Salix gooddingii
				RWF	Salix gooddingii - Quercus lobata / Wetland Herbs	RWF - Salix gooddingii
				RWF	Salix gooddingii / Rubus discolor	RWF - Salix gooddingii
				RWF	Salix gooddingii / wetland herbs	RWF - Salix gooddingii
3	18	RWF - Salix laevigata	RWF - Salix laevigata			
3	19	RWF - RWF	RWF - RWF			
4	20	VRF - Alnus rhombifolia	VRF - Alnus rhombifolia	VRF	White Alder (Alnus rhombifolia)	VRF - Alnus rhombifolia
				VRF	Alnus rhombifolia / Cornus sericea	VRF - Alnus rhombifolia
				VRF	Alnus rhombifolia / Salix exigua (Rosa californica)	VRF - Alnus rhombifolia
				VRF	White Alder (Alnus rhombifolia) - Arroyo willow (Salix lasiolepis) restoration	VRF - Alnus rhombifolia
4	21	VRF - Fraxinus latifolia		VRF	Quercus lobata - Fraxinus latifolia	RWF-Quercus lobata
				VRF	Oregon Ash (Fraxinus latifolia)	VRF - Fraxinus latifolia
4	23	VRF - Salix lucida	VRF - Salix lucida	VRF	Shining Willow (Salix lucida)	VRF - Salix lucida
4	24	VRF - VRF	VRF - VRF			
5	26	WVO - Quercus agrifolia	WVO - Quercus agrifolia	WVO	Coast Live Oak (Quercus agrifolia)	WVO - Quercus agrifolia
5	30	WVO - Quercus lobata	WVO - Quercus lobata	WVO	Valley Oak (Quercus lobata)	WVO - Quercus lobata
				WVO	Valley Oak (Quercus lobata) restoration	WVO - Quercus lobata
5	31	WVO - Quercus wislizeni - tree	WVO - Quercus wislizeni - tree			
5	33	WVO - WVO	WVO - WVO			
9	46	CSS - Baccharis pilularis	CSS - Baccharis pilularis	CSS	Coyotebush (Baccharis pilularis)	CSS - Baccharis pilularis
				RWS	Baccharis pilularis / Annual Grasses & Herbs	CSS - Baccharis pilularis
9	54	CSS - Lupinus albifrons	CSS - Lupinus albifrons			
				CSS	Microphyllous Shrubland	CSS - Microphyllous Shrubland
11	66	RIS - Rubus armeniacus	RIS - Rubus armeniacus	RIS	Blackberry (Rubus discolor)	RIS - Rubus armeniacus
11	68	RIS - Tamarix spp.	RIS - Tamarix spp.			
11	69	RIS - RIS	RIS - RIS			
11	351	RIS - Phragmites australis – Arundo donax – Alopecurus pratensis Semi-natural Stands	RIS - Phragmites australis – Arundo donax – Alopecurus pratensis Semi-natural Stands	FEM	Common Reed (Phragmites australis)	RIS - Phragmites australis – Arundo donax – Alopecurus pratensis Semi-natural Stands
				RIS	Giant Cane (Arundo donax)	RIS - Phragmites australis – Arundo donax – Alopecurus pratensis Semi-natural Stands
12	74	RWS - Cephalanthus occidentalis	RWS - Cephalanthus occidentalis	RWS	Buttonbush (Cephalanthus occidentalis)	RWS - Cephalanthus occidentalis
12	77	RWS - Rosa californica	RWS - Rosa californica	RWS	California Wild Rose (Rosa californica)	RWS - Rosa californica
12	78	RWS - Salix exigua	RWS - Salix exigua	RWS	Narrow-leaf Willow (Salix exiqua)	RWS - Salix exigua
				RWS	Salix exigua - (Salix lasiolepis - Rubus discolor - Rosa californica)	RWS - Salix exigua
12	79	RWS - Salix lasiolepis	RWS - Salix lasiolepis	RWS	Arroyo Willow (Salix lasiolepis)	RWS - Salix lasiolepis
				RWS	Salix lasiolepis - (Comus sericea) / Scirpus spp.- (Phragmites australis - Typha spp.) complex unit	RWS - Salix lasiolepis
				RWS	Salix lasiolepis - Mixed brambles (Rosa californica - Vitis californica - Rubus discolor)	RWS - Salix lasiolepis
12	80	RWS - Sambucus nigra	RWS - Sambucus nigra	RWS	Mexican Elderberry (Sambucus mexicana)	RWS - Sambucus nigra
12	81	RWS - Vitis californica - provisional	RWS - Vitis californica - provisional			
12	82	RWS - RWS	RWS - RWS			
13	83	SSB - Allenrolfea occidentalis	SSB - Allenrolfea occidentalis	SSB	Allenrolfea occidentalis mapping unit	SSB - Allenrolfea occidentalis
13	84	SSB - Atriplex lentiformis	SSB - Atriplex lentiformis			
13	86	SSB - Frankenia salina	SSB - Frankenia salina	SSB	Alkali Heath (Frankenia salina)	SSB - Frankenia salina
				SSB	Frankenia salina - Distichlis spicata	SSB - Frankenia salina
13	87	SSB - Isocoma acradenia	SSB - Isocoma acradenia			
13	89	SSB - SSB	SSB - SSB	SSB	Alkaline vegetation mapping unit	SSB - SSB
				SSB	Juncus bufonius (salt grasses)	SSB - Juncus bufonius (salt grasses)
13	88	SSB - Suaeda moquinii	SSB - Suaeda moquinii	SSB	Suaeda moquinii - (Lasthenia californica) mapping unit	SSB - Suaeda moquinii
15	90	CAI - Centaurea (solstitialis, mexicana) Aggregated to CAI	CAI - CAI			
15	337	CAI - Conium maculatum–Foeniculum vulgare Semi-natural Stands	CAI - Conium maculatum–Foeniculum vulgare Semi-natural Stands	CAI	Poison Hemlock (Conium maculatum)	CAI - Conium maculatum–Foeniculum vulgare Semi-natural Stands
15	338	CAI - Cortaderia (jubata, selloana) Semi-natural Stands	CAI - Cortaderia (jubata, selloana) Semi-natural Stands	CAI	Pampas Grass (Cortaderia selloana - C. jubata)	CAI - Cortaderia (jubata, selloana) Semi-natural Stands
15	92	CAI - CAI	CAI - CAI	CAI	Bromus diandrus - Bromus hordeaceus	CAI - CAI
				CAI	Intermittently or temporarily flooded undifferentiated annual grasses and forbs	CAI - CAI
				CAI	Italian Rye-grass (Lolium multiflorum)	CAI - CAI
				CAI	Lolium multiflorum - Convolvulus arvensis	CAI - CAI
				CAI	Rabbitsfoot grass (Polypogon maritimus)	CAI - CAI
				CAI	Ruderal Herbaceous Grasses & Forbs	CAI - CAI
				CAI	Seasonally flooded undifferentiated annual grasses and forbs	CAI - CAI
				CAI	Tall & Medium Upland Grasses	CAI - CAI
16	94	CFG - CFG	CFG - CFG	CAI	California Annual Grasslands - Herbaceous	CFG - CFG
	346	VPB - Grindelia (camporum, stricta) (Aggregated to CFG)	CFG - CFG			
18	98	DAM - Atriplex prostrata-Cotula coronopifolia	DAM - Atriplex prostrata-Cotula coronopifolia			
18	99	DAM - Bassia hyssopifolia	DAM - Bassia hyssopifolia			
20	106	FEM - Schoenoplectus (acutus, californicus)	FEM - Schoenoplectus (acutus, californicus)	FEM	California Bulrush (Scirpus californicus)	FEM - Schoenoplectus (acutus, californicus)
				FEM	Hard-stem Bulrush (Scirpus acutus)	FEM - Schoenoplectus (acutus, californicus)
				FEM	Mixed Scirpus / Floating Aquatics (Hydrocotyle - Eichhornia) Complex	FEM - Schoenoplectus (acutus, californicus)
				FEM	Mixed Scirpus / Submerged Aquatics (Egeria-Cabomba-Myriophyllum spp.) complex	FEM - Schoenoplectus (acutus, californicus)
				FEM	Mixed Scirpus Mapping Unit	FEM - Schoenoplectus (acutus, californicus)
				FEM	Scirpus acutus - (Typha latifolia) - Phragmites australis	FEM - Schoenoplectus (acutus, californicus)
				FEM	Scirpus acutus - Typha angustifolia	FEM - Schoenoplectus (acutus, californicus)
				FEM	Scirpus acutus -Typha latifolia	FEM - Schoenoplectus (acutus, californicus)
				FEM	Scirpus acutus Pure	FEM - Schoenoplectus (acutus, californicus)
				FEM	Scirpus californicus - Eichhornia crassipes	FEM - Schoenoplectus (acutus, californicus)
				FEM	Scirpus californicus - Scirpus acutus	FEM - Schoenoplectus (acutus, californicus)
20	107	FEM - Typha (angustifolia, domingensis, latifolia)	FEM - Typha (angustifolia, domingensis, latifolia)	FEM	Typha angustifolia - Distichlis spicata	FEM - Typha (angustifolia, domingensis, latifolia)
				FEM	Broad-leaf Cattail (Typha latifolia)	FEM - Typha (angustifolia, domingensis, latifolia)
				FEM	Narrow-leaf Cattail (Typha angustifolia)	FEM - Typha (angustifolia, domingensis, latifolia)
20	108	FEM - FEM	FEM - FEM			

Table 1 (continued): Crosswalk for 2007 to 2016 mapping classes (use zoom tool to view table)

22	109	NRW - Cynodon dactylon–Crypsis spp.–Paspalum spp. Semi-natural stands	NRW - Cynodon dactylon–Crypsis spp.–Paspalum spp. Semi-natural stands			
22	110	NRW - Managed annual and perennial wetland vegetation	NRW - Managed annual and perennial wetland vegetation	NRW	Managed Annual Wetland Vegetation (Non-specific grasses & forbs)	NRW - Managed annual and perennial wetland vegetation
				NRW	Managed alkali wetland (Crypsis)	NRW - Managed annual and perennial wetland vegetation
				NRW	Intermittently Flooded Perennial Forbs	NRW - Managed annual and perennial wetland vegetation
				NRW	Polygonum amphibium	NRW - Managed annual and perennial wetland vegetation
				NRW	Smartweed Polygonum spp. - Mixed Forbs	NRW - Managed annual and perennial wetland vegetation
				NRW	Temporarily Flooded Perennial Forbs	NRW - Managed annual and perennial wetland vegetation
				NRW	Scirpus spp. in managed wetlands	NRW - Managed annual and perennial wetland vegetation
22	111	NRW - Persicaria lapathifolia - Xanthium strumarium	NRW - Persicaria lapathifolia - Xanthium strumarium			
22	112	NRW - NRW	NRW - NRW			
22	291	NRW - Lepidium latifolium	NRW - Lepidium latifolium	NRW	Lepidium latifolium - Salicornia virginica - Distichlis spicata	NRW - Lepidium latifolium
				NRW	Perennial Pepperweed (Lepidium latifolium)	NRW - Lepidium latifolium
24	118	SAM -Schoenoplectus americanus	SAM -Schoenoplectus americanus	FEM	American Bulrush (Scirpus americanus)	SAM -Schoenoplectus americanus
24	121	SAM - SAM	SAM - SAM			
26	122	TBM - Bolboschoenus maritimus	TBM - Bolboschoenus maritimus			
26	123	TBM - Distichlis spicata	TBM - Distichlis spicata	TBM	Saltgrass (Distichlis spicata)	TBM - Distichlis spicata
				TBM	Distichlis spicata - Annual Grasses	TBM - Distichlis spicata
				TBM	Distichlis spicata - Juncus balticus	TBM - Distichlis spicata
				TBM	Distichlis spicata - Salicornia virginica	TBM - Distichlis spicata
26	124	TBM - TBM	TBM - TBM			
26	290	TBM - Salicornia pacifica	TBM - Salicornia pacifica	SSB	Pickleweed (Salicornia virginica)	TBM - Salicornia pacifica
				TBM	Salicornia virginica - Cotula coronopifolia	TBM - Salicornia pacifica
				TBM	Salicornia virginica - Distichlis spicata	TBM - Salicornia pacifica
28	125	TFF - Azolla (filiculoides, mexicana) - Aggregated to TFF, NTF	TFF - NTF			
28	126	TFF - Lemna minor and Relatives - Aggregated to TFF, NTF	TFF - NTF			
28	128	TFF - Aggregated to TFF, NTF	TFF - NTF			
				FAV	Generic Floating Aquatics	TFF - NTF
30	31	VPG - VPG	VPG - VPG			
31	132	VPB - VPB	VPB - VPB	VPB	Vernal Pools	VPB - VPB
				SSB	Suaeda moquinii - (Lasthenia californica) mapping unit	VPB - VPB
32	134	WTM - Carex barbarae	WTM - Carex barbarae	WTM	Santa Barbara Sedge (Carex barbarae) Stands	WTM - Carex barbarae
32	137	WTM - Leymus cinereus – Leymus triticoides Alliance	WTM - Leymus cinereus – Leymus triticoides Alliance	WTM	Creeping Wild Rye Grass (Leymus triticoides)	WTM - Leymus cinereus – Leymus triticoides Alliance
32	138	WTM - Juncus arcticus (var. balticus, mexicanis)	WTM - Juncus arcticus (var. balticus, mexicanis)	WTM	Juncus balticus - meadow vegetation	WTM - Juncus arcticus (var. balticus, mexicanis)
32	140	WTM - WTM	WTM - WTM			
32	350	WTM - Horsetail (Equisetum spp.) Alliance	WTM - Horsetail (Equisetum spp.) Alliance	WTM	Horsetail (Equisetum spp.)	WTM - Horsetail (Equisetum spp.) Alliance
33	141	AGR - AGR	AGR - AGR	AGR	Agriculture	AGR - AGR
34	142	BGS - BGS	BGS - BGS	BGS	Levee Rock Riprap	BGS - BGS
				BGS	Sparsely or Unvegetated	BGS - BGS
				BGS	Tidal Mudflats	BGS - BGS
35	143	URB - URB	URB - URB	URB	Urban Developed - Built Up	URB - URB
36	144	Wat - Wat	Wat - Wat	Wat	Shallow flooding with minimal vegetation at time of photography	Wat - Wat
				Wat	Water	Wat - Wat
37	145	SVP - SVP	SVP - SVP	SSB	Salt scalds and associated sparse vegetation	SVP - SVP
40	148	TFB - TFB	TFB - TFB	FEW	Hydrocotyle ranunculoides	TFB - TFB
51	200	QMG - QMG	QMG - QMG	QMG		
85	288	WDT - Cornus sericea	WDT - Cornus sericea	WDT	California Dogwood (Cornus sericea)	WDT - Cornus sericea
				WDT	Cornus sericea - Salix exigua	WDT - Cornus sericea
				WDT	Cornus sericea - Salix lasiolepis / (Phragmites australis)	WDT - Cornus sericea
86	293	LSH - Carpobrotus edulis and other ice	LSH - Carpobrotus edulis and other ice			
				DIVISION	Seasonally Flooded Grasslands	DIVISION - Seasonally Flooded Grasslands
				DIVISION	Temporarily Flooded Grasslands	DIVISION - Temporarily Flooded Grasslands
23	116	NTF - NTF	TFF - NTF			
				FAV	Algae	Removed - Algae
				FAV	Brazilian Waterweed (Egeria - Myriophyllum) Submerged	Removed - Brazilian Waterweed (Egeria - Myriophyllum) Submerged
23	114	NTF - Ludwigia (hexapetala, peploides) - Aggregated to TFF, NTF	TFF - NTF	FAV	Ludwigia peploides	TFF - NTF
				FAV	Floating Primrose (Ludwigia peploides)	TFF - NTF
				FAV	Milfoil - Waterweed (generic submerged aquatics)	Removed - Milfoil - Waterweed (generic submerged aquatics)
				FAV	Pondweed (Potamogeton sp.)	Removed - Pondweed (Potamogeton sp.)
23	113	NTF - Eichhornia crassipes - Aggregated to TFF, NTF	TFF - NTF	FAV	Water Hyacinth (Eichhornia crassipes)	TFF - NTF
				FORMATION	Temporarily or Seasonally Flooded - Deciduous Forests	FORMATION - Temporarily or Seasonally Flooded - Deciduous Forests
				MACROGROUP	Exotic Vegetation Stands	Exotic Vegetation Stands
				MACROGROUP	Intermittently or Temporarily Flooded Deciduous Shrublands	Intermittently or Temporarily Flooded Deciduous Shrublands
				RESTORATION	Restoration Sites	Restoration Sites
				UNK	Unknown	Unknown
				WCM	California Hair-grass (Deschampsia caespitosa)	WCM - California Hair-grass (Deschampsia caespitosa)
				WCM	Deschampsia caespitosa - Lilaeopsis masonii	WCM - Deschampsia caespitosa - Lilaeopsis masonii

Results from Change Detection

Change detection was performed on the areas where the 2007 (2005 base imagery) map and the 2019 (2016 base imagery) map overlapped. This was done by clipping each map until they were identical in surface area and boundary and then analyzing each map for the acres covered by each individual alliance or group and comparing how that acreage changed between 2005 and 2016.

2005 original mapping acres = 725,884.28
2005 clipped mapping acres = 723,426.30

2016 original mapping acres = 737,621.24
2016 clipped mapping acres= 723,426.30

Change detection on these clipped maps showed that there was a loss of 25,463 acres of agriculture. Much of this loss was conversion of agricultural land to urban or managed marsh. Change detection results showed a gain of 17,535 acres of urban land and a gain of 10,848 acres of managed marsh. If a parcel of agriculture was out of production for 5 years or more the GIC attributed the land as California Introduced Annual and Perennial Herbaceous (CAI), which could account for some of the acreage loss in agriculture (and acreage gain in CAI) in 2016.

There was an increase of 6,043 acres of riparian tree vegetation, and another 1,142 acres of riparian shrub since 2005. Some of this acreage can be explained by the 600-acre restoration project that occurred on Hog Slough.

The loss of Bare Gravel and Sand (BGS) can partially be explained due to the fact that much of what was mapped as BGS in 2005 was riprap and was less than 10 meters wide, which falls below the GIC's minimum mapping width that was used in 2016. In 2016, these thin riprap areas were often merged into CAI or less commonly to some other adjacent alliance.

Cornus sericea showed a loss of 1,057 acres. When the GIC talked to Todd Keeler-Wolf at DFW's VegCAMP about this he was confident that there was at least some *Cornus sericea* in the Delta around 2005-2007. The GIC was not able to confirm any *Cornus* via aerial photo interpretation and did not find a single shrub of this species when doing accuracy assessments in 2019. Most of what was mapped as *Cornus* in 2005 is now *Salix lucida*, *Salix lasiolepis*, *Cephalanthus occidentalis*, or group-level Freshwater Emergent Marsh (FEM).

The analysis shows a loss of 5,614 acres of 'Exotic Vegetation Stands'; this was a macrogroup category that was used in 2005 but not used in 2016 mapping. Some of this acreage in 2016 is covered by the Groups 'Introduced North American Mediterranean Forest (IMF)' and 'Riparian Introduced Scrub (RIS)', which covered 1,723 and 1,973 acres, respectively. While some stands may have been removed as part of restoration projects, the majority of this discrepancy is probably due to differences in mapping techniques between 2005 and 2016, such as delineating stands of non-native trees within urban areas (2005) versus including them as part of the surrounding urban polygon (2016).

The loss of *Lepidium latifolium* was probably due to it being misidentified as *Conium maculatum–Foeniculum vulgare* Semi-natural Stands in 2005. Several of the GIC's

Lepidium polygons that were accuracy assessed wound up being *Conium* or *Foeniculum*, indicating that these species are commonly mistaken for each other.

In 2005, 3,469 acres of the Group 'Algae, Brazilian Waterweed, Milfoil, and Potamogeton sp.' were mapped, whereas zero acres were mapped in 2016. These are all submerged vegetation types which the GIC was not required under contract to map, so this should not be understood as a true loss of these vegetation types.

Quercus lobata is mapped under both the California Broadleaf Forest and Woodland (WVO) and Riparian Evergreen and Deciduous Woodland (RWF) groups. WVO describes an open upland woodland while RWF describes a riparian forest. When open woodland occurs directly adjacent to riparian forest, there can be difficulty in determining which group to use. From 2005 to 2016 there was a loss in *Quercus lobata* mapped under WVO which can be partially explained by an increase in it being mapped under RWF. However, there was a total gain of 1,095 acres of mapped *Q. lobata* (in either group). This is most likely due to multiple restoration projects.

The loss in Temperate Pacific Tidal Salt and Brackish Meadow (TBM) can most likely be explained by a gain in Naturalized Warm-Temperate Riparian/Wetland (NRW). Stands mapped under these groups are often a mosaic of different species, oftentimes with multiple species falling under both groups.

The macrogroup Floating Aquatic Vegetation (FAV) was split into two groups after 2005 by VegCAMP: Temperate Freshwater Floating Mat (TFF) & Naturalized Temperate Pacific Freshwater Vegetation (NTF). To do change detection the 2016 NTF and TFF were aggregated to compare to the 2005 FAV.

In general, imagery and technology have greatly improved since the previous mapping effort, which can account for some vegetation types being misidentified in 2005 and changed to the correct alliance in 2016.

See Table 2 for a summary table of all change detection from 2005 to 2016.

Table 2: Results from change detection (use zoom tool to view table)

Group	Alliance	Common Name	2007 Acres	2007 Total Group Acres	2016 Acres	2016 Total Group Acres	Alliance Acre Change	Group Acre Change
Riparian / Wetland Vegetation								
Central and South Coastal California Seral Scrub (CSS)								
CSS	Baccharis pilularis	Coyote Brush	79.69		70.58		-9.11	
CSS	Lupinus albifrons (Not mapped in 2007)	Silver lupine	0.00		10.54		10.54	
CSS	Microphyllous Shrubland (Not mapped in 2016)		0.30		0.00		-0.30	
		Total Acres		79.99		81.11		1.13
Freshwater Emergent Marsh (FEM)								
FEM	FEM	Freshwater Emergent Marsh	0.00		2,793.79		2,793.79	
FEM	Schoenoplectus (acutus, californicus)	Bulrush	9,138.16		11,526.55		2,388.39	
FEM	Typha (angustifolia, domingensis, latifolia)	Cattail	463.68		1,812.58		1,348.90	
		Total Acres		9,601.85		16,132.92		6,531.08
Naturalized Warm-Temperate Riparian/Wetland (NRW)								
NRW	Cynodon dactylon–Crypsis spp.–Paspalum spp. Semi-natural stands (Not mapped in 2007)	Bermuda grass	0.00		508.54		508.54	
NRW	Managed annual and perennial wetland vegetation	Duck Clubs etc.	6,479.14		17,327.54		10,848.40	
NRW	Persicaria lapathifolia - Xanthium strumarium (Not mapped in 2007)	Knotweed, Cocklebur	0.00		2.62		2.62	
NRW	Lepidium latifolium	Broad leaved pepper grass	1,726.06		272.32		-1,453.74	
NRW	NRW	Naturalized Warm-Temperate Riparian/Wetland	0.00		9,238.90		9,238.90	
		Total Acres		8,205.20		27,349.92		19,144.72
Riparian Introduced Scrub (RIS)								
RIS	Rubus americanus	Himalayan Blackberry	1,204.53		1,516.06		311.53	
RIS	Tamarix spp. (Not mapped in 2007)	Saltcedar	0.00		19.72		19.72	
RIS	Phragmites australis – Arundo donax – Alopecurus pratensis Semi-natural Stands	Giant Cane, Common Reed. Meadow foxtail	433.17		411.56		-21.61	
RIS	RIS	Riparian Introduced Scrub	0.00		26.26		26.26	
		Total Acres		1,637.70		1,973.60		335.90
Riparian Evergreen and Deciduous Woodland (RWF)								
RWF	Acer negundo	Box Elder	75.68		133.82		58.14	
RWF	Juglans hindsii and hydribs	Black Walnut	20.77		376.06		355.29	
RWF	Platanus racemosa (Not mapped in 2007)	Sycamore	0.00		65.79		65.79	
RWF	Populus fremontii	Freemont Cottonwood	640.39		4,178.22		3,537.83	
RWF	Quercus lobata	Valley Oak	1,541.66		4,535.67		2,994.02	
RWF	Salix gooddingii	Goodding's Willow	3,677.59		2,332.90		-1,344.68	
RWF	Salix laevigata (Not mapped in 2007)	Red Willow	0.00		35.22		35.22	
RWF	RWF	Riparian Evergreen and Deciduous Woodland	0.00		342.23		342.23	
		Total Acres		5,956.09		11,999.91		6,043.83
Southwestern North American Riparian Wash/Scrub (RWS)								
RWS	Cephalanthus occidentalis	Buttonwillow	7.45		188.39		180.94	
RWS	Rosa californica	California Wild Rose	98.29		0.17		-98.12	
RWS	Salix exigua	Narrowleaf Willow	1,382.70		1,427.91		45.21	
RWS	Salix lasiolepis	Arroroy Willow	2,485.72		3,433.13		947.41	
RWS	Sambucas nigra	Blue Elderberry	17.30		7.68		-9.62	
RWS	Vitis californica - provisional (Not mapped in 2007)	California Wild Grape	0.00		25.49		25.49	
RWS	RWS	Southwestern North American Riparian Wash/Scrub	0.00		51.66		51.66	
		Total Acres		3,991.46		5,134.43		1,142.97
Sparsely Vegetated Alkali Playa/Pool (SVP)								
SVP	SVP	Salt scalds and associated sparse vegetation	65.09		181.77		116.68	
		Total Acres		65.09		181.77		116.68
Temperate Freshwater Floating Mat (TFF) & Naturalized Temperate Pacific Freshwater Vegetation (NTF)								
TFF	TFF , NTF	TFF , NTF	951.10		2,603.43		1,652.33	
TFF	Azolla (filiculoides, mexicana) - Aggregated to TFF, NTF	Mosquito Fern						
TFF	Lemna minor and Relatives - Aggregated to TFF, NTF	Common Duckweed						
NTF	Ludwigia (hexapetala, peploides) - Aggregated to TFF, NTF	Floating Primrose						
NTF	Eichhornia crassipes - Aggregated to TFF, NTF	Water Hyacinth						
		Total Acres		951.10		2,603.43		1,652.33
California Vernal Pool Basin (VPB)								
VPB	VPB	Vernal Pools	207.55		374.01		166.46	
		Total Acres		207.55		374.01		166.46
California Vernal Pool Grassland Matrix (VPG)								
VPG	VPG (Not Mapped in 2007)	California Vernal Pool and Grassland Matrix	0.00		12,572.39		12,572.39	
		Total Acres		0.00		12,572.39		12,572.39
Vancouverian Riparian Deciduous Forest (VRF)								
VRF	Alnus rhombifolia	White Alder	609.64		349.57		-260.07	
VRF	Fraxinus latifolia	Oregon Ash	1.27		90.40		89.14	
VRF	Salix lucida	Pacific Willow	78.50		220.74		142.24	
VRF	VRF		0.00		95.46		95.46	
		Total Acres		689.41		756.18		66.77
Western Cordilleran Montane-boreal Mesic Wet Meadow (WCM)								
WCM	Deschampsia caespitosa)	California Hair-grass	1.22		0.00		-1.22	
WCM	Deschampsia caespitosa - Lilaeopsis masonii		0.54		0.00		-0.54	
		Total Acres		1.77		0.00		-1.77
Western Dogwood Thicket (WDT)								
WDT	Cornus sericea	Dogwood	1,062.63		5.60		-1,057.03	
		Total Acres		1,062.63		5.60		-1,057.03
California Warm Temperate Marsh/Seep (WTM)								
WTM	Carex barbarae	Santa Barbara Sedge	15.11		11.64		-3.47	
WTM	Leymus cinereus – Leymus triticoides Alliance	Creeping Wildrye	2.56		3.92		1.37	
WTM	Juncus arcticus (var. balticus, mexicanis)	Artic rush	45.43		1.84		-43.59	
WTM	Horsetail (Equisetum spp.) Alliance		83.09		104.30		21.21	
WTM	WTM	California Warm Temperate Marsh/Seep	0.00		434.78		434.78	
		Total Acres		146.19		556.48		410.29
DIVISION / FORMATION								
DIVISION	DIVISION - Seasonally Flooded Grasslands	Seasonally Flooded Grasslands	49.39		0.00		-49.39	
DIVISION	DIVISION - Temporarily Flooded Grasslands	Temporarily Flooded Grasslands	7.65				-7.65	
FORMATION	FORMATION - Temporarily or Seasonally Flooded - Deciduous Forests	Temporarily or Seasonally Flooded - Deciduous Forests	139.65				-139.65	
MACROGROUP	Intermittently or Temporarily Flooded Deciduous Shrublands	Intermittently or Temporarily Flooded Deciduous Shrublands	535.85				-535.85	
		Total Acres		732.54		0.00		-732.54
Exotic								
MACROGROUP	Exotic Vegetation Stands	Exotic Vegetation Stands	5,614.25		0.00		-5,614.25	
		Total Acres		5,614.25		0.00		-5,614.25
Restoration								
Restoration	Restoration Sites	Restoration Sites	30.92		0.00		-30.92	
		Total Acres		30.92		0.00		-30.92
		Total Riparian Vegetation Acres	**32,596.01**		**79,721.77**			
		Total Riparian Vegetation Change Acres						**40,748.06**

Table 2: (continued) Results from change detection (use zoom tool to view table)

Non-Riparian Vegetation Change								
California Introduced Annual and Perennial Herbaceous (CAI)								
CAI	CAI	California Introduced Annual and Perennial Herbaceous	37,065.30		42,778.04		**5,712.73**	
CAI	Centaurea (solstitialis, mexicana) Aggregated to CAI	Yellow Starthistle	0.00		0.00			
CAI	Conium maculatum–Foeniculum vulgare Semi-natural Stands	Poison hemlock, Fennel	765.61		397.29		**-368.32**	
CAI	Cortaderia (jubata, selloana) Semi-natural Stands	Pampas grass	18.62		54.11		**35.49**	
		Total Acres		**37,849.53**		**43,229.44**		**5,379.90**
California Annual Forbs and Grasses (CFG)								
CFG	CFG - Aggreated with VPB - Grindelia (camporum, stricta)	California Annual Forbs and Grasses	31,203.02		3,863.02		**-27,340.00**	
		Total Acres		**31,203.02**		**3,863.02**		**-27,340.00**
Western North American disturbed alkaline marsh and meadow (DAM)								
DAM	Atriplex prostrata-Cotula coronopifolia (not mapped in 2007)	Brass buttons	0.00		0.57		**0.57**	
DAM	Bassia hyssopifolia (Not mapped in 2007)	Five-horn smotherweed	0.00		91.44		**91.44**	
		Total Acres		0.00		**92.02**		**92.02**
Introduced North American Mediterranean Forest (IMF)								
IMF	Ailanthus altissima - provisional	Tree of Heavan	4.29		27.02		**22.73**	
IMF	Eucalyptus (globulus, camaldensis)	Bluegum, Redgum	187.85		442.38		**254.53**	
IMF	Ornamental Trees (not Mapped in 2007)	Ornamental Trees	0.00		337.67		**337.67**	
IMF	Robinia pseudoacacia	Black locust	85.89		24.30		**-61.59**	
IMF	Nicotiana glauca (not mapped in 2016)	Tobacco brush	1.82		0.00		**-1.82**	
IMF	IMF	Introduced North American Mediterranean Forest	0.00		892.34		**892.34**	
		Total Acres		**279.86**		**1,723.71**		**1,443.86**
California-vancourverian Semi-natural Littoral Scrub and Herb Vegetation (LSH)								
LSH	Carpobrotus edulis and other ice (Not mapped in 2007)	Ice plant	0.00		4.30		**4.30**	
		Total Acres		0.00		**4.30**		**4.30**
Southwestern North American alkali marsh/seep vegetation (SAM)								
SAM	Schoenoplectus americanus	American Bulrush	15.34		8.98		**-6.36**	
SAM	SAM		0.00		5.43		**5.43**	
		Total Acres		15.34		**14.41**		**-0.93**
Southwestern North American salt basin and high marsh group (SSB)								
SSB	Allenrolfea occidentalis	Iodine bush	260.52		325.56		**65.04**	
SSB	Atriplex lentiformis (Not mapped in 2007)	Big salt brush	0.00		42.45		**42.45**	
SSB	Frankenia salina	Alkali Heath	26.62		51.92		**25.30**	
SSB	Isocoma acradenia (Not mapped in 2007)	Alkali goldenbrush	0.00		52.60		**52.60**	
SSB	Suaeda moquinii	Bush Seepweed	70.64		50.55		**-20.09**	
SSB	Juncus bufonius (Not mapped in 2016)	Salt grasses	6.47		0.00		**-6.47**	
SSB	SSB	Alkaline vegetation mapping unit	28.14		201.51		**173.37**	
		Total Acres		**392.39**		**724.59**		**332.20**
Temperate Pacific tidal salt and brackish meadow (TBM)								
TBM	Bolboschoenus maritimus (Not mapped in 2007)	Bulrush	0.00		15.10		**15.10**	
TBM	Distichlis spicata	Salt grasses	4,879.34		1,721.35		**-3,157.99**	
TBM	Salicornia pacifica	Pickleweed	22.32		253.61		**231.29**	
TBM	TBM		0.00		254.62		**254.62**	
		Total Acres		**4,901.66**		**2,244.67**		**-2,656.98**
Temperate Pacific freshwater aquatic bed – (TFB)								
TFB	TFB		7.32		2.62		**-4.70**	
		Total Acres		**7.32**		**2.62**		**-4.70**
California Broadleaf Forest and Woodland (WVO)								
WVO	Quercus agrifolia	Coast Live Oak	83.47		118.26		**34.80**	
WVO	Quercus lobata	Valley Oak	2,114.72		215.27		**-1,899.45**	
WVO	Quercus wislizenii - tree (Not mapped in 2007)	Interior Live Oak	0.00		83.63		**83.63**	
WVO	WVO	California Broadleaf Forest and Woodland	0.00		42.52		**42.52**	
		Total Acres		**2,198.19**		**459.68**		**-1,738.50**
		Total Non-Riparian Vegetation Acres	**76,847.30**		**52,358.47**			
		Total Non-Riparian Vegetation Change Acres						**-24,488.84**
Other								
Unknown								
UNK	UNK	Unknown	100.52		0.00		**-100.52**	
		Total Acres		**100.52**		**0.00**		**-100.52**
Removed								
Removed	Removed - Algae	Algae	397.15		0.00		**-397.15**	
Removed	Removed - Brazilian Waterweed (Egeria - Myriophyllum) Submerged	Brazilian Waterweed	2,996.21		0.00		**-2,996.21**	
Removed	Removed - Milfoil - Waterweed (generic submerged aquatics)	Milfoil - Waterweed	70.96		0.00		**-70.96**	
Removed	Removed - Pondweed (Potamogeton sp.)	Pondweed	5.16		0.00		**-5.16**	
		Total Acres		**3,469.47**		**0.00**		**-3,469.47**
		Total Non-Riparian Vegetation Acres	**3,569.99**		**0.00**			
		Total Non-Riparian Vegetation Change Acres						**-3,569.99**
Non-Vegetation Change								
Agriculture (AGR)								
AGR	AGR	Agriculture	473,231.68		447,768.28		**-25,463.40**	
		Total Acres		**473,231.68**		**447,768.28**		**-25,463.40**
Bare - Gravel/Sand (BGS)								
BGS	BGS	Bare - Gravel/Sand	8,220.01		439.22		**-7,780.79**	
		Total Acres		**8,220.01**		**439.22**		**-7,780.79**
Stripmines, quarries and gravel pits (QMG)								
QMG	QMG (Not mapped in 2007)	Stripmines, quarries and gravel pits	0.00		270.46		**270.46**	
		Total Acres		**0.00**		**270.46**		**270.46**
Urban (URB)								
URB	URB	Urban	61,747.08		79,282.39		**17,535.31**	
		Total Acres		**61,747.08**		**79,282.39**		**17,535.31**
Water (WAT)								
WAT	WAT	Water	60,836.49		63,585.72		**2,749.23**	
		Total Acres		**60,836.49**		**63,585.72**		**2,749.23**
		Total Non-Vegetation Acres	**604,035.27**		**591,346.07**			
		Total Non-Vegetation Change Acres						**-12,689.20**
		Total Mapped Acres		**723,426.27**		**723,426.30**		

2019 Accuracy Assessment

Sample Allocation and Field Sampling

An independent sample of mapped polygons was selected by DFW's VegCAMP to test the accuracy of the major mapped vegetation types in this project. First, a prioritized selection of mapped polygons was created. Only polygons that intersected parcels that the GIC had permission to enter or polygons that intersected publicly accessible roads were selected, and all polygons that had been previously surveyed were removed. Next, the allocation was stratified by vegetation type to try to ensure that all vegetation types would receive enough samples to be adequately evaluated for accuracy. From this subset, polygons were selected at random.

GIC assigned field crews such that the person who delineated and attributed a polygon did not perform the accuracy assessment for that polygon. GIC field staff were given unattributed polygons to survey for accuracy. Each polygon was given a priority level so that the types with the fewest polygons had higher priority. Figure 5 shows how a portion of the allocation looked during the accuracy assessment effort.

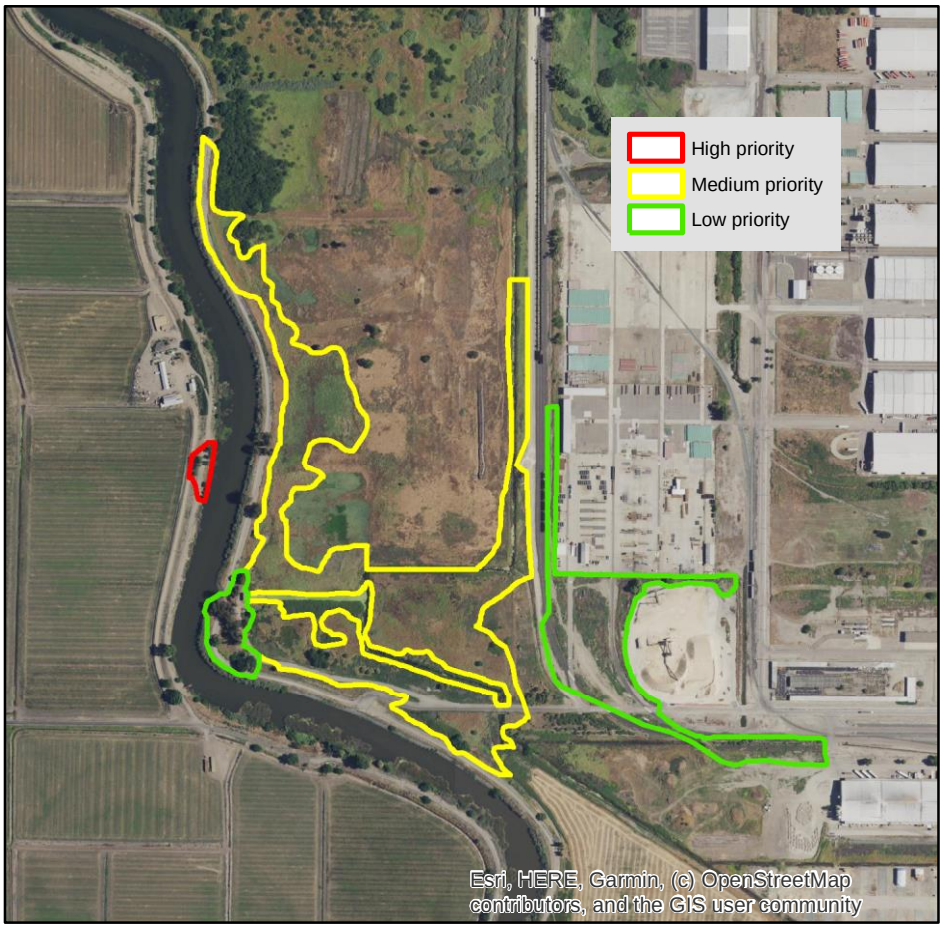

Figure 5. Example of the 2019 accuracy assessment allocation, showing polygons on Rough and Ready Island. Polygons are color-coded by priority.

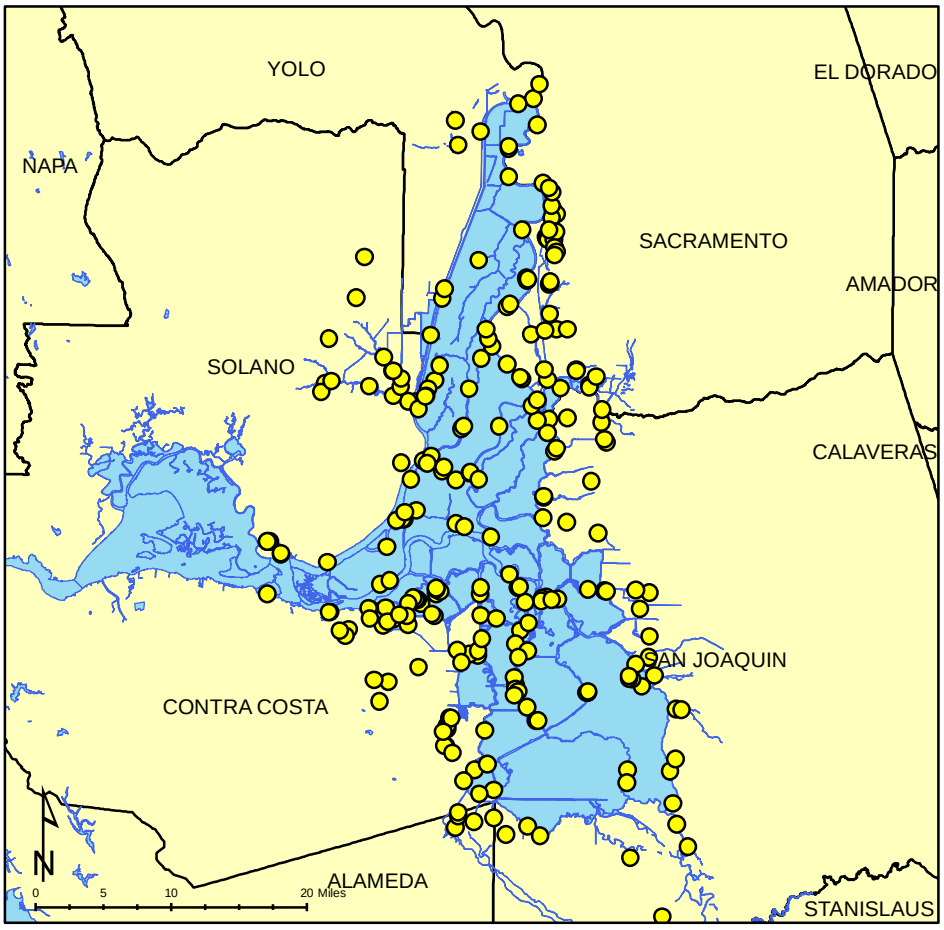

Figure 6. Locations of accuracy assessment samples collected in the 2019 Delta remap project.

The Department of Water Resources provided a boat to access sites that were not accessible via land; all other polygons were assessed via land by foot.

Survey locations were recorded with global positioning system (GPS) receivers using Universal Transverse Mercator (UTM) coordinates based on the North American 1983 datum (NAD 83). One GPS location was recorded within a representative location of each Accuracy Assessment survey. When a stand was inaccessible due to distance or water, and the stand could be clearly viewed, survey data were collected remotely. The GPS location information was recorded at each survey basepoint and a distance and bearing to the stand center were taken. Distance to the stand was measured using a digital rangefinder. Compass bearings were true north using a declination of 16° east. GPS points were later downloaded and the points were shifted to the stand center via trigonometric calculations using the distance and bearing.

A DFW VegCAMP member who had not previously been involved in the project reviewed map delineations and attributes and compared them to the Accuracy Assessment field data. Then each polygon was given a fuzzy logic score for accuracy.

Using a traditional method of accuracy assessment, only one possible answer (considered to be the best answer by an 'expert' in the field) is compared to the map label. However, vegetation map classes do not always lend themselves to unambiguous attribution. While a

map label of the *Distichlis spicata* Alliance may be considered absolutely correct for a particular site, a mapper may only be able to discern a map label of the Temperate Pacific Tidal Salt and Brackish Meadow Group, which is still accurate but not as specific. An alternative method for evaluating map accuracy, and the one chosen for use in this assessment, is based on the use of fuzzy sets, first developed by Gopal and Woodcock (1994). With the fuzzy logic method of accuracy assessment, for each evaluation site, the map label is assigned a ranking score based on the degree of ecological similarity with the ground data. The numeric scoring used in this assessment is shown in Table 3. The scores for alliances and groups with more than 5 Accuracy Assessments performed can be found in Table 4. The protocol used for the 2007 and 2019 Accuracy Assessment efforts can be found in Appendix B.

The field and scoring data were entered into an Access database, available from VegCAMP.

Note: 414 Accuracy Assessments were previously completed for the 2007 mapping effort and the results can be found in a separate report.

Table 3. 2019 Accuracy Assessment fuzzy logic scoring points.

Reason for Score	Score
Photo interpreter completely correct	5
Correct Group OR next level up in hierarchy	4
Threshold/transition between PI call and Final call	4
Based on close ecological similarity	3
Correct Macrogroup OR next level up in hierarchy	3
Correct Division	2
Some floristic/hydrologic similarity	2
Correct only at Lifeform	1
No similarity above Formation and incorrect Lifeform	0
Survey removed because significant change in polygon	none
Survey removed because inadequate portion of the polygon viewed	none
Survey removed because field/PI data are incomplete, inadequate or confusing	none
Supplementary point, not scored	none

From 4/29/2019 to 5/10/2019, 246 samples were collected to assess the accuracy of the mapped polygons using the Accuracy Assessment Field Form and Accuracy Assessment Protocol for the Delta. Several of these samples were disregarded by DFW for three reasons. Firstly, the crew performing the assessment was only able to view/access a small portion of the polygon. A second exemption was for mapping classes with less than five surveys done for that class. And lastly, the vegetation in the polygon had changed significantly from the time it was attributed to the time it was accuracy assessed. The contingency table (Table 5) displays the vegetation map types surveyed for accuracy. Each row in the table represents a type as mapped by the photo interpreters (the producers); by reading across the row, one can see what the field surveyors (users) assessed the mapped polygon types to be on the ground. Numbers on the diagonal show when the producers and users agreed on a specific polygon's vegetation map type. Note that the table displays the numbers of assessed polygons by type and does not incorporate fuzzy scores.

Two forms of accuracy (users' and producers') can be estimated from the data (Story and Congalton 1986). Users' accuracy provides an estimate of commission error, or how well

spatial mapping data actually represent what is found on the ground, i.e., if the user goes to a location mapped as a certain type, what is the probability it is in fact that type? Producers' accuracy, on the other hand, measures omission error, or the probability that the vegetation type observed in the field is mapped as that type. Producers' accuracy may inform the mappers if a mapping type is even detectable (Story and Congalton 1986, Lea and Curtis 2010).

The overall accuracy of each of the 16 adequately sampled types was between 80% and 83% (averaging users' and producers' scores for each). These scores are above the minimally acceptable average correctness put forth by VegCAMP standards. Table 4 shows the users' and producers' accuracy scores for sampled types.

Bolboschoenus maritimus was not mapped in 2007 and therefore the GIC did not have a reference signature for this alliance when mapping in 2016. Based on field observations while conducting accuracy assessments, there is significantly more of this vegetation type than has been mapped, especially along Highway 37. Further sampling of this type (and inclusion in a vegetation key and classification) would improve future mapping efforts.

Table 4: Users' and producers' polygon count and average closeness-of-fit (fuzzy) scores per map class, in order of the classification hierarchy. Types with Users' or Producers' counts less than 5 were not scored.

Producers	Producers' Score	Producers' Count	Users' Score	Users' Count
Ailanthus altissima - provisional	96.0	5	93.3	6
Robinia pseudoacacia	80.0	9	96.7	6
IMF	73.3	9	80.0	7
Platanus racemosa	90.0	10	90.0	6
Populus fremontii	96.7	6	91.1	9
Quercus lobata	87.5	8	71.8	17
Salix gooddingii	83.3	6	82.0	10
Alnus rhombifolia	51.4	7	68.0	5
Quercus agrifolia	85.0	8	85.7	7
Baccharis pilularis	80.0	7	83.3	6
Rubus armeniacus	80.0	7	62.5	8
Salix exigua	100.0	7	88.0	10
Salix lasiolepis	88.6	7	83.3	6
CAI	85.7	7	54.8	27
Schoenoplectus (acutus, californicus)	91.1	9	90.0	10
NRW	56.0	5	60.0	8
Mean Overall Accuracy	**82.8**		**80.0**	

Table 5: Contingency table from accuracy assessment, type mapped vs. observed in the field (use zoom tool to view table)

Type Mapped \ Observed Type in Field	Ailanthus altissima - provisional	Eucalyptus (globulus, camaldulensis)	Robinia pseudoacacia	IMF	Acer negundo	Juglans hindsii and hybrids	Phragmites australis	Platanus racemosa	Quercus agrifolia	Salix gooddingii	Salix laevigata	RWF	Alnus rhombifolia	Fraxinus latifolia	Salix lucida	VRF	Populus fremontii	Quercus lobata	Quercus wislizenii - tree	WVO	Baccharis pilularis	Rubus armeniacus	Tamarix spp.	Cephalanthus occidentalis	Salix exigua	Salix lasiolepis	Vitis californica - provisional	RWS	Allenrolfea occidentalis	Frankenia salina	Centaurea (solstitialis, mexicana)	CAI	DAM	Persicaria lapathifolia - Xanthium strumarium	Schoenoplectus (acutus, californicus)	FEM	Managed annual and perennial wetland vegetation	NTF	Eichhornia crassipes	Ludwigia (hexapetala, peploides)	NRW	Schoenoplectus americanus	SAM	Distichlis spicata	TBM	VPB	Elymus (Leymus) triticoides	WTM	BGS	SVP	TFB	Salicornia pacifica	Lepidium latifolium	Grand Total
Ailanthus altissima - provisional	4		1																																																			5
Eucalyptus (globulus, camaldulensis)																																																					0
Robinia pseudoacacia	1		5		1	2																																															9
IMF	1	1		4		3																																															9
Acer negundo																																																					0
Juglans hindsii and hybrids																																																					0
Phragmites australis																																																					0
Platanus racemosa								5		1							3	1																																				10
Quercus agrifolia									5									1	2																																			8
Salix gooddingii										4			1													1																												6
Salix laevigata				1						1	1																																										3
RWF				2						2			1				1	1																																			7
Alnus rhombifolia					2				1				1					2							1																													7
Fraxinus latifolia					1	1		1		1		1	1	1												1																													8
Salix lucida													1		3																																								4
VRF					1													1		1				1				1																										5
Populus fremontii												1				5																																							6
Quercus lobata						1												6	1																																			8
Quercus wislizenii - tree									1					1				5	1																																				8
WVO																																																					0
Baccharis pilularis																					5								1			1																						7
Rubus armeniacus																						5					1					1																						7
Tamarix spp.																								1	1																													2
Cephalanthus occidentalis																								3																														3
Salix exigua																									7																														7
Salix lasiolepis										1														1	1	4																												7
Vitis californica - provisional																																																						0
RWS																																																						0
Allenrolfea occidentalis																																																						0
Frankenia salina																																																						2
Centaurea (solstitialis, mexicana)																																																						4
CAI						1																																																7
DAM																																																						2
Persicaria lapathifolia - Xanthium strumarium																																																						0
Schoenoplectus (acutus, californicus)							1																													7													1				9
FEM														1										4								1				1																	7
Managed annual and perennial wetland vegetation																																		1				2														3
NTF																					1																	5											1				7
Eichhornia crassipes																																			2		4															6
Ludwigia (hexapetala, peploides)																																																				0
NRW																					1											1		1					1								1						5
Schoenoplectus americanus																					1														2																		3
SAM																																																					0
Distichlis spicata																																1															2		2					1	6
TBM																														1		3																	3					7
VPB																														1		1																		2		1			5
Elymus (Leymus) triticoides																																																					0
WTM																					1																													2		1					4
BGS																																																							0
SVP																																																							2
TFB																																																							0
Salicornia pacifica																														2																								1	4
Lepidium latifolium																																5																						5
Grand Total	6	1	6	7	5	8	1	6	7	10	1	2	5	2	4	0	9	17	4	1	6	8	0	10	10	6	1	1	3	2	0	27	0	2	10	0	0	2	0	9	8	0	1	2	0	4	2	2	2	0	2	1	1	224

Diagnostic Vegetation Key and Descriptions

Table 6 contains the key for distinguishing the classified vegetation types created in 2007. Due to the diversity of vegetation in the fine-scale mapping area, and to avoid an excessively long document, a series of paired statements (or couplets) was not developed for each option. Instead, sets of characteristics with choices beneath them are provided. The key first leads the user to the general options, and the individual selections for the vegetation associations are listed beneath these options. The user needs to work through the numbered list of types from the more general to the most specific options until the best fit is reached. The choices are identified by a combination of alphanumeric codes, using capital letters, numerals, upper- and lowercase letters, and decimal points to distinguish the different key levels. The most basic, general levels in the key are on the left side of the alphanumeric
code, and the most specific are on the right side. This coding system in the key relates to a series of left indentations. Thus, down the left-hand side of the pages are the major groupings; nested within them are the subgroupings. The preliminary key directs the user to the major groups, such as forest/woodland, shrubland, and herbaceous, with the specific choices beneath them. The more specific lists within these are generally based on presence/absence or dominance/sub-dominance of species until arriving at the optimum choice. Since there may be more than two alternatives in a group, the user must be sure to work through all of the options in a list before they decide on the best choice.

Vegetation descriptions follow the key, in which the alliances and associations are nested within the following groupings: tree-overstory (forest/woodland), shrub-overstory, and herbaceous. The key and descriptions hopefully will afford further refinement to the understanding of the project area's vegetation, both from the standpoint of classification and mapping.

Note: The GIC under contract was required to map vegetation types to the alliance level and did not use the association levels listed in the following key.

Table 6. Key for distinguishing classified vegetation types in the Delta

KEY FOR DISTINGUISHING CLASSIFIED VEGETATION TYPES IN THE DELTA 2007

Class A. Vegetation with an overstory of trees (at least 5 m tall). Absolute tree canopy cover is generally greater than 5%, but occasionally may be less than 10% over a denser understory of shrub and/or herbaceous species. If the latter, trees are evenly distributed across the stand and are ecologically significant members of the stand (stand is thus "characterized" by trees, even if not "dominated" by them) = **Tree-Overstory Vegetation**

Class B. Vegetation characterized by woody shrubs or subshrubs in the canopy. Tree species, if present, generally total less than 5% absolute cover. Herbaceous species may total higher cover than shrubs. Shrubs are usually at least 10% cover, except for Iodine bush *(Allenrolfea occidentalis)* and Mojave seablite *(Suaeda moquinii)*, which may have cover as low as 5% = **Shrub-Overstory Vegetation**

Class C. Vegetation characterized by non-woody, herbaceous species or perennial subshrubs in the canopy including grass, graminoid, and broad-leaved herbaceous species. Shrubs, if present, usually comprise <10% absolute cover. Trees, if present, generally compose <5% absolute cover = **Herbaceous Vegetation**

<u>Class A.</u> Tree-Overstory Vegetation

Group I. Woodlands and forests characterized by evergreen (non-winter deciduous) trees.

I.A. Overstory is dominated by one or more species of the non-native tree, Eucalyptus (*Eucalyptus*) . . .

***Eucalyptus* Alliance**

I.B. Overstory is dominated by coast live oak (*Quercus agrifolia*). In the Delta, largely represented by a phase of an unknown association characterized by *Quercus agrifolia/Equisetum hyemale* . . .

***Quercus agrifolia* Alliance**

Group II. Woodlands and forests characterized by winter-deciduous species.

II.A. Overstory is dominated by non-native trees.

IIA.1. Tree-of-Heaven *(Ailanthus altissima)* dominates the overstory. In the Delta, these are planted groves . . .

***Ailanthus altissima* Alliance**

IIA.2. Black locust *(Robinia pseudoacacia)* dominates the overstory. In the Delta, these are planted groves . . .

***Robinia pseudoacacia* Alliance**

II.B. Overstory is dominated by native trees.

IIB.1. White alder *(Alnus rhombifolia)* comprises 10% or more cover in these stands. Other major woody species may include willows (*Salix* spp.), which may have significantly higher cover than white alder, but not other hardwood trees such as valley oak *(Quercus lobata)* . . .

***Alnus rhombifolia* Alliance**

IIB1.a. White alder *(Alnus rhombifolia*) is typically the strongly dominant tree, with the presence of narrowleaf willow *(Salix exigua)* and California wild rose *(Rosa californica)* at 1% or greater; no red-osier dogwood *(Cornus sericea)* present . . .

***Alnus rhombifolia / Salix exigua (Rosa californica)* Association**

Two phases of this Association occur in the Delta, one with a significant amount of narrowleaf willow *(Salix exigua)* in the tree or shrub layer, and the other without much narrowleaf willow but with an understory containing California wild rose *(Rosa californica)* . . .

***Alnus rhombifolia / Salix exigua* phase**
***Alnus rhombifolia / Rosa californica* phase**

IIB1.b. White alder *(Alnus rhombifolia*) is typically the strongly dominant tree with an understory of red-osier dogwood *(Cornus sericea).* Arroyo willow *(Salix lasiolepis)* may be a dominant in the shrub layer . . .

***Alnus rhombifolia / Cornus sericea* Provisional Association**

One phase of this association is present in the Delta, characterized by over 10% cover of both shining willow *(Salix lucida)* and red-osier dogwood *(Cornus sericea)* . . .

***Alnus rhombifolia / Salix lucida-Cornus sericea* phase**

IIB1.c. White alder *(Alnus rhombifolia*) is typically the strongly dominant tree, and narrowleaf willow *(Salix exigua),* California wild rose *(Rosa californica),* and red-osier dogwood *(Cornus sericea)* are not significant in the understory . . .

***Alnus rhombifolia* Association**

IIB.2. Oregon ash (*Fraxinus latifolia*) makes up more than 50% of the overstory tree canopy . . .

***Fraxinus latifolia* Alliance**

IIB.3. Box-elder (*Acer negundo*) dominates the tree layer or codominates with Oregon ash (*Fraxinus latifolia*), Fremont cottonwood *(Populus fremontii)*, or Goodding's willow *(Salix gooddingii).* Valley oak has 5% or less cover . . .

***Acer negundo* Alliance**

IIB3.a. Box-elder (*Acer negundo*) dominates the tree layer or codominates with Oregon ash (*Fraxinus latifolia*) or Fremont cottonwood *(Populus fremontii)*, and Goodding's willow *(Salix gooddingii)* is present . . .

***Acer negundo - Salix gooddingii* Provisional Association**

IIB.4. Northern California Black Walnut hybrids *(Juglans X hindsii)* strongly dominate the overstory . . .

***Juglans X hindsii* Alliance**

IIB.5. Fremont cottonwood *(Populus fremontii)* is the sole dominant or is strongly dominant over white alder *(Alnus rhombifolia),* and Goodding's willow *(Salix gooddingii)* is absent . . .

***Populus fremontii* Alliance**

IIB.6. Valley oak *(Quercus lobata)* is the sole dominant in the overstory or it codominates the overstory with box-elder *(Acer negundo),* white alder *(Alnus rhombifolia)*, Oregon ash *(Fraxinus latifolia)*, Fremont cottonwood *(Populus fremontii)*, or California sycamore *(Platanus racemosa)* . . .

***Quercus lobata* Alliance**

IIB6.a. Valley oak *(Quercus lobata)* is the sole dominant in the overstory or it codominates the overstory with Fremont cottonwood *(Populus fremontii)* or Oregon ash *(Fraxinus latifolia).* Himalaya berry *(Rubus discolor)* usually dominates the understory, although when absent it is replaced by California wild rose *(Rosa californica)* or Pacific blackberry *(Rubus ursinus)* . . .

***Quercus lobata / Rubus discolor* Association**

Two phases of this association occur in the Delta, one in which California wild rose *(Rosa californica)* is present in equal or greater cover than Pacific blackberry *(Rubus ursinus).* The second phase must have at least 5% cover of Santa Barbara sedge *(Carex barbarae)* and either wild rose or Pacific blackberry are present . . .

***Quercus lobata / Rosa californica* phase**
***Quercus lobata / Rubus discolor / Carex barbarae* phase**

IIB6.b. Valley oak *(Quercus lobata)* occurs as the dominant species, with box elder *(Acer negundo)* as a codominant or subdominant . . .

***Quercus lobata - Acer negundo* Provisional Association**

IIB6.c. Valley oak *(Quercus lobata)* generally occurs at 20% cover and white alder *(Alnus rhombifolia)* is present but averages >5% cover . . .

***Quercus lobata - Alnus rhombifolia* Association**

IIB.6.d. Valley oak *(Quercus lobata)* and Oregon ash *(Fraxinus latifolia)* generally codominate, although the latter may have low cover. White alder *(Alnus rhombifolia)* and box elder *(Acer negundo)* are largely absent. California grape *(Vitis californica)* averages 10% cover, but may be absent . . .

***Quercus lobata - Fraxinus latifolia / Vitis californica* Association**

In addition there is one phase of this association in the Delta, in which the California grape *(Vitis californica)* is largely absent.

***Quercus lobata - Fraxinus latifolia* phase**

IIB.7. One or more willow species are the primary tree(s) in the riparian overstory. If Goodding's willow *(Salix gooddingii)* and Fremont cottonwood *(Populus fremontii)* are present, then either may dominate. (Note: although most willows may be considered shrubs in this area, they can also be tall enough to be identified as tree willows and therefore are included in both the tree overstory key and the shrub overstory portions of this key. However, other true trees in this section (IIB) take precedence over the usual shrub-like narrowleaf willow (*Salix exigua)* and arroyo willow (*Salix lasiolepis)* in this portion of the key).

IIB7.a. The stand is strongly dominated (over 40% cover) by shining willow *(Salix lucida)* with no other strong dominants; most stands have high cover of Cornus sericea as an understory shrub . . .

***Salix lucida* Alliance**
(Classified into shrubland for mapping purposes)

IIB7.b. Goodding's willow *(Salix gooddingii)* has the highest cover in the tree layer; stands that do not classify into one of the three described associations are typically strongly dominated by *S. gooddingii* and are classified to Alliance level only . . .

***Salix gooddingii* Alliance**

IIB7b.1. Goodding's willow *(Salix gooddingii)* dominates the tree layer and there is no woody understory, just wetland herbaceous plants . . .

***Salix gooddingii* / wetland herb Provisional Association**

IIB7b.2. Goodding's willow *(Salix gooddingii)* is the dominant tree or may codominate with valley oak *(Quercus lobata).* Stands may rarely have Fremont cottonwood *(Populus fremontii)* as a codominant. The understory is characterized by Bermuda grass *(Cynodon dactylon),* ryegrass *(Lolium multiflorum),* willow-herbs *(Polygonum* spp.*)*, cocklebur *(Xanthium* sp.*)*, and other wetland species . . .

***Salix gooddingii - Quercus lobata* / wetland herb Provisional Association**

IIB7b.3. Either Goodding's willow *(Salix gooddingii)* or Fremont cottonwood *(Populus fremontii)* dominate, and understory species do not include wetland herbs listed in IIB7b.2 . . .

***Salix gooddingii - Populus fremontii* Association**

IIB7.c. Narrowleaf willow *(Salix exigua)* is the dominant shrub/tree species, or it may be replaced by arroyo willow *(Salix lasiolepis),* or both may be present. If only arroyo willow is present, then Himalaya berry *(Rubus discolor)* is over 5% cover. If red-osier dogwood *(Cornus sericea)* has >10% cover, see red-osier dogwood shrub alliance . . .

***Salix exigua* Alliance**
(Classified into shrubland for mapping purposes)

IIB7c.1. Narrowleaf willow *(Salix exigua)* is the dominant shrub/tree species, or it may be replaced by arroyo willow *(Salix lasiolepis),* or both may be present. If only arroyo willow is present, then Himalaya berry *(Rubus discolor)* is over 5% cover . . .

***Salix exigua - (Salix lasiolepis) - Rubus discolor* Association**

This association has two phases in the Delta, one in which arroyo willow and Himalaya berry are largely absent but California wild rose codominates with narrowleaf willow, and the other in which arroyo willow and Himalaya berry codominate . . .

***Salix exigua - Rosa californica* Phase**
***Salix lasiolepis - Rubus discolor* Phase**

IIB7.d. Arroyo willow *(Salix lasiolepis)* cover is over 50% and no other willows are dominant or subdominant, and Himalaya berry *(Rubus discolor)* is less than 5% cover . . .

***Salix lasiolepis* Alliance**
***Salix lasiolepis* Great Valley Provisional Association**

Class B. Shrub-Overstory Vegetation

I.A. One or more willow species *(Salix spp.)* dominate the shrub layer, generally considered to be 5 m or less in height. (Note: although most willows may be considered shrubs in this area, they can also be tall enough to be identified as tree willows and therefore are included in both the tree overstory key and the shrub overstory portions of this key.) . . .

IA.1. The stand is strongly dominated (over 40% cover) by shining willow *(Salix lucida)* with no other strong dominants . . .

***Salix lucida* Alliance**
(Classified into shrubland for mapping purposes)

IA.2. Narrowleaf willow *(Salix exigua)* is the dominant shrub species, or it may be replaced by arroyo willow *(Salix lasiolepis),* or both may be present. If only arroyo willow is present, then Himalaya berry *(Rubus discolor)* is over 5% cover. If red-osier dogwood *(Cornus sericea)* has >10% cover, see red-osier dogwood alliance . . .

***Salix exigua* Alliance**
(Classified into shrubland for mapping purposes)

IA2.i. Narrowleaf willow *(Salix exigua)* is the dominant shrub species, or it may be

replaced by arroyo willow *(Salix lasiolepis),* or both may be present. If only arroyo willow is present, then Himalaya berry *(Rubus discolor)* is over 5% cover . . .

***Salix exigua - (Salix lasiolepis) - Rubus discolor* Association**

This association has two phases in the Delta, one in which arroyo willow and Himalaya berry are largely absent but California wild rose codominates with narrowleaf willow, and the other in which arroyo willow and Himalaya berry codominate . . .

***Salix exigua - Rosa californica* Phase**
***Salix lasiolepis - Rubus discolor* Phase**

IA.3. Arroyo willow *(Salix lasiolepis)* cover is over 50% and no other willows are dominant or subdominant, and Himalaya berry *(Rubus discolor)* is less than 5% cover . . .

***Salix lasiolepis* Great Valley Provisional Alliance**
(Classified into shrubland for mapping purposes)

I.B. Silver bush lupine *(Lupinus albifrons)* is the most prevalent species in the overstory shrub layer, which may be very sparse, represented locally by the . . .

***Lupinus albifrons* Antioch Dunes Association**

I.C. Coyote bush *(Baccharis pilularis)* dominates the shrub layer or codominates with arroyo willow *(Salix lasiolepis)* or Himalaya berry *(Rubus discolor)* . . .

***Baccharis pilularis* Alliance**

I.C.1. Coyote bush dominates the shrub layer, with an understory of annual grasses and herbs . . .

***Baccharis pilularis* / Annual Grass-Herb Association**

I.D. Himalaya berry *(Rubus discolor)* is the sole dominant of the shrub layer . . .

***Rubus discolor* Alliance**

I.E. California wild rose *(Rosa californica)* is the sole dominant of the shrub layer . . .

***Rosa californica* Alliance**

I.F. Elderberry *(Sambucus mexicana)* dominates the shrub layer . . .

***Sambucus mexicana* Alliance**

I.G. Red-osier dogwood *(Cornus sericea)* dominates the shrub layer or codominates it with shrubby arroyo willow *(Salix lasiolepis)* or narrowleaf willow *(Salix exigua)* . . .

***Cornus sericea* Alliance**

IG.1. Red-osier dogwood *(Cornus sericea)* codominates the shrub layer with narrowleaf willow *(Salix exigua).* Shining willow *(Salix lucida)* may also codominate . . .

***Cornus sericea - Salix exigua* Provisional Association**

IG.2. Red-osier dogwood *(Cornus sericea)* codominates the shrub layer with arroyo willow *(Salix lasiolepis)* . . .

***Cornus sericea - Salix lasiolepis* Association**

This association has one phase in the Delta, characterized by the occurrence of common reed *(Phragmites australis)* . . .

***Cornus sericea-Salix lasiolepis / Phragmites australis* Phase**

I.H. Buttonwillow (*Cephalanthus occidentalis)* strongly dominates the shrub layer or codominates with Goodding's willow *(Salix gooddingii)* or Himalaya berry *(Rubus discolor)* . . .

***Cephalanthus occidentalis* Alliance**

I.I. Deer brush *(Lotus scoparius)* is the most prevalent species in the shrub layer.

I.I.1. Occasional in weedy, sandy areas throughout Delta . . .

***Lotus scoparius* Alliance**

I.I.2. Occurs at Antioch Dunes . . .

***Lotus scoparius* Antioch Dunes Association**

I.J. Iodine bush *(Allenrolfea occidentalis)* comprises at least 5% cover . . .

***Allenrolfea occidentalis* Alliance**

I.K. Mojave seablite *(Suaeda moquinii)* comprises at least 5% cover . . .

***Suaeda moquinii* Alliance**

Class C. Herbaceous Vegetation

Group I: Vegetation dominated by grasses or grass-like species, and lacking a significant overstory of trees or shrubs.

I.A. Tall (generally 1.5 meter or more) grass and grass-like species are dominant . . .

IA.1. Stands have 30% or more cover of common reed . . .

***Phragmites australis* Alliance**

IA.2. Stands have at least 10% cover of hardstem bulrush (*Schoenoplectus acutus).* When giant bulrush *(Schoenoplectus californicus)* is present, it is much lower in cover than hardstem bulrush. Broadleaf cattail *(Typha latifolia)* occasionally codominates . . .

***Schoenoplectus acutus - (Schoenoplectus tabernaemontani)* Alliance**

IA2.a. Hardstem bulrush (*Schoenoplectus acutus)* makes up 50% or more cover, and no other species has greater than 5% cover . . .

***Schoenoplectus acutus* – pure Provisional Association**

IA2.b.Stands have at least 10% cover of hardstem bulrush (*Schoenoplectus acutus)* and narrowleaf cattail *(Typha angustifolia)* comprises at least 5% cover . . .

***Schoenoplectus acutus - Typha angustifolia* Provisional Association**

IA2.c. Broadleaf cattail *(Typha latifolia)* comprises 10% or greater cover, but not more than the cover of hardstem bulrush (*Schoenoplectus acutus).* No common reed *(Phragmites australis*) present . . .

***Schoenoplectus acutus - Typha latifolia* Provisional Association**

IA2.d. Hardstem bulrush (*Schoenoplectus acutus)* comprises 10% or greater cover, and common reed *(Phragmites australis*) is present. Broadleaf cattail *(Typha latifolia)* may be present . . .

Schoenoplectus acutus - Phragmites australis **Association**

IA2.e. Hardstem bulrush (*Schoenoplectus acutus)* comprises 10% or greater cover, and cocklebur *(Xanthium strumarium)* is present . . .

Schoenoplectus acutus - Xanthium strumarium **Provisional Association**

IA.3. Stands generally have at least 10% cover of giant bulrush *(Schoenoplectus californicus)*. If hardstem bulrush (*Schoenoplectus acutus)* is present, it has less cover than, or is a codominant with, giant bulrush . . .

Schoenoplectus californicus **Alliance**

IA3.a. Giant bulrush *(Schoenoplectus californicus)* generally codominates the stand with water hyacinth *(Eichhornia crassipes)* only . . .

Schoenoplectus californicus - Eichhornia crassipes **Provisional Association**

IA3.b. Hardstem bulrush (*Schoenoplectus acutus)* is subdominant or codominant with giant bulrush . . .

Schoenoplectus californicus - Schoenoplectus acutus **Provisional Association**

IA.4. Stand is dominated by American bulrush (*Schoenoplectus americanus*) . . .

Schoenoplectus americanus **Alliance**

IA.5. Stand has over 50% cover of broadleaf cattail *(Typha latifolia)* and common reed (*Phragmites australis*) is not present . . .

Typha latifolia **Alliance**

IA5.a. Stand has over 50% cover of broadleaf cattail *(Typha latifolia)* and common reed (Phragmites australis) is not present. Water fern *(Azolla filiculoides)* may be abundant . . .

Typha latifolia **- pure Provisional Association**

IA.6. Narrowleaf cattail *(Typha angustifolia)* is the sole dominant above 0.5 m tall . . .

Typha (angustifolia, domingensis) **Tidal Herbaceous Alliance**

IA.6.a. Narrowleaf cattail *(Typha angustifolia)* and saltgrass *(Distichlis spicata)* are the only species with at least 5% cover . . .

Typha angustifolia - Distichlis spicata **Provisional Association**

IA.7. Giant reed *(Arundo donax)* is the dominant species . . .

Arundo donax **Alliance**

IA.8. Pampas grass *(Cortaderia selloana, C. jubata)* is the dominant species . . .

Cortaderia (selloana, jubata) **Alliance**

I.B. Shorter (generally <1.5 meter or more) grass and grass-like species are dominants, with no grasses taller than 1.5 meter making up 20% or more cover (if this is the case, see IA) . . .

IB.1. Stands have at least 10% cover of tufted hairgrass . . .
***Deschampsia caespitosa* Tidal Herbaceous Alliance**

IB1.a. Stands have at least 10% cover of tufted hairgrass and the rare species Mason's Lilaeopsis *(Lilaeopsis masonii)* is present . . .
***Deschampsia caespitosa - Lilaeopsis masonii* Provisional Association**

IB.2. Santa Barbara sedge *(Carex barbarae)* is the dominant species . . .
***Carex barbarae* Alliance**

IB.3. Creeping wildrye *(Leymus triticoides)* is dominant species over 0.5m tall . . .
***Leymus triticoides* Alliance**

IB.4. Toadrush *(Juncus bufonius)* is the dominant species . . .
***Juncus bufonius* non-classified stands**

IB.5. Saltgrass *(Distichlis spicata)* has over 20% cover and perennial pepperweed *(Lepidium latifolium)*, if present, is lower in cover . . .
***Distichlis spicata* Alliance**

IB5.a. Saltgrass *(Distichlis spicata)* has over 20% cover and occurs with a high cover of non-native annual grasses such as soft chess *(Bromus hordeaceus),* ryegrass *(Lolium multiflorum),* rabbitsfoot grass *(Polypogon monspeliensis),* or rattail fescue *(Vulpia myuros)* . . .
***Distichlis spicata* - Annual grasses Provisional Association**

IB5.b. Saltgrass *(Distichlis spicata)* is codominant with pickleweed *(Salicornia virginica)* . . .
***Distichlis spicata - Salicornia virginica* Provisional Association**

IB5.c. Saltgrass *(Distichlis spicata)* is codominant with Baltic rush (*Juncus balticus*) . . .
***Distichlis spicata - Juncus spp.* Provisional Association**

IB.6. Annual ryegrass *(Lolium multiflorum)* is the dominant grass species and saltgrass *(Distichlis spicata)* is not above 10% cover. Some annual herbs may attain equal or higher cover depending on the time of year . . .
***Lolium multiflorum* Alliance**

IB6.a. Annual ryegrass *(Lolium multiflorum)* is the dominant species or is codominant with non-native brome species *(Bromus hordeaceus, B. diandrus),* and bindweed *(Convolvulus arvensis)* is present . . .
***Lolium multiflorum - Convolvulus arvensis* Provisional Association**

IB6.b. Annual ryegrass *(Lolium multiflorum)* is the dominant species and owl's-clover *(Triphysaria eriantha)* is generally codominant. An important indicator species is shining pepper-grass *(Lepidium nitidum)* . . .

***Lolium multiflorum - Triphysaria eriantha* Association (Witham 2003)**

IB6.c. Annual ryegrass *(Lolium multiflorum)* is the dominant species and smooth goldfields (*Lasthenia glabrata* ssp. *glabrata*) is generally codominant. The popcornflower *Plagiobothrys stipitatus* var. *stipitatus* is an important indicator of this type . . .

***Lolium multiflorum - Lasthenia glabrata* ssp. *glabrata* Association (Witham 2003)**

IB6.d. Annual ryegrass *(Lolium multiflorum)* is the dominant species and yellowcarpet *(Blennosperma nanum)* is an important indicator species . . .

***Lolium multiflorum - Blennosperma nanum* Association (Witham 2003)**

IB.7. Stands strongly dominated by Bermuda grass *(Cynodon dactylon)*, or codominant with Birdfoot trefoil *(Lotus corniculatus)* . . .

***Cynodon dactylon* Alliance**

IB.8. Stands strongly dominated by upland annual introduced grasses including soft chess *(Bromus hordeaceus)*, ripgut brome *(B. diandrus)*, wild oat *(Avena fatua),* barley (*Hordeum* spp.), rattail fescue *(Vulpia myuros)* . . .

California Annual Grassland / Herbaceous Alliance

IB8.a. Stands largely dominated by soft chess *(Bromus hordeaceus)* and ripgut brome *(B. diandrus)* . . .

***Bromus diandrus - Bromus hordeaceus* Association Provisional Association**

IB.9. Stands characterized by annual or perennial species associated with managed wetlands, such as Dallis grass *(Paspalum distichum)*, barnyardgrass *(Echinochloa crus-galli),* picklegrass (*Crypsis* spp.), or umbrella sedge *(Cyperus eragrostis)* . . .

Managed wetland vegetation (non-specific introduced graminoid and forb mixed stands)

Group II. Vegetation dominated by annual or perennial forbs and lacking a significant overstory of trees or shrubs.

II.A. Annual or perennial forb vegetation dominated by floating or submerged aquatic plants.

IIA.1. Water primrose *(Ludwigia peploides* ssp. *montevidensis, L. p.* ssp*. peploides,* or *Ludwigia hexapetala)* dominates the stand . . .

***Ludwigia (peploides)* Provisional Association**

IIA.2. Water Hyacinth *(Eichhornia crassipes)* dominates the stand . . .

***Eichhornia crassipes* Alliance**

IIA2.a. Water Hyacinth *(Eichhornia crassipes)* is the sole (or almost sole) plant present . . .

***Eichhornia crassipes* - pure Provisional Association**

IIA.3. Parrotfeather (*Myriophyllum* sp.), fanwort *(Cabomba caroliniana),* or Brazilian elodea *(Egeria densa)* comprise at least 10% of the stand, often with water fern *(Azolla filiculoides)* or floating mats of algae dominating the stand . . .

***Egeria – Cabomba - Myriophyllum* spp. Provisional Association (temporarily placed within the National Classification under *Myriophyllum* spp. Permanently Flooded Herbaceous Alliance)**

IIA.4. Waterweed *(Potamogeton pectinatus)* dominates the stand . . .

***Potamogeton pectinatus* Provisional Association (temporarily placed within the National Classification under *Potamogeton* spp. - *Ceratophyllum* spp. - *Elodea* spp. Alliance)**

IIA.5. Water pennywort *(Hydrocotyle ranunculoides)* dominates the stand . . .

***Hydrocotyle ranunculoides* Alliance**

IIA.6. Valley arrowhead *(Sagittaria sanfordii)* dominates the stand . . .

***Sagittaria sanfordii* Alliance**

IIA.7. Water smartweed *(Polygonum amphibium)* or willow weed *(P. lapathifolium)* comprise over 50% cover of the stand . . .

***Polygonum amphibium (P. lapathifolium)* Provisional Association (temporarily placed within the National Classification under *Polygonum* spp. - Mixed Forbs Temporarily Flooded Herbaceous Alliance)**

IIA.8. Large mosquito-fern (*Azolla filiculoides*) is the sole dominant species . . .

***Azolla filiculoides* Alliance**

II.B. Annual or perennial forb vegetation not dominated by floating or submerged aquatic plants.

IIB.1. Vegetation dominated primarily by native species.

IIB1.a. Alkali heath *(Frankenia salina)* is the dominant species or codominates with saltgrass *(Distichlis spicata)* . . .

***Frankenia salina* Alliance**

IIB1.b. Pickleweed *(Salicornia virginica)* is the dominant species . . .

***Salicornia virginica* Alliance**

IIB1b.i. Pickleweed *(Salicornia virginica)* is the dominant species, with saltgrass *(Distichlis spicata)* at <30% relative cover . . .

***Salicornia virginica - Distichlis spicata* Provisional Association**

IIB1b.ii. Vegetation dominated by pickleweed with an ephemeral annual component of brass buttons (Cotula coronopifolia), which may cover enough ground to codominate in the early growing season . . .

***Salicornia virginica - Cotula coronopifolia* Provisional Association**

IIB1.c. Scouring rush *(Equisetum arvense, E. hyemale)* is the sole dominant species over 0.5 meters in height . . .

***Equisetum (arvense, variegatum, hyemale)* Alliance**

IIB1.d. Whitehead navarretia *(Navarretia bakeri*) is the dominant spring annual (at bottom of drying vernal pools) . . .

Vernal pool stands

IIB1.e. California goldfields *(Lasthenia californica)* is the dominant early spring annual (associated with alkaline clay soils on west side of study area) . . .

***Lasthenia californica* Alliance**

IIB.2. Vegetation dominated primarily by non-native species.

IIB2.a. Fennel *(Foeniculum vulgare)* is the dominant species . . .

***Foeniculum vulgare* Alliance**

IIB2.b. Perennial pepperweed *(Lepidium latifolium)* is the dominant species . . .

***Lepidium latifolium* Alliance**

IIB2b.i. Perennial pepperweed *(Lepidium latifolium)* is the dominant species, with pickleweed *(Salicornia virginica)* and saltgrass *(Distichlis spicata)* present at less than 30% relative cover each . . .

***Lepidium latifolium - Salicornia virginica - Distichlis spicata* Provisional Alliance**

IIB2.c. Tall weedy forbs such as mustard (*Brassica* sp.), poison-hemlock (*Conium maculatum)*, and milk thistle *(Silybum marianum)* either dominate or codominate the stand . . .

Ruderal herbaceous (non-native annual forbland)

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APPENDIX A: Mapping Standards

Minimum categorization level

Vegetation Types

Vegetated polygons were mapped to the alliance level of the National Vegetation Classification System (NVCS) hierarchy if it was possible to discern the vegetation type at the given resolution of the imagery. Otherwise, vegetation was mapped to the group level. Classification of groups and alliances can be found in the key provided in Table 4 and also in Vegetation Alliances and Associations of the Great Valley Ecoregion, California (Buck-Diaz et al. 2012) and A Manual of California Vegetation (Sawyer et al. 2009).

Vegetation Cover

Tree type alliances were mapped when trees were > 5% of the polygon. The percent of absolute tree cover was estimated taking into account the porosity of the tree canopy. Canopy of vegetation over water was digitized following the canopy line (as opposed to estimating the shoreline beneath the canopy). If there was a change in canopy overstory density or size class within the same alliance, the polygon was segregated if it was >5 acres. If it was the understory layer that changed and the alliance remained the same, the polygon was segregated if it was >10 acres.

Shrub vegetation alliances were mapped when tree cover was <5%, and shrub cover was >10%. The percent of absolute shrub cover was estimated taking into account the porosity of the shrub layer. A few shrubs such as *Allenrolfea occidentalis* and *Suaeda moquinii* were determined by the Department of Fish and Wildlife (DFW) to be exempt from this standard rule, and were mapped at a lower percentage of cover.

Herbaceous vegetation types were mapped to the group/alliance level when tree cover was <5%, shrub cover was <10%, and the herbaceous plant cover was >10%. The percent of absolute herbaceous cover was estimated taking into account the porosity of the herbaceous layer. Most of the herbaceous polygons were left at the group level due to the limits of aerial photo interpretation and resolution.

Note: All vegetation cover was estimated using “Birdseye Total Cover,” i.e. what can be seen on the aerial photo excluding understory layers when covered by an overstory layer.

Agriculture, Urban, Water, Mining, Pasture and Grazing, Barren Gravel, and Roads

- The Minimum mapping unit (MMU) for agricultural polygons (AGR) was 5 acres.
- The MMU for urban polygons (URB) was 5 acres.
- The MMU for water (WAT) was one acre.
- The MMU for quarry, mining, and gravel (QMG) was one acre.
- Pasture and grazing land that didn’t appear to be irrigated was mapped as the California Introduced Annual and Perennial Herbaceous group (CAI) if over 1 acre in size. If the pasture land was less than 10 acres and appeared to be irrigated, it was usually grouped with AGR, unless it was in an urban setting, in which case it was grouped with URB (for example, pastures around ranchette housing). If it was irrigated and over 10 acres, it was mapped as AGR.
- Bare Gravel and Sand (BGS) polygons were delineated when the polygon consisted of < 5% tree cover, <10% shrub cover, <10% herbaceous plant cover, and was over one acre in size.
- Roads less than 10 meters were dissolved into other polygon types, while roads wider than 10 meters were labeled as URB or AGR depending on what they were

adjacent to. Major highways were mapped as URB. Tree canopy hanging over roads, regardless of road width, was mapped as the tree type.

Appendix: B

Accuracy Assessment Protocol

This protocol describes Accuracy Assessment (AA) data collection procedures. The primary purpose of the AA fieldwork is to supply data to test the accuracy of a specific vegetation map. The information collected can also contribute additional data for the classification of vegetation communities. The primary sampling units are the vegetation polygons delineated by photo interpreters in the creation of the vegetation map.

If an entire AA polygon cannot be fully investigated due to terrain or other reasons, as much of the polygon as can be evaluated should be assessed.

Note that a delineated polygon may differ from the conventional definition of a stand of vegetation. A stand is the basic physical unit of vegetation in a landscape. It has no set size. Some stands of vegetation are very small while some may be several square kilometers in size. A stand is defined by two main unifying characteristics:

1) It has *compositional* integrity. Throughout the site, the combination of species is similar. The stand is differentiated from adjacent stands by a discernable boundary that may be abrupt or indistinct.

2) It has *structural* integrity. It has a similar history or environmental setting that affords relatively similar horizontal and vertical spacing of plant species. For example, a hillside forest originally dominated by the same species that burned on the upper part of the slopes, but not the lower, would be divided into two stands. Likewise, sparse woodland occupying a slope with very shallow rocky soils would be considered a different stand from an adjacent slope with deeper, moister soil and a denser woodland or forest of the same species.

The structural and compositional features of a stand are often combined into a term called *homogeneity*. For an area of vegetated ground to meet the requirements of a stand, it must be homogeneous.

A properly delineated polygon may contain more than one stand. One example is a stand that is below the minimum mapping unit (MMU); it cannot be mapped separately and will be absorbed into the surrounding vegetation type. Another example is vegetation that is difficult to identify accurately on photo imagery. Several similar-looking stands may be grouped into one polygon and assigned a vegetation type at a high level, such as Group.

Selecting a location to sample within a polygon

Because many polygons are large, it may be difficult to summarize the species composition, cover, and structure of an entire stand. We are also usually trying to capture the most information as efficiently as possible. Thus, we may be forced to select a representative portion to sample.

Once you are inside the polygon, you must find a representative example of the vegetation in the polygon. Look for variations in species composition and in stand structure. In the process, decide whether the polygon includes more than one mappable vegetation type or if the stand boundaries don't seem to match up with the polygon delineation. A vegetation type is considered mappable if it is large enough to meet MMU and can be delineated without creating unreasonably shaped polygons. Small variations in vegetation that are repeated throughout the polygon should be included in your sample. Once you assess the variation within the polygon, attempt to find a sample area that captures the stand's species composition and structural condition.

If more than one vegetation type is present, fill out an AA form for each type ONLY IF each type is mappable (i.e., it is large enough to meet MMU and can be delineated without creating unreasonably

shaped polygons). Check the “More than 1 vegetation type in this polygon” box and include notes on how the polygon should be split. It may be helpful to drawing the dividing lines on a paper copy of the vegetation map.

You must be able to view a minimum of 20% of the polygon that you are assessing (10% for polygons that are larger than 40 acres). If you see less, the Accuracy Assessment survey will be discarded. Record the percentage of the polygon that you can see from the survey point. If you see more of the polygon from the road or from another vantage point, record the total percent of the polygon that was viewed.

In some cases, safe travel to the allocated polygons may not be possible. The reasons include gated roads or roads in poor condition, one-way foot travel between vehicle and polygon in excess of an hour, and other safety concerns. If a polygon is inaccessible, make a note on the map as to the reason it cannot be reached.

Survey Activities

When a survey location has been chosen, a waypoint is recorded on a GPS device. At a minimum, these data should be recorded in the device: Waypoint ID, Polygon UID, Date, Surveyors, GPS Name, Projected, and Map Unit.

Four photos are taken in the cardinal directions, starting at the north and proceeding in a clockwise direction (N, E, S, W). Additional photos may be taken of the stand vegetation if considered useful.

The paper Accuracy Assessment Field Form is filled out completely. Descriptions of all fields on the form are provided below.

How to enter fields on the form

Surveyor: The full name of the person recording should be provided on the first field form for the day. On successive forms, initials can be recorded.

Other Surveyors: The full names of each person assisting should be provided on the first field form for the day. On successive forms, initials of each person assisting can be recorded.

Date: The date the AA point was sampled. Use the standard U.S. format of “month-day-year” or use letters to write out the month.

Location Name: The name of the property, park, or the location within large holdings (like USFS or BLM properties).

Waypoint ID: The Waypoint ID in this format: GPS device name + date (yymmdd) + time (hhmm). For example, for a survey taken on iPad “V” on March 27 at 1:45 in the afternoon, the Waypoint ID will be “V1903271345.”

Polygon UID: The unique identifier (UID) assigned to each polygon, displayed in the GPS data and on paper maps.

GPS name: The name/number assigned to the GPS unit.

Projected? Yes / No / Base: Circle the appropriate option:

****Note**: If you are not able to enter the polygon, a point *must* be taken where you are standing. The distance, bearing, and inclination to the vegetation you are describing must be recorded on the datasheet.

> **Yes** - The point is a projected, or offset point. The surveyor used a bearing and distance to project the point to match what they are describing with the survey.
>
> **No** - The surveyors are in the vegetation they are describing and the point is where the observer was standing for photographs. This location can also be used as a base location for an offset survey.
>
> **Base** - Base point only. This is where a surveyor was standing when taking an offset survey to describe vegetation not at that point. No plant data or vegetation descriptions are associated with this location. However, cardinal photos taken at this point will be stored in a directory of this name.

Bearing (°): The compass bearing from the Base point to the Projected point.

Distance (m): The distance in meters from the Base point to the Projected point, determined by use of a range finder.

Inclination (°): The vertical offset from the Base point to the Projected point.

Base Waypoint ID: For a projected point, this is the location where the surveyor was standing when the information was collected. Cardinal photographs will be taken at this point and will be stored on the computer under this ID. Photographs of the stand vegetation will be taken from this point and will be stored on the computer under the Projected point's ID.

Base / Projected UTMs or Decimal degrees: If the point is projected, circle whether the coordinates of the base point or the offset point have been recorded. These will generally be for the base point.

PDOP: The accuracy of the GPS location. Record the error reading if provided on your device.

GPS coordinates: Record either UTM coordinates, easting (**UTME**) and northing (**UTMN**), or decimal degrees, **LAT** (latitude) and **LONG** (longitude). Record this information from a GPS unit.

Camera name / Photo #s: Write the name of the camera, JPG numbers, and direction of photos. *Take four photos in the main cardinal directions (N, E, S, W) clockwise from the north, from the GPS location.* This symbol can be used to indicate the cardinal photos: 

. Make sure to take additional photos of the general composition of the stand if the cardinal photos do not do an adequate job; note the JPG numbers and a description and direction of each additional photo.

Species list and coverage

List up to twelve species that are dominant or that are characteristically consistent throughout the stand. These species may or may not be abundant, but they should be constant representatives in the survey. When different layers of vegetation occur in the stand, make sure to list species from each stratum. As a general guide, make sure to list at least 1-2 of the most abundant species per stratum.

Strata:

> **T = Overstory tree.** A woody perennial plant that has a single trunk.
>
> **S = Shrub.** A perennial, woody plant that is multi-branched and doesn't die back to the ground every year.
>
> **H = Herb.** An annual or perennial that dies down to ground level every year.
>
> **N = Non-vascular.** Includes mosses, liverworts, hornworts, and algae.

Species: Use Jepson Manual nomenclature. When uncertain of an identification (which you intend to confirm later) use parentheses to indicate what part of the determination needs to be confirmed. For

example, you could write out *Brassica* (*nigra*) if you are sure it is a *Brassica* but you need further clarification on the specific epithet.

% cover: provide the % absolute aerial cover for each species listed. All species percent covers may total over 100% because of overlap.

C: If a species collection is made, it should be indicated with a "C" (for collected). If the species is later keyed out, cross out the species name or description and write the keyed species name in pen on the data sheet. Do not erase what was written in the field, because this information can be used if specimens get mixed up later. If the specimen is then thrown out, add a "T" to the "C" in that column (CT = thrown out after confirmation) or cross out the "C". If the specimen is kept but is still not confidently identified, add a "U" to the "C" (CU = collected and unconfirmed). In this case the unconfirmed species epithet should be put in parentheses [e.g. *Hordeum (murinum)*]. If the specimen is kept and is confidently identified, add a "C" to the existing "C" (CC = collected and confirmed). If the specimen is later deposited in an herbarium, add a "D" to the existing "C" (CD = collected and deposited) and note the receiving herbarium.

Notes: Describe the stand age or seral stage, disturbance history, nature and extent of land use, and other site environmental and vegetation factors. Include recommendations for line-work revision, discernibility of the vegetation based on season and topography, problems with classification interpretation, homogeneity of vegetation, and unusual sightings of plants or animals.

Map Unit Name: Enter the vegetation type name here*.* Refer to the *Key to vegetation types in the Great Valley Ecoregion of California* to select the type. If the vegetation in this polygon does not exactly match the descriptions in the key, enter the best-fitting vegetation type here and the second-best type in the next field (see **Secondary** below). For further verification of the vegetation, refer to the Stand Tables.
Note: You must select a Map Unit Name from the key or the classification hierarchy. Do not invent a vegetation type based on the species list.

Secondary (Optional): Assign a second-best-fitting name for the vegetation within the polygon. Assign a secondary code **only** if there is some ambiguity in assigning the polygon to a primary vegetation. Note the reason for assigning a secondary call within the "*Confidence in map unit ID"* field below.

Confidence in map unit ID? L M H Explain: Note the level of confidence you feel in the map unit identification by circling **L**ow, **M**oderate, or **H**igh. This is an area to describe how well the stand characteristics match the Vegetation Key. Are all diagnostic species present in proper proportions? If not, how do they differ? If a secondary type is identified, what made the stand type ambiguous? ***Note that if you choose low or moderate confidence, you should have a secondary call, as an alternative way to classify the vegetation.***

Linework problems: Check the box if the polygon boundary line does not surround a distinct vegetation type. Examples for which you would check the box include situations where there is more than one type of mappable vegetation within the polygon, when a portion of the boundary includes part of an adjacent stand, or when the stand continues beyond the polygon boundary. If checked, provide comments in the Notes section to explain.

More than 1 vegetation type in this polygon: Check if there is more than one vegetation type within the polygon. If the polygon includes more than one type, note the additional vegetation types in the Notes section. Your survey should be taken in the vegetation type that covers the largest area in the polygon. If the additional vegetation types meet the MMU, then take a survey in each type as described above.

Vegetation change since imagery taken: Check the box if the vegetation in the polygon has changed since the aerial imagery used as the base of the vegetation map was taken. If yes, provide a description in the Notes section of how the vegetation has changed (for example: burned, developed,

visible dominance change over time).

Conifer Cover: The total foliar cover (considering porosity) of all live conifer trees, disregarding overlap of individual trees.

Hardwood Cover: The total foliar cover (considering porosity) of all live hardwood trees, disregarding overlap of individual trees.

Total Tree Cover: The total foliar cover (considering porosity) of all live tree species, disregarding overlap of individual trees. This value may be less than the sum of the conifer and hardwood covers due to overlap.

Shrub Cover: The total foliar cover (considering porosity) of all live shrubs, disregarding overlap.

Herb Cover Class: The total cover (considering porosity) of all herbaceous species, disregarding overlap. Circle the appropriate cover class range.

Tree Height: Circle the height range of the modal tree height.

Tree DBH: Circle one of the tree size classes provided. Size class is based on the average diameter at breast height (dbh) of each trunk (standard breast height is 4.5ft or 137cm). When marking the main size class, make sure to estimate the mean diameter of all trees over the entire stand, and weight the mean toward the larger tree dbh's.

Invasives: Circle the appropriate level.

Isolated Tree: Circle **Yes** if the vegetation is not a tree type but contains isolated trees that make up less than 5% cover.

Rough % of polygon viewed:

Enter a rough estimate of the **percent of the polygon** that you were able to assess from your point.

Total % viewed:

If you were able to view any additional area while driving or walking around or through the polygon, add that to the percent viewed from the point and record it here.

Accuracy Assessment Field Form

Surveyor: *Other Surveyors:*	**Date:**
Location Name:	
Waypoint ID: **Polygon UID:**	**GPS Name** _____ **Projected? Yes / No / Base** If Yes, enter: **Bearing (°):** _____ **Distance (m):** _____ **Inclination (°):** _____ If Yes, enter: **Base Waypoint ID**: _____ **Base** UTMs / **Projected** UTMs (circle one) Record either UTMs or Decimal Degrees **UTME** ____ ____ ____ ____ ____ ____ **UTMN** ____ ____ ____ ____ ____ ____ ____ **PDOP: +/-** Decimal degrees: **LAT** __ __ . __ __ __ __ __ __ **LONG** __ __ __ . __ __ __ __ __ __
Camera name: **Photo #s:**	

Strata	Species	% cover	C		Species	% cover	C

Notes:

Map Unit Name:	Secondary:

Confidence in map unit ID: L M H Explain:

Describe above:	Linework problems □	More than 1 vegetation type in this polygon □	Vegetation change since imagery taken □

Conifer Cover: _____ Hardwood Cover: _____ Total Tree Cover: _____ Shrub Cover: _____

Herb Cover Class woody cover <2% 2–9% 10–39% 40-59% >59% >40%

Tree Height <1m 1-5m 5-20m 20-50m >50m NA

Tree DBH <1” 1-6” >6-11” >11-24” >24”

Invasives (absolute cover) none: <5% low: 5-25% moderate: 25-50% high: >50%

Isolated Tree NO YES

Rough % of polygon viewed from point _____ Total % viewed _____