Historical Wetlands of the Southern California Coast

AN ATLAS OF US COAST SURVEY T-SHEETS, 1851-1889

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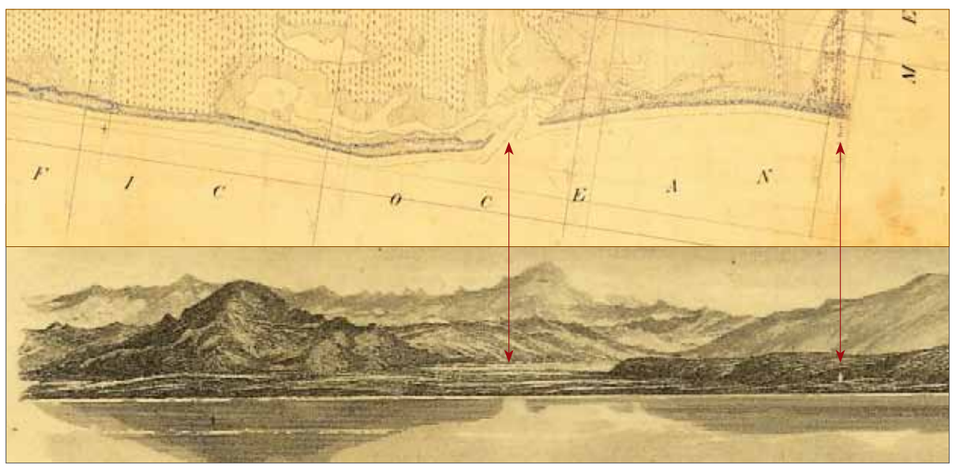

Executive Summary

This report (the "T-sheet Atlas") presents the first regional assessment of the relative distribution and abundance of different wetland habitat types along the historical Southern California coastline ("South Coast"). We acquired, interpreted, digitized, and performed initial analysis of 26 T-sheets for the South Coast. These data can be accessed through the T-sheet Atlas, a GIS database, and an interactive website (www.caltsheets.org). Images of each T-sheet, with corresponding habitat information overlaid on aerial photography, are presented in the Atlas, along with guidance for appropriate interpretation and application.

Major findings of the study include the following.

- There were about 20,000 ha (49,400 acres) of estuarine habitats along the Southern California coast prior to modern development.
- The most common estuarine habitat type was vegetated wetlands (i.e. salt or brackish marsh), followed by subtidal waters and intertidal flats. Salt flat and open water were smaller components of the regional habitat mosaic.
- The subregional distribution of estuarine habitat types was heterogeneous. For example, subtidal waters predominated in one subregion - Mission Bay/Silver Strand. Vegetated wetlands were the dominant habitat type in all other subregions. Salt flat was found predominantly in the San Pedro and Oceanside regions.
- Most of the estuarine habitat area of Southern California was found in a relatively small number of systems. The top 21 systems accounted for 98% of the estuarine habitat area.
- Distinct habitat mixes can be identified among these systems, suggesting a preliminary set of regional coastal estuarine patterns or archetypes. The most common archetype was broad tidal marshes with adjacent intertidal flats and smaller areas of subtidal water, open water, and salt flat. Several other patterns were observed in different physiographic settings.

The T-sheet Atlas and associated geodatabase provide a tool for efforts to understand how these coastal wetland systems work and how they can be best managed over time. Future research should incorporate additional historical and contemporary data sources to better understand early historical conditions, system dynamics, and change through time.

Acknowledgments

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We would like to thank the students at California State University Northridge Center for Geographic Studies who worked on the project, especially Veronica Rojas and Danielle Bram. The quality of the T-sheet geodatabase is due in large part to their dedication, and that of contributors Mami Odaya and April Robinson at SFEI. Bronwen Stanford and Micha Salomon of SFEI also contributed to the Atlas.

Special thanks go to Dr. John Cloud of the NOAA Central Library for making high-resolution scans of the T-sheets available and sharing his knowledge about USCS history. The insightful comments of our technical reviewers – Krista Jones and Jim O'Connor (USGS), Brian Collins (University of Washington), Wayne Engstrom (Cal State Fullerton), and Wayne Ferren – substantially improved the quality and clarity of the Atlas. Peter Baye, Bryant Chesney, John Cloud, Josh Collins, David Jacobs, Carolyn Lieberman, Larry Smith, and members of the Science Advisory Panel of the Southern California Wetland Recovery Project also provided helpful advice and comment.

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Cover credits:

Counter clockwise from top left: portion of T-1345; portion of T-365; U.S. Coast and Geodetic Survey 1852; T-576; T-576 with features digitized; same area overlaid on USDA 2005 imagery

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AVAILABLE ONLINE AT *WWW.CALTSHEETS.ORG*

1. INTRODUCTION

This report presents the results of an effort to acquire, interpret, and digitize the renowned 19th-century United States Coast Survey maps of the Southern California coast ("South Coast") for use in local and regional wetland management. The extent of South Coast wetlands has been dramatically reduced over the past 150 years, and remaining wetlands are heavily altered. Scientists, managers, and the public face challenging decisions about which areas should be acquired; what kinds of habitats should be restored where; and how these estuarine systems can grow and adapt over time to support target habitats and functions.

Without information about how systems functioned under more natural conditions, these challenges are much more difficult (NRC 1992). Recent research has shown that restoration and management strategies have frequently been based on misunderstandings or misconceptions about the historical landscape (Kondolf 2006, Grossinger et al. 2007, Minnich 2008, Montgomery 2008). Reliable reconstructions of historical conditions reveal the array of natural habitats and functions that ideally should be conserved within the region (Ambrose and Bear 2008). By examining historical landscape patterns, scientists can discover how native habitats were organized along topographic, hydrologic, and climatic gradients (Collins and Montgomery 2001) – essential information for designing future habitat mosaics in the context of contemporary and projected conditions. As a result, historical ecology can help identify previously unrecognized restoration opportunities and strategies (e.g., Grossinger et al. 2007, Whipple et al. 2011). Perhaps most importantly, historical information can help develop a shared understanding of regional habitat values, leading to broadly supported targets for conservation (Hanley et al. 2009).

This T-sheet Atlas has been developed to further these objectives by increasing the accessibility and usability of the early US Coast Survey T-sheets of the Southern California coast. These maps provide the best information about how Southern California estuaries looked and functioned before the dramatic changes of the 20th century. The Atlas explores the technical information provided by the T-sheets, while also discussing the limitations and challenges to their use.

The T-sheet Atlas is part of the Southern California Historical Coastal Wetland Mapping Project, whose goals are to:

- Acquire high-resolution, full-color digital scans of the T-sheets and make them available locally,
- Provide georeferenced versions of the T-sheets for use in GIS,
- Develop GIS layers using a simple, straightforward classification system,
- Provide background information and guidance to facilitate the interpretation of T-sheets by users,
- Describe and interpret T-sheets for several of the most critical current wetland planning areas in an easily accessible format, and
- Carry out initial explorations of regional estuarine habitat patterns, as a starting point for further analysis.

The Atlas and the associated digital files are designed in concert to meet these goals.

T-Sheets and 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 intercalibration, and help document change-through-time in response to land use.

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, Grossinger et al. 2007, Stein et al. 2007), 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 all historical documents, they represent a snapshot in time and a selective, limited view of the landscape. Southern California estuaries were dynamic systems that changed naturally through time. They also had potentially experienced some level of Euro-American impact by the second half of the 19th century (e.g., ranching, early agriculture). T-sheet information can be best interpreted in comparison to other early documents and with an understanding of local land use and climate history.

The T-sheets were also not intended for direct publication and use. They were "manuscript maps" produced for subsequent compilation into published nautical charts (Cloud, pers. comm.). The historical T-sheets are a uniquely valuable dataset, but one that should be interpreted with caution – particularly when examined in isolation.

The T-sheets are thus most useful as a starting point for using a range of historical references to develop a fuller understanding of how coastal watersheds and wetlands operated under more natural conditions, and how they have changed through time. This information can be developed through local historical ecology studies that supplement the T-sheets with a variety of other earlier and subsequent data sources, as demonstrated recently for the San Gabriel River (Stein et al. 2007) and in progress for Ballona Creek and Ventura County.

Atlas Structure

This first chapter of this report describes the context and objectives of the project. The second chapter gives a brief historical background about T-sheets and discusses their value and limitations. In the third chapter, we describe the methods used to select, acquire, georeference, vectorize, interpret, and classify T-sheet data. The fourth chapter examines parts of seven of the T-sheets in detail, discussing pertinent features and interpretation at seven areas of current wetland conservation interest (Ormond Beach, Mugu Lagoon, Ballona wetlands, Seal Beach, Buena Vista and San Elijo lagoons, and Tijuana Estuary). This section is intended to demonstrate how we interpreted the T-sheets and to facilitate the accurate interpretation of other T-sheets by users. In this chapter, the original T-sheet and the mapped, classified features are shown on facing pages, with the GIS layers overlaid on contemporary imagery. In Chapter 5, we present initial observations about regional patterns of coastal wetland distribution and abundance. In Appendix A, classification and interpretation are discussed in more detail. A document that provides the same past-present comparison for the other 19 T-sheets, but without discussion, can be downloaded online (available at *www.caltsheets.org).*

ONLINE RESOURCES

The T-Sheet Atlas and associated GIS layers are available at *www.caltsheets.org.*

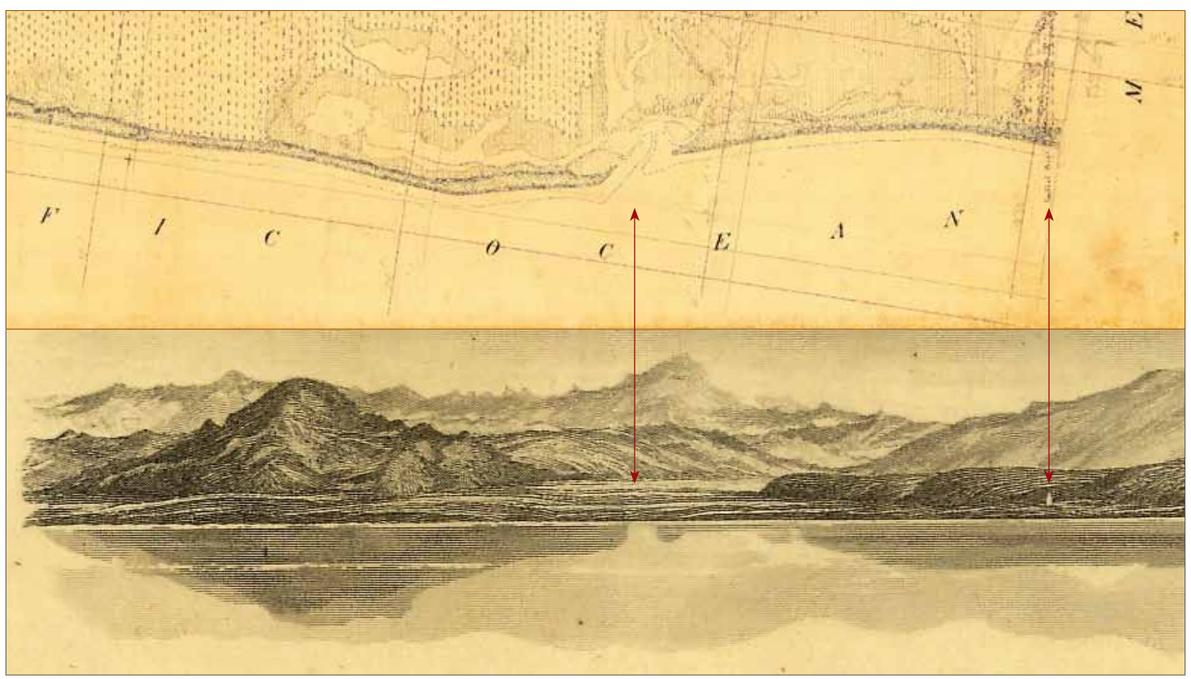


Figure 1. The boundary monument between the United States and Mexico just south of San Diego is depicted on both the T-sheet (T-365) and a USCS sketch of the area. The sketch provides a mariner's view of Tijuana Slough. (US Coast and Geodetic Survey 1852, courtesy of NOAA Photo Library)

2. BACKGROUND: WHAT ARE T-SHEETS?

Between 1851 and 1900, the United States Coast Survey (US Coast and Geodetic Survey after 1878; now National Ocean Survey; here referred to as the Coast Survey or USCS) produced a series of detailed topographic surveys of the Southern California coast. These surveys (commonly referred to as "T-sheets") represent the single most important data source for understanding the physical and ecological characteristics of the coastline prior to extensive Euro-American modification (NRC 1990). T-sheets have been used by researchers studying America's shoreline for years, providing baseline information for assessing coastal erosion (e.g., Leatherman 1983), wetland loss and change (Britsch and Dunbar 1993, Wray et al. 1995, Bromberg and Bertness 2005, Simenstad et al. in press), and the history of shoreline modification (e.g., Morton 1974). More background about the Coast Survey is provided by Shalowitz (1964), Grossinger et al. (2005), Cloud (2007), and the NOAA history website (*www.history.noaa.gov*).

In California, coastal scientists have used the T-sheets to provide site-specific perspective on earlier conditions, as well as for several larger, synthetic assessments of regional historical conditions and change (e.g., Goals Project 1999, SCWMG 1997, Hapke et al. 2006). T-sheets have been used by Southern California researchers, but detailed and consistent information about historical wetlands has not been available (SCWRP 2001). Researchers, managers, and the public have been hindered in the use of the T-sheets by several barriers, including the difficulty of acquisition from federal archives, the unavailability of high-resolution digital files, and the lack of accurately georeferenced data for use in GIS. Additionally, because of their history and inconsistent symbology there have been substantial challenges in their interpretation.

There are several reasons that the T-sheets are particularly useful:

THE T-SHEETS WERE PRODUCED RELATIVELY EARLY. Since the T-sheets were created to facilitate commercial use of the coast, they tend to precede intensive American development. While they followed Spanish/Mexican colonization, and reflect thousands of years of prior indigenous land use, they nevertheless show the landscape before some of the major drivers of coastal wetland modification such as large-scale filling, diking, and river regulation. This means that they may be used to help understand the physical and ecological processes responsible for wetland formation and maintenance. They also can show what kinds and patterns of wetlands supported native species in the recent past.

THEY WERE THE PRODUCT OF AN AGENCY WITH HIGH SCIENTIFIC STANDARDS. Established in 1807 by Thomas Jefferson to complete "an accurate chart of every part of the coasts (Shalowitz 1964)," the Coast Survey was led by some of the leading physical scientists of the time (see Lewis 1954, Slotten 1993, Thompson 1979). The agency used highly accurate methods and the latest scientific techniques, including geodetic controls, plane table surveying and triangulation in the field, and such innovations as geomagnetic measurements and use of the telegraph to determine exact longitude (Shalowitz 1957, Manning 1988; Figures 1 - 5). As a result, the T-sheets are accurate enough to use in GIS to overlay on contemporary maps and imagery, or quantify habitat areas.

THE MAPS WERE PRODUCED AT AN UNUSUALLY LARGE SCALE. Most of the Southern California T-sheets were produced at a scale of

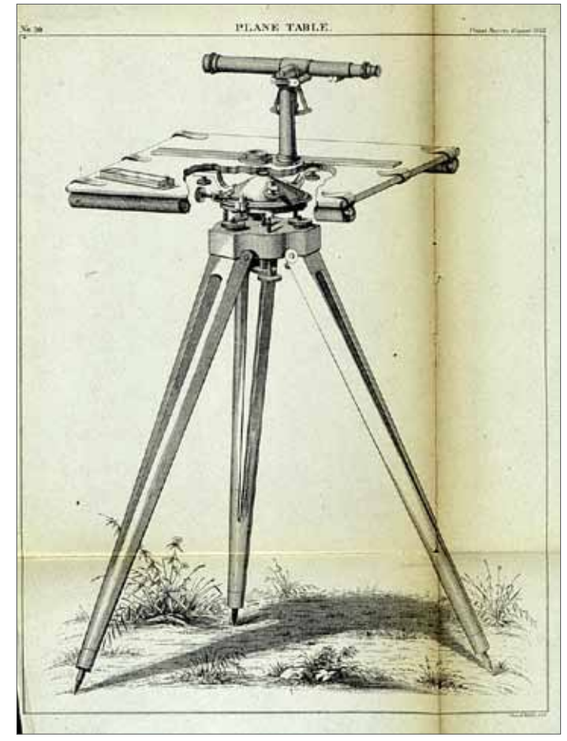


Figure 2. Plane table. The 1865 Superintendent's report included a diagram of plane table with cutaway showing tripod head, which allowed the table to rotate and level independently of the tripod. The alidade is mounted on top, with a ruler for establishing lines. (U.S. Coast and Geodetic Survey 1865, courtesy of NOAA Photo Library)

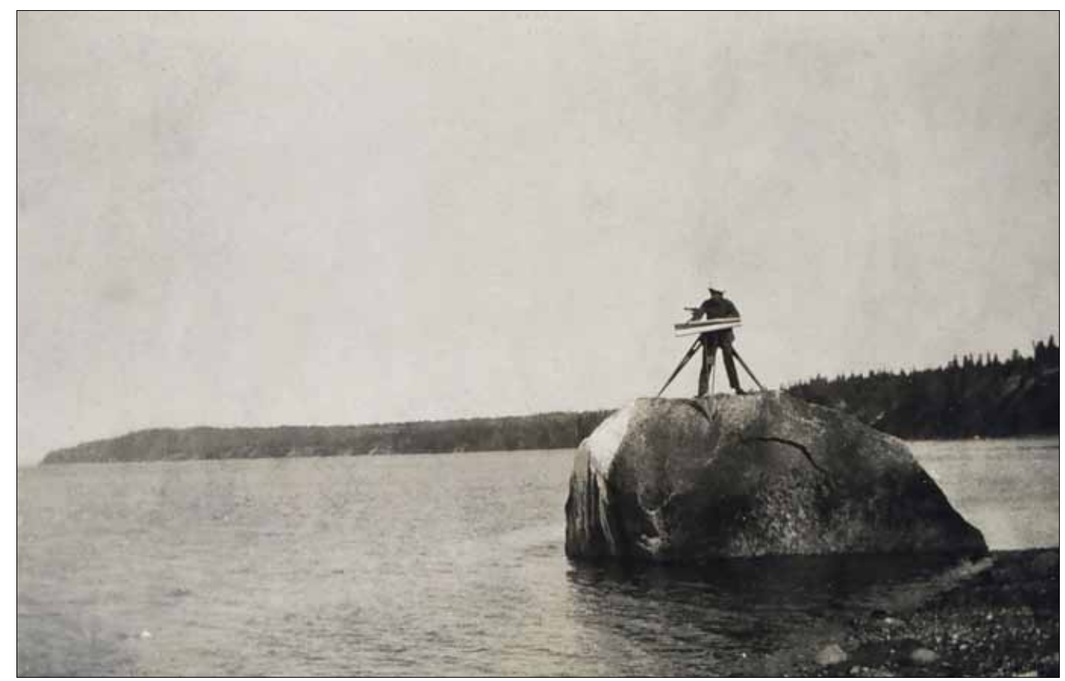


Figure 3. Coast Survey plane table mapping. The surveyor is using the plane table on an offshore rock in Cook Inlet, Alaska, circa 1910. The alidade can be seen on top of the surface of the plane table. (U.S. Coast and Geodetic Survey ca. 1910, courtesy of NOAA photo library)

1:10,000. For comparison, the historical US Geological Survey topographic quadrangles were commonly compiled at 1:62,500 scale, or smaller. This means that the same feature would be shown more than six times larger on a T-sheet (more than 36x greater area). Even modern USGS quadrangles are produced at the scale of 1:24,000, less than half the resolution of the 19th-century T-sheets. This means the T-sheets show most of the wetland features that we map in present day inventories.

THE T-SHEETS EXTEND INLAND BEYOND THE SHORELINE. Ferdinand Hassler, the founding superintendent of the Coast Survey, placed great value on the topographic (as opposed to purely nautical) mapping role of the agency, insisting that the maps should extend "to the ridge of mountains which determine the heads of the coastal rivers" (Allen 1997). While the T-sheets unfortunately do not cover full coastal watersheds, the inland component of coastal mapping continued to some degree. The T-sheets therefore nearly always cover the full extent of tidal wetlands (except where marshes were extremely broad) and often illustrate the terrestrial, palustrine, or fluvial habitats immediately inland of tidal wetlands. Given the significance of the upland transition zone for ecological diversity and migration in response to sea level rise, these features are particularly important.

Conversely, there are several reasons that the T-sheets can be difficult to use:

THE SOUTH COAST T-SHEETS WERE PRODUCED OVER FOUR DECADES (1851-1889), DURING WHICH CONDITIONS AND METHODS WERE CHANGING. The downside of the Survey's attention to detail and accuracy was the slow pace of the agency's progress. As a result, while the Southern California T-sheets collectively form a continuous picture of the coast, the individual surveys show substantial variability. This means that T-sheets must be examined in the context of local land use and climatic history, as well as compared to each other and other documents.

T-SHEETS DO NOT STRICTLY ADHERE TO A UNIFORM SET OF SYMBOLS. In the mid-19th century, the Coast Survey was still developing standardized methods and procedures to apply new techniques over a large geographic area (Raabe et al. 2004, Askevold 2005). It was difficult to secure "complete uniformity where field parties [were] scattered over a wide area" (Shalowitz 1964: 194) such as California. Because of the "very unequal style of representation," and their status as draft, interim products, there is no single legend that can be relied upon to interpret T-sheets (Hergesheimer 1881). As a result, interpretation can be challenging.

SURVEYORS VARIED IN THEIR LEVEL OF DETAIL AND USE OF SYMBOLS. While surveyors operated within a context of high spatial accuracy, some showed more detail than others (Grossinger 1995) or did not represent certain kinds of features (Grossinger and Askevold 2005). The interaction between surveyor, draftsman, and/or engraver resulted in symbol sets being used differently (Allen 1997). It is easy to misinterpret differences due to surveyor style as actual differences in wetland structure between locations.

T-SHEETS DON'T SHOW EXACTLY WHAT WE WANT. The Coast Survey recorded many landscape characteristics of interest to students of present-day wetlands, including hydrographic characteristics (e.g., low waterline, subtidal waters) and vegetation (marsh, forest, unvegetated areas). However, their primary focus was on landmarks for coastal navigation. They do not make all distinctions that we would like them to make, so it can be difficult to translate T-sheets directly into modern wetland classification. The T-sheets also do not show all the details we might like to see, such as plant species and salinity patterns. Corroborating sources such as textual descriptions, early botanical specimens, and other local maps can often help build a richer picture of finer scale wetland characteristics.

AVAILABLE VERSIONS OF THE T-SHEETS HAVE ALSO BEEN OF LOW QUALITY. One of the other main difficulties in using T-sheets – poor quality reproductions – has been eliminated for much of the region through the acquisition of high quality color scans from the National Archives.

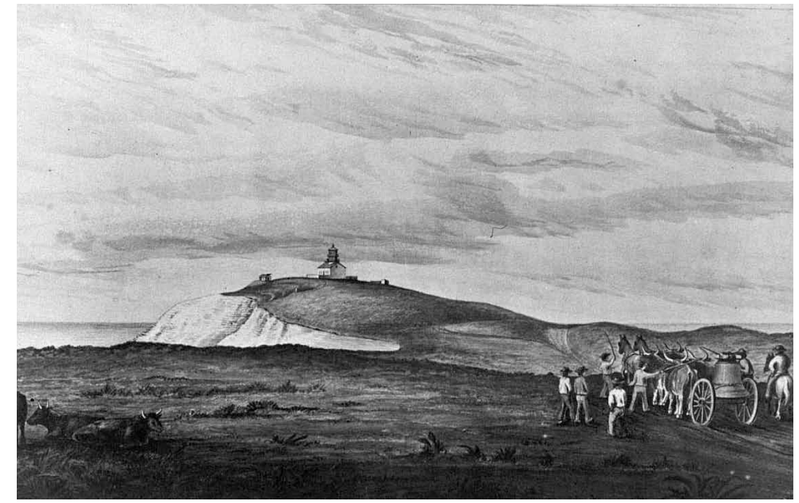


Figure 4. 1859 drawing of the Point Conception lighthouse, by Major Hartman Bache. (Hartman Bache was the uncle of Alexander D. Bache, the second superintendent of the U.S. Coast Survey; Bache 1859, courtesy of NOAA Photo Library)

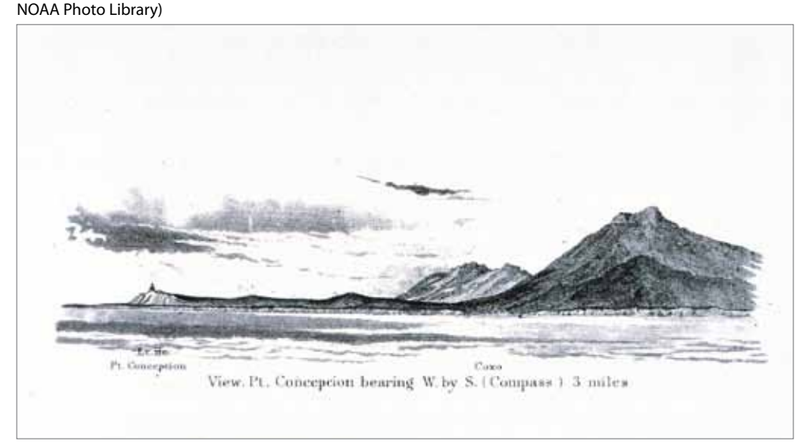
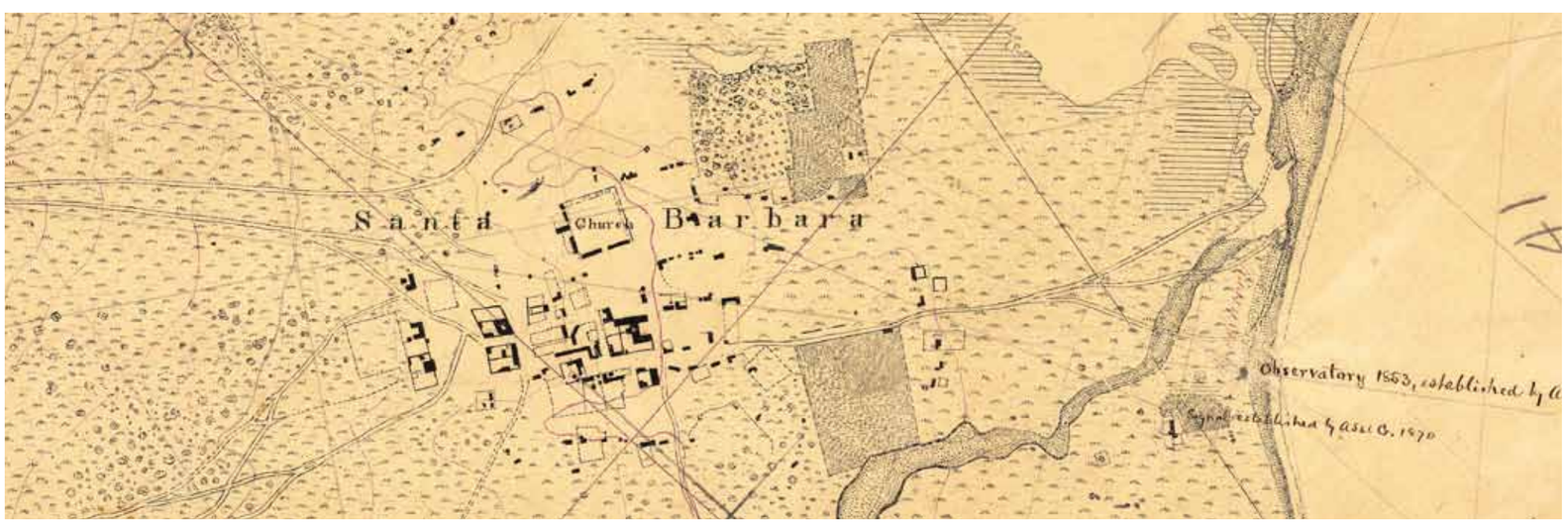


Figure 5. A seaward view of Point Conception and the Point Conception lighthouse from the Santa Barbara Channel. (Davidson 1869, courtesy of NOAA Photo Library)



3. METHODS

Geographic Scope

Forty-one maps comprise the earliest available T-sheets for the Southern California coast between Point Conception and the Mexican border. For this project, funding was available through the State Coastal Conservancy (SCC) to acquire, georeference and vectorize 25 T-sheets. A twenty-sixth T-sheet, T-1427, was added to cover Topanga Canyon (funded by the Los Angeles Regional Water Quality Control Board), for a total of 26 maps (Table 1; Figure 6).

Of the 41 potential surveys, fifteen represent mostly steep shoreline topography (e.g., Santa Ynez Mtns., Santa Monica Mtns., Palos Verdes Hills) with relatively few coastal wetlands. As a result, we were able to cover most of the estuarine habitat area of Southern California. (Communications with the SCWRP Science Advisory Panel and SCC staff helped guide T-sheet selection.) We estimate that estuarine habitats on the remaining T-sheets account for no more than 200 ha, or less than 1% of the Southern California total. Nevertheless, it should be recognized that many small estuaries (e.g., canyon or creek mouths) and a few somewhat larger features (e.g., Gaviota wetlands, Malibu creek mouth, La Jolla lagoon) are not represented in the T-sheet data set at this time. Funding will be sought to fill these gaps in the near future to complete a continuous T-sheet picture of South Coast estuaries.

Seven of the 26 T-sheets were chosen as priority areas, for early digitization (Figure 6). These receive a fuller discussion and interpretation in the Atlas to meet immediate needs for historical data to inform current wetland planning efforts (see Chapter 4).

Acquisition

High-resolution and full-color digital imagery of original topographic manuscript maps stored at the National Archives and Records Administration (NARA II, College Park, MD) were obtained through Dr. John Cloud (Geographer, 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 as part of the Climate Data Modernization Program. For example, T-sheet 576 is 29.2 inches wide and 50.2 inches in height; once scanned, the tiff file is approximately 90 megabytes, and is 8777 pixels by 15057 pixels (300 pixels per inch). Dr. Cloud also provided ancillary T-sheet materials, such as later resurveys and other relevant USCS documents, as well as guidance in T-sheet history and interpretation. 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).

Georeferencing

For decades, researchers have recognized the spatial accuracy of the T-sheets and their potential for comparison to contemporary maps (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). Possible methods to georeference the T-sheets include 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 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.

After evaluation of each of these methods, we found that 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). Finding physical features that have persisted between the T-sheets and the

HISTORICAL ECOLOGY AND RESTORATION PLANNING

The perspective provided by historical ecology often provides valuable insight to the restoration planning process. Restoration goals should be informed by knowledge of conditions before modern development and by an understanding of how human-induced changes translate to changes in habitat form and function. This helps answer fundamental questions: How do landscapes change? What is natural? Given the complexity of contemporary landscapes and projected future changes, how do we choose appropriate targets?

A reliable understanding of the historical landscape is an essential, but not sufficient, component to answering these questions. When integrated with contemporary data and future projections, historical information helps identify restoration opportunities and develop realistic management strategies. Often these would not be recognized without historical perspective.

However, historical information is not directly predictive of the future. Forcing functions, including land use and climate, can change. Other controls, such as topography and geology, may be relatively stable. By showing what types of habitats persisted where, regional historical analysis can help us understand the relative importance of these processes, how they have changed, and how these processes may affect the sustainability or maintenance needs of proposed designs.

As discussed in the Introduction, recent research has shown how little we often know about the systems we seek to restore — and, conversely, the benefits of historical ecology for informing restoration planning. Historical ecology is not an answer in and of itself, but a tool for scientists and managers seeking to understand and ameliorate the dramatic changes of the past 250 years.

Table 1. South Coast T-sheets digitized in this study (listed chronologically and numerically).

T-Sheet	Year	Surveyor	Pages	Areas of Interest
T-333	1851	A M Harrison	B36-37	San Diego Bay (partial)
T-363	1852	A M Harrison	B34-35	Mission Bay
T-364	1852	A M Harrison	B38-39	San Diego Bay (partial)
T-365	1852	A M Harrison	36-39	Tijuana Estuary, San Diego Bay (partial)
T-373	1852	A M Harrison	B6-7	Santa Barbara
T-576	1855	W M Johnson	12-15	Oxnard Plain lagoons, Ormond Beach
T-683	1855	W M Johnson	B12-13	Ventura and Santa Clara river mouths
T-892	1859	W M Johnson	B16-17	San Pedro waterfront
T-893	1857	W M Johnson	16-19	Mugu Lagoon
T-1127	1869	W E Greenwell & S Forney	B10-11	Carpinteria Marsh
T-1128	1869	W E Greenwell & S Forney	B8-9	Carpinteria Marsh
T-1230	1870	W E Greenwell & S Forney	B4-5	Goleta Slough
T-1267	1871	W E Greenwell	B2-3	Goleta Slough
T-1283	1872	A W Chase	B18-19	Long Beach
T-1345	1873	A W Chase	24-27	Bolsa Chica, Los Cerritos
T-1369	1874	A W Chase	B20-21	Santa Ana River mouth
T-1392	1875	A W Chase, E Ellicott, & F A Lawson	B22-23	Newport Bay
T-1427	1875-1876	A W Chase	B14-15	Topanga Canyon mouth
T-1432b	1876	A W Chase	20-23	Ballona wetlands
T-1645	1885	Unknown, likely Aug F Rodgers	B24-25	Dana Pt.
T-1898	1887-1888	Aug F Rodgers & John E McGrath	32-35	San Elijo Lagoon
T-1899	1887-1888	Aug F Rodgers & John E McGrath	28-31	Buena Vista Lagoon, Agua Hedionda Lagoon
T-1900	1887	Aug F Rodgers	B30-31	San Luis Rey River
T-2014	1889	Aug F Rodgers & John Nelson	B32-33	San Dieguito and Los Penasquitos
T-2015	1889	Aug F Rodgers & John Nelson	B28-29	Las Flores Creek
T-2016	1889	Aug F Rodgers & John Nelson	B26-27	San Mateo Lagoon

Figure 6. Locations of the 26 digitized South Coast T-sheets. Seven of the maps (shown in red) are interpreted in detail on pages 12-39.

contemporary highly modified landscape is difficult. National Geodetic Survey marks have often been re-surveyed, making the historical location difficult to ascertain. Additionally, each map bears only a few survey marks unevenly distributed across the sheet. By not relying on persistent geographic features or geodetic control points, this approach also permits those data to be used for accuracy assessment (Figure 7).

With the high-resolution T-sheet scans, we were able to identify graticules that had been updated by NOS 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 ESRI ArcGIS 9.1 software.

The results of this method were tested in several ways. For three T-sheets, 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 (USDA 2005). For the selected sample T-sheets, the average error was 19.28 m. 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. All georeferenced T-sheets were also compared for consistency to the recent effort by USGS to map changes in sandy and rocky shorelines (Hapke et al. 2006); initial measurement of difference was less than 10 meters.

While this method consistently and efficiently produced a high level of registration accuracy (generally within 20 m), it is possible that in some places registration could be improved with additional ground control points. Given the number of T-sheets, we did not intensively evaluate local correspondence for each T-sheet. Georeferencing should be considered suitable for general uses, but highly localized uses would benefit from more intensive local accuracy assessment. A number of sources of potential error (including georeferencing, original mapmaker error, digitizing accuracy, etc.) contribute to the overall positional accuracy of georeferenced T-sheet features (Shalowitz 1964, Crowell et al. 1991). While these historical maps may in many cases be georeferenced within 10-15 m, they should not be assumed to have a potential error of less than 50 m.

Vectorization

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 9.1.

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. We mapped a total of over 2,800 polygons and about 5,000 lines, including all estuarine areas such as subtidal waters, tidal flat, tidal marsh, lagoon, and associated features. Where these features (particularly subtidal) 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). All creeks directly connecting to the ocean were also mapped. We did not map anthropogenic features such as jetties, roads, and railroads in the few cases where they crossed wetlands. 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, features and levels of detail should be chosen carefully to ensure comparability across T-sheets. For example, in the regional assessment described in Chapter 5, we used five general classes that were likely mapped consistently across the study area.

Edgematching

To combine the T-sheets into a single geodatabase, 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.

Interpretation and Classification

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: 50; Askevold 2005) and their accurate interpretation is a nontrivial task.

There are several reasons for the variability in the use of symbols.

- Official symbol sets changed through time, as instruction manuals were revised and updated (Shalowitz 1964: 194-210)
- Surveyors were permitted some freedom to aesthetically represent unique arrays of features (Shalowitz 1964:193, 201; Allen 1997). Individual styles inevitably varied. At least five different lead surveyors were responsible for the maps studied here (Figure 8).

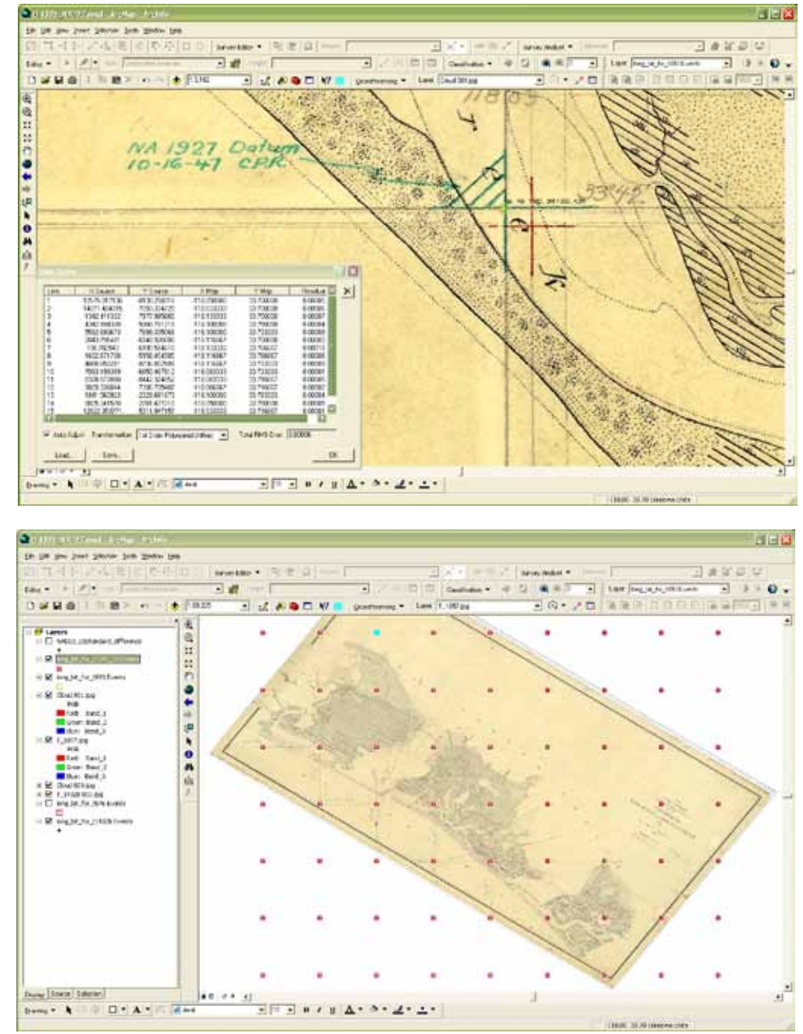


Figure 7. Georeferencing historical T-sheets. Top: T-sheet showing longitude and latitude grid on T-sheet updated to NAD 27 (in green). Bottom: Grid of longitude and latitude points used to georeference T-sheet.

T-SHEETS AND HISTORICAL ECOLOGY

T-sheets have been traditionally used to document baseline or reference conditions for the nation's shorelines (NRC 1990). Coastal features were mapped as landmarks for mariners to use in coming decades, so features with a high level of annual- or decadal-scale variability were not generally documented (Cloud, pers. comm.). However, estuaries by their nature are dynamic systems. Local historical ecology studies, which bring together a wide range of historical data, are essential to provide a greater understanding of the variability of habitat patterns and the mechanisms of change over time. The T-sheets provide a relatively consistent baseline dataset for future analysis.

WHAT DOES THIS MEAN? SOME INTERPRETATION STRATEGIES

- Consider the surveyor. Examining neighboring sheets by the same surveyor can help explain map interpretation questions. Annotation on another map may clarify the meaning of a symbol. If a surveyor shows a feature type in several maps, its absence in another map may be meaningful. (However, sometimes map detail corresponds more with the field aid than the chief of the survey party (Grossinger 1995).)
- Consider the date. In a few cases, the earlier, pre-Civil War maps appear less detailed and might not include some features.
- Examine the edges. Often the edges of maps were not mapped as completely, because those features were going to be covered in the adjacent map. In this case, one map may have more detail than another in the area of overlap. Where surveys were more widely spaced in time, the overlap area may be independently surveyed, providing two perspectives on the same place.
- Consult Coast Survey archival materials and Shalowitz (1964).
- Consult other sources. The best way to understand T-sheets is to compare them to other historical sources, such as other early surveys (including Coast Survey hydrographic charts), Spanish/Mexican-era materials, textual documents, and early aerial photography.

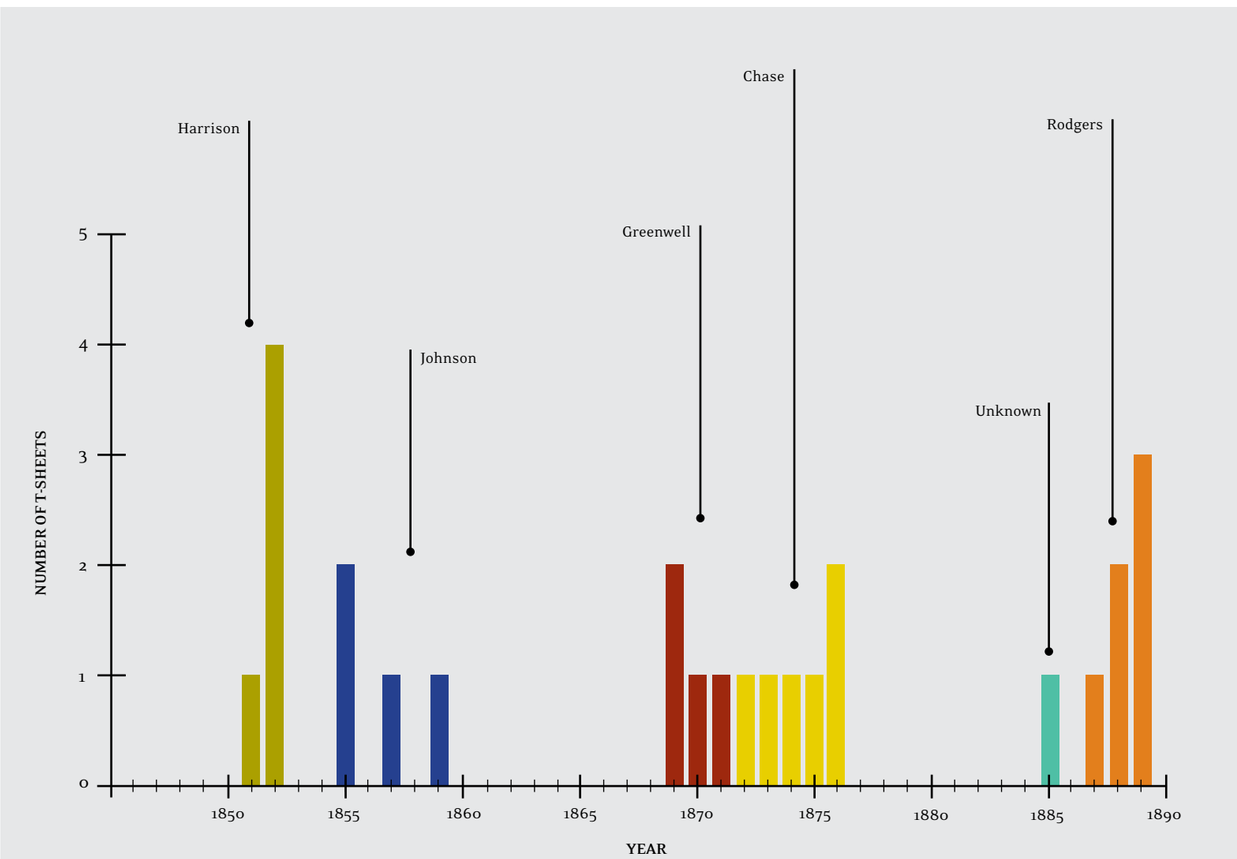


Figure 8. Distribution of the 26 T-sheets by surveyor and year. Several surveyors each produced a group of T-sheets over a 2 to 5 year period.

- Individual surveyors occasionally used different symbols to represent identical features on different maps (Allen 1997), presumably by accident or due to a change of technique.
- T-sheets were interim products for compilation in published nautical charts. They were not designed for external use and scrutiny.
- Changes introduced by draftsmen during the engraving process can result in inaccurate symbology (e.g., omission of the tufts of grass intended to accompany horizontal lines (Shalowitz 1964: 189-191)).

The general meaning of many symbols can be readily interpreted, as symbols are often similar to those used today (Allen 1997). But interpreting the subtleties of different depictions into modern classification systems, across maps with varying symbologies, can be challenging. Several approaches are available, and are best used in combination.

The T-sheet literature provides some important references. Shalowitz' comprehensive 1964 treatise discusses the origin, meaning, and variability of many symbols. Also important are the contemporary instruction manuals and related agency documents (e.g., Whiting 1861, Hergesheimer 1881; Figure 9). Additionally, surveyors occasionally left interpretive guidance where interpretation might have been unclear, by writing notes on the surface of the map or in the accompanying descriptive reports, or adding words directly on the map feature (e.g., "Alkali," T-1345, page 25). (Some of these useful annotations (e.g., "Line of Salt Grass," T-893, page 17) were written in faint pencil that is now visible in the high-resolution color scans.) The names of triangulation points can also occasionally be descriptive (particularly on maps by AW Chase: see T-1345). Nonstandard symbols can also often be interpreted, or their definition clarified, by comparison with other historical maps of the same area (e.g., Shalowitz 1964: 191) and early aerial photographs. Other historical sources such as Mexican-era maps (*diseños*) and local narratives often provide additional descriptive information to clarify a feature's interpretation (Grossinger 2005); this was particularly the case in the Ventura County area, where a concurrent historical ecology study is underway. In addition, even after much change in the landscape, fieldwork is often helpful to understand historical maps.

We drew upon the Coast Survey literature, map annotations, and intercalibration with other historical source materials (primarily in Ventura County) to interpret and classify coastal features illustrated by the T-sheets. To reduce the risk of "overinterpreting" T-sheet features, we decided 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 cases, 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. However, given the variation among systems and surveyors, these translations could not be accurately made across the entire dataset, so we utilized the more transparent and direct classification approach. Table 2 shows some of the potential translations from the limited T-sheet classification into contemporary terminology.

We classified features as they were depicted by the Coast Survey, rather than inferring likely conditions in different seasons or at different points in time. In general, features shown by USCS surveyors are those that would be relatively persistent. 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.

In Mugu Lagoon, the T-sheets did not extend fully to the inland wetland margin, but we were able to draw upon other sources of information compiled in the Ventura Historical Ecology Study to document the inland extent of the marsh. (These additional sources are attributed in the GIS.) Other T-sheets covered all or nearly all of the coastal wetlands in their area, with the possible exception of ecotonal areas that might have been subject to the highest tides.

Classification Overview

This section provides rationale for the interpretation and classification of each of the feature types digitized from the T-sheets. Table 2 shows the three categories of attributes applied to T-sheet features.

Using these attributes, we mapped 21 different habitat types across the 26 T-sheets. This full level of detail is provided in the GIS geodatabase to provide as much information as possible for local project planning. For the presentation and comparison of T-sheets in chapters 4 and 5, however, we used a simplified (lumped) classification, as shown at the bottom of Table 2 and discussed in chapter 5. Detailed discussion of each classification is provided in Appendix A. Chapter 4 provides illustrations of how these interpretations were applied for the seven selected T-sheets. We encourage users to refer directly to the T-sheet images and geodatabase in areas of interest to make use of that full level of detail.

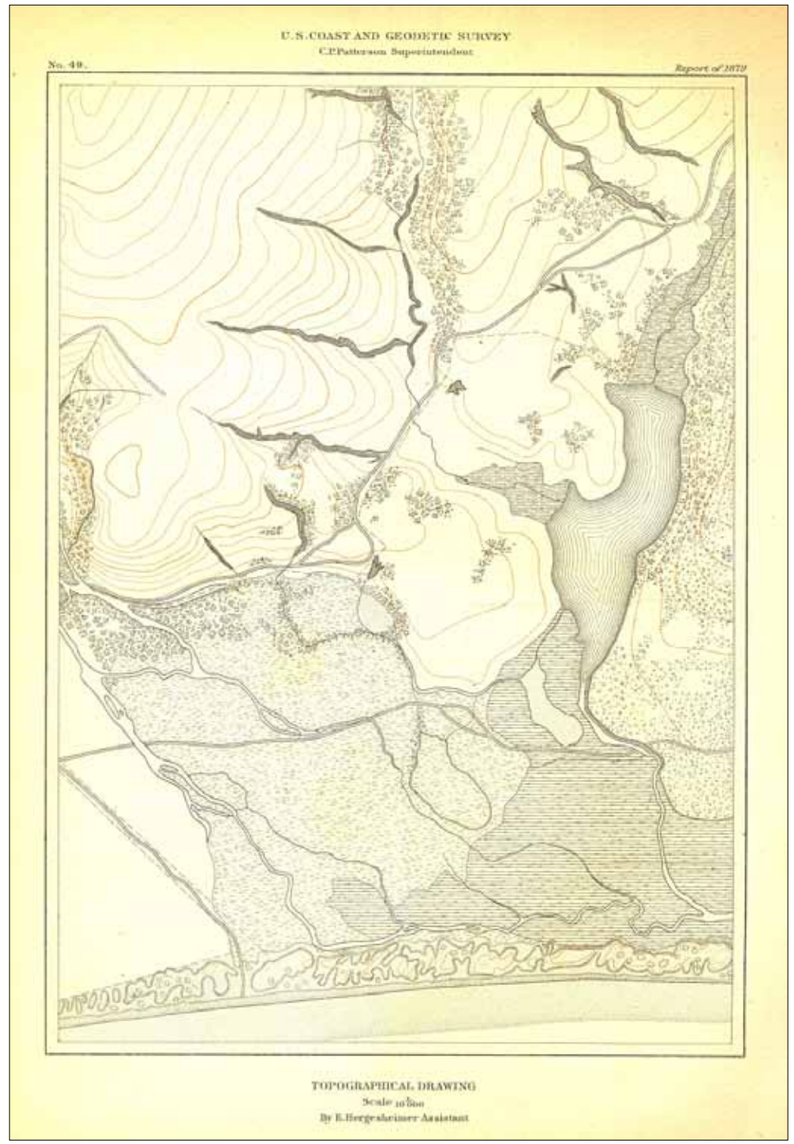


Figure 9. T-sheet mapping guidance. In 1879, U.S. Coast and Geodetic Survey Assistant Hergesheimer was sent to the Pacific Coast to study coastal features and develop standardized symbols. This was a schematic he created to help standardize common features that the surveyors would encounter when mapping coastal systems.

CAVEATS FOR USING THE EARLY T-SHEETS

- T-sheets should be interpreted with an understanding of the symbology, surveyor, and era of the individual survey.
- T-sheets are most useful when interpreted in the context of other historical data and used as a starting point for broader historical ecological research,
- T-sheets do not necessarily show the appropriate or achievable habitat patterns at a given site in the future,
- T-sheets and historical ecological mapping are one important scientific data set to be considered in restoration planning, along with analyses of current conditions, priority species needs, and climate projections.

Table 2. Classification approach used to interpret T-sheet features into a geodatabase. See Appendix A for discussion.

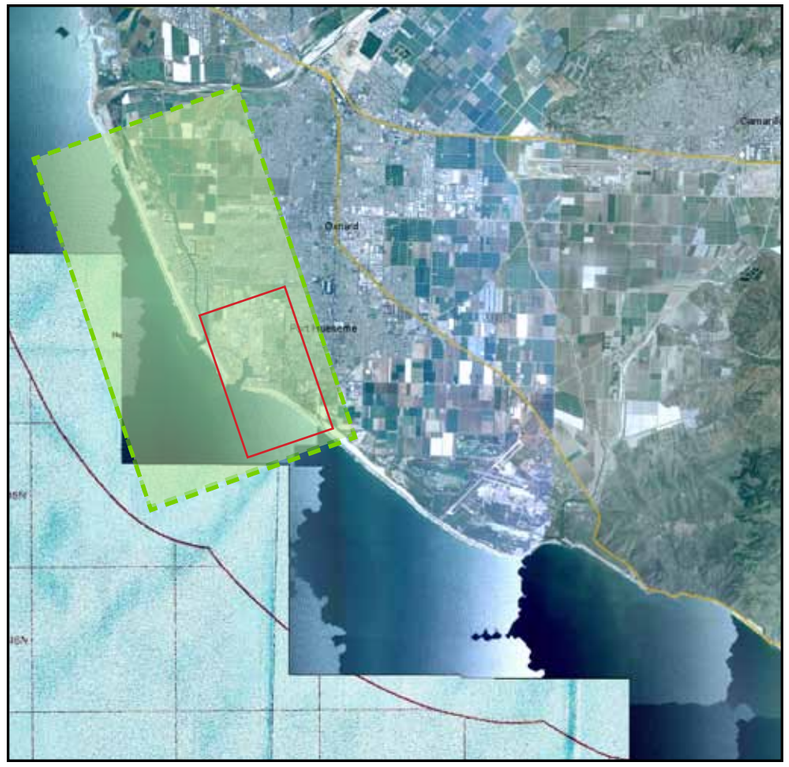
Level I	Level 1 Description	Level II	Level II Description	Tidal Regime (as depicted by T-sheet)	Tidal Regime Description	Common Terms	Grouping Used in Chapter 5
Vegetated	An array of symbols on the T-sheets are used to indicate vegetation type	Upland	Upland features were generally indicated by the grassland symbol. These were only mapped as islands within coastal wetland systems.	N/A		island	Vegetated, Upland
		Woody	Conventional map symbols indicate woody vegetation.	N/A		woodland, thicket (potentially riparian)	Vegetated, Woody
		Emergent Marsh; Extreme High (elevation)	A number of variations on marsh symbology were used, some indicating different tidal elevations.	Intertidal	Tidal areas shown as draining at low tide.	high marsh transition zone	Vegetated Wetland
				Non-tidal	Areas shown as not directly connected to tidal waters (presumably intermittently tidal).	palustrine marsh, marsh ecotone	(not used)
		Emergent Marsh; High (elevation)		Intertidal	Tidal areas shown as draining at low tide.	tidal marsh, salt marsh, brackish marsh, freshwater tidal marsh, high marsh, middle marsh, marsh plain	Vegetated Wetland
				Non-tidal	Areas shown as not directly connected to tidal waters.	non-tidal salt marsh, occasionally-tidal salt marsh	
		Emergent Marsh; Low (elevation)		Intertidal	Tidal areas shown as draining at low tide.	low-elevation tidal marsh, young marsh	
				Non-tidal	Areas shown as not directly connected to tidal waters.	low-elevation marsh, young marsh	
Unvegetated	Areas without vegetation or water are generally indicated with a stipple (dotted) pattern. We also classified areas without vegetation that are exposed at low tide (e.g., tidal flat) as unvegetated.	High (elevation)	High elevation unvegetated areas (e.g., salt flats) are generally indicated by stipple and/or annotation. Low elevation unvegetated areas are defined by the line of MLLW.	Intertidal	Tidal areas shown as draining at low tide.	salt flat, alkali flat, panne, playa (dry lake bed)	Salt Flat
				Non-tidal	Areas shown as not directly connected to tidal waters.	salt flat, alkali flat, panne, playa (dry lake bed)	
		Low (elevation)		Intertidal	Tidal areas shown as draining at low tide.	tidal flat, mudflat, sandflat	Intertidal Flat
				Non-tidal	Areas shown as not directly connected to tidal waters.	salt flat, alkali flat, panne, playa (dry lake bed)	Salt Flat
Open Water	Areas with no fill (or, occasionally, multiple concentric "inlines" indicating persistent water) are mapped as open water. We distinguished elongate open water features as channels.	N/A		Subtidal	Tidal waters shown as not draining at low tide.	subtidal water, subtidal channel	Subtidal Water
				Intertidal	Tidal areas shown as draining at low tide (ponds may retain water, however).	marsh pond, pan/panne	Open Water
				Non-tidal	Areas shown as not directly connected to tidal waters.	lagoon, open water in closed estuary	
Channel		N/A		Subtidal	Tidal waters shown as not draining at low tide.	subtidal water, subtidal channel	Subtidal Water
				Intertidal	Tidal areas shown as draining at low tide.	tidal channel, tidal marsh flat	Intertidal Flat
				Non-tidal	Areas shown as not directly connected to tidal waters.	channel in closed estuary	Open Water
				Undefined		fluvial channel, gravel bar, sandy riverbed	(not used)
Beach	stipple (dotted) patterns at ocean margin	N/A		Intertidal	Tidal areas shown as draining at low tide.	beach	Beach
Dune	stipple/hatch patterns representing topographic complexity at beach margin	N/A		N/A		coastal dune	Dune (graphics only)

4. DISCUSSION OF ANNOTATED T-SHEETS

In this chapter, we use annotation to show how different T-sheets depict a range of estuarine habitats and other geographic features. Based on discussions with local managers and researchers, we chose areas of interest on seven T-sheets to describe and interpret in detail (shown in red, at right). There are 7 four-page sets, covering, from north to south, Ormond Beach, Mugu Lagoon, Ballona Wetlands, Seal Beach, Buena Vista Lagoon, San Elijo Lagoon, and Tijuana Estuary. The first two-page spread of each set displays an area of interest in a given T-sheet (e.g., Mugu Lagoon) at nearly original scale. The following spread shows, at smaller scale, the full T-sheet (on the left), and the corresponding GIS layer of the T-sheet over modern imagery (on the right). Please note the legend is standardized; not all features are necessarily shown on each T-sheet. (Also, map colors can shift slightly depending on the underlying imagery. The inset view shows the GIS layer with no transparency; these colors match the legend exactly.)

ORMOND BEACH	REGISTER Nº.:	T-576
	PUBLISHED:	1855
	SURVEYOR:	W. M. JOHNSON

T-576 covers the Ventura County shoreline from McGrath Lake, on the south side of Santa Clara River, to Ormond Beach. The survey is both relatively early (1855) and detailed, with the copious annotation found on William Johnson's T-sheets. The map shows the broad barrier beach-dune system extending down coast from the mouth of the Santa Clara, associated with the river's large sediment supply. The portion shown on the opposite page focuses on the southern end of the map – the Pt. Hueneme-Ormond Beach area – where substantial wetlands were found behind a narrower beach-dune system.



The green shaded box denotes the extent of T-sheet 576 and the red solid line indicates the area of detail depicted on the next page.

The complex aeolian and alluvial topography is shown with solid and dashed (intermediate) red contour lines. The interval is 20 feet (10 feet for dashed lines), indicating that the dunes were taller to the north, with high points consistently above 60 feet. The letter "d" indicates depressions. Herbaceous vegetation is indicated by grass tufts. The small red circles along the landward margin of the beach are a nonstandard symbol, but thought to indicate dune tussocks. Shalowitz (1964:189) notes that "[n]o definite reason is known for the use of this symbol by the topographers, but it is believed to have been intended to represent small sand dunes probably covered with brush or scrub growth."

Like other 1850s-era Coast Survey maps, this one represents salt marsh using parallel lines without the traditional tufts. Some marsh areas are shown on this map (and the neighboring T-893 of Mugu Lagoon) with more tightly spaced parallel lines. These may represent lower elevation marsh vegetation. It may be significant that the marshes are shown without a solid boundary line on the landward margin. This convention typically indicates a less distinct boundary, suggesting a relatively broad ecotone between high marsh plain and adjacent terrestrial vegetation (e.g., Shalowitz 1964:189).

We classified these marshes as *non-tidal, vegetated, high* or *low elevation.* The parallel lines symbol literally translates as "salt marsh;" however, this tends to be used as a general designation for coastal, salt-affected wetlands. Supplementary evidence from the Ventura Historical Ecology Study indicates that some of these lagoons were fed by freshwater springs, maintaining fresh-brackish-saline gradients. Johnson does indicate a freshwater pond (by multiple concentric outlines) along the drainage to one of the lagoons, while labeling the major open water features as "Salt Water." (He labels McGrath Lake, at the north end of the map, as freshwater.) The lagoons' square-end shapes and the presence of wide, vegetated barrier dunes suggests that these systems opened relatively infrequently, but the non-tidal designation is intended solely to refer to the condition indicated by the T-sheet. These repeating, elongate lagoons represent former river mouths of the Santa Clara River.

Within these lagoons (classified as *open water, non-tidal*) the conventional dotted line of low water can be identified. This presumably indicates the boundary between unvegetated flat and open water at the time of the survey (rather than a true "low water" line). The map has another interesting feature, shown in the same red color as the contours: revisions made 19 years later, in 1874. These show the new town of Hueneme, a wharf, and slight changes to the shoreline and lagoon margins. This resurvey documents changes on the order of 10-40 m, showing both the precision of the survey techniques and the relative stability of the feature over that period.

The series of neighboring lagoonal-wetland systems along the Ormond Beach shoreline had similar habitat mosaics. While they are typically thought of as lagoons, most of their area was vegetated, as shown by the T-sheet. If we distinguish the four major systems shown by this T-sheet (the northernmost one cut off in this view is visible on the next page), vegetated wetland covered 58-72% of the area, with open water and salt flat ranging from 28 to 42%. Since the mouths of the Ventura and Santa Clara rivers had relatively small wetland areas, the Ormond Beach wetlands (which cumulatively covered about 350 ha) represent the second largest coastal wetland area in Ventura County, after Mugu Lagoon.

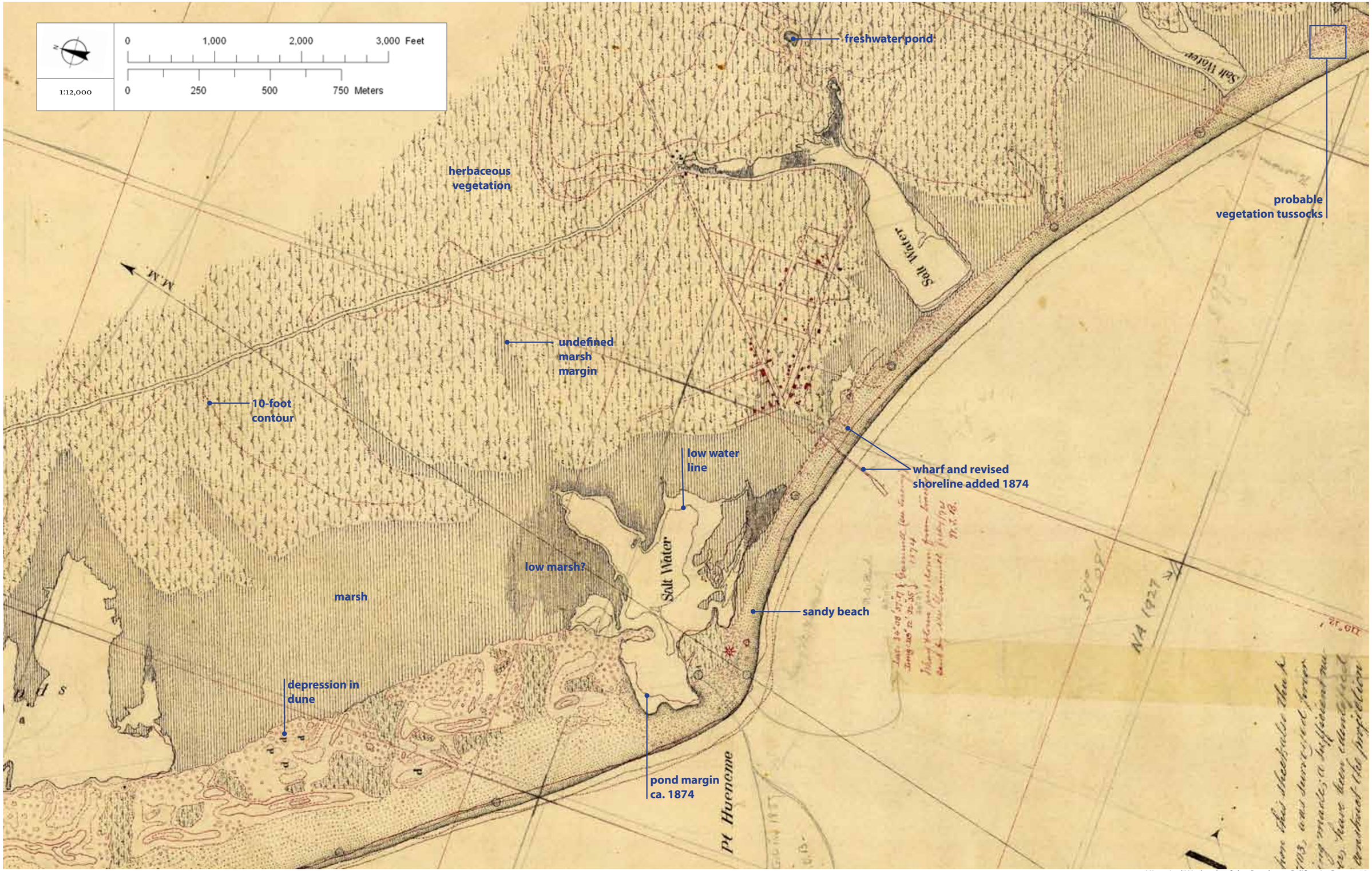


Figure 10. Portion of T-576.

REGISTER Nº.:	T-576
PUBLISHED:	1855
SURVEYOR:	W. M. JOHNSON
LOCALE:	McGRATH LAKE, PT. HUENEME, ORMOND BEACH

N

1:34,000

0 1,000 2,000 4,000 6,000 8,000 Feet

0 500 1,000 2,000 Meters

Figure 11. T-576 (full extent).

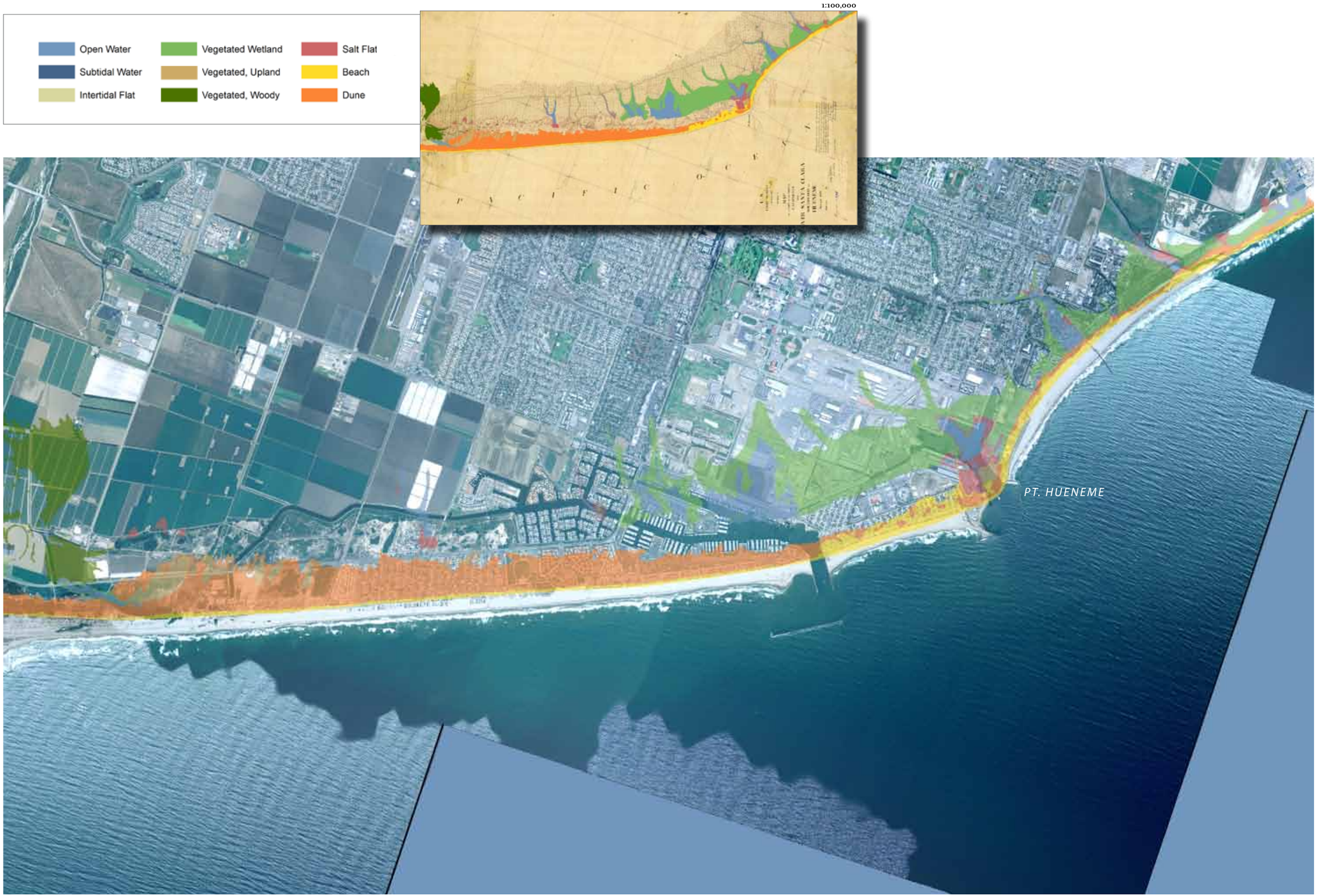
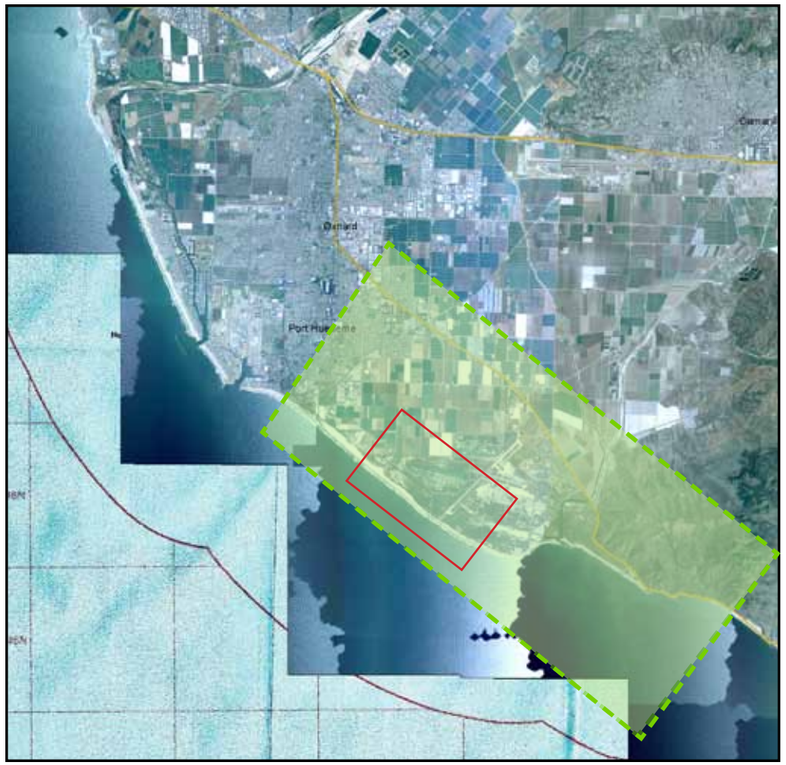


Figure 12. Coastal features digitized from T-576, overlaid on modern aerial photography (USDA 2005), at same scale as facing T-sheet.

MUGU LAGOON

REGISTER Nº.:	T-893
PUBLISHED:	1857
SURVEYOR:	W. M. JOHNSON



The green shaded box denotes the extent of T-sheet 893 and the red solid line indicates the area of detail depicted on the next page.

William Johnson produced USCS map T-893 – covering Mugu Lagoon and the southern end of Ormond Beach – in 1857, two years after the adjoining map to the north (T-576). The map shows the predominant estuarine habitat type at Mugu Lagoon as vegetated wetland (65%), with the remainder of the area distributed among subtidal water (12%), intertidal flat (10%), salt flat (8%), and open water ponds (5%). The subtidal area (labeled "Laguna") is relatively large compared to most other Southern California systems as shown by the T-sheets. Adjacent tidal flats are quite narrow at the north end of the system (shown in the adjacent view) but much larger towards the lagoon mouth (see following spread). The mouth of Mugu Lagoon is the only opening shown by the T-sheets in the continuous barrier beach-dune system between Santa Clara River and Point Mugu.

The map shows many small and a few very large ponds or pannes along with extensive channel networks. One such feature (further south than this view) is labeled "Pond" to distinguish it from adjacent dunes of similar shape. Tidal marsh (*vegetated, tidal*) is shown by parallel lines. As in T-576 to the north, the interpretation of the more tightly spaced parallel lines is uncertain. While the symbol can indicate lower elevation marsh, it also shows some correspondence in location to areas indicated as "Juncal" in another 19th-century map of the system (Bard 1870), indicating *Juncus* stands. More information may help interpret what was clearly a prominent vegetation pattern.

Covering about 1240 ha, Mugu Lagoon was one of the largest coastal wetland systems in Southern California. It was also notable for broad transitional areas to the adjacent upland. Stippling indicates unvegetated areas at the high end of the marsh that could be considered salt flats, alkali flats, or playas (see T-1345 section). Inland of these areas Johnson makes an unusual distinction between two different densities of grass "tufts." The meaning of this differentiation would be indecipherable except for a line of faint script lettering barely visible in the high-resolution scans. The phrase "Line of salt grass" defines a transitional, high marsh zone, presumably dominated by *Distichlis* spp., between the salt pannes and the upland vegetation community. We mapped this area as *vegetated-extreme high elevation-tidal* in contrast to the other high and low elevation marshes. It is likely that a similar but narrower ecotone characterized the undefined landward marsh margins shown in other parts of this T-sheet and T-576 to the north. (This zone has been mapped based on additional sources in the Ventura Historical Ecology Study.)

Mugu Lagoon reflects the sequence of recent shoreline progradation, in the form of several prominent beach ridges representing former shoreline positions (Warme 1971, Thompson 1994). At the northern (left) edge of the Mugu system , one can also see the interface with a different kind of coastal wetlands "archetype" – the linear lagoons that dominate the shoreline to the north.

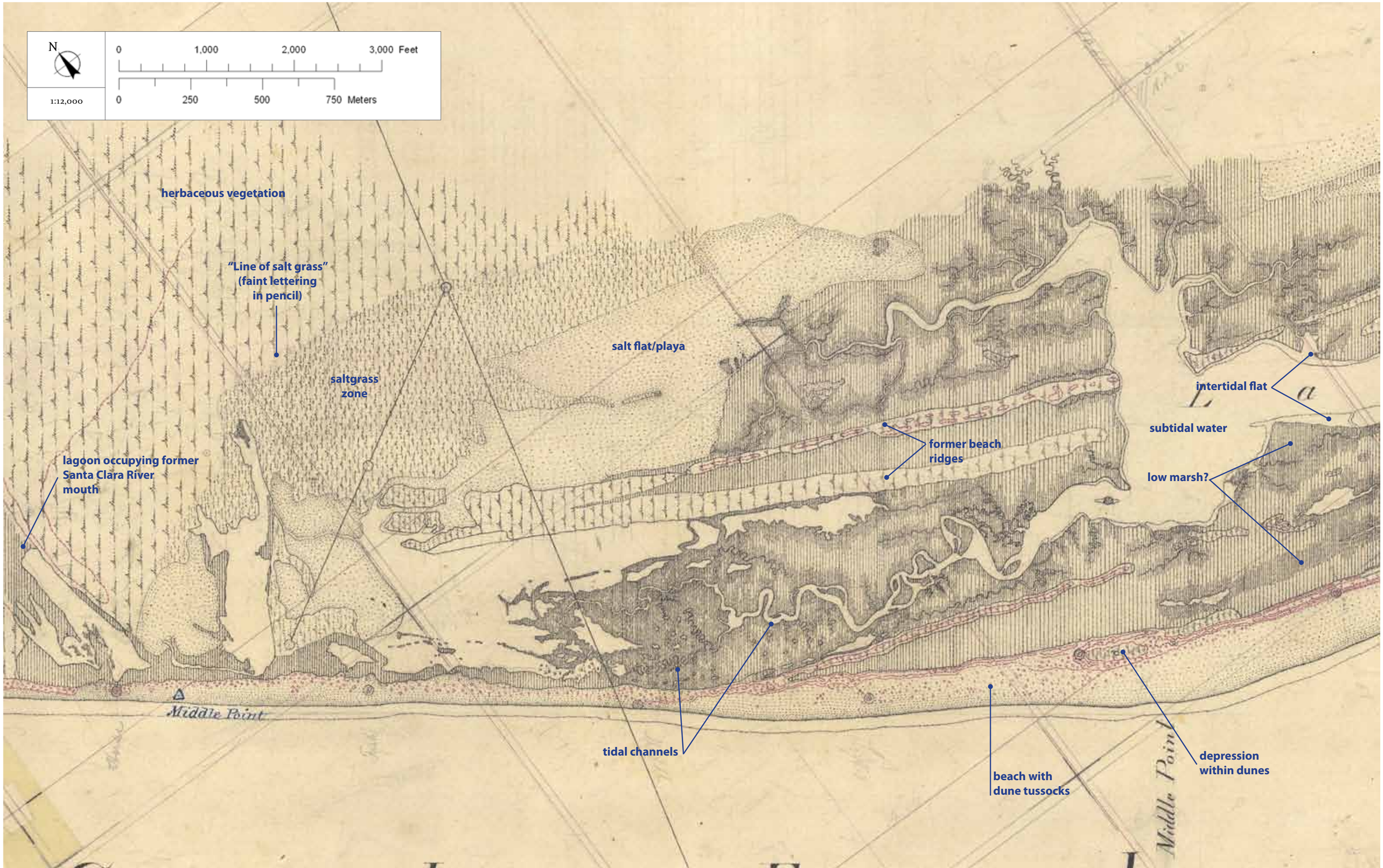


Figure 13. Portion of T-893.

REGISTER Nº.:	T-893
PUBLISHED:	1857
SURVEYOR:	W. M. JOHNSON
LOCALE:	ORMOND BEACH, MUGU LAGOON

N

1:34,000

0 1,000 2,000 4,000 6,000 8,000 Feet

0 500 1,000 2,000 Meters

Figure 14. T-893 (full extent).

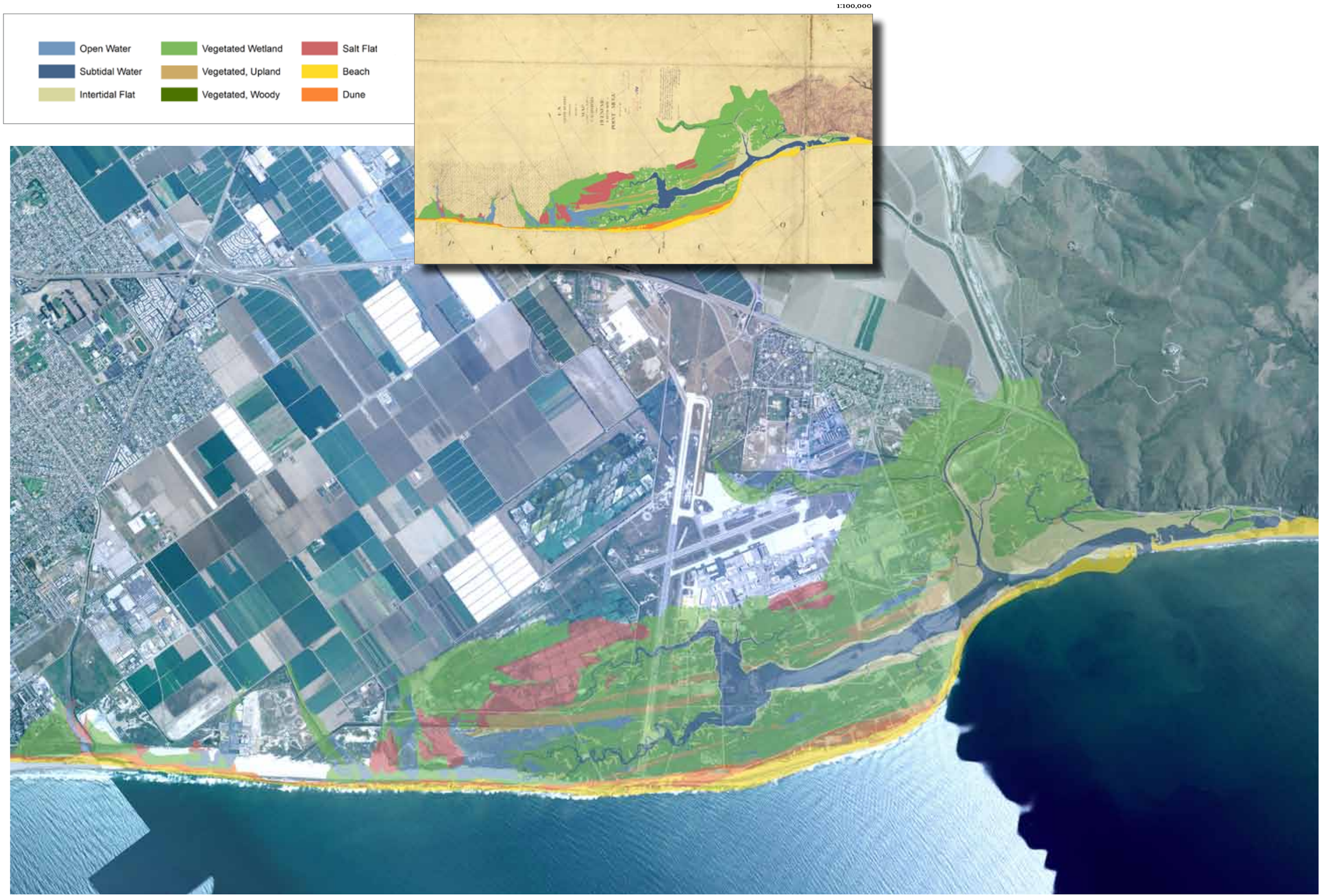
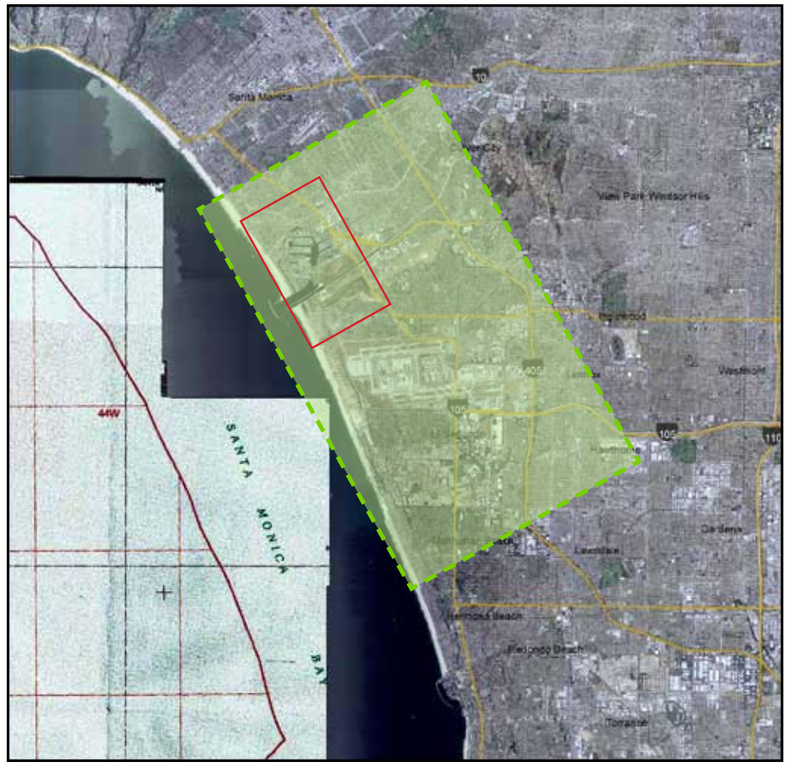


Figure 15. Coastal features digitized from T-893, overlaid on modern aerial photography (USDA 2005), at same scale as facing T-sheet.

BALLONA WETLANDS

REGISTER Nº.:	T-1432b
PUBLISHED:	1876
SURVEYOR:	A.W. CHASE

T-1432b, published in 1876, includes one major estuary: the Ballona wetlands, which covered 711 ha. The map was surveyed by A. W. Chase, who did a number of other Southern California T-sheets. For unknown reasons, this map was produced at a scale of 1:20,000, substantially smaller than most other Southern California T-sheets (which were mapped at 1:10,000).



The green shaded box denotes the extent of T-sheet 1432b and the red solid line indicates the area of detail depicted on the next page.

The Ballona wetlands (shown at right) were dominated at this time by vegetated wetlands (70%), as indicated by horizontal lines with occasional vertical "tufts." Significant unvegetated areas are shown, including tidal flat (16%) and salt flat (8%), with smaller areas of open water ponds (3%). Several different representations are used to depict these areas, suggesting that the marshland exhibited a range of hydrologic regimes with varying degrees of surface water persistence. There are also some topological and symbolic anomalies, making a few interpretations challenging.

The enclosed, stippled areas indicate dry pannes or salt flats. Enclosed areas with multiple concentric internal lines indicate the presence of surface water. According to USCS conventions (and affirmed on other T-sheets in the region), this pattern should refer to freshwater ponds, which is plausible for the y-shaped pond near the mouth of Ballona Creek, but seems unlikely for the features in the middle of the marsh, away from presumable freshwater input (and with the lagoon mouth open to the tides). The two elongate ponds along the south edge bluffs could probably be termed salinas (salt ponds), as they are depicted equivalently to such features in South San Francisco Bay (Collins and Grossinger 2004). These would receive water only from extreme high tides and produce evaporative salts in late summer.

Definitive subtidal area (defined by the line of low water) accounts for just 3% of the system. However, the exact terminus of subtidal channels is imprecise in some places because of the difficulty of depicting multiple parallel lines in small channels. The line of mean lower low water also stops abruptly at one point. As a result, there may have been somewhat more subtidal area (e.g., subtidal channel may have extended some distance upstream towards Ballona Creek). But the predominant pattern is large intertidal areas with relatively narrow subtidal channels. The lagoon opening is narrow enough that it may have been subject to frequent closure.

Bellona [sic] Creek and a smaller tributary enter the marsh from the east. An unusual symbol type that looks like miniature trees is shown extending along the creek's tidal course. Based on their position and similarity to other 19th-century map symbols, these symbols may indicate taller marsh vegetation, such as willows, tules, or cattails. This would suggest a strong fresh to brackish gradient towards the creek mouth. This symbol is also used for a much smaller area to the north, where a small channel emerges from the marsh plain and terminates in a small pond. This depiction may indicate a spring or unshown tributary near the marsh margin, creating a brackish channel with willows (and/or tules).

In 1876, the marsh has a single tidal source, at the northwestern edge of the bluffs. The entry subtidal channel runs parallel to the coastline between the outer beach and an inner line of dunes, which is broken through by channel branches at three major points. The southernmost branch connects to a narrow tidal channel and upland tributary along the bluffs; this may be a formerly larger upland drainage channel, now mostly abandoned. As with all T-sheets, much more understanding of the wetland characteristics and processes could be obtained by integrating other historical data sources.

For example, one secondary source is the 1887 USCGS resurvey that was prodded by the proposed development of a port at Ballona. The map mostly reproduces the earlier survey, while focusing on changes resulting from dredging at the channel mouth. The surveyor, Ferdinand Westdahl, described the dredging operations and sediment dynamics associated with jetty construction in a handwritten note on the map. He noted the difficulty of maintaining the newly excavated channel mouth, stating that "the channel between the jetties, instead of scouring as it was expected to do, filled up so as to leave but a narrow channel at low water."

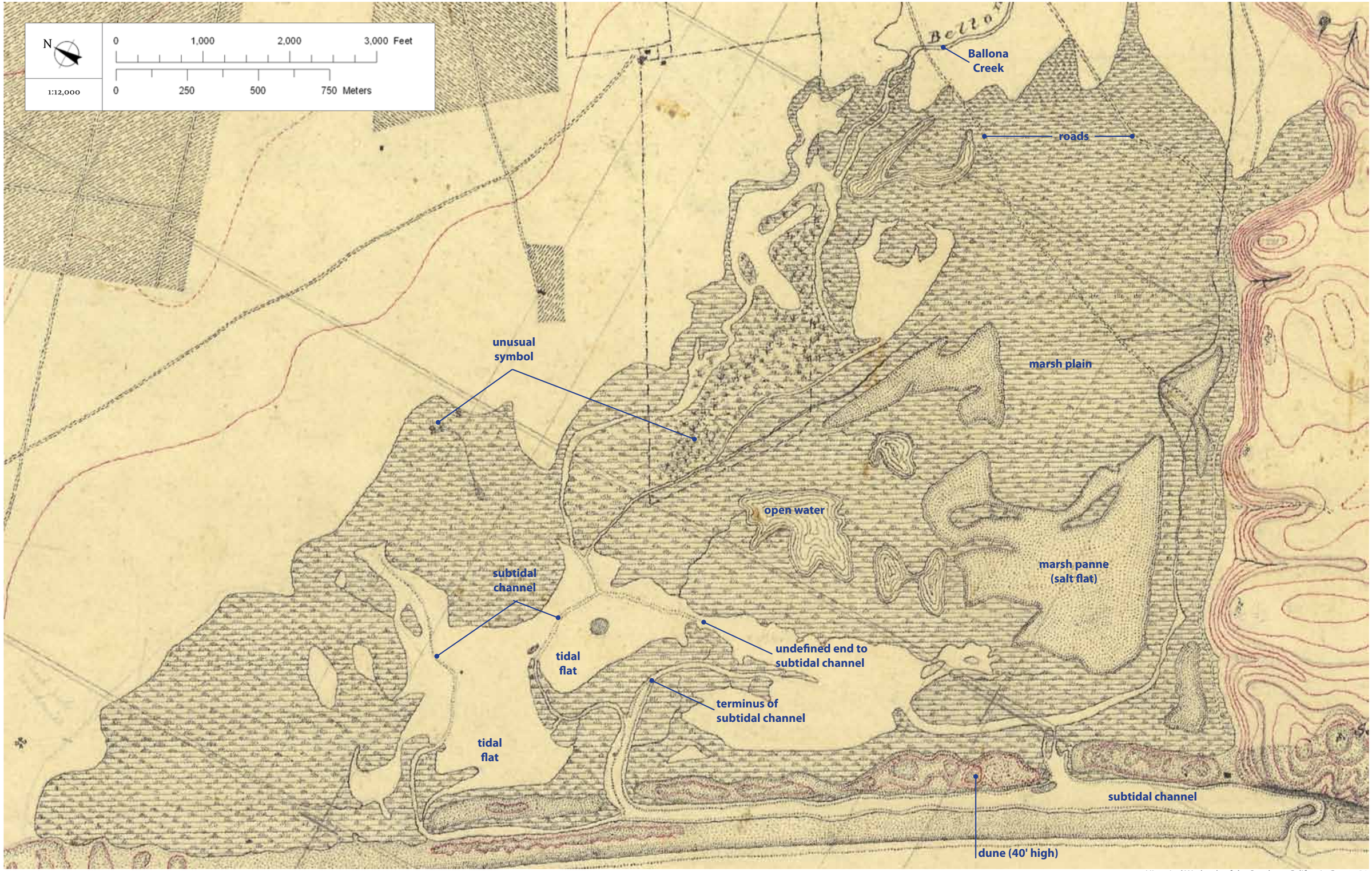


Figure 16. Portion of T-1432B.

REGISTER Nº.:	T-1432b
PUBLISHED:	1876
SURVEYOR:	A. W. CHASE
LOCALE:	BALLONA WETLANDS

N

1:34,000

0 1,000 2,000 4,000 6,000 8,000 Feet

0 500 1,000 2,000 Meters

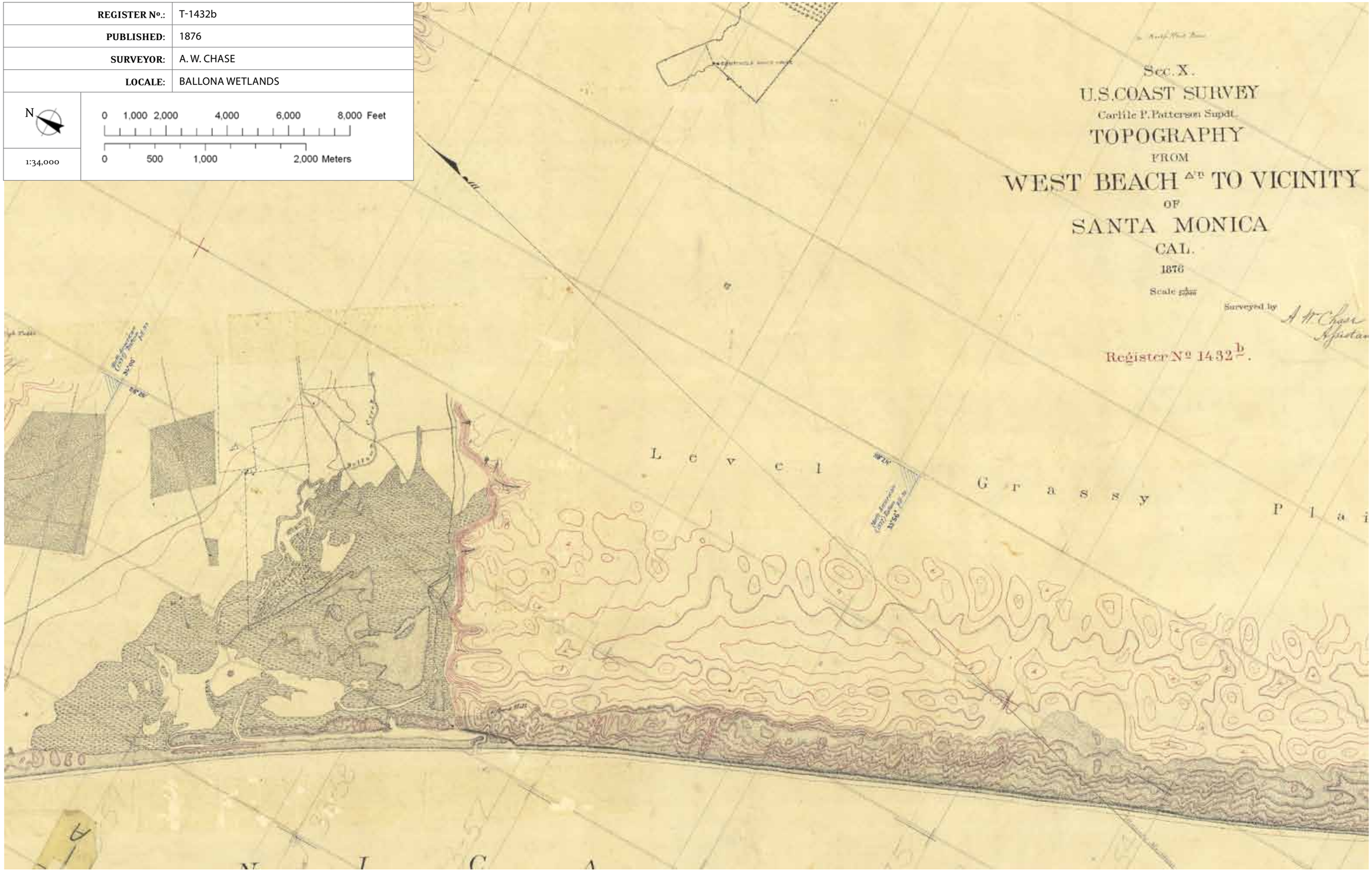


Figure 17. T-1432b (full extent)

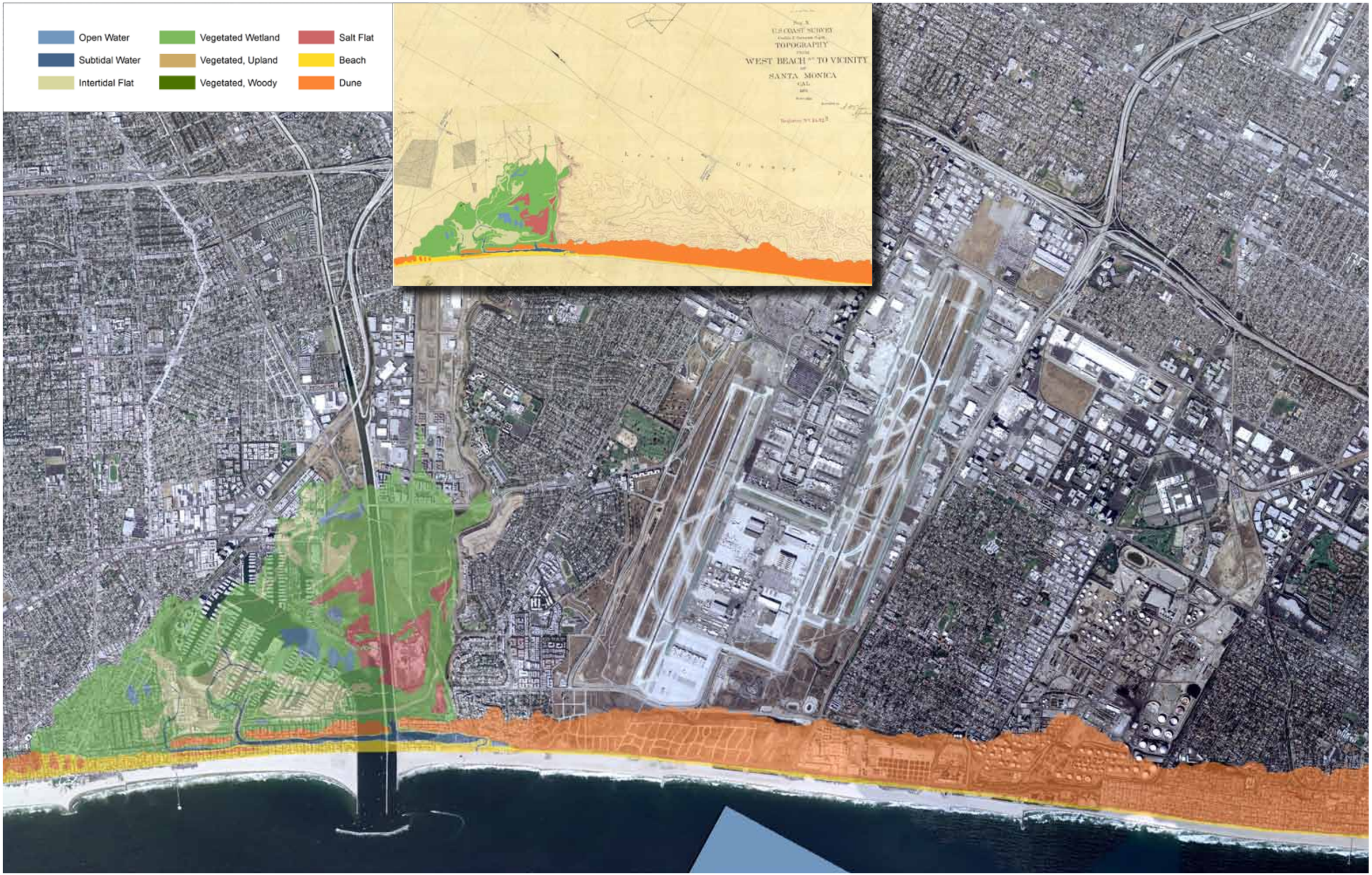
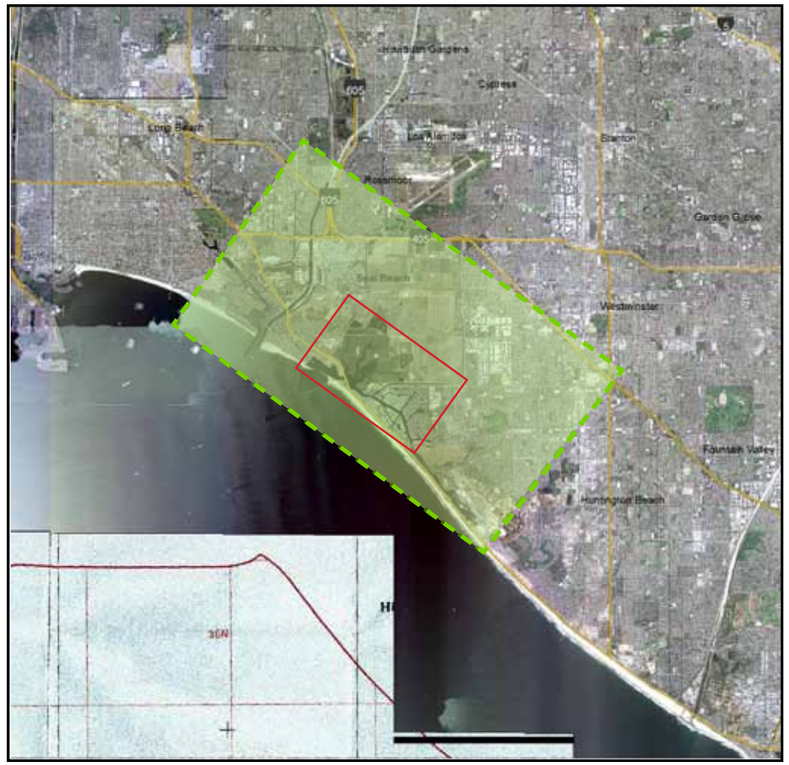


Figure 18. Coastal features digitized from T-1432b, overlaid on modern aerial photography (USDA 2005), at same scale as facing T-sheet.

SEAL BEACH	REGISTER Nº.:	T-1345
	PUBLISHED:	1873
	SURVEYOR:	A.W. CHASE

Like the map of Ballona, T-1345 was produced by A. W. Chase. These maps of LA County follow the Johnson maps of Ventura County and the Harrison maps of southern San Diego County by two decades, reflecting some of the stylistic changes during that time. A helpful element of Chase's maps is that triangulation stations – the small red circles with center dots shown on all T-sheets – are consistently named for their landscape context (e.g., "Little Hill" clarifies the interpretation of a feature that could also be interpreted as open water).



The green shaded box denotes the extent of T-sheet 1345 and the red solid line indicates the area of detail depicted on the next page.

T-1345 covers parts of Alamitos Bay and Bolsa Chica, and all of the Seal Beach wetlands, which are shown at right. The Seal Beach wetlands covered 834 ha, of which 75% was vegetated tidal wetlands – indicated by the use of the traditional salt marsh symbol of continuous parallel lines with occasional tufts. Subtidal area, representing 6% of the system area, existed as the deep water portions of the larger tidal channels extending from the inlet mouth. Unvegetated tidal flats between the subtidal areas and the vegetated marsh surface represented about 13% of the system. Large salt flats, labeled "Alkali," were found towards the upland margin and were another significant (7%) component of the habitat mosaic. Interestingly, this map shows no explicit isolated surface waters within the marsh plain. Chase shows few or no marsh ponds in neighboring large marshland areas as well. (Ponds shown on T-1283 were clearly copied from Johnson's earlier map.) Other sources may be able to confirm whether there were more open water features than shown.

One of the most interesting characteristics of this map and neighboring T-1369 is the explicit depiction of large areas of freshwater marsh at the inland margin of salt marsh. Several hundred hectares of freshwater marsh were shown at the edge of the Seal Beach wetlands, as well as the adjacent wetland systems to the north and south. Freshwater marsh is indicated by the irregularly broken horizontal line pattern in contrast to to continuous lines of the salt marsh (Shalowitz 1964). Fresh conditions are also implied by the use of concentric internal lines to identify ponds, typically meaning freshwater pond (Hergesheimer 1881). The presence of groves of trees within the marsh, both here and in the neighboring systems, also suggests perennially fresh or nearly fresh conditions. (Larger groves on neighboring sheets are labeled "Willow Swamps.")

It is not obvious whether to consider these adjacent freshwater marshes as tidal or non-tidal. Tidal channel networks extend into a few such areas, suggesting that they could be considered freshwater tidal marshes. Another piece of information is provided by a letter by Chase, describing the equivalent boundary on the adjacent map T-1369. Shalowitz (1964:181) reproduces part of this letter as an example of a site where the "inner edge of the marsh was very carefully delineated." Chase wrote that "Care was taken to delineate exactly the division line between salt and fresh water marsh, a point that may be of future value in land dispute." Shalowitz makes it clear that the salt marsh margin is intended to mark the edge of tidal lands ("the dividing line between marsh land and the fast or upland") – the relevant boundary for public trust versus private land. Based upon this information, we did not classify these areas as part of the estuarine complexes. However it should be considered that some portion may have received at least occasional tidal inundation.

The adjacent systems, Bolsa Chica and Alamitos Bay (including the Los Cerritos wetlands), had very similar characteristics to the Seal Beach wetlands. As seen in the spread on the following pages, vegetated wetlands predominated in each system (66-75%), with 13-25% intertidal flat, and 6-8% subtidal water. Each was bordered by freshwater marshes and willow swamps.

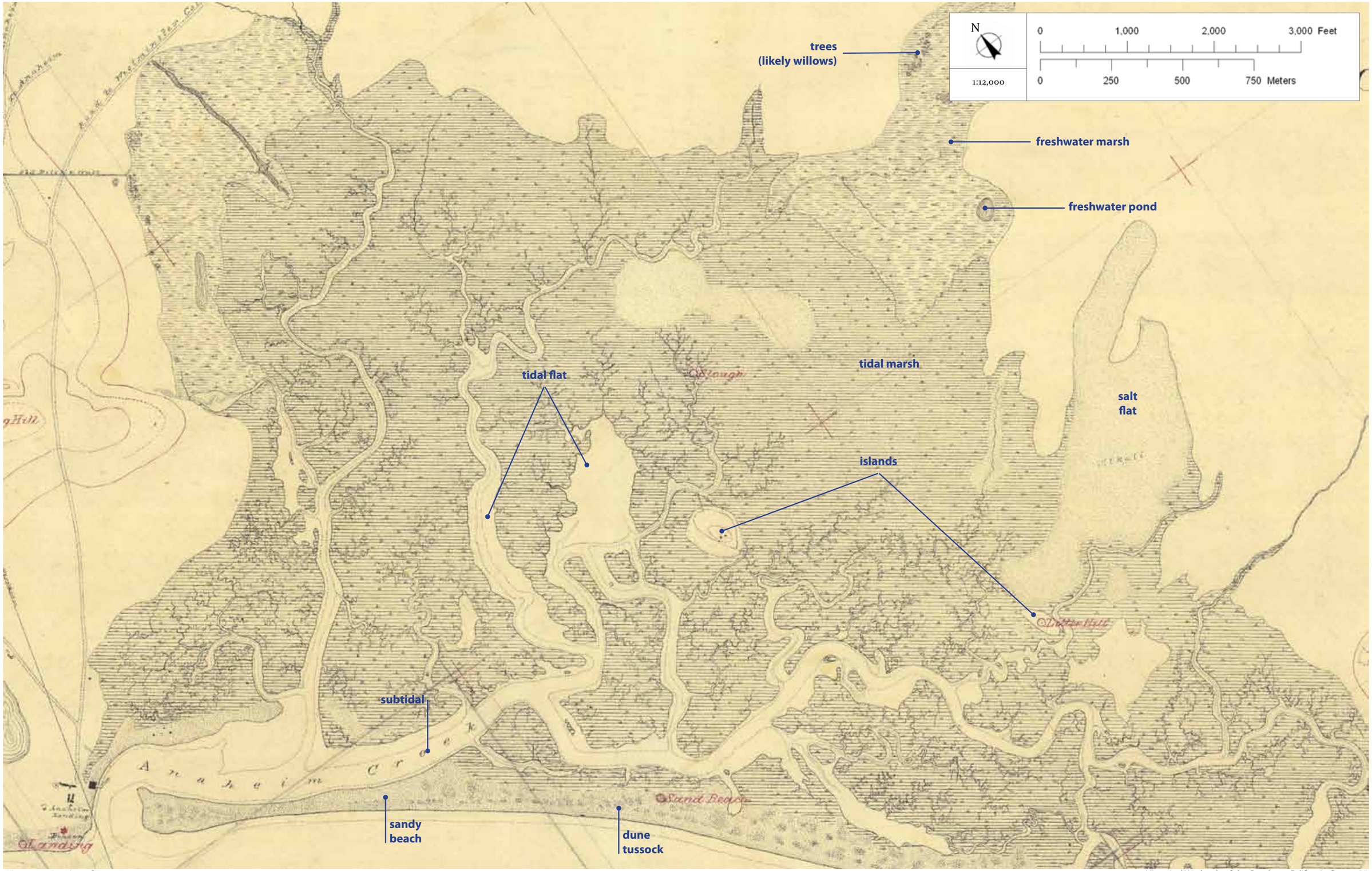


Figure 19. Portion of T-1345.

REGISTER Nº.:	T-1345
PUBLISHED:	1873
SURVEYOR:	A. W. CHASE
LOCALE:	ALAMITOS BAY TO BOLSA CHICA

N

1:34,000

0 1,000 2,000 4,000 6,000 8,000 Feet

0 500 1,000 2,000 Meters

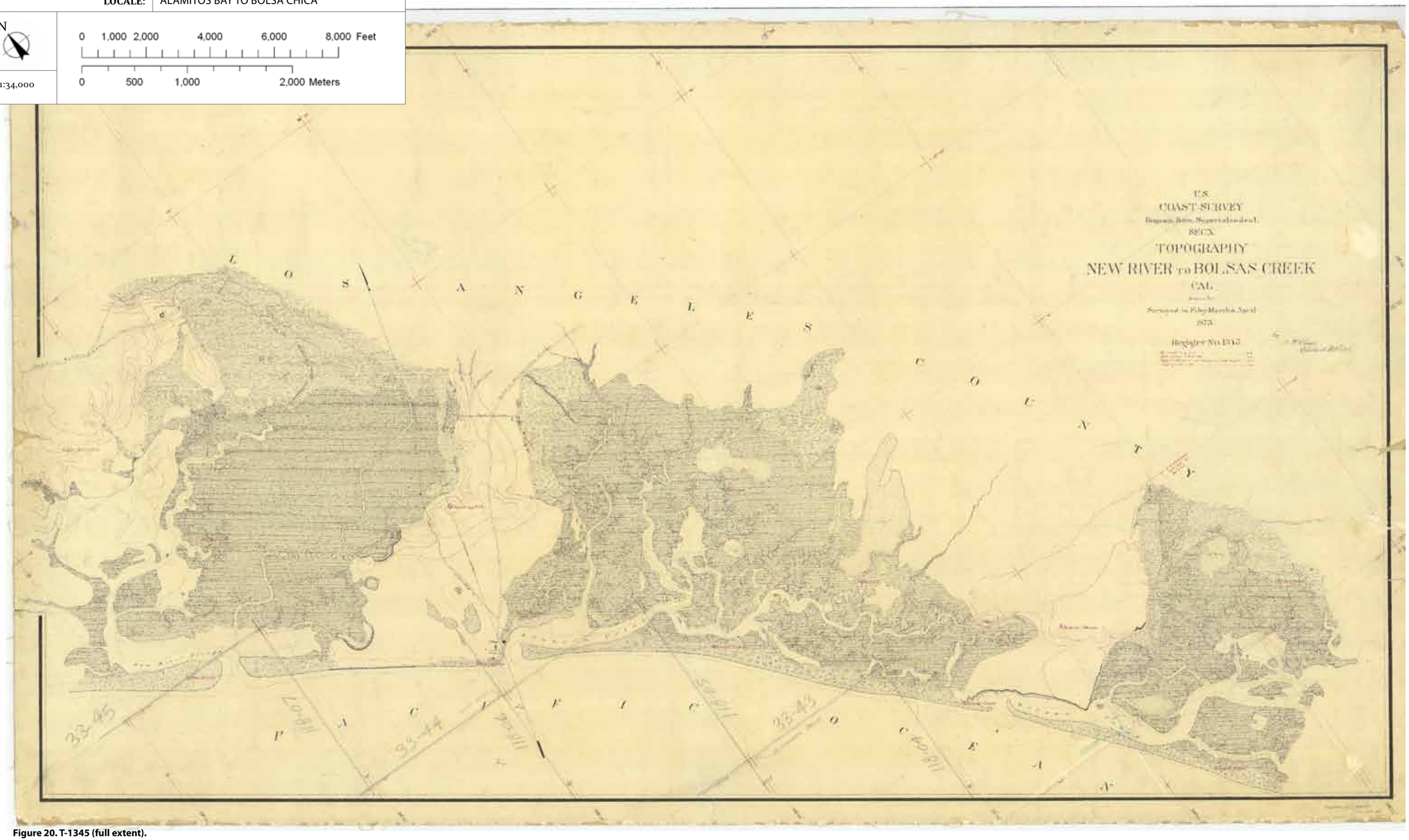
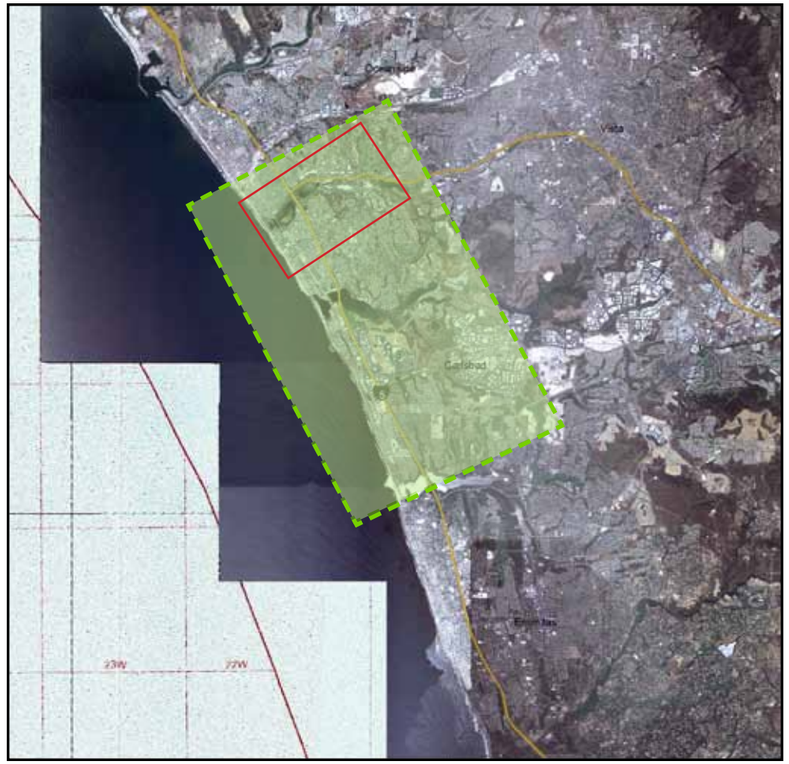


Figure 20. T-1345 (full extent).

Figure 21. Coastal features digitized from T-1345, overlaid on modern aerial photography (USDA 2005), at same scale as facing T-sheet.

BUENA VISTA LAGOON

REGISTER Nº.:	T-1899
PUBLISHED:	1887-1888
SURVEYOR:	RODGERS & MCGRATH



The green shaded box denotes the extent of T-sheet 1899 and the red solid line indicates the area of detail depicted on the next page.

T-1899, produced in 1887-88, shows a series of three estuaries along the San Diego County coast: Buena Vista, Aqua Hedionda, and Batiquitos lagoons. This map is part of a series of surveys along the San Diego shoreline led by Augustus Rodgers in the late 1880s. The timing and detail of these maps create some limitations.

Rodgers had an impressively long career in the field for the Coast Survey (he surveyed San Francisco Bay marshes as early as 1854), but his work was less detailed than some other surveyors (Grossinger 1995). As in his other maps, T-1899 does not have a highly detailed depiction of estuarine features. Nevertheless, a significant amount of information is provided.

Buena Vista Lagoon, the northernmost wetland system on T-1899, is shown as covering 123 ha. Of this total, 29 ha (24%) is shown explicitly as vegetated wetlands. Within the vegetated marsh plain no small channels or ponds are shown. It is not known whether these features were more limited here than in other systems, or whether they were simply not shown. We know Rodgers did not tend to show these features (Grossinger 1995), so these marshes may have had more complex drainage and surface water characteristics than shown. (Other historical sources could potentially document additional features.)

This system and the neighboring ones to the south are shown with closed barrier beaches; the frequency of breaching and closure is not known. Open water is indicated near the location of the most recent opening by concentric circles indicating ponds or pools.

The open water areas terminate adjacent to a large, difficult-to-interpret area that is fringed by a narrow, diagrammatic marsh boundary. The lack of a defined inner edge indicates that the marsh continues. But the presence of a marsh island suggests that the intervening area is not completely vegetated. Given the multiple roads crossing the system, and the lack of concentric circles, it appears not to be deep water. The notation on an adjacent similar-looking but smaller area ("Pond in Winter, White alkali flat in summer" T-2015) suggests that these areas may have been unvegetated flats that filled with water in the rainy season and dried out in the summer. (Unlike some other surveyors, Rodgers did not use a stipple pattern to indicate salt pannes or flats.) While the exact meaning of the symbology is somewhat uncertain here, Rodgers appears to be showing similar patterns in these adjacent systems along the San Diego County Coast.

Because of its relatively late date, this T-sheet and the neighboring ones also show more direct evidence of anthropogenic modifications, notably the presence of railroad crossings. The California Southern Railroad was constructed along the coast between San Diego and Oceanside in the early 1880s (several years before the USCS maps) crossing the series of systems from San Margarita to Soledad Valley. Given that most crossings used bridges over the major channels, rather than a continuous levee, they seem unlikely to have caused major impacts by this time. However, Buena Vista drainage appears to have been the most modified of these systems, as levees crossed both of the major sloughs. Very similar wetland patterns are observed in the neighboring Aqua Hedionda and Batiquitos, though, which did have bridges across the major inlet channels (and presumably less impacts to tidal circulation). Further information contemporary and prior to the T-sheet will be essential to clarifying the natural characteristics and dynamics of these systems.

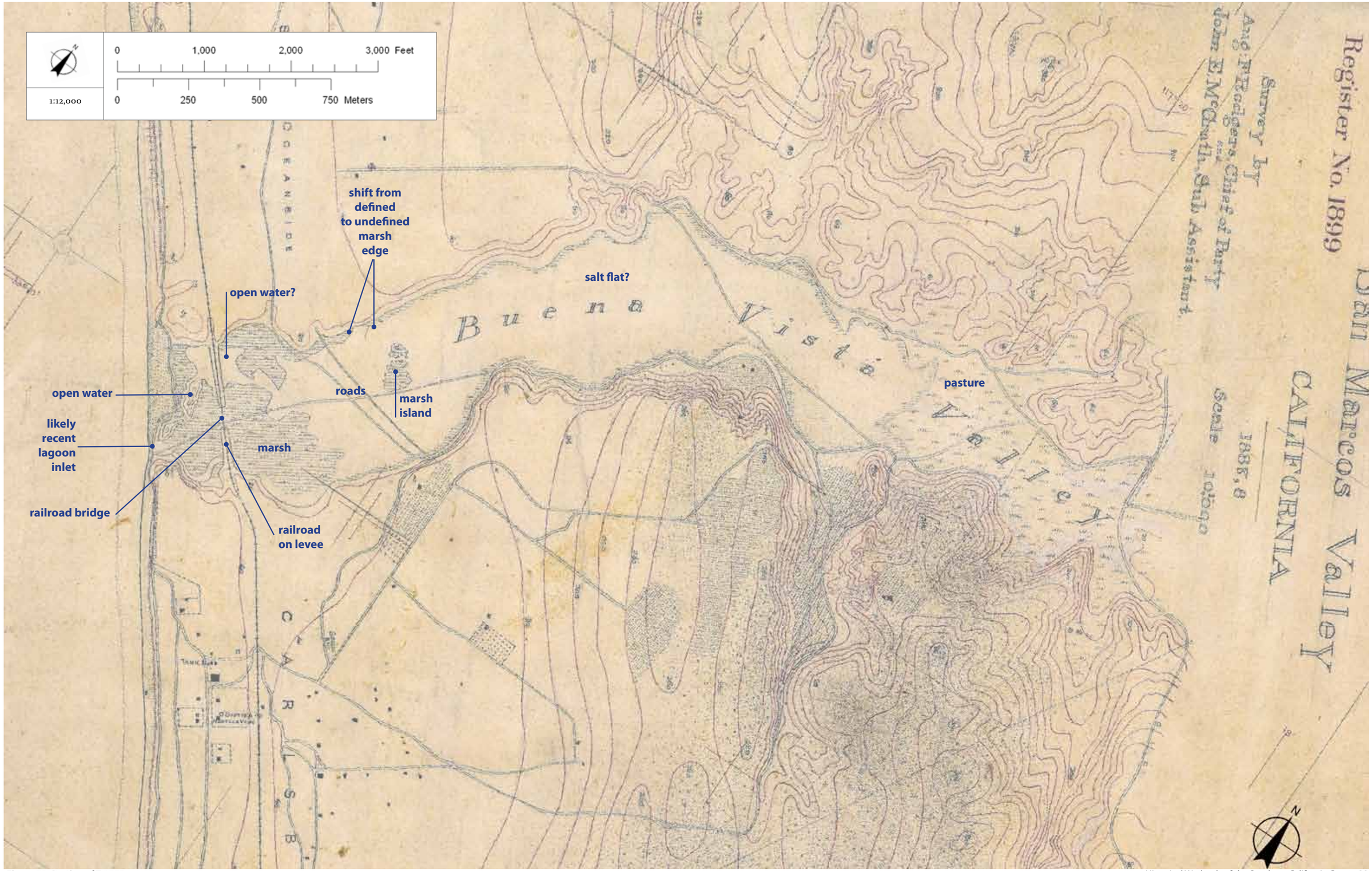


Figure 22. Portion of T-1899.

REGISTER Nº.:	T-1899
PUBLISHED:	1887-1888
SURVEYOR:	AUGUSTUS F. RODGERS AND JOHN E. MCGRATH
LOCALE:	BUENA VISTA LAGOON TO BATIQUITOS LAGOON

N

0 1,000 2,000 4,000 6,000 8,000 Feet

0 500 1,000 2,000 Meters

1:34,000

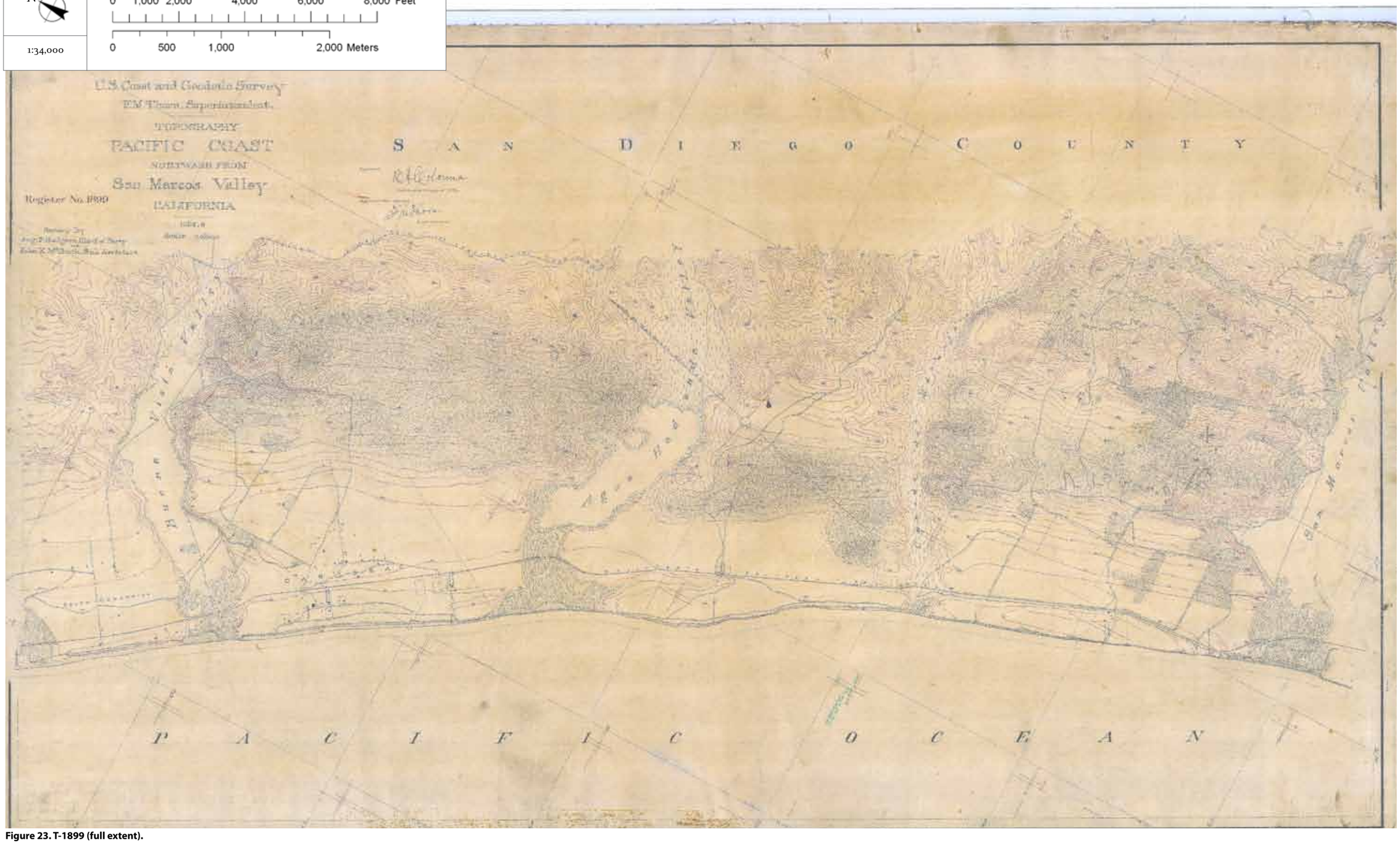


Figure 23. T-1899 (full extent).

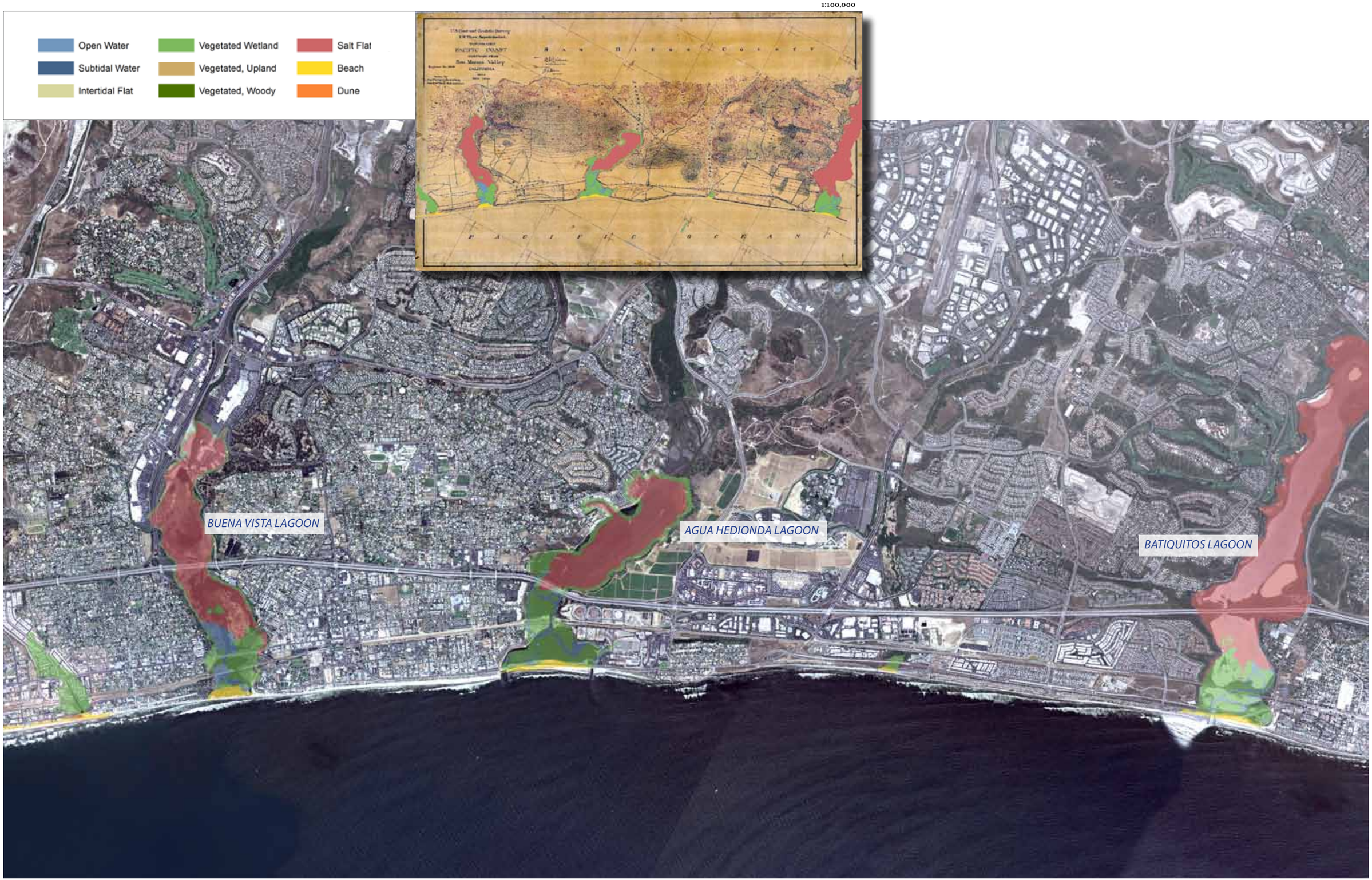
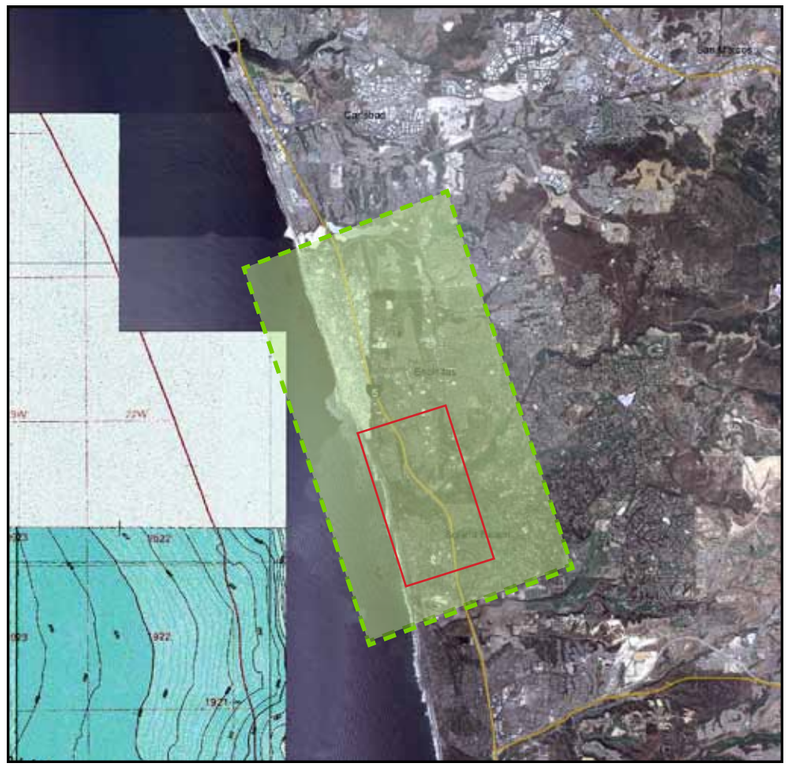


Figure 24. Coastal features digitized from T-1899, overlaid on modern aerial photography (USDA 2005), at same scale as facing T-sheet.

SAN ELIJO LAGOON	REGISTER Nº.:	T-1898
	PUBLISHED:	1887-1888
	SURVEYOR:	RODGERS & MCGRATH



The green shaded box denotes the extent of T-sheet 1898 and the red solid line indicates the area of detail depicted on the next page.

T-1898 was produced at the same time (1887-88) and by the same surveying team (Rodgers and McGrath) as T-1899, the map immediately adjacent to the north. T-1898 shows San Elijo Lagoon and the southern edge of Batiquitos Lagoon. Like the other T-sheets of northern San Diego County, T-1898 has certain limitations because of its timing and detail. As one of the last areas to be surveyed by the Coast Survey, this part of the coast exhibits more significant modifications by the time of the T-sheets.

The resolution of this digital map reproduction is lower than the other T-sheets because the original map is not available in the National Archives files. The version used here is a copy circa 1914, with all the original information but at reduced scale. Subsequent information showing recent development was added in red in 1914 as a provisional update.

San Elijo Lagoon, depicted on the page at right, is depicted similarly to other nearby systems in north San Diego County, notably Buena Vista, Aqua Hedionda, and Batiquitos lagoons. San Elijo is shown as having 84 ha of vegetated wetland. However, the inland wetland margin is a straight line and appears to be artificial. Inland of this presumed levee, the map shows a blank area crisscrossed by roads, similar to that shown on other neighboring T-sheets (see T-1899 discussion). The extent and interpretation of this area is not well defined. It is likely that vegetated wetlands extended further inland along the tidal channel and perhaps behind the apparent levee. As discussed in the T-1899 section, this area may have been seasonally flooded salt flats, i.e., unvegetated areas. According to the T-sheet, the area does not appear to have had deep or permanent open water. On the other hand, other historical sources for these north San Diego County systems suggest more persistent open water (Jacobs, pers. comm.).

Within the marsh, two large open water ponds are shown at the southern marshland margin. One of these ponds (the one adjacent to the beach) can be seen in current imagery to occupy nearly the same size and shape. The major tidal channel, whose plan form is also similar to the contemporary condition, terminates in a fairly large open area shown as connected to the channel. Additional marsh features may have been present but not shown, given Rodgers's style (Grossinger 1995). In fact, a few additional channels can be seen in a 1957 oblique image of the site *(www.sanelijo.org/history).*

Near the mouth of the system, the California Southern Railroad crosses the main channel with a bridge and most of the vegetated wetlands with a levee. The channel is shown as open to the ocean. The line of mean lower low water (MLLW) does not extend inland along the channel, indicating that the channel was tidally exposed, creating 6 ha (3%) of tidal flat. (It is possible that there was a narrow subtidal channel too small to be depicted.) The area of uncertain interpretation towards the landward margin accounts for 55% of the estimated total system area. Additional historical sources will be important to clarify the interpretation of early conditions and historical changes at this site.

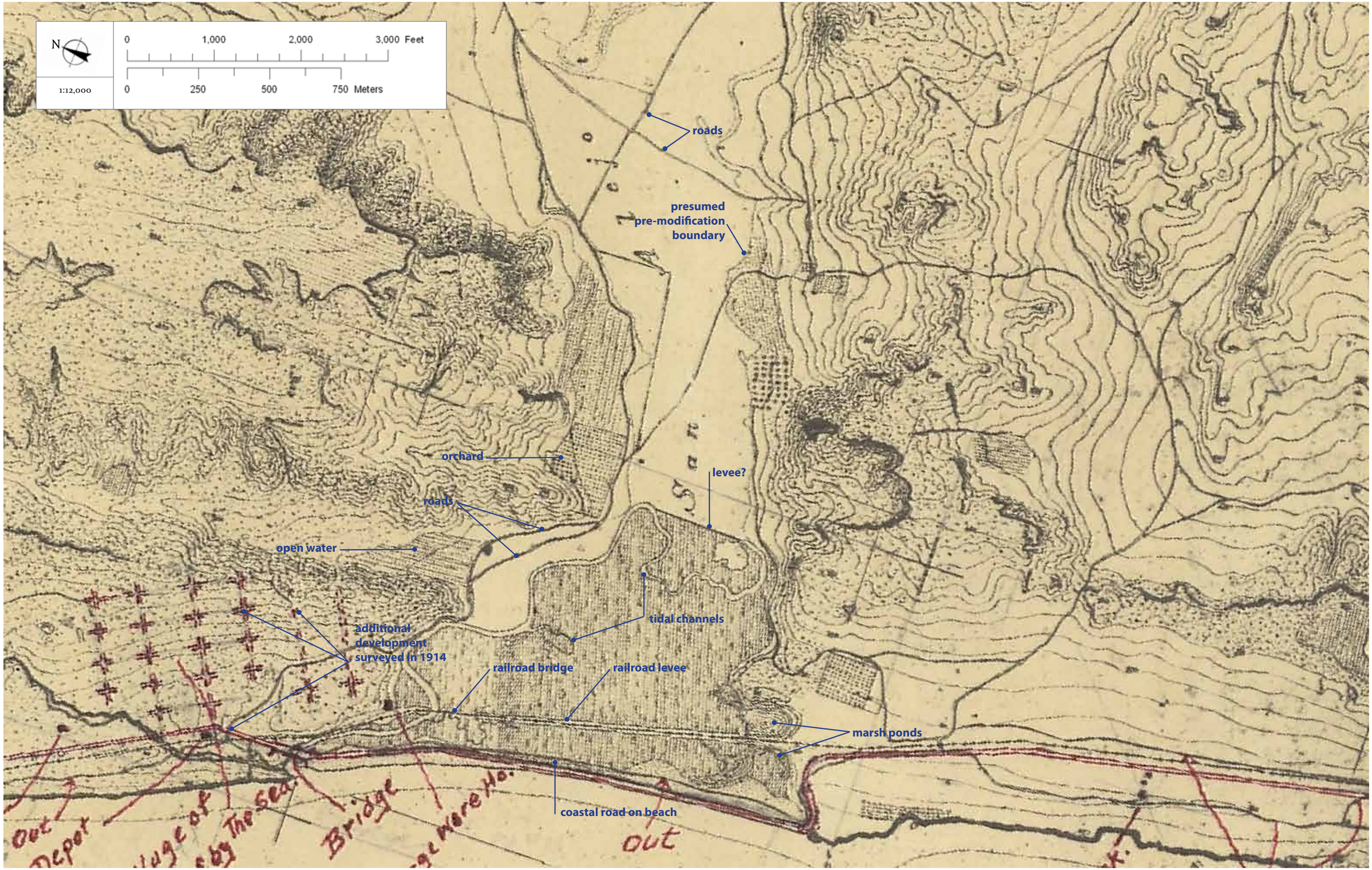


Figure 25. Portion of T-1898.

REGISTER Nº.:	T-1898
PUBLISHED:	1887-1888
SURVEYOR:	AUGUSTUS F. RODGERS AND JOHN E. MCGRATH
LOCALE:	BATIQUITOS LAGOON TO SAN ELIJO LAGOON

N

0 1,000 2,000 4,000 6,000 8,000 Feet

0 500 1,000 2,000 Meters

1:34,000

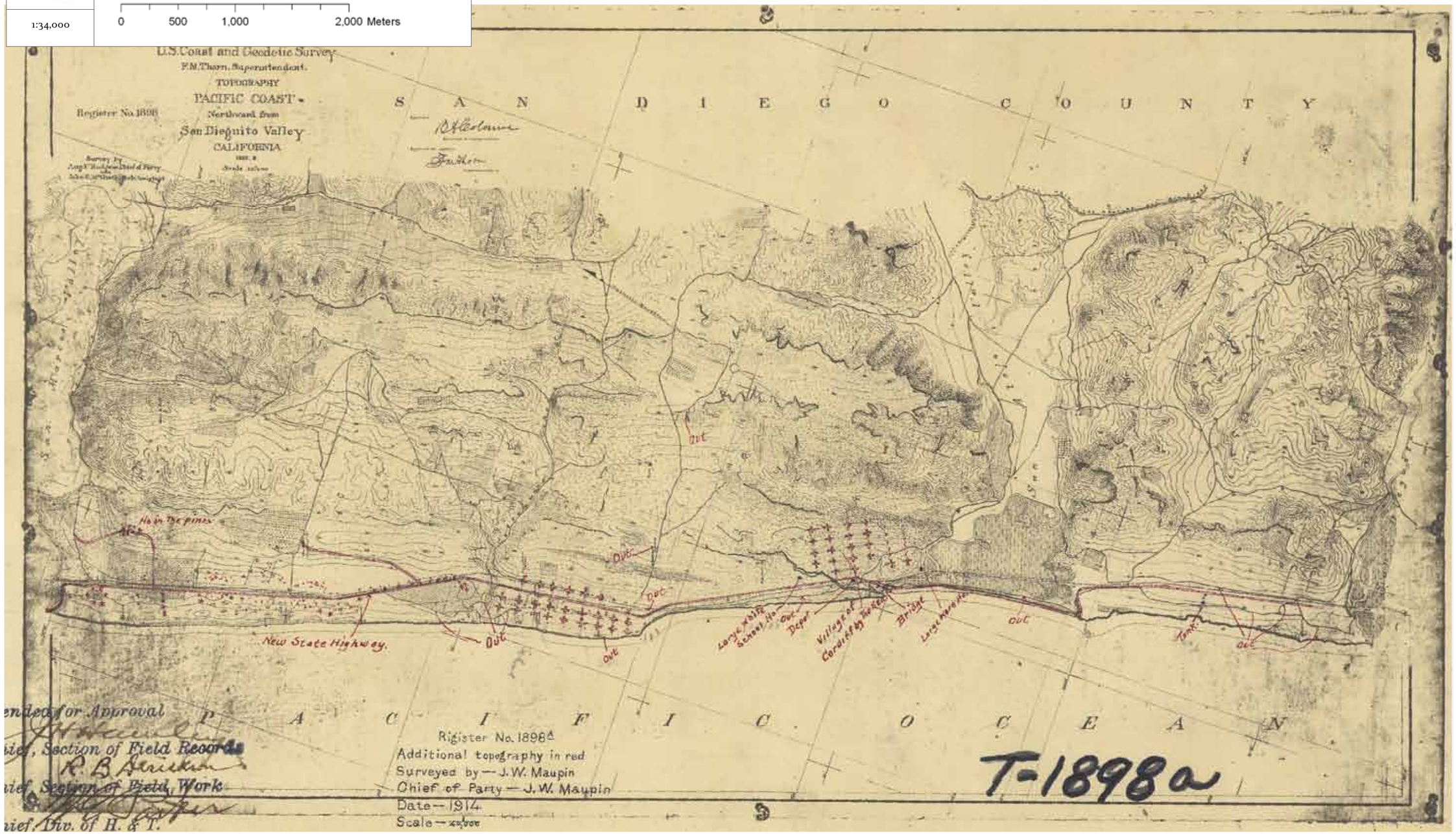


Figure 26. T-1898 (full extent).

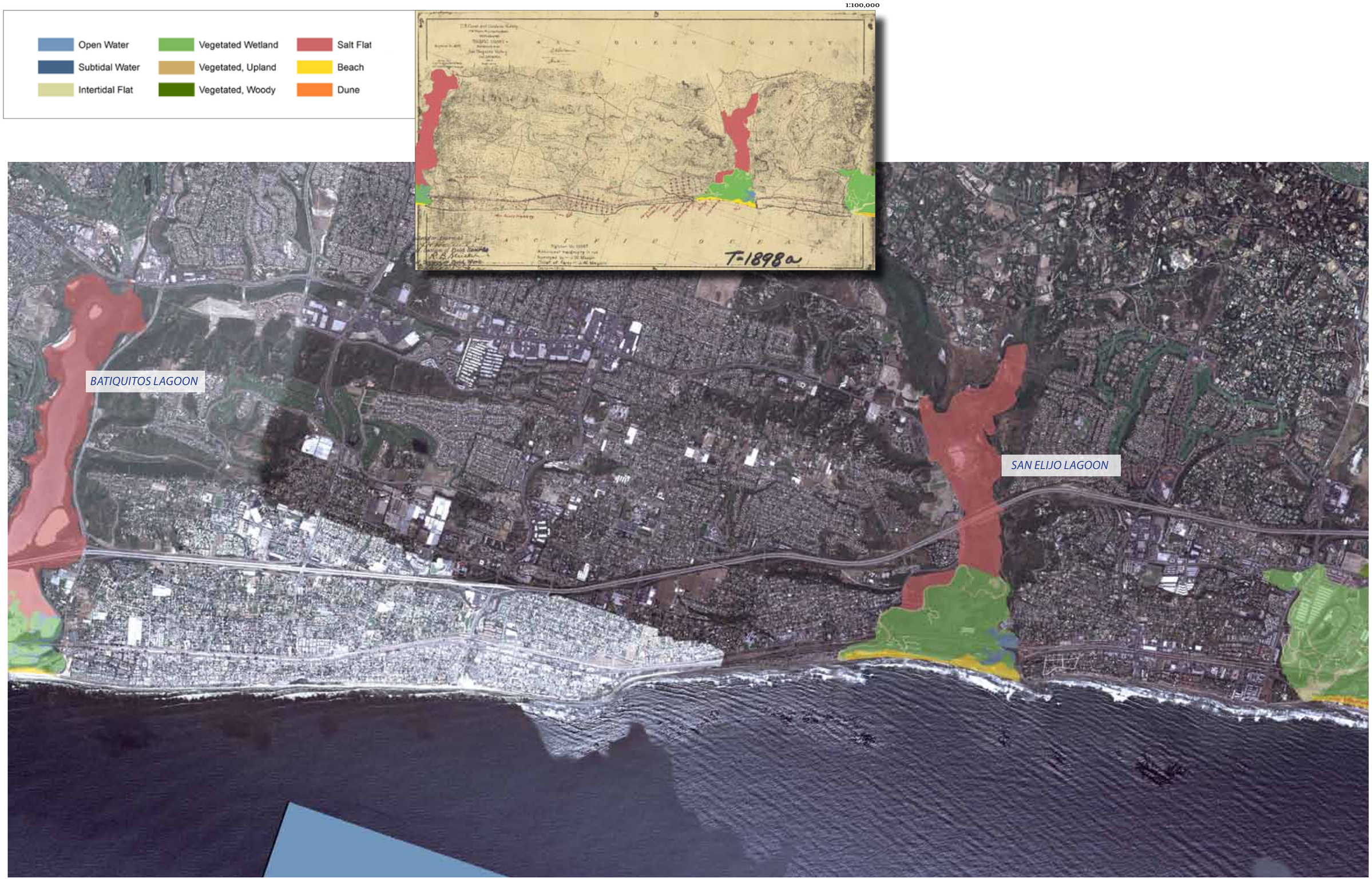
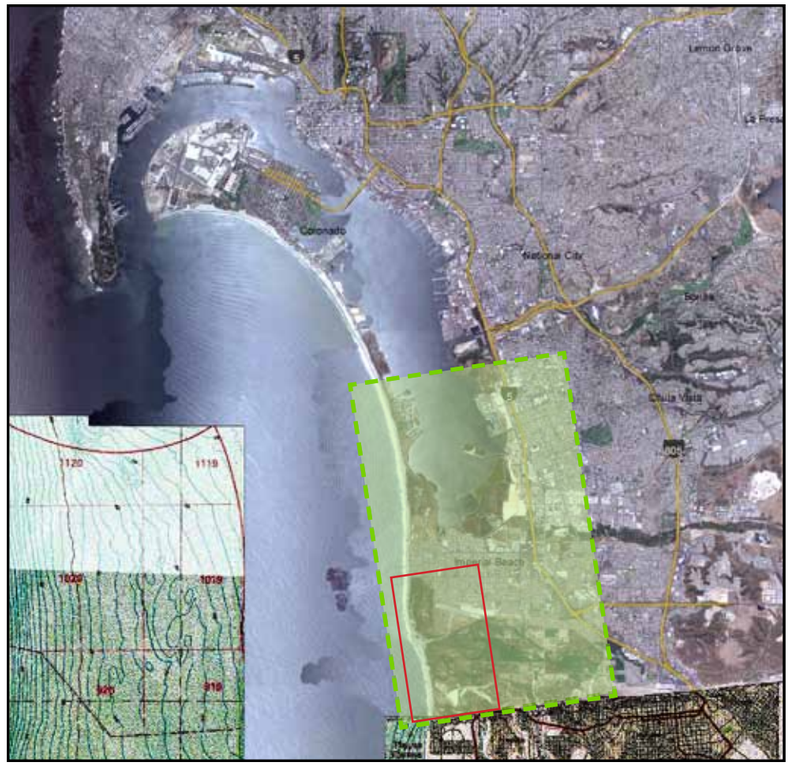


Figure 27. Coastal features digitized from T-1898, overlaid on modern aerial photography (USDA 2005), at same scale as facing T-sheet.

TIJUANA ESTUARY	REGISTER Nº.:	T-365
	PUBLISHED:	1852
	SURVEYOR:	A. M. HARRISON



The green shaded box denotes the extent of T-sheet 365 and the red solid line indicates the area of detail depicted on the next page.

Completed in 1851-52, the maps of San Diego Bay and Tijuana Estuary represent the first significant portion of the Southern California shoreline surveyed by the Coast Survey (smaller areas of the Santa Barbara shoreline (T-373) and Coronado Islands (T-332) were also mapped in this time frame). T-365 and the adjoining two maps of San Diego Bay were all produced by the same surveyor, A. M. Harrison.

T-365 exhibits several prominent coastal features through the use of mapping symbology. Emergent wetland vegetation is indicated by closely spaced parallel lines, a nonstandard, incomplete version of the conventional symbol for "salt marsh" produced by draftsman's omission of the tufts of grass intended to accompany the parallel lines (Shalowitz 1964: 189-191). Since tidal salt marsh and tidal brackish or freshwater marsh were often not distinguished (Shalowitz 1964: 181), these areas may also include brackish or fresh tidal marsh.

T-365 shows Tijuana Estuary (facing page) and the southern part of San Diego Bay. In southern San Diego Bay, vegetated wetland and tidal flat occurred in the contemporary salt pond areas (see the following spread). At the northern end of Tijuana estuary, the map shows several areas of "salt marsh" as isolated areas in the surrounding grassland – a pattern not commonly found on other Southern California T-sheets. Several similar non-tidal salt marshes to the north are shown without a defined outer boundary, suggesting a broad ecotone between the surrounding grassland and salt marsh plant species (perhaps with alkali meadow characteristics).

Harrison shows several very large enclosed open water ponds or pannes in Tijuana Estuary. An elongate open water feature occupies the very southern margin of the estuary, an area at the distal end of tidal influence (and probably with muted tidal influence due to the protruding upland). Handwritten lettering spelling out "Pond" is visible in the high resolution scan.

In this map very few smaller ponds are illustrated within the rest of the marshland. This may not be an accurate representation, as some surveyors tended not to show marsh ponds (Grossinger 1995). However, in San Francisco Bay, comparison of an 1853 Harrison map to an 1861 landscape photograph of the same site indicated that the surveyor did record small ponds at this site (Grossinger et al. 2005: 33). Other sources could be consulted to resolve this question.

Large proportions of intertidal flat (unvegetated, low intertidal) are indicated as the area between the dotted line of MLLW and the lower limit of marsh vegetation. This line is expected to be fairly accurate in Tijuana Estuary, where the land-based topographic survey team would have been able to observe its position directly. It may be less accurate in the broad open waters of San Diego Bay (where the hydrographic team would likely have been more effective with soundings). A network of narrow subtidal channels extending through the marshlands is defined by the area contained by the dotted line of MLLW. Few small tidal channels are shown within the broad vegetated marsh areas; it is not obvious whether this is an accurate depiction or a more skeletal representation, as is common with T-sheets of this early vintage.

In a few spots, a broken lined pattern with no outline is used to indicate low elevation tidal marsh. In contrast to most of the vegetated marsh surface, which would be flooded only by extreme high tides, these areas would be mostly flooded at high tide (Shalowitz 1964: 182, 200, 203, 205). Varying densities of stippling indicate beach and dunes along the outer coastline (Shalowitz 1964).

At least seven grassy islands are shown within Tijuana Estuary, while none are indicated in South San Diego Bay. Near the mouth of Tijuana Estuary, it appears that a former beach ridge has been stabilized with vegetation, forming an archipelago. Islands toward the landward margin are likely remnant natural levee deposits from tributary creeks. A number of prominent peninsulas extending into the marshland also presumably reflect upland alluvium deposited along former stream courses. A few areas of the upland margin are depicted with closely spaced horizontal lines indicating steep banks; other areas are relatively gradual topographic transistions.

The upland portions of T-365 use the conventional tufted symbol for grassland or pasture. Harrison supplemented the symbol with a handwritten note in one of the corners of the survey, which states that "all that portion of this sheet represented as being covered with grass is also covered with low artemesia, or wild sage bushes [underlining by Harrison]". The note also explains some nonstandard symbols shown in several places along the tidal marsh-upland margin that had "cactus" and/or "mescal trees."

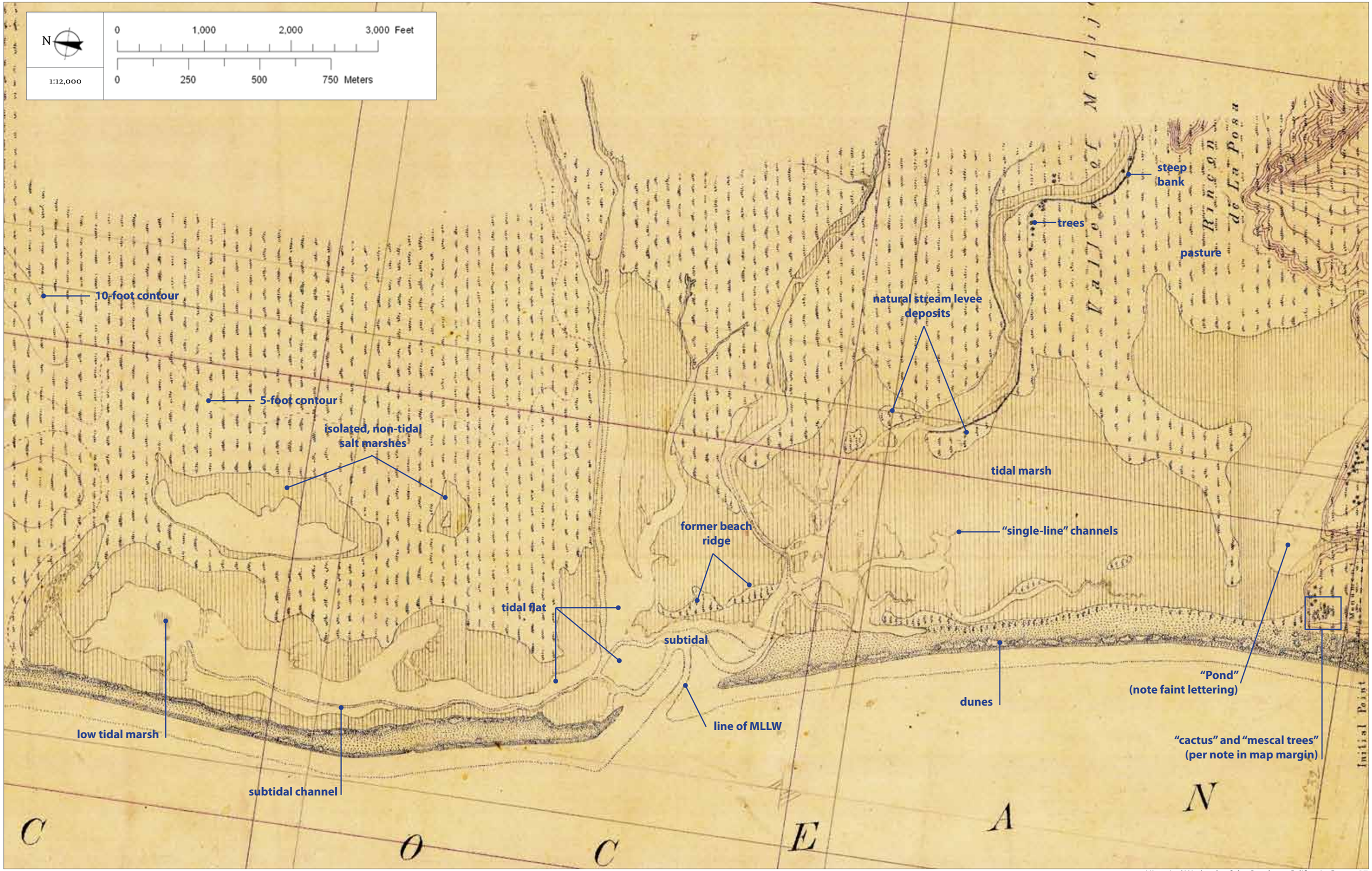


Figure 28. Portion of T-365.

REGISTER Nº.:	T-365
PUBLISHED:	1852
SURVEYOR:	A. M. HARRISON
LOCALE:	TIJUANA ESTUARY, SOUTHERN PART OF SAN DIEGO BAY

N

1:34,000

0 1,000 2,000 4,000 6,000 8,000 Feet

0 500 1,000 2,000 Meters

Figure 29. T-365 (full extent).

Figure 30. Coastal features digitized from T-365, overlaid on modern aerial photography (USDA 2005), at same scale as facing T-sheet.

5. REGIONAL PATTERNS

To assess regional, subregional, and local estuarine habitat mixes, we combined the detailed classification of 21 habitat types into five major categories: Subtidal Water, Intertidal Flat, Vegetated Wetland, Open Water, and Salt Flat. This simplified classification was created by grouping basic water regime and vegetation characteristics, as shown in Table 2 (see Chapter 3). Subtidal habitats were combined into a single Subtidal Water category representing waters with a surface connection to the ocean at low tide. *Unvegetated- low elevation-intertidal* and *channel-intertidal* were combined to Intertidal Flat. Vegetated estuarine wetlands of low, high, and extreme high elevation, including those shown as tidal and non-tidal (i.e. behind barrier beaches/dunes), were considered Vegetated Wetlands. We combined open water intertidal areas (generally marsh ponds) and open water non-tidal areas (generally surface waters behind barrier beaches) into Open Water. Unvegetated salt flats (Unvegetated high elevation) and salt flats in closed lagoons (low elevation, non-tidal) were combined into Salt Flat.

Different approaches to grouping these habitats could potentially be taken for differing objectives. For example, *open water-intertidal* could be distinguished from *open water-non-tidal* to note the different geomorphic context and controls. In this case, we grouped the two types because of similar infrequent tidal connection and the potential for seasonal evaporation. It should be noted that Open Water and Salt Flat may share similar characteristics at certain times of the year. Some Open Water areas may become Salt Flat in the dry season (or dry years); Salt Flats are seasonally inundated.

Regional Totals

We interpret the 26 T-sheets as showing 19,554 ha (48,319 acres) of estuarine habitat in Southern California during the mid-to late 19th century. Some smaller estuaries from T-sheets not in this study were not mapped; we estimate these to account for less than 200 ha. While these maps show some significant features, the missing systems are probably within the error of the overall T-sheet mapping. In the marshes of San Pedro Bay, 100-200 ha of adjacent freshwater marsh could potentially be tidal. Some similar ecotonal areas might also simply not have been mapped by some surveyors. Given these relatively small potential additional areas the total amount of estuarine habitats in the region during this time period was probably close to 20,000 ha (49,400 acres). This measurement is consistent with previous estimates, which range from 45,000 to 55,000 acres (SCWRP 2001).

The most common estuarine habitat type was vegetated wetlands. There were about 7700 ha of vegetated wetlands, representing 39% of all the mapped coastal wetland features (Table 3). Subtidal waters accounted for a slightly smaller area: 6600 ha, or 34%. The third most common habitat type was intertidal flats, which covered about 3500 acres (18%). Salt Flat (1254 ha; 6%) and open water (435 ha; 2%) were smaller components of the regional habitat mosaic.

Subregional Distribution of Major Habitat Types

To assess subregional distribution we divided the South Coast into six parts. These subregions were defined by the littoral cells between major shoreline protrusions (Griggs et al. 2005), with the additional division of the Santa Barbara cell into Santa Barbara and Ventura portions (divided at Pitas Pt.). Figure 31 illustrates the seven subregions and their relative amounts of the major estuarine habitat types. Figure 32 shows the same data in a different way, highlighting the relative proportion of each habitat type found in each subregion.

Table 3. Historical distribution of estuarine habitat types by subregion, and for the region as a whole, based on USCS T-sheets.

Subregion	Habitat Type	Area (ha)	Percent of Subregion	% of Total South Coast Estuarine Areas
Mission Bay and Silverstrand	Intertidal Flat	1,879	20%	
	Open Water	20	0%	
	Salt Flat	0	0%	
	Subtidal Water	5,683	60%	
	Vegetated Wetland	1,966	21%	
Mission Bay and Silverstrand Total		9,547		49%
Oceanside	Intertidal Flat	78	5%	
	Open Water	69	5%	
	Salt Flat	470	32%	
	Subtidal Water	12	1%	
	Vegetated Wetland	854	58%	
Oceanside Total		1,484		8%
San Pedro Bay	Intertidal Flat	1,256	23%	
	Open Water	16	0%	
	Salt Flat	505	9%	
	Subtidal Water	714	13%	
	Vegetated Wetland	3,034	55%	
San Pedro Total		5,524		28%
Santa Monica Bay	Intertidal Flat	114	16%	
	Open Water	22	3%	
	Salt Flat	55	8%	
	Subtidal Water	20	3%	
	Vegetated Wetland	501	70%	
Santa Monica Total		712		4%
Ventura	Intertidal Flat	126	7%	
	Open Water	201	12%	
	Salt Flat	143	8%	
	Subtidal Water	152	9%	
	Vegetated Wetland	1,067	63%	
Ventura Total		1,689		9%
Santa Barbara	Intertidal Flat	92	15%	
	Open Water	107	18%	
	Salt Flat	81	14%	
	Subtidal Water	29	5%	
	Vegetated Wetland	289	48%	
Santa Barbara Total		599		3%
Grand Total		19,554		100%
TOTAL REGION	Intertidal Flat	3,544	18%	
	Open Water	435	2%	
	Salt Flat	1,254	6%	
	Subtidal Water	6,609	34%	
	Vegetated Wetland	7,711	39%	
	Grand Total	19,554	100%	

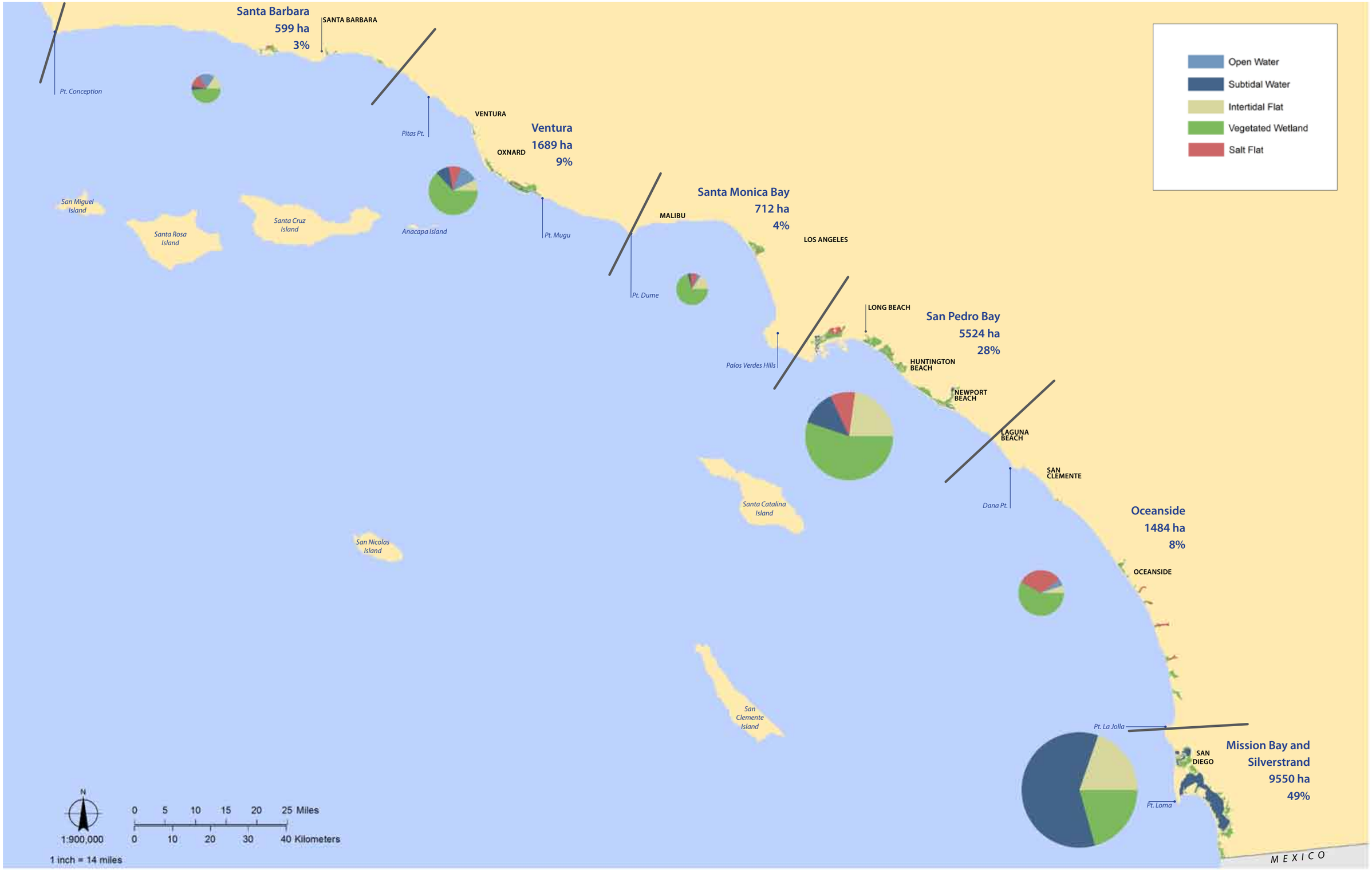


Figure 31. South Coast subregions and associated historical estuarine habitats. Pie chart colors represent habitat types; pie chart size represents the proportional amount of habitats in the subregion, compared to the other subregions.

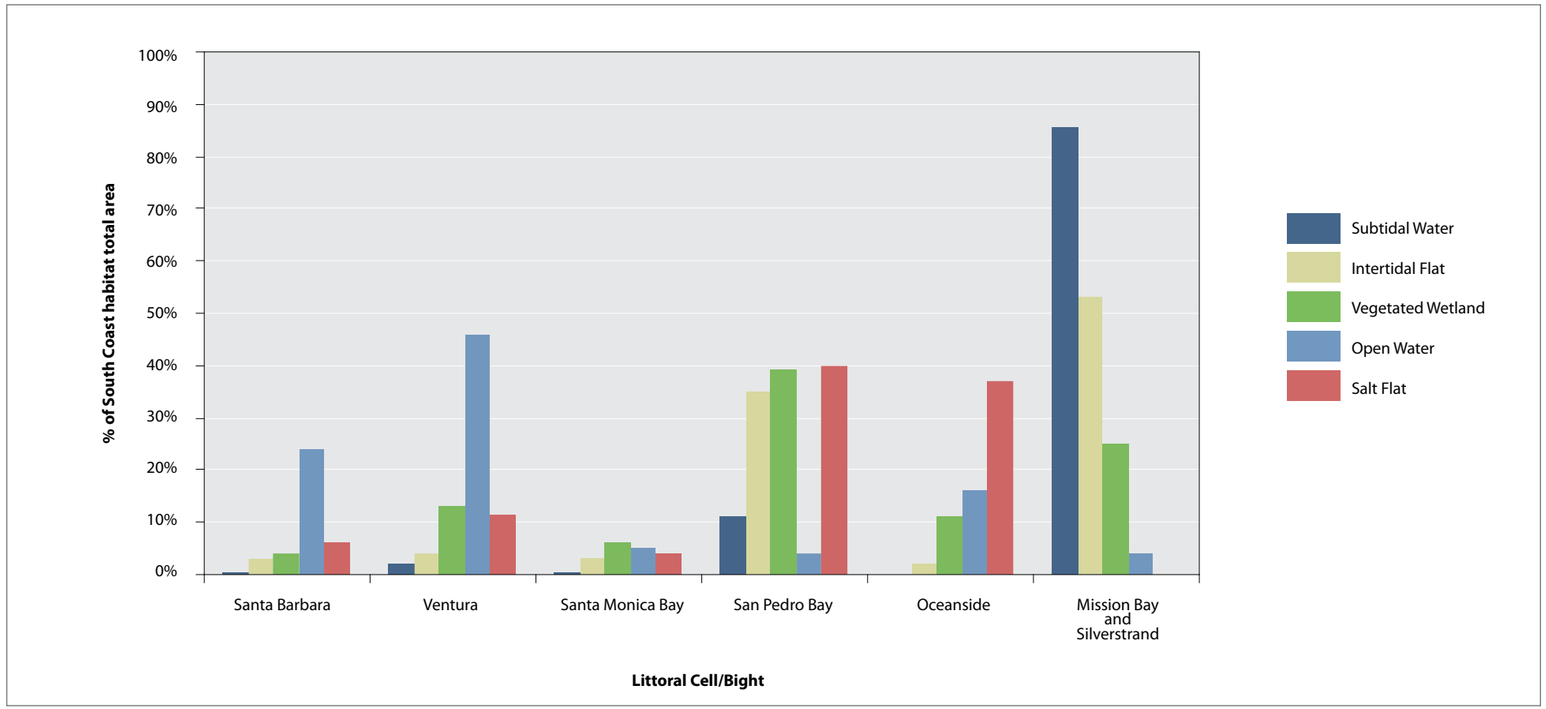


Figure 32. Distribution of estuarine habitat types by subregion. Not all subregions were created equal. The habitat mosaic varied dramatically among subregions. As a result, certain habitat types were associated with particular subregions: San Pedro Bay had nearly 40% of the region's vegetated wetlands, while Mission Bay/Silverstrand had 86% of the subtidal habitat.

Estuarine habitats were not distributed evenly along the Southern California coast. Nearly half (49%, 9547 ha) of South Coast estuarine habitats were found in the Mission Bay/Silver Strand subregion, a relatively short stretch of shoreline with hard bedrock prominences protecting large bays. Almost 30% (5524 ha) of the region's estuarine habitats were found in the five major systems of San Pedro Bay. The remaining 4490 ha (23%) were distributed between the Santa Barbara, Ventura, Santa Monica, and Oceanside subregions, which each had much smaller amounts (599-1689 ha) of estuarine habitat, despite long shorelines.

The mosaic or mix of habitat types was also quite heterogeneous along the coast. For example, subtidal waters predominated in only one subregion, Mission Bay/Silver Strand, which accounted for 86% of the subtidal habitat in all of Southern California. (The subtidal habitat in Mission and San Diego bays represented 29% of all the estuarine habitats of Southern California.) Subtidal waters accounted for 60% of Mission Bay/Silver Strand's estuarine habitats; in no other subregion did the subtidal proportion exceed 13%.

Vegetated wetlands were the dominant habitat type in all of the other subregions, ranging from 48% to 70% of the subregional total. The largest amount of vegetated wetlands (3034 ha) was found in the systems along San Pedro Bay, accounting for 39% of the South Coast's total. Tidal flats were a significant component (15-23%) of the Santa Barbara, Santa Monica, San Pedro, and Mission Bay/Silver Strand subregions, but less common (5-7%) in Ventura and Oceanside. Most (88%) of the tidal flats were associated with the subregions with the largest estuaries – San Pedro and Mission Bay/Silver Strand. Open water areas were disproportionately represented in the Santa Barbara and Ventura subregions, which accounted for 71% of the total despite their small size. Salt Flat was found predominantly (78%) in the San Pedro and Oceanside subregions. The Oceanside systems accounted for 37% of the salt flat habitat, despite representing less than 8% of the region.

Several ecotonal habitat types were also mapped, but with somewhat less confidence in the consistency of their representation throughout the region. Large freshwater wetlands were found adjacent to the San Pedro Bay wetlands. Willow swamps were found in San Pedro Bay and Ventura (associated with the Ventura and Santa Clara river mouths).

South Coast Estuaries and Regional "Archetypes"

To assess local habitat mixes, we identified 21 independent estuaries along the coastline. These systems were defined by having independent ocean outlets and intervening uplands. We compared the habitat mixes of these 21 systems.

Most of the estuarine habitat of Southern California was found in a relatively small number of systems. The nine largest systems together represented 85% of the total area. There were only 11 systems greater than 300 ha in size. These top 21 systems accounted for 98% of the estuarine habitat area.

Several fairly distinct habitat mixes can be identified among these systems, suggesting a preliminary set of regional coastal wetland or estuarine "archetypes" (Figure 33; Table 4). These emerging archetypes are described below; they should be considered preliminary observations based on a new dataset, presented for vetting and comparison with other data. These patterns are presumably controlled by physical factors such as geomorphic context, coastal processes, and watershed characteristics (Jacobs et al. 2010). We do not evaluate here the land forms and processes associated with these different estuary patterns. But further research on this topic should help local scientists and managers understand the physical factors controlling local wetland formation and maintenance. These habitat patterns show some correspondence to contemporary classification of estuaries (Ferren et al. 1995, Grewell et al. 2007), but also some differences (e.g., some habitat mixes are consistent across estuaries of different structural origin).

SUBTIDAL DOMINANT SYSTEMS – Two systems – Mission Bay and San Diego Bay – were dominated by low elevation habitats. In each of these systems, subtidal water was the prevalent habitat and subtidal water and intertidal flat together represented the majority of the habitat area. Subtidal water/intertidal flat represented 85% (SDB) and 67% (MB) of these systems; in all other systems, these habitats accounted for less than 45%.

Mission Bay and San Diego Bay are associated with similar prominent bedrock headlands and distinct littoral cells from the rest of the coast. They are also two of the three largest coastal systems of Southern California (SDB, 7433 ha; MB, 1734 ha). Mission Bay and especially San Diego Bay might also be considered complex estuaries with multiple subordinate systems surrounding open bays. As discrete systems, the individual wetland systems around Mission and San Diego bays would likely appear more similar to other South Coast systems than they do as single systems.

Large systems do appear to have greater proportion of subtidal habitat. As shown in Figure 34, the percentage of subtidal habitat is strongly correlated to system size. (This relationship holds even when Mission Bay and San Diego Bay are removed ($r^2 = 0.81$).) Accordingly, the five largest systems (San Diego Bay, LA Harbor, Mission Bay, Newport Bay, and Mugu Lagoon) had the five greatest proportions of subtidal habitat. Conversely, all systems smaller than 1000 ha had less than 10% subtidal habitat.

TIDAL MARSH-TIDAL FLAT DOMINANT SYSTEMS – The most common estuary archetype was broad tidal marshes with adjacent intertidal flats. All of the midsized systems (the fourth through the 10th largest; 347-1448 ha) and one smaller system (Carpinteria, 114 ha) shared these characteristics. Each of these eight systems had at least 55% tidal marsh and 10-29% tidal flat; on average there was four times as much tidal marsh as flat (range from 2 to 6). Tidal marsh and flat together covered an average of 88% of the area of the systems (at least 75% of each system), with subtidal water (0-12%), open water (0-5%), and salt flat (0-8%) as minor components. The one exception to these proportions was Newport Bay, which, as the fourth-largest system, had most of these characteristics but also substantial subtidal habitat (i.e., characteristics intermediate between the subtidal-dominant and tidal marsh-tidal flat-dominant archetypes: 18% subtidal, 27% intertidal flat, 55% vegetated

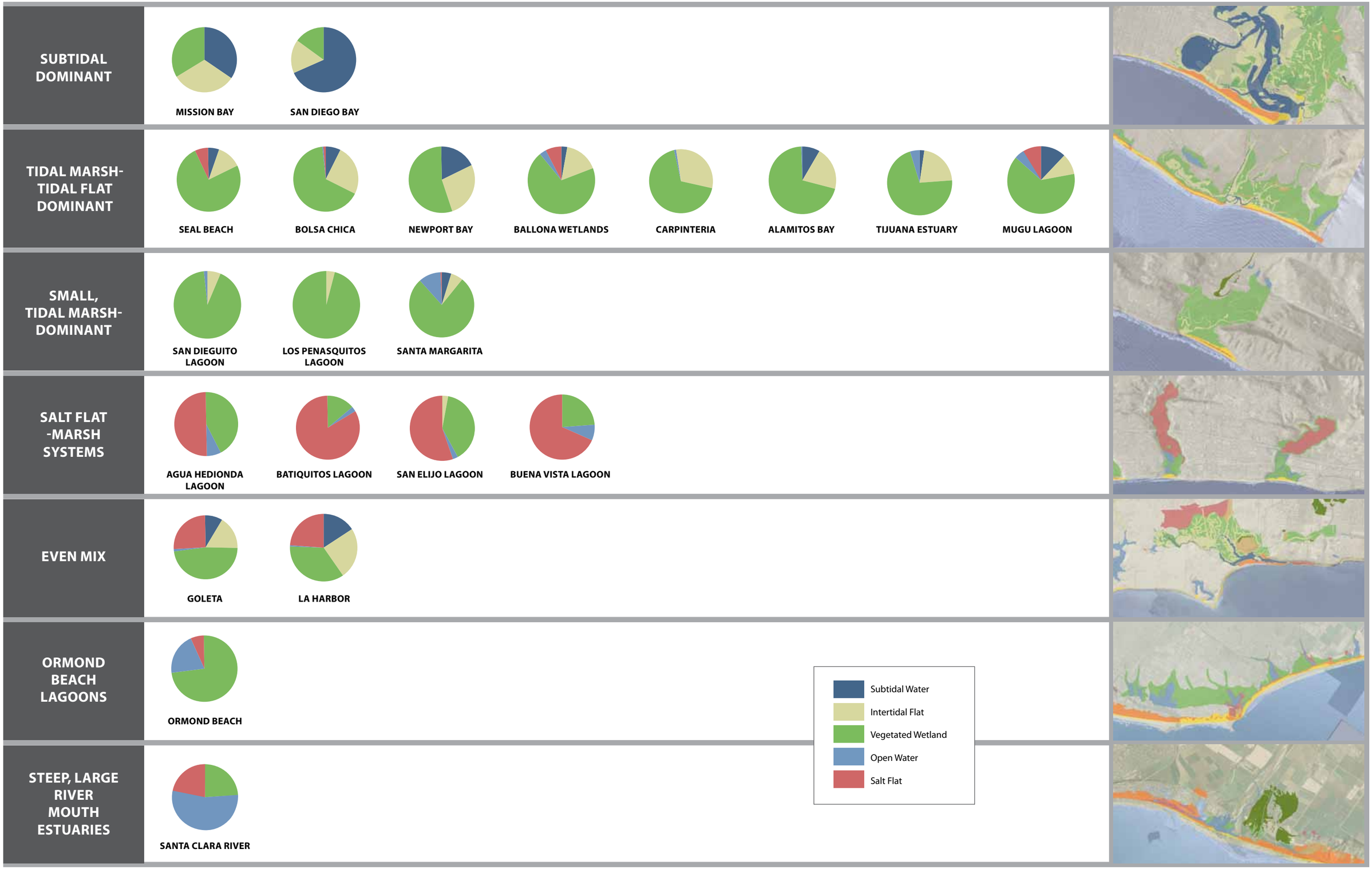


Figure 33. Different habitat mixes along the South Coast. The similarity observed among many independent systems (described further in Table 4) suggests that there are strong and consistent underlying physical controls on habitat formation and maintenance. These regional "archetypes" are not strict categories, but ways of thinking about the different kinds of coastal wetland systems historically supported by the region. An example map of each archetype is provided at right.

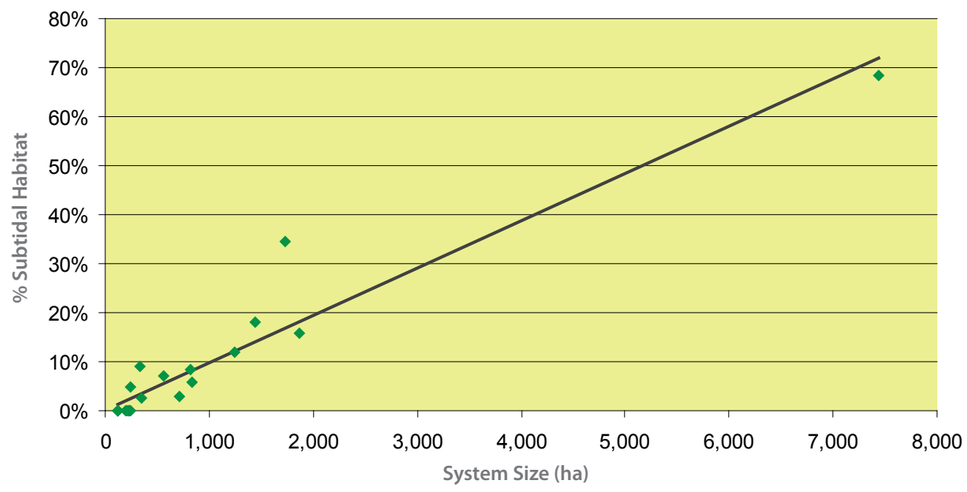


Figure 34. Relationship between coastal system size and the proportion of subtidal habitat. These 21 systems account for an estimated 98% of the mapped historical estuarine habitat.

Table 4. Habitat mosaics associated with regional estuary archetypes.

	Subtidal Water		Intertidal Flat		Vegetated Wetland		Open Water		Salt Flat		Size (ha)		
	Avg %	Range	Avg %	Range	Avg %	Range	Avg %	Range	Avg %	Range	Aver-age	Range	Bight Location
Subtidal dominant	52%	35-68%	24%	17-32%	24%	15-33%	0%	0-0%	0%	0-0%	4,583	1,734-7,433	Mission Bay and Silverstrand
Tidal marsh-tidal flat dominant	7%	0-18%	21%	10-31%	68%	55-75%	2%	0-5%	3%	0-8%	760	110-1,448	Santa Barbara, Ventura, Santa Monica, San Pedro, MB and Silverstrand
Small, tidal marsh dominant	2%	0-5%	5%	4-6%	88%	77-96%	4%	0-11%	0%	0-1%	229	197-249	Oceanside
Salt flat-marsh systems	0%	0-0%	1%	0-3%	30%	14-42%	5%	3-8%	64%	51-83%	174	123-231	Oceanside
"Even mix" systems	12%	9-16%	21%	17-24%	41%	36-47%	1%	1-2%	25%	24-25%	1,092	323-1,861	Santa Barbara, San Pedro
Ormond Beach lagoons	0%	0-0%	0%	0-0%	66%	58-73%	28%	21-37%	5%	0-10%	86	32-221	Ventura

wetlands). All of these systems were shown with open outlets to the ocean. They included many of the most significant estuaries of the region, such as those at Ballona, Newport Bay, Bolsa Chica, Seal Beach, LA Harbor, Alamitos Bay, Mugu Lagoon, and Carpinteria.

SMALL, TIDAL MARSH-DOMINANT SYSTEMS – Three systems were composed of greater than 75% tidal marsh (average of 88%): Santa Margarita, San Dieguito, and Los Penasquitos lagoons. These systems had much less tidal flat (≤6%) than the tidal marsh-tidal flat dominant systems, and only small proportions of other habitat types. These relatively small and similarly sized systems (197-249 ha) each occupied narrow valleys incised within San Diego County marine terraces. Each was shown with an open outlet to the ocean by the T-sheet.

SALT FLAT-MARSH SYSTEMS – Four adjacent systems along the San Diego shoreline had extremely similar characteristics as shown by the T-sheets, but differed from all other systems. Buena Vista, Aqua Hedionda, Batiquitos, and San Elijo lagoons each covered between 123 and 231 ha, had less than 50% vegetated wetland (average 30%), and had greater than 50% (average 64%) apparent salt flat. These systems also shared a similar uncertainty in the depiction of the upper portion of the system (see discussions of T-1898 and T-1899). Additional historical sources, especially prior to railroad construction, should be consulted to better understand the characteristics of these apparently very similar functioning systems.

"EVEN MIX" SYSTEMS – Two systems – Goleta and LA Harbor – stand out as having substantial (9-48%) amounts of each of the four most common habitat types – subtidal water, intertidal flat, vegetated wetland, and salt flat. Tidal marsh was the most common habitat, but occupied less than 50% of these systems. Interestingly, while Goleta and LA Harbor appear strikingly similar in their "pinwheel" pie charts and GIS depictions (see Figure 33), they are of very different sizes (328 and 1861 ha). Mugu Lagoon, with 8% or more of each of those four habitat types, approaches the relatively even habitat mix characteristic of these systems but was dominated by tidal marsh (65%).

ORMOND BEACH LAGOONS – The series of lagoons between the Santa Clara River mouth and Mugu Lagoon shared similar characteristics and origin. While only one was large enough to be considered among the top 21 systems, there were four sizable and distinct wetland complexes, each covering 32 to 221 acres. Vegetated emergent wetlands were the dominant component of these systems (58-73%), but with large amounts of open water (21-37%) impounded by sand dams. Occupying abandoned mouths of Santa Clara River, each of these wetlands were shown as closed, behind substantial beach-dune systems.

STEEP, LARGE RIVER MOUTH ESTUARIES – The mouths of the Santa Clara River and Ventura River were notable as very small estuaries with little tidal marsh. These systems at high-energy stream mouths were dominated by willow-cottonwood swamps that transitioned into relatively small amounts of estuarine habitat types (in apparent contrast to the estuaries of other large South Coast rivers).

Regional Perspective

Using this data set, we can begin to recognize some of the richness and diversity of Southern California coastal wetlands, providing some perspective on the kinds of systems we might seek to understand, conserve, and restore into the future (Figures 35-41).

The Southern California coast exhibited a wide range of estuarine habitat mixes, from largely subtidal bays to expansive marsh plains with tidal flats and adjacent freshwater marshes to smaller wetlands dominated by marsh or flat. These habitats were not distributed uniformly, but rather occurred in varying mosaics and at different scales along the coast in relation to shoreline and watershed processes.

Vegetated emergent marsh was the most common estuarine habitat type on the South Coast and the major component of 14 of the 21 largest systems. Subtidal water was the second most common habitat type but, except for Mission and San Diego bays, subtidal habitats were a relatively small component of coastal systems (less than 19%). Persistent high groundwater on the margin of San Pedro Bay made for extensive ecotonal freshwater marshes and riparian swamps at the edge of tidal influence. (Because of their substantial area and transitional character, these are included as Vegetated Wetlands in the map series.) Unvegetated, seasonally flooded pannes or salt flats were a substantial component (greater than 24%) of seven of the top 21 systems. Most of the San Diego County estuaries had little tidal flat and subtidal habitat, but the large systems at the southern end had the largest subtidal-intertidal flat component in all of Southern California. The wanderings of the Santa Clara River made for an unusual series of spring-fed lagoons in Ventura County that were probably rarely tidal but expressed compressed linear gradients from saline to freshwater wetland. Saltwater ponds ranging from 5 ha to 50 ha trapped behind broad dune systems were most common in Santa Barbara County and on the Oxnard plain.

While the snapshot view of the T-sheets should be supplemented with other data to assess the dynamics of barrier beach opening/closure, this sampling showed 16 of the 21 systems as open (closed systems included Buena Vista, Aqua Hedionda, and Batiquitos lagoons in San Diego County and Santa Clara River mouth and Ormond Beach in Ventura County). Even systems portrayed as open, however, often had relatively narrow, dynamic outlets to the ocean, which may have closed periodically.

POINT CONCEPTION TO RINCON POINT: SANTA BARBARA COUNTY (SANTA BARBARA LITTORAL CELL) As would be expected given the relatively steep shoreline, Santa Barbara County had fewer and smaller wetlands than other parts of the South Coast. Goleta Slough and Carpinteria, the two largest estuaries, were each less than 350 ha and shown as open systems. These were predominantly tidal marsh with smaller components of subtidal channel and tidal flat (not distinguished by the Carpinteria T-sheet).

There were four other coastal wetland complexes greater than 10 hectares in the subregion. In contrast to the larger Goleta and Carpinteria systems, these were mostly (50-100%) open water, presumably because they were impounded behind small dune systems. Smaller open water lagoons and marshes were found at the mouths of small drainages.

VENTURA RIVER MOUTH TO MUGU LAGOON: VENTURA COUNTY Ventura County exhibited three distinct patterns of estuarine morphology. The steep mouths of the Ventura and Santa Clara rivers formed truncated deltas with very little wetland area. These systems had little marsh, some open water and adjacent flats, and large marginal willow-cottonwood riparian forests.

Between Santa Clara River and Mugu Lagoon, the Oxnard plain was incised by a unique series of at least 10 distinct linear lagoons extending inland from the arcuate shoreline. Here the shoreline was a broad deltaic headland formed by the Santa Clara River alluvial fan. Former routes of the Santa Clara River during the recent Holocene left abandoned river mouths to be impounded by barrier beaches and dunes built by the large amount of sand down coast from the Santa Clara River. These back-barrier systems were made up of emergent marsh, open water, and salt flat.

In contrast to the other two kinds of Ventura County systems, Mugu Lagoon was a large tidal marsh complex dominated by vegetated marsh plain but with significant components of subtidal channel, tidal flat, marsh ponds, and salt flat.

SANTA MONICA MOUNTAINS TO PALOS VERDES PENINSULA (SANTA MONICA LITTORAL CELL) There was relatively little estuarine habitat along this shoreline, despite the broad lowlands between Santa Monica and Redondo Beach. While there were a number of small canyon mouth wetland complexes, Ballona wetlands (a former LA River mouth) was the dominant feature. Ballona was comprised mostly of vegetated marsh with significant components of tidal flat and salt flat and smaller amounts of subtidal habitat and open water.

PALOS VERDES PENINSULA TO DANA POINT: LOS ANGELES HARBOR-NEWPORT BAY (SAN PEDRO LITTORAL CELL) Over 28 percent of the Southern California estuarine habitats were found in this relatively small area. These systems were characterized by substantial subtidal channels, extensive tidal flats and vegetated wetlands, and few marsh ponds (although the surveyor may have been disinclined to show ponds). Several systems here have explicit extensive adjacent extensive freshwater wetlands (with freshwater ponds) and willow swamp. They also display repeated large salt flats at their upland margins. Alamitos Bay, Seal Beach, and Bolsa Chica formed a sequence of remarkably similar systems in terms of size and habitat mix (6-8% subtidal water, 13-25% intertidal flat, and 66-75% vegetated wetland).

DANA POINT TO POINT LA JOLLA (OCEANSIDE LITTORAL CELL) Most of the estuarine habitats in this subregion were found in the San Diego County portion. The striking pattern of repeating parallel barrier beach wetlands systems of northern San Diego County is distinct from other parts of the South Coast. These relatively linear systems occupy the mouths of coastal valleys cut into the marine terraces of San Diego County. Two general kinds of systems can be distinguished. Penasquitos, San Dieguito, and Santa Margarita lagoons were shown as large tidal marshes open to the ocean with little tidal flat or subtidal habitat. In contrast Buena Vista, Aqua Hedionda, and Batiquitos lagoons were shown differently, as closed systems with smaller marshes behind closed barrier beaches. Their major portion is represented by an uncertain depiction that appears to be unvegetated and dry.

MISSION BAY-TIJUANA ESTUARY (MISSION BAY AND SILVERSTRAND LITTORAL CELLS) Mission and San Diego bays were large bays with broad subtidal waters and tidal flat, and smaller tidal marsh systems on the bay margins. Harrison was not among the most detailed Coast surveyors (Grossinger et al., 2005) so there may have been more marsh complexity. Tidal flat was especially prominent in Mission Bay. Tijuana Estuary was different from all other San Diego County estuaries in having extensive marshes (71%), substantial tidal flats (21%), and little subtidal water (3%) – more like many of the systems in other Southern California counties.

Conclusions

South Coast estuaries displayed distinct characteristics along different parts of the Southern California shoreline. Identifiable, repeating patterns are observed among independent systems, suggesting that we can identify fundamental differences in the physical processes controlling different kinds of wetland systems. Some habitat differences are clearly attributed to topographic and geologic context. System size also seems to an important factor in determining habitat mix. When integrated with contemporary information, the distinct subregional patterns may help identify subregional targets and priorities.

Next Steps

A number of steps can be taken to apply the T-sheet dataset to regional wetland management in the future.

INCORPORATION OF MISSING T-SHEETS While the existing dataset represents most of the estuarine habitat area of Southern California, small systems are left out. These may have distinct values associated with small estuaries and lagoons that are relevant for restoration planning. The acquisition of these additional T-sheets representing many steeper shorelines has recently been funded as a next phase to the project.

FURTHER ANALYSIS OF COASTAL WETLAND PATTERNS The discussion of regional estuarine patterns presented here represents a very preliminary look at a complex dataset. Further research should be conducted to identify spatial patterns and relate them to physical characteristics of the given sites, such as watershed size, runoff, and slope; valley shape; shoreline orientation; sediment supply; tidal prism; and other factors (e.g., Jacobs et al. 2010). The T-sheet dataset provides a valuable resource to improve our understanding of how wetland habitats are created and maintained, which can help guide the design of successful and sustainable projects.

As part of such analysis, the historical patterns should be compared to current conditions. Detailed contemporary wetland mapping is currently underway by SCCWRP and CSUN. When complete, this work will provide an excellent comparative dataset to analyze changes in total amount, relative abundance, and subregional distribution, using appropriate crosswalks between historical and contemporary wetland classifications.

One important element of South Coast wetlands that was not analyzed here is tidal channels. In many places the T-sheets provide substantial information about channel network distribution and density, but the depiction of channels is relatively inconsistent. Estimates of historical channel density can be developed, however, using areas of greatest detail and complementary sources (Goals Project 1999). Given the importance of channel networks to a variety of wetland functions, such analysis might help guide wetland restoration targets and designs.

LOCAL HISTORICAL ECOLOGY STUDIES Coastal wetlands lie at the bottom of the adjacent watersheds. The T-sheets provide only limited information about the adjacent upland, wetlands, and fluvial habitats that interface with coastal features and provide much of the habitat diversity. The T-sheets also only provide a snapshot of condition. Fuller historical ecology studies – as demonstrated on San Gabriel River and in Ventura County – provide a much deeper understanding of the natural function of estuaries and coastal watersheds, mechanisms of change over time, and potential management scenarios.

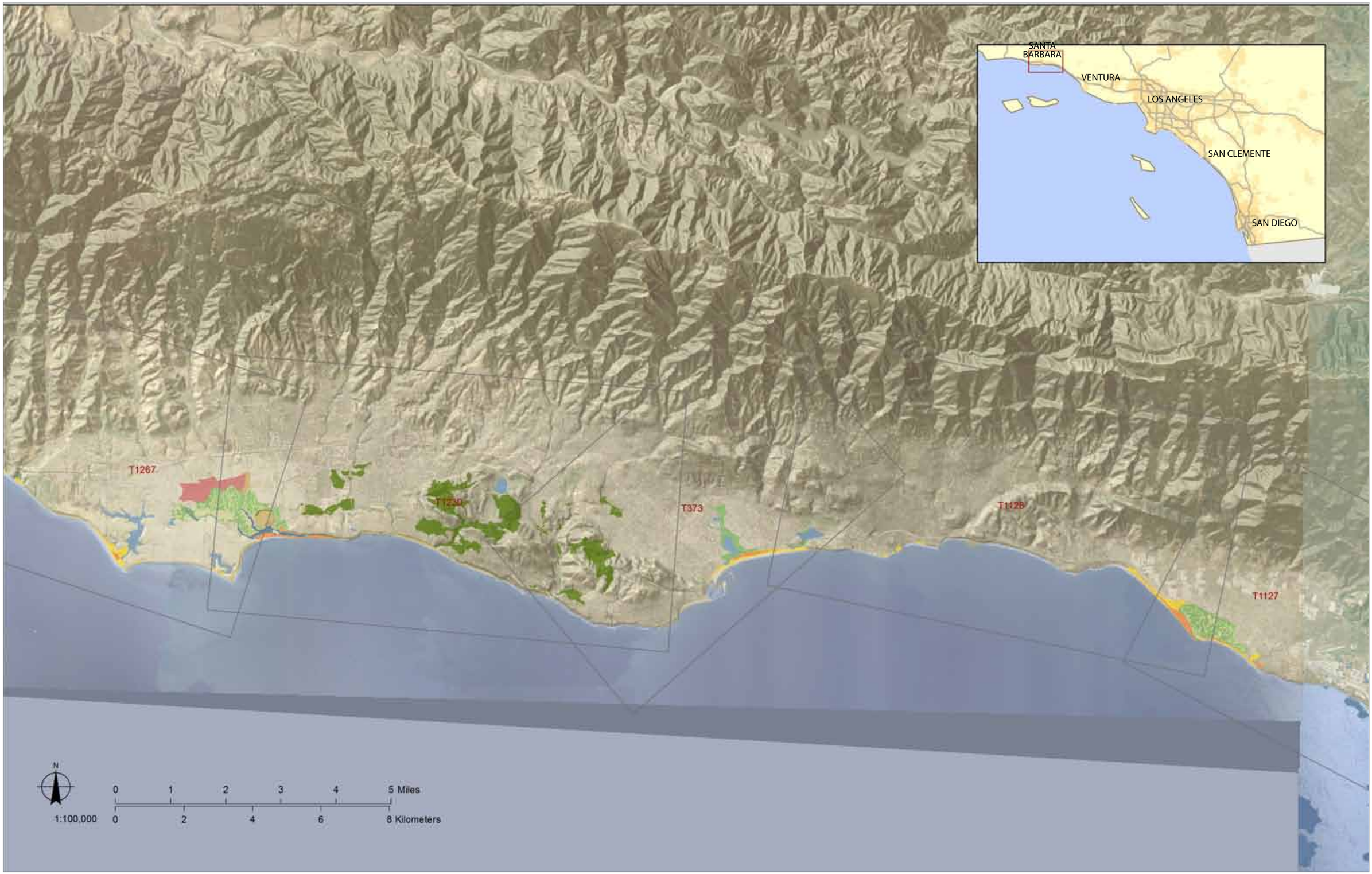


Figure 35. Historical estuarine and related habitats of the Southern California coast, as shown by early T-sheets: Santa Barbara subregion.

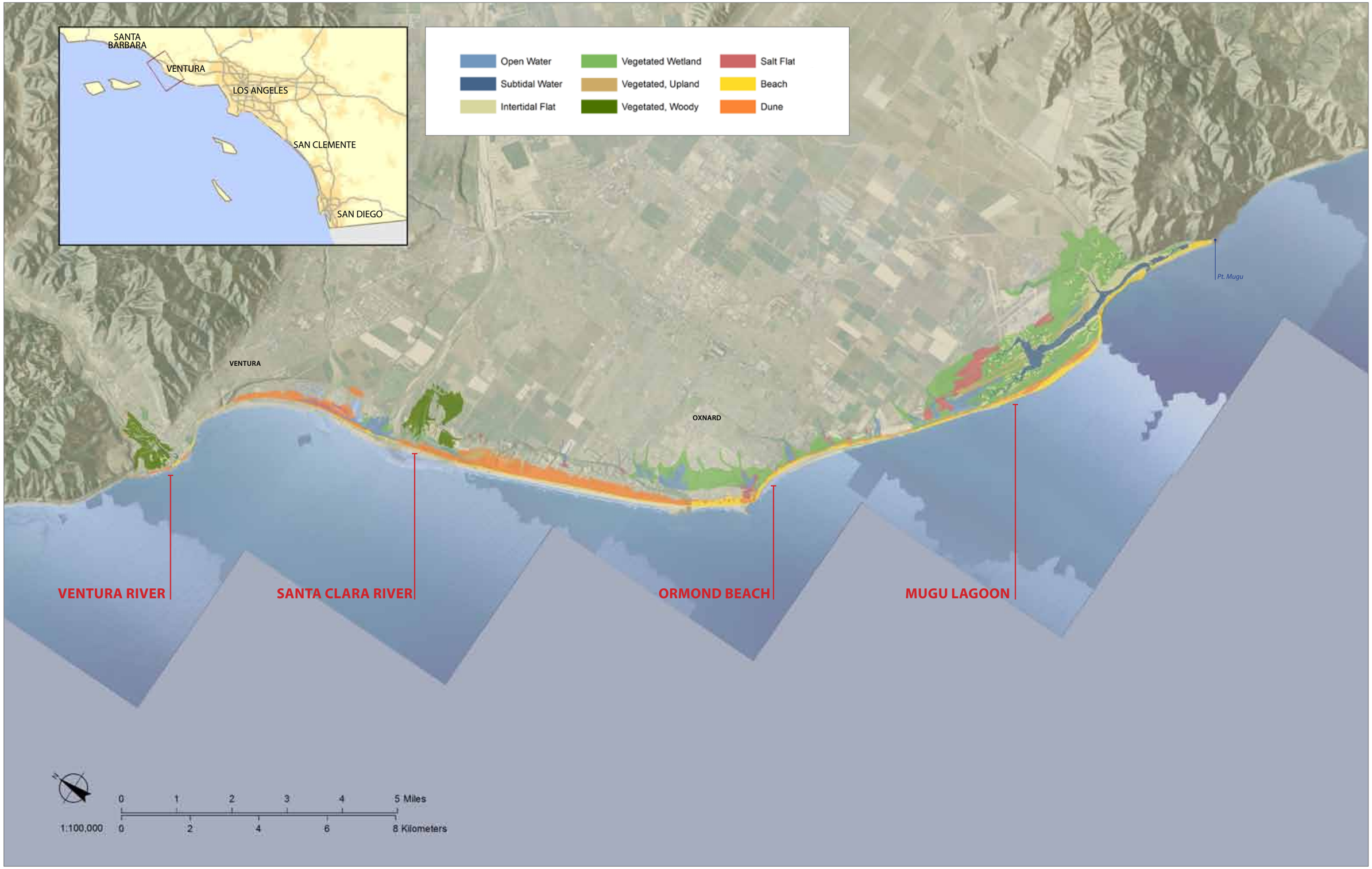


Figure 36. Historical estuarine and related habitats of the Southern California coast, as shown by early T-sheets: Ventura subregion.

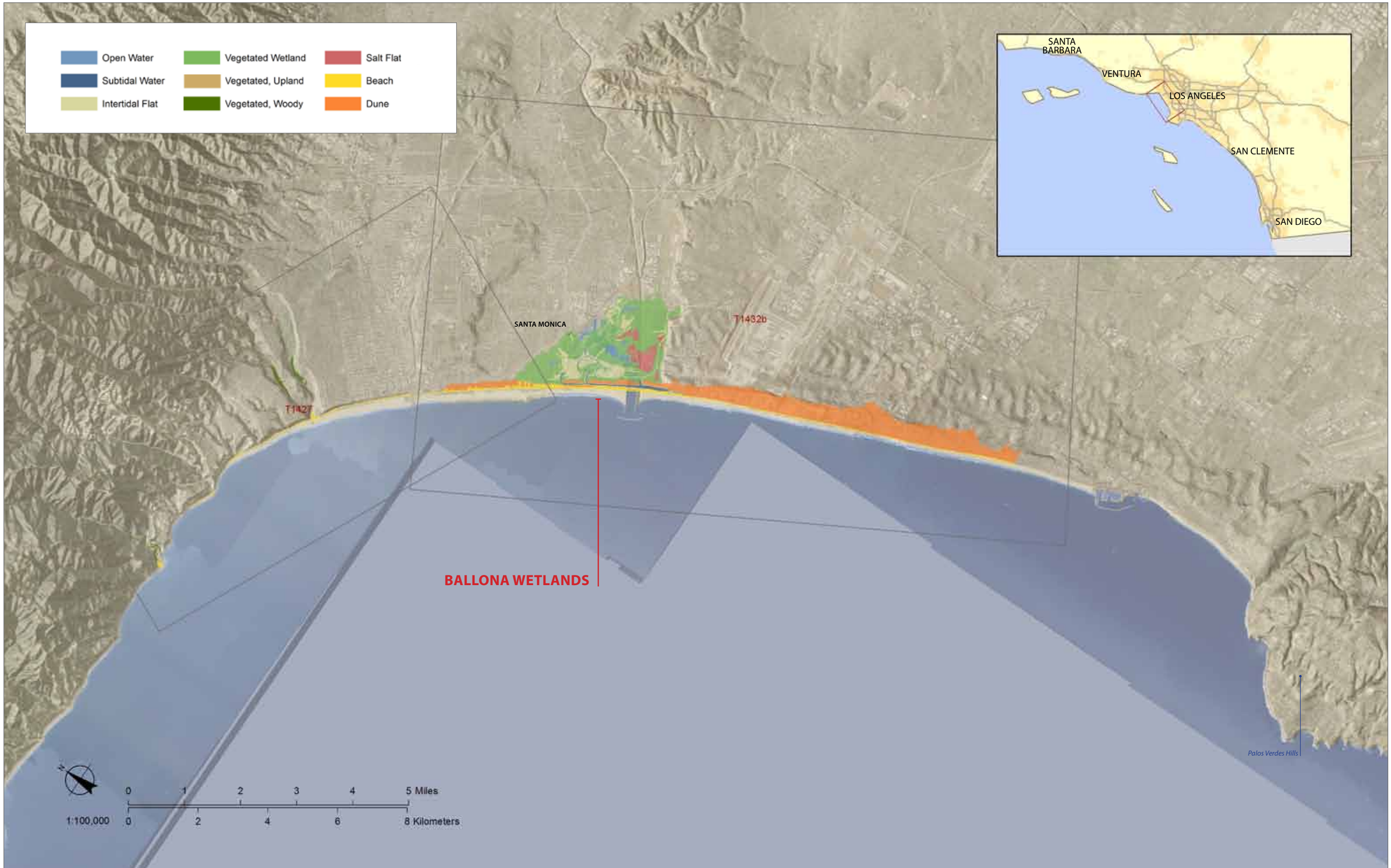


Figure 37. Historical estuarine and related habitats of the Southern California coast, as shown by early T-sheets: Santa Monica Bay subregion.

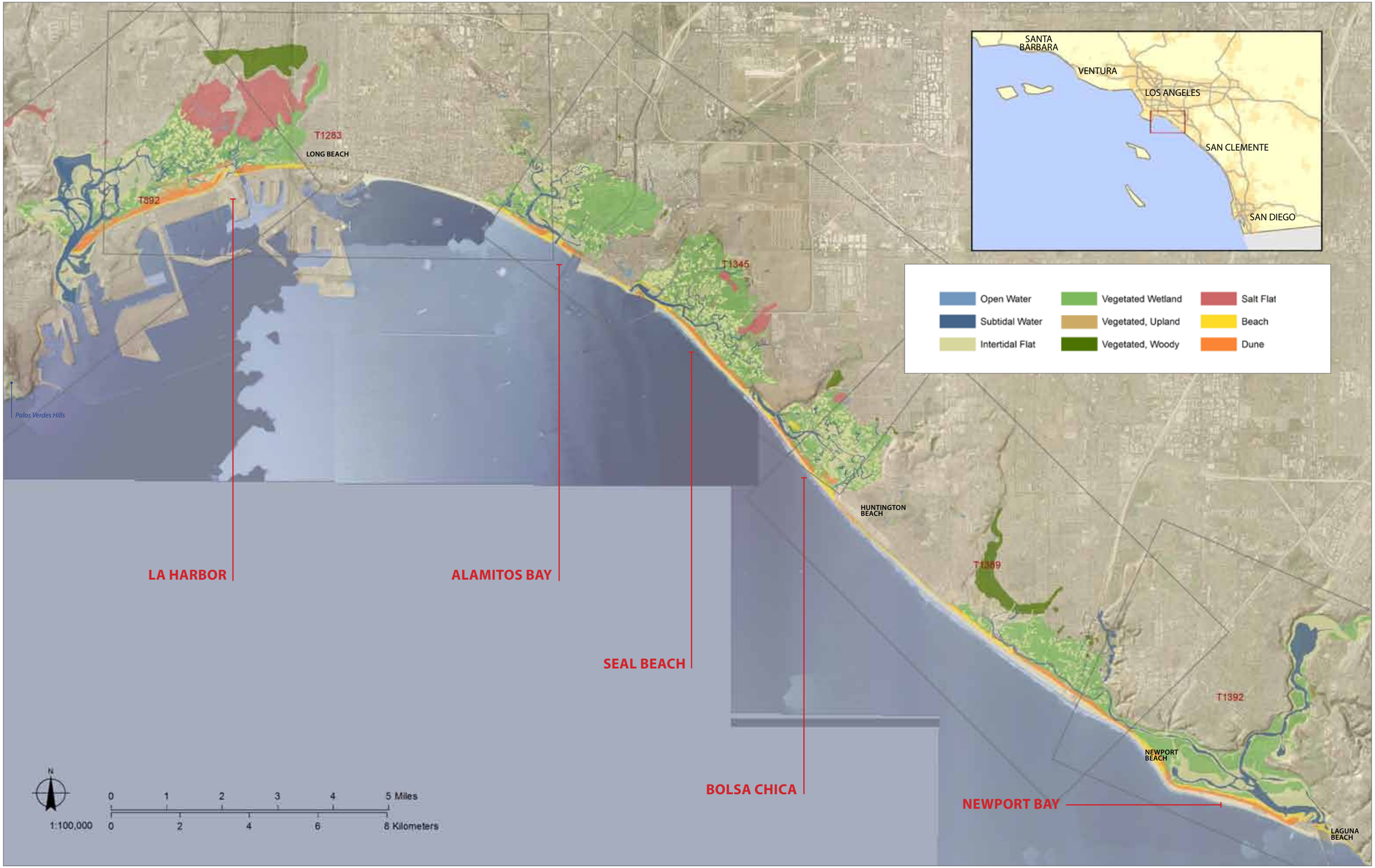


Figure 38. Historical estuarine and related habitats of the Southern California coast, as shown by early T-sheets: San Pedro Bay subregion.

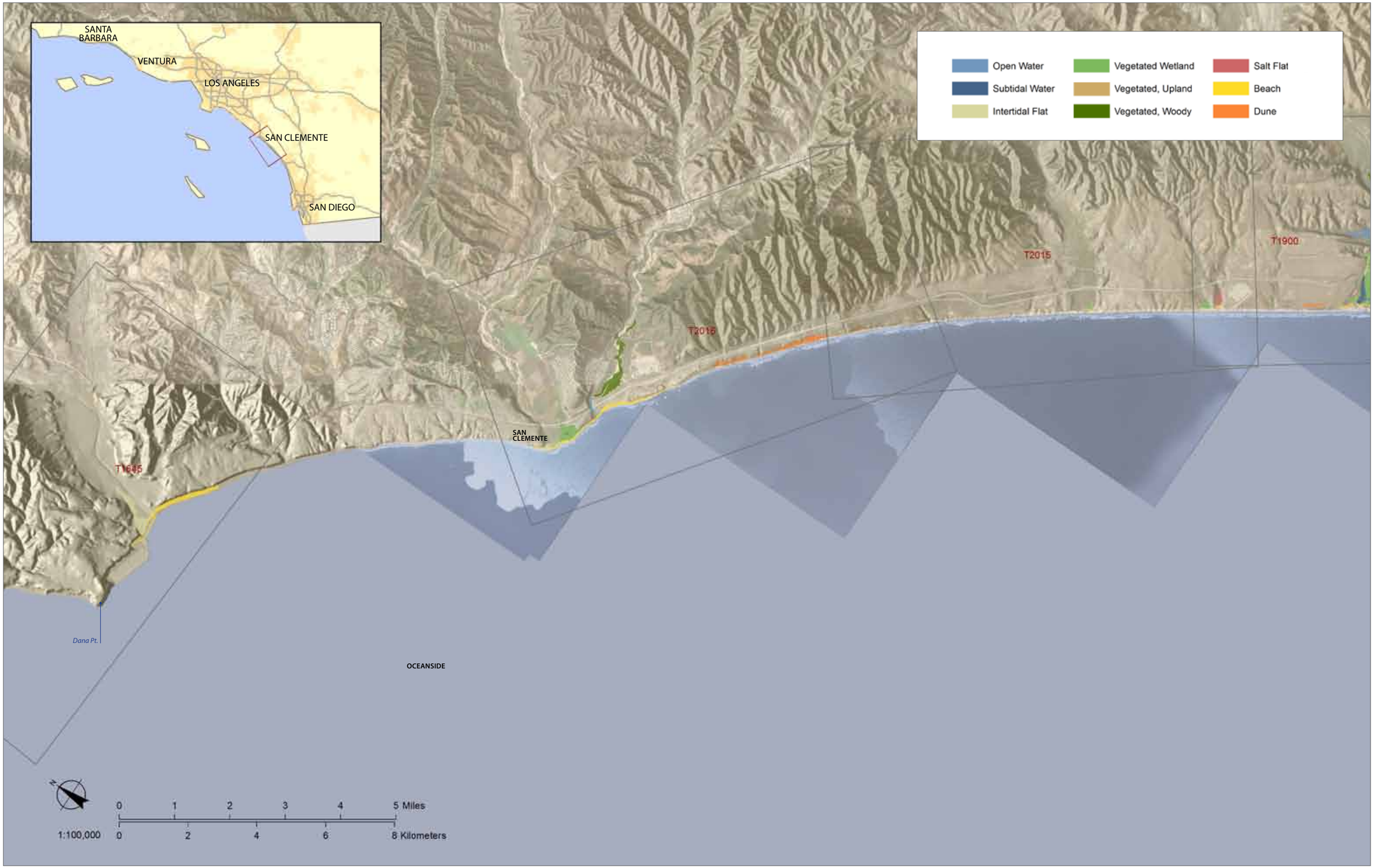


Figure 39. Historical estuarine and related habitats of the Southern California coast, as shown by early T-sheets: Oceanside subregion (north)

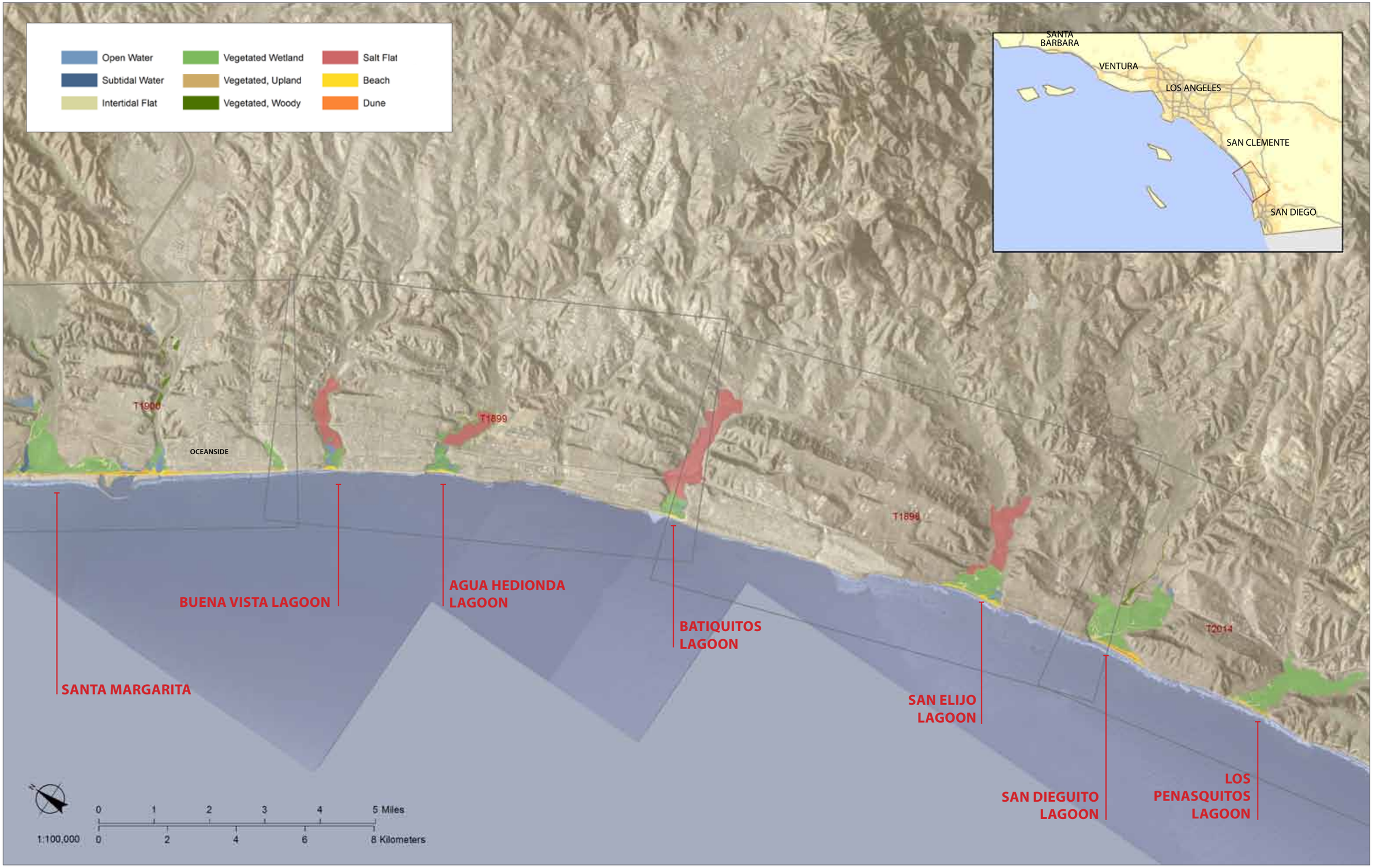


Figure 40. Historical estuarine and related habitats of the Southern California coast, as shown by early T-sheets: Oceanside subregion (south).

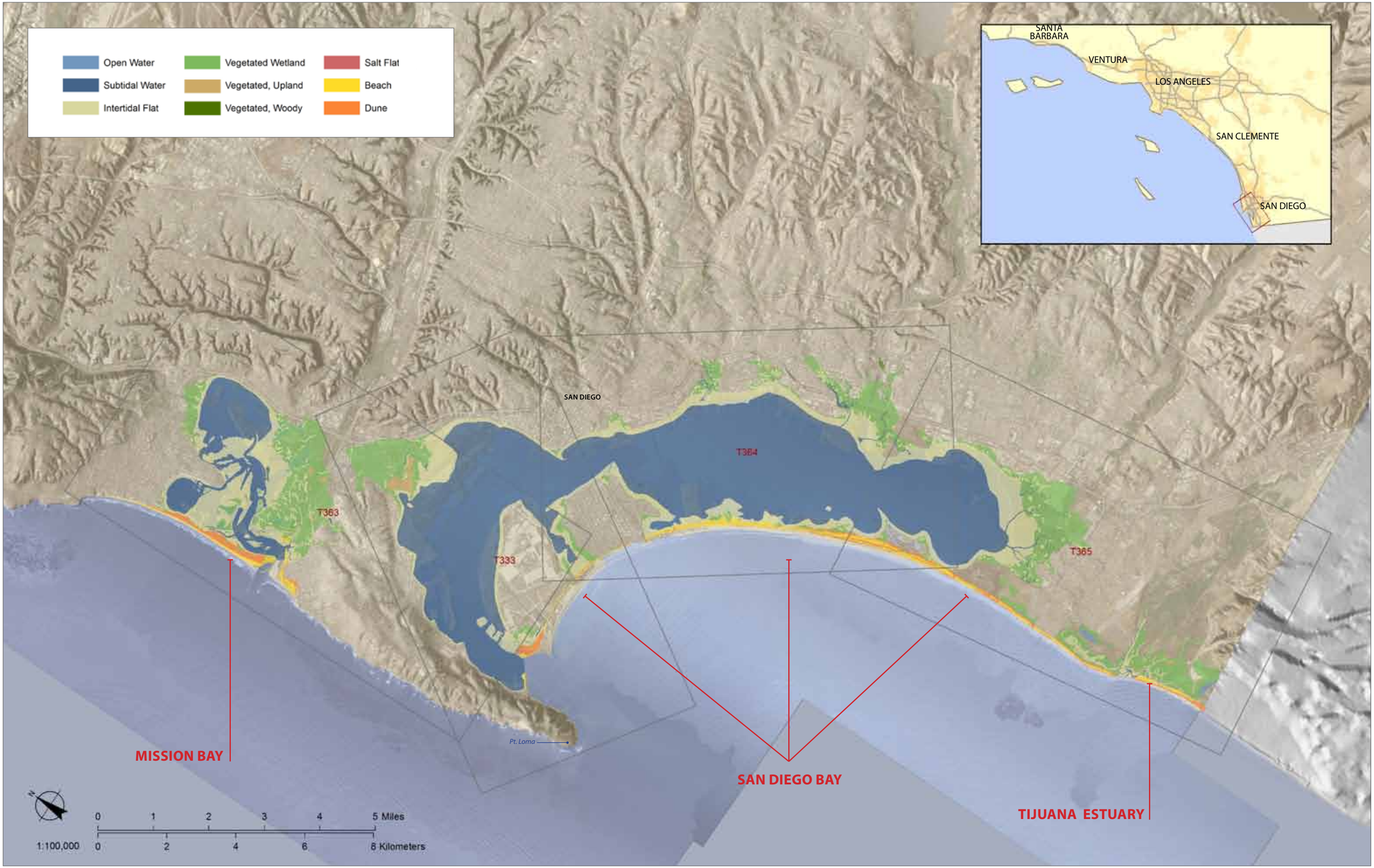


Figure 41. Historical estuarine and related habitats of the Southern California coast, as shown by early T-sheets: Mission Bay/Silverstrand subregion.

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U.S. Coast and Geodetic Survey. 1865. Diagram of a plane table with cutaway showing tripod head. *Coast and Geodetic Survey Superintendent's Report for 1865.* NOAA's Historical Coast & Geodetic Survey Collection. Photo credit NOAA Central Library. http://www.photolib.noaa.gov/htmls/theb1699.htm. *Courtesy of NOAA Photo Library.*

U.S. Coast and Geodetic Survey. ca. 1910. Plane table setup on a boulder. NOAA's Historical Coast & Geodetic Survey Collection. Photo credit Family of Rear Admiral Leo O. Colbert, C&GS. http://www.photolib.noaa.gov/htmls/theb1705.htm. *Courtesy of NOAA Photo Library.*

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VEGETATED AND UNVEGETATED

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 non-tidal (see p. 24-25).

VEGETATED—EMERGENT MARSH—HIGH ELEVATION—NON-TIDAL

In instances where the salt marsh symbols described above were used with no direct tidal connection, we attributed the feature as non-tidal. 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 NON-TIDAL

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—INTERTIDAL

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-TIDAL

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).

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.

VEGETATED—UPLAND

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.

UNVEGETATED—HIGH ELEVATION—INTERTIDAL OR NON-TIDAL

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.

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

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—NON-TIDAL and CHANNEL—NON-TIDAL

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

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—UNDEFINED

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–undefined*.

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)

NON-TIDAL

To record whether wetland features were shown with a tidal connection we included a non-tidal modifier. It should be noted that along the Southern California coast, one of the most dynamic features is the opening and closing of lagoonal systems behind barrier beaches. In the absence of information about the frequency of lagoon opening/closure, we aimed to preserve the original data, recording these systems as they were depicted in the corresponding survey. But it is entirely likely that some features shown as "non-tidal" at the time of the survey because of a barrier beach would have been open to the tides at other times, and vice versa. Because of the significance to navigation, we might expect T-sheets to attempt to show the more common condition (Cloud, pers. comm.). But additional information should be gathered to gain a better picture of the frequency of opening/closure of specific systems.

AREAS OF UNCERTAINTY

While this classification system was able to organize the vast majority of T-sheet coastal wetland information with a high-level confidence, a small proportion of features remain difficult to interpret. There are a number of places where T-sheets symbology and/or topology are contradictory or incomplete. For example, there are some marsh channels that are shown as subtidal on one end and intertidal at the other end, with no indication of the transition. In other areas, detailed depictions of the line of mean lower low water abruptly terminate midway across an embayment. Some features are shown differently by two adjacent T-sheets. In these cases, the differences may represent actual change (e.g., T-892 (1859) vs. T-1283 (1872)). In these cases we rely on the earlier map (Shalowitz 1964:191). In other cases, the earlier depiction appears to be a sketch while the latter view is more detailed; here we use the later map. Careful observers will note areas that could be classified slightly differently. Fortunately these features represent a very small proportion of the overall total.