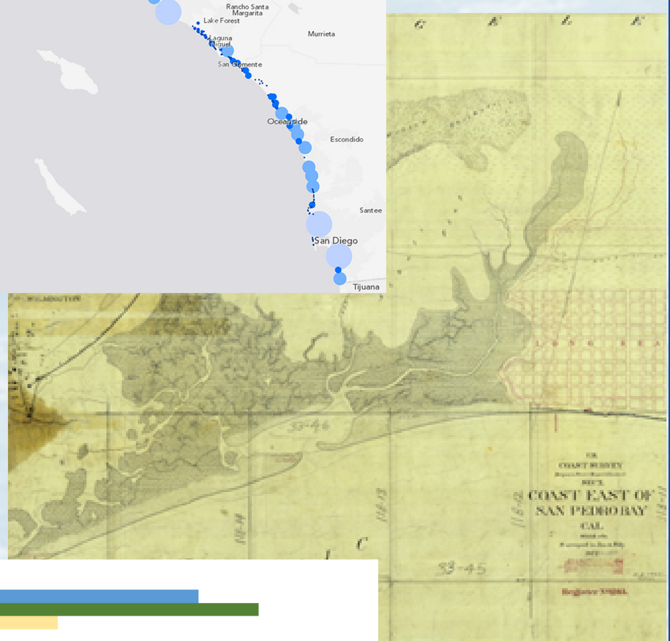
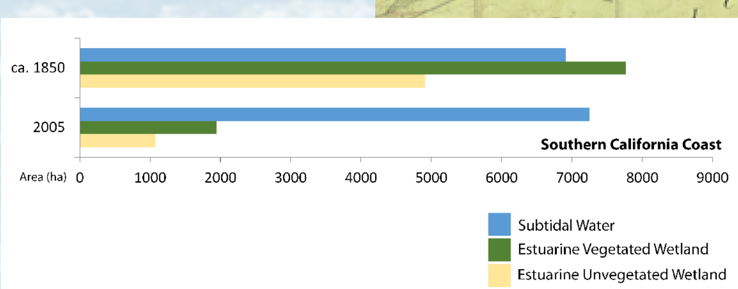
Wetlands of the Southern California Coast: Historical Extent and Change Over Time





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SCCWRP Technical Report 826
SFEI Report 720

Wetlands of the Southern California Coast – Historical Extent and Change Over Time

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EXECUTIVE SUMMARY

Southern California's coastal wetlands are an interrelated set of resources that collectively provide a broad suite of ecological, hydrological, and biogeochemical functions. Managing and restoring these systems requires a regional perspective that can inform holistic decision making. Knowledge of historical conditions provides a baseline of the extent and condition of wetlands lost, and is important to guide regional planning. The U.S. Coast and Geodetic Survey topographic sheets (T-sheets) provide the most important single source for understanding the physical and ecological characteristics of the US shoreline prior to Euro-American modification. Their depictions of coastal wetlands and other estuarine habitat types can provide relatively consistent information about the extent and distribution of those systems along the southern California Bight (SCB) prior to substantial human alteration. Although most appropriately used in conjunction with other data sources, the T-sheets can provide a foundation for regional analysis and a platform on which future, more detailed investigations can be based.

This project builds on earlier efforts to provide comprehensive analysis of the 40 T-sheets that cover the SCB from Point Conception to the US-Mexico border. High quality scans of the original T-sheets produced between 1851 and 1889 were obtained along with the surveyor notes. T-sheets were digitized, georeferenced, and interpreted in order to provide a map of coastal estuaries (both large and small) and coastal drainage systems representing conditions along the SCB coast in the mid-late 19th Century. This analysis was used to answer the following questions:

1. How much total estuarine habitat was there historically (i.e., as mapped on the T-sheets) compared to today?

2. How many total coastal *systems* occurred historically?

3. What has happened to historical estuarine habitat types?

Extent of coastal estuarine habitats

The SCB coast supported approximately 19,591 hectares of estuarine habitats. Approximately 40% of this area was vegetated wetlands (e.g., salt marsh), 25% was unvegetated wetlands (e.g. salt flat and mudflat), and the remaining 35% was subtidal water. In addition to these habitat types, an additional 5,496 hectares of "other wetlands" were mapped on the T-sheets. These included dune and beach, woody vegetated wetlands, high marsh habitat, isolated ponds, and riverine habitat.

Over half (~57% or ~11,000 hectares) of all historical estuarine habitats were found in San Diego County, mostly associated with Mission and San Diego Bays. Both Los Angeles and Orange Counties contained about 15% each of the total historical estuarine area. The largest expanses of historical salt flats occurred in Los Angeles County.

Number of estuarine systems

A total of 331 coastal systems occurred along the SCB coast. Approximately 2/3 of these systems consisted of small coastal drainages without any associated terminal wetlands. Individual coastal systems were relatively evenly distributed along the coast, with each county having between 60 and 90 systems. The distribution of systems by size was also relatively uniform across the counties. The exceptions were a slightly higher concentration of medium and large systems in San Diego County and slightly more channel only systems in Los Angeles County. On a regional scale, larger systems occur in three areas

distributed along the SCB coastline, south San Diego, Long Beach, and Southern Ventura County. These three nodes were connected through strings of medium and smaller wetlands.

The 331 systems can be grouped in 15 distinct archetypes (or distinct compositions) representing combinations of size and dominant habitats. These archetypes tended to be spatially aggregated along the coast into loose "families" of systems.

Change over time

Since ca. 1850 there has been an overall loss of 9,317 hectares, or 48% of historical estuarine habitat types along the SCB coast. Estuarine vegetated wetlands have experienced the greatest loss in terms of absolute area (-5819 ha, 75% loss), while estuarine unvegetated wetlands have experienced the greatest proportional loss of 78% of historical extent (Figure ES-1). In contrast, the contemporary landscape represents a 5% increase in subtidal habitat from historical extent. These differential losses have shifted the proportional composition of southern California estuaries. Historically there was a relatively even split between estuarine vegetated (40%), estuarine unvegetated (25%), and subtidal water (35%). Currently the proportional composition is heavily weighted towards subtidal water (71%) while estuarine vegetated (19%) and unvegetated (10%) make up less than ⅓ of the total area combined.

Declines in estuarine area vary by county. Total losses across all counties range from 62% in Santa Barbara to 31% in San Diego. Additionally, the composition of estuaries in the counties has shifted. In the southern most counties (Los Angeles, Orange, and San Diego) there has been a significant increase in subtidal water while both intertidal and vegetated wetlands have decreased. Santa Barbara and Ventura Counties have maintained an estuarine composition similar to that seen in ca. 1850.

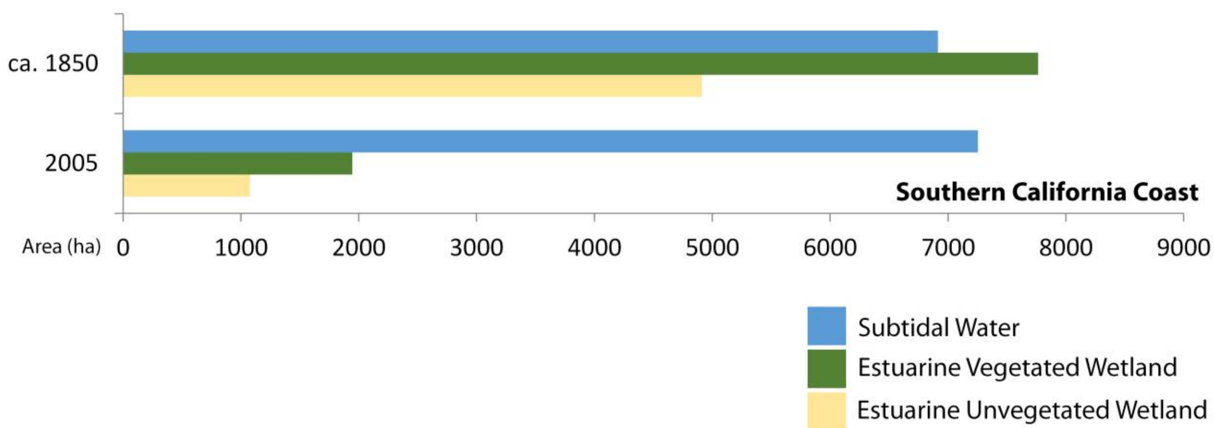

Figure ES-1. Change in overall extent and composition of estuarine habitat types between ca. 1850 and ca. 2005

Our estimated estuarine habitat losses, although substantial, are significantly lower than previously reported estimates of over 90% total wetland loss in California. Overall estuarine habitat area changes reflect and, to some extent, hide the disproportionate impacts to different estuarine habitat types. For example subtidal habitat has increased slightly while other types have decreased dramatically. Differences from other estimates may also be explained by the fact that our analysis is more precise than that used to produce previous estimates and/or that previous estimates may have included other wetland types or locations not included in this study. Lower than "expected" rates of loss may also reflect policies and programs over the last 40 years aimed at protecting and restoring coastal wetlands. Looking to the future, knowledge of historical wetland extent and patterns of loss can be used to inform future planning for diverse and resilient coastal landscapes.

This report provides a synthesis of the main results of our analysis. Scanned images of the T-sheets, GIS and Google Earth layers of the maps, and the underlying data from this project are available at www.caltsheets.org.

Acknowledgements

Funding for this work was provided the California State Coastal Conservancy (Agreement 06-061), U.S. Fish and Wildlife Service (Co-op Agreement #80211AJ111), and the California State Wildlife Conservation Board. Dr. John Cloud was instrumental in helping us obtain high resolution scans of the T-sheets that formed the basis for much of our analysis. We thank the Wetland Recovery Project Wetland Managers Group for their input and feedback at key junctures of this project. We also thank Wayne Engstrom, Walter Heady, Megan Cooper, David Jacobs, and Richard Ambrose for their insightful and constructive comments on the draft report. Finally, we are indebted to the talented surveyors and cartographers who produced the T-sheets that have provided valuable insight into historical conditions along the Southern California Bight.

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BACKGROUND AND INTRODUCTION

Coastal wetlands and other estuarine habitat types have been impacted over the past 150 years due to combinations of development pressure, shoreline erosion, changes in water and sediment production and effects of sea level rise (Van Dyke and Wasson 2005, Stedman and Dahl 2008, Gedan et al 2009). Despite increased management attention, pressure on coastal environments continues; the most recent report on status and trends in the coastal watersheds of the United States estimates 38,450 ha (95,000 acres) of estuarine wetland loss between 2004 and 2009 (Dahl and Stedman 2013).

Continued emphasis on restoration and management of wetlands is imperative given the ongoing threat from both short-term impacts and long-term climatic change. This need is especially pronounced in the coastal environment where wetlands are shaped by both marine and terrestrial (watershed) processes and are subject to a wide range of stressors.

Southern California estuaries naturally function as an inter-related set of systems that collectively support a diversity of natural communities and process along the entire Southern California Bight (SCB), i.e., the area of the coastline between Point Conception and the U.S.-Mexico border. They play critical roles by providing migratory shorebird habitat, acting as nursery and refugia for fisheries, protecting shorelines from erosion, supporting littoral sand delivery and distribution and supporting regional metapopulations of wildlife and plant species (Zedler 1996). Recognition of these broader relationships has fostered discussion of the need to develop regional restoration goals for the greater wetland resources throughout the SCB. This regional perspective will complement the current site-scale planning processes that are associated with specific restoration projects, and may allow more holistic decisions regarding resource allocation and restoration prioritization.

Knowledge of historical conditions provides a baseline of the extent and condition of wetlands lost, and is important to guide regional planning in the SCB. Understanding historical conditions provides valuable context for the relationship between landscape-scale process and wetland composition, and can inform decisions about appropriate restoration targets at different positions along the Southern California coastline. While not meant to provide a blueprint for the future, reconstructing historical patterns can provide critical information to stakeholders. This knowledge can inform decisions regarding restoration and management by improving our understanding of both cultural and natural (i.e. geomorphic) processes that led to current conditions (Jacobs et al. 2011). This is especially relevant in discussions among stakeholders with disparate restoration goals, as it provides for an educated place to initiate conversations. Furthermore, understanding historical conditions can provide insight into key drivers of change over long-time periods that should be considered during planning for long-term restoration and management (White and Walker 1997, Rhemtulla and Mladenoff 2007, Etter et al. 2008, Wiens et al. 2012).

The U.S. Coast and Geodetic Survey topographic sheets (T-sheets) provide the most important single source for understanding the physical and ecological characteristics of the US shoreline prior to Euro-American modification. Between 1851 and 1900, the United States Coast Survey (US Coast and Geodetic Survey after 1878; now National Ocean Survey) produced T-sheets as detailed topographic surveys of the Southern California coast. T-sheets have been used by researchers studying America's shoreline for years, providing baseline information for assessing coastal erosion (e.g., Leatherman 1983), and wetland loss and change (Britsch and Dunbar 1993, Wray et al. 1995, Bromberg and Bertness 2005). Their depictions of coastal wetlands and estuaries can provide relatively consistent information about the extent and distribution of those systems along the SCB prior to substantial human alteration. Although most appropriately used in conjunction with other data sources (see below), the T-sheets can provide a foundation for regional analysis and a platform on which future, more detailed investigations can be based (Raabe et al 2012). A comprehensive evaluation of T-sheets along the entire SCB is a critical element for regional planning and management goal setting.

In January 2011, the Historical Atlas of the Southern California Coast (Grossinger et al. 2011) and the associated T-sheet website (www.caltsheets.org) were released. The original T-sheet analysis (referred to as Phase I in this report) was limited by funding that was only sufficient to digitize and map 26 of the 41 T-sheets that cover the SCB. These 26 T-sheets include most of the larger coastal wetlands in the region, but did not provide a comprehensive coverage of the entire Southern California coast. This project builds on that original effort by completing the digitization and analysis of the remaining T-sheets that cover the SCB coastline and expanding on the breadth and depth of analysis (Figure 1). Specifically this second effort includes:

- Obtaining, digitizing, and georectifying the remaining 14 T-sheets
- Updating mapping on the original 26 T-sheets to ensure consistent approach for all 40 T-sheets
- Mapping small coastal drainage/channel systems shown on all 40 T-sheets
- Applying a consistent classification system to all historical wetland areas

This project also includes development of a change assessment methodology and classification crosswalk for preliminary comparison of historical T-sheets and contemporary wetland mapping. This comparison is used to answer the following questions that can support both regional and local planning efforts:

1. How much total estuarine habitat was there historically (i.e., as mapped on the T-sheets) compared to today?
    a. What were the relative contributions of differing estuarine habitat types?
2. How many total coastal *systems* occurred historically?
    a. What was the distribution of coastal systems in terms of typology, size and location?
3. What has happened to historical estuarine habitats
    a. How much estuarine habitat has been converted into different habitat types?
    b. How much estuarine habitat has been converted into non-estuarine habitat?
    c. How much new estuarine habitat has been created in areas that did not historically contain these habitats?

T-Sheets vs Historical Ecology

Reconstructions of historical conditions are most reliable when based upon a diverse array of independent documents (Grossinger 2005). Documents of different timing and origin reveal different aspects of the landscape, provide corroboration, and help document change-through-time in response to land use (Grossinger et al. 2007).

Historical ecology studies synthesizing a broad historical data set are being developed for many estuaries along the west coast of the United States to inform environmental management (e.g., Goals Project 1999, Collins et al. 2003, Stein et. al. 2010, Whipple et al. 2012), including Southern California.

T-sheets are one of the most valuable single sources for such efforts, but are most useful when examined in combination with other historical data such as early written accounts, Mexican land grant records, ethnographic information, and other early American maps.

Like some historical documents, T-sheets represent a snapshot in time and a selective, limited view of the landscape. Southern California estuaries were dynamic systems that changed seasonally, interannually and decadally. They also had potentially experienced some level of Euro-American impact by the second half of the 19th century (e.g., ranching, early agriculture, even development). In addition, not all historical wetland features are depicted with comparable accuracy or detail across all T-sheets. Therefore, T-sheet information can be best interpreted in conjunction with other early documents and with an understanding of local land use and climate history.

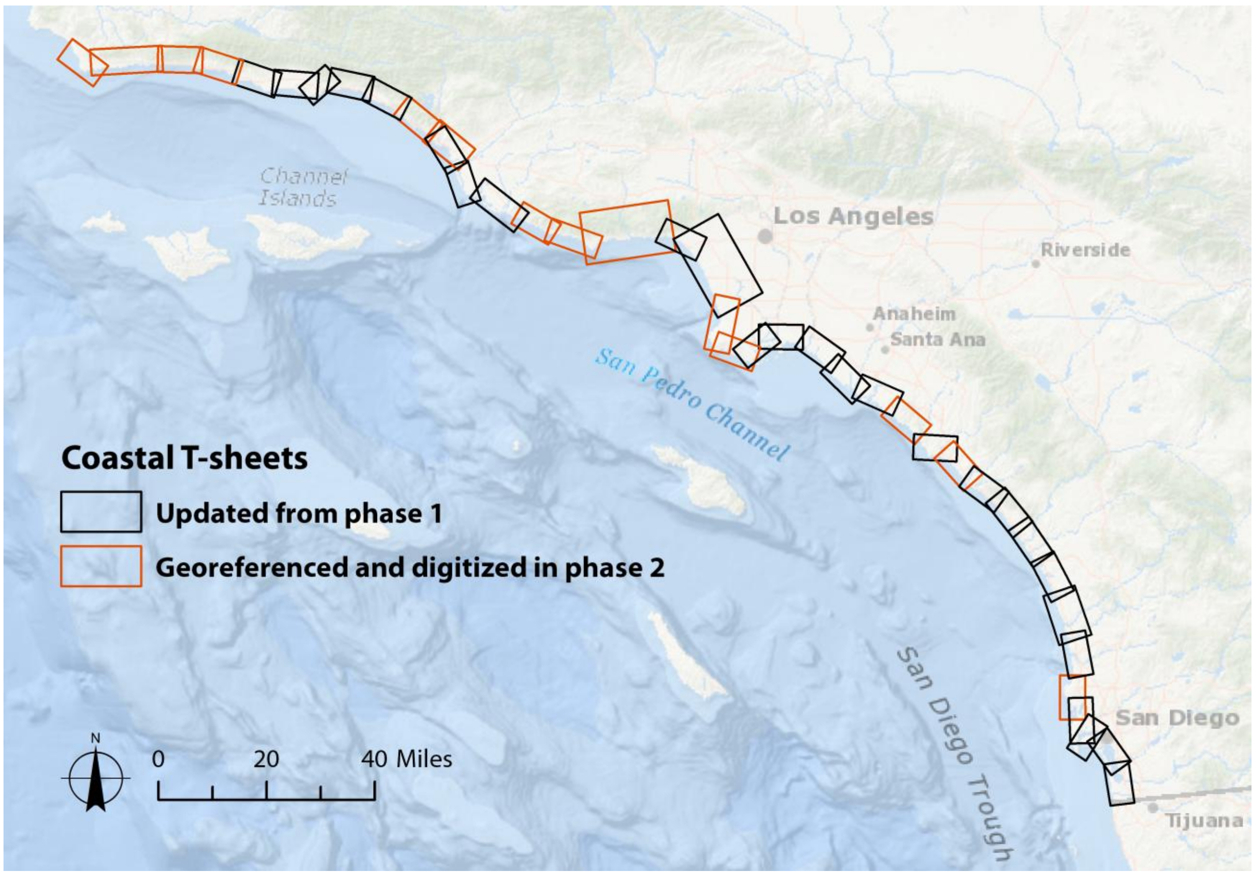


Figure 1. Extent of the 40 southern California T-sheets mapped and analyzed in this study. 26 T-Sheets were georeferenced previously for the phase 1 study, with digitization updated for phase 2. Fourteen additional T-sheets filling in the gaps left in phase 1 were georeferenced, digitized, and edge-matched for this study. *(Map background provided by (*Environmental Systems Research Institute *(ESRI), DeLorme,* General Bathymetric Chart of the Oceans *(GEBCO), and National Oceanic Atmospheric Administration (NOAA) National Geophysical Data Center(NGDC)).*

Structure of the Report

This report updates the 2011 T-sheet atlas (Grossinger et al. 2011) and provides a comprehensive synthesis of results from the analysis of all 40 T-sheets (Figure 1). The scope of the analyzed data is limited to the California Coast from Point Conception to the U.S-Mexico border. It is important to clarify that the northern coastline of Santa Barbara County is excluded from the study. This contrasts with the other four counties assessed in this study, whose entire coastlines are included. Some County lines were extended westwards (off-shore) so historical and contemporary estuarine wetlands and subtidal waters that fall outside of county lines could be included in county-level analyses and summaries.

The methods section of this document briefly summarizes past efforts and provides additional information on new analysis, such as mapping of coastal drainage systems and the classification crosswalk that allows comparison of the T-sheets to contemporary wetland maps. The remainder of the document summarizes major results and key conclusions that answer the primary study questions stated above. We synthesize historical extent and distribution by major habitat type, typology of major historical coastal wetland and drainage systems, assess change in estuarine habitat extent and distribution, and summarized type conversion patterns over the past 135-150 years. This written report summarizes key findings and conclusions. More detailed mapping results, including GIS files and Google Earth layers are available from the companion web site at http://www.caltsheets.org/

METHODS

This project consisted of mapping and digitizing the 14 T-sheets not done during Phase 1, updating the Phase 1 T-sheets to ensure consistency between the two efforts, and producing a comprehensive analysis of extent and change over time.

Data acquisition

High-resolution and full-color digital imagery of original historical topographic manuscript maps stored at the National Archives and Records Administration (NARA II, College Park, MD) were obtained through Dr. John Cloud (Geographer, (National Oceanic Atmospheric Administration (NOAA) Central Library, Silver Spring, MD). The manuscript maps were scanned full-size and in color (RGB) at a resolution of 300 pixels per inch, and saved as raw tiff files. Ancillary T-sheet materials, such as later resurveys and other relevant U.S. Coast Survey documents, as well as guidance in T-sheet history and interpretation were also provided by Dr. Cloud. One T-sheet, T-1898 (1887-88), could not be obtained in original form. However, T-1898A, which included changes mapped in 1914 on a photo-reduction of the original T-sheet, was obtained and used as a substitute (with a resulting slightly lower resolution).

In order to perform a change assessment, contemporary coastal wetlands vector GIS data covering the same project area extent was acquired from both the National Wetlands Inventory (NWI) and Center for Geographical Studies (CGS) at California State University, Northridge. Data was acquired from NWI for all coastal wetland features within the Ventura River, Los Angeles River, and San Gabriel River watersheds; and parts of the South Coast, Dominguez Channel, and Santa Ana River watersheds. Data covering remaining areas in the SCB was acquired from CGS (CGS 2012).

Georeferencing

The projection and transformation of updated NAD 1927 latitude/longitude graticules (spaced at one minute intervals on the map) produced a repeatable and accurate georectification and provided control points evenly distributed across the extent of the map sheet (Daniels and Huxford 2001, Smith and Cromley 2006). For decades, researchers have recognized the spatial accuracy of the T-sheets and their potential for comparison to contemporary maps (National Research Council (NRC) 1990). However, bringing 19th-century cartographic data into a modern coordinate system and GIS is not a trivial task (Crowell et al. 1991, Thieler et al. 2005). Traditional georeferencing methods, such as using physical features (such as hills, rock outcrops, railroad or road intersections) that appear on the T-sheet and are identifiable in contemporary imagery, using the triangulation survey markers found on T-sheets and matching them with the georeferenced location of National Geodetic Survey markers, or using the latitude/longitude graticules found on the T-sheets to project and transform the map are problematic given changes in the landscape over the last 150 years. The graticule approach permits the aforementioned methods to be used for accuracy assessment (Figure 2).

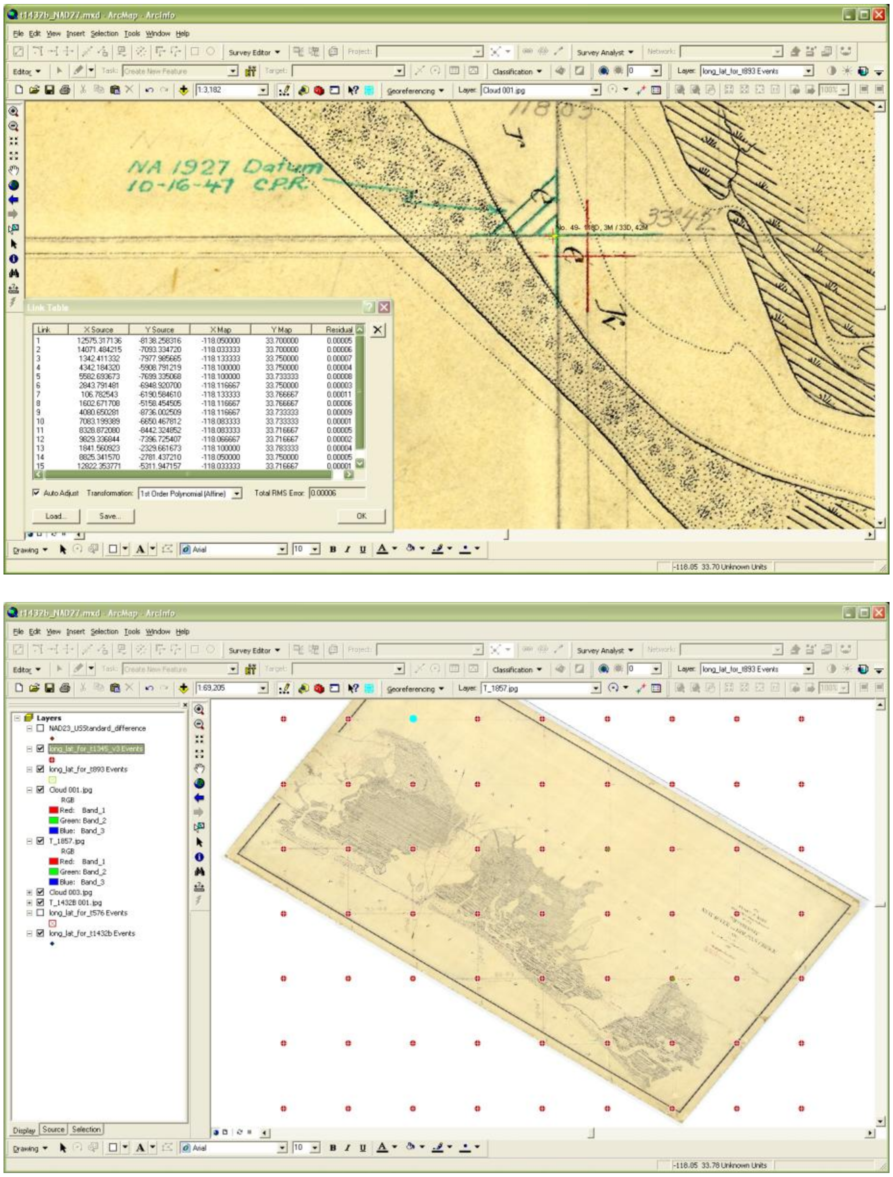


Figure 2. Georeferencing historical T-sheets. Top: T-sheet showing longitude and latitude grid on T-sheet updated to NAD 27 (in green). Bottom: Grid of longitude and latitude points used to georeference T-sheet.

With the high-resolution T-sheet scans, we were able to identify graticules that had been updated by National Ocean Service staff from the earlier, now-obsolete datums (U.S. Standard Datum of 1901 and North American Datum of 1913; see Dracup 2001) to NAD 1927. (This information was previously very difficult to interpret, as fine line work and handwritten text was often not legible in low resolution bitmaps.) All possible tick marks were used to create NAD 1927 coordinates, which were then projected to NAD 1983 using Environmental Systems Research Institute *(*ESRI) ArcGIS 9.x software. The results of this method were tested in several ways. We tried using both persistent features and corresponding matching geodetic survey marks to measure error. We found the survey marks to be difficult to use because of moved marks and changes in station names. We found it more useful to test for error by searching for persistent physical features and measuring distance (error) between the georeferenced T-sheet and contemporary aerial photography (U.S. Department of Agriculture (USDA) 2005). For selected sample T-sheets, the average error was 12.43 meters, considered an acceptable offset when working with historical maps and making coarse scale comparisons to contemporary maps. This assessment suggested the method was working effectively. To ensure no major positional errors on other maps, we examined each T-sheet against apparent corresponding features in aerial photography.

Vectorization/Digitizing

The georeferenced, high-resolution T-sheets provide base images from which landscape features can be vectorized (digitized) into spatially accurate GIS vector layers for interpretation and analysis. We manually vectorized, through heads-up digitizing, selected coastal features using a consistent set of rules and classification (see Classification section below). Because we observed variation in how features were depicted among different T-sheets, these methods were iteratively refined. Features were vectorized at a scale of 1:3,000 to 1:5,000 and stored in geo-databases in ArcGIS 10.0.

While the T-sheets often cover a broad zone of several miles of coastal watersheds including uplands, we focused on mapping coastal wetlands and related features. Phase I T-sheets were updated to be consistent with the current (expanded) mapping effort that includes small coastal wetlands and coastal drainages and channels. Combined mapping efforts from Phases I and II have produced a total of over 3,300 polygonal and 8,000 linear features. These numbers include all estuarine areas such as subtidal waters, intertidal waters, emergent marsh, and other associated features. Channels were mapped if 1) they connect to, or terminate within 400 m of the Ocean and are roughly 400 m or longer, 2) they connect to a wetland complex or linear waterbody, and 3) they are connecting or discontinuous tributaries of the above examples. Where wetland features (particularly subtidal areas) were continuous with the ocean, we created a boundary at the ocean opening. We also mapped features immediately adjacent to these estuarine habitats, including beach, dune, forest, freshwater marsh, and creeks (but not the broad grasslands often indicated adjacent to wetlands). We did not map anthropogenic features such as jetties, roads, and railroads in the few cases where they crossed wetlands, as this data would not be useful for the analysis performed during the course of this project. Most features were mapped as polygons, except channels mapped as single lines by the original surveyor; these were mapped as lines. The objective of our approach was to capture as many features of potential interest as possible. Given the differences among T-sheets, their inland extent, and what surveyors chose to represent, the suite of features varies somewhat among T-sheets. For analyses purposes, features and levels of detail should be chosen carefully to ensure comparability across T-sheets.

In order to produce a continuous dataset, we had to resolve conflicts at the edges of adjacent maps. T-sheets often meet in the middle of large wetland systems (e.g., San Diego Bay is comprised of three independent T-sheets). In some cases there is substantial overlap. We edited and joined features at the T-sheet margins to create a continuous GIS layer. To resolve differences, we generally relied on the earlier map, except for cases in which the later map was more detailed. (Often the first survey only sketches the margin, anticipating full detail on the adjacent map.) As a result, polygons at the seam between T-sheets may represent information from more than one T-sheet. The associated maps, years, and surveyors are recorded in the attribute files.

T-sheet Interpretation and Classification

Interpretation

Despite being produced by a national program with high technical standards, T-sheets do not strictly adhere to a uniform set of symbols. Individual surveys were also printed without legends. As a result the use of symbols can be inconsistent (Allen 1997, Askevold 2005) and their accurate interpretation is a nontrivial task.

We drew upon the Coast Survey literature, map annotations, and inter-calibration with other historical source materials to interpret and classify coastal features illustrated in the T-sheets. To reduce the risk of "overinterpreting" T-sheet features, we classified features based on simple categories that could be confidently interpreted across the full range of T-sheets. We focused on two major elements that were documented by surveyors and relevant to contemporary wetland classification: position on a moisture/inundation gradient and dominant vegetative character.

In many instances, a strong case could be made to define individual features into more specific wetland classes (e.g., "tidal marsh," "first-order channel," "salt pan"), as is discussed below in the T-sheet Classification section. However, given the variation among systems and surveyors, these translations could not be accurately made across the entire dataset, so we utilized a more transparent and direct classification approach. Table 1 shows examples of translations from the limited T-sheet classification into contemporary terminology.

The features on the T-sheets are those that would be relatively persistent and were mapped and classified as depicted, rather than inferring likely conditions in different seasons or at different points of time. For example, the extent of tidal inundation can vary greatly based on time of day, yet surveyors in the field intended to show "average conditions" so that the surveys would be most reliable and useful to navigators at different times of year and in the future (Cloud, pers. comm.). However, more information will need to be collected to understand the dynamics of these systems, especially the frequency of closure of barrier beach systems.

T-sheet Classification

Features digitized from the T-sheets were classified using a three-level hierarchical system (Table 1). Classification was based on readily observable features from the T-sheets and we did not attempt to infer dynamism, such as intermittency of mouth opening. Level 1 separates features into broad classes that are interpreted directly from T-sheet symbology (e.g., open water, vegetated, channel). Level II attributes were applied based on the features relative elevation and/or landscape position. Level lll attributes identify the hydrology of the feature as interpreted from the T-sheet. Using these attributes, we mapped 24 different habitat types across the 40 T-sheets. This full level of detail is provided in the GIS geodatabase (available from the web site) to offer as much information as possible for detailed analysis. For the presentation and comparison of T-sheets in this report, however, we used a simplified (lumped) classification, as shown to the far right of Table 1. Finally, we provided descriptions and other frequently used terms for given classifications in the "Common Terms" field. Classification definitions are provided in Appendix A.

Table 1. T-sheet Classification Levels I, II, III, conflated classification used in the analyses and contemporary/historical crosswalk, and common terms closely associated to the T-sheet feature

Level I	Level II	Level III (Interpreted Hydrology)	Common Terms	Simplified Classification
Vegetated	Woody	n/a	Upland thicket (potentially riparian)	Vegetated, Woody (maps only)
	Emergent Marsh, Extreme High Elevation	Supratidal	High marsh transition zone	(not used in Phase II). *Vegetated Wetland used in Mugu Lagoon only*
		Non-estuarine	Palustrine marsh, marsh ecotone	(not used)
	Emergent Marsh, High Elevation	Intertidal	Tidal marsh, salt marsh, brackish marsh, freshwater tidal marsh, high marsh, middle marsh, marsh plain	Vegetated Wetland
		Outlet Closed	Salt marsh where outlet is closed to the Ocean	
	Emergent Marsh, Low Elevation	Intertidal	Low-elevation tidal marsh, young marsh	
		Outlet Closed	Low-elevation marsh, young marsh	
Unvegetated	High Elevation	Intertidal/Supratidal	Salt flat, alkali flat, panne, playa (dry lake bed)	Salt/Unvegetated Flat
		Outlet Closed	Salt flat, alkali flat, panne, playa (dry lake bed)	
		Non-estuarine	Salt flat	
	Low Elevation	Intertidal	Tidal flat, mudflat, sandflat	Intertidal Flat
		Outlet Closed	Salt flat, alkali flat, panne, playa (dry lake bed)	Salt/Unvegetated Flat

Open Water	n/a	Subtidal	Subtidal water, subtidal channel	Subtidal Water
		Intertidal/Supratidal	Marsh pond, pan/panne	Open Water
	Coastal terminus: <Terminus_Type> (if any, otherwise n/a)	Outlet Closed	Lagoon, open water in closed estuary	Open Water
	n/a	Non-estuarine	Pond, lake	Open Water
Channel	n/a	Subtidal	Subtidal water, subtidal channel	Subtidal Water
		Intertidal	Tidal channel, tidal marsh flat	Intertidal Flat
	Coastal terminus: <Terminus_Type> (if any, otherwise n/a)	Fluvial	River, stream, coastal drainage	River/Stream
		Gully	Gully	Gully
	Bar/Island	Fluvial	Sand bar, point bar	River/Stream
Beach	n/a	Supratidal	Beach	Beach (maps only)
Dune	n/a	n/a	Coastal dune	Dune (maps only)
Upland Vegetated	n/a	n/a	Island	Upland Vegetated (maps only)

Historical – Contemporary Comparison

A primary objective of this effort was to use the contemporary data coupled with the T-sheet historical data to estimate the amount, location, and type of change in estuarine wetland habitats over 150 years from c 1850 to 2005. Comparison of the historical and contemporary data sets required resolving differences in the spatial extent of mapping and in the classification systems. The contemporary mapping provides comprehensive coverage of much of Southern California, while the T-sheets covered only the area within about 2km of the coast. In order to perform a meaningful comparison, only the area common to both datasets was used, primarily the entire surveyed extent of the original T-sheets. Everything in the contemporary dataset which fell outside of the area surveyed from the T-sheet was excluded from the analysis.

A classification crosswalk was generated to create a relationship between the historical and contemporary datasets. As mentioned in the previous sections, the historical data has been classified based on the T-sheet classification; however, the contemporary data has been classified using a modified version of the Cowardin classification system (Cowardin et al. 1979). The Cowardin classification is a hierarchical system that classifies habitat based on the following categories: system, sub-system, and class. Additionally, there are a number of modifiers that can be applied to the classification to denote water regime, water chemistry, soils, and special modifiers which indicate any anthropogenic influence on the features, to provide more information for a given feature. The full Cowardin Classification is shown in Appendix B.

Differences in how the two classification systems classify wetland features made the task of creating an accurate and effective crosswalk challenging. This is because the historical data is classified based on physical features depicted in the T-sheets, while the Cowardin system is based on the frequency of flooding and dominant plant type. Due to these differences, classifications within the two systems do not always have a 1:1 relationship and are not always mutually exclusive.

In order to align the datasets, a simplified version of the Cowardin classification system was used in both the historical and contemporary datasets. The simplified Cowardin classification used only the system, subsystem, and class levels to maintain an accurate comparison. Additional classes in the contemporary dataset were disregarded. The historical classification was then crosswalked to this simplified Corwardin classification based on the T-sheet feature’s interpreted hydrology and wetland structure. This approach created the 1:1 relationship between the contemporary and historical data necessary for the change analysis. Features mapped within the each dataset have been grouped into the following classes for purposes of historical-contemporary comparisons: Estuarine Subtidal, Estuarine Vegetated, Estuarine Unvegetated, Marine Pacific Ocean, Marine Beach, Palustrine Vegetated, Palustrine Unvegetated, Lake, and Riverine (Table 2).

Table 2. Simplified Cowardin, et al. 1979 classification for use in the wetland change analysis

Cowardin System, Subsystem, and Class (code)	Simplified Cowardin Classification used for Analyses	T-sheet Summary/Website Classification	T-sheets Data Classification
Marine Subtidal Unconsolidated Bottom (M1UB)	Marine Pacific Ocean	Pacific Ocean	Open Water Subtidal
Marine Intertidal Unconsolidated Shore (M2US)	Marine Beach	Beach (maps only)	Beach
Estuarine Subtidal Unconsolidated Bottom (E1UB)	Estuarine Subtidal	Subtidal Water	Open Water Subtidal
		Open Water	Channel Subtidal, Open Water Outlet Closed
Estuarine Intertidal Emergent (E2EM)	Estuarine Vegetated	Vegetated Wetland	Vegetated Wetland (not including Non-estuarine)
Estuarine Intertidal . Unconsolidated Shore (E2US)	Estuarine Unvegetated	Intertidal Flat	Unvegetated Intertidal Channel Intertidal
		Salt/Unvegetated Flat	Unvegetated (not including Non-estuarine)
		Open Water	Open Water Intertidal/Supratidal
Riverine	Riverine	River/Stream Gully	Channel Fluvial Gully
Palustrine (Unconsolidated Bottom (PUB)	Palustrine Unvegetated	Open Water	Open Water Non-estuarine
Palustrine Unconsolidated Shore (PUS)	Palustrine Unvegetated	Unvegetated flat	Unvegetated Non-estuarine
Palustrine Emergent (PEM)	Palustrine Vegetated	Vegetated Wetland	Vegetated Wetland Non-estuarine

ANALYSIS AND RESULTS

Question 1: How much total estuarine habitat was there historically?

The Southern California Bight historically supported 19,591 hectares of estuarine habitat. Vegetated wetlands and subtidal water account for the majority of the historical estuarine area with 7,764 hectares and 6,914 hectares, respectively. Intertidal flats, open water, and salt flats make up the remaining ¼of the total with 4,914 hectares combined (Figure 3). Vegetated wetlands include both low and high tidal marshes. Subtidal water includes embayments and deep channels that do not dewater at low tide. Much of the historical vegetated wetlands and subtidal water are found in large marsh complexes and bays along the coast. In addition to the estuarine habitats, an additional 5,496 hectares of "other wetlands" were mapped on the T-sheets. These included 2,982 hectares of dune and beach, 1,061 hectares of woody vegetated wetlands, and 792 hectares of high marsh habitat. The balance were habitats associated with rivers and other isolated ponds; these habitats were not identified and symbolized consistently across all T-sheets and likely underestimate the actual regional extent. Because of this inconsistency and because they are not considered "estuarine wetlands" for the purposes of this analysis, they are not included in subsequent summaries of extent or change. The 19,591 hectares noted above also does not include a summary of historical channels, a primary focus of this effort. For information on the analysis of streams please refer to the Coastal System Analysis section (below).

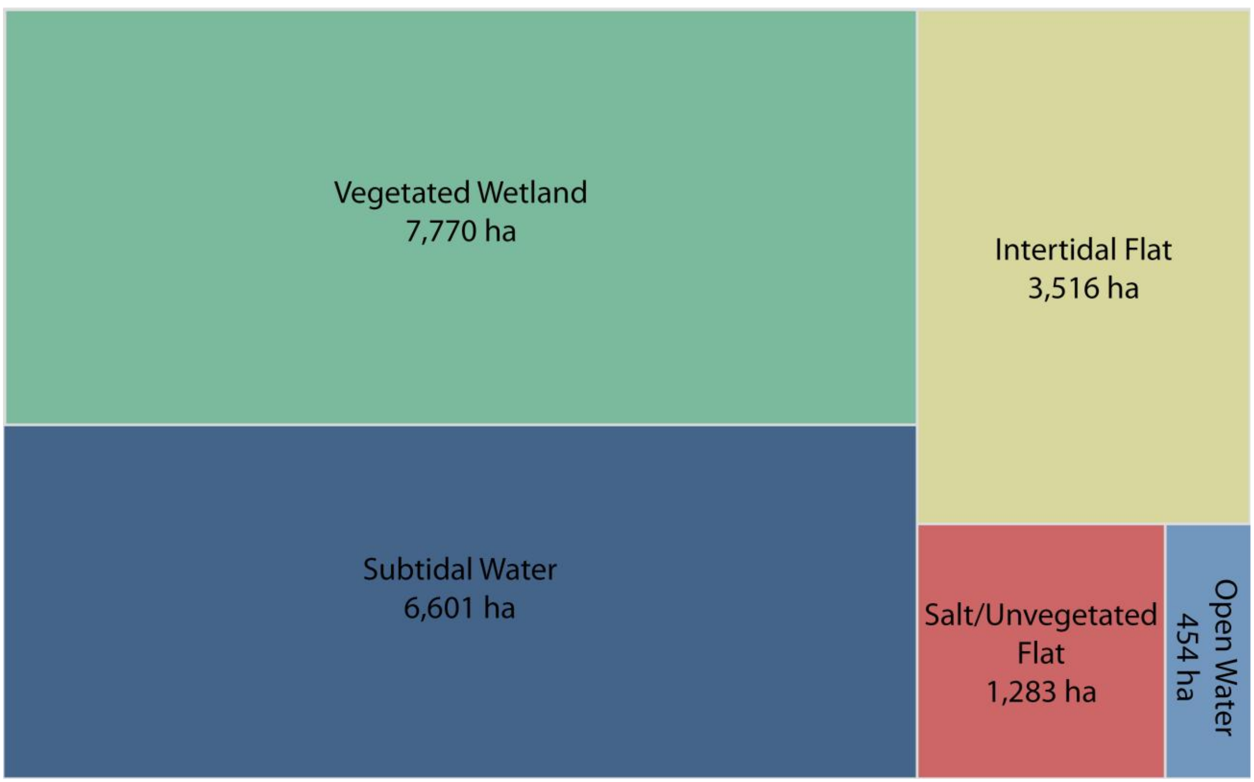


Figure 3. Distribution of historical estuarine habitats by type. Size of each rectangle corresponds to the proportion of total historical area comprised of each habitat type.

Over half (~57% or ~11,000 hectares) of the total regional estimate of historical estuarine features was found in San Diego County, a large part of which is due to Mission and San Diego Bays with almost

6,000 hectares of subtidal water. San Diego County also had the largest portions of vegetated and intertidal flat habitat in the region with almost 3,000 and 2,000 hectares, respectively (Figure 4). Both Los Angeles and Orange Counties contained about 15% each of the total historical estuarine habitat with very similar amounts of vegetated wetlands, intertidal flats, and subtidal and open water. However, Los Angeles County had the largest expanse of historical salt flats in the region.

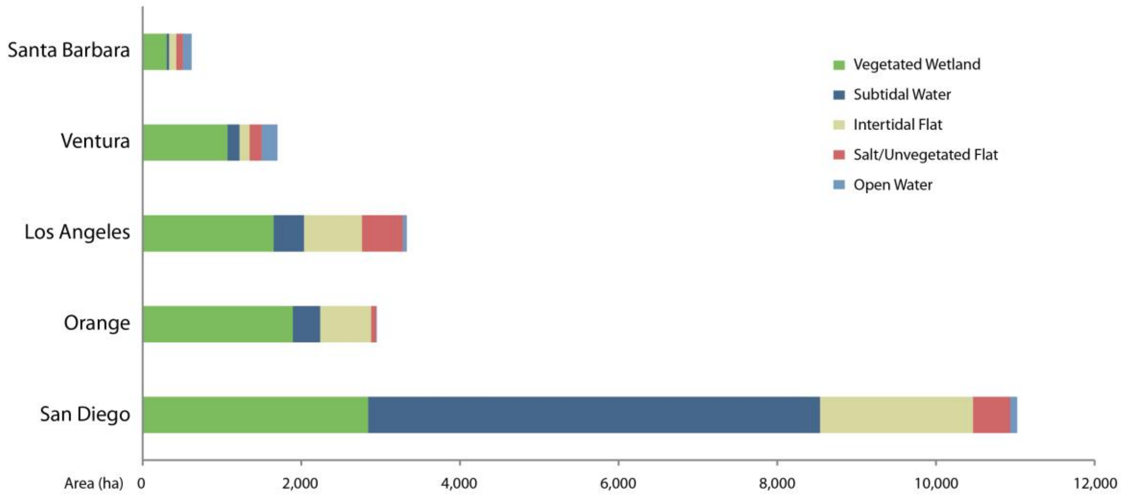


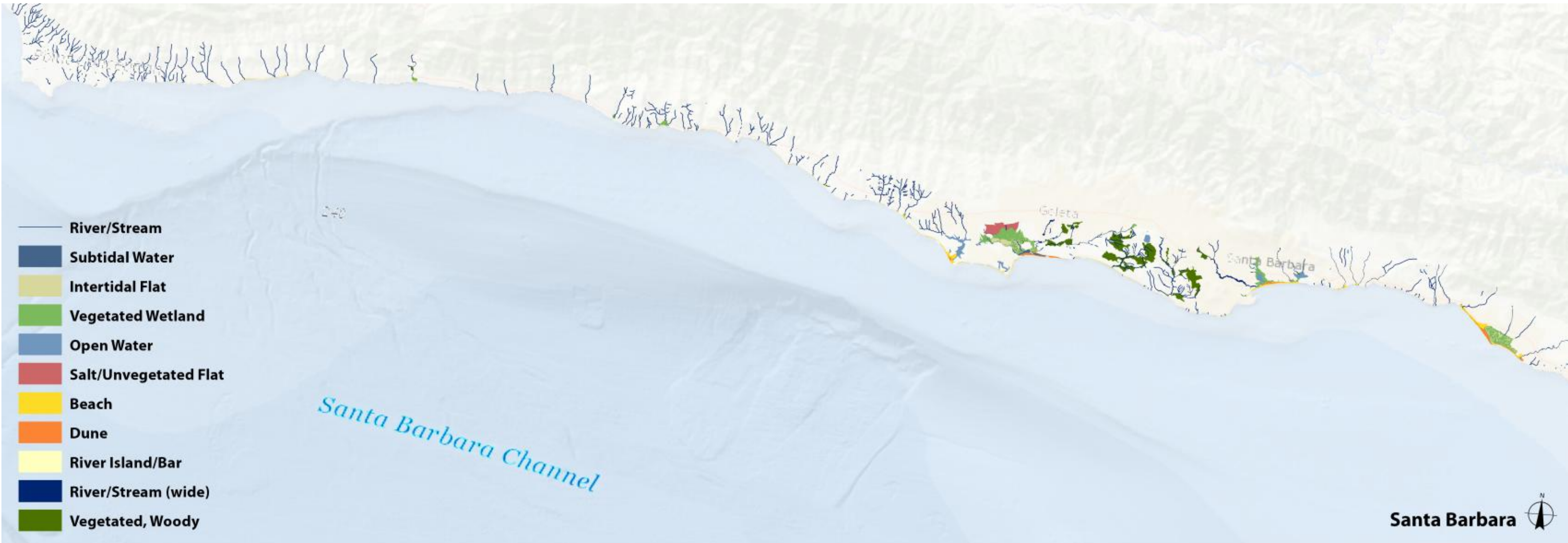
Figure 4. Proportion of historical estuarine habitat types by county

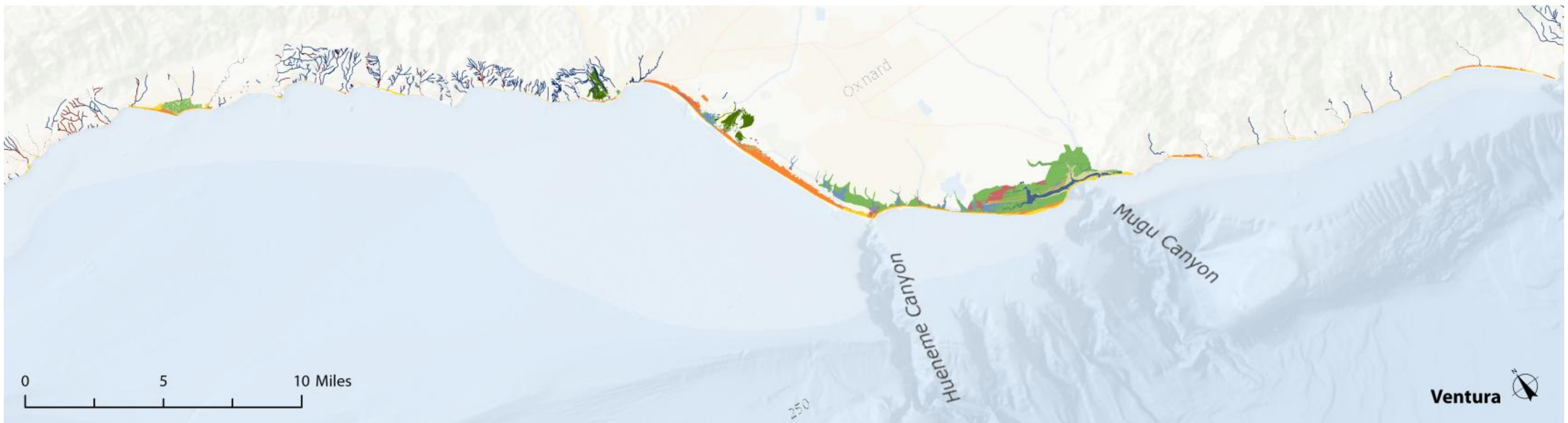
Question 2: How many total coastal systems occurred historically?

Coastal wetland systems for the purpose of this study are defined as one or more aquatic features that drain to a common point in the landscape. Systems range greatly in size, from the smallest systems that consist only of small streams with no measurable estuarine area, to the major complexes such as San Diego Bay that consisted of a mixture of estuarine habitat types and covered thousands of hectares.

A total of 331 coastal systems were identified in Southern California's coastal Region (Figure 5). The dominant system, in terms of total number, is the channel-only type. These are systems lacking additional estuarine habitats and make up 225 of the total systems in the study area. There is an inverse relationship between system size and abundance, with most systems being small and large systems being relatively rare (Figure 6).

Individual coastal systems were relatively evenly distributed along the coast with each county having between 60 and 90 systems (Figure 6). The exception was that the northern region of the study area with rocky headlands contained fewer systems compared to the southern region. The distribution of systems by size was also relatively uniform across the counties. The exceptions were a slightly higher concentration of medium and large systems in San Diego County and slightly more channel only systems in Los Angeles County (Figure 7). On a regional scale, larger systems occur in three areas distributed along the SCB coastline, south San Diego, Long Beach, and Southern Ventura County. These three nodes are connected through strings of medium and smaller estuaries (Figure 6).


River/Stream
Subtidal Water
Intertidal Flat
Vegetated Wetland
Open Water
Salt/Unvegetated Flat
Beach
Dune
River Island/Bar
River/Stream (wide)
Vegetated, Woody
Santa Barbara Channel
Goleta
Santa Barbara
Santa Barbara


Oxnard
Hueneme Canyon
Mugu Canyon
0
5
10 Miles
Ventura


Santa Monica Bay
Santa Monica Canyon
Redondo Canyon
208
Inglewood
South Gate
Lynwood
Norwalk
Paramount
Bellflower
Cerritos
Compton
Lakewood
Hawthorne
Gardena
Redondo Beach
Torrance
Carson
Long Beach
Los Angeles Harbor
San Pedro Bay
Los Angeles
Irvine
Lake Forest
Laguna Niguel
Dana Point
San Clemente
40
Los Angeles Harbor
San Pedro Bay
River/Stream
Subtidal Water
Intertidal Flat
Vegetated Wetland
Open Water
Salt/Unvegetated Flat
Beach
Dune
River Island/Bar
River/Stream (wide)
Vegetated, Woody
0
5
10 Miles
Orange

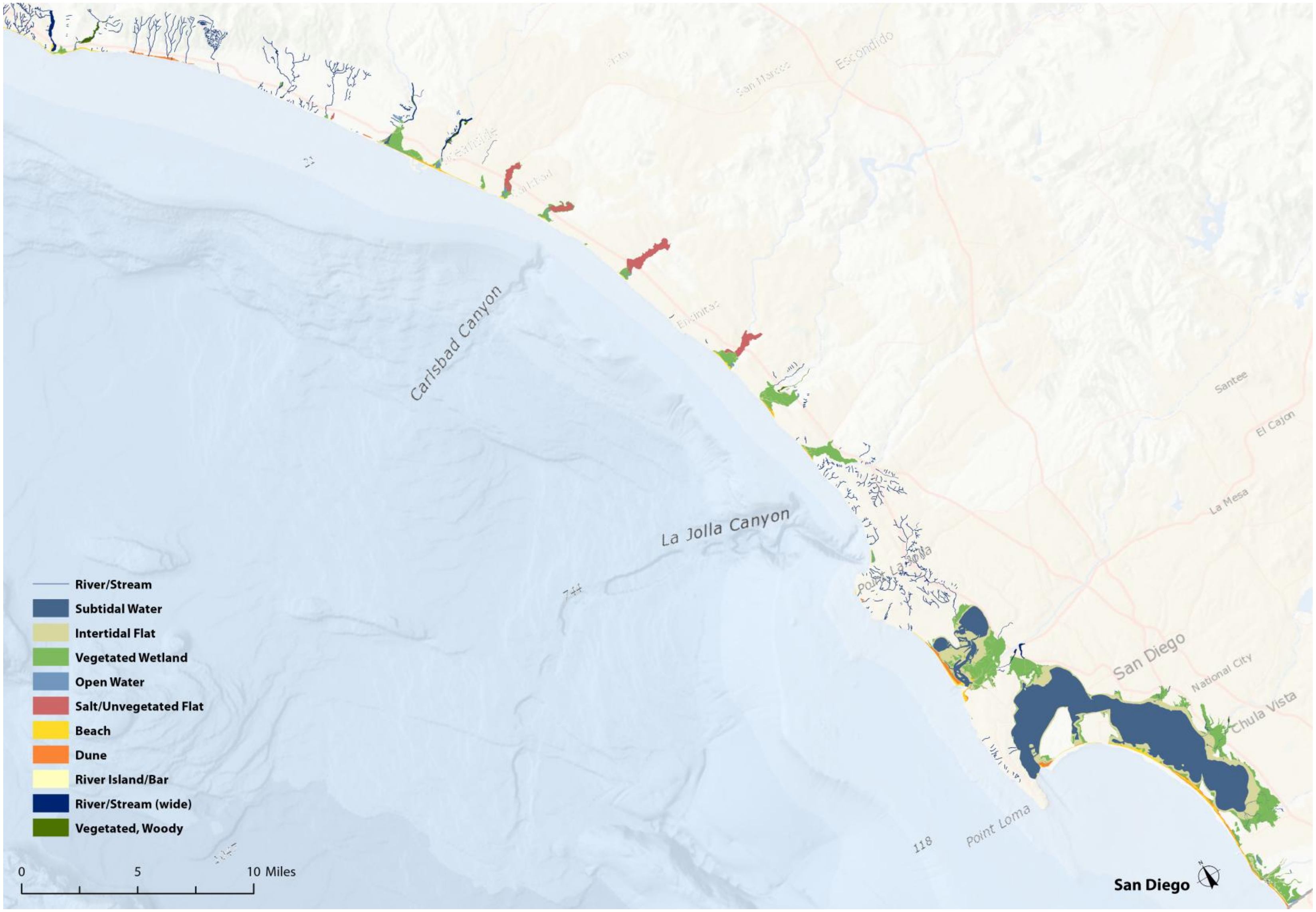


Figure 5a-e. Distribution of historical estuarine wetlands, streams, and other features along the Southern California Coast. ***(Map background provided by ESRI, DeLorme, GEBCO, and NOAA NGDC).***

Figure 6. Distribution of coastal systems across the study area. The sizes of the circles are symbolic and not proportional to the actual sizes of the systems. Inset graph shows distribution of wetland systems by size class *(Map background provided by ESRI, DeLorme, and Navteq).*

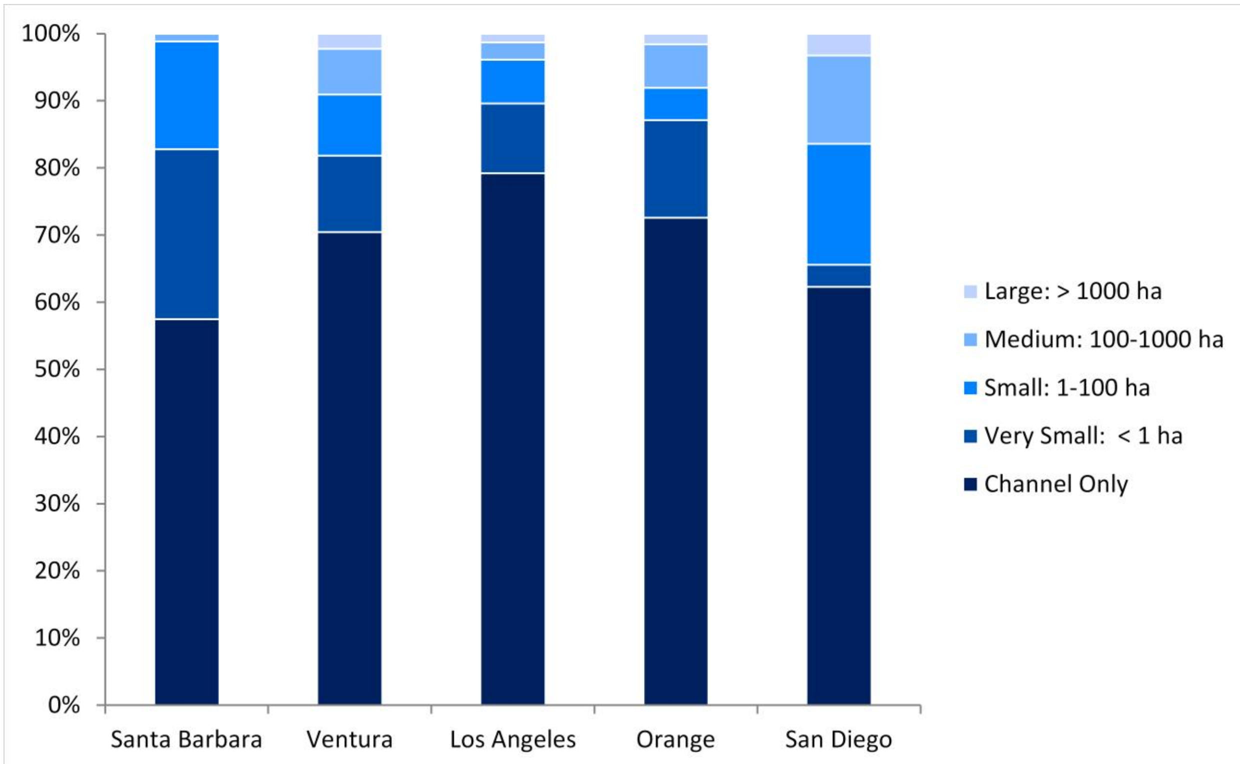


Figure 7. Proportional distribution of system sizes by county.

System Archetypes

Grouping coastal systems into similar categories based on their size and composition (i.e., archetypes) can help organize the natural complexity in a way that facilitates further analysis and interpretation. Archetypal analysis can be used to help understand relationships between landscape settings and drivers (e.g., watershed size, littoral position) and wetland composition and structure. It can also help managers develop restoration and management strategies reflective of these general patterns in structure and composition.

Archetypes were based on the five size classes previously identified (channel only, very small, small, medium, large) combined with the dominant habitat types present in each system. This resulted in 15 unique archetypes; examples of these archetypes are shown in Figures 8-10. As previously stated, the majority of systems consist of channel only systems or small and very small coastal wetlands. Most small and very small wetlands were associated with some sort of stream feature, with only 9 of 308 (3%) being isolated coastal lagoons or wetlands (Table 3). Of the 299 systems that included coastal streams and were less than 100 hectares in size, 73 (25%) of the streams were associated with some sort of small or very small coastal estuary. However, these features were likely variable over time and this proportion may have fluctuated based on climatic and tidal cycles.

Unlike small and very small systems which were relatively evenly distributed along the coast, medium and large systems tended to occur in geographic clusters (Table 4). For example, medium size, tidal marsh-flat dominant systems occurred largely along the north Orange County-South Los Angeles County coast. In contrast medium size, salt-flat dominant systems occur along the northern San Diego coast. These patterns may result from influences of geologic origin, coastal geomorphology, and associated watershed characteristics. Further investigation would help better elucidate these patterns and their potential influencing mechanisms.

T-sheet depictions of Archetypes

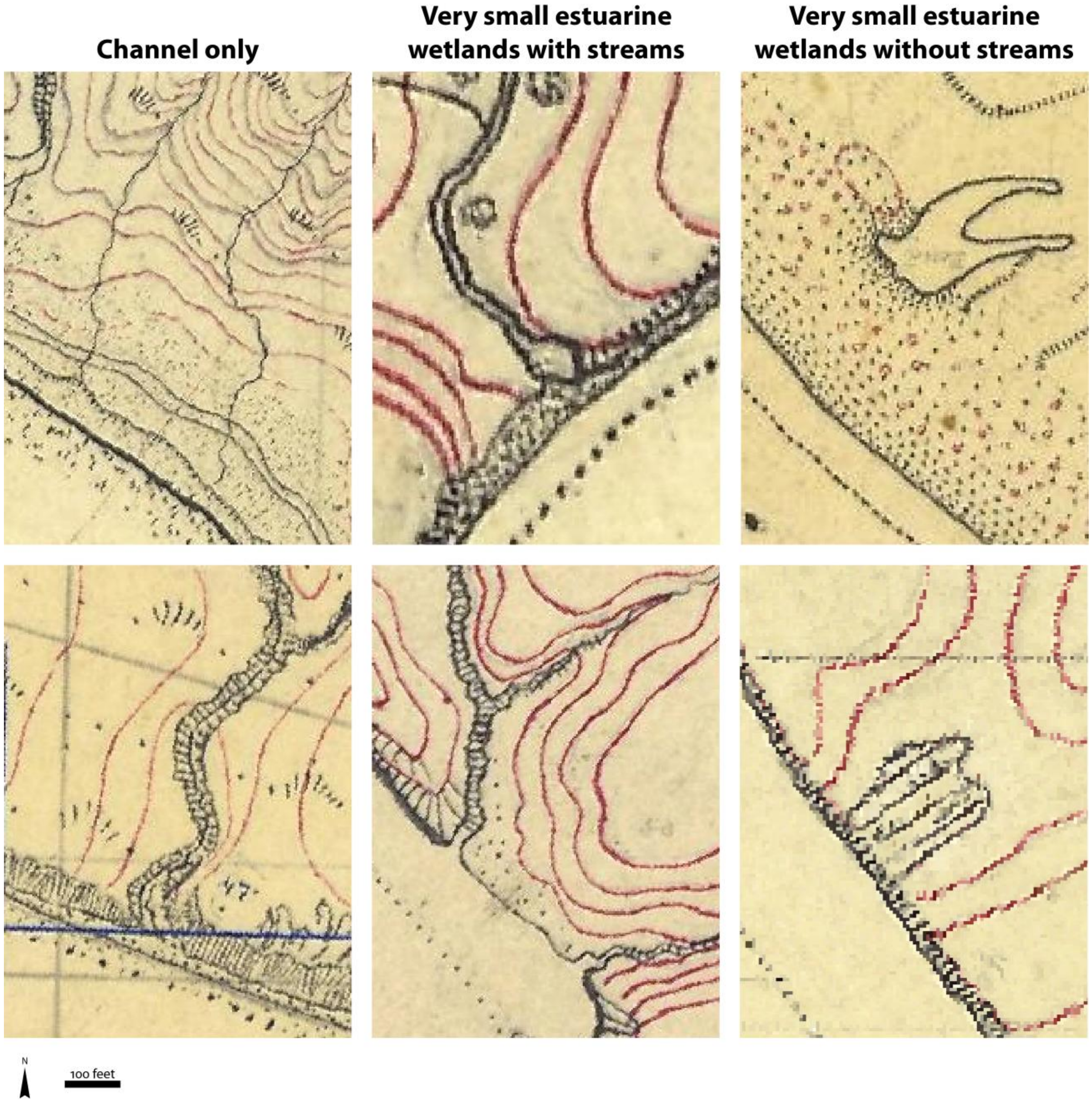


Figure 8. Archetype Examples of systems with less than 1 hectare of wetlands. (Channel only and Very small systems)

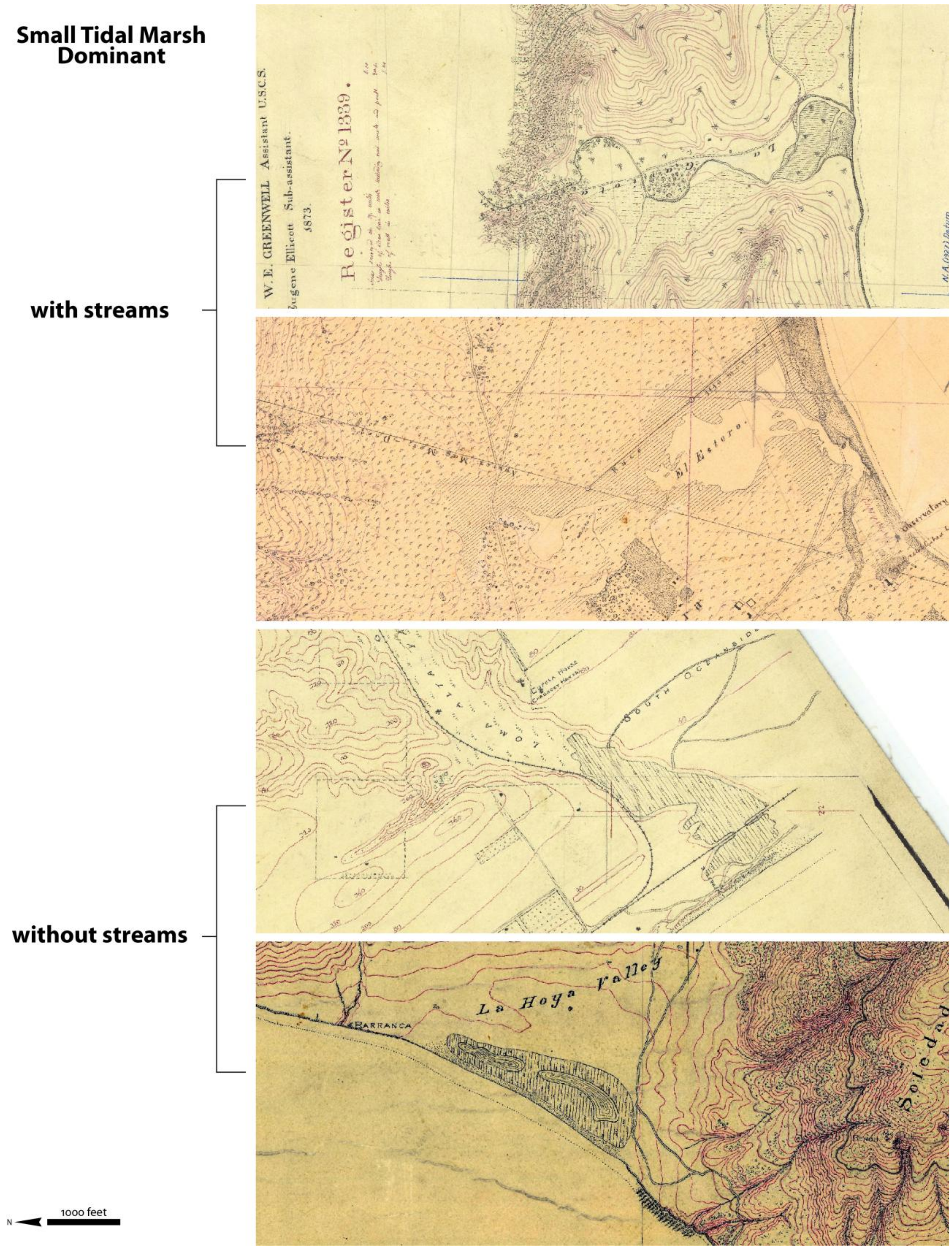


Figure 9. Archetype Examples of small tidal marsh dominant systems with between 1 and 100 hectares of wetlands.

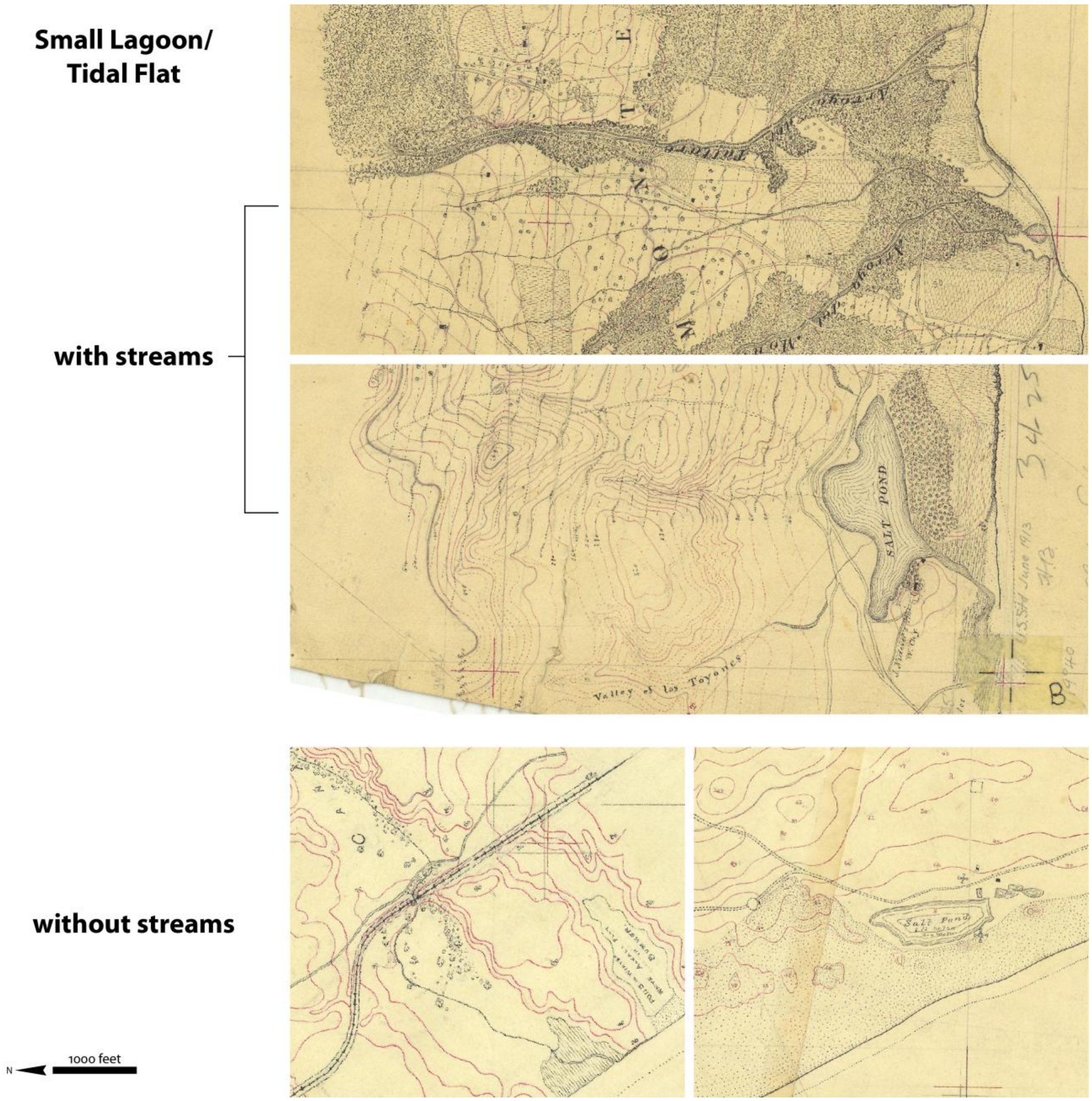


Figure 10. Archetype Examples of small lagoon/tidal flat systems with between 1 and 100 hectares of wetlands.

Table 3. Archetype assignments for systems with less than 100 hectares of wetland. See Figures 8-10 for examples of small system archetypes

System Size	Wetland Composition	Archetype	Total Number
Channel only (0 ha)	NA	Channel only	225
Very small (<1 ha)	NA	Very small estuarine wetland with streams	44
	NA	Very small estuarine wetland without streams	2
Small (1-100 ha)	>60% Vegetated wetland	Small Tidal Marsh Dominant with Streams	7
		Small Tidal Marsh Dominant without Streams	5
	>60% Unvegetated wetland + Open water	Small Lagoon/Tidal Flat with Streams	23
		Small Lagoon/Tidal Flat without Streams	2

Table 4. Archetype assignments for medium and large sized systems.

Archetype	Systems	Count
Medium Tidal Marsh Tidal Flat Dominant	Seal Beach, Bolsa Chica, Ballona Wetlands, Carpinteria, Alamitos Bay, Tijuana Estuary	6
Medium Tidal Marsh Dominant	San Dieguito, Los Penasquitos, Santa Margarita 1	3
Medium Salt Flat Marsh Systems r	Agua Hedionda, Batiquitos, San Elijo, Buena Vista Lagoons	4
Medium Even Mix & Open Water	Goleta, Ormond Beach	2
(Medium) Large Steep River Mouth Estuaries Large Even Mix	Santa Clara River, Ventura River, San Juan Capistrano River	3
Large Subtidal Dominant	Mission Bay, San Diego Bay	2
Large Tidal Marsh Tidal Flat Dominant	Newport Bay, Mugu Lagoon	2
Large Even Mix	Los Angeles Harbor	1
	TOTAL	23

Question 3. What has happened to historical estuarine habitats?

Understanding the historical estuarine habitats along the Southern California Coast is critical information but just part of the story. In order to fully understand both the losses and gains in wetland habitat and therefore establish a successful path for restoration, it is critical to know how the past compares to the present. Using the classification crosswalk described in the methods section, we compared the change in extent and type of estuarine habitats as shown on the T-sheets with the most recent wetland mapping for the southern California coast.

Change in Total Estuarine Area from ca. 1859 to 2005

Since ca. 1850 there has been an overall loss of 9,317 hectares or 48% of historical estuarine habitats along the Southern California Coast (Table 5). However, losses have not been even across the major habitat types. Estuarine vegetated habitats have experienced the greatest loss in terms of absolute area (-5819 ha, 75% loss), while estuarine unvegetated habitats have experienced the greatest proportional loss of 78% of historical extent (Table 5). In contrast, the contemporary landscape includes 339 ha more subtidal water, a 5% increase from historical extent. These differential losses have shifted the proportional composition of southern California estuaries. Historically there was almost an even split between estuarine vegetated (40%), estuarine unvegetated (25%), and subtidal water (35%). Currently the proportional composition is heavily weighted towards subtidal water (71%) while estuarine vegetated (19%) and unvegetated (10%) make up less than ⅓ of the total area combined (Table 5). These general patterns are illustrated in the area between the ports of Los Angeles/Long Beach and Bolsa Chica where historical large marsh complexes have been converted to open water harbors and marinas, resulting in a 100% increase in subtidal water compared to historical conditions (Figure 11).

Declines in estuarine area vary by county (Figure 12. Total losses across all counties range from 73% in Los Angeles to 31% in San Diego. Additionally, the composition of estuarine habitats in the counties has shifted. In the southern most counties (Los Angeles, Orange, and San Diego) there has been a significant increase in subtidal water while both intertidal and vegetated habitats have decreased. Santa Barbara and Ventura Counties have maintained a composition similar to that seen in ca. 1850.

Historically estuarine unvegetated habitats made up about 25% of the estuarine composition in the SCB, ranging from 20% in Ventura County to 38% in Los Angeles County. Today estuarine unvegetated habitats range from as little as 2% in Los Angeles County to 21% in Ventura County. This change equates to 98% of unvegetated estuarine habitats in Los Angeles (LA) and 49% in Ventura being converted to other wetland types or lost completely. Orange and San Diego Counties have experienced loss of estuarine unvegetated habitats of 627 hectares (88%) and 1,644 hectares (68%), respectively. Santa Barbara has lost 90% of the County's estuarine unvegetated habitats with only 18 hectares remaining of historical 178 hectares (Table 6).

Table 5. Amount of hectares, proportion of wetland type, and amount of change from c 1850 to 2005. Red negative values indicate a loss.

Wetland Type	c 1850 Total Wetlands (ha)	% of Total Historical Wetlands	2005 Total Wetlands (ha)	% of Total Contemporary Wetlands	Absolute Change	% Change
Estuarine Vegetated	7,764	40%	1,945	19%	-5,819	-75%
Estuarine Unvegetated	4,913	25%	1,076	10%	-3,837	-78%
Subtidal Water	6,914	35%	7,253	71%	339	+5%
Total	19,591		10,274		-9,317	-48%

Vegetated estuarine habitats, i.e., tidal marsh, has seen significant decreases along the coast as well. Historical distribution of this habitat type ranged from 26% (San Diego) to 64% (Orange Today the distribution ranges from 7% (Los Angeles) to 67% (Santa Barbara). There is no county that has increased or even maintained the total area of vegetated estuarine habitat since ca. 1850. However, in Santa Barbara, Ventura, and San Diego the relative proportion is similar to the historical proportion.

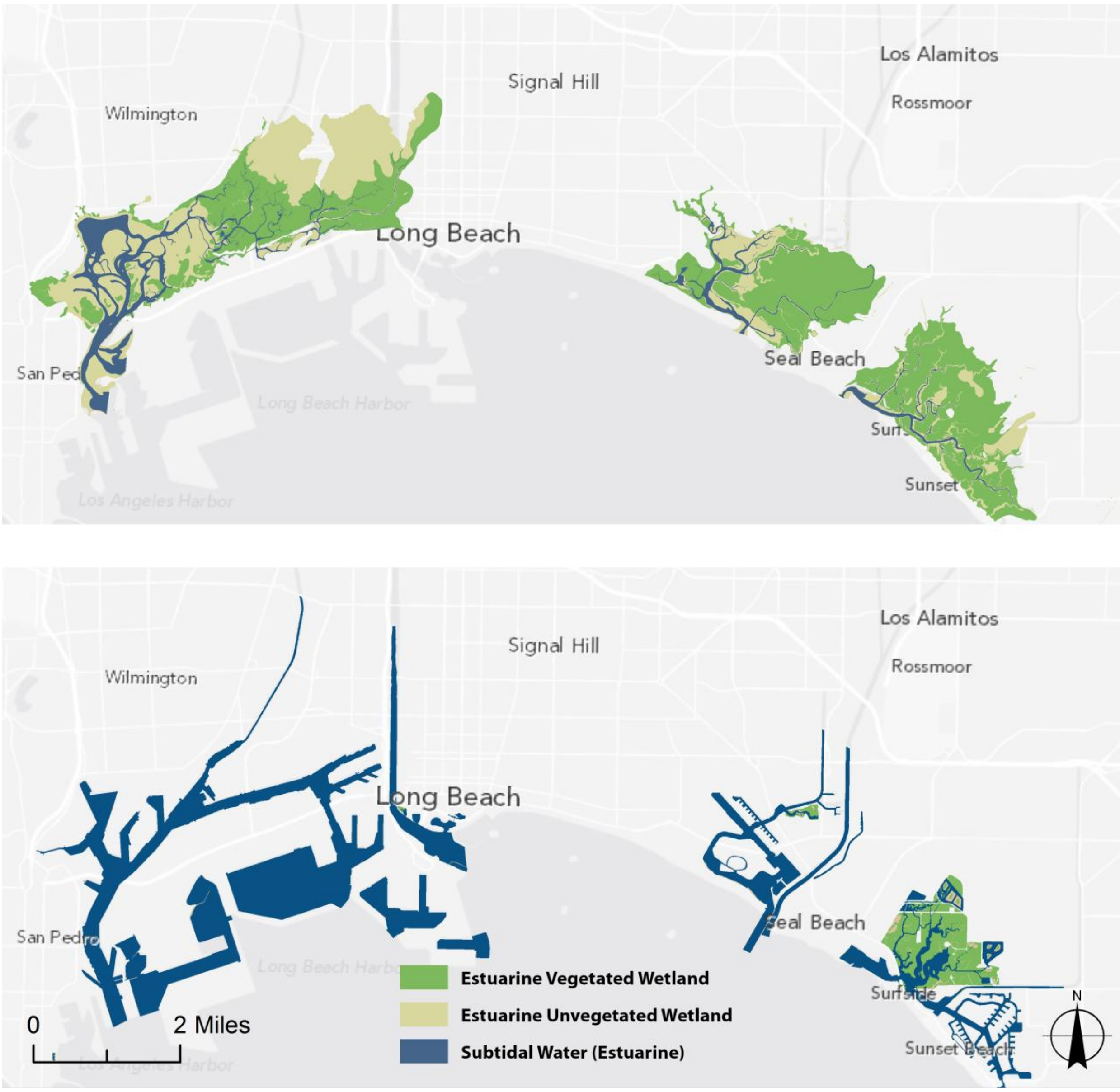


Figure 11. Comparison of historical and contemporary estuarine wetlands in Los Angeles/Long Beach Harbor, Alamitos, and Seal Beach. ***(Map background provided by ESRI, DeLorme, and Navteq).***

Table 6. Change in Total Habitat Area by Estuarine Habitat Type and County

		Total Historical Estuarine Area (ha)	Total Contemporary Estuarine Area (ha)	Absolute Change	% of Total Historical Wetlands in County	% of Total Contemporary Wetlands in County	% of Total Historical Wetlands in Region	% of Total Change
Santa Barbara	Estuarine Unvegetated Wetland	178	18	160	29	10	1	2
	Estuarine vegetated Wetland	306	116	190	50	67	2	2
	Subtidal Water	134	38	96	22	22	1	1
Santa Barbara Total		**618**	**172**	**446**			**3**	**5**
Ventura	Estuarine Unvegetated Wetland	336	169	167	20	22	2	2
	Estuarine vegetated Wetland	1,065	471	594	63	60	5	6
	Subtidal Water	285	146	139	17	19	1	-1
Ventura Total		**1,686**	**786**	**900**			**9**	**10**
Los Angeles	Estuarine Unvegetated Wetland	1,262	22	1,240	38	2	6	13
	Estuarine vegetated Wetland	1,654	64	1,590	50	7	8	17
	Subtidal Water	395	816	421	12	90	2	5
Los Angeles Total		**3,311**	**902**	**2,409**			**17**	**26**
Orange	Estuarine Unvegetated Wetland	710	83	627	24	7	4	7
	Estuarine vegetated Wetland	1,895	421	1,474	64	33	10	16
	Subtidal Water	348	758	410	12	60	2	4
Orange Total		**2,953**	**1,262**	**1,691**			**15**	**18**

San Diego	Estuarine Unvegetated Wetland	2,428	783	1,645	22	11	12	18
	Estuarine vegetated Wetland	2,844	873	1,971	26	12	15	21
	Subtidal Water	5,752	5,495	257	52	77	29	3
San Diego Total		**11,023**	**7,151**	**3,872**			**56**	**42**
Grand Total		***19,591***	***10,274***	***9,317***				

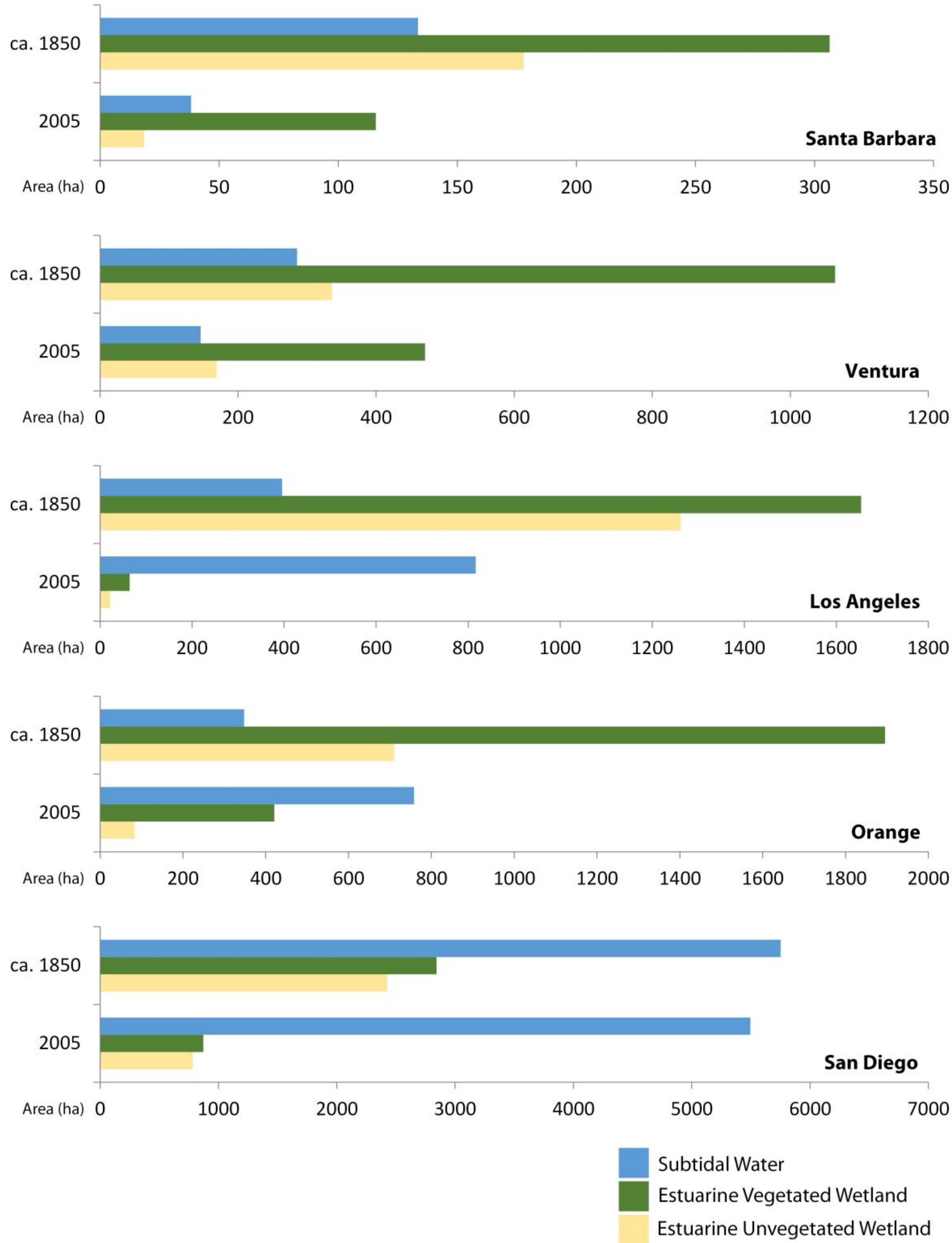


Figure 12. Change in total estuarine area by county. Changes represent difference between mapping representing ca. 1850 and 2005.

Historical Estuarine Habitat Conversion

Building upon the previous analysis, we aimed to further understand Southern California estuarine change by exploring type conversion in more detail. To do this, we analyze the current land cover types occupying historical estuarine areas mapped for this project. This analysis does not attempt to interpret the cause of the conversion but simply the nature of the conversion. We have categorized the results of this analysis into five change types:

1. **No Change** – The feature is the same estuarine type in both historical and contemporary mapping
2. **Change to another estuarine type** – The feature is no longer the historical estuarine type, but is another estuarine type
3. **Change to non-estuarine wetland** – The feature is no longer the historical estuarine type, but is a freshwater wetland type
4. **Change to non-estuarine upland**– The feature is no longer the historical estuarine type and has been converted to upland; developed, agriculture, or other non wetland
5. **Change to non-estuarine marine** – The feature is no longer the historical estuarine type and has been converted to marine deepwater habitat (i.e., the ocean). These areas are no longer considered estuarine. In contrast, conversion to subtidal estuarine habitat would be considered a change to another estuarine type.

The largest type conversion experienced is the change of estuarine habitats to non-wetland features (Figure 13). Of the 19,591 hectares of historical estuarine habitats, 8,368 hectares or 43% have been converted to non-estuarine features, i.e., developed, agricultural, or open space land uses. Thirty-four percent or 6,604 hectares of historical estuarine habitats are the same type in the 2005 mapping. However, 74% of this category is due to large subtidal water features such as Mission and San Diego Bays remaining the same. In contrast, only about 1,700 hectares of historical vegetated and unvegetated estuarine habitats have remained the same type. . Twenty percent (20%) of historical estuarine habitats have been converted to a different estuarine type. For example, tidal flat in ca. 1850 is now tidal marsh. For example, tidal flat in ca. 1850 is now tidal marsh. A lesser amount, only 880 hectares or 4% of historical estuarine habitats have been converted to freshwater wetlands. Finally, a nominal amount of the total historical estuarine extent has been converted to marine habitats.

In each county, at least 1/3 of all historical estuarine habitats have been converted to non-wetland land uses. In three counties, Santa Barbara, Los Angeles, and Orange Counties, ½ of historical estuaries have been converted to non-wetlands (Figure 14). Ten to fifteen percent of historical estuarine habitats have been converted to non-tidal, generally freshwater, wetlands in Santa Barbara, Ventura, and Orange Counties. Across all counties 10-25% of historical estuarine habitats still exist, but have been converted to a different type. San Diego County accounts for the largest portion of the total historical estuarine habitats with no change in the contemporary landscape. Again, this is largely due to Mission and San Diego Bays in San Diego County. In the remaining four counties the percentage of estuarine area that has remained unchanged ranges from 7% in Los Angeles to 30% in Ventura with Santa Barbara and Orange both around 15%.

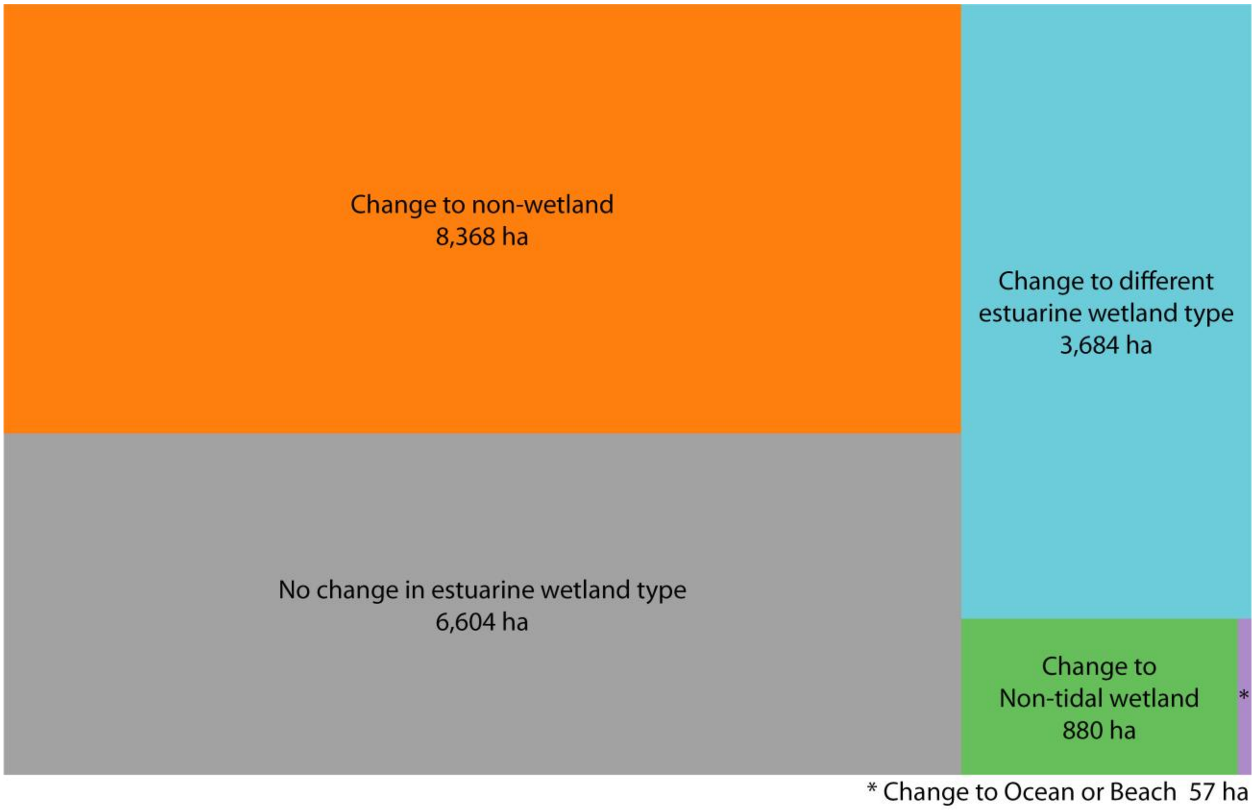


Figure 13. Proportion of estuarine type conversion in Southern California coastal region. Change is between ca. 1850 and 2005. A nominal amount of historical estuarine habitat has been converted to marine. A detailed breakdown of the type conversion can be seen in Table 7.

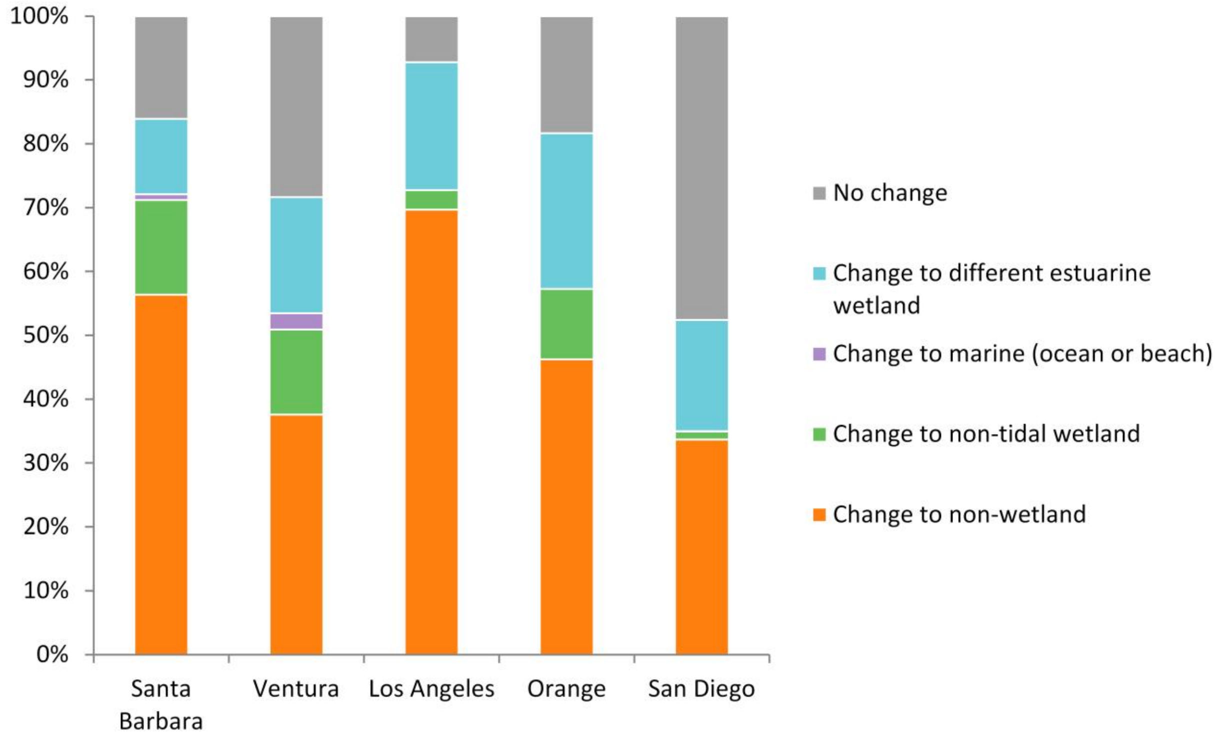


Figure 14. Proportion of estuarine type conversion by county. Change is between ca. 1850 and 2005

New Estuarine Habitats

In some areas, new estuarine habitats have been created after ca. 1850. These areas are located outside of the historical extent of wetlands mapped on the T-sheets. For the purposes of this report, new estuarine habitats were not part of the historical distribution but are newly created or have been extended from historical areas due to natural migration, creation or restoration activities. New estuarine habitats were included in the overall change analysis but for simplicity separated from the historical type conversion analysis. This summary includes only contemporary estuarine features that do not coincide with historical estuarine features.

Eight historical land cover types were identified as the predecessors to the new estuarine habitats now present (Table 7). For simplicity, the eight land covers have been conflated into three broad historical land cover types: marine, non-tidal wetlands, or non-wetlands. These broad categories loosely parallel those used in the previous analysis. Due to the limitations of the T-sheets, the non-wetland category could include non-tidal wetlands that were not mapped on the original T-sheet as these features were outside the scope and purpose of the T-sheets and therefore inconsistently mapped by surveyors. The omission of upland features on the T-sheets does not necessarily mean no wetland feature existed. For this analysis, if no feature was mapped on the T-sheet we assume no wetland feature existed. These results may overestimate the non-wetland category and underestimate non-tidal wetland category.

The results of this analysis show that in 2005 the SCB has 2,081 hectares of estuarine habitats (including subtidal water) that were not historically present as seen on the T-sheets. Approximately 67% of this "new" estuarine area was converted from the marine category (Figure 15). Most of this was "reclamation" of ocean habitat; however about 150 hectares of beach and dune were also converted to estuarine habitats (Table 7). The majority of this conversion was associated with the creation of the Ports of Los Angeles/Long Beach. Most of the remaining new estuarine area (approximately 600 ha) resulted from the conversion of non-wetland areas including agriculture, undeveloped open space, and developed areas. The remaining 100 ha consist of former non-tidal wetlands, such as emergent and woody vegetated wetlands, open water wetlands, and streams/rivers that were converted to contemporary estuarine habitats.

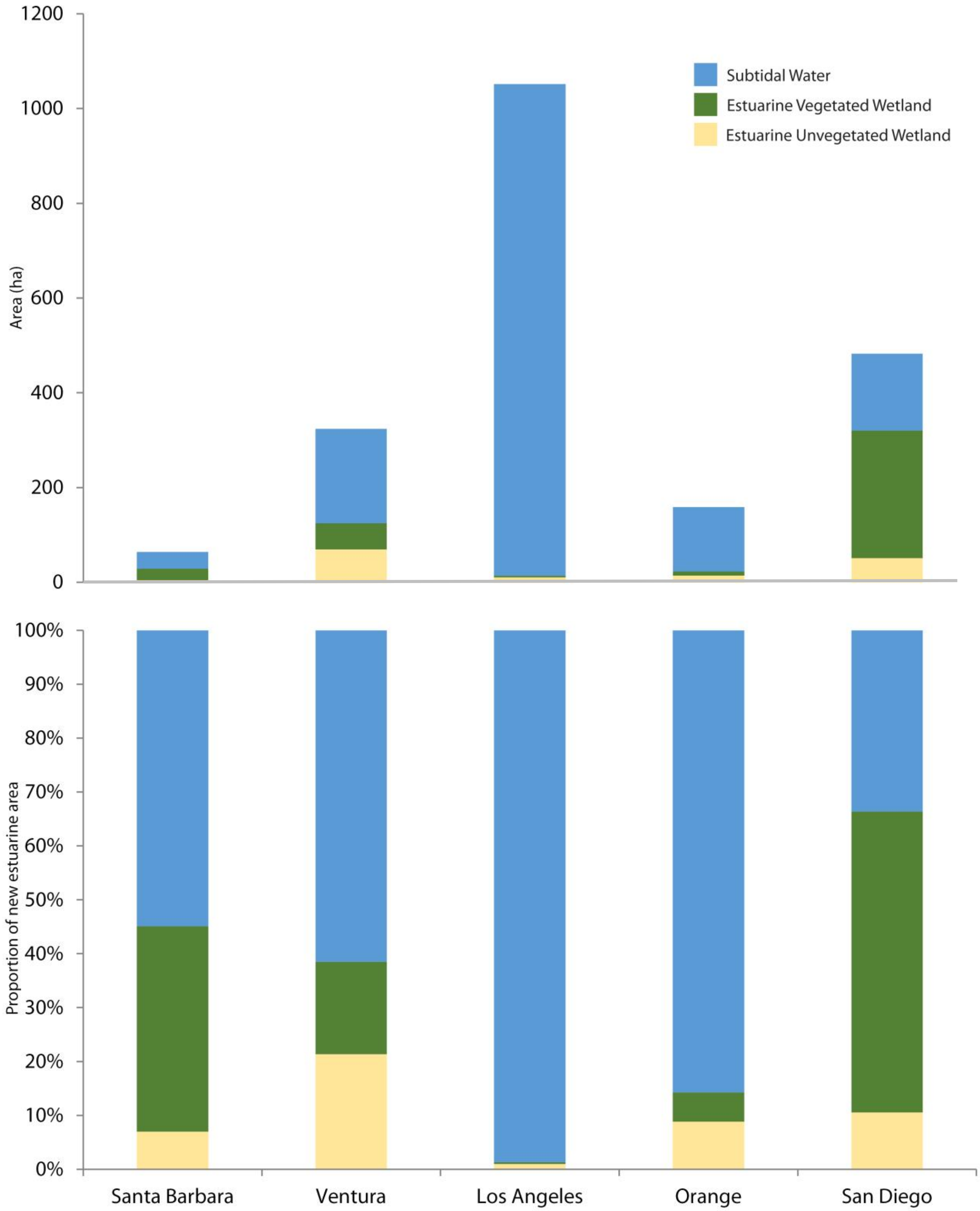


Figure 15. Proportion (top) and area (bottom) of new estuarine habitat by county. Area was non-estuarine habitat in ca. 1850 and is estuarine in the contemporary landscape.

Table 7. Detailed breakdown of change and persistence of historical estuarine habitat. Numerical values indicate hectares converted from historically estuarine areas to contemporary land cover types. The sizes of the circles are proportional to the quantity of change (or persistence for the gray colored cells).

Contemporary Land Cover		Historical Estuarine Habitat: Subtidal Water	Historical Estuarine Habitat: Estuarine Vegetated Wetland	Historical Estuarine Habitat: Estuarine Unvegetated Wetland
Estuarine	Subtidal Water	4,891	985	1,378
Estuarine	Estuarine Vegetated Wetland	132	1,313	526
Estuarine	Estuarine Unvegetated Wetland	152	512	399
Non-estuarine	Vegetated non-tidal wetland	35	360	113
Non-estuarine	Unvegetated non-tidal wetland	23	204	108
Non-estuarine	Stream	3	17	5
Non-estuarine	Lake	9	1	0
Marine	Beach	12	20	21
Marine	Ocean	1	1	2
Non-wetland	Non-wetland	1,655	4,338	2,375

CONCLUSIONS, MANAGEMENT IMPLICATIONS, AND NEXT STEPS

This report provides the first comprehensive view of the composition of estuaries and coastal streams along the SCB (ca. mid-late 1800s). Together they show a complex mosaic of approximately 25,000 hectares of estuarine and wetland habitat and over 330 coastal systems. Of the 25,000 ha mapped, approximately 19,600 ha was estuarine subtidal, vegetated, or unvegetated habitat. The remaining 5,400 ha consisted of dune and beach habitat, woody vegetated wetlands, high marsh habitat, and other isolated ponds. Most of historical systems were small (i.e., less than 100 hectares) and coastal drainage networks comprised approximately 2/3 of all systems along the SCB. Larger wetland systems were distributed in the southern portion of Ventura County, at the southern Los Angeles County-Northern Orange County border and along the San Diego coast. These larger systems were connected by series of small coastal estuaries and together formed a relatively continuous chain of estuarine systems along the SCB coast. This interconnected system of estuaries likely functioned as a complex metapopulation that allowed exchange of materials and organisms along the SCB.

Estimated overall estuarine habitat loss within our study area was approximately 48%, which is lower than widely cited statewide estimates of over 90% (Dahl 1990, Huspeni and Lafferty 2004, Zedler 2004). However, losses of vegetated and unvegetated estuarine area (e.g., salt marsh, salt flat, mudflat) were closer to 80%, which is more similar to previously cited estimates. Furthermore, statewide estimates are heavily influenced by extensive wetland loss from the San Francisco-Bay Delta Region, loss of freshwater wetlands from the Central Valley, and other potential wetland types that were not mapped on the historical T-sheets. For example, more detailed historical ecology studies performed within the SCB found vast inland wetland complexes associated with these coastal systems no longer exist, suggesting that the overall loss of wetlands within the SCB is much greater than the overall 48% estimate along the coast (Beller et al. 2011, Dark et al. 2011, Stein et al. 2007). In addition, losses of coastal dunes and changes to beach habitats were not quantified as part of our analysis, and should be the focus of subsequent studies that can build from the T-sheet results.

It is possible, that the lower levels of loss compared to previous estimates reflect the regulatory and management attention given to coastal wetlands over the past 30 years. In recognition of the ecological importance of these systems and the fact that they only occur in specific geographies along the coast, estuarine wetlands are subject to more regulations (e.g., the California Coastal Act) and proposed projects are scrutinized more heavily to avoid and minimize losses. This increased attention may be partly responsible for lower losses along the coast compared to statewide estimates.

Given trends of land use change along the Southern California coast over the last 150 years, it is not surprising that change analysis results indicate a substantial overall loss of estuarine habitats since ca. 1850. This is consistent with general trends of wetland loss across the country indicated in the recent US Fish and Wildlife's Wetlands Status and Trends report (Dahl and Stedman 2013). Similar patterns of loss have been reported in other regions of the U.S. (e.g., Fletcher et al. 2012) and California, most notably the San Francisco Bay Area. Much of this loss has been due to conversion to land use practices including agriculture, grazing, and development. Filling of these critical wetlands for infrastructure and development was a common practice throughout the early 20th century (Goals Report 1999).

In addition to overall loss, there has been substantial type-conversion since the mid-19th century. Understanding this type conversion is key to developing restoration plans that reflect historical trends. The proportion of subtidal habitat has increased from approximately 35% of the total estuarine habitat to over 70%, with most of the conversion occurring to the larger systems in the Los Angeles, Orange, and San Diego County areas. In addition, marine areas have been converted to subtidal habitats in the form of both small marinas (e.g., Oceanside harbor) and large ports and harbors (e.g., Port of Long Beach/Los Angeles) which has further altered the overall composition of estuarine habitats.

The loss of estuarine habitat through land use change and type conversion is indicative of both a loss in biodiversity and functionality compared to contemporary wetland systems within the SCB. Healthy estuaries are among the most productive ecosystems on the planet, comparable to rainforests and coral reefs. Nearly 45% of the Nation's endangered and threatened species depend on wetland habitats, emphasizing the importance of this productivity (U.S. Fish and Wildlife Service (USFWS) 1995). In addition to providing habitat for fish and wildlife, estuaries benefit humans by improving water quality, protecting coastal communities against damage from erosion and flooding, and providing recreational opportunities for wildlife viewing and exploration, hunting, fishing, and tourism (Dahl and Stedman 2013). The historical estuaries of the SCB likely supported a much greater diversity of plants and wildlife than the contemporary subtidal habitats that dominate the current landscape. Converting subtidal habitats back to diverse estuarine systems may not be realistic in many places. However, restoration plans that support development of a greater diversity of habitat types would support the potential for restoring some of the naturally biodiverse communities and functions of historical estuaries in the SCB region.

Both regional and site-specific restoration planning can be informed by the knowledge of historical patterns and contemporary losses. We recognize that these ecosystems are greatly modified today by humans and were likely modified to some extent at the time the T-sheets were mapped as well. For this reason, restoration of historical processes or structures may be impossible if not undesirable. Despite the continued impacts from humans and potential threats associate with climate change, we still must manage and sustain ecosystems within the inherent limits and tolerances of species and communities (Swetnam et al. 1999). Knowledge of these historical conditions helps to define these limits creating an opportunity for the development of restoration goals and planning that are more effective in managing today's wetland ecosystems within the SCB. Lost habitats can be prioritized and restoration designs can be adjusted based on considerations of the composition of historical estuaries. Investigation of the relationship between wetland structure and landscape setting can also inform management by providing insight into key processes that govern wetland form and stressors that, if managed, can promote resiliency.

Results of this historical analysis should be used with caution. The T-sheet analysis provides a relatively simplistic view of historical estuaries at a single point in time. Full historical ecology studies of estuaries and their contributing watersheds are needed to provide a more complete understanding of wetland composition and insight into wetland processes. Studies that encompass longer time periods and varying climatic conditions are necessary to more fully understand the dynamism of coastal systems and how they may respond to future changes in climate and anthropogenic activities. Southern California's coastal watersheds have changed dramatically over the past 150 years. Watershed processes such as sediment and water delivery, and constraints such as development and infrastructure barely resemble conditions that controlled estuarine processes in the 19th century. These changes as well as contemporary management priorities and anticipated future changes must be considered in restoration planning. Nonetheless, the historical perspective provided by this T-sheet analysis provides a valuable foundation for building an integrated decision making framework.

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APPENDIX A CLASSIFICATION DEFINITIONS

VEGETATED, UNVEGETATED & UPLAND VEGETATED

Vegetated, emergent marsh–High elevation–Intertidal

This category refers to vegetated, intertidal marsh plains. In most cases these could be considered tidal marsh or estuarine emergent wetlands. The symbol — closely spaced parallel lines with grass tufts — literally refers to "salt marsh." However, the symbol may also include brackish or even freshwater tidal marsh, since the landward edge of true salt marsh was a lower priority feature for the Survey and sometimes not very accessible (Shalowitz 1964: 181).

In California T-sheets, a nonstandard, incomplete version of the conventional salt marsh symbol with the tufts omitted is common (e.g., p. 37). This permutation of the salt marsh representation using only the closely spaced parallel lines was produced by draftsman's error and indicates no difference in vegetation from the tufted form (Shalowitz 1964: 189-191). Given the presence of low elevation marshes on some of the T-sheets (see below), we record all other marshes as high elevation. However, Shalowitz (177) is careful to note that no specific information is provided by the T-sheets about marsh elevation, except relative to low water and low marsh. Our "high elevation" category probably includes both what would be called "middle marsh" and "high marsh" in contemporary terminology, as the T-sheets did not distinguish these parts of the marsh plain. In San Pedro Bay, extensive freshwater marsh is shown bordering salt marsh. The extension of tidal channels into this area suggests that it may have been subject to some tidal influence, but the symbology and discussion by Shalowitz suggest that these areas were not generally subject to the tides. As a result they are classified as outlet closed (see p. 24-25).

Vegetated, emergent marsh–High elevation–Outlet closed

In instances where the salt marsh symbols described above were used with no direct tidal connection, we attributed the feature as outlet closed. This classification primarily refers to marshes that are part of a closed lagoonal system (e.g., see p. 28-29). It also includes some isolated, non-tidal marshes that were nevertheless depicted with the salt marsh symbol (see p. 36-37). These marshes presumably had salt tolerant vegetation — otherwise they would have been shown as freshwater marsh.

Vegetated, emergent marsh–Low elevation – Intertidal or Outlet closed

Low elevation marsh was occasionally shown at the margin of the standard, higher elevation marsh. While the symbol did not appear in the official list until 1892, when it was termed "submerged marsh," this symbolic practice was described as early as 1865 (Harrison 1867) to show marsh areas mostly flooded at high tide (e.g., "grassy shoals" or "grass upon flats, or shoals covered at high tide"; Shalowitz 1964: 182, 200, 203, 205). The feature is depicted with a symbol similar to conventional salt marsh, but without a bounding line and often with gaps in the horizontal lines. We interpret several of permutations of this symbol as referring to low elevation marsh (see p. 36-37). These areas likely correspond to what we would call cordgrass (Spartina foliosa) marsh.

Vegetated, emergent marsh–Extreme high elevation–Supratidal

This class refers to wetlands depicted immediately inland of, and distinct from, emergent tidal wetlands, with some indication of at least occasional tidal inundation. It includes seasonal wetlands such as the saltgrass zone (Distichlis spicata) indicated by a nonstandard grassland symbol and confirmed by the annotation “line of saltgrass” at Mugu Lagoon (see p. 16-17). We would expect much or all of these areas to receive occasional inundation by the highest tides, but they may also include a component of adjacent palustrine, non-tidal wetlands. It is also likely that smaller instances of this habitat were not shown, or that other surveyors depicting the same habitat would lump it into the adjacent tidal or palustrine unit. Large areas depicted as freshwater marsh adjacent to salt marsh along San Pedro Bay have some indications of tidal influence (e.g., extensions of channel networks); these may have also had some occasional tidal influence.

Vegetated, emergent marsh–Extreme high elevation–Non-estuarine

This classification is applied to the freshwater marshes shown along the inland margin of salt marsh on the shores of San Pedro Bay. These areas appear to have been above regular influenced by the tides. Full discussion of the interpretation is provided in the T-1345 section (see p. 24-25) of the Phase I report.

Vegetated–Woody

In some places woody vegetation was a significant component of the landward margin of the estuarine ecosystem. Some maps explicitly indicate that these were wetlands, by using the “Wooded Marsh”

symbol (Shalowitz 1964: 201). Others use versions of the clumpy, cloudlike woodland symbol without the horizontal lines indicative of inundation, but use annotations such as “Willow Thickets” (T-1283) or “Willow Swamps” (T-1369) to convey the wetland context. In other cases, that symbol is used without the helpful annotation but we have other evidence confirming the swamp status. (For example at the mouth of Santa Clara River, the woodland shown by Johnson in 1855 (T-683) is further illustrated by a circa 1840 *diseño* showing a *sausal* (willow grove) and an ecologist’s 1870s description of an willow trees and cottonwoods at the same site (Cooper 1887).) These features would be considered palustrine scrub-shrub or forested wetlands, riparian scrub, or woodland. Many of these woodland features adjacent to estuarine wetlands extend well upslope, however, and provide no direct information about their wetland character. The symbol varies by surveyor, with general similarities to standard symbols described as “Round Leaf” or “Deciduous and Undergrowth” (Cooper 1887). In the absence of other corresponding information, we classified these areas simply as woody vegetation. While some are undoubtedly riparian forest or woodland, others cannot be confirmed without additional information.

Unvegetated–High elevation–Intertidal/Supratidal, Outlet closed, & Non-estuarine

These features are generally found at the landward edge of marshland, indicated as enclosed shapes with widely spaced stipple pattern. This pattern would typically indicate a dry sandy substrate, but a number of these features are annotated with the word ”Alkali” (T-1345) or “Alkali flat” (T-1283), indicating seasonally-evaporative salt flats or playas. Shalowitz (1964: 191) confirms this interpretation, noting it as an unusual symbol. Since these features lie within or at the margin of tidal marshlands, we presumed that they receive at least occasional inundation by the highest tides. As noted by Engstrom (2006), the salt deposits in one of these features were sampled by early soil scientists and determined to be of saline origin, suggesting they should be considered part of the tidal marsh complex. Several large features without this fill pattern and with unusual, indeterminate boundaries to surrounding marshland are found in San Diego County (see p. 28-29, 32-33). They appear to be distinct from open water areas, which have solid line edges, sometimes at the margin of these features. The presence of multiple roads across these features suggests that they are seasonally dry. (The frequency and position of roads (e.g., not limited to narrow points) would not be practical on levees.) These features may be equivalent to the stippled areas labeled “Alkali” in other surveys (e.g., T-1345), but more information is needed to develop a full interpretation. At river mouths, high elevation unvegetated areas may include sandbars, which are typically shown with a similar stipple pattern.

Unvegetated–Low elevation–Intertidal

This classification refers to the area between the dotted line of mean lower low water (MLLW) and lower limit of marsh vegetation or land, typically referred to as tidal flat (e.g., mudflat, sand flat, shellflat). The interpretation of the dotted low water line as MLLW is well established (Whiting 1861; Shalowitz 1964: 185, 189-190). However the appropriate use of this line from the T-sheets is somewhat complicated. MLLW was mapped by both the Topographic and Hydrographic survey parties, with the understanding that the topographic, land-based plane table survey would be more accurate near the shore (where soundings were difficult) while hydrographic soundings from boats would be more effective in the open water, away from the shore (Whiting 1861, Shalowitz 1964:184). Accordingly, we only captured tidal flats within the estuarine context (where they are likely to be surveyed accurately and not shown by the H-sheets). In some places, it would be informative to examine the MLLW line on the H-sheets, which have not been obtained at this time. It should be noted that tidal flats often extend continuously into tidal channels. That is, tidal channels that were contiguous with broad adjacent intertidal areas are also mapped as unvegetated, low elevation (e.g., tidal flat). Unvegetated intertidal areas with elongate shapes and unconnected to more broad areas were classified as channel, intertidal (see below). This distinction was made to allow such features to be tabulated and visualized independently, but the habitats can be considered largely similar. A similar area was defined by the dotted line of MLLW in some cases where direct tidal connection was not shown. These features, which may reflect more seasonal inundation, are mapped similarly but with the "non-tidal" classification.

In the case of a few features, such as the mouth of San Juan Creek, the T-sheet indicates a fairly large intertidal area relative to the size of the barrier beach opening. However, given that the area is shown explicitly as intertidal, and subtidal waters were indicated by the same surveyor in neighboring systems, we recorded the T-sheet representation.

Upland Vegetated

This class refers to islands, generally with low, herbaceous vegetation, surrounded by other mapped features, most commonly within the marsh plain (see p. 17, 37). These areas are frequently depicted with the traditional symbol for grass or pasture: grass tufts, with no horizontal lines (Shalowitz 1964: 189-90; see p. 17, 37). But small hills within the marshlands can also be depicted simply as closed polygons with no symbol, which could also mean salt pond. On T-1345, one of these features is used as a triangulation station and labeled "Little Hill," confirming its interpretation and suggesting that other nearby features are, at least in this case, hills rather than ponds (see p. 24-25). Given the potential alternative meanings of this symbol, its interpretation should be considered on a case-by-case basis within the local context. We only digitized these islands of upland vegetation within estuaries, rather than the extensive areas of upland often shown farther inland on the T-sheets.

OPEN WATER and CHANNEL

As discussed above, surface waters are indicated in T-sheets by outlined shapes with no fill or, less frequently, with concentric inlines (Hergesheimer 1881, Shalowitz 1964: 200, 205).

Open water–Subtidal and Channel–Subtidal

Subtidal areas remain filled at low water and are indicated by the T-sheets as the area below or bounded by the dotted line of mean lower low water. While this is a consistent, well-documented delineation, there are sites where the interpretation is not obvious, either because the map is incomplete or because of complex landscape topology. We also noted a few areas suggested as subtidal by the presence of the symbology representing a persistent pond (multiple concentric outlines) within a larger open water (presumably intertidal) area. We classified the extensive, elongate networks of subtidal water as *channel–*

subtidal. These features intergrade into the *open water– subtidal* class and in many cases could be considered equivalent habitats. Some uncertainty was associated with the upstream extent of subtidal channels. In many cases, the parallel low water lines converge, indicating the narrowing of the channel. (We did not map the upstream continuation of very narrow subtidal channel sometimes indicated with a single dotted line; however, these can be seen on the original maps.) In cases where it was not clear where to terminate the subtidal channel, we made a somewhat arbitrary distinction based on adjacent habitats and representation of similar features in other places. While these uncertainties generally involve relatively small areas (and thus are unlikely to significantly affect, for example, quantification of major habitat proportions), they could affect the interpretation of specific areas. For this reason, it is recommended to use the T-sheet GIS in combination with the georeferenced raster images.

Open water–Intertidal/Supratidal

This classification refers to enclosed bodies of water subject to some, generally limited, tidal connection. Because they are enclosed by vegetation (or vegetation and upland margin) we expect these features to occupy relatively high marsh elevations and receive infrequent tidal filling. These include the features that would be referred to as marsh ponds or pannes (e.g., "Pond," p. 37, T-365). Some of these features were shown as connected to single-line tidal channels, but a number of those were shown with concentric inlines indicating persistent water. These may have different tidal regimes than the other, more isolated open water areas. There were a few anomalous features shown as open water within tidal flats (T-892). These could potentially be vegetated marsh areas without fill due to engraver's error.

Many of these waters may evaporate in the late summer, becoming equivalent to unvegetated, extreme high elevation areas (e.g., salt flats).

Open water–Outlet closed

Areas indicated as water but with no tidal connection were classified as *open water–outlet-closed*. These include the open water in closed lagoons, (e.g., "Salt Water Pond," T-576).

Channel–Intertidal

We classified all single-line channels within tidal systems as intertidal channels, even though subtidal conditions were not always explicitly shown as terminating before channels narrowed to single-line representation. Unvegetated intertidal areas with elongate shapes and unconnected to more broad areas were also classified as *channel– intertidal* (see *unvegetated–intertidal* description above). Frequently the T-sheets did not indicate the transition between subtidal, intertidal, and supratidal waters extending upstream at river mouths. If the T-sheet was interpreted literally, subtidal or intertidal habitat would extend well upstream into steep watersheds. In these cases, we made somewhat arbitrary boundaries between based on adjacent habitats.

Channel–Fluvial

Where tidal or non-tidal channels extended well upstream beyond coastal wetland features, we made a somewhat arbitrary breakpoint at the upper limit of wetland features. Given the need for more information about these upland creeks, they were referred to as *channel–fluvial*. Additionally, elongate features indicated as water but with no tidal connection were classified as *channel–fluvial*.

Channel–Gully

Gullies are delineated on the T-sheets with hachures but with no channel line on the bottom.

BEACH and DUNE

Sandy substrates along the shoreline are represented with a variety of permutations on the standard stippled pattern. Sandy beach is distinguished from dune topography by contours, stipple patterns, or hachures, as illustrated by Shalowitz (1964: 189, 204)

CLASSIFICATION CHANGES COMPARED TO PHASE I

A number of T-sheet classification changes have been made during this project that apply to all of the categories (Level I, Level II and Level III). All features mapped in Phase I have been updated to reflect the new classification.

Level I Changes:

The 'Upland Vegetated' classification was created to isolate non-wetland vegetated features from the vegetated wetland features identified in the 'Vegetated' class.

Level II Changes:

- 'Terminus Type' Classification (we used this direct observation instead of inferring intermittency):
  - Added to both the Level I 'Open Water' and 'Channel' categories.
  - Provides additional information about the relationship between the stream or wetland feature and the location where the feature terminates (e.g., pond/lagoon, ocean, non-wetland, etc.)
  - Coastal terminus is applied to features that cannot be given 'subtidal' or 'intertidal' Level III classifications based on T-sheet symbology.
  - Only applied when features fall within 400 m of the coast.
- 'Bar/Island' Classification:
  - Added to the Level I 'Channel' category.
  - Used to identify unvegetated features that have been formed due to sediment deposition (e.g., sandbars, point bars, etc.).

Level III Changes:

- Title changed to *Interpreted Hydrology* from *Tidal Regime.*
- 'Non-tidal' was changed to 'outlet closed' (for non-channel features). Tidal regime can only be reliably inferred from T-sheet delineations in certain instances (i.e., subtidal and intertidal). Many

features are in fact tidally influenced, but cannot be mapped as such because information provided on the T-sheets is not sufficient. As a result, ‘non-tidal’ was changed to ‘outlet closed’ which describes the mapped feature rather than making inferences about the tidal regime.

- ‘Intertidal’ changed to ‘supratidal’ within the ‘Extreme High’ and ‘High Elevation’ Level II categories. Supratidal refers to features that are not regularly influenced by the tides and occur beyond the high tide zone.
- A ‘non-estuarine’ category was created to refer to wetland features that do not appear to be tidally influenced.
- ‘Non-tidal’ and ‘undefined’ for the Level I ‘channel’ category have been lumped into ‘fluvial’. ‘Gully’ has been added as a Level III classification for the Level I ‘channel’ category.

APPENDIX B: COWARDIN CLASSIFICATION

The NWI's mapping methodology is the federal standard for wetland mapping and is consistent with that being used for California's Statewide Wetland Inventory. Mapping is done in a geographic information system and based on interpretation of color-infrared and true-color aerial photography with some field-based ground truthing. Collateral data sources are also used and include: National Hydrography Data (USGS 2004), hydric soils data (NRCS 2005), USGS topographic maps, and land use. All maps produced go through a watershed stakeholder review process designed to identify any inaccuracies and increase stakeholder involvement and accuracy in the final product. However, the majority of the mapping is performed based on interpretation of aerial photography and collateral data. Data acquired from CGS has been mapped per NWI's mapping methodologies, however, a finer minimum mapping unit was used and the data has gone through a more extensive stakeholder review process to validate mapping and classification accuracy at a local scale.

The NWI uses the Cowardin Classification system which is shown below:

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

SYSTEM: M - MARINE

SUBSYSTEM: 1 - SUBTIDAL

CLASS / Subclass:

- RB – ROCK BOTTOM
  - 1 Bedrock
  - 2 Rubble
- UB – UNCONSOLIDATED BOTTOM
  - 1 Cobble-Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
- AB – AQUATIC BED
  - 1 Algal
  - 3 Rooted Vascular
  - 5 *Unknown Submergent*
- RF - REEF
  - 1 Coral
  - 3 Worm
- OW - *OPEN WATER/ Unknown Bottom*

SUBSYSTEM: 2 - INTERTIDAL

CLASS / Subclass:

- AB – AQUATIC BED
  - 1 Algal
  - 3 Rooted Vascular
  - 5 *Unknown Submergent*
- RF– REEF
  - 1 Coral
  - 3 Worm
- RS – ROCKY SHORE
  - 1 Bedrock
  - 2 Rubble
- US - UNCONSOLIDATED SHORE
  - 1 Cobble-Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic

SYSTEM: E - ESTUARINE

SUBSYSTEM: 1 - SUBTIDAL

CLASS / Subclass:

- RB - ROCK BOTTOM
  - 1 Bedrock
  - 2. Rubble
- UB – UNCONSOLIDATED BOTTOM
  - 1 Cobble-Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
- AB – AQUATIC BED
  - 1 Algal
  - 3 Rooted Vascular
  - 4 Floating Vascular
  - 5 *Unknown Submergent*
  - 6 *Unknown Surface*
- RF – REEF
  - 1 Mollusc
  - 2 Worm
- OW - *OPEN WATER/ Unknown Bottom*

SUBSYSTEM: 2 - INTERTIDAL

CLASS / Subclass:

- AB – AQUATIC BED
  - 1 Algal
  - 3 Rooted Vascular
  - 4 Floating Vascular
  - 5 *Unknown Submergent*
  - 6 *Unknown Surface*
- RF– REEF
  - 1 Mollusc
  - 2 Worm
- SB – STREAMBED
  - 1 Cobble Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
- RS - ROCKY SHORE
  - 1 Bedrock
  - 2 Rubble
- US – UNCONSOLIDATED SHORE
  - 1 Cobble-Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
- EM -EMERGENT
  - 1 Persistent
  - 2 Nonpersistent
- SS – SCRUB-SHRUB
  - 1 Broad-Leaved Deciduous
  - 2 Needle-Leaved Deciduous
  - 3 Broad-Leaved Evergreen
  - 4 Needle-Leaved Evergreen
  - 5 Dead
  - 6 *Deciduous*
  - 7 *Evergreen*
- FO – FORESTED
  - 1 Broad-Leaved Deciduous
  - 2 Needle-Leaved Deciduous
  - 3 Broad-Leaved Evergreen
  - 4 Needle-Leaved Evergreen
  - 5 Dead
  - 6 *Deciduous*
  - 7 *Evergreen*

SYSTEM: R - RIVERINE

SUBSYSTEM: 1 – TIDAL; 2 – LOWER PERENNIAL; 3 – UPPER PERENNIAL; 4 – INTERMITTENT; 5 – *UNKNOWN PERENNIAL*

CLASS / Subclass:

- RB – ROCK BOTTOM
  - 1 Bedrock
  - 2 Rubble
- UB – UNCONSOLIDATED BOTTOM
  - 1 Cobble-Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
- *SB – STREAMBED
  - 1 Bedrock
  - 2 Rubble
  - 3 Cobble Gravel
  - 4 Sand
  - 5 Mud
  - 6 Organic
  - 7 Vegetated
- AB – AQUATIC BED
  - 1 Algal
  - 2 Aquatic Moss
  - 3 Rooted Vascular
  - 4 Floating Vascular
  - 5 *Unknown Submergent*
  - 6 *Unknown Surface*
- RS – ROCKY SHORE
  - 1 Bedrock
  - 2 Rubble
- US – UNCONSOLIDATED SHORE
  - 1 Cobble-Gravel
  - 2 Sand
  - 3 Mud
  - 4 Organic
  - 5 Vegetated
- **EM – EMERGENT
  - 2 Nonpersistent
- OW – *OPEN WATER/ Unknown Bottom*

* STREAMBED is limited to TIDAL and INTERMITTENT SUBSYSTEMS, and comprises the only CLASS in the INTERMITTENT SUBSYSTEM.
** EMERGENT is limited to TIDAL and LOWER PERENNIAL SUBSYSTEMS.

Classification of Wetlands and Deepwater Habitats of the United States
Cowardin ET AL. 1979 as modified for National Wetland Inventory Mapping Convention

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

SYSTEM: L- LACUSTRINE

SUBSYSTEM: 1 - LIMNETIC

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	

SUBSYSTEM: 2 - LITTORAL

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	RS – ROCKY SHORE	US – UNCONSOLIDATED SHORE	EM – EMERGENT	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	2 Nonpersistent	

SYSTEM: P - PALUSTRINE

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	US – UNCONSOLIDATED SHORE	ML – MOSS-LICHEN	EM – EMERGENT	SS – SCRUB-SHRUB	FO – FORESTED	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Moss 2 Lichen	1 Persistent 2 Nonpersistent	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	

MODIFIERS

In order to more adequately describe the wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

WATER REGIME: Non-Tidal		WATER REGIME: Tidal		WATER CHEMISTRY: Coastal Halinity	WATER CHEMISTRY: Inland Salinity	WATER CHEMISTRY: pH Modifiers for all Fresh Water	SOIL	SPECIAL MODIFIERS	
A Temporarily Flooded	H Permanently Flooded	K *Artificially Flooded*	*S Temporary-Tidal	1 Hyperhaline	7 Hypersaline		g Organic	b *Beaver*	h *Diked/Impounded*
B Saturated	J Intermittently Flooded	L Subtidal	*R Seasonal-Tidal	2 Euthaline	8 Eusaline	a Acid	n Mineral	d *Partially Drained/Ditched*	r Artificial Substrate
C Seasonally Flooded	K Artificially Flooded	M Irregularly Exposed	*T Semipermanent-Tidal	3 Mixohaline *(Brackish)*	9 Mixosaline	t Circumneutral		f Farmed	s *Spoil*
D *Seasonally Flooded/ Well Drained*	W Intermittently Flooded/Temporary	N Regularly Flooded	*V Permanent-Tidal	4 Polyhaline	0 Fresh	i Alkaline			x Excavated
E *Seasonally Flooded/ Saturated*	Y Saturated/Semipermanent/ Seasonal	P Irregularly Flooded	U *Unknown*	5 Mesohaline					
F Semipermanently Flooded	Z Intermittently Exposed/Permanent			6 Oligohaline					
G Intermittently Exposed	U *Unknown*			0 Fresh					

*These water regimes are only used in tidally influenced, freshwater systems.

NOTE: Italicized terms were added for mapping by the National Wetlands Inventory program.