

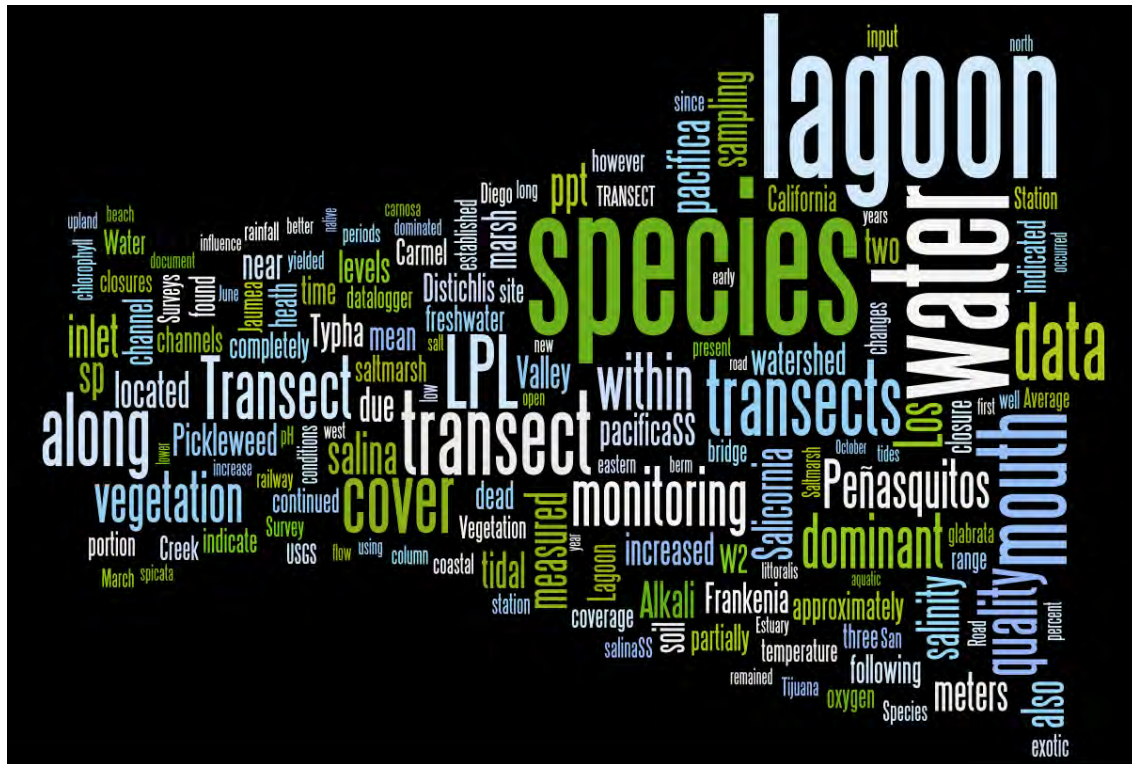
## **APPENDIX A**

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# Physical, Chemical and Biological Monitoring of Los Peñasquitos Lagoon

## OF LOS PEÑASQUITOS LAGOON

July 1, 2012- June 30, 2013



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## I. INTRODUCTION

Los Peñasquitos Lagoon (LPL) is a relatively small estuary (511 acres) in northern San Diego County. The Lagoon is situated at the coastal outlet of the Los Peñasquitos Watershed, which encompasses just under 60,000 acres (Weston Solutions 2009). Like all coastal estuaries in southern California, LPL experiences a Mediterranean climate, which is characterized by highly seasonal precipitation events occurring primarily during the winter months. There is little to no rainfall during the dry summer. As a result, most coastal lagoons in southern California, under natural conditions, experience a seasonal salinity cycle, with relatively high salinities in summer and lower, but variable, salinities during wet winter periods when flooding potential is highest (Purer 1942). Salinity variation within coastal estuary wetlands is primarily a function of input of saline water from the ocean, input of freshwater from the watershed, evaporation of surface waters, and transpiration by plant species.

The LPL watershed is comprised of three sub-drainage basins that direct drainage to LPL by way of three creeks. Carmel Creek drains the Carmel Valley sub-watershed, which encompasses approximately 11,180 acres and serves as the northern most drainage to the lagoon. Los Peñasquitos Creek drains the Los Peñasquitos sub-watershed that encompasses just over 37,000 acres that includes Los Peñasquitos Canyon and Lopez Canyon. Carroll Creek drains the Carroll Canyon sub-watershed that encompasses approximately 11,000 acres and serves as the most southern drainage to LPL. Los Peñasquitos Creek merges with Carroll Creek in Sorrento Valley before entering the lagoon.

The Los Peñasquitos Watershed is the fourth most populated watershed in San Diego County with over 50% of the land urbanized (SANDAG 1998). Historically, it is likely that all three tributaries were largely dry during summer months, aside from Los Peñasquitos Creek that may have flowed year round during exceptionally wet seasons. As the watershed developed, however, dry-weather flows into the lagoon dramatically increased (Greer and Stow 2003, White and Greer 2006). It has been demonstrated that shifts in vegetation occurring in the lagoon, representing loss of species associated with saline habitats and increases in fresh- and brackish-water species, are correlated with increased urbanization of the watershed (Greer 2001, Greer and Stow 2003, White and Greer 2006).

Historic evidence, including mollusc middens left by indigenous peoples, notes by Spanish explorers, maps from the 1800s, and photographs, indicate that LPL may have once remained open to the sea relatively consistently, although it is likely there were periods of mouth restriction and closure. Development of a railway line through the lagoon in 1888, however, was followed by the first recorded closure of LPL's inlet. The railway line consisted of an elevated track placed on top of an earthen berm that cut across the eastern edge of LPL and just west of what is now the closed portion of Sorrento Valley Road. The berm effectively cut off a majority of storm runoff from Carmel Valley during winter and spring months and most likely reduced the ability of the lagoon to remain open. Realignment of the railway through the middle of the Lagoon in the 1920s and construction of Highway 101 in the 1930s accelerated the impairment of Los Peñasquitos Lagoon through altered hydrology that included the blocking of historic tidal channels and the relocation of the Lagoon's inlet. As a result, inlet closures occurred more frequently and for extended durations that at times lasted for more than a year (Cole and Wahl 2000, Hastings and Elwany 2012). The impacts of the railway realignment and Highway 101 construction are further described below.

In 1925, the railway was relocated west of the original alignment and placed on an elevated berm that bisected the lagoon. The railway line remains in the same location today, entering the lagoon from the south at Sorrento Valley and exiting at the northwest-most point of the lagoon, where historic survey maps indicate the location of the LPL's inlet prior to its relocation in 1932. The new railway berm cut off many of the lagoon's natural tidal channels and provided only three bridge spans where water could flow from the watershed toward the inlet. Much like the original railway berm, the new alignment impounded storm runoff from the lagoon's three main tributaries on the eastern side of the berm (Figure 1). Impoundment behind the railway berm increased the residence time for floodwaters within the lagoon, dramatically reducing lagoon outflow rates through the inlet. Reduction in the outflow rates lead to increased frequency and, at times, duration of inlet closures as deposition rates of marine sediments in the inlet area outpaced scouring rates from floodwaters exiting the lagoon. Impoundment of floodwaters in the eastern portion of the lagoon also facilitates habitat conversion from salt marsh to brackish marsh and riparian habitat due to reduced salinity levels in soils and lagoon channels, as well as increased elevations due to deposition of sediments in the eastern portion of the lagoon.



Figure 1. Flood Event at Los Peñasquitos Lagoon, February 2002. Photo by City of San Diego.

A pattern of frequent and extended mouth closure was further aggravated by construction of Historic Highway 101 in 1932-33. The first coastal road was constructed in 1915 and consisted of a 15-foot "strip of concrete" that connected San Diego's beach communities (<http://www.gbcnet.com/ushighways/US101/101pics2a.html>). Moving north to south, the road cut inland toward what is now Carmel Valley Road, curved back to the coastline and crossed the lagoon near the current inlet location before proceeding up Torrey Pines Grade, which is now located within the Torrey Pines State Reserve (Figure 2). This original road, however, became outdated and was replaced by Highway 101. The stretch of Highway 101 along LPL is now referred to as Torrey Pines Road. The new road no longer cut inland at LPL, but instead ran along the section of dunes



that separated the lagoon from the beach. The road was placed on an elevated berm with two bridge spans to the north, where the road enters the southern portion of the city of Del Mar. The lagoon inlet was fixed under the lower bridge span, near where the original bridge crossed the lagoon. An upper bridge was constructed near the historic location of LPL's inlet to allow the railway to pass underneath and continue north along the coastal bluffs along Del Mar Beach (Figure 3).



Figure 2. Ford Model "A" driving the coast (pre-Highway 101) with Los Peñasquitos Lagoon in the background, 1920s (Note the bridge traversing the lagoon). Photo from US 101 Photo Gallery (<http://www.gbcnet.com/ushighways/US101/101pics2a.html>).



Figure 3. Construction of the upper bridge at Los Peñasquitos Lagoon along Highway 101, 1932. Photo from US 101 Photo Gallery (<http://www.gbcnet.com/ushighways/US101/101pics2a.html>).

From 1950-1975, direct discharges of sewage into LPL's tributaries occurred from three wastewater treatment plants. In the 1960s, direct discharges of treated effluent containing nitrates and phosphates from upstream sewage treatment facilities reached new highs. This nutrient addition contributed to algal growth in lagoon waters, and with decomposition of senescent vegetation, led to the depletion of dissolved oxygen and hypoxic conditions. Mosquitoes and midges proliferated, and the odors associated with decaying organics increased. While these direct discharges ceased with the implementation of wastewater pumping stations near the lagoon in 1978, raw sewage discharges still occurred due to failures at these pump stations. Pump Station 64, located in Sorrento Valley, has spilled millions of gallons of untreated sewage into LPL with 60 spills occurring between 1977 and 1986. This pump station was responsible for 2.3 million gallons (~ 8,700 m<sup>3</sup>) of untreated sewage that was discharged into the lagoon during a countywide power outage on September 9, 2011.

The Los Peñasquitos Lagoon Foundation, California Coastal Conservancy, and concerned community members developed an LPL Enhancement Plan in 1985 to deal with these problems. Two key programs identified in the Plan were annual monitoring of water quality parameters, aquatic habitats and terrestrial habitats, as well as mechanical opening of the lagoon mouth before water quality became poor enough to kill channel organisms. These programs were partially funded through mitigation payments made by local developers and homeowners' associations in the watershed and are administered by the Los Peñasquitos Lagoon Foundation with support from California State Parks and California Coastal Conservancy.

As part of this management program, the Pacific Estuarine Research Laboratory (PERL), based at San Diego State University, was contracted to monitor lagoon resources and use the data in its studies of regional wetland ecosystems. PERL monitored the physical and chemical characteristics of LPL channel water from 1987 - 2004, and sampled benthic invertebrates, fish, and saltmarsh vegetation from 1988 - 2004 (Covin 1987, Nordby and Covin 1988, Nordby 1989, Nordby 1990, Boland 1991, Boland 1992, Boland 1993, Gibson et al. 1994, Williams 1995, Williams 1996, Williams 1997, Williams et al. 1998a, Williams et al. 1999, Ward et al. 2000, Ward et al. 2001, West et al. 2002). These studies led to the timely opening of the mouth and an increase in our knowledge of the biology of southern California's estuaries (e.g., Nordby and Zedler 1991, Zedler 2000, Noe 2001a,b). In July 2004, LPL monitoring was transferred to the Southwest Wetlands Interpretive Association (SWIA) and the Tijuana River National Estuarine Research Reserve (TRNERR).

## II. METHODS

### DESCRIPTION OF STUDY SITE

Water quality was sampled at three stations that have been monitored since 1987 (Figure 4). The monitoring stations are described below:

*Station W1 (Via Grimaldi, formerly Milligan House)* – Station W1 is located along Carmel Valley Road (at the Via Grimaldi intersection) in the northern arm of the estuary. This station consists of a channel approximately 20 meters (m) wide and 1.0 m deep and sediments composed of clay covered with a shallow layer of organic matter.

*W2 (Railroad Trestles)* – Station W2 is located at the large railroad bridge that crosses the main lagoon channel; water quality readings are taken from the catwalk near the middle of the channel, where water depths are approximately 2.0 m.

*W3 (Mouth)* – Station W3 is located in one of the channels closest to the lagoon's Pacific Ocean outlet and is most directly exposed to ocean flows. This site is fairly shallow, with sandy sediments and a highly variable width (8 - 40 m) because of its dynamic hydrology.



Figure 4 - Water Quality Sampling Stations and Vegetation Transects within Los Peñasquitos Lagoon.

## RAINFALL AND WEATHER MONITORING

Rainfall in San Diego can be sporadic and highly variable across the county in both presence/absence as well as measurable amounts. Therefore, measuring precipitation onsite is important for accuracy purposes. In the past, rainfall amounts measured at Lindbergh Field were used as this airport has the longest running rainfall monitoring program, which facilitates historic comparisons of both annual and seasonal rainfall data. Rainfall measured at Lindbergh Field, however, can differ greatly from rainfall occurring at LPL and its watershed both annually and for each storm event. Local rainfall data was collected at the weather station located near water quality sampling station W2 (Figure 4). In addition, air temperature and relative humidity were measured.

## STREAM FLOW DATA

Flow rates for LPL's major tributaries (Carmel Creek, Los Peñasquitos Creek and Carroll Canyon Creek) were not measured during this monitoring period, as it was determined that this effort did not capture flow data for specific storms, but rather just for a specific time frame (i.e. the day flow was measured). Continuous stream flow data for Los Peñasquitos Creek is available from a USGS Gauge 11023340 located in the upper portion of Los Peñasquitos Canyon, within the city of Poway (Figure 5; <http://waterdata.usgs.gov>). This gauge does not capture complete flow data for this sub-watershed due to its location in the upper half of this drainage. The USGS has operated other stream flow gauges at the lower reaches of Carmel Valley and Carroll Canyon, but only for a short duration.

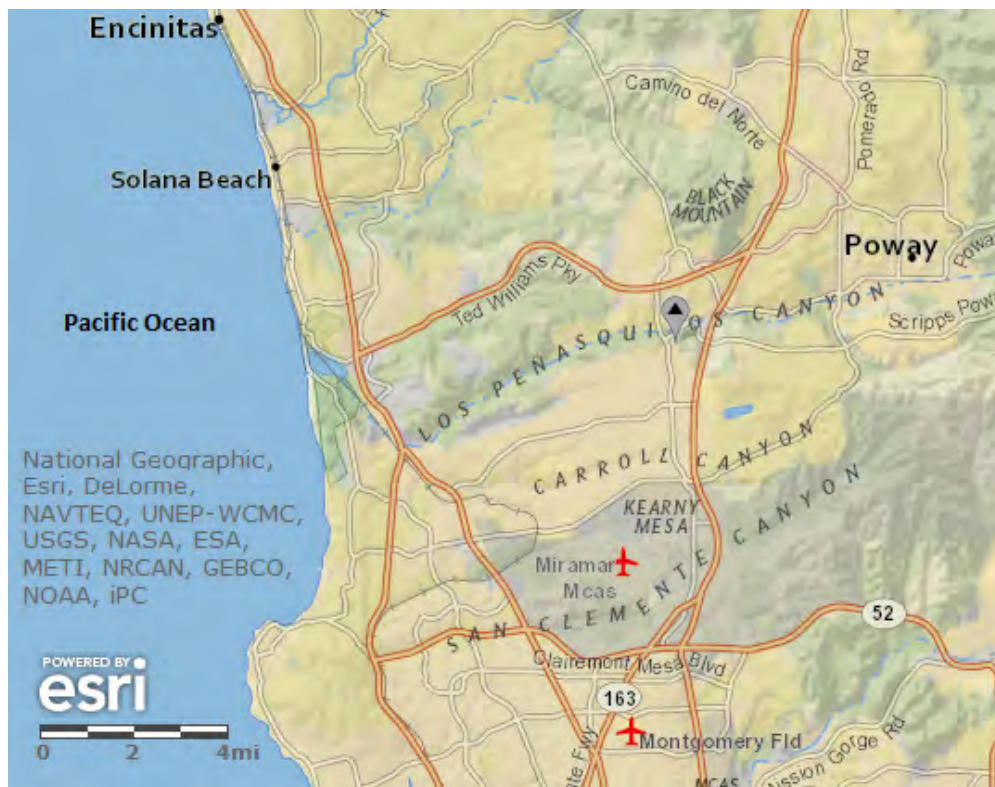


Figure 5 - Location of USGS Gauge 11023340 (grey symbol) in Los Peñasquitos Canyon. Graphic modified from [http://nwis.waterdata.usgs.gov/nwis/nwismap/?site\\_no=11023340&agency\\_cd=USGS](http://nwis.waterdata.usgs.gov/nwis/nwismap/?site_no=11023340&agency_cd=USGS).



## WATER SAMPLING

### *CONTINUOUS WATER SAMPLING*

Intensive water quality sampling was conducted at Station W2, located at the northern-most railroad trestle (Figure 4) using a YSI model 6600 multi-parameter datalogger installed at a fixed position approximately 0.30 m off the channel bottom. Data from this logger is available in real-time through telemetry (<http://torreypines.trnerr.org/#>) along with weather information recorded near W2. The following water quality parameters were measured every 15 minutes by the datalogger at W2:

Salinity in practical salinity units (psu)

Water temperature (°Celsius)

Dissolved Oxygen (DO) in milligrams per liter (mg/L)

Water level (m)

Turbidity in Nephelometric Turbidity Units (NTU)

pH

Chlorophyll (µg/L)

*Salinity.* Salinity is a key parameter measured to assess water quality conditions for aquatic species residing in LPL's channels and chemical processes occurring within the water column. Salinity is measured in practical salinity units (psu), which is assessed as electrical conductivity and is a function of temperature (note: psu values are very similar to parts per thousand (ppt), which has been reported previously). Salinity can be used to determine the extent and degree of tidal mixing within the lagoon channels, as well as an indirect measure of freshwater input from the watershed. Prior to the urbanization of the watershed and perennial nature of the lagoon's tributaries, water trapped within the lagoon during mouth closures would often become hypersaline. Year round freshwater input into the lagoon since 1996, however, precludes hypersaline conditions for the most part, even during summer months with no precipitation. Salinity also can help to determine the fate of organic material within the lagoon, primarily its ability to dissolve in the water column or become adsorbed to fine sediments (e.g., clay).

*Water temperature.* Water temperature is another key parameter measured to assess water quality conditions for aquatic species residing in LPL's channels and chemical processes occurring within the water column. Water temperature can have profound impacts on dissolved oxygen (DO) levels within water found in lagoon channels, as DO can drop quickly during warmer temperatures (see below).

*Dissolved Oxygen (DO).* DO is perhaps one of the most important water quality parameters for aquatic species residing in LPL's channels and is the most used parameter for triggering opening of the lagoon inlet during closures. DO is measured in concentrations of milligrams per liter (mg/L) of water. DO levels within lagoon channels depend greatly on tidal mixing within the lagoon, as ocean waters replenish DO levels within the lagoon and keep water

temperatures relatively cooler throughout the water column. This is important because oxygen solubility decreases with increasing temperatures. During inlet closures, DO can drop to levels considered stressful to most marine organisms, which is below 5mg/L. During extended inlet closures, DO levels can drop and remain below 5mg/L, resulting in fish kills. DO is also sensitive to day / night cycles. The lack of photosynthetic production of oxygen at night coupled with DO depletion due to respiration by aquatic species produces lower oxygen levels.

Water level. Water levels are measured at station W2 continuously to determine tidal influence and water input from the watershed during inlet closures. Tidal influence is important to monitor as it influences salinity, temperature and DO within lagoon channels. Measuring water levels during inlet closures is important in showing the contribution of fresh water input from the watershed, especially during periods of no measurable precipitation.

Turbidity. Turbidity is monitored to determine the presence and density of particulate matter suspended in the water column. Turbidity can impede photosynthesis of algae and aquatic plant species living within the lagoon channels. Turbidity is measured in Nephelometric Turbidity Units (NTU) and is measured as follows. As light emitted from a probe intersects suspended particles within the water column, the light scatters. The backscatter of light is detected by the probe and is used as a proxy for turbidity. The nephelometer (probe) measures for particle density of suspended particulates in a liquid as a function of light reflection off the particles.

pH. pH is measured along a range of 0 to 14 to assess acidity (below 7) or basicity (above 7) of water within the lagoon channel at Station W2. Typically, water within coastal lagoons has a pH of approximately 8, which is indicative of ocean water, or even higher due to hypersaline conditions. pH levels within LPL, however, seem to fluctuate due to the presence and magnitude of tidal mixing and/or fresh water input from the watershed and peripheral drainages that empty into the lagoon. In coastal lagoons, salinity-related changes in chemical reaction rates are important and are generated both by mixed-controlled changes in the relative concentrations of reactants and by the influence of ambient ionic strength on the activities of the reacting species. Thus, pH influences the ability of organic material to dissolve in the water column. When salinity levels increase, organic compounds become less soluble in water and, instead become more adsorbable, leading to increased sorption on sediment particles. pH levels can also affect aquatic species within the lagoon channels and sudden changes, even by a small amount, can be stressful for fish. Many species, however, can adapt to shifts in pH levels if they are gradual. Extreme changes in pH can result from the input of acidic or basic waste into coastal waters or lagoon tributaries.

Chlorophyll. Chlorophyll is a useful parameter for indirectly assessing primary producer biomass within the water column. In some cases, it might be used to predict eutrophication in lagoons, serving as an indicator of dissolved inorganic nitrogen (DIN) often associated with runoff from the watershed during rain events. The extent to which it is useful in tidally-exchanged wetlands is unclear, but under investigation. It is measured in micrograms per liter (µg/L).

## *SPATIAL WATER SAMPLING*

Spatial water quality monitoring was conducted (approximately) on a monthly basis at stations W1, W2 and W3 (Figure 4). Measurements were made at the surface and bottom of the channel using a YSI 600xlm multi-parameter water quality datalogger connected to a YSI 650 MDS (Multi-parameter Display System). Spatial water quality monitoring measured water temperature, salinity, and DO.

Monthly nutrient and chlorophyll sampling began in April 2011. The water sample is collected at Station W2 and analyzed according to established National Oceanic and Atmospheric Administration (NOAA) and National Estuarine Research Reserve (NERR) protocols. The parameters assessed are orthophosphate, nitrate / nitrite (combined), ammonium, and chlorophyll. Data are compared to samples collected from the Tijuana River Estuary and south San Diego Bay, collected as part of the larger TRNERR effort.

## LAGOON MOUTH MONITORING

The main contributing factor to a low dissolved oxygen (DO) event is a lagoon mouth closure, especially during periods of warm ambient temperatures (e.g. summer months). Supplemental to the water quality monitoring that document these low DO events, a profile of the channel at the mouth is obtained monthly using a laser measuring device (Hilti® brand). With the bridge over the lagoon as reference, the distance from the beach to the bridge is calculated approximately every 3 meters (using the posts of the eastern bridge railing as markers). In this manner, relative heights of the channel and surrounding beach are calculated in a cost and time effective way (Figure 15). Pictures are also taken of the mouth (Figure 14). This monitoring can assist in the decision-making process of manually re-opening the lagoon mouth. In addition, efforts are made to coordinate with the Los Peñasquitos Lagoon Foundation (LPLF) with regard to sharing data (e.g. total amount of sand removed from the inlet and hauled to Torrey Pines State Beach) from annual mechanized excavation of the inlet area.

Monitoring of annual accretion and/or erosion rates has been performed at LPL since 1995 by Coastal Environments, a coastal engineering firm specializing in coastal wetlands and nearshore processes. Efforts consisted of surveys along established transects within LPL (Figure 6) that are located within the Lagoon's transitional/upland area, across lagoon channels, and at the ocean inlet. While this effort has been performed annually since 1995, surveys were not performed in 2012/2013 due to funding limitations.



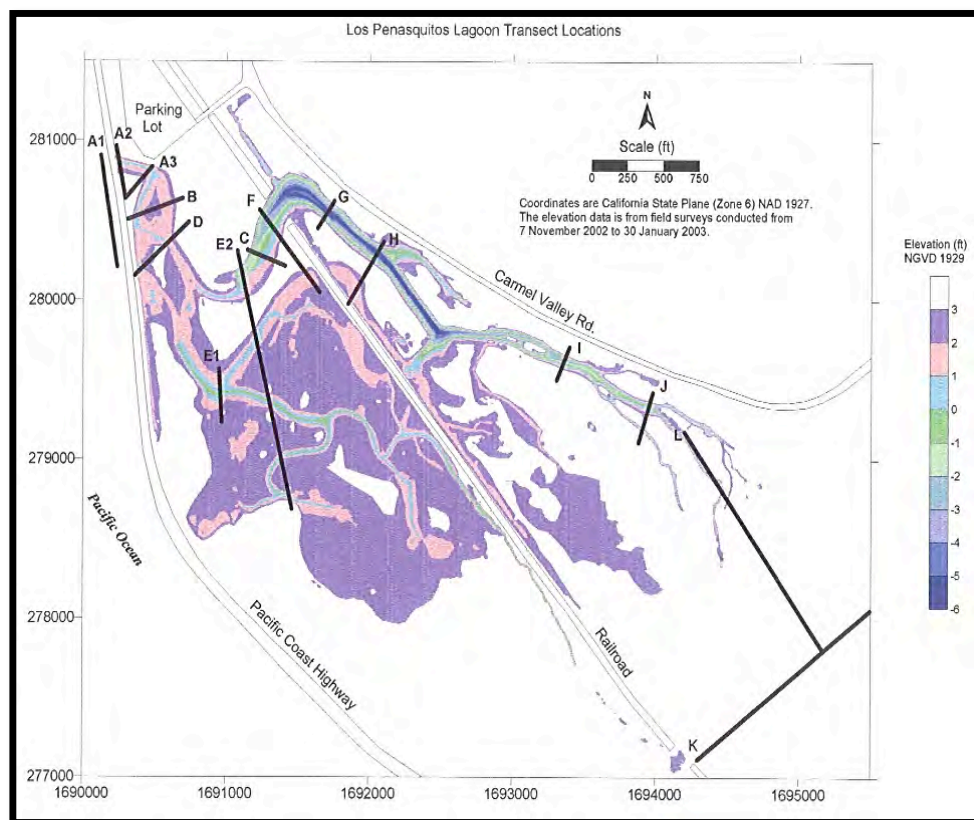


Figure 6 – Locations of accretion/erosion transects.

## VEGETATION AND SOIL SAMPLING

Vegetation monitoring was conducted to document changes in species composition and to determine the magnitude of historic saltmarsh habitat invasion by upland/exotic species. Vegetation is monitored in nine areas (Figure 4) during the fall. Five of these areas have been monitored since 1986 (transects 1- 5), four since 1990 (transects 9, 11, and 12) and one since 2001 (transect 13A and B). Individual transects are described more thoroughly in the results and discussion section.

Two (or more) stakes mark the position of each permanent transect, which vary in length from 20 to 320m. A 0.25-m<sup>2</sup> circular quadrat was laid down at five meter intervals along each transect. Total percent cover of vegetation in each plot was recorded, as well as percent cover for each species. Note that the cumulative cover of the individual species can represent values greater than the total percent cover, to account for the fact that plants often overlay each other in a three-dimensional canopy.

In March 2008, we added an additional springtime transect to monitor *Lasthenia glabrata* *ssp. coulteri*, an annual native plant placed on the 1B List (Plants Rare, Threatened, or Endangered in California and Elsewhere) with a threat ranking of 0.1 (seriously threatened in

California) by the California Native Plant Society. The transect is located along the eastern portion of the lagoon in an area of expanding freshwater influence. It is designed to document the changing vegetation communities associated with increased freshwater input and its potential impacts to *L. glabrata ssp. coulteri*. It extends 140 meters along a trail between two patches of *L. glabrata*. The presence of *L. glabrata* was recorded at five-meter intervals on either side of the trail. *L. glabrata* was most abundant on the western side of the transect. In order to better characterize *L. glabrata* and associated vegetation, percent cover of all species within a 1m<sup>2</sup> square quadrat was recorded every five meters along the western side of the transect.

Prior to 1996, soil salinities were determined in the field. In 1996 a switch was made to the use of soil pastes to better account for inconsistencies in measuring the salinity of dry and wet soils. Using a 2-cm diameter corer, at least three 10-cm deep soil cores were obtained at equally spaced intervals along each transect. Soil salinities were determined by taking samples back to the laboratory, rehydrating them with deionized water to form soil pastes (Richards 1954), and then expressing the interstitial water onto a temperature compensated refractometer using 10-ml syringes fitted with filter paper (PERL 1990). Recent comparisons show that this method, while consistent across all samples, results in elevated salinity readings relative to field measurements of expressed interstitial waters.

In the Spring of 2012, we conducted pilot sampling for a new monitoring protocol being established through the NERR System-Wide Monitoring Program (SWMP). The funding for implementation of this monitoring in both LPL and the Tijuana Estuary is being leveraged by NOAA NERR funding. In general, this monitoring is designed to assess vegetation changes along the marsh - upland gradient, both to provide this information for extant communities and also to allow for change detection due to factors such as climate change and sea level rise. In March 2012, two sets of vegetation transects were added to the existing array (described above). These transects run across elevation gradients in order to sample through marsh habitat and into the upland transition zone. Site SWMP-1 consists of 3 transects of 69m, 72m, and 75m that run parallel to the train tracks from the northeast to the southwest, respectively, and cross Transects 1A and 1B perpendicularly. Site SWMP-3 consisted of additions to Transect 3, lengthening it into the upland zone by 45m, and adding two replicate transects of 40m each in the upland zone. In October 2012, the previously mentioned two replicate transects were extended into the low marsh by 80m, resulting in SWMP-3 consisting of a total of 3 transects, one transect 145m long and two transects 120m long. A 1m<sup>2</sup> quadrat was laid down approximately every 10m along each transect. Percent cover of vegetation and individual species were recorded.

### III. RESULTS & DISCUSSION

#### WEATHER MONITORING

##### *RAINFALL*

Daily rainfall values for the LPL meteorological station are shown in figure 7 and relative humidity and air temperature values are shown figure 8.

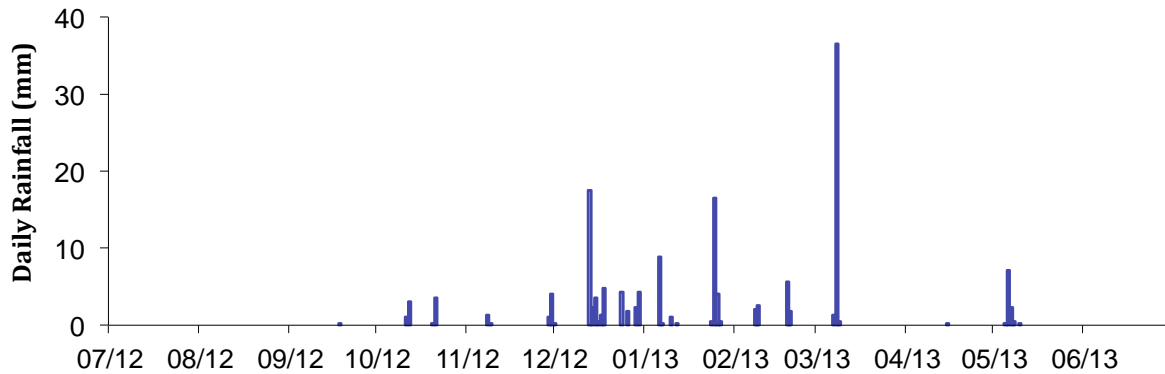


Figure 7 - Daily rainfall as measured at the LPL weather station.

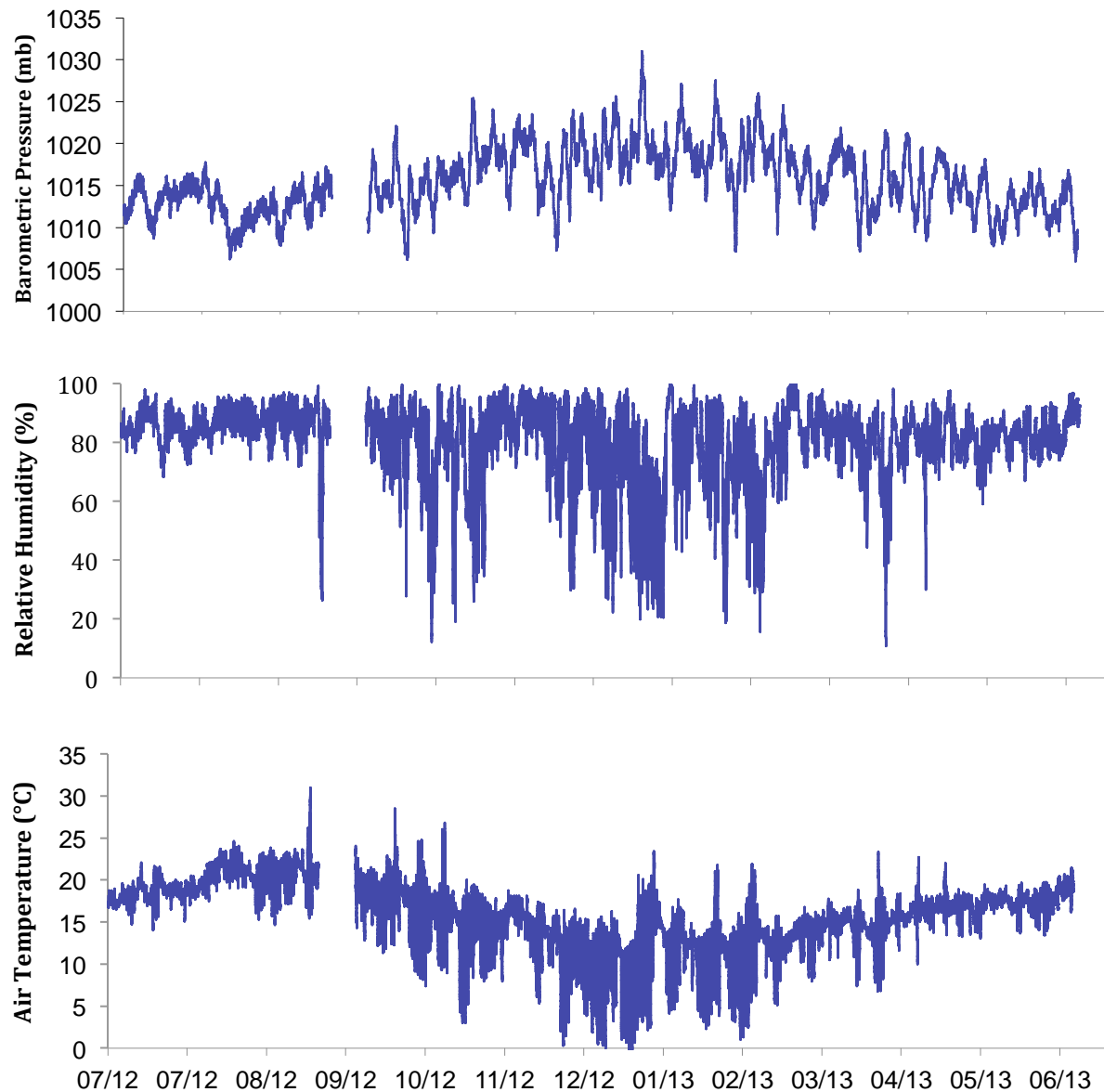


Figure 8 - Barometric pressure, humidity, and air temperature as measured at the LPL weather station.

### STREAM FLOW – LOS PEÑASQUITOS CREEK (USGS GAUGE)

Stream flow data taken from USGS Gauge 11023340 for July 2012 – June 2013 indicated a year of moderate flow events from October 2012 through the first half of March 2013 (Figure 9). Flow rates were relatively low (maximum of ca. 400  $\text{ft}^3/\text{s}$ ) compared to peaks in previous years (Figure 10).

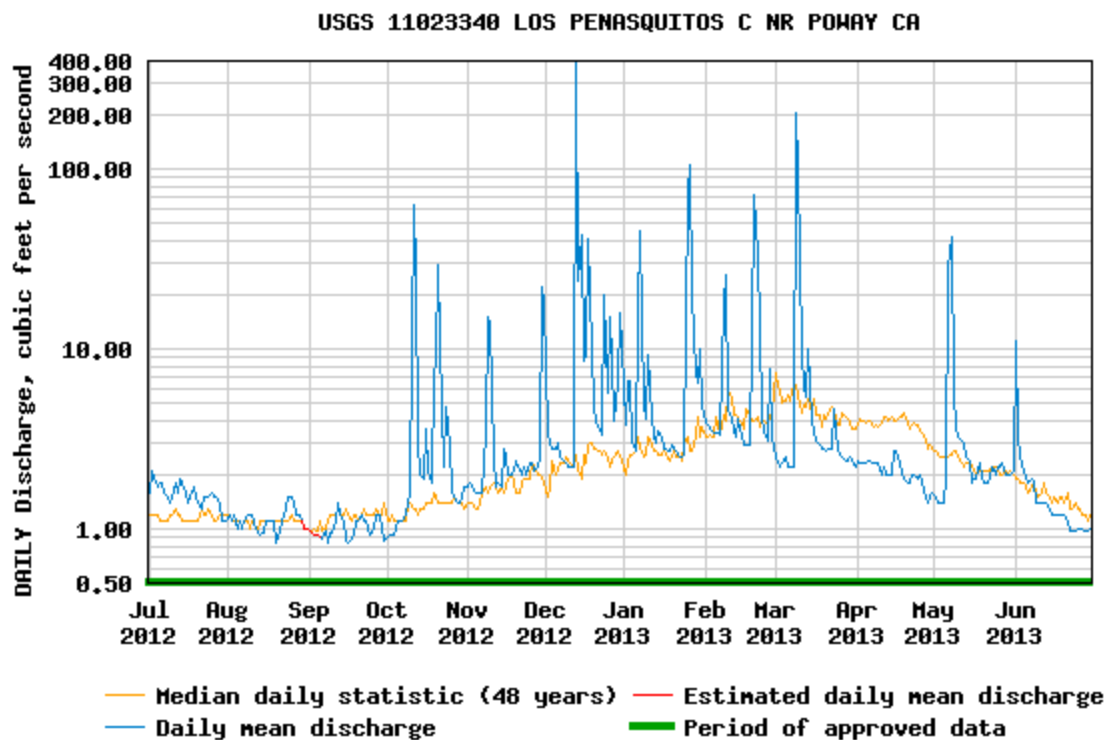


Figure 9 - USGS Gauge 11023340 Flow Rates for Los Peñasquitos Creek. Graphic by USGS.

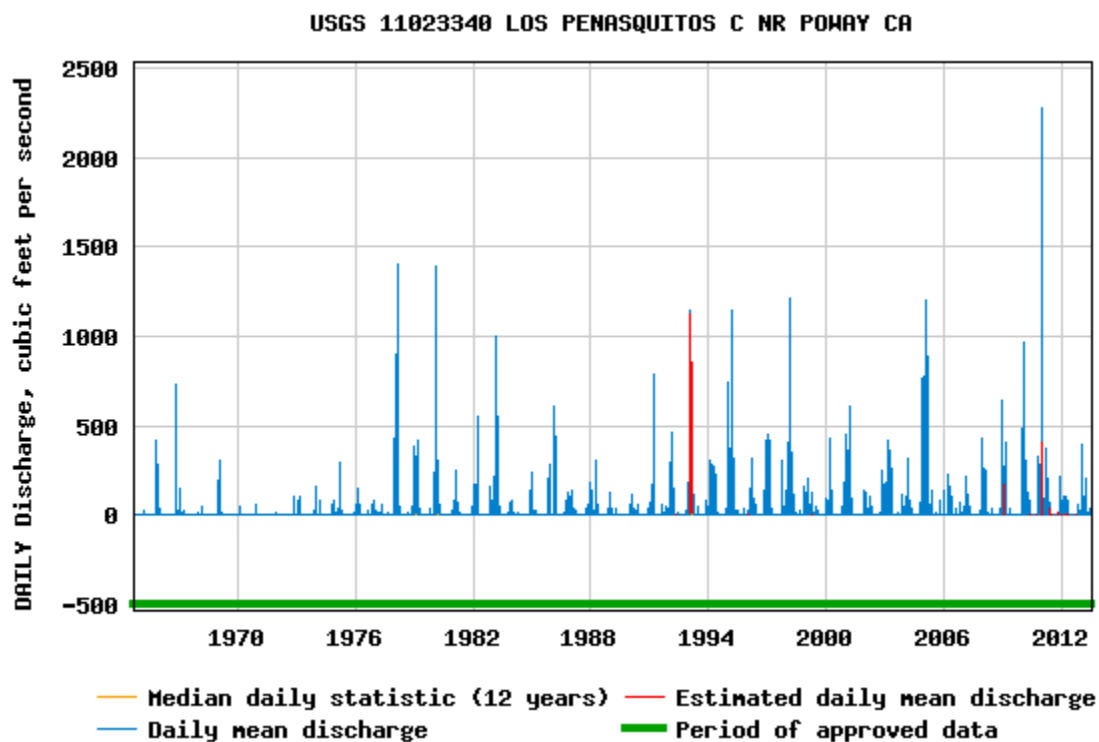


Figure 10 - Long term record for USGS Gauge 11023340 on Los Peñasquitos Creek. Graphic by USGS.

## WATER SAMPLING

### *LAGOON WATER CONDITIONS*

Water conditions in the lagoon are assessed with both periodic spatial sampling (Figure 11) and continuous data retrieval from the data logger deployed at the railroad trestle (Figure 12). The spatial sampling data shows the difference in water quality parameters at varying depths. The surface water samples are generally lower in salinity than near bottom samples due to the density differences between lighter, fresher water and denser, more saline water (Figure 11). Water quality parameters at sampling station W3, however, were generally similar between surface and near bottom samples because the water at this site is generally shallow and well mixed. During the periods of periodic mouth closure in the spring, salinities and dissolved oxygen both tended to decrease. The inlet was mechanically breached on May 13, 2013, but tidal mixing was relatively muted due to the volume of sand within the inlet and along Torrey Pines State Beach, causing the inlet to close within 12 hours of being opened. These closures occurred each morning of the weeklong inlet excavation effort that occurred in May, which has not happened in the last 10 years of inlet maintenance.

The data collected every 15 minutes with the data logger, and the real-time data delivery system at this logger site, greatly facilitates water quality assessments as well as indicates problems which need rapid attention. Overall, the water quality was generally good throughout the monitoring period, except for times during which the lagoon mouth was greatly restricted or closed, from mid-February to late June. There was the typical period of low minimum oxygen values in the fall (Figure 12), caused by decaying organic matter from the summer growing season leading to relatively large oxygen demand, especially early in the morning (before oxygen-producing photosynthesis occurs during daylight hours). Even during these periods, however, maximum values show recovery to oxygenated conditions. Low oxygen events also occurred related to mouth closures (discussed below). Finally (and unfortunately), there was equipment malfunction on the morning of January 8th. A replacement sonde was not deployed until the morning of January 18<sup>th</sup>.

During the aforementioned mouth closure, two additional data loggers were installed at approximately .25m and 1m water depth to better profile the water column (Figure13). Data was collected starting April 18<sup>th</sup>, shortly after discovering the mouth was completely closed, through May 13<sup>th</sup>, immediately following the first mechanical opening of the mouth.

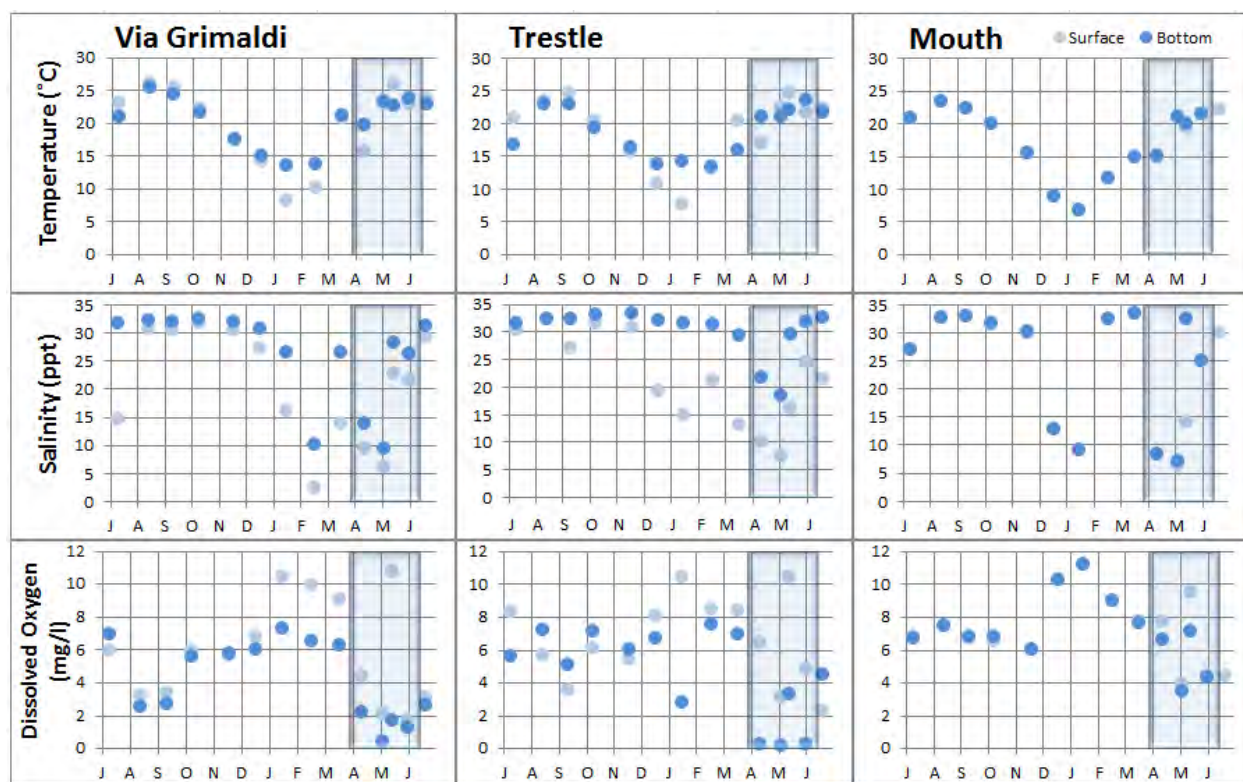


Figure 11 - Spatial water quality data, July 2012 – June 2013. Shaded areas indicate periods of mouth closure.



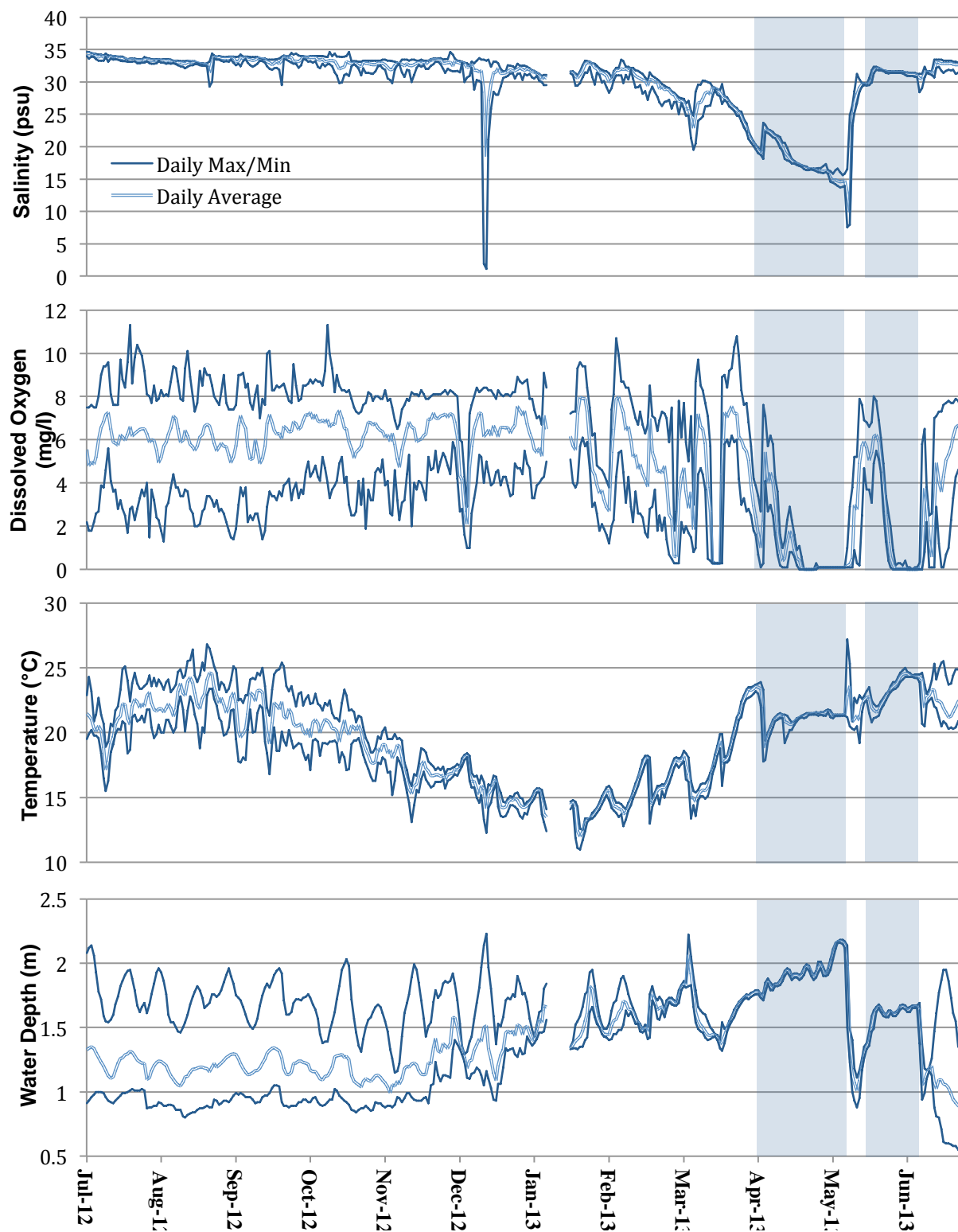


Figure 12 - Water quality data from the data logger at station W2. Data are presented as daily means, maximums, and minimums. Shaded regions indicate the presence and estimated duration of a lagoon inlet closure. Gaps indicate periods when the data logger was inoperative (Jan 8-18) or individual probes failed.

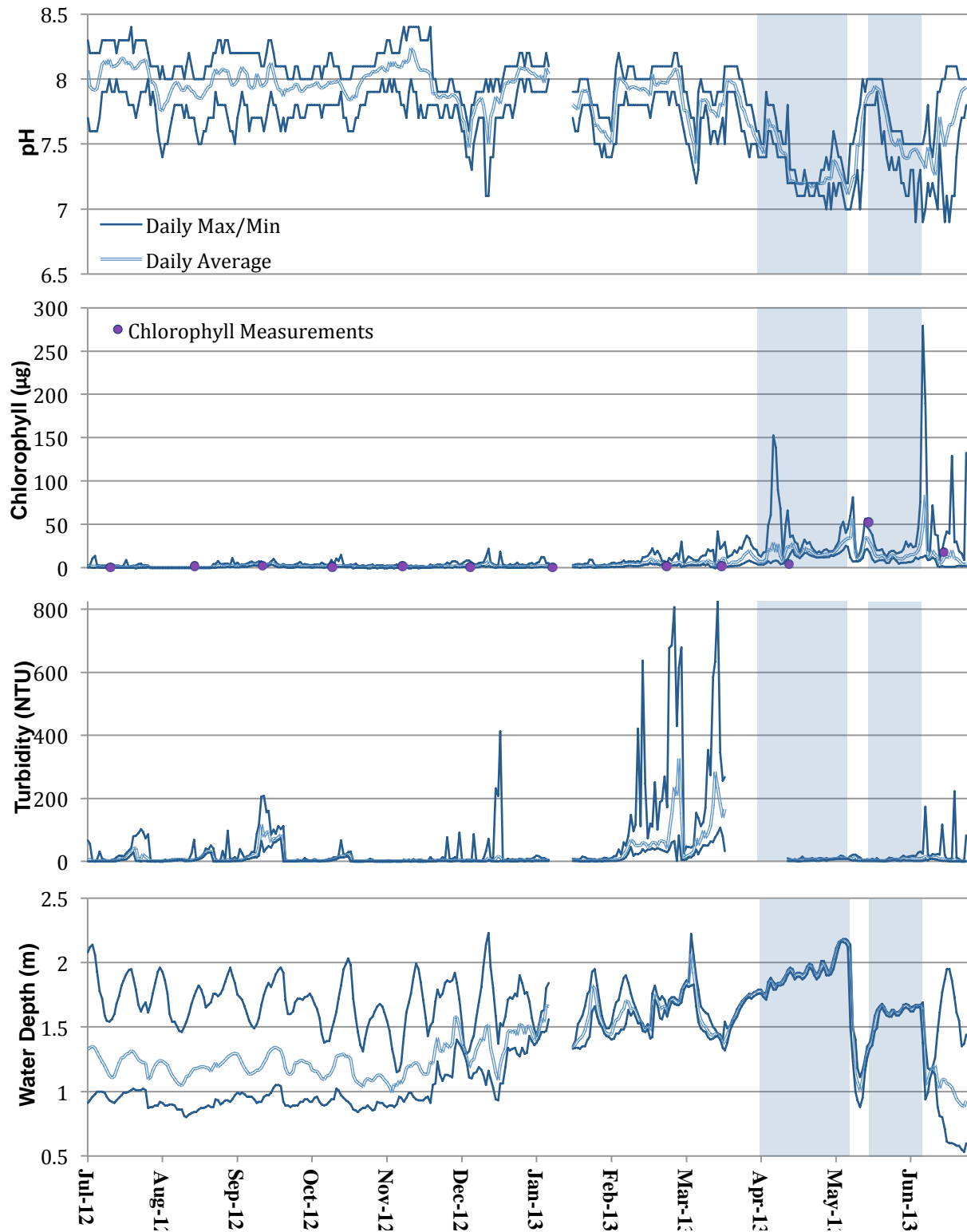


Figure 12, continued - Water quality data from the data logger at station W2. Data are presented as daily means, maximums, and minimums. Shaded regions indicate the presence and estimated duration of a lagoon inlet closure. Gaps indicate periods when the data logger was inoperative (Jan 8-18) or individual probes failed. Purple dots represent chlorophyll measurements of water samples analyzed in the laboratory.

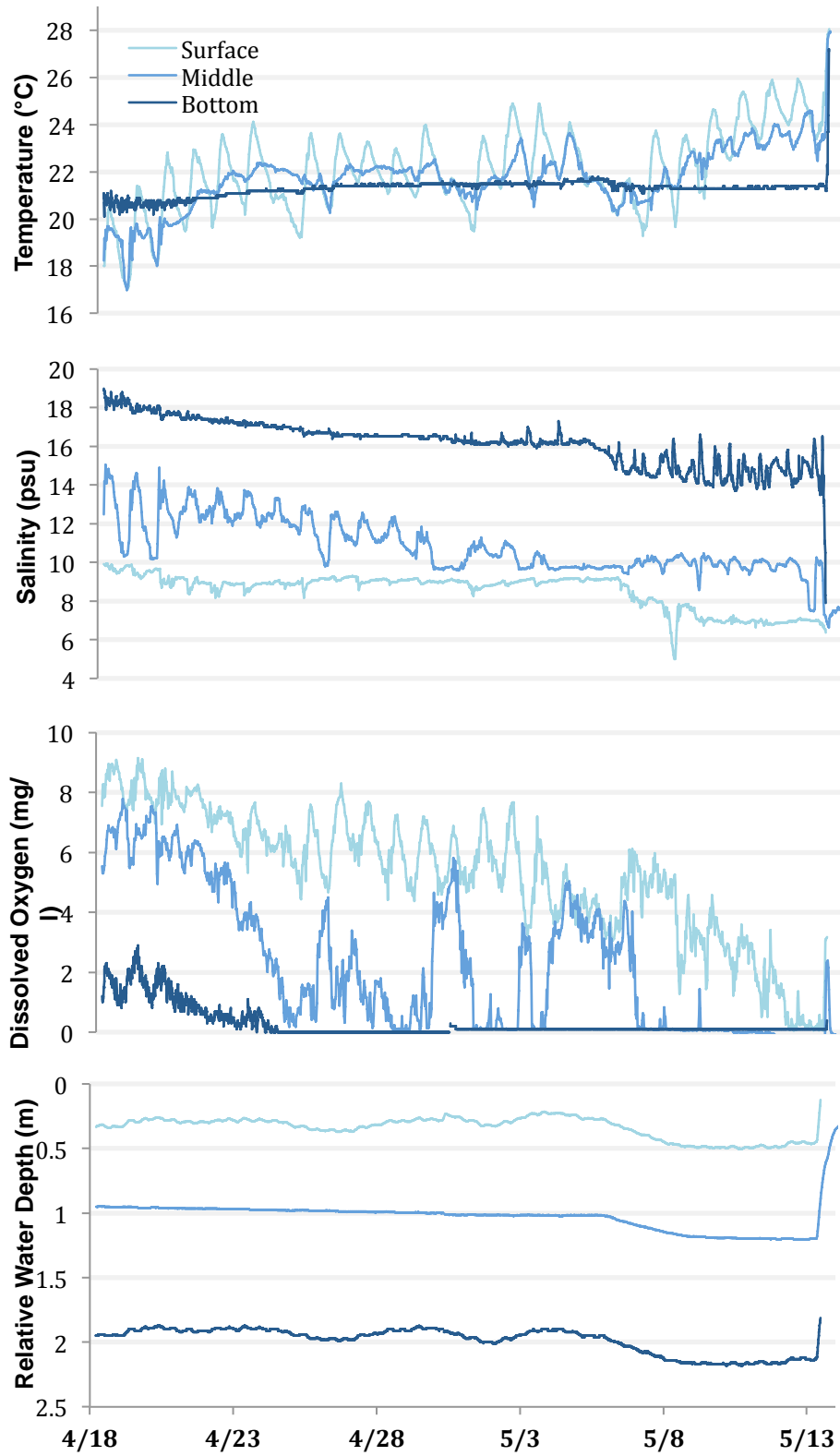


Figure 13 – Data from the 3 data loggers deployed during the mouth closure to assess water quality parameters vertically in the water column at Station W2.

## MOUTH MONITORING

### *OCEANSIDE LITTORAL CELL & AN EROSION SHORELINE*

Torrey Pines State Beach is located in the southern portion of the Oceanside Littoral Cell that is bounded by Dana Point to the north and La Jolla Cove to the south (See Figures 14a-c). Within this littoral cell, sand moves primarily in a southern direction due to the dominant longshore current and large waves common during winter months. Ultimately, the sand is removed from the littoral cell when it is deposited into lagoon inlets and offshore canyons that include the La Jolla Canyon and Scripps Canyon located south of LPL.

Formed primarily during the late Holocene period, many of the beaches within the Oceanside Littoral Cell have experienced an ongoing trend of erosion due, in part, to anthropogenic modifications along the shoreline and within the coastal watershed. Coastal armoring (e.g. sea walls) and modifications to coastal tributaries (e.g. dams and channelized floodplains) have reduced natural sediment inputs to the Oceanside Littoral Cell from terrestrial sources. Shoreline developments (e.g. harbors and jetties) have also modified the natural movement of sand within the Oceanside Littoral Cell, resulting in increased accretion rates on some beaches and erosion on others.

### *SEASONAL VARIATION IN COASTAL EROSION & ACCRETION RATES AT TORREY PINES STATE BEACH & LOS PEÑASQUITOS LAGOON INLET*

Seasonality plays a major role in erosion and accretion rates within the Oceanside Littoral Cell and Torrey Pines State Beach is no exception. Studies conducted by SIO and others have documented seasonal variation of both beach width and vertical profiles at Torrey Pines State Beach. Winter months are defined by beach loss due to scouring of sand off the beach, while summer months tend to show beach gains caused by accretion of sand.

During winter months, shoreline erosion is the dominant process at Torrey Pines State Beach as sand is scoured off beaches by large waves and storm surge. Large waves during the winter are caused primarily by intense storms formed in the Aleutian Islands region of the Northeastern Pacific. The oblique angle of the winter swells (e.g. 280 to 310 degrees) and the predominant north-south longshore current scours sand off the beach at Torrey Pines. While some sand is retained offshore in the form of sand bars, much of it is removed from the system as it is pushed into the inlet at LPL or south into the two submarine canyons, La Jolla Canyon and Scripps Canyon. Storm surge can accompany these large waves as storm fronts move down the coast toward San Diego, increasing water surface elevations along the nearshore. Coastal erosion can be greatly accelerated when large waves coincide with storm surge and high tides, as beach run up is maximized.

In contrast, summer months are characterized by shoreline accretion as sand is moved from offshore sand bars, back onto the beach at Torrey Pines. Tidal action seems to be the primary forcing mechanism for moving sand along the nearshore due to the relative lack of wave activity during summer months at Torrey Pines State Beach. Within north county San Diego, beaches north of Encinitas tend to be more exposed to summer wave activity, which arrives from a predominantly southern direction (e.g. 175 to 210 degrees). While Torrey Pines does receive waves from a southerly direction, wave height and energy is relatively diminished due to shadowing and wrapping effects caused by the La Jolla peninsula that are then modified by La Jolla Canyon and Scripps Canyon. As a result, longshore erosion is diminished along Torrey Pines State Beach during summer months.



Figure 14a – Oceanside Littoral Cell – Dana Point to La Jolla



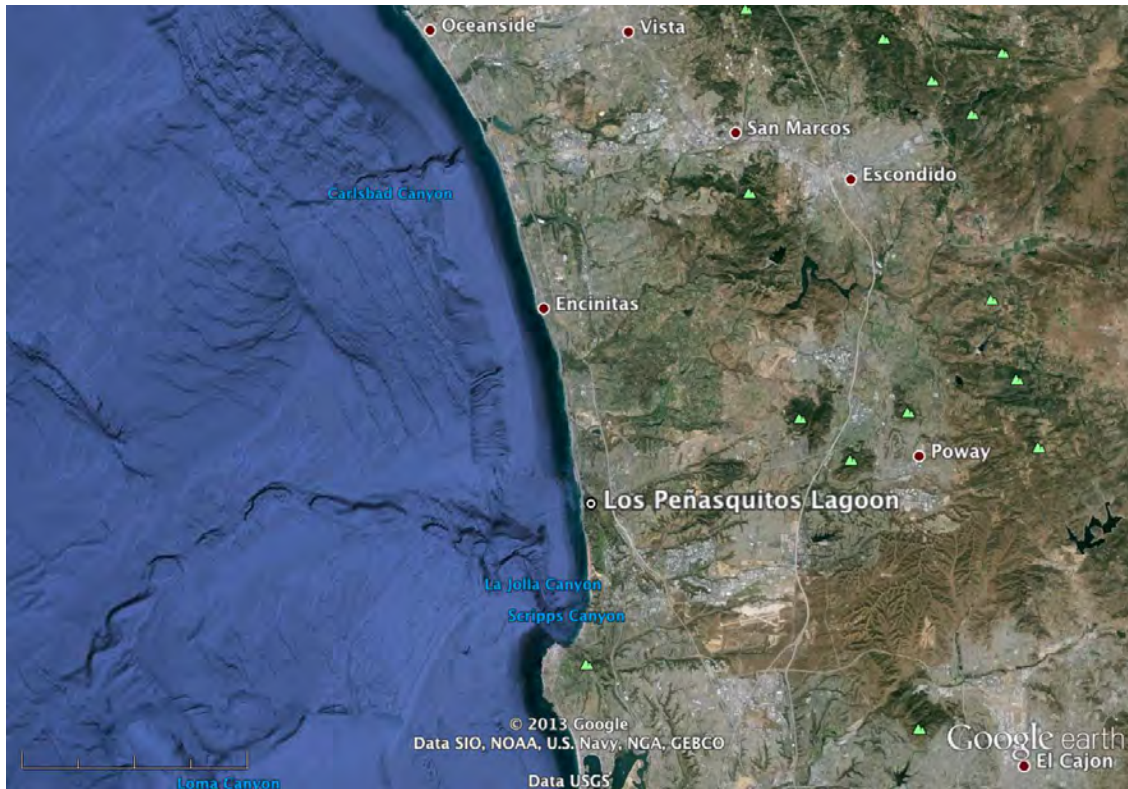


Figure 14b – Oceanside Littoral Cell – Oceanside to La Jolla



Figure 14c – Oceanside Littoral Cell – Los Peñasquitos Lagoon

## *LAGOON MOUTH CONDITIONS*

The lagoon mouth remained open for much of the latter half of 2012 (Figure 15a and 17). New analyses indicate that, by comparing the relative depths at Station W2 and the tidal data from Scripps Pier in La Jolla, it can be discerned when tidal influence at LPL becomes restricted.

In early October (see Figure 17), “normal” tidal fluctuations are seen in that the high tides in the lagoon follow closely the high tides as measured at Scripps. It is apparent that at all times, the lagoon does not experience the low tides that the adjacent beach experiences. Some degree of tidal perching is to be expected, and is also evident at the Tijuana River Estuary (Figure 18). As sand deposits and shoaling occurs at the mouth, the low tides get initially slightly truncated, as seen in figure 17 in early November. It appears that by early November, the lagoon mouth was beginning to close. This is confirmed by examining the mouth profiles on November 8th and December 6<sup>th</sup>, which show no significant channel (figure 15b). Thanks to a large storm during December 12<sup>th</sup>-14<sup>th</sup>, the mouth reopened (see figure 15b) and remained open through January, however, it is clear in the water depth data that tidal influence was restricted (missing data is due to a malfunction of the sonde). It was noticed (pers. obs.) through February and March the mouth was highly restricted evidenced by a limited outflow (i.e., a trickle) during low tides. As seen in Figure 15c, the mouth profile is practically flat through this period. Shoaling of the channel and surrounding beach continued until enough sand was deposited to restrict all tidal influence, resulting in the closing of the lagoon around March 23<sup>rd</sup> (pers. obs. and figure 15c).

Mouth closures often occur during neap tide series, with subsequent spring series potentially helping to re-open the system. This may have occurred at least on three occasions, once in early December, in late January, and again in early March, as oxygen levels are seen to drastically drop concomitantly with an increase in water level (see figure 17). A relatively stronger tidal signal returned as spring tides returned and oxygen levels recovered quickly after these re-openings. It was apparent, though, by the end of April there was too much sediment deposited at the mouth to expect it to open naturally, which led LPLF and CSP to attempt to open the mouth May 13<sup>th</sup> -17<sup>th</sup>. The mouth did not stay open for very long - upon examining the water depth data for Station W2, it seems that almost immediately after excavation the mouth closed again. Returning on June 7<sup>th</sup>, it was confirmed that the mouth was indeed closed. Another reopening event began on June 12<sup>th</sup>. Figure 15d shows the mouth profile before and after each manual reopening. As of the end of June, the mouth remained open (see figures 15d and 17). It is possible that the deposition of sand within the LPL inlet and just north of the inlet along Torrey Pines State Beach was augmented by beach nourishment activities that occurred under the Regional Beach Sand Project II (RBSP II). A description of RBSP II and beach profile information is provided in the Appendix.



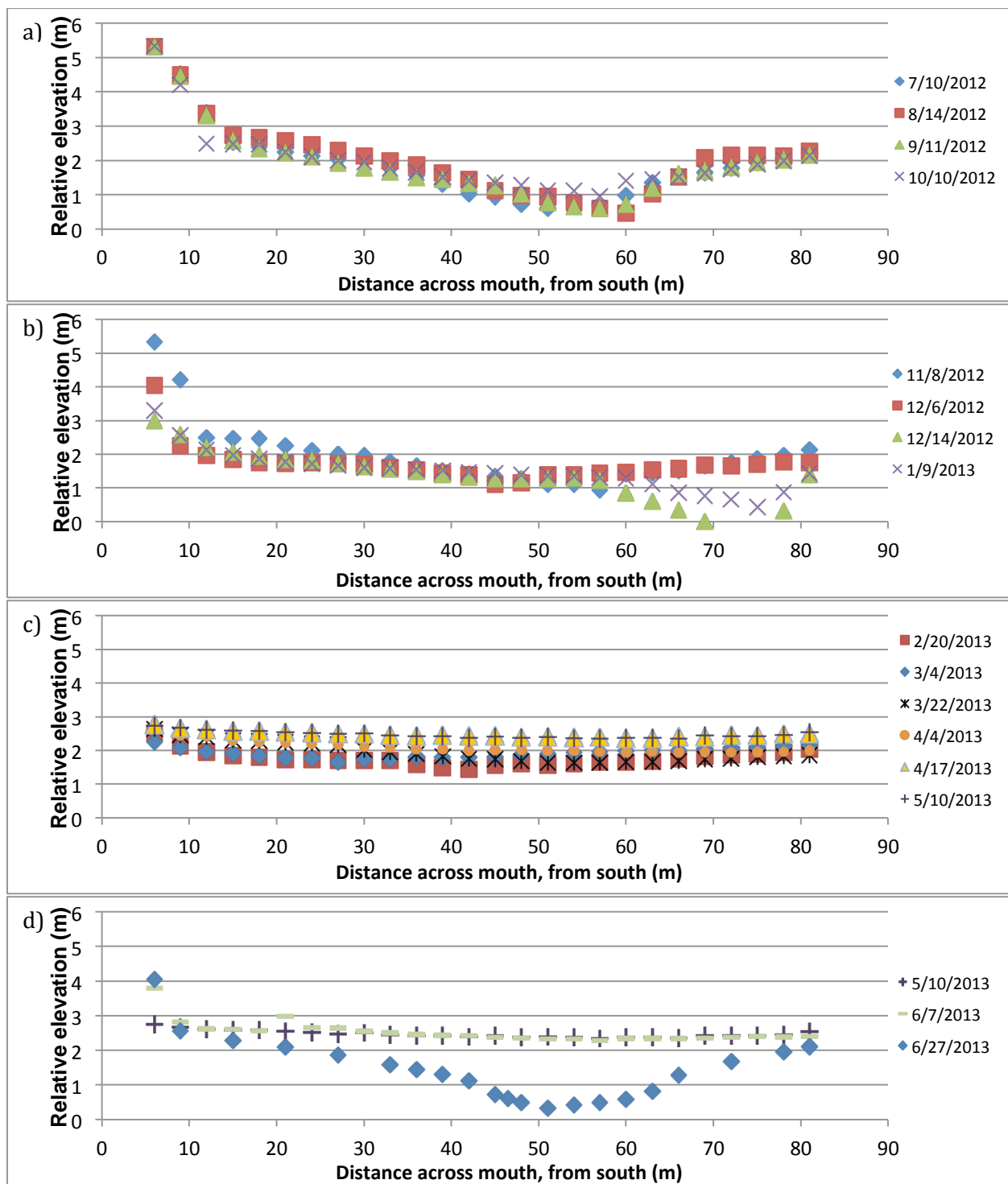


Figure 15 - Relative elevations at lagoon mouth, see text (above).



Figure 16 – Pictures of the lagoon mouth corresponding to the mouth profile sampling.





Figure 16, continued – Pictures of the lagoon mouth corresponding to the mouth profile sampling.



Figure 16, continued – Pictures of the lagoon mouth corresponding to the mouth profile sampling.

### *Inlet Management at LPL 2013*

An uncharacteristically large volume of sand was observed within the inlet at LPL during the spring of 2013. The inlet closed on March 23<sup>rd</sup> and remained closed until it was mechanically breached on May 14<sup>th</sup>. Funding issues coupled with the increased volume of sand at the inlet played a major role in the duration of this closure. The additional amount of sand within the Lagoon inlet required two separate efforts between May 2013 and June 2013 to mechanically remove ocean-borne sediments to restore connectivity with the ocean and allow impounded waters to drain. The estimated volume of sand removed from LPL during these two maintenance efforts was 40,000 cy and it is anticipated that a third maintenance effort may be needed before the Spring of 2014, since approximately 20,000 cy of sand still occlude the inlet area (M. Hastings, pers. comm.). This represents a 41% increase in the amount of sand removed annually from the Lagoon inlet between 2008-2012. Elevated beach profiles reduce tidal mixing within lagoon channels since the Lagoon is cut off from ocean waters for most of the tidal cycle. Furthermore, shoaling processes move sand off the beach and nearshore area, back into the lagoon inlet, further reducing and often negating tidal mixing within Los Peñasquitos Lagoon. Photos taken at Los Peñasquitos Lagoon in May 2013 and June 2013, as well as beach profile elevations using LIDAR data are provided in the Appendix to demonstrate elevated beach profiles.



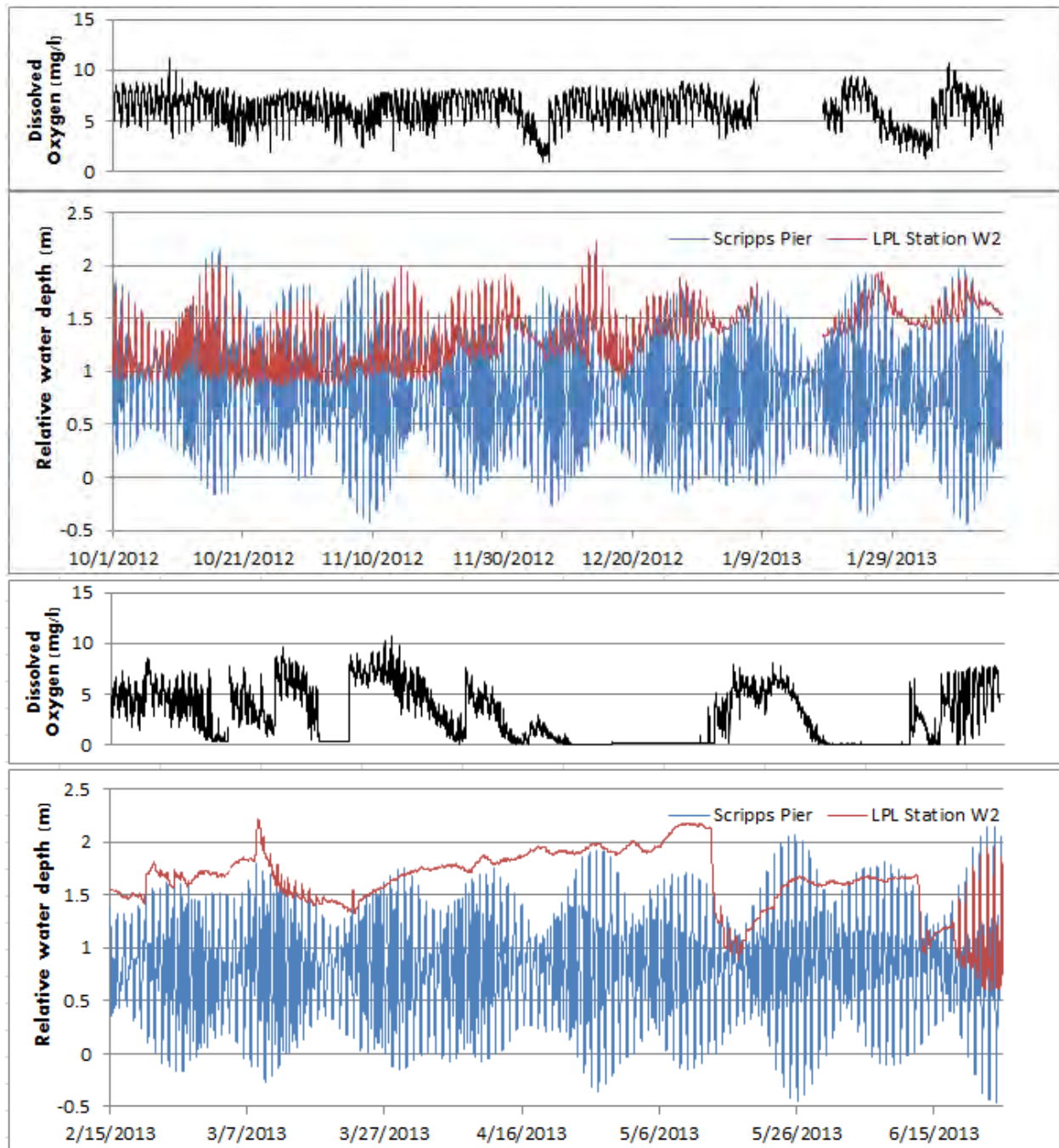


Figure 17 - 15-minute water depth and dissolved oxygen (DO) data from LPL Station W2 and 6-minute water depth from Scripps Pier for periods of intermittent mouth closures and re-openings.

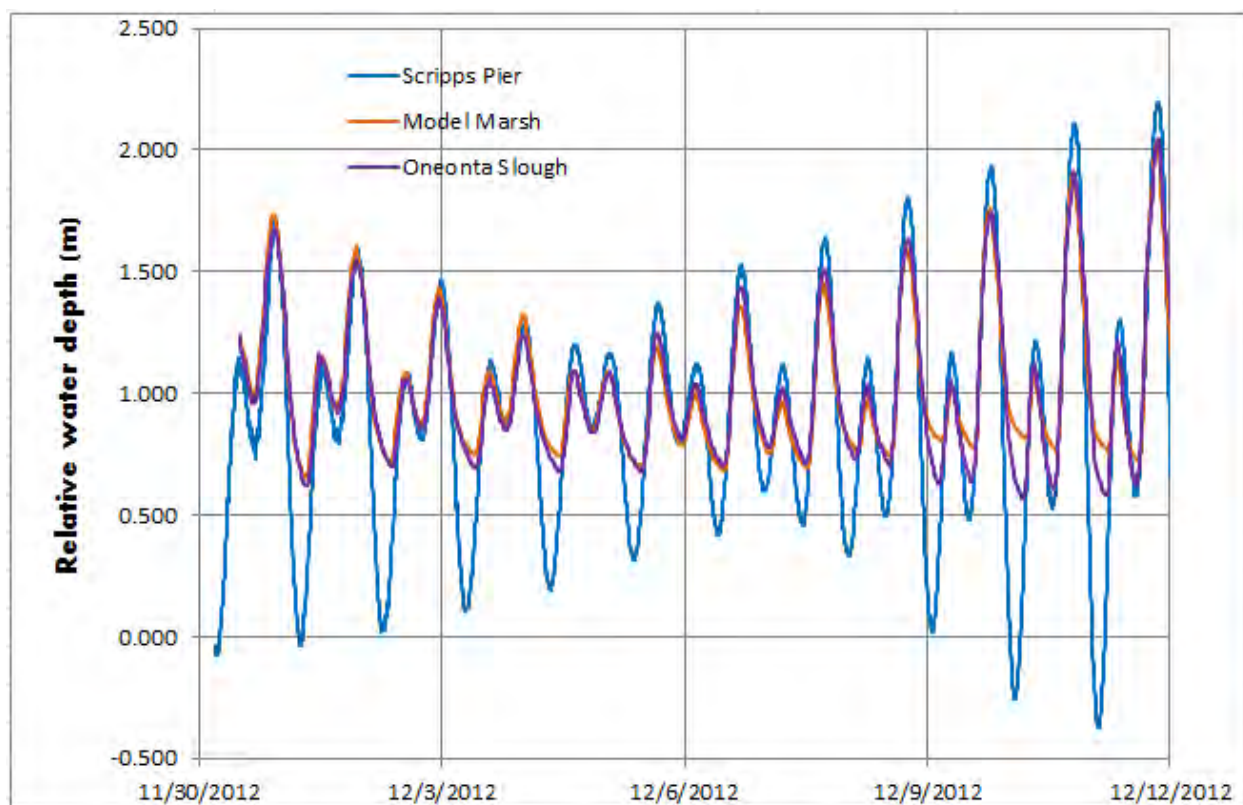


Figure 18 - 15-minute water depth data from two sites at the Tijuana River Estuary and 6-minute water depth from Scripps Pier for an irrelevant time period to show normal tidal influence at these sites. Oneonta Slough and Model Marsh are two sites being monitored for water quality in the northern arm and southern arm, respectively, of the estuary.

## NUTRIENTS AND CHLOROPHYLL

Monthly nutrient sampling commenced in April 2011 concomitant with sampling in the Tijuana River Estuary and south San Diego Bay. Monthly data from July 2012 - June 2013 are shown in Figure 19. The nutrient data for LPL levels tend to be more comparable to those found in San Diego Bay and typically lower than those found in the Tijuana Estuary, which receives sewage contaminated flows from Mexico.

Due to the mouth closure, elevated spikes in chlorophyll occurred in May and June as a result of an abundance of algal growth. These measurements of chlorophyll concentration, using a procedure to extract chlorophyll from whole cells, correlate well (see Figure 12) with estimates of chlorophyll concentration calculated by the datalogger's chlorophyll probe, which uses the fluorescent properties of chlorophyll as a proxy for its concentration. A light emitting diode (LED; at a wavelength of  $\sim 470\text{nm}$ ) induces chlorophyll fluorescence (at wavelengths of 650-700nm) and it is only this fluorescence that is then measured by a photodetector within the probe. These *in vivo* analyses are only estimates of chlorophyll concentration, though, and will not be as accurate as those using the extractive procedure (YSI Inc. 2011).

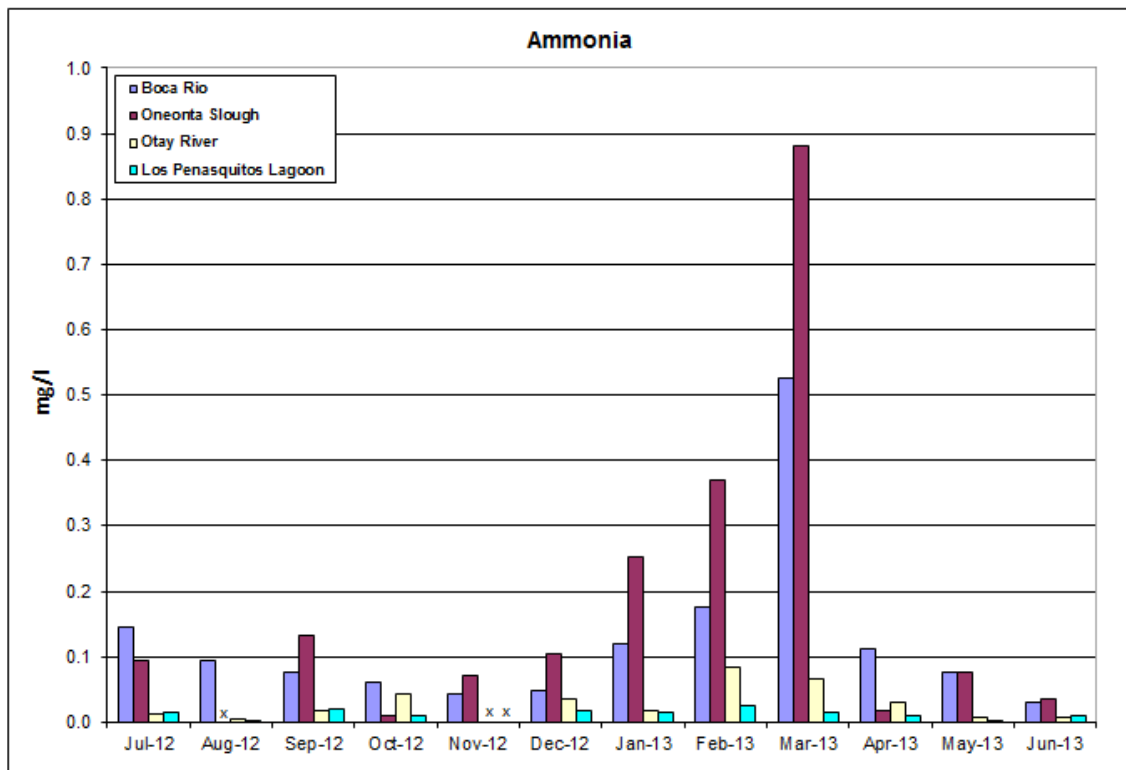
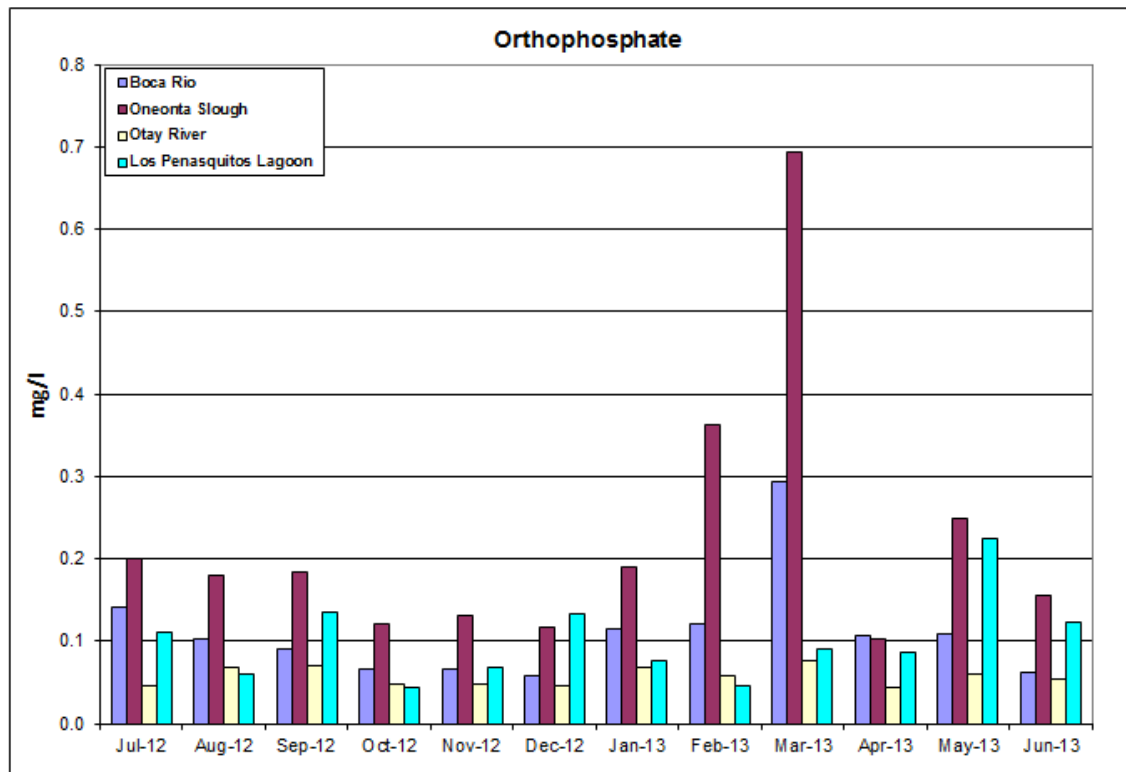


Figure 19 - Monthly nutrient data for two Tijuana Estuary sites (Boca Rio and Oneonta Slough), a San Diego Bay site (Otay River), and Los Peñasquitos Lagoon. “x” indicates no data.



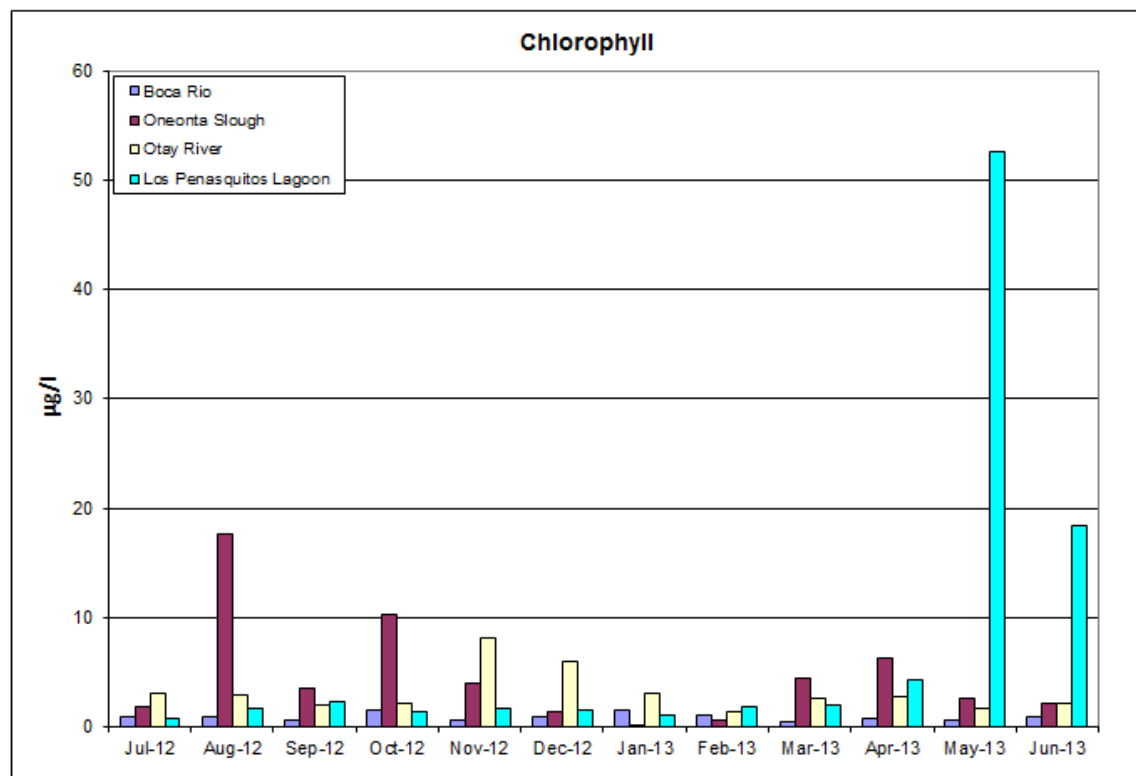
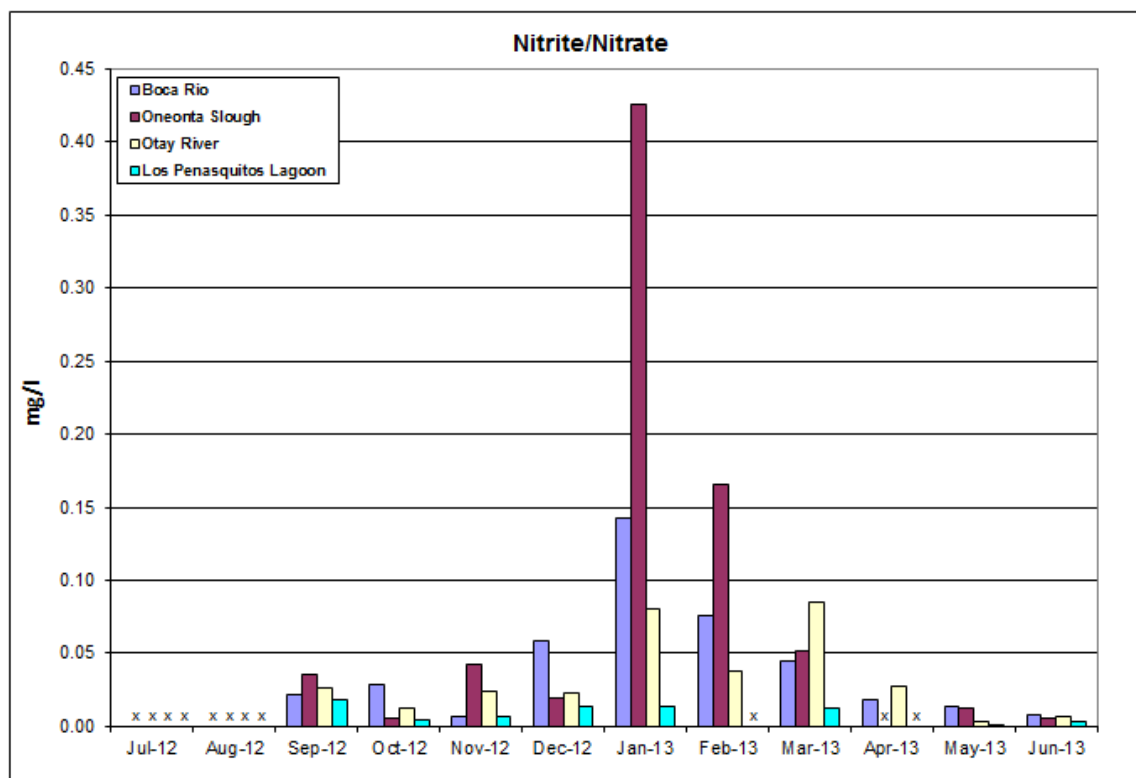


Figure 19, continued - Monthly nutrient data for two Tijuana Estuary sites (Boca Rio and Oneonta Slough), a San Diego Bay site (Otay River), and Los Peñasquitos Lagoon. "x" indicates no data.

## VEGETATION

<sup>SS</sup> = Saltmarsh Species

<sup>SSOP</sup> = Saltmarsh Species, Obligate Parasite

<sup>ES</sup> = Exotic Species

<sup>TSA</sup> = Transitional Species, Alkali

<sup>TSB</sup> = Transitional Species, Brackish

<sup>TSR</sup> = Transitional Species, Riparian

### *FALL 2012 VEGETATION MONITORING - TRANSECTS*

Vegetation transects throughout the lagoon were first established in 1991 to serve as long-term monitoring areas. The rationale for each transect's establishment, brief description, and change in mean percent cover of dominant vegetation types are described below and in Figure 20, as well as in Table 1. It should be noted that the names for pickleweed, shoregrass, saltmarsh bulrush, spearscale, bristly ox tongue, and Canadian horseweed have been changed from *Sarcoconia pacifica* to *Salicornia pacifica*, from *Monanthachloe littoralis* to *Distichlis littoralis*, from *Scirpus maritimus* to *Bolboschoenus maritimus ssp. paludosus*, from *Atriplex triangularis* to *Atriplex prostrata*, from *Picris echioides* to *Helminthotheca echioides*, and from *Conyza canadensis* to *Erigeron canadensis*, respectively. All references to these plant species have been updated to reflect these changes. Additional plant names are found in Table 3.

Vegetation surveys conducted along the transects for the 2012/2013 monitoring program occurred in October 2012. Overall, the dominant species found along the transects with regard to mean % cover were the following:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 32.3%



Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 29.2%



Alkali heath (*Frankenia salina*)<sup>SS</sup> – 19.0%



Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 7.3%

Survey indicated that 1.2% was completely or partially dead



Goldenbush (*Isocoma menziesii*) – 3.1%

Survey indicated that 1.2% was completely or partially dead



Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> – 2.4%

Survey indicated that 1.6% was completely or partially dead



Alkali weed (*Cressa truxillensis*) – 1.3%



TRANSECT 1. Transect 1 is located in the northwestern portion of the lagoon, west of the railroad and near the north beach parking lot (Figure 4). It is composed of two parallel 50-meter transects running approximately east to west. This site receives no tidal flushing and the soil tends to remain quite dry except following rainfall events or during a mouth closure. These transects were originally established to document the invasion of upper marsh and remnant dune habitat by upland weeds and exotic iceplant/hottentot fig (*Carpobrotus edulis*)<sup>ES</sup>.

Dominant vegetation types (mean % cover) when the transect was established in 1991 encompassed a mixture of saltmarsh, transition, and exotic species. Saltmarsh species dominated this transect, accounting for approximately 70% coverage. Individual species and their mean % cover found along this transect in 1991 included:

Alkali heath (*Cressa truxillensis*)<sup>SS</sup> – 25%

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 23%

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 22%

Iceplant/hottentot fig (*Carpobrotus edulis*)<sup>ES</sup> – 16%

Ragweed (*Ambrosia* sp.)<sup>TSA</sup> – 5%

Surveys along this transect performed in 2012 indicated that this transect was still dominated by saltmarsh species, however, there was a decline in mean % coverage of saltmarsh species and an increase % coverage for transitional species since 1991. There was also a decline in overall % coverage by exotic species that was most likely due to a manual removal program adopted in 1996 that virtually eliminated *C. edulis*<sup>ES</sup> from this site. Since 1998, there has been no *C. edulis* present along the transects, though the species is present in patches in the vicinity. *D. spicata*<sup>SS</sup> has remained the dominant saltmarsh species since the removal effort in 1996. Exotic species found included rabbitfoot grass (*Polypogon monspeliensis*)<sup>ES</sup>, dock (*Rumex sp.*)<sup>ES</sup>, sow thistle (*Sonchus sp.*)<sup>ES</sup>, wild radish (*Raphanus sativus*)<sup>ES</sup>, and Italian ryegrass (*Festuca perrennis*)<sup>ES</sup>, with the latter two only seen outside the transects this sampling year. Average soil salinity in 2012 was 12 ppt, with a range of 8 – 18 ppt.

Surveys along Transect 1 yielded the following mean % cover by dominant species:

Goldenbush (*Isocoma menziesii*)<sup>TSA</sup> – 32%

Survey indicated that 12% was completely or partially dead

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 22% (-1% from 1991 survey)

Survey indicated that 9% was completely or partially dead

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 11% (-11% from 1991 survey)

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 8% (-17% from 1991 survey)

Perennial glasswort (*Arthrocnemum subterminalis*)<sup>SS</sup> – 4%

Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – < 1%

TRANSECT 2. Transect 2 is located in the northwestern part of the lagoon near the entrance to the north beach parking lot, to the east of the railroad (Figure 4). It consists of two parallel 50-meter transects running north to south under utility lines. The site receives tidal water via a narrow channel that runs under the road at the parking lot entrance connecting to the main tidal channel approximately 175 meters to the southeast. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 46%

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 31%

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 19%

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 18%

Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – 14%

Species composition at Transect 2 has remained similar to what it was in 1991 though percent cover of each species has fluctuated. *S. pacifica*<sup>SS</sup>, *J. carnosa*<sup>SS</sup>, *F. salina*<sup>SS</sup>, *D. spicata*<sup>SS</sup>, and *C. truxillensis*<sup>SS</sup> have been present at this site since 1991. The obligate parasite, Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> was not found on this transect prior to 1995, but has been found

annually since then. *S. pacifica*<sup>SS</sup> was the dominant species in 2012 with a percent cover of 54% as opposed to *J. carnosa*<sup>SS</sup>, which was the dominate saltmarsh species at this transect in 1991 with 46% cover. Average soil salinity in 2012 was 42 ppt, with a range of 31 – 58 ppt.

Surveys along Transect 2 yielded the following mean % cover by dominant species:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 54% (+23% from 1991 survey)

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 19% (same % as in 1991 survey)

Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – 10% (-4% from 1991 survey)

Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 9% (-37% from 1991 survey)

Saltmarsh dodder (*Cuscuta salina*)<sup>OPSS</sup> – 8%

Survey indicated that 3% was completely or partially dead

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 5% (-13% from 1991 survey)

Survey indicated that < .1% was completely or partially dead

TRANSECT 3. Transect 3 is located in the western lagoon, just east of Highway 101, which is now referred to as N. Torrey Pines Road (Figure 4). This transect is 100 meters long, with 20 quadrats. It was established to document how *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup> dominance were correlated with periods of tidal exclusion and changes in soil salinity. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 56%

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 28%

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 20%

From 1991-2002, three species have shared dominance at this site: *S. pacifica*<sup>SS</sup>, *D. spicata*<sup>SS</sup> and *F. salina*<sup>SS</sup>. Since then, *F. salina*<sup>SS</sup> has become the dominant species (65%) followed by *S. pacifica*<sup>SS</sup> (36%). There are many freshwater species just west of Transect 3 where runoff from Highway 101 (a.k.a. N. Torrey Pines Road) enters the lagoon via a drainpipe. During the rainy season, this is likely a significant source of freshwater; continued monitoring will indicate any vegetative changes associated with this. Average soil salinity in 2012 was 64 ppt, with a range of 27 – 82 ppt.

Surveys along Transect 3 yielded the following mean % cover by dominant species:

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 65% (+37% from 1991 survey)

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 36% (-20% from 1991 survey)

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 13% (-7% from 1991 survey)

Survey indicated that 3% was completely or partially dead



Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> – > 2%

Survey indicated that the majority (2%) was completely or partially dead

Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – > 1%

Survey indicated that < 1% was completely or partially dead

TRANSECT 4. Transect 4 is also located in the western portion of LPL, east of Transect 3 (Figure 4). It is 80 meters long, oriented north to south, composed of 17 quadrats, and was established for the same reasons as Transect 3. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 38%

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 27 %

From the time monitoring began in 1991 until 2001, two species, *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup>, have dominated along the transect. In 2012, a small amount of saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> was found and *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup> are still the dominant species. Average soil salinity in 2012 was 86 ppt, with a range of 38 – 113 ppt.

Surveys along Transect 4 yielded the following mean % cover by dominant species:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 54% (+16% from 1991 survey)

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 36% (+9% from 1991 survey)

TRANSECT 5. Transect 5 is located in the southwestern portion of the lagoon, close to the upland transition zone (Figure 4). This transect is 50 meters long with 11 quadrats. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 44%

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 39%

Shoregrass (*Distichlis littoralis*)<sup>SS</sup> – 34%

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 10%.

From 1991 to 1998, *S. pacifica*<sup>SS</sup> coverage steadily increased to 89%, and has remained the dominant species since. Surveys along this transect performed in 2012 indicated that this transect was still dominated by saltmarsh species, with *S. pacifica*<sup>SS</sup> being the dominant species (69%). Average soil salinity in 2012 was 70 ppt, with a range of 50 – 90 ppt.

Surveys along Transect 5 yielded the following mean % cover by dominant species:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 69% (+30% since 1991 survey)

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 22% (-22% since 1991 survey)

Shoregrass (*Distichlis littoralis*)<sup>SS</sup> – 14% (-20% since 1991 survey)

Transects 9, 11 and 13 are all located in the northeast corner of the lagoon, near the Sorrento Valley and Carmel Valley Road intersection (Figure 4). Extensive development within the watershed has greatly increased disturbance, predominately through an increase in freshwater inflows. These three transects were established to monitor the expansion of exotic species near increased freshwater inflows along Carmel Valley Creek.

TRANSECT 9. Transect 9 is 40 meters long and is comprised of 9 quadrats. Vegetation at the time of transect establishment in 1991 was dominated by Pickleweed (*Salicornia pacifica*)<sup>SS</sup> with some Cattails (*Typha* sp.)<sup>TSB</sup>:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 81%

Cattails (*Typha* sp.)<sup>TSB</sup> – 20%

*Typha* sp.<sup>TSB</sup> cover has increased in recent years to 39% in 2012, though it dropped from 69% in 2011. *S. pacifica*<sup>SS</sup> has decreased along the transect over the past 13 years to 3% cover. *J. carnosa*<sup>SS</sup> was first present in the transect in 2000 (13%) and has since increased to 68% cover. Habitat conversion with regard to increases in % coverage of *Typha* sp.<sup>TSB</sup> are most likely due to perennial freshwater input from Carmel Valley and continuous dry weather flows from a storm drain outfall located at the northern end of this transect at Carmel Valley Road. Average soil salinity in 2012 was 48 ppt, with a range of 35 – 82 ppt.

Surveys along Transect 9 yielded the following mean % cover by dominant species:

Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 68%

Cattails (*Typha* sp.)<sup>TSB</sup> – 39% (+19% since 1991 survey; -30% from 2011 survey)  
Survey indicated that 28% was completely or partially dead

Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> – 9%  
Survey indicated that 8% was completely or partially dead

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 3% (-78% since 1991 survey)

Salt marsh fleabane (*Pluchea odorata*)<sup>SS</sup> – 2%

TRANSECT 11. Transect 11 is 20 meters long and comprises 5 quadrats (Figure 4). When originally set up in 1991, Transect 11 ran west to east for 60 meters, starting east of a small creek and was dominated by *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup>, though several exotic and transition species were also present. Vegetation at the time of transect establishment in 1991 was comprised of the following dominant species, consisting primarily of salt marsh species:

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 64%

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 36%

Spearscale (*Atriplex prostrata*)<sup>TSA</sup> – 16%

Curly dock (*Rumex crispus*)<sup>ES</sup> – 2%

Cattail (*Typha* sp.)<sup>TSB</sup> – 1%

By 1999, the eastern portion of the transect resembled a brackish marsh/riparian community dominated primarily by Cattail (*Typha* sp.)<sup>TSB</sup> and Willow (*Salix* sp.)<sup>TSR</sup>. *Typha* sp.<sup>TSB</sup> had also reached the edge of the creek. Assuming that *Typha* sp.<sup>TSB</sup> may not easily ‘jump’ the creek, in 2000 the transect was extended 30 meters to the west to further document the invasion of transitional and brackish species onto the marsh plain in this area of the lagoon. Since 2000, the eastern 60 meters of transect has been impassable due to extremely thick coverage by Cattail (*Typha* sp.)<sup>TSB</sup> and Willow (*Salix* sp.)<sup>TSR</sup>. The use of aerial photography and remote sensing data is needed to more accurately document the spread of Cattail (*Typha* sp.)<sup>TSB</sup> and Willow (*Salix* sp.)<sup>TSR</sup>. Since 2004, the transect includes only the area west of the creek. In 2008, only 25 meters of the 30-meter transect could be measured due to changes in the creek. In 2010, the transect was shortened again to 20 meters. Within this 20-meter section of Transect 11, *J. carnosus*<sup>SS</sup> (100%) was the dominant species in 2012. *C. salina*<sup>SS</sup>, *D. spicata*<sup>SS</sup>, *F. salina*<sup>SS</sup>, *S. pacifica*<sup>SS</sup>, and *A. prostrata*<sup>ES</sup> were also present with minimal coverage (< 1%). Average soil salinity in 2012 was 22 ppt, with a range of 19 – 25 ppt.

**TRANSECT 12.** Transect 12 runs the length of the eastern marsh, using SDG&E utility lines as an overhead guide (Figure 4). It was originally established to provide a rough estimate of exotic species invasion within the middle of the marsh and consisted of 5 sections of 135 meters each. It is the longest of the vegetation transects; 320 meters were sampled at 66 locations in 2012. *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup> were the dominant species in 1991, comprising 63% and 15% mean coverage, respectively. Upland transition species, including *R. crispus*, *A. prostrata*, *E. canadensis*, *Xanthium strumarium*, and exotic annual grasses were also present.

In 2008, there was a large increase in *J. carnosus*<sup>SS</sup>, compared to covers of less than 20% in recent years. *S. pacifica* was also still common at the site. The exotic species *Festuca perennis* and *Polypogon monspeliensis* were the dominant invaders. Over the years as exotic cover expanded, sampling diminished due to the difficulty of traversing through the stand of *Typha* sp.<sup>TSB</sup>. The last two of the original sections were not sampled in 2012, as *Typha* sp.<sup>TSB</sup> cover became too dense. As mentioned for transect 11, aerial photography and remote sensing would better characterize the spread of this exotic species as it is easily discernible from the height at which this type of data is collected. Average soil salinity in 2012 was 34 ppt, with a range of 5 – 75 ppt.

Surveys along Transect 12 yielded the following mean % cover by dominant species:

Fleshy Jaumea (*Jaumea carnosus*)<sup>SS</sup> – 49%

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 30% (-33% from 1991 survey)

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 17% (+2% from 1991 survey)

Unidentifiable dead grasses – 16%

Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> – > 2%

Survey indicated that the majority (2%) was completely or partially dead

Spearscale (*Atriplex prostrata*)<sup>ES</sup> – 1%

TRANSECT 13. Transect 13 was established in 2001 to enhance the ability to detect the expansion of exotic species near Carmel Valley due to increased, perennial freshwater inflows from this sub-watershed. Transect 13 was also created to replace Transect 10, which became impassable when *Typha* sp.<sup>T<sub>SB</sub></sup> expanded to the creek edge. Transect 13 is approximately 50 meters west of Transect 9 in the northeastern portion of the lagoon (Figure 4). It was originally 100 meters long and was comprised of two parallel 50 meter transects, 13A and 13B, which ran approximately south (adjacent to channel edge) to north (towards Carmel Valley Road). The exact location of transect 13A could not be found due to coverage by *Typha* sp.<sup>T<sub>SB</sub></sup> and was discontinued in 2004. In 2011, 13A was again located and surveyed. In 2001, *S. pacifica*<sup>SS</sup> overwhelmingly dominated Transect 13B with ~85% cover. The transects in 2012 indicated that coverage by *S. pacifica*<sup>SS</sup> had been reduced to 4%. At the same time, *J. carnosus* has increased from 6% cover in 2001 to become the dominant species in 2012 (89%). Average soil salinity in 2012 was 53 ppt, with a range of 39 – 68 ppt.

Surveys along Transect 13 yielded the following mean % cover by dominant species:

Fleshy Jaumea (*J. carnosus*)<sup>SS</sup> – 89%

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 7%

Shoregrass (*Distichlis littoralis*)<sup>SS</sup> – 7%

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 4% (-81% from 2001 survey)

Spiny rush (*Juncus acutus*)<sup>T<sub>SA</sub></sup> – 2%

Toad rush (*Juncus balticus*)<sup>T<sub>SA</sub></sup> – 1%

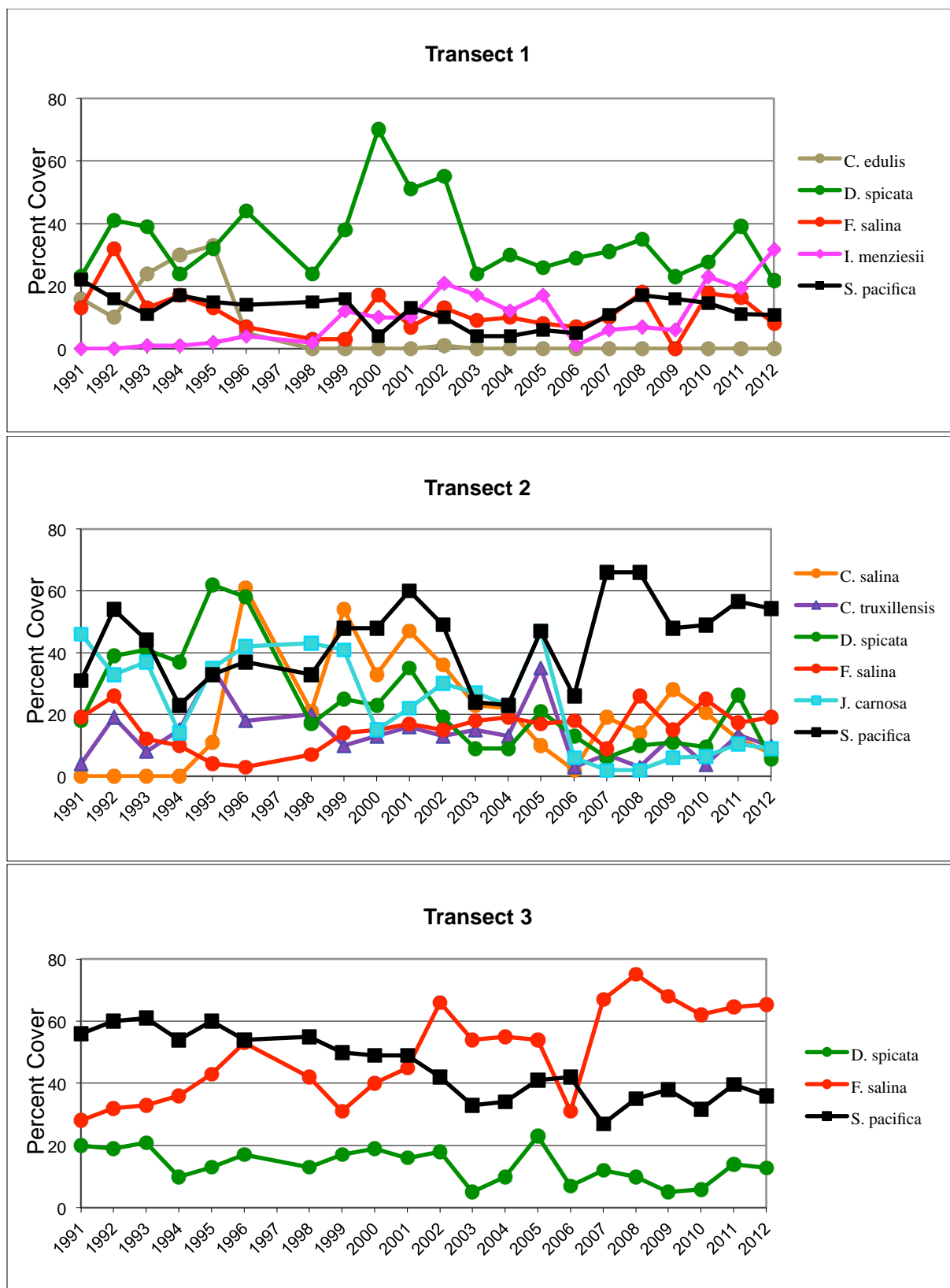


Figure 20 - Long-term vegetation data for dominant species for transects 1 – 5, 9, and 11 – 13, displaying % cover from 1991 – 2012.

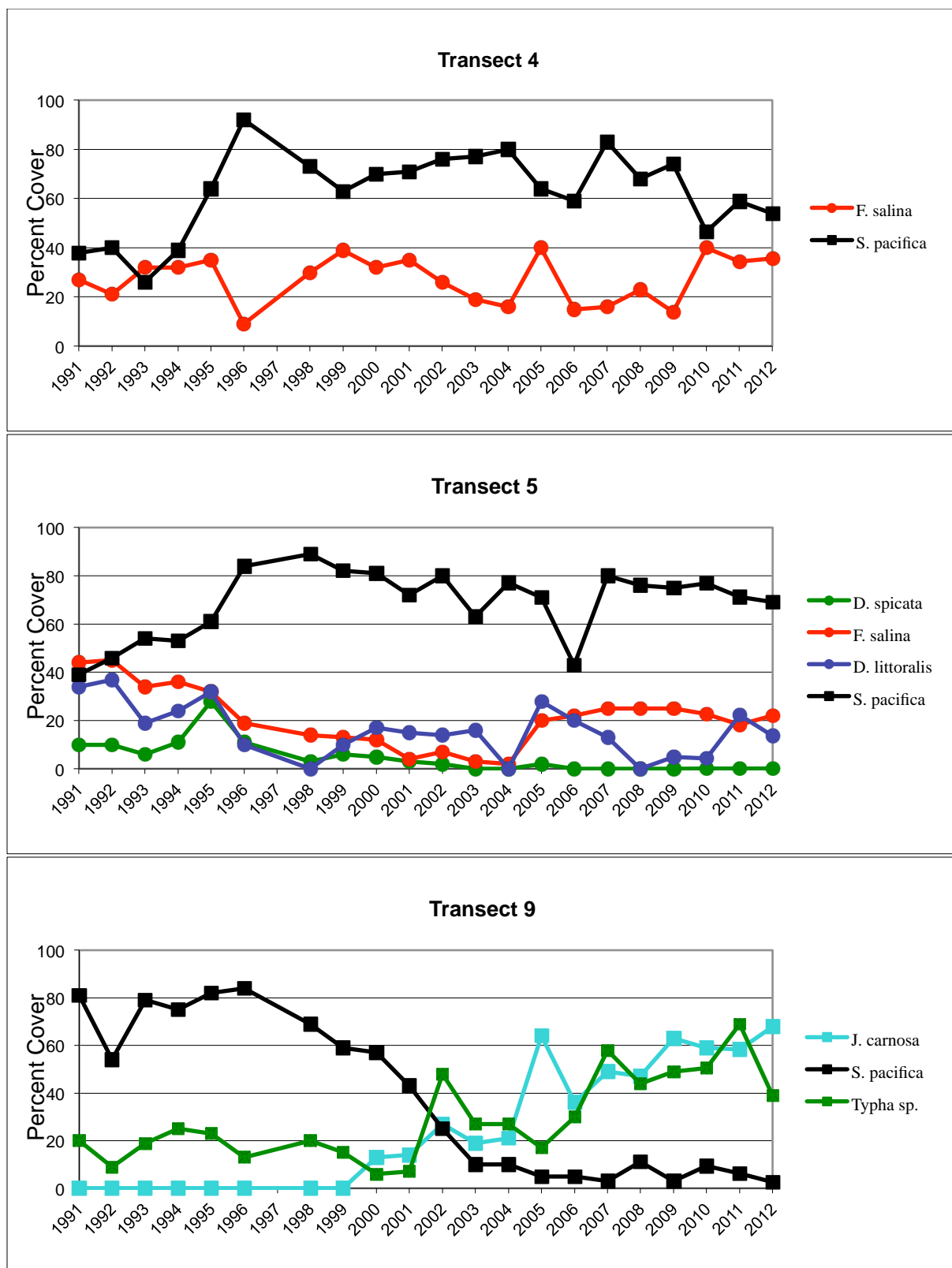


Figure 20, continued - Long-term vegetation data for dominant species for transects 1 – 5, 9, and 11 – 13, displaying % cover from 1991 – 2012.



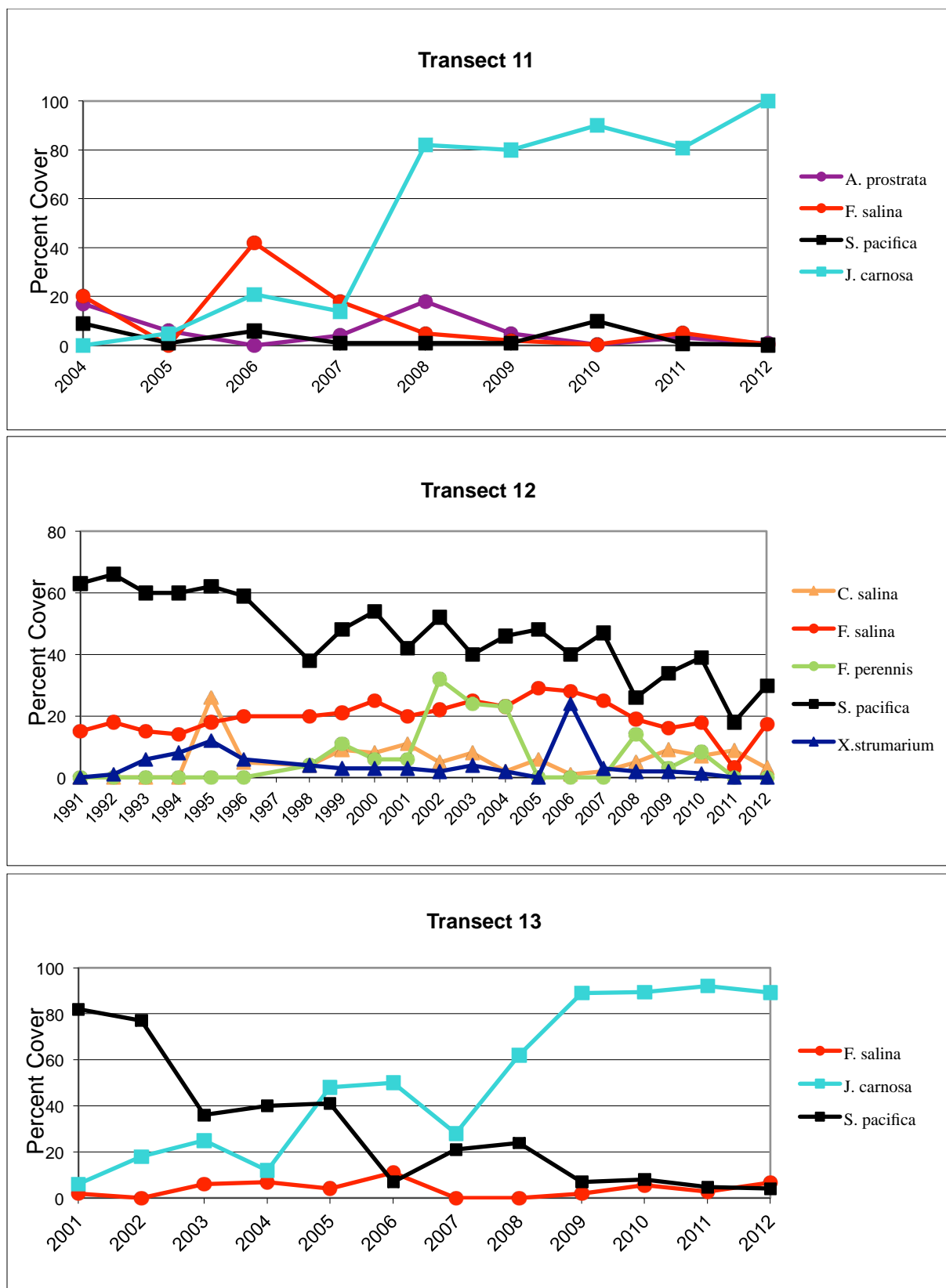


Figure 20, continued - Long-term vegetation data for dominant species for transects 1 – 5, 9, and 11 – 13, displaying % cover from 1991 – 2012, continued.

## SPRING 2012 VEGETATION MONITORING – TRANSECTS

**TRANSECT 14.** Annual *Lasthenia glabrata* ssp. *coulteri* monitoring took place for the sixth year in March 2013 along Transect 14. The average cover of *Lasthenia glabrata* ssp. *coulteri* was 4.2%, indicating an increase in cover from last year, but an overall decline over the entire sampling period (Figure 21). The dominant species was *S. pacifica*<sup>SS</sup> with lower coverage of several native salt marsh species. *Cotula coronopifolia* and *Parapholis incurva*, both non-native species, were also present. Average soil salinity in 2012 was 33 ppt, with a range of 5 – 82 ppt.

Surveys along Transect 14 yielded the following mean % cover by dominant species:

Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 45%

Alkali heath (*Frankenia salina*)<sup>SS</sup> – 6%

Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 21%

Shoregrass (*Distichlis littoralis*)<sup>SS</sup> – 2%

Curved Sicklegrass (*Parapholis incurva*)<sup>ES</sup> – 4%

Brass Buttons (*Cotula coronopifolia*)<sup>ES</sup> – 8%

Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 2%

Perennial glasswort (*Arthrocnemum subterminale*)<sup>SS</sup> – 4%

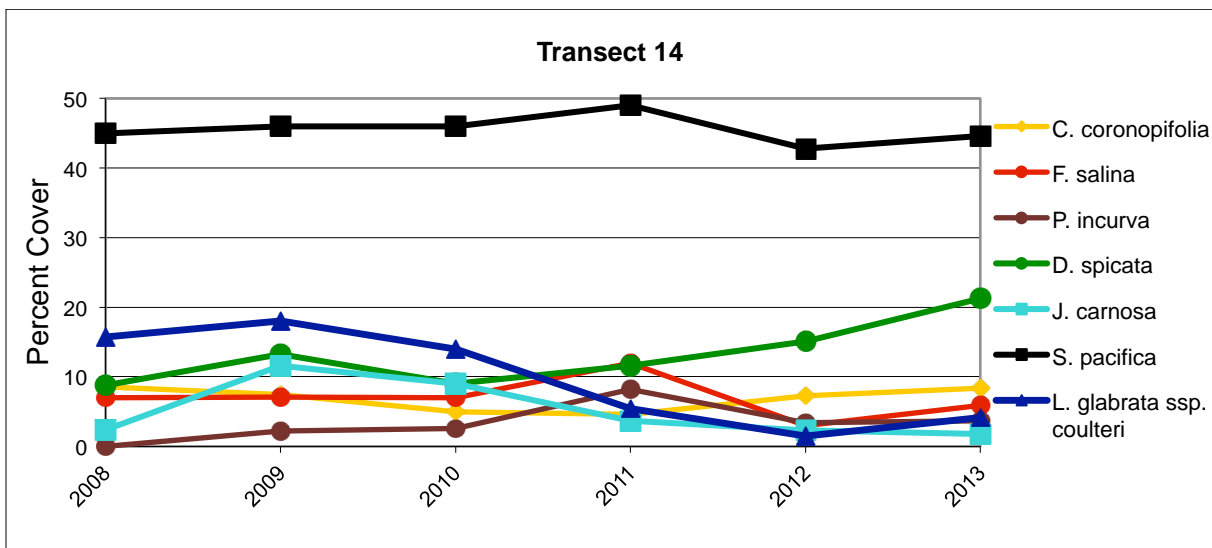


Figure 21 - Long-term data for spring vegetation transect 14, displaying % cover of *Lasthenia glabrata* ssp. *coulteri* and other dominant species.

| Transect #                              | 1   | 2       | 3       | 4      | 5      | 9      | 11     | 12      | 13      | 14      |
|---|---|---------|---------|--------|--------|--------|--------|---------|---------|---------|
| Average Soil Salinity (ppt)             | 12  | 42      | 64      | 86     | 70     | 48     | 22     | 34      | 53      | 33      |
| Mean total percent cover                | 96  | 94      | 99      | 86     | 92     | 97     | 100    | 100     | > 99    | 90      |
| Wrack / Litter percent cover            | 22  | 1       | 0       | 0      | 0      | 0      | 0      | 1       | 0       | 0       |
| <b>Saltmarsh species</b>                | <b>Mean % cover of individual species</b> |         |         |        |        |        |        |         |         |         |
| Amblyopappus pusillus*                  | < .1                                      |         |         |        |        |        |        |         |         |         |
| Arthrocnemum subterminale               | 4   |         |         |        |        |        |        |         |         | 4       |
| Cressa truxillensis                     | < 1                                       | 10      | 1       |        | < .1   |        |        | < 1     |         | < 1     |
| Cressa truxillensis*                    | < .1                                      |         | < 1     |        |        |        |        | < .1    |         | < 1     |
| Cuscuta salina                          |   | 5       | < 1     | < 1    | < .1   | 1      | < 1    | < 1     | < .1    | < 1     |
| Cuscuta salina*                         |   | 3       | 2       | < 1    | < 1    | 8      | < 1    | 2       | < 1     | < .1    |
| Distichlis spicata                      | 13  | 5       | 10      | < 1    | < 1    |        | < 1    |         | 7       | 21      |
| Distichlis spicata*                     | 9   | < .1    | 3       |        |        |        |        |         |         |         |
| Distichlis littoralis                   | < .1                                      |         |         |        | 14     |        |        |         |         | 2       |
| Frankenia salina                        | 8   | 19      | 65      | 36     | 22     |        | < 1    | 17      | 7       | 6       |
| Frankenia salina*                       |   |         |         |        |        |        |        | < 1     |         |         |
| Jaumea carnosa                          |   | 9       |         |        | < 1    | 68     | 100    | 49      | 89      | 2       |
| Lasthenia glabrata ssp. coulteri        |   |         |         |        |        |        |        |         |         | 4       |
| Limonium californicum                   |   | < .1    |         |        |        |        |        |         |         |         |
| Pluchea odorata                         |   |         |         |        |        | 2      |        | < 1     |         |         |
| Salicornia pacifica                     | 11  | 54      | 36      | 54     | 69     | 3      | < 1    | 30      | 4       | 45      |
| <b>Transitional species</b>             |   |         |         |        |        |        |        |         |         |         |
| Atriplex californica                    | < .1                                      |         |         |        |        |        |        |         |         |         |
| Atriplex californica*                   |   |         | 1       |        |        |        |        |         |         |         |
| Baccharis pilularis                     | 2   |         |         |        |        |        |        |         |         |         |
| Bolboschoenus maritimus ssp. paludosus  |   |         |         |        |        | < 1    |        |         |         |         |
| Bolboschoenus maritimus ssp. paludosus* |   |         |         |        |        |        |        | < 1     | < 1     |         |
| Heliotropium curassavicum               | 1   |         |         |        |        |        |        |         |         |         |
| Isocoma menziesii                       | 20  |         |         |        |        |        |        |         |         |         |
| Isocoma menziesii*                      | 12  |         |         |        |        |        |        |         |         |         |
| Juncus acutus                           |   |         |         |        |        |        |        |         | 2       |         |
| Juncus balticus                         |   |         |         |        |        |        |        |         | 1       |         |
| Pterostegia drymarioides*               | 2   |         |         |        |        |        |        |         |         |         |
| Spergularia sp.                         |   |         |         |        |        |        |        |         |         | < 1     |
| Typha sp.                               |   |         |         |        |        | 11     |        | < 1     |         |         |
| Typha sp.*                              |   |         |         |        |        | 28     |        |         |         |         |
| Xanthium strumarium*                    |   |         |         |        |        |        |        | < .1    |         |         |
| <b>Exotic species</b>                   |   |         |         |        |        |        |        |         |         |         |
| Atriplex prostrata                      |   |         |         |        |        |        | < 1    | 1       |         | < .1    |
| Cotula coronopifolia                    |   |         |         |        |        |        |        |         |         | 8       |
| Helminthotheca echioides                |   |         |         |        |        |        |        |         |         | < .1    |
| Lactuca serriola                        |   |         |         |        |        |        |        |         |         | < .1    |
| Medicago polymorpha                     |   |         |         |        |        |        |        |         |         | < 1     |
| Mesembryanthemum nodiflorum             |   |         |         |        |        |        |        |         |         | < .1    |
| Parapholis incurva                      |   |         |         |        |        |        |        |         |         | 4       |
| Polypogon monspeliensis                 |   |         |         |        |        |        |        |         |         | 4       |
| Polypogon monspeliensis*                | < 1                                       |         |         |        |        |        |        | < 1     |         | < 1     |
| Rumex sp.                               | < .1                                      |         |         |        |        |        |        |         |         | < .1    |
| Sonchus sp.                             | < .1                                      |         |         |        |        |        |        |         |         | < 1     |
| Unidentifiable Dead Grass(es)           |   |         |         |        |        |        |        | 16      |         | < 1     |
| Number of transects / total length (m)  | 2 / 100                                   | 2 / 100 | 1 / 100 | 1 / 80 | 1 / 50 | 1 / 40 | 1 / 20 | 3 / 320 | 2 / 100 | 1 / 140 |
| Number of quadrats                      | 22  | 22      | 20      | 17     | 11     | 9      | 5      | 66      | 22      | 29      |

Table 1. Mean percent cover of Los Peñasquitos Lagoon vegetation transects. All transects were surveyed in October 2012 except for transect 14 (March 2013). Asterisks (\*) indicate species that were completely or partially dead at the time of sampling.

### TRANSECTS - SWMP Protocols

As part of the National Estuarine Research Reserve's System Wide Monitoring Program (SWMP), new transects were established across elevation zones to detect shifts in vegetation with increasing elevation, from marsh assemblages to those characteristic of the upland transition zone. The first full sampling occurred in October 2012 and March 2013 (Figure 20). These new transects will allow for the monitoring of vegetation and habitat changes that will occur in response to sea level rise.

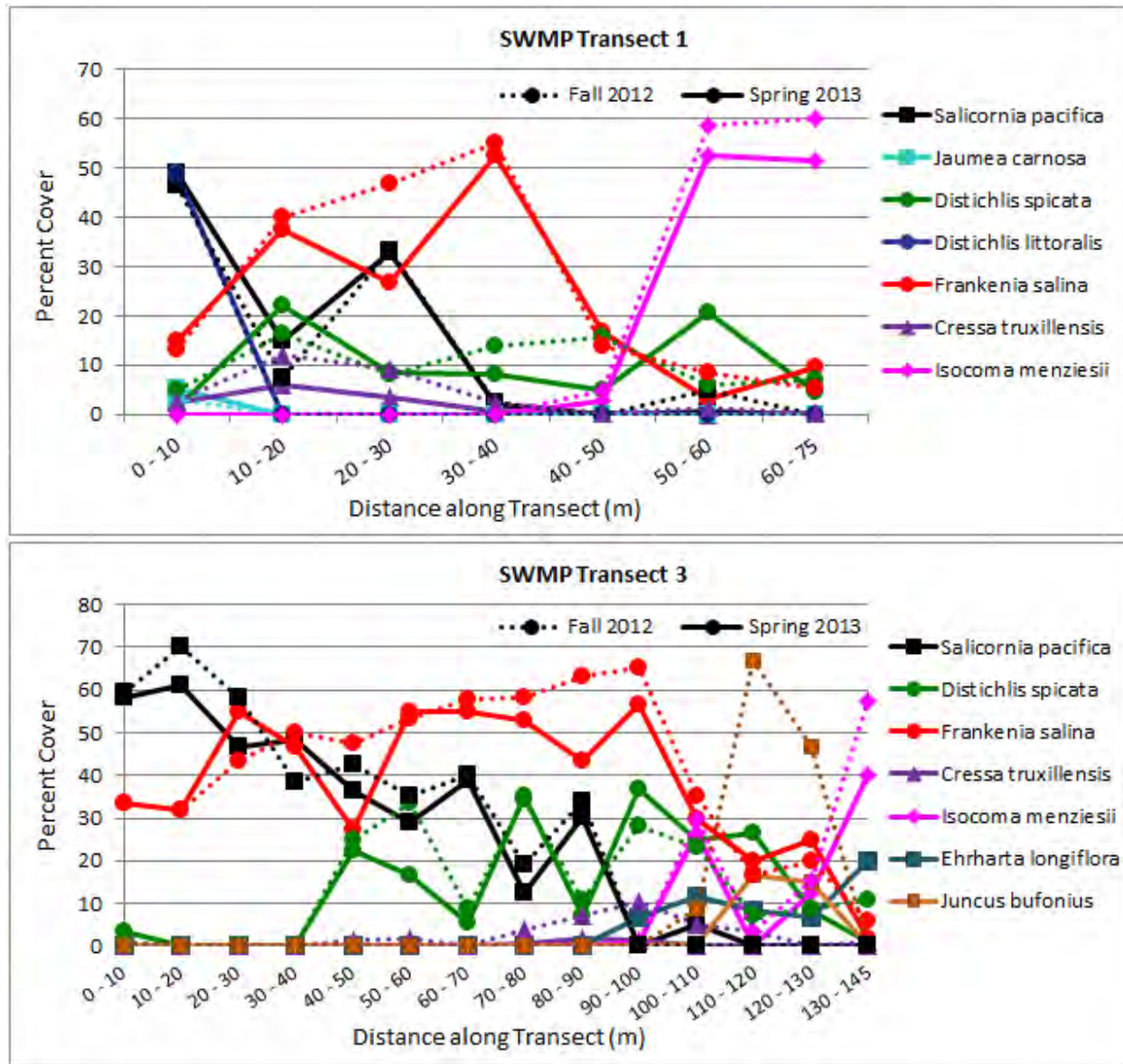


Figure 22 - Data from transects across vegetation zones. Transects begin in the tidal marsh and end in the upland transition zone. *Ehrharta longiflora* was not identified in the fall, however, there was significant cover (16%) of dead grass that was unidentifiable in those quadrats where it was present in the spring.

|  | FALL 2012                          |         | SPRING 2013 |         |
|--|------------------------------------|---------|-------------|---------|
| Transect #                             | SWMP 1                             | SWMP 3  | SWMP 1      | SWMP 3  |
| Average Soil Salinity (ppt)            | 26                                 | 54      | 12          | 15      |
| Mean total percent cover               | > 99                               | 95      | 99          | 94      |
| Wrack / Litter percent cover           | 19                                 | 0       | 13          | 7       |
| <b>Saltmarsh species</b>               | Mean % cover of individual species |         |             |         |
| <i>Amblyopappus pusillus</i>           | < 1                                |         | < 1         |         |
| <i>Arthrocnemum subterminale</i>       | 4                                  |         | 3           |         |
| <i>Cressa truxillensis</i>             | 1                                  | 1       | < 1         | < 1     |
| <i>Cressa truxillensis*</i>            | 2                                  | 1       | < 1         | < .1    |
| <i>Cuscuta salina</i>                  | < 1                                | < 1     | < 1         | < 1     |
| <i>Cuscuta salina*</i>                 | 2                                  | 1       | < 1         |         |
| <i>Distichlis spicata</i>              | 5                                  | 12      | 5           | 14      |
| <i>Distichlis spicata*</i>             | 4                                  | 2       | 3           |         |
| <i>Distichlis littoralis</i>           | 9                                  |         | 9           |         |
| <i>Frankenia salina</i>                | 22                                 | 42      | 20          | 39      |
| <i>Frankenia salina*</i>               |                                    | < 1     |             |         |
| <i>Jaumea carnosa</i>                  | < 1                                | < 1     | 1           | 2       |
| <i>Limonium californicum</i>           | < .1                               |         | < 1         |         |
| <i>Salicornia pacifica</i>             | 15                                 | 29      | 16          | 27      |
| <b>Transitional species</b>            |                                    |         |             |         |
| <i>Ambrosia psilostachya</i>           | < 1                                | < .1    | < 1         | < 1     |
| <i>Atriplex californica</i>            | < .1                               | < 1     | < 1         | < 1     |
| <i>Baccharis pilularis</i>             |                                    |         |             | < 1     |
| <i>Cylindropuntia prolifera</i>        |                                    | < .1    |             | < .1    |
| <i>Elymus triticoides</i>              |                                    |         | < .1        | < 1     |
| <i>Galium</i> sp.                      |                                    |         |             | < .1    |
| <i>Isocoma menziesii</i>               | 7                                  | 6       | 6           | 5       |
| <i>Isocoma menziesii*</i>              | 13                                 | < .1    | 11          | < 1     |
| <i>Juncus balticus</i>                 |                                    | 2       |             | 2       |
| <i>Juncus balticus*</i>                |                                    | 6       |             | 4       |
| <i>Lepidium virginicum</i>             |                                    |         | < .1        |         |
| <i>Pseudognaphalium biolettii</i>      |                                    |         | < 1         |         |
| <i>Pterostegia drymarioides</i>        |                                    |         | 12          | < .1    |
| <i>Pterostegia drymarioides*</i>       | 7                                  |         |             |         |
| <b>Exotic species</b>                  |                                    |         |             |         |
| <i>Anagallis arvensis</i>              |                                    |         | < 1         |         |
| <i>Atriplex prostrata</i>              | < .1                               | < 1     |             | < .1    |
| <i>Bromus</i> sp.                      |                                    |         |             | < 1     |
| <i>Carpobrotus edulis</i>              |                                    |         | < .1        |         |
| <i>Ehrharta longiflora</i>             |                                    |         | 3           | 3       |
| <i>Erodium cicutarium</i>              |                                    |         |             | < .1    |
| <i>Lactuca serriola</i>                |                                    |         | < .1        |         |
| <i>Melilotus indicus</i>               |                                    |         | < .1        |         |
| <i>Oxalis pes-caprae</i>               |                                    |         | < 1         |         |
| <i>Parapholis incurva</i>              |                                    |         | < 1         |         |
| <i>Polypogon monspeliensis*</i>        | < 1                                |         |             |         |
| <i>Raphanus sativus</i>                | < 1                                |         | < 1         |         |
| <i>Rumex</i> sp.                       | < 1                                |         | < 1         |         |
| <i>Sonchus</i> sp.                     | < 1                                |         | 2           | < 1     |
| Unidentifiable Dead Grass(es)          |                                    | 7       |             |         |
| Number of transects / total length (m) | 3 / 216                            | 3 / 385 | 3 / 216     | 3 / 385 |
| Number of quadrats                     | 21                                 | 42      | 21          | 42      |

Table 2. Mean percent cover of Los Peñasquitos Lagoon SWMP vegetation transects. Fall transects were surveyed in October 2012 and spring transects were surveyed in March 2013. Asterisks (\*) indicate species that were completely or partially dead at the time of sampling.

Table 3. Plant species found on LPL vegetation transects, 1991-2013.

| <u>Scientific Name</u>   | <u>Common Name</u>               | <u>CNPS Rare Plant Rank</u> <sup>†</sup>  |
|--|----------------------------------|---|
| <u>Saltmarsh Species</u>   |                                  |   |
| <i>Amblyopappus pusillus</i>   | dwarf coastweed / pineapple weed |   |
| <i>Arthrocnemum subterminale</i><br>( <i>Salicornia subterminalis</i> )                        | Parish's glasswort               |   |
| <i>Cressa truxillensis</i>   | alkali weed                      |   |
| <i>Cuscuta salina</i>  | salt marsh dodder                |   |
| <i>Distichlis littoralis</i><br>( <i>Monanthochloe littoralis</i> )                            | shore grass                      |   |
| <i>Distichlis spicata</i>  | saltgrass                        |   |
| <i>Frankenia salina</i> ( <i>Frankenia grandifolia</i> )                                       | alkali heath                     |   |
| <i>Jaumea carnosa</i>  | fleshy Jaumea                    |   |
| <i>Limonium californicum</i>   | California sea lavender          |   |
| <i>Lasthenia glabrata</i> ssp. <i>coulteri</i>   | Coulter's goldfields             | 1B.1 - Rare, threatened, or endangered in California & elsewhere; .1: seriously endangered in California) |
| <i>Pluchea odorata</i> var. <i>odorata</i>   | salt marsh fleabane              |   |
| <i>Salicornia depressa</i><br>( <i>Salicornia europaea</i> )                                   | glasswort                        |   |
| <i>Salicornia pacifica</i><br>( <i>Salicornia virginica</i> ,<br><i>Sarcocornia pacifica</i> ) | pickleweed / Pacific swampfire   |   |
| <i>Spergularia marina</i>  | salt marsh sand spurry           |   |
| <u>Transition Species</u>  |                                  |   |
| <i>Acmispon glaber</i> ( <i>Lotus scoparius</i> )  | deerweed / CA broom              |   |
| <i>Ambrosia psilostachya</i>   | western ragweed                  |   |
| <i>Atriplex californica</i>  | CA saltbush                      |   |
| <i>Baccharis pilularis</i>   | coyote brush                     |   |
| <i>Baccharis salicifolia</i>   | mule fat / seep willow           |   |
| <i>Baccharis sarothroides</i>  | broom baccharis                  |   |
| <i>Bolboschoenus maritimus</i> ssp. <i>paludosus</i> ( <i>Scirpus maritimus</i> )              | alkali bulrush                   |   |



|   |   |  |
|---|---|--|
| <i>Cylindropuntia prolifera</i>                                   | coastal cholla  |  |
| <i>Erigeron canadensis</i> ( <i>Conyza canadensis</i> )           | Canadian horsetweed   |  |
| <i>Eleocharis sp.*</i>  | spikerush   |  |
| <i>Elymus triticoides</i>   | Beardless wild rye  |  |
| <i>Galium sp.*</i>  | bedstraw  |  |
| <i>Heliotropium curassavicum</i>                                  | salt heliotrope / Chinese Parsley                                   |  |
| <i>Isocoma menziesii</i> var. <i>menziesii</i>                    | Menzie's / Coast goldenbush   |  |
| <i>Juncus acutus</i> ssp. <i>Leopoldii</i>                        | Leopold's rush / southwestern spiny rush                            | 4.2 - Uncommon in California;<br>.2: Fairly endangered in California |
| <i>Juncus balticus</i> ssp. <i>Ater</i>                           | Baltic rush   |  |
| <i>Lepidium virginicum*</i>                                       | Virginia pepperweed / wild pepper grass                             |  |
| <i>Pilularia americana</i>  | American pillwort   | CBR – Considered but rejected  |
| <i>Psuedognaphalium bioletti</i> ( <i>Gnapalium bicolor</i> )     | two-color rabbit-tobacco, Bioletti's cudweed, bicolored everlasting |  |
| <i>Pterostegia drymarioides</i>                                   | granny's hairnet / fairymist  |  |
| <i>Salix sp</i>   | willow  |  |
| <i>Typha sp</i>   | cattail   |  |
| <i>Xanthium strumarium</i>  | cocklebur   |  |
| <u>Exotic Species</u>   |   |  |
| <i>Anagallis arvensis</i>   | scarlet pimpernel.  |  |
| <i>Atriplex prostrate</i> ( <i>Atriplex triangularis</i> )        | spearscale  |  |
| <i>Brassica nigra</i>   | black mustard   |  |
| <i>Bromus hordeaceus</i>  | soft brome / soft chess   |  |
| <i>Cakile maritime</i>  | European sea rocket   |  |
| <i>Carpobrotus edulis</i>   | hottentot fig / iceplant  |  |
| <i>Cortaderia selloana</i>  | Uruguayan pampas grass  |  |
| <i>Cotula coronopifolia</i>                                       | brass buttons   |  |
| <i>Crypsis schoenoides</i>  | swamp picklegrass   |  |
| <i>Dysphania ambrosioides</i> ( <i>Chenopodium ambrosioides</i> ) | Mexican tea   |  |

|  |                               |
|--|-------------------------------|
| <i>Ehrharta longiflora</i>                                     | longflowered veldtgrass       |
| <i>Erodium cicutarium</i>                                      | red stemmed filaree           |
| <i>Festuca perennis</i><br>( <i>Lolium multiflorum</i> )       | Italian ryegrass              |
| <i>Helminthotheca echioides</i><br>( <i>Picris echioides</i> ) | bristly oxtongue              |
| <i>Lactuca serriola</i>  | prickly wild lettuce          |
| <i>Lythrum hyssopifolia</i>                                    | Hyssop's loosestrife          |
| <i>Medicago polymorpha</i>                                     | bur medic / bur clover        |
| <i>Melilotus indicus</i>                                       | annual yellow sweetclover     |
| <i>Mesembryanthemum nodiflorum</i>                             | slender leaved iceplant       |
| <i>Oxalis pes-caprae</i>                                       | Bermuda buttercup / sourgrass |
| <i>Parapholis incurve</i>                                      | curved sicklegrass            |
| <i>Polypogon monspeliensis</i>                                 | rabbitsfoot grass             |
| <i>Raphanus sativus</i>  | wild radish                   |
| <i>Rumex crispus</i>   | curly dock                    |
| <i>Sonchus asper</i>   | prickly sow thistle           |
| <i>Sonchus oleraceus</i>                                       | common sow thistle            |

<sup>†</sup> for more information on the California Native Plant Society's ranking system, visit <http://www.cnps.org/cnps/rareplants/inventory/>

( ) indicates old nomenclature

\* was not identified to its lowest taxonomic rank

## IV. CONCLUSIONS AND RECOMMENDATIONS

The conditions in Los Peñasquitos Lagoon appear to be fairly typical of recent years, aside from the inlet closure sequence requiring two openings. A primary concern remains this closure of the lagoon mouth, which can quickly lead to deteriorated water quality. This last year saw a major mouth closure that spanned almost two months (March - May) and was characterized by decreased water quality (i.e. DO bottoming out at 0 mg/l) and subsequent recovery with returned tidal exchange. The inlet closure resulted in some fish kills and impacts to salt marsh vegetation due to inundation from perennial flows of freshwater from the watershed (pers. obs.).

Mechanical clearing of the mouth occurred in mid- May 2012 by California State Parks. The inlet was mechanically breached on May 13<sup>th</sup>, resulting in a large outflow of impounded waters that scoured the inlet area back down to MSL. In past years, when impounded waters were released by breaching the inlet, the inlet had remained open and allowed excavation efforts to focus on reconnecting the Lagoon's main tidal channel to the ocean inlet. However, unlike past years, the breach of the inlet on May 13<sup>th</sup> was not successful in keeping the inlet open. When crews arrived at the inlet on May 14<sup>th</sup>, the inlet was closed to tidal circulation. This closure was due most likely to the large amount of sand north of the inlet that dispersed horizontally during the tidal cycle that occurred over night, settling within the inlet area that had been scoured by the large outflow the day before.

Another excavation of the inlet area was conducted at the inlet in mid-June by the City of San Diego. Efforts focused primarily on removing sand from the inlet area, west of the lower bridge between Transects A1 and A2 (See Figure 6). Even though a substantial amount of sand was removed from this area, the inlet still closed over night until the final days of the 8-day excavation effort. Ultimately, the second excavation effort proved to be successful in restoring connectivity between the ocean and the lagoon's channels, as the inlet remained opened through the summer months and into the fall of 2013. Beach nourishment activities in the region may have contributed to the extended lagoon closure, the repeated closures during excavation efforts, and the need for two separate efforts to keep the lagoon inlet open. Efforts should be made to better characterize baseline elevations and grain size within the LPL inlet and along Torrey Pines State Beach to better quantify impacts of future beach nourishment efforts planned for the region.

The continued discharge of freshwater during the dry season also remains a problem. Several vegetation transects near the back of lagoon continue to indicate a type conversion from salt- to brackish-water habitats. This represents the most apparent long-term biotic change seen in the lagoon. Vegetation surveys should continue in this area to document this conversion.

In recent years, the monitoring program has been shifting to accommodate management needs while preserving core long-term elements. A key change this year was the piloting of the new, cross-elevation SWMP vegetation transects. This will provide the basis for a much expanded effort, which will bring LPL into a national network of sentinel sites. We also have recently installed a mouth camera, which is collecting images that at this point need to be manually downloaded. We continue to work on suitable telemetry solutions for the camera. In addition, Los Peñasquitos Lagoon has been a focal location in a region-wide assessment of eutrophication in coastal lagoons, and continuing analyses of the results of this work will provide

a better picture of both abiotic and biotic responses to nutrient loading. The first peer-reviewed publications are being finalized now.

Consideration of further adaptation of the monitoring program is also warranted. Monitoring efforts should also look to increase the use of continuous water quality monitoring and real-time delivery of this data through telemetry at other locations within the lagoon. Currently there is only one such datalogger, located near the ocean inlet (StationW2), used primarily to show the effects of the ocean inlet on water quality within the western portion of the lagoon. Expanding the use of continuous water quality monitoring and real-time access to the data will greatly improve monitoring efforts and restoration of the lagoon's native habitats through better characterization of water quality and trends, instead of "snap-shots" of water quality provided by one-time sampling efforts. Use of real-time data will also provide quick access to data, which is sometimes required to guide management decisions, and will help avoid loss of data by notifying monitoring and management staff when data loggers are offline, instead of discovering this in the field during retrieval.

Continuous monitoring of the downstream segments of the lagoon's three main tributaries will be needed to better quantify freshwater inputs from the watershed and pollutant loading, and to better characterize the temporal and spatial dynamics of hypoxic events. Through such efforts, the LPL monitoring program can continue to provide the tools necessary for successful adaptive management of this urban lagoon and help guide future restoration efforts currently being developed through the updated Los Peñasquitos Lagoon Enhancement Plan. Data sets generated from continuous monitoring of stream flow at the base of the lagoon's tributaries will improve our understanding of sedimentation within the lagoon by capturing peak flows and runoff volumes during storm events that can deliver sediment from the watershed to LPL. Continuous monitoring of stream flow at the base of the lagoon's tributaries will also help to better characterize dry weather flows entering LPL. A result of an urbanized watershed, perennial dry weather inputs of freshwater contribute to habitat conversion within LPL by leaching salt from lagoon soils and reducing salinity within lagoon channels. An example of habitat conversions in LPL is readily observed along the eastern portion of the Lagoon where areas of historic salt marsh (e.g. *Salicornia pacifica* and *Frankenia salina*) have been converted to brackish/riparian habitats defined by species such as cattails (*Typha*), mule fat (*Baccharis salicifolia*), and arroyo willow (*Salix lasiolepis*). Dry weather flows also contribute to vector issues by creating ideal breeding habitat for mosquitoes and midges. One species of freshwater mosquito, *Culex tarsalis*, present within LPL has been identified by the County of San Diego's Department of Environmental Health as a threat to public health and safety due to its ability to transmit West Nile Virus and Equine Encephalitis to human hosts within a two-mile radius from the lagoon.

## V. ACKNOWLEDGEMENTS

We wish to thank Kellie Uyeda, Marya Ahmad, and Amanda Thygersen for assistance in the field and laboratory, the staff of the Torrey Pines State Reserve for their continued cooperation, and Bob Guza at the Scripps Institution of Oceanography for providing the beach elevation survey data. We also thank Mike Hastings at the Los Peñasquitos Lagoon Foundation

for his continued valuable input, and Mitra and Darius Fattahipour at HoundSystems for their work on the datalogger telemetry and the LPL data website. This work was funded by the California Coastal Conservancy.

## **VI. REFERENCES and LITERATURE CITED**

Boland, J. 1991. The physical, chemical and biological monitoring of Los Peñasquitos Lagoon; 1990-1991. Final report prepared for the Los Peñasquitos Lagoon Foundation.

Boland, J. 1992. The physical, chemical and biological monitoring of Los Peñasquitos Lagoon; 1991-1992. Final report prepared for the Los Peñasquitos Lagoon Foundation.

Boland, J. 1993. Maintaining an open mouth at Los Peñasquitos Lagoon 1991-1993: review and recommendations. Report prepared for the Los Peñasquitos Lagoon Foundation.

Carpelan, L.H. 1961. Salinity tolerances of some fishes of a southern California coastal lagoon. *Copeia* 1: 32-39.

City of Poway, City of Del Mar, City of San Diego, County of San Diego and California Department of Transportation. January 2009. Chapman, J. W., and J. A. Dorman. 1975.

Covin, J. 1987. Los Peñasquitos Lagoon vegetation monitoring. Report prepared for the Los Peñasquitos Lagoon Foundation.

Diagnosis, systematics, and notes on *Grandidierella japonica* (Amphipoda: Gammaridea) and its introduction to the Pacific Coast of the United States. *Bulletin of the Southern California Academy of Sciences* 74:104-108.

Gibson, D., G.D. Williams, J. Boland 1994. The physical, chemical and biological monitoring of Los Peñasquitos Lagoon; 1993-94. Final report prepared for the Los Peñasquitos Lagoon Foundation. 19 pp + appendices.

Greer, K.A. 2001. Vegetation type conversion in Los Peñasquitos Lagoon: an examination of the role of watershed urbanization. M.A. Thesis, San Diego State University, San Diego, California, 111 pp.

Greer, K.A., and D. Stow. 2003. Vegetation type conversion in Los Peñasquitos Lagoon, California: an examination of the role of watershed urbanization. *Environmental Management* 31: 489–503.

Mudie, P.J., B. Browning, J. Speth. 1974 The natural resources of Los Peñasquitos Lagoon and recommendations for use and development. Coastal Wetlands Series #7, California Dept. Fish and Game.

Noe, G.B., and J. B. Zedler. 2001a. Variable rainfall limits the germination of upper intertidal marsh plants in southern California. *Estuaries* 24(1):30-40.

- Noe, G.B., and J. B. Zedler. 2001b. Spatio-temporal variation of salt marsh seedling establishment in relation to the abiotic and biotic environment. *Journal of Vegetation Science* 12(1):61-74.
- Nordby, C. 1989. Physical/chemical and Biological Monitoring of Los Peñasquitos Lagoon. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Nordby, C. 1990. Physical-chemical and Biological Monitoring of Los Peñasquitos Lagoon. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Nordby, C. and J. Covin. 1988. Physical/chemical and Biological Monitoring of Los Peñasquitos Lagoon. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Nordby, C. and J. Zedler. 1991. Responses of fishes and benthos to hydrologic disturbances in Tijuana Estuary and Los Peñasquitos Lagoon, California. *Estuaries* 14: 80-93.
- Oliver, I. and A. J. Beattie. 1993. A possible method for the rapid assessment of biodiversity. *Conservation Biology* 7(3):562-568.
- Purer, E. A. 1942. Plant ecology of the coastal saltmarshlands of San Diego County. *Ecol. Monogr.* 12:82-111.
- Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. *Agricultural handbook No. 60.* United States Department of Agriculture, Washington, D. C.
- San Diego Association of Governments (SANDAG) 1998. Watersheds of the San Diego Region. Special SANDAG Publication.
- Usui, C.A. 1981. Behavioral, metabolic, and seasonal size comparisons of an introduced gobiid fish, *Acanthogobius flavimanus*, and a native cottid, *Leptocottus armatus*, from upper Newport Bay, California. M.S. Thesis, California State University Fullerton, California, USA.
- Ward, K.M., M. Cordrey and J. West. 2000. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1999-2000. Annual report prepared for the Los Peñasquitos Lagoon Foundation. 46 pp
- Ward, K.M., J. West, and M. Cordrey. 2001. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 2000-2001. Annual report prepared for the Los Peñasquitos Lagoon Foundation. 48 pp.
- West, J., and M. Cordrey. 2002. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 2001-2002. Annual report prepared for the Los Peñasquitos Lagoon Foundation. 38 pp.
- Weston Solutions, Inc. 2009. TMDL Monitoring for Sedimentation/Siltation in Los Peñasquitos Lagoon. Final report prepared in response to Investigation Order R9-2006-076. Prepared for
- White, M.D., and K.A. Greer. 2006. The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Peñasquitos Creek, California. *Landscape and Urban Planning*, 74, 125–138.



Williams, G.D. 1995. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1994-95. Final report prepared for the Los Peñasquitos Lagoon Foundation. 27 pp.

Williams, G.D. 1996. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1995-96. Final report prepared for the Los Peñasquitos Lagoon Foundation. 33 pp.

Williams, G.D. 1997. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1996-97. Final report prepared for the Los Peñasquitos Lagoon Foundation. 39 pp.

Williams, G. D., G. Noe, and J. Desmond. 1998a. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1997-98. Final report prepared for the Los Peñasquitos Lagoon Foundation. 48 pp.

Williams, G.D., J. Desmond, J. Zedler. 1998b. Extension of two nonindigenous fishes, *Acanthogobius flavimanus* and *Poecilia latipinna*, in San Diego Bay marsh habitats. *Cal. Fish and Game*, 84:1-17.

Williams, G. D., J. West, M. Cordrey, and K. Ward. 1999. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon. Annual report submitted to the Los Peñasquitos Lagoon Foundation. Pacific Estuarine Research Lab, San Diego State University, San Diego, CA.

Williams, G. D., J. M. West, and J. B. Zedler. 2001. Shifts in fish and invertebrate assemblages of two southern California estuaries during the 1997-98 El Niño. *Bulletin of the Southern California Academy of Sciences* 100(3):212-237.

YSI Inc. 2011. 6-series Multiparameter Water Quality Sondes User Manual.

Zedler, J.B. 1991. Invasive exotic plants: threats to coastal ecosystems. p 49-62. In: *Perspectives on the marine environment*. Eds. P.M. Grifman and S.E. Yoder. USC Sea Grant Publication.

Zedler, J.B. (ed.). 2001. *Handbook for Restoring Tidal Wetlands*. CRC Press. Boca Raton, Florida.

## Appendix

### *REGIONAL BEACH SAND PROJECTS*

The Regional Beach Sand Project (RBSP) is a shoreline management effort conducted by the San Diego Association of Governments (SANDAG) in an attempt to address eroding shorelines along the San Diego coast. Beach replenishment was selected as the preferred alternative over shoreline armoring or other hard-structure solutions and consisted of dredging sand from offshore deposits and then pumping it onto receiver sites (i.e., beaches). Initiated through the work of local elected officials from the San Diego region's 18 cities and county, sand placement under the RBSP has occurred twice since the project's inception; once in 2001 (RBSP I) and again in 2012 (RBSP II). Both RBSP I and RBSP II are summarized below ([www.sandag.org](http://www.sandag.org)), and potential interactions with mouth maintenance at LPL are identified (pers. obs., M. Hastings pers. comm.).

#### *RBSP I*

RBSP I occurred in 2001 and involved 2 million cubic yards of sand pumped onto twelve beaches within San Diego County. RBSP I was funded by the United States Congress through the United States Navy, the California Department of Boating and Waterways, and local municipalities participating in the project. Torrey Pines State Beach was selected to receive sand in RBSP I, receiving approximately 209,272 cubic yards of sand in April 2001. Monitoring conducted by Scripps Institution of Oceanography (SIO) provided some interesting observations about the receiver site at Torrey Pines State Beach (R.J. Seymour *et al.* 2004. *Rapid erosion of a Southern California beach fill*. Coastal Engineering 52: 151-158; M.L. Yates *et al.* 2009. *Seasonal persistence of a small southern California beach fill*. Coastal Engineering 56: 559-564). According to their studies, elevated beach fill remained in place with little to no change to beach elevations above Mean Sea Level (MSL) through the summer and into the fall of 2001 due in most part to the lack of significant wave activity (i.e., large waves). Beach profiles along the Torrey Pines receiver site contrasted with "control" sites located adjacent to the receiver site. While beach profiles above MSL at the control sites displayed accretion rates characteristic of late spring and summer months, the receiver site at Torrey Pines "displayed little to no change."

Sand placed on Torrey Pines State Beach during RSBP I was removed during the first winter storm that occurred in November 2001. This storm was characterized as having 3-meter significant wave height and a majority of the sand was scoured off the beach at the nourishment site and formed a large offshore sandbar. Following the seasonal patterns of shoreline accretion, some of the sand moved back onto the beach face during summer of 2002 and formed a wider beach above MSL at the original disposal site at Torrey Pines State Beach (M.L. Yates *et al.* 2009). The results of the SIO study suggest that sand was leaking from the nourishment site once nourishment was completed, even during a period of small waves. After 20 months, the

nourishment site at Torrey Pines State Beach was undetectable compared to control areas (Yates *et al.* 2009).

### Inlet Management at LPL 2002

An uncharacteristically large volume of sand was observed within the inlet at LPL during the spring and summer of 2002 that had not been observed since mechanized removal of sand began in 1985 (M. Hastings pers. comm. with M. Wells, 2002). It was determined at the time that the additional sand was most likely associated with the beach nourishment at Torrey Pines State Beach in 2001. Additional funding was provided by SANDAG as mitigation to augment efforts to remove sand mechanically from the Lagoon inlet in 2002. Results from the SIO study (Yates *et al.*, 2009) appear to support this conclusion with the addition of material at the LPL inlet caused by potential movement away from the nearby nourishment site.

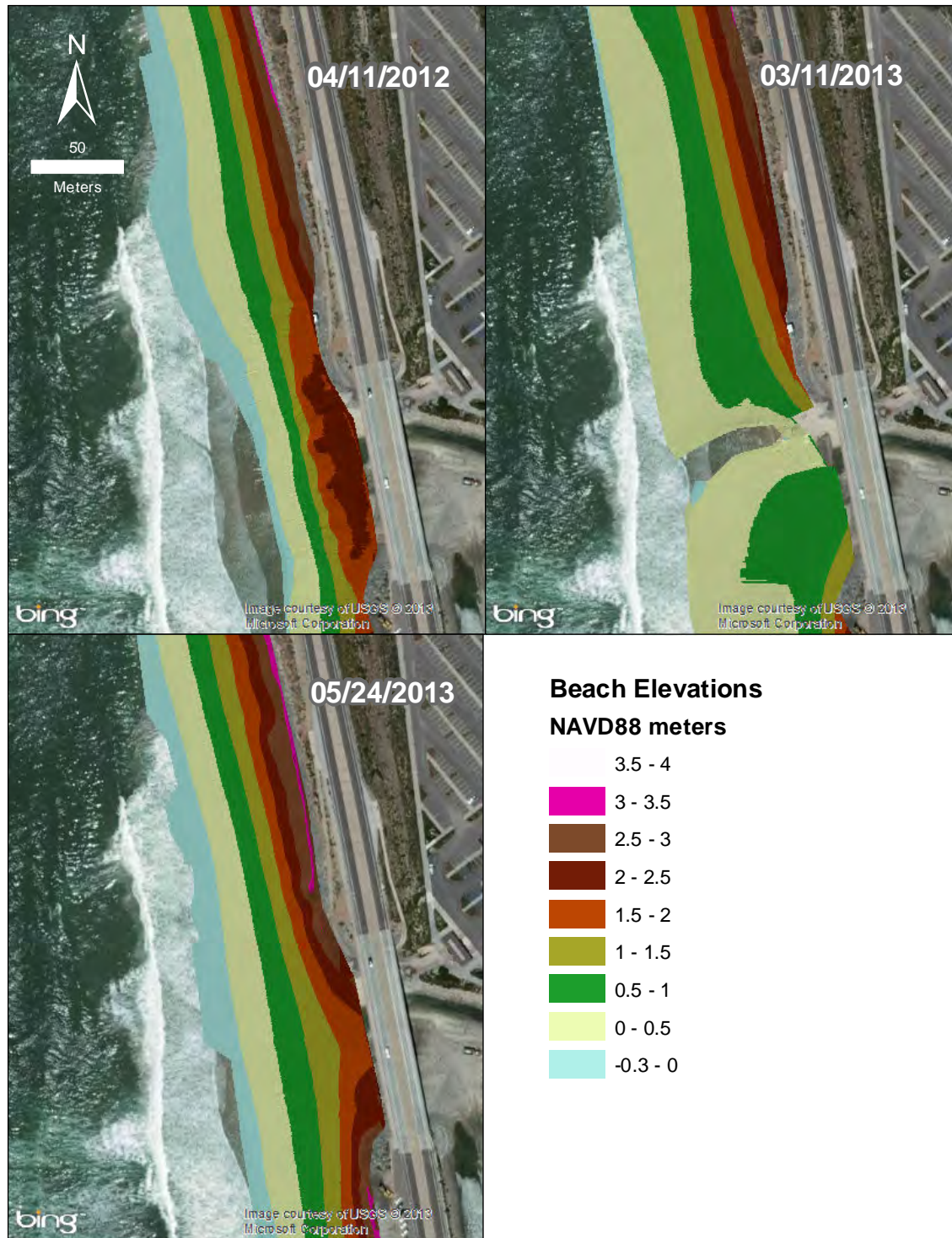
### RBSP II

RBSP II occurred in 2012 and involved 1.5 million cubic yards of sand pumped onto eight beaches within San Diego County that were identified as being badly eroded. Funding was provided by the California Department of Boating and Waterways and the region's coast cities. Since the City of San Diego was unable to provide matching funds for Torrey Pines State Beach, it was not selected by SANDAG to receive sand during RBSP II. Aside from the exclusion of Torrey Pines as a receiver site, two other changes occurred for RBSP II: seasonal placement of sand and grain size of sand placed on receiver sites.

While RSBP I placed sand on the receiving sites during the spring in 2001, RBSP II placed sand on the receiving sites from October to early December 2012. Within the Oceanside Littoral Cell, the following amounts of sand were placed during RSBP II from north to south: Oceanside - 292,000 cy placed between Oceanside Blvd and Buccaneer Park between October 5 - 20, 2012; Carlsbad - 358,000 cy placed at South Carlsbad between November 15 - 23, 2012 and North Carlsbad between November 27 - December 7, 2012; Encinitas - 287,000 cy placed between Batiquitos Lagoon and Cardiff State Beach from October 20 - November 4, 2012; Solana Beach - 140,000 cy placed at Fletcher Cove between November 4 - 7, 2012 and between November 27 - December 7, 2012.

In addition to placing sand on receiver sites in the fall and early winter months, RSBP II focused on placing predominantly coarse grain sizes on receiver sites under the premise that sand loss at receiver sites during RSBP I was due, in part, to the predominance of smaller grain sizes of sand that were easily mobilized and lost offshore during the first winter storm events (M. Hastings pers. comm.). Coarse grain sizes used in RSBP II was one of the indicators used to

associate this program's role in blocking the inlet at LPL in 2013 due to increased sand deposition within the inlet area and elevated beach profiles at Torrey Pines State Beach. Grain size analyses performed at the LPL inlet in May 2013 indicated a greater proportion of coarse to moderately coarse material within the Lagoon than in previous years, which matches the material type used by SANDAG for beach nourishment in November 2012 (M. Hastings pers. comm.). Furthermore, beach elevations at Torrey Pines State Beach north of the LPL inlet appeared higher than in previous years. See below for beach elevation profiles on three dates (survey data provided by Bob Guza, SIO) as well as photographs.



Beach elevation profiles showing increased elevations during the May, 2013 mouth closure compared to the April, 2012 mouth and the open-mouth condition in March, 2013. Elevation survey data provided by Bob Guza, SIO.



Photographs of lagoon mouth and excavation activities (M. Hastings)



View of Beach Profile, Northern Edge of Los Peñasquitos Lagoon Inlet. May 14, 2013.



View of Beach Profile, Northern Edge of Los Peñasquitos Lagoon Inlet. May 14, 2013.





**View of Beach Profile, Northern Edge of Los Peñasquitos Lagoon Inlet. May 15, 2013**

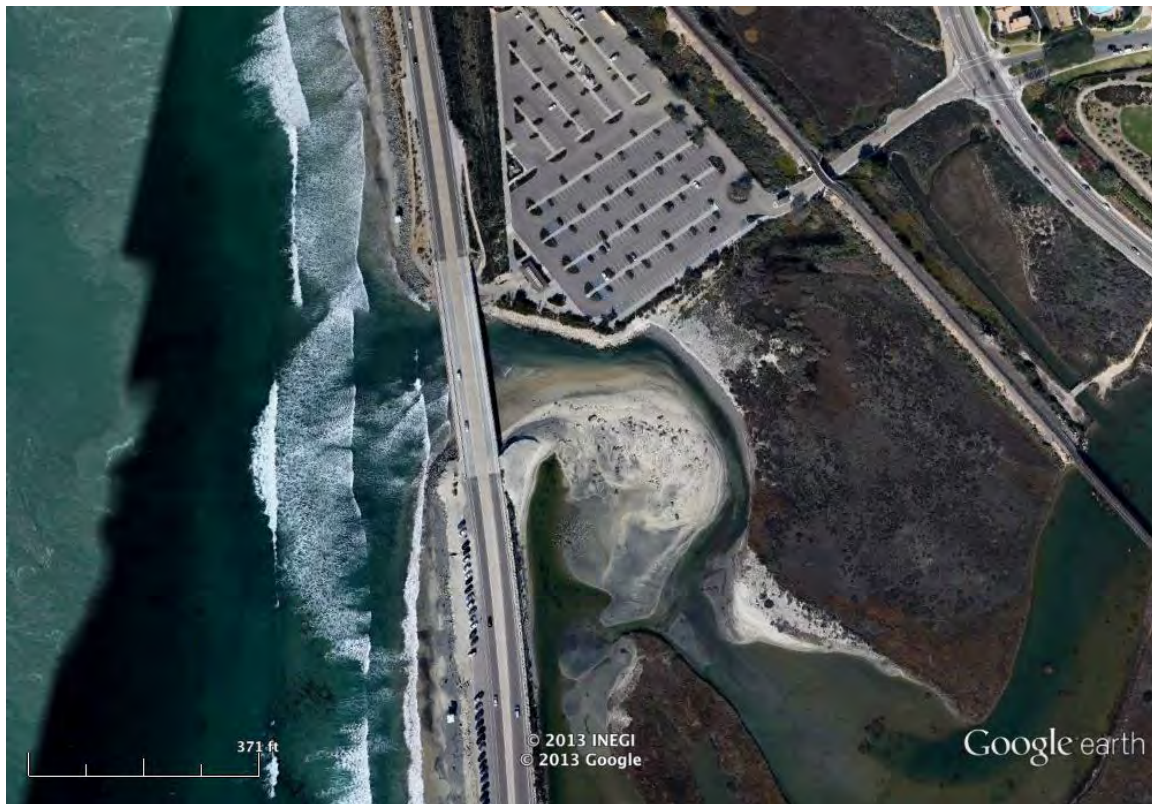


**View of Beach Profile, Southern Edge of Los Peñasquitos Lagoon Inlet. June 12, 2013. Approximately 3-6 feet of additional sand above the lagoon inlet waterline.**



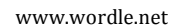


View of Beach Profile, Northern Edge of Los Peñasquitos Lagoon Inlet. June 17, 2013. The inlet area had already been excavated multiple times prior to this photo.



Overview of Los Peñasquitos Lagoon Inlet. November 12, 2012. Note the large, exposed sand spit within the Lagoon that occludes the inlet and restricts tidal exchange.

## July 1, 2011- June 30, 2012



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# **I. INTRODUCTION**

Los Peñasquitos Lagoon (LPL) is a relatively small estuary (511 acres) in northern San Diego County, situated at the coastal outlet of the 59,300-acre Los Peñasquitos Watershed (Weston Solutions 2009). Like all coastal estuaries in southern California, LPL experiences a Mediterranean climate, which is characterized by highly seasonal precipitation events occurring primarily during the winter months. There is little to no rainfall during the dry summer. As a result, most coastal lagoons in southern California, under natural conditions, experience a seasonal salinity cycle, with relatively high salinities in summer and lower, but variable, salinities during wet winter periods when flooding potential is highest (Purer 1942). Salinity variation within coastal estuaries wetlands is primarily a function of input of saline water from the ocean, input of freshwater from the watershed, evaporation of surface waters, and transpiration by plant species.

The LPL watershed is comprised of three sub-drainage basins that direct drainage to LPL by way of three creeks. Carmel Creek drains the Carmel Valley sub-watershed, which encompasses just over 10,000 acres and serves as the northern most drainage to the Lagoon. Los Peñasquitos Creek drains the Los Peñasquitos sub-watershed that encompasses approximately 44,600 acres that includes Los Peñasquitos Canyon and Lopez Canyon. Carroll Creek drains the Carroll Canyon sub-watershed that encompasses approximately 10,500 acres and serves as the most southern drainage to LPL. Los Peñasquitos Creek merges with Carroll Creek in Sorrento Valley before entering the Lagoon.

Over 50% of the land within the Peñasquitos watershed is urbanized (SANDAG 1998). Historically, it is likely that all three tributaries were largely dry during summer months. As the watershed developed, however, dry-weather flows into the lagoon dramatically increased (Greer and Stow 2003, White and Greer 2006). It has been demonstrated that shifts in vegetation occurring in the lagoon, representing loss of species associated with saline habitats and increases in fresh- and brackish-water species, are correlated with increased urbanization of the watershed (Greer 2001, Greer and Stow 2003, White and Greer 2006).

Historic evidence, including mollusc middens left by indigenous peoples, notes by Spanish explorers, maps from the 1800's, and photographs, indicate that LPL may have once remained open to the sea relatively consistently, although it is likely there were periods of mouth restriction and closure. However, development of a railway line through the lagoon in 1888 was followed by the first recorded closure of LPL's inlet. Construction of Highway 101 and realignment of the railway line through the middle of the lagoon in the early 1900s led to increased frequency and duration of inlet closures at the lagoon. Constructed in 1888, the first railway line was placed within Los Peñasquitos Lagoon. It consisted of an elevated track placed on top of an earthen berm that cut across the eastern edge of LPL along what is now the closed portion of Sorrento Valley Road. The berm effectively cut off a majority of storm runoff from Carmel Valley during winter and spring months and most likely reduced the ability of the lagoon to remain open.

In 1925, the railway was relocated west of the original alignment and placed on an elevated berm that bisected the lagoon. The railway line remains in the same location today, entering the lagoon from the south at Sorrento Valley and exiting at the northwest-most point of the lagoon, where historic survey maps indicate the location of the LPL's inlet prior to its



relocation in 1932. The new railway berm cut off many of the lagoon's natural tidal channels and provided only three bridge spans where water could flow from the watershed toward the inlet. Much like the original railway berm, the new alignment impounded storm runoff from the lagoon's three main tributaries on the eastern side of the berm (Figure 1). Impoundment behind the railway berm increased the residence time for floodwaters within the lagoon, dramatically reducing lagoon outflow rates through the inlet. Reduction in the outflow rates lead to increased frequency and, at times, duration of inlet closures as deposition rates of marine sediments in the inlet area outpaced scouring rates from floodwaters exiting the lagoon. Impoundment of floodwaters in the eastern portion of the lagoon also facilitates habitat conversion from salt marsh to brackish marsh and riparian habitat due to reduced salinity levels in soils and lagoon channels, as well as increased elevations due to deposition of sediments in the eastern portion of the lagoon.



Figure 1. Flood Event at Los Peñasquitos Lagoon, February 2002. Photo by City of San Diego.

A pattern of frequent and extended mouth closure was further aggravated by construction of Historic Highway 101 in 1932-33. The first coastal road was constructed in 1915 and consisted of a 15-foot “strip of concrete” that connected San Diego’s beach communities. (<http://www.gbcnet.com/ushighways/US101/101pics2a.html>) Moving north to south, the road cut inland toward what is now Carmel Valley Road before curving back to the coastline and crossing the lagoon near the current inlet location before proceeding up Torrey Pines Grade, which is now located within the Torrey Pines State Reserve (Figure 2). However, the original road became outdated and was replaced by Highway 101 in the early 1930s. The stretch of Highway 101 along Los Peñasquitos Lagoon, now referred to as Torrey Pines Road, was constructed between 1932 and 1933. The new road no longer cut inland at LPL, but instead ran along the section of dunes that separated the lagoon from the beach. The road was placed on an elevated berm with two bridge spans to the north, where the road enters the southern portion of the City of Del Mar. The lagoon inlet was fixed under the lower bridge span, near where the original bridge crossed the lagoon.

An upper bridge was constructed near the historic location of the LPL's inlet to allow the railway to pass underneath and continue north along the coastal bluffs along Del Mar Beach (Figure 3).



Figure 2. Ford Model "A" driving the coast (pre-Highway 101) with Los Peñasquitos Lagoon in the background, 1920s (Note the bridge traversing the lagoon). Photo from US 101 Photo Gallery (<http://www.gbcnet.com/ushighways/US101/101pics2a.html>)



Figure 3. Construction of the upper bridge at Los Peñasquitos Lagoon along Highway 101, 1932. Photo from US 101 Photo Gallery (<http://www.gbcnet.com/ushighways/US101/101pics2a.html>)

From 1950-1975, direct discharges of sewage into LPL's tributaries occurred from three wastewater treatment plants. In the 1960s direct discharges of treated effluent containing nitrates and phosphates from upstream sewage treatment facilities reached new highs. This nutrient addition contributed to algal growth in lagoon waters, and with decomposition of senescent vegetation, led to the depletion of dissolved oxygen and hypoxic conditions. Mosquitoes and



midges proliferated, and the odors associated with decaying organics increased. While these direct discharges ceased with the implementation of wastewater pumping stations near the lagoon in 1978, raw sewage discharges still occurred due to failures at these pump stations. Pump Station 64, located in Sorrento Valley, has spilled millions of gallons of untreated sewage into LPL with 60 spills occurring between 1977 and 1986. This pump station was responsible for 2.3 million gallons ( $\sim 8,700 \text{ m}^3$ ) of untreated sewage that was discharged into the lagoon during a countywide power outage on September 9, 2011.

The Los Peñasquitos Lagoon Foundation, California Coastal Conservancy, and concerned community members developed an LPL Enhancement Plan in 1985 to deal with these problems. Two key programs identified in the Plan were annual monitoring of water quality parameters, aquatic habitats and terrestrial habitats, as well as mechanical opening of the lagoon mouth before water quality became poor enough to kill channel organisms. These programs were partially funded through mitigation payments made by local developers and homeowners' associations in the watershed and are administered by the Los Peñasquitos Lagoon Foundation with support from California State Parks and California Coastal Conservancy.

As part of this management program, the Pacific Estuarine Research Laboratory (PERL), based at San Diego State University, was contracted to monitor lagoon resources and use the data in its studies of regional wetland ecosystems. PERL monitored the physical and chemical characteristics of Los Peñasquitos Lagoon channel water from 1987 - 2004, and sampled benthic invertebrates, fish, and saltmarsh vegetation from 1988 - 2004 (Covin 1987, Nordby and Covin 1988, Nordby 1989, Nordby 1990, Boland 1991, Boland 1992, Boland 1993, Gibson et al. 1994, Williams 1995, Williams 1996, Williams 1997, Williams et al. 1998a, Williams et al. 1999, Ward et al. 2000, Ward et al. 2001, West et al. 2002). These studies led to the timely opening of the mouth and an increase in our knowledge of the biology of southern California's estuaries (e.g., Nordby and Zedler 1991, Zedler 2000, Noe 2001a,b). In July 2004, LPL monitoring was transferred to the Southwest Wetlands Interpretive Association (SWIA) and the Tijuana River National Estuarine Research Reserve (TRNERR).

## II. METHODS

### DESCRIPTION OF STUDY SITE

Water quality was sampled at three stations that have been monitored since 1987 (Figure 4). The monitoring stations are described below:

- *Station W1 (Via Grimaldi, formerly Milligan House)* – Station W1 is located along Carmel Valley Road (at the Via Grimaldi intersection) in the northern arm of the estuary. This station consists of a channel approximately 20 meters (m) wide and 1.0 m deep and sediments composed of clay covered with a shallow layer of organic matter.
- *W2 (Railroad Trestles)* – Station W2 is located at the large railroad bridge that crosses the main lagoon channel; water quality readings are taken from the catwalk near the middle of the channel, where water depths are approximately 2.0 m.
- *W3 (Mouth)* – Station W3 is located in one of the channels closest to the lagoon's Pacific Ocean outlet and is most directly exposed to ocean flows. This site is fairly shallow, with

sandy sediments and a highly variable width (8.0 - 40 m) because of its dynamic hydrology.

## RAINFALL AND WEATHER MONITORING

Rainfall in San Diego can be sporadic and highly variable across the County in both presence/absence as well as measurable amounts. Therefore, measuring precipitation onsite is important for accuracy purposes. In the past, rainfall amounts measured at Lindbergh Field were used as this airport has the longest running rainfall monitoring program, which facilitates historic comparisons of both annual and seasonal rainfall data. However, rainfall measured at Lindbergh Field can differ greatly from rainfall occurring in Los Peñasquitos Lagoon and its watershed both annually and for each storm event. Local rainfall data was collected at the weather station located near water quality sampling station W2 (Figure 4). In addition, we measured air temperature and relative humidity, although the temperature probe was faulty during portions of this deployment (which also affects humidity). We thus provide temperature and humidity data for the Torrey Pines weather station at the State Park Visitor Center.



Figure 4 - LPL Sampling Stations

## STREAM FLOW DATA

Flow rates for the LPL's major tributaries (Carmel Creek, Los Peñasquitos Creek and Carroll Canyon Creek) were not measured during this monitoring period, as it was determined that this effort did not capture flow data for specific storms, but rather just for a specific time frame (i.e. the day flow was measured). Continuous stream flow data for Los Peñasquitos Creek is available from a USGS Gage 11023340 located in upper portion of Los Peñasquitos Canyon, within the City of Poway (Figure 5; <http://waterdata.usgs.gov>). This gage does not capture complete flow data for this sub-watershed due to its location in the upper half of this drainage. The USGS has operated other stream flow gages at the lower reaches of Carmel Valley and Carroll Canyon, but only for a short duration.

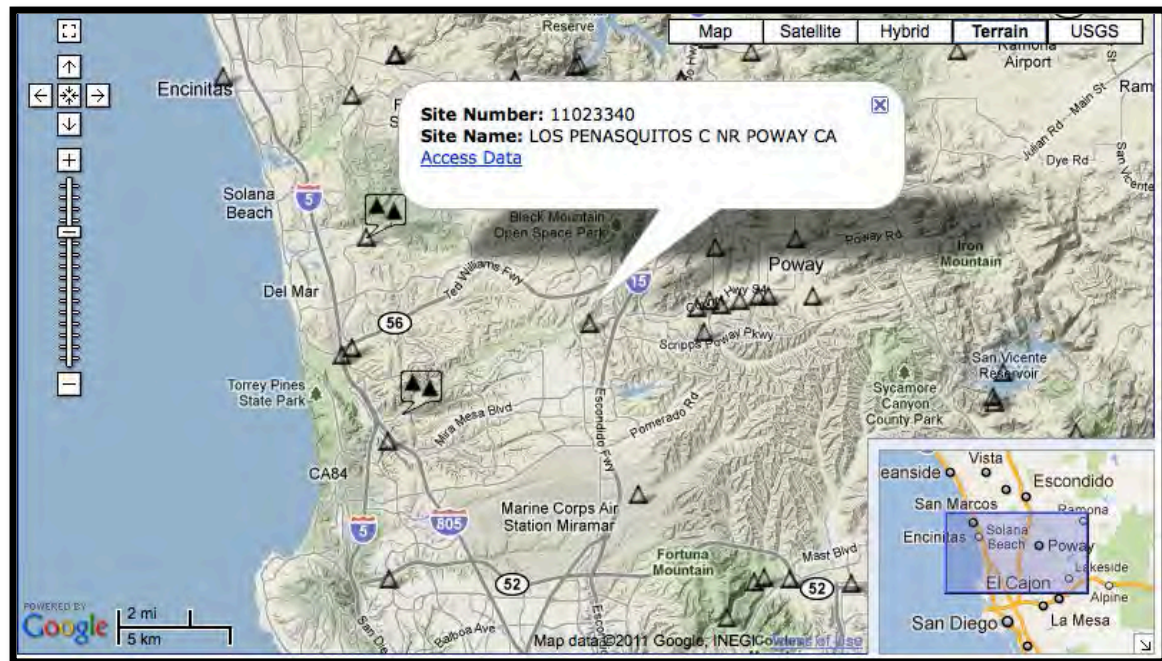


Figure 5 - Location of USGS Gage 11023340 in Los Peñasquitos Canyon

## WATER SAMPLING

### CONTINUOUS WATER SAMPLING

Intensive water quality sampling was conducted at Station W2, located at the northern-most railroad trestle (Figure 4) using a YSI model 6600 multi-parameter datalogger installed at a fixed position approximately 0.30 m off the channel bottom. Data from this logger is available in real-time through telemetry (<http://76.12.205.63/main.html#>) along with weather information recorded near W2. The following water quality parameters were measured every 15 minutes by the datalogger at W2:

- Salinity in practical salinity units (psu)
- Water temperature (°Celsius)
- Dissolved Oxygen (DO) in milligrams per liter (mg/L)
- Water level (m)
- Turbidity in Nephelometric Turbidity Units (NTU)
- pH
- Chlorophyll (µg/L)

*Salinity.* Salinity is a key parameter measured to assess water quality conditions for aquatic species residing in LPL's channels and chemical processes occurring within the water column. Salinity is measured in parts per thousand (ppt), which is assessed as electrical conductivity (and is a function of temperature). Salinity can be used to determine the extent and degree of tidal mixing within the lagoon channels, as well as an indirect measure of freshwater

input from the watershed. Prior to the urbanization of the watershed and perennial nature of the lagoon's tributaries, water trapped within the lagoon during mouth closures would often become hypersaline. However, year round freshwater input into the lagoon precludes hypersaline conditions for the most part, even during summer months with no precipitation. Salinity also can help to determine the fate of organic material within the lagoon, primarily its ability to dissolve in the water column or become adsorbed to fine sediments (e.g., clay).

Water temperature. Water temperature is another key parameter measured to assess water quality conditions for aquatic species residing in LPL's channels and chemical processes occurring within the water column. Water temperature can have profound impacts on dissolved oxygen (DO) levels within water found in lagoon channels, as DO can drop quickly during warmer temperatures.

Dissolved Oxygen (DO). DO is perhaps one of the most important water quality parameters for aquatic species residing in LPL's channels and is the most used parameter for triggering opening of the lagoon inlet during closures. DO is measured in concentrations of milligrams per liter of water (mg/L). DO levels within lagoon channels depend greatly on tidal mixing within the lagoon, as ocean waters replenish DO levels within the lagoon and keep water temperatures relatively cooler within the water column. During inlet closures, DO can drop to levels considered stressful to most marine organisms, which is below 5mg/L. During extended inlet closures DO levels can drop and remain below 5mg/L, resulting in fish kills. DO is also sensitive to day / night cycles, with the lack of photosynthetic production of oxygen at night, coupled with DO depletion due to respiration by aquatic species, tending to produce lower levels. DO saturation in the water is also controlled by temperature, and DO tends to decline more rapidly during warmer conditions. DO also can drop dramatically during sewage spills, as observed in the case of the massive sewage spill from Pump Station 64 on September 9, 2011 from data collected by San Diego Coastkeeper (pers. comm.).

Water level. Water levels are measured at station W2 continuously to determine tidal influence and water input from the watershed during inlet closures. Tidal influence is important to monitor as it influences salinity, temperature and DO within lagoon channels. Measuring water levels during inlet closures is important in showing the contribution of fresh water input from the watershed, especially during periods of no measurable precipitation.

Turbidity. Turbidity is monitored to determine the presence and density of particulate matter within the lagoon channels. Turbidity can impede photosynthesis of algae and aquatic plant species living within the lagoon channels. Turbidity is measured using Nephelometric Turbidity Units (NTU). A property of particles is that they will scatter a light beam focused on them. Measuring this scatter of light is considered a more precise measure of turbidity in water, as particle density is a function of light reflection off the particle. A nephelometer measures suspended particulates in a liquid for particle density as a function of light reflection off the particle.

pH. pH is measured along a range of 0 to 14 to assess acidity (below 7) or alkalinity (above 7) of water within the lagoon channel at Station W2. Typically, water within coastal lagoons has a pH of 8, which is indicative of ocean water, or even higher due to hypersaline conditions. However, pH levels within LPL seems to fluctuate due to the presence and magnitude of tidal mixing and/or fresh water input from the watershed and peripheral drainages



that empty into the lagoon. In coastal lagoons, salinity-related changes in chemical reaction rates are important and are generated both by mixed-controlled changes in the relative concentrations of reactants and by the influence of ambient ionic strength on the activities of the reacting species. pH measures acidity or alkalinity of the water which can determine the ability of organic material to dissolve in the water column. When salinity levels increase, organic compounds become less soluble in water and, instead become more sorbable, leading to increased sorption in sediment particles. pH levels can also affect aquatic species within the lagoon channels and sudden changes, even by a small amount, can be stressful for fish. However, many species can adapt to shifts in pH levels if they are gradual. Extreme changes in pH can indicate as a result of acidic or alkaline waste into coastal waters or lagoon tributaries.

*Chlorophyll.* Chlorophyll is a useful parameter for indirectly assessing primary producer biomass within the water column. In some cases, it might be used to predict eutrophication in lagoons, serving as an indicator of dissolved inorganic nitrogen (DIN) often associated with runoff from the watershed during rain events. The extent to which it is useful in tidally-exchanged wetlands is unclear, but under investigation. It is measured in micrograms per liter ( $\mu\text{g/L}$ )

#### *SPATIAL WATER SAMPLING*

Spatial water quality monitoring was conducted (approximately) on a monthly basis at stations W1, W2 and W3 (Figure 4). Measurements were made at the surface and bottom of the channel using a YSI 600xlm multi-parameter water quality datalogger connected to a YSI 650 MDS (Multi-parameter Display System). Spatial water quality monitoring measured water temperature, salinity, and DO.

Monthly nutrient and chlorophyll sampling began in April 2011. The water sample is collected at Station W2 and analyzed according to protocols established by National Ocean and Atmospheric Agency (NOAA) and National Estuarine Research Reserve (NERR) protocols. The parameters assessed are orthophosphate, nitrate / nitrite (combined), ammonium, and chlorophyll. Data are compared to samples collected from the Tijuana River Estuary and south San Diego Bay, collected as part of the larger TRNERR effort

#### VEGETATION AND SOIL SAMPLING

Vegetation monitoring was conducted to document changes in species composition and to determine the magnitude of historic saltmarsh habitat invasion by upland/exotic species. Vegetation is monitored in nine areas (Figure 4) during the fall. Five of these areas have been monitored since 1986 (transects 1- 5), four since 1990 (transects 9, 11, and 12) and one since 2001 (transect 13A and B).

Two (or more) stakes mark the position of each permanent transect, which vary in length from 40 to 260m. Transects #1, 2, and 3 are comprised of two 50-m sections (100 m total). A 0.25-m<sup>2</sup> circular quadrat was laid down at five meter intervals along each transect. Total percent cover of vegetation in each plot was recorded, as well as percent covers of each species type. Note that the cumulative cover of the individual species can represent values greater than the



total percent cover, to account for the fact that plants often overly each other in a three-dimensional canopy.

In March 2008, we added an additional springtime transect to monitor *Lasthenia glabrata* ssp. *coulteri*, an annual native plant placed on the 1B List (Plants Rare, Threatened, or Endangered in California and Elsewhere) with a threat ranking of 0.1 (seriously threatened in California) by the California Native Plant Society. The transect is located along the eastern portion of the lagoon in an area of expanding freshwater influence. It is designed to describe the changing vegetation communities associated with the increased freshwater and its potential impacts to *L. glabrata*. It extends 140 meters along a trail between two patches of *L. glabrata*. The presence of *L. glabrata* was recorded at five-meter intervals on either side of the trail. *L. glabrata* was most abundant on the western portion of the transect. In order to better characterize the *L. glabrata* and associated vegetation, percent cover of all species within a 1m<sup>2</sup> square quadrat was recorded every five meters along the western portion of the transect.

After suspending soil salinity sampling the previous year, we conducted a more restricted sampling program during the fall vegetation sampling. Prior to 1996, soil salinities were determined in the field. In 1996 a switch was made to the use of soil pastes to better account for inconsistencies in measuring the salinity of dry and wet soils. Using a 2-cm diameter corer, at least three 10-cm deep soil cores were obtained at equally-spaced intervals along each transect. Saturated soil pastes (Richards 1954) were prepared in the laboratory. We extruded water from the soil pastes using 10-ml syringes fitted with filter paper and measured salinity with a temperature-compensated refractometer. Recent comparisons show that this method, while consistent across all samples, results in elevated salinity readings relative to field measurements of expressed interstitial waters. During this year's sampling, results from Transects 1, 11, and 12 yielded indeterminate results and were not included.

In the Spring of 2012, we conducted some pilot sampling for a new monitoring protocol being established through the NERR System-Wide Monitoring Program (SWMP). The funding for implementation of this monitoring in both LPL and the Tijuana Estuary is being leveraged by NOAA NERR funding. We will provide a full description of this sampling in the next report, but also highlight the pilot sampling here. In general, this monitoring is designed to assess vegetation changes along the marsh - upland gradient, both to provide this information for extant communities and also to allow for change detection due to factors such as climate change and sea level rise. In March 2012, two sets of vegetation transects were added to the existing array (described above). These transects run across elevation gradients in order to sample through marsh habitat and into the upland transition zone. Site SWMP-1 consists of 3 transects of 69m, 72m, and 75m that run parallel to the train tracks from the northeast to the southwest, respectively, and cross Transects 1A and 1B perpendicularly. Site SWMP-3 consists of additions to Transect 3, lengthening it into the upland zone by 40m, and adding two replicate transects of 40m each in the upland zone. A 1m<sup>2</sup> square quadrat was laid down approximately every 10m along each transect. Percent cover of vegetation and individual species were recorded.

### III. RESULTS & DISCUSSION

#### WEATHER MONITORING

##### *RAINFALL*

Daily rainfall values for the LPL meteorological station, as well as relative humidity and air temperature values, are shown in Figures 6 and 7.

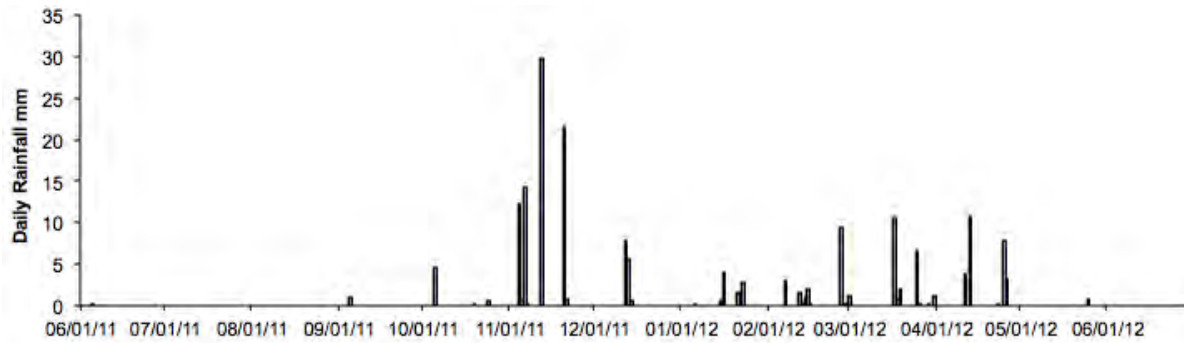


Figure 6 - Daily rainfall as measured at the LPL weather station

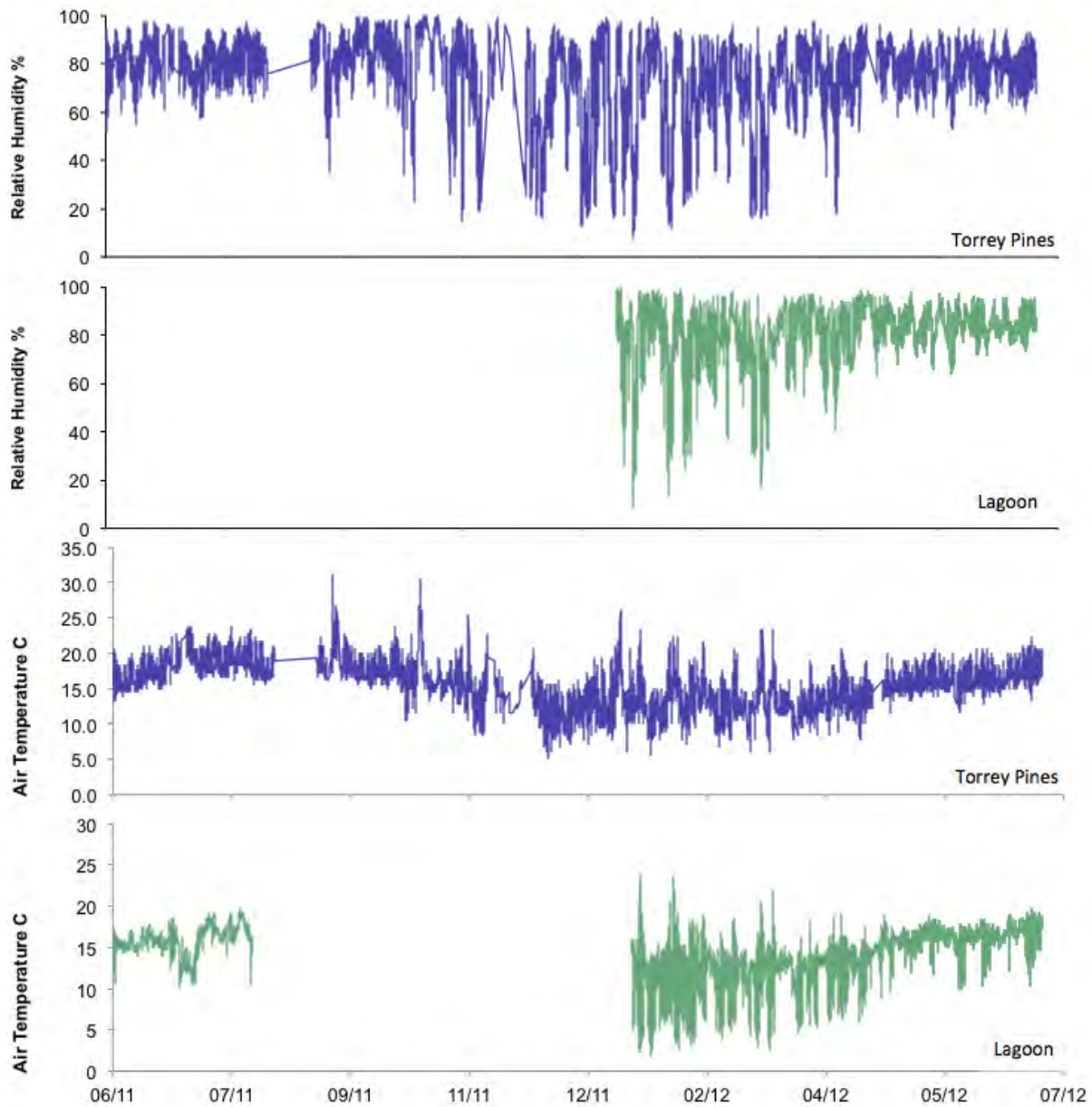


Figure 7 - Relative humidity and air temperature as measured at the Torrey Pines and LPL weather stations

## STREAM FLOW – LOS PEÑASQUITOS CREEK (USGS GAGE)

Stream flow data taken from USGS Gage 11023340 for July 2011 – June 2012 indicated a year of moderate flow events from November 2011 and April 2012 (Figure 8). Flow rates were relatively low (max. of ca. 200 cfs) compared to peaks in previous years (Figure 9).

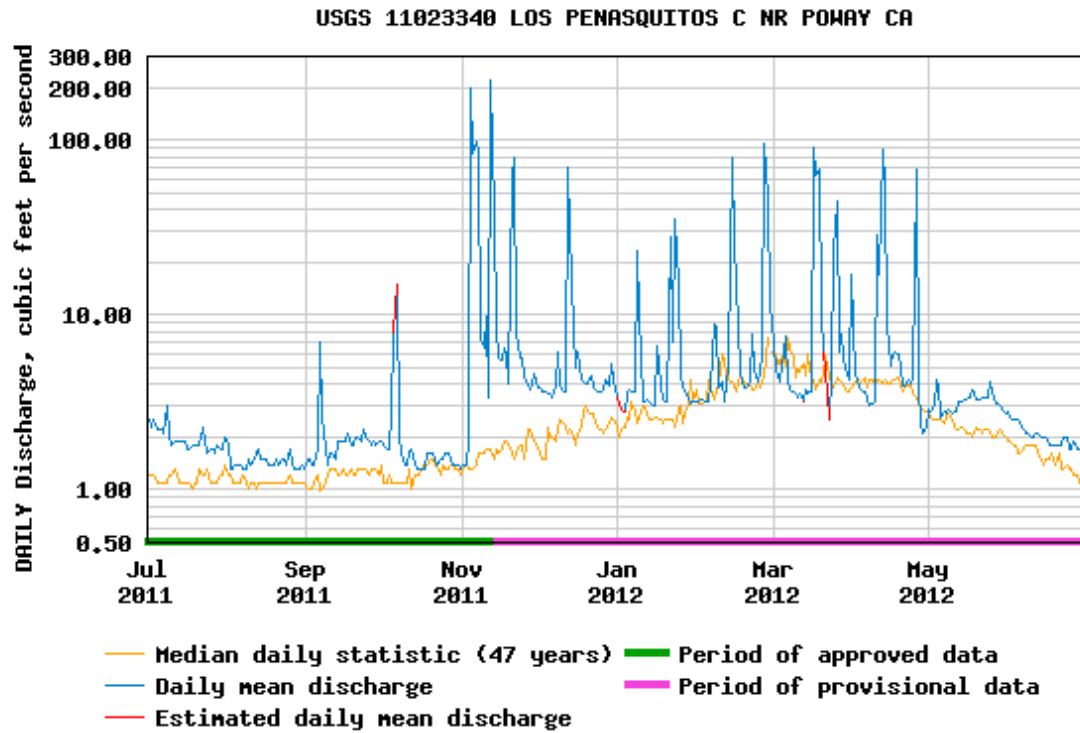


Figure 8 - USGS Gage 11023340 Flow Rates for Los Peñasquitos Creek. Graphic by USGS

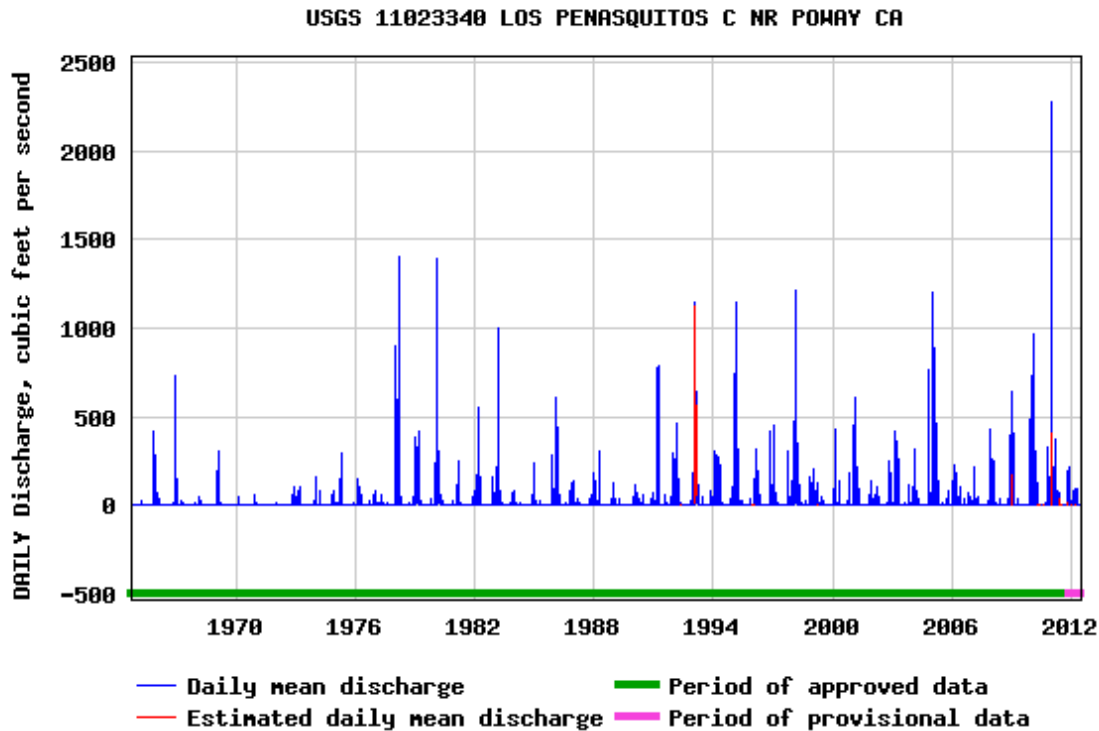


Figure 9 - Long term record for USGS Gage 11023340 on Los Peñasquitos Creek. Graphic by USGS

## WATER SAMPLING

### *LAGOON WATER CONDITIONS*

Water conditions in the lagoon are assessed with both periodic spatial sampling (Figure 10) and data retrieval from the datalogger deployed at the railroad trestle (Figure 11). The spatial sampling data shows the difference in water quality parameters at varying depths. The surface water samples are generally lower in salinity than near bottom samples due to the density differences between lighter, fresher water and denser, more saline water (Figure 10). However, water quality parameters at sampling station W3 were generally similar between surface and near bottom samples because the water at this site is generally shallow and well mixed.

The data collected every 15 minutes with the datalogger, as well as the real-time data delivery system at this logger site, greatly facilitates water quality assessments as well as indicates problems which need rapid attention. Overall, the water quality was generally good throughout the monitoring period. There was the typical period of low minimum oxygen values in the fall (Figure 11), caused by decaying organic matter from the summer growing season leading to relatively large oxygen demand, especially early in the morning (before oxygen-producing photosynthesis occurs during daylight hours). Even during these periods, however, maximum values show recovery to oxygenated conditions. We also noted low oxygen events related to episodic mouth closures (discussed below). Finally (and unfortunately), there was equipment malfunction during the September 2011, sewage spill. Data for two days after the

spill, however, indicate no unusual conditions for the monitored parameters, most likely due to the sampling location being near the inlet and subject to tidal mixing, which most likely influenced elevated DO levels.

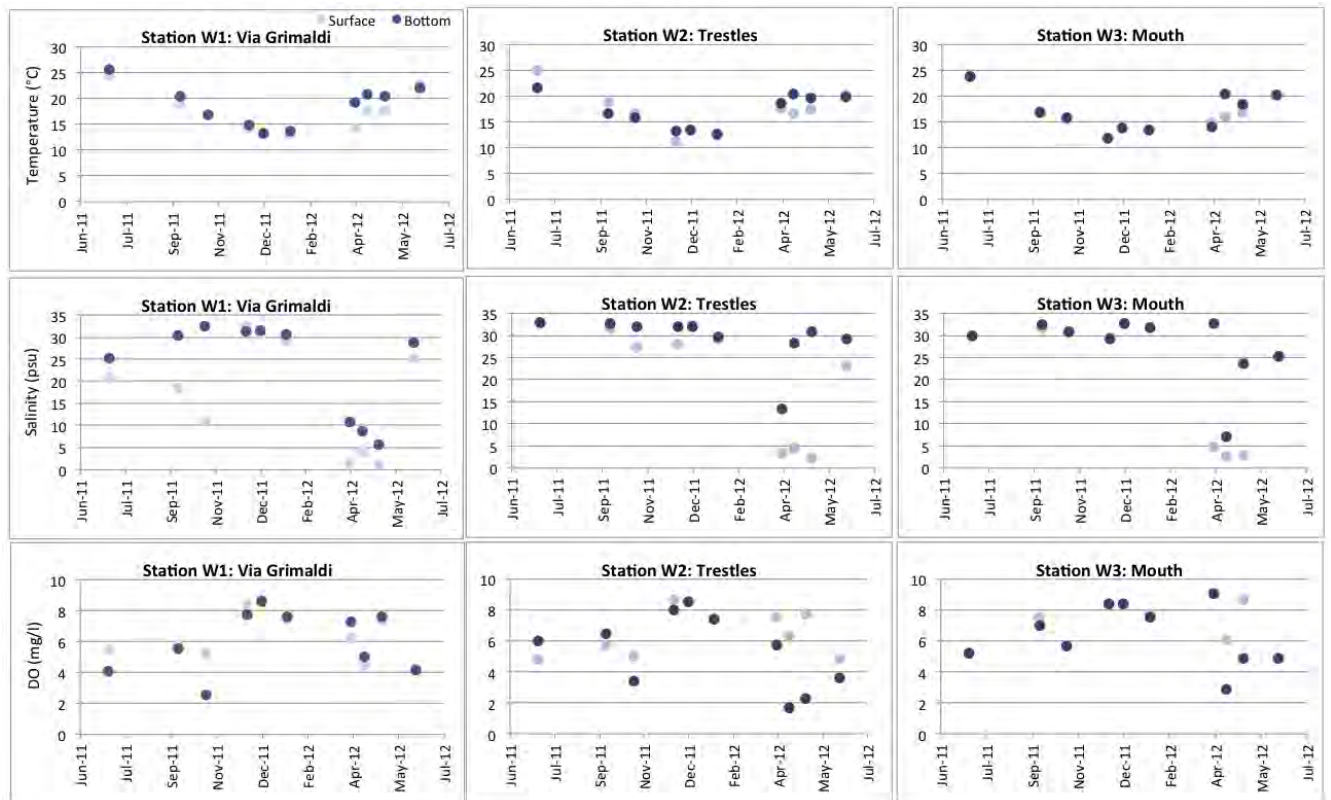
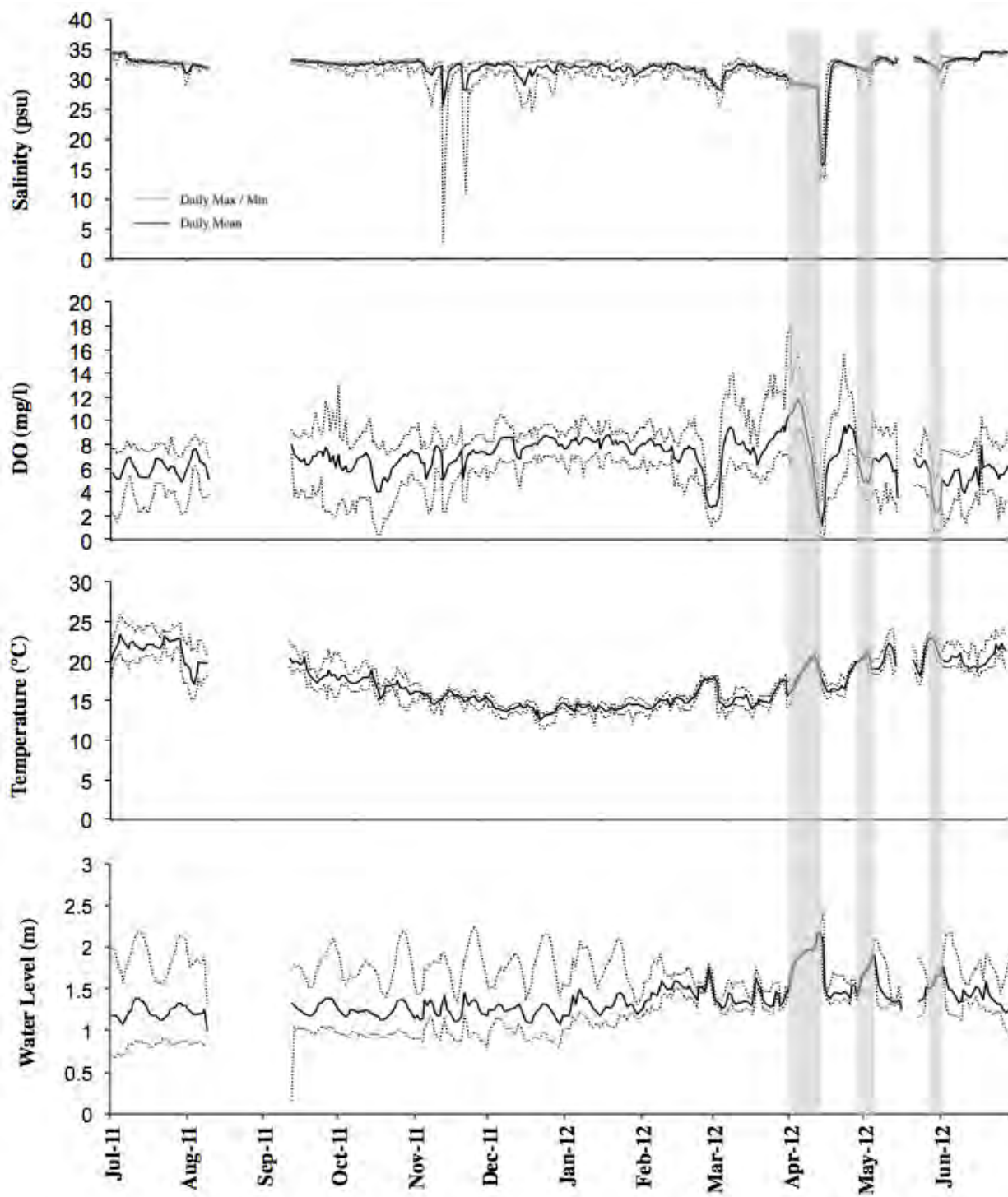


Figure 10 - Spatial water quality data





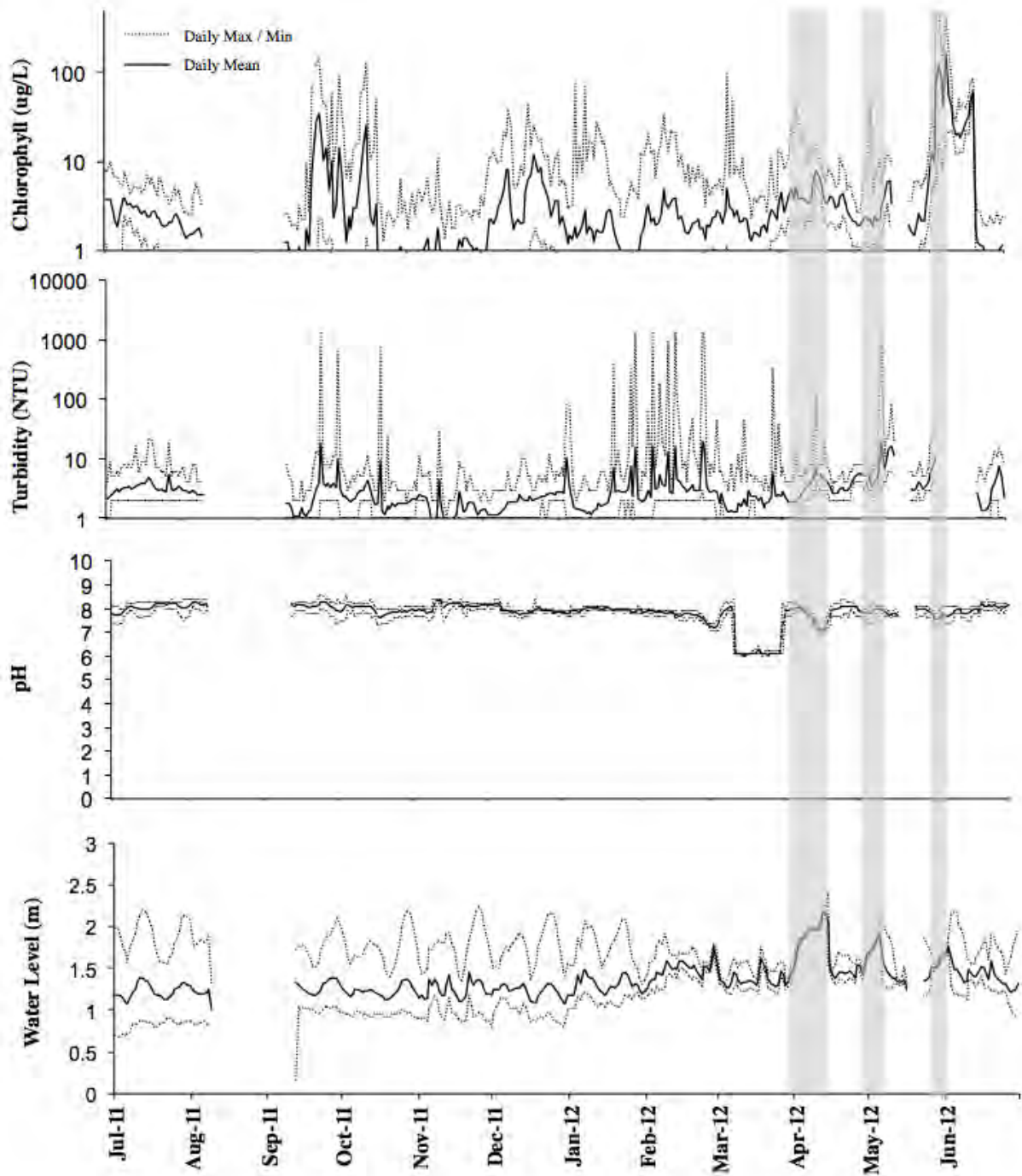


Figure 11 - Water quality data from deployed datalogger at Railroad Trestles. Data are presented as daily means, maximums, and minimums. Grey columns indicate the presence and estimated duration of a lagoon inlet closure. Gaps indicate periods when the data logger was inoperational.

## *LAGOON MOUTH CONDITIONS*

Although the lagoon mouth largely stayed open throughout the year (pers. obs. and Figure 12), there was a period of mouth closures followed by natural re-openings in April and May. These typically occurred during neap tide series, with subsequent spring series helping to re-open the system. Water quality data (15-min. data) from this period (Figure 13) indicate that water levels increased in the lagoon and there was a lack of tidal signal during closures. Oxygen levels decreased during closures, but recovered quickly after re-opening (Figure 13). It is noted that one of these closures / re-openings occurred after mechanical mouth clearing that occurred from May 14-18, 2012, which was more limited in scope than those that occurred in previous years. Approximately 14,600 cubic yards (cy) of sand was removed from the lagoon inlet during the 2012 operation. This amount was about 13,000 cy less than the average amount of sand removed during previous inlet maintenance efforts dating back to 2008. In June, California State Parks (CSP) provided supplemental lagoon maintenance efforts to remove additional sand from inlet area. Efforts focused on excavating just east of the lower bridge to improve connectivity between the ocean and lagoon channels. Generally this is performed as the final stage during annual maintenance, but funding limitations reduced the scope of work for 2012. CSP provided an excavator and bulldozer along with operators, working from June 25-27. Excavated spoils remained onsite and placed near the southern abutment of the lower bridge since beach disposal was not an available option.

Project cost is a key variable that influences the total amount of sand removed from the Lagoon and placed on Torrey Pines State Beach. Through adaptive management, LPLF has been successful in keeping project costs relatively low (i.e. approximately \$3.80/cubic yard) while creating multiple benefits beyond restoring tidal mixing within lagoon channels that include beach nourishment and improved public access and safety on Torrey Pines State Beach. It is estimated that there is approximately 60,000 cy of “beach quality” sand <sup>1</sup> available for removal from the Lagoon’s inlet area.

<sup>1</sup> Grain size being  $\geq$  90% sand of (primarily) marine origin.

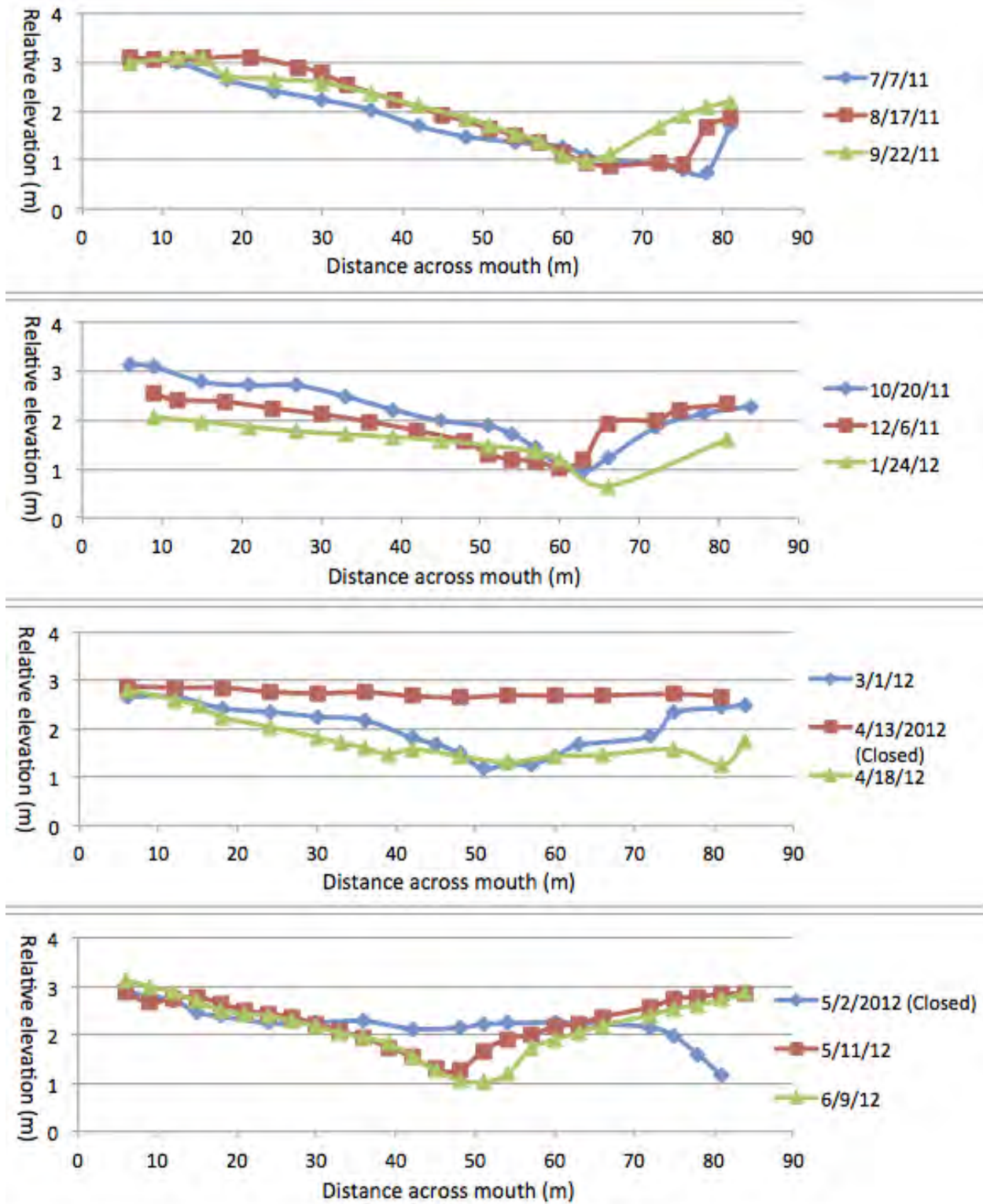


Figure 12 - Relative elevations at lagoon mouth

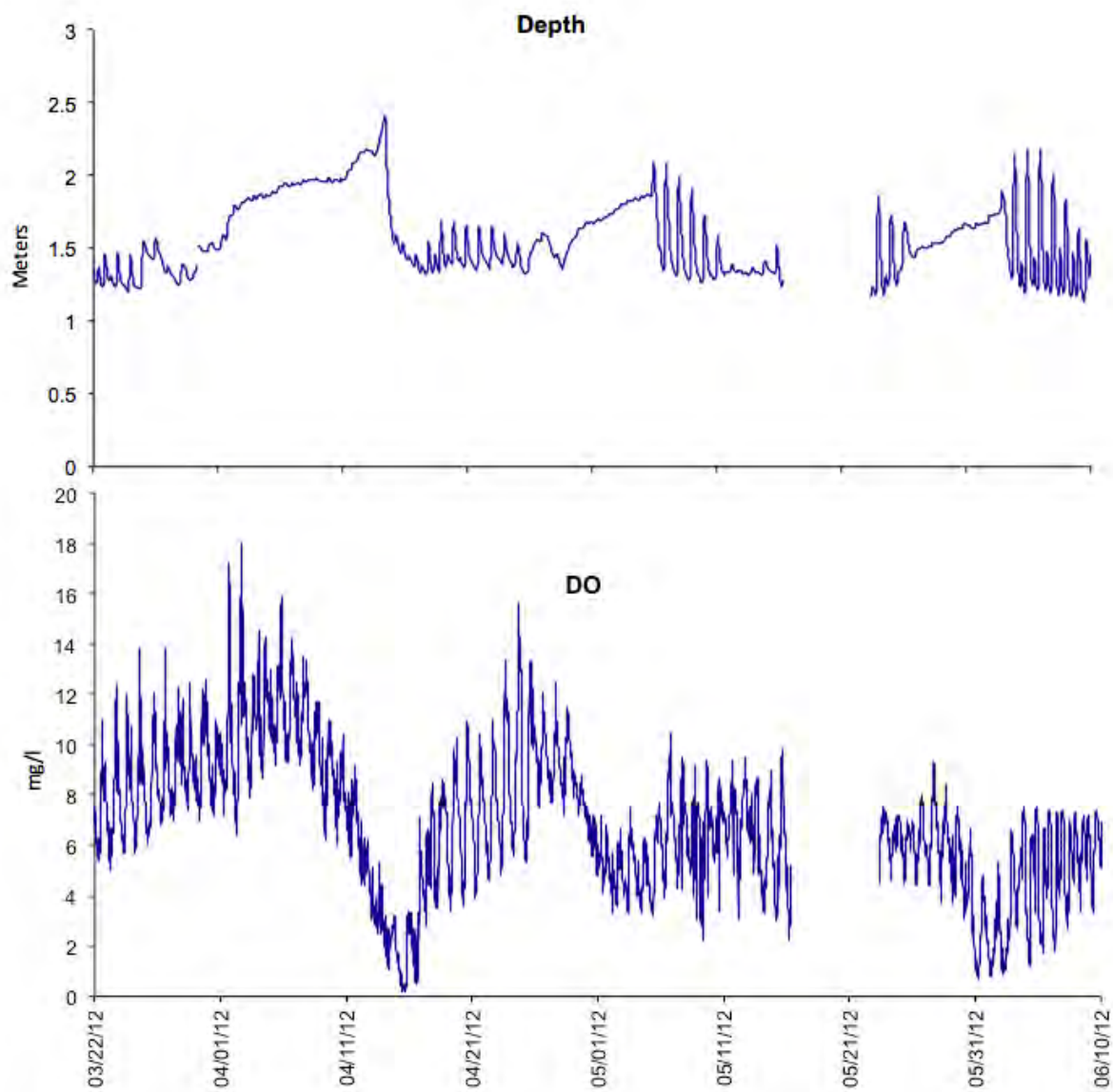


Figure 13 - 15-min. water depth and dissolved oxygen (DO) data for periods of intermittent mouth closures and re-opening

## NUTRIENTS AND CHLOROPHYLL

Monthly nutrient sampling commenced in April 2011 concomitant with sampling in the Tijuana River Estuary and south San Diego Bay. Monthly data from July 2011 - June 2012 are shown in Figure 14. The nutrient data for LPL levels tend to be more comparable to those found in San Diego Bay and typically lower than those found in the Tijuana Estuary, which receives sewage contaminated flows from Mexico.

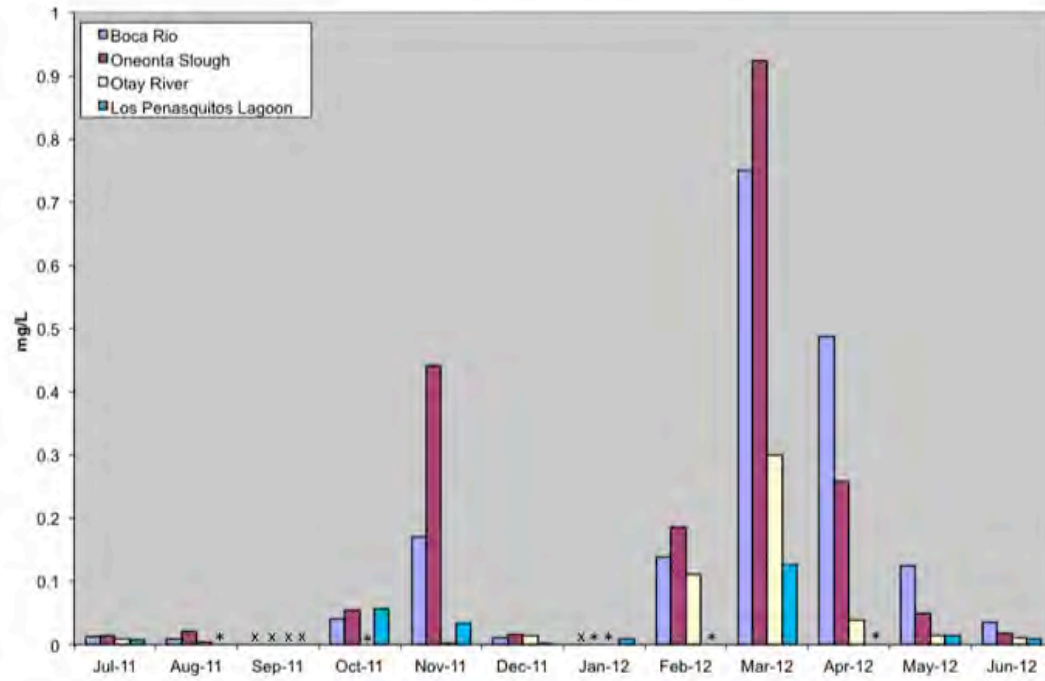
### Sewage Spill – September 9, 2011

Between September 8<sup>th</sup> and 9<sup>th</sup> approximately 2.3 million gallons of untreated sewage was discharged into the confluence of Los Peñasquitos Creek and Carroll Creek from the City of San Diego's Pump Station 64. The spill entered LPL from the southeast, downstream of the confluence and was carried to the Pacific Ocean by way of the Lagoon's main southern channel that runs along the southwest side of the railway berm. The spill resulted in beach closures from Del Mar in the north to La Jolla Shores in the south, as well as documented fish kills and elevated concentrations of indicator bacteria and ammonia within the Lagoon's southern channel. The full impact of the sewage spill on lagoon water quality and habitats is not completely captured by the monitoring program due to the absence of monitoring stations in this area of LPL. Efforts are currently underway to expand the monitoring program to include the southern channels and surrounding uplands. The results from samples taken at Monitoring Station W2 are briefly described below.

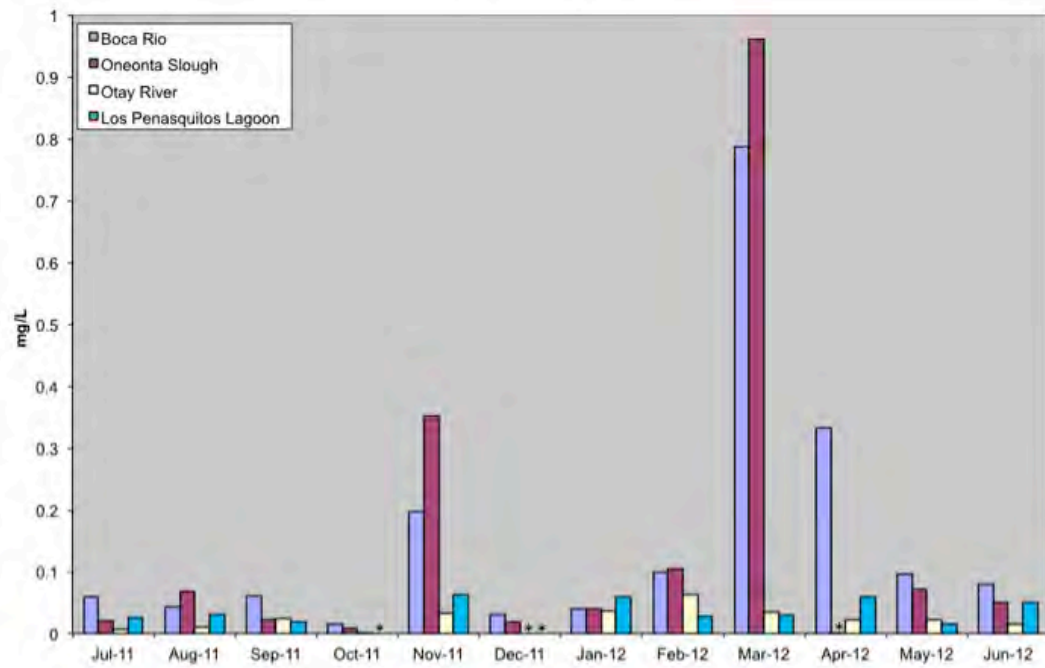
The sampling program failed to detect a noticeable signal in ammonia after the September 9<sup>th</sup> sewage spill when samples were taken on September 12<sup>th</sup> at Station W2. However, it should be noted that samples taken at W2 are not really representative of water quality within the southern lagoon channels that received the sewage flows during the spill. Station W2 is located in the Lagoon's main, northern channel near the northern railroad trestle and is used to monitor water quality as it relates primarily to drainage from Carmel Creek, runoff from the Torrey Pines Community area and tidal mixing at the Lagoon inlet. The spill that occurred on September 9<sup>th</sup> occurred at the southeast end of LPL, near the confluence of Los Peñasquitos Creek and Carroll Creek and entered Lagoon through its main southern channel. In order for contaminated waters to reach Station W2 they would have to backflow from the main southern channel, up the main northern. While this may have occurred to some degree during the rising tide on September 12<sup>th</sup> (i.e. ~ +5.12 feet NGVD at 9:53 am), sampling results were most likely affected by tidal mixing and year round flows of freshwater from Carmel Creek that both could have diluted concentrations of indicator bacteria within the sample area. Follow-up surveys and water quality testing conducted by CSP and San Diego Coastkeeper indicate that sewage effluent was still present in the Lagoon's southern channel on September 29<sup>th</sup>. These results indicate that contaminated water had remained within LPL 20 days beyond the date of the spill. More information about the results from this additional monitoring, including data sets and water sampling locations, can be found at [lospenasquitos.org](http://lospenasquitos.org).



### Nitrite/Nitrate



### Ammonia



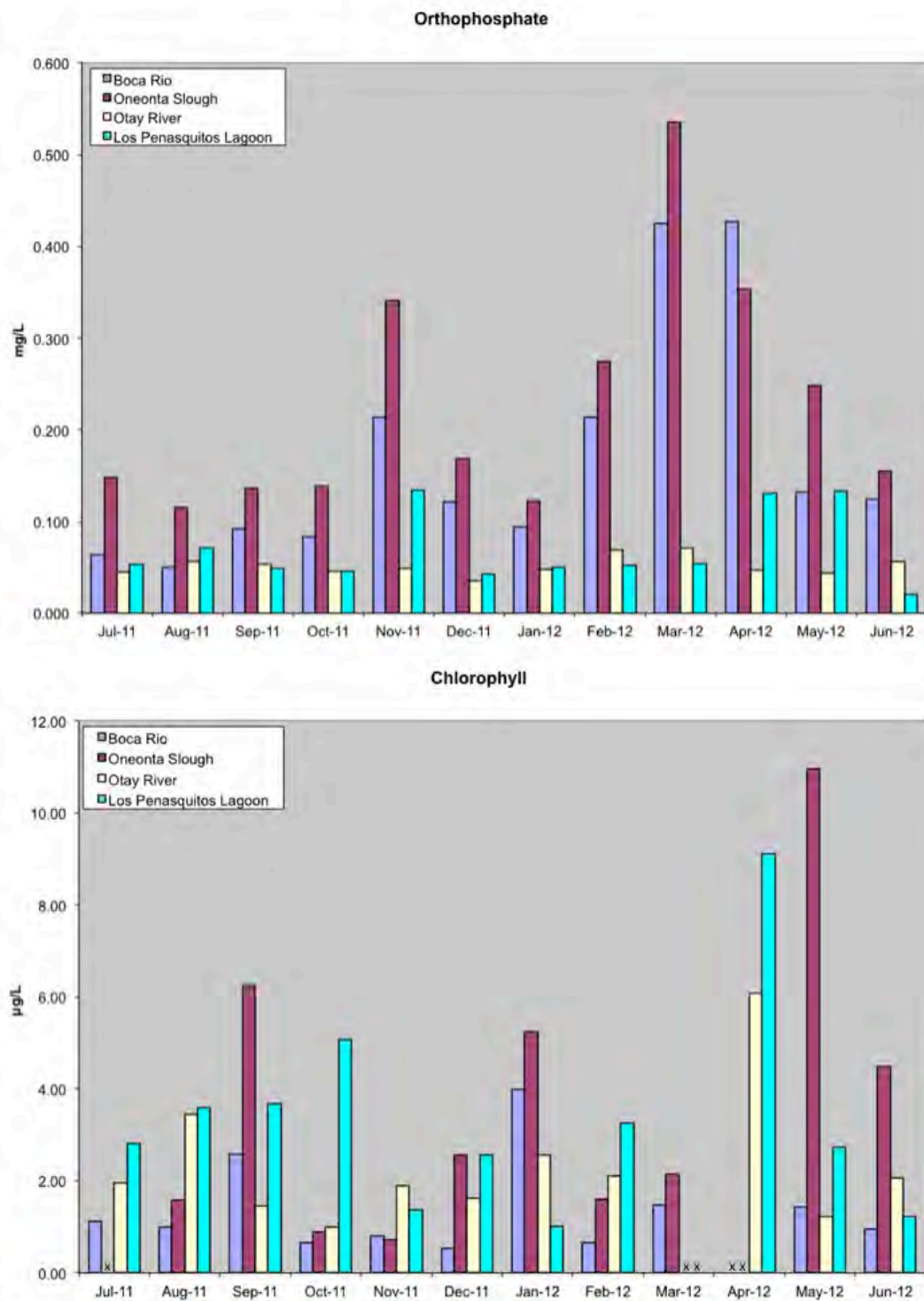


Figure 14 - Monthly nutrient data for two Tijuana Estuary sites (Boca Rio and Oneonta Slough), a San Diego Bay site (Otay River), and Los Peñasquitos Lagoon. \* indicates reading below instrument detection limit; x indicates no data

## VEGETATION

<sup>SS</sup> = Saltmarsh Species

<sup>TSA</sup> = Transitional Species, Alkali

<sup>SSOP</sup> = Saltmarsh Species, Obligate Parasite

<sup>TSB</sup> = Transitional Species, Brackish

<sup>ES</sup> = Exotic Species

<sup>TSR</sup> = Transitional Species, Riparian

### *FALL 2012 VEGETATION MONITORING - TRANSECTS*

Vegetation transects throughout the lagoon were first established in 1991 to serve as long-term monitoring areas. The rationale for each transect's establishment, brief description, and change in mean percent cover of dominant vegetation types are described below and in Figure 15 as well as Table 1. It should be noted that the names for pickleweed, shoregrass, and Italian ryegrass have been changed from *Sarcoconia pacifica* to *Salicornia pacifica*, from *Monanthachloe littoralis* to *Distichlis littoralis*, and from *Lolium multiflorum* to *Festuca perennis*, respectively. All references to these plant species have been updated to reflect these changes. Additional plant names are found in Table 2.

Vegetation surveys conducted along the transects for the 2011/2012 monitoring program occurred in October 2011. Overall, the dominant species found along the transects with regard to mean % cover were the following:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 32.1%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 13.4%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 21.2%
- Saltmarsh Daisy (*Lasthenia glabrata*)<sup>SS</sup> – 2.5%
- Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 29.3%
- Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> – 5.5%

*TRANSECT 1.* Transect 1 is located in the northwestern portion of the lagoon, west of the railroad and near the north beach parking lot (Figure 4). It is composed of two parallel 50 meter transects running approximately east to west. This site receives no tidal flushing and the soil tends to remain quite dry except following rainfall events or during a mouth closure. These transects were originally established to document the invasion of upper marsh and remnant dune habitat by upland weeds and exotic iceplant/hottentot fig (*Carpobrotus edulis*)<sup>ES</sup>.

Dominant vegetation types (mean % cover) when the transect was established in 1991 encompassed a mixture of saltmarsh, transition, and exotic species. Saltmarsh species dominated this transect, accounting for approximately 70% coverage. Individual species and their mean % cover found along this transect in 1991 included:

- Alkali heath (*Cressa truxillensis*)<sup>SS</sup> – 25%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 23%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 22%
- Iceplant/hottentot fig (*Carpobrotus edulis*)<sup>ES</sup> – 16%

- Ragweed (*Ambrosia* sp.)<sup>TSA</sup> – 5%

Surveys along this transect performed in 2011 indicated that this transect was still dominated by saltmarsh species. However, there was a decline in mean % coverage of saltmarsh species and increase % coverage for transitional species since 1991. There was also a decline in overall % coverage by exotic species that was most likely due to a manual removal program adopted in 1996 that virtually eliminated *C. edulis*<sup>ES</sup> from this site. Since then *D. spicata*<sup>SS</sup> has remained the dominant saltmarsh species. Exotic species found included wild radish (*Raphanus sativus*)<sup>ES</sup>, Italian ryegrass (*Festuca perrennis*)<sup>ES</sup>, and rabbitfoot grass (*Polypogon monspeliensis*)<sup>ES</sup>.

Surveys along Transect 1 yielded the following mean % cover by dominant species:

- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 39%
  - Survey indicated that 5% was completely or partially dead
- Goldenbush (*Isocoma menziesii*)<sup>TSA</sup> – 19%
  - Survey indicated that 2% was completely or partially dead.
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 17%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 11%
- Perennial glasswort (*Arthrocnemum subterminalis*)<sup>SS</sup> – 4%
- Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – 1%
- Vernal Pool Goldfields (*Lasthenia glabrata*)<sup>SS</sup> – 16%
- Wild radish (*Raphanus sativus*)<sup>ES</sup> – 3%

TRANSECT 2. Transect 2 is located in the northwestern part of the lagoon near the entrance to the north beach parking lot, to the east of the railroad (Figure 4). It consists of two parallel 50 meter transects running north to south under utility lines. The site receives tidal water via a narrow channel that runs under the road at the parking lot entrance connecting to the main tidal channel approximately 175 meters to the southeast. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

- Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 46%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 31%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 19%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 18%
- Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – 14%.

Species composition at Transect 2 has remained similar to what it was in 1991 though percent cover of each species has fluctuated. *S. pacifica*<sup>SS</sup>, *J. carnosa*<sup>SS</sup>, *F. salina*<sup>SS</sup>, *D. spicata*<sup>SS</sup>, and *C. truxillensis*<sup>SS</sup> have been present at this site since 1991. The obligate parasite, Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> was not found on this transect prior to 1995, but has been found annually since then. *S. pacifica*<sup>SS</sup> was the dominant species in 2011 with a percent cover of 57% as opposed to *J. carnosa*<sup>SS</sup> (46%) which was the dominate saltmarsh species at this transect in 1991. Average soil salinity in 2011 was 20.8 ppt, with a range of 10 - 27 ppt.

Surveys along Transect 2 yielded the following mean % cover by dominant, saltmarsh species:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 57%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 17%
- Saltmarsh dodder (*Cuscuata salina*)<sup>OPSS</sup> – 12%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 26%
  - Survey indicated that 20% was completely or partially dead.
- Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 11%
- Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – 13%.

TRANSECT 3. Transect 3 is located in the western lagoon, just east of Highway 101, which is now referred to as N. Torrey Pines Road (Figure 4). This transect is 100 meters long, with 21 quadrats. It was established to document how *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup> dominance were correlated with periods of tidal exclusion and changes in soil salinity. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 56%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 28%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 20%

From 1991-2002, three species have shared dominance at this site: *S. pacifica*<sup>SS</sup>, *D. spicata*<sup>SS</sup> and *F. salina*<sup>SS</sup>. Since then, *F. salina*<sup>SS</sup> has become the dominant species (65%) followed by *S. pacifica*<sup>SS</sup> (40%). There are many freshwater species just west of Transect 3 where runoff from Highway 101 (a.k.a. N. Torrey Pines Road) enters the lagoon via a drainpipe. During the rainy season, this is likely a significant source of freshwater; continued monitoring will indicate any vegetative changes associated with this. Average soil salinity in 2011 was 42.3 ppt, with a range of 10-59 ppt.

Surveys along Transect 3 yielded the following mean % cover by dominant, saltmarsh species:

- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 65%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 40%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 14%
- Saltmarsh dodder (*Cuscuata salina*)<sup>SSOP</sup> – 1%
- Alkali weed (*Cressa truxillensis*)<sup>SS</sup> – 4%.

TRANSECT 4. Transect 4 is also located in the western portion of LPL, east of Transect 3 (Figure 4). It is 80 meters long, oriented north to south, composed of 17 quadrats, and was established for the same reasons as Transect 3. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 38%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 27 %

From the time monitoring began in 1991 until 2001, two species, *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup>, have dominated along the transect. In 2011, a small amount of saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> was found and *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup> are still the dominant species. Average soil salinity in 2011 was 45.0 ppt, with a range of 35-65 ppt.

Surveys along Transect 4 in 2011 yielded the following mean % cover by dominant, saltmarsh species:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 59%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 34%

TRANSECT 5. Transect 5 is located in the southwestern portion of the lagoon, close to the upland transition zone (Figure 4). This transect is 50 meters long with 11 quadrats. Vegetation at the time of transect establishment in 1991 was comprised of native saltmarsh species, including:

- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 44%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 39%
- Shoregrass (*Distichlis littoralis*)<sup>SS</sup> – 34%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 10%.

From 1991 to 1998, *S. pacifica*<sup>SS</sup> coverage steadily increased to 89%, and has remained the dominant species since. Surveys along this transect performed in 2011 indicated that this transect was still dominated by saltmarsh species, with *S. pacifica*<sup>SS</sup> being the dominant species (71%). Average soil salinity in 2011 was 30.3 ppt, with a range of 21-40 ppt.

Surveys along Transect 4 yielded the following mean % cover by dominant saltmarsh species:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 71%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 18%
- Shoregrass (*Distichlis littoralis*)<sup>SS</sup> – 22%

Transects 9, 11 and 13 are all located in the northeast corner of the lagoon, near the Sorrento Valley and Carmel Valley Road intersection (Figure 4). Extensive development within the watershed has greatly increased disturbance, predominately through an increase in freshwater inflows. These three transects were established to monitor the expansion of exotic species near increased freshwater inflows along Carmel Valley Creek.



TRANSECT 9. Transect 9 is 40 meters long and comprises 9 quadrats. Vegetation at the time of transect establishment in 1991 was dominated by Pickleweed (*Salicornia pacifica*)<sup>SS</sup> with some Cattails (*Typha* sp.)<sup>TSB</sup>:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 81%
- Cattails (*Typha* sp.)<sup>TSB</sup> – 20%

*Typha* sp.<sup>TSB</sup> cover has increased in recent years to 69% in 2011 (Table 3). *S. pacifica*<sup>SS</sup> has decreased along the transect over the past 13 years to 6% cover. *J. carnosa*<sup>SS</sup> was first present in the transect in 2000 (13%) and has since increased to 58% cover. Habitat conversion with regard to increases in % coverage of *Typha* sp.<sup>TSB</sup> are most likely due to perennial freshwater input from Carmel Valley and continuous dry weather flows from a storm drain outfall located at the northern end of this transect at Carmel Valley Road. Average soil salinity in 2011 was 21.3 ppt, with a range of 14 - 31 ppt.

Surveys along this transect performed in 2011 indicated the following mean % coverage by dominant species:

- Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 58%
- Cattails (*Typha* sp.)<sup>TSB</sup> – 69%.
- Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> – 12%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 6%

TRANSECT 11. Transect 11 is 25 meters long and comprises 6 quadrats (Figure 4). When originally set up in 1991, Transect 11 ran west to east for 60 meters, starting east of a small creek and was dominated by *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup>, though several exotic and transition species were also present. Vegetation at the time of transect establishment in 1991 was comprised of the following dominant species, consisting primarily of salt marsh species:

- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 64%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 36%
- Spearscale (*Atriplex triangularis*)<sup>TSA</sup> – 16%
- Curly dock (*Rumex crispus*)<sup>ES</sup> – 2%
- Cattail (*Typha* sp.)<sup>TSB</sup> – 1%

By 1999, the eastern portion of the transect resembled a brackish marsh/riparian community dominated primarily by Cattail (*Typha* sp.)<sup>TSB</sup> and Willow (*Salix* sp.)<sup>TSR</sup>. *Typha* sp.<sup>TSB</sup> had also reached the edge of the creek. Assuming that *Typha* sp.<sup>TSB</sup> may not easily ‘jump’ the creek, in 2000 the transect was extended 30 meters to the west to further document the invasion of transitional and brackish species onto the marsh plain in this area of the lagoon. Since 2000, the eastern 60 meters of transect has been impassable due to extremely thick coverage by Cattail (*Typha* sp.)<sup>TSB</sup> and Willow (*Salix* sp.)<sup>TSR</sup>. The use of aerial photography and remote sensing data is needed to more accurately document the spread of Cattail (*Typha* sp.)<sup>TSB</sup> and Willow (*Salix* sp.)<sup>TSR</sup>. Since 2004, the transect includes only the area west of the creek. In

2008, only 25 meters of the 30-meter transect could be measured due to changes in the creek. Within this 25-meter section of Transect 11, *J. carnosus*<sup>SS</sup> (97%) was the dominant species in 2011 (Table 3). *C. salina*<sup>SS</sup> (9%) was also relatively common at the site.

**TRANSECT 12.** Transect 12 runs the length of the eastern marsh, using SDG&E utility lines as an overhead guide (Figure 4). It is the longest of the vegetation transects (260 meters) and has 14 quadrats. It was originally established to provide a rough estimate of exotic species invasion within the middle of the marsh. *S. pacifica*<sup>SS</sup> and *F. salina*<sup>SS</sup> were the dominant species in 1991, comprising 63% and 15% mean coverage, respectively. Upland transition species, including *R. crispus*, *A. triangularis*, *C. canadensis*, *Xanthium strumarium*, and annual grasses were also present.

In 2008, there was a large increase in *J. carnosus*<sup>SS</sup>, compared to covers of less than 20% in recent years. *S. pacifica* was also still common at the site. The exotic species *Festuca perennis* and *Polypogon monspeliensis* were the dominant invaders.

Surveys along this transect performed in 2011 indicated the following mean % coverage by dominant species:

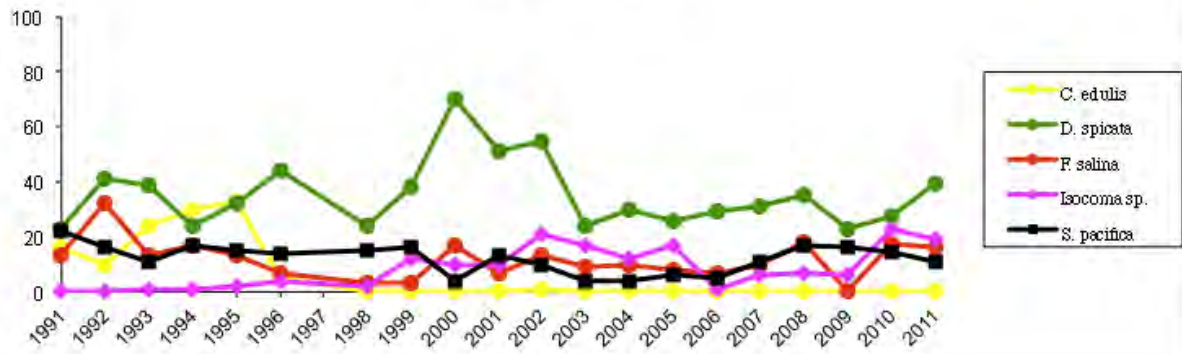
- Fleshy Jaumea (*J. carnosus*)<sup>SS</sup> – 72%
- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 21%
- Saltmarsh dodder (*Cuscuta salina*)<sup>SSOP</sup> – 10%
  - Survey indicated that 4% was completely or partially dead
- Rabbitfoot Grass (*Polypogon monspeliensis*)<sup>ES</sup> – 8%

**TRANSECT 13.** Transect 13 was established in 2001 to enhance the ability to detect the expansion of exotic species near Carmel Valley due to increased, perennial freshwater inflows from this sub-watershed. Transect 13 was also created to replace Transect 10, which became impassable when *Typha* sp.<sup>TSB</sup> expanded to the creek edge. Transect 13 is approximately 50 meters west of Transect 9 in the northeastern portion of the lagoon (Figure 4). It was originally 100 meters long and was comprised of two parallel 50 meter transects, 13A and 13B, which ran approximately south (adjacent to channel edge) to north (towards Carmel Valley Road). The exact location of transect 13A could not be found due coverage by *Typha* sp.<sup>TSB</sup> and was discontinued in 2004. In 2001, *S. pacifica*<sup>SS</sup> overwhelmingly dominated Transect 13B with ~85% cover. Surveys of this transect in 2011 indicated that coverage by *S. pacifica*<sup>SS</sup> had been reduced to 5%. At the same time, *J. carnosus* has increased from 6% cover in 2001 to become the dominant species in 2011 (92%). Average soil salinity in 2011 was 23.5 ppt, with a range of 16 - 30 ppt.

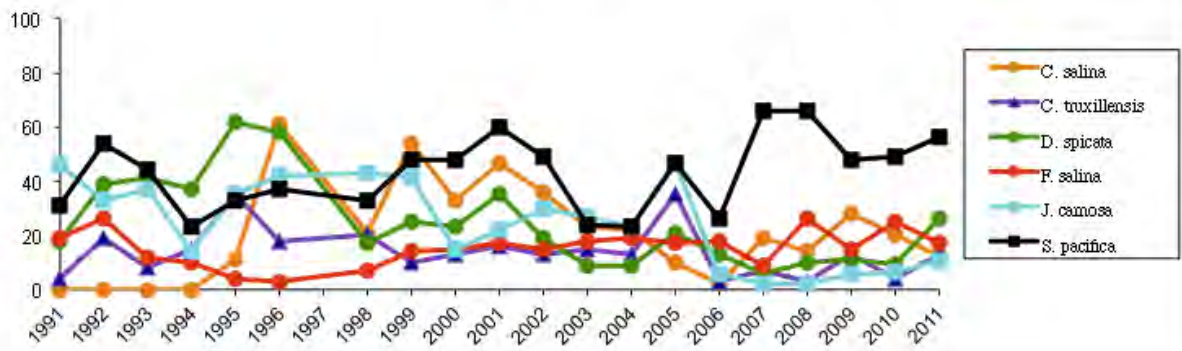
Table 1. Vegetation community and soil salinities for fall, 2011.

| Transect #                         | 1   | 2   | 3   | 4   | 5   | 9   | 11  | 12  | 13  |
|------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Average Soil Salinity              | -   | 21  | 42  | 45  | 30  | 21  | -   | -   | 24  |
| Mean Total % Plant Cover           | 99  | 99  | 100 | 91  | 100 | 99  | 100 | 100 | 100 |
| Mean % Cover of Individual Species |     |     |     |     |     |     |     |     |     |
| <b>Saltmarsh species</b>           |     |     |     |     |     |     |     |     |     |
| <i>Arthrocnemum subterminale</i>   | 4   |     |     |     |     |     |     |     |     |
| <i>Cressa truxillensis</i>         | 1   | 13  | 4   |     | <1% |     |     |     |     |
| <i>Cuscuta salina</i>              |     | 12  | 1   | <1% | <1% | 12  | 4   | 6   | 1   |
| <i>Cuscuta salina*</i>             |     |     |     |     |     |     | 5   | 4   | 8   |
| <i>Distichlis spicata</i>          | 35  | 6   | 14  |     | <1% |     | 2   |     | 7   |
| <i>Distichlis spicata*</i>         | 5   | 20  |     |     |     |     |     |     |     |
| <i>Distichlis littoralis</i>       |     |     |     |     | 22  |     |     |     |     |
| <i>Frankenia salina</i>            | 17  | 17  | 65  | 34  | 18  |     | 1   | 3   | 3   |
| <i>Frankenia salina*</i>           |     |     |     |     |     |     | 5   | 1   |     |
| <i>Jaumea carnosa</i>              |     | 11  |     |     | <1% | 58  | 97  | 72  | 92  |
| <i>Sarcocornia pacifica</i>        | 11  | 57  | 40  | 59  | 71  | 6   | 1   | 21  | 5   |
| <b>Transitional species</b>        |     |     |     |     |     |     |     |     |     |
| <i>Ambrosia acanthicarpa</i>       | 3   |     |     |     |     |     |     |     |     |
| <i>Atriplex triangularis</i>       |     |     |     |     |     | <1% | 4   |     |     |
| <i>Baccharus sarothroides</i>      | 1   |     |     |     |     |     |     |     |     |
| <i>Isocoma sp.</i>                 | 18  |     |     |     |     |     |     |     |     |
| <i>Isocoma sp.*</i>                | 2   |     |     |     |     |     |     |     |     |
| <i>Juncus bufonius</i>             |     |     |     |     |     |     |     |     | 8   |
| <i>Lasthenia sp.</i>               | 16  |     |     |     |     |     |     |     |     |
| <i>Pluchea odorata</i>             |     |     |     |     |     | 2   |     |     |     |
| <i>Pterostegia drymaroides</i>     | 5   |     |     |     |     |     |     |     |     |
| <i>Scirpus maritimus</i>           |     |     |     |     |     |     |     |     | 4   |
| <i>Scirpus maritimus*</i>          |     |     |     |     |     |     |     |     | <1% |
| <i>Typha sp.</i>                   |     |     |     |     |     | 69  |     |     |     |
| <b>Exotic species</b>              |     |     |     |     |     |     |     |     |     |
| <i>Lolium multiflorum</i>          | 4   |     |     |     |     |     |     |     |     |
| <i>Polypogon monspeliensis</i>     | 2   |     |     |     |     |     |     | 8   |     |
| <i>Raphanus sativus*</i>           | 4   |     |     |     |     |     |     |     |     |
| Transect length (m)                | 100 | 100 | 100 | 80  | 50  | 40  | 20  | 260 | 100 |
| Number of quadrats                 | 22  | 22  | 21  | 17  | 11  | 9   | 5   | 14  | 22  |

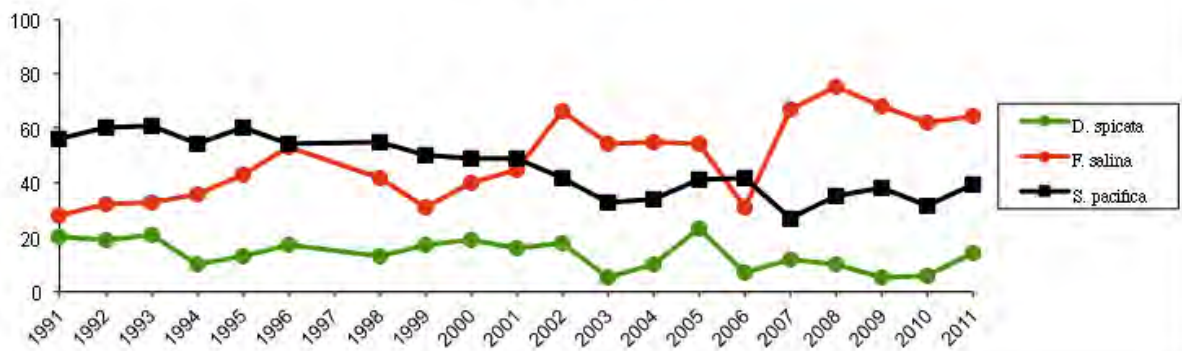
**Transect 1**

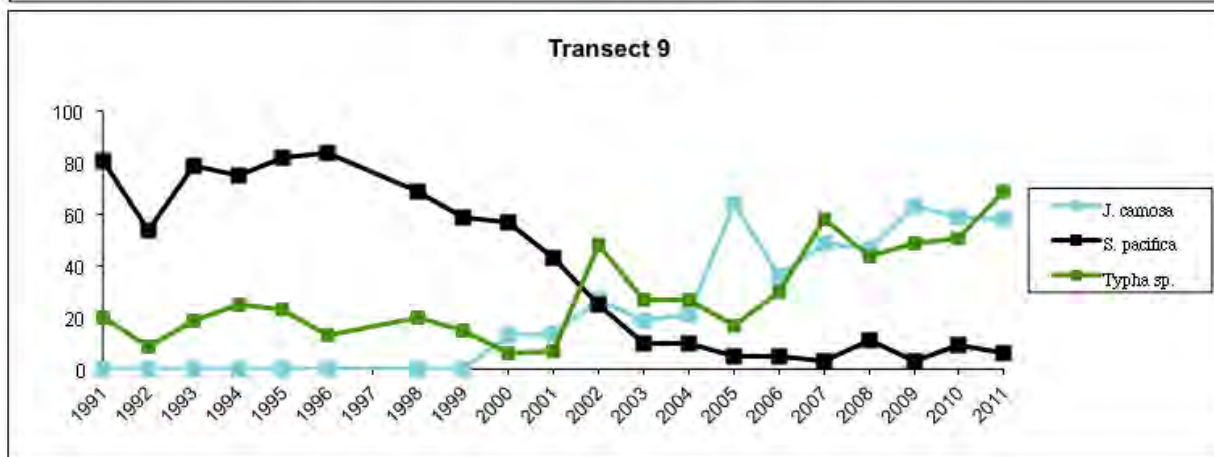
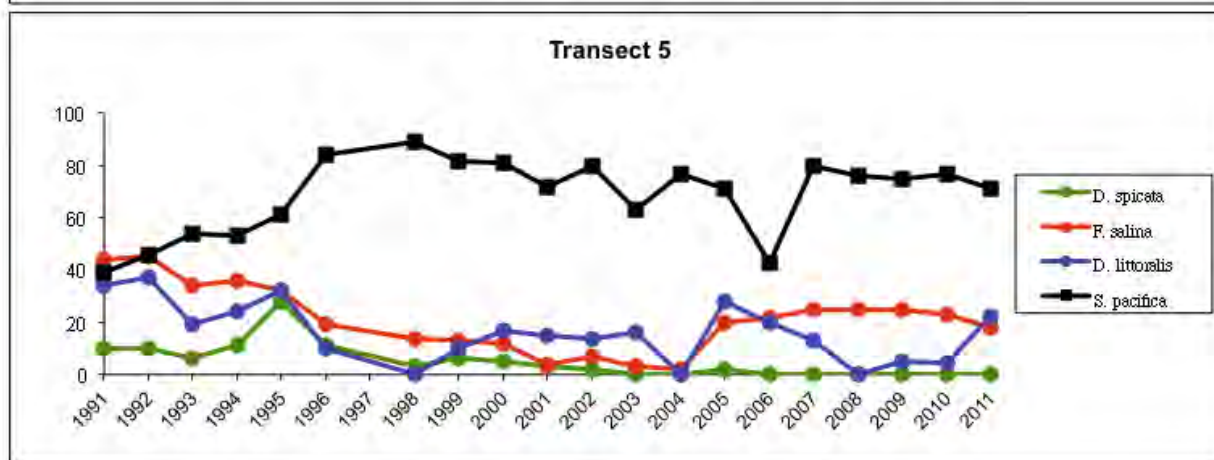
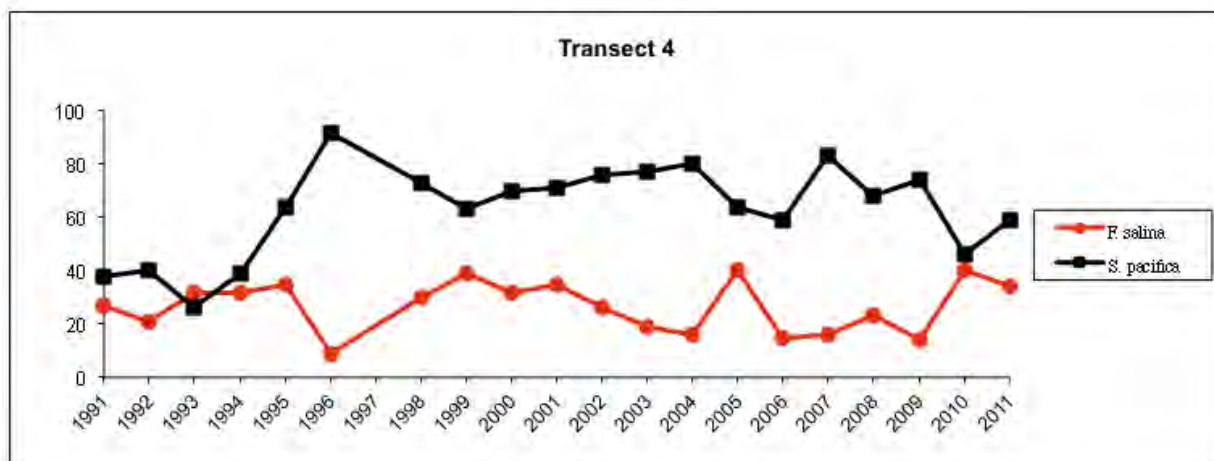


**Transect 2**



**Transect 3**







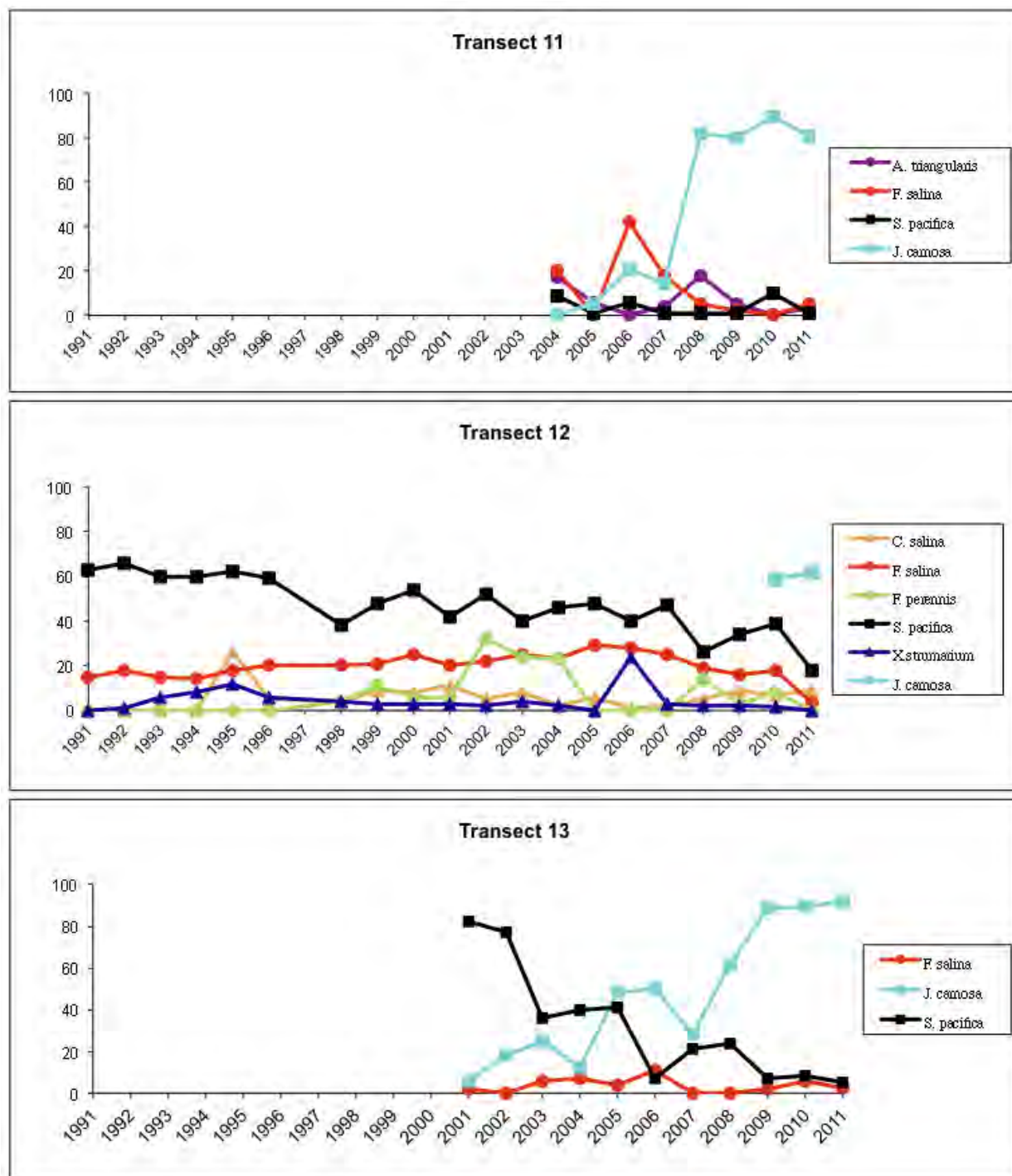


Figure 15 - Long-term vegetation data for dominant species



## SPRING 2012 VEGETATION MONITORING – TRANSECTS

TRANSECT 14. Annual *Lasthenia glabrata* ssp. *coulteri* monitoring took place for the fifth year in March 2012 on Transect 14 (Table 5). The average cover of *Lasthenia glabrata* ssp. *coulteri* was 1.5%, indicating a decline in cover from the previous 4 years. The dominant species was *S. pacifica*<sup>SS</sup> (Table 5) with lower quantities of several native salt marsh species present. *Cotula coronopifolia* and *Parapholis incurva*, both non-native species, were also present. Results from the 2012 survey found the following dominant species along Transect 14:

- Pickleweed (*Salicornia pacifica*)<sup>SS</sup> – 43%
- Alkali heath (*Frankenia salina*)<sup>SS</sup> – 3%
- Saltgrass (*Distichlis spicata*)<sup>SS</sup> – 15%
- Shoregrass (*Distichlis littoralis*)<sup>SS</sup> – 3%
- Curved Sicklegrass (*Parapholis incurva*)<sup>ES</sup> – 3%
- Brass Buttons (*Cotula coronopifolia*)<sup>ES</sup> – 7%
- Fleshy Jaumea (*Jaumea carnosa*)<sup>SS</sup> – 2%
- Perennial glasswort (*Arthrocnemum subterminalis*)<sup>SS</sup> – 4%

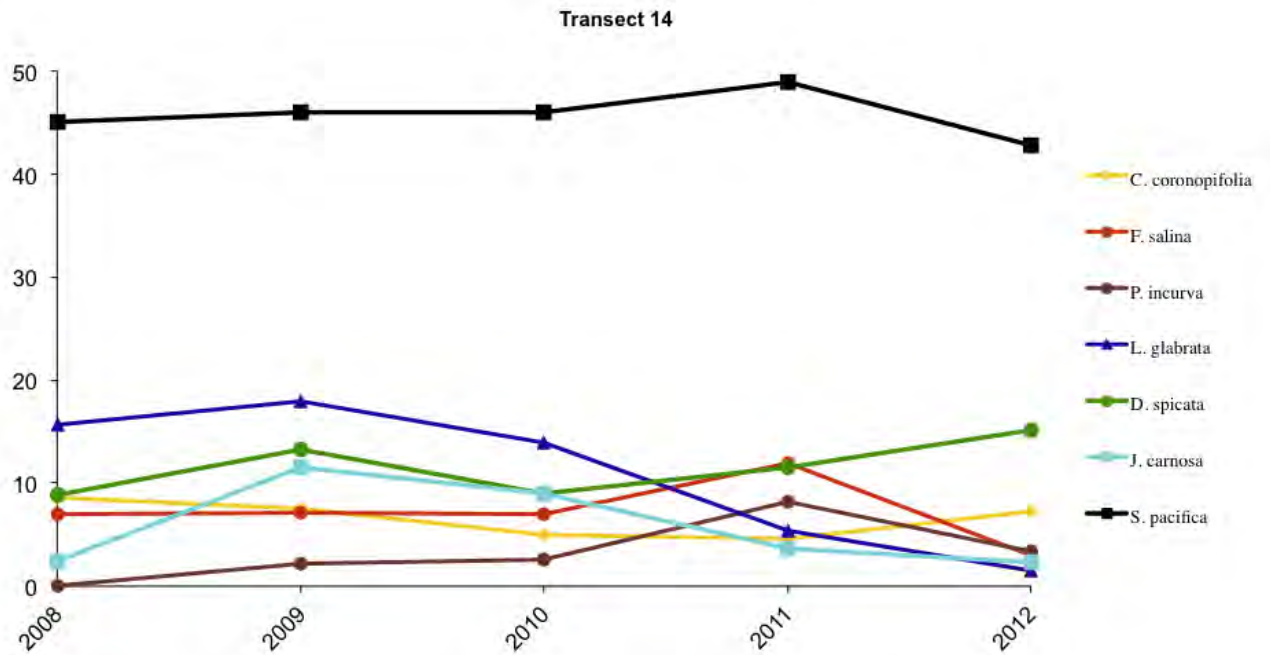


Figure 16 - Long-term data for spring vegetation transect

### TRANSECTS - SWMP Protocols

Pilot sampling across elevation zones (Figure 17) was able to detect shifts in vegetation with increasing elevation, from marsh assemblages to those characteristic of the upland transition zone. This sampling will be the basis of the full sampling which will occur in fall 2012.

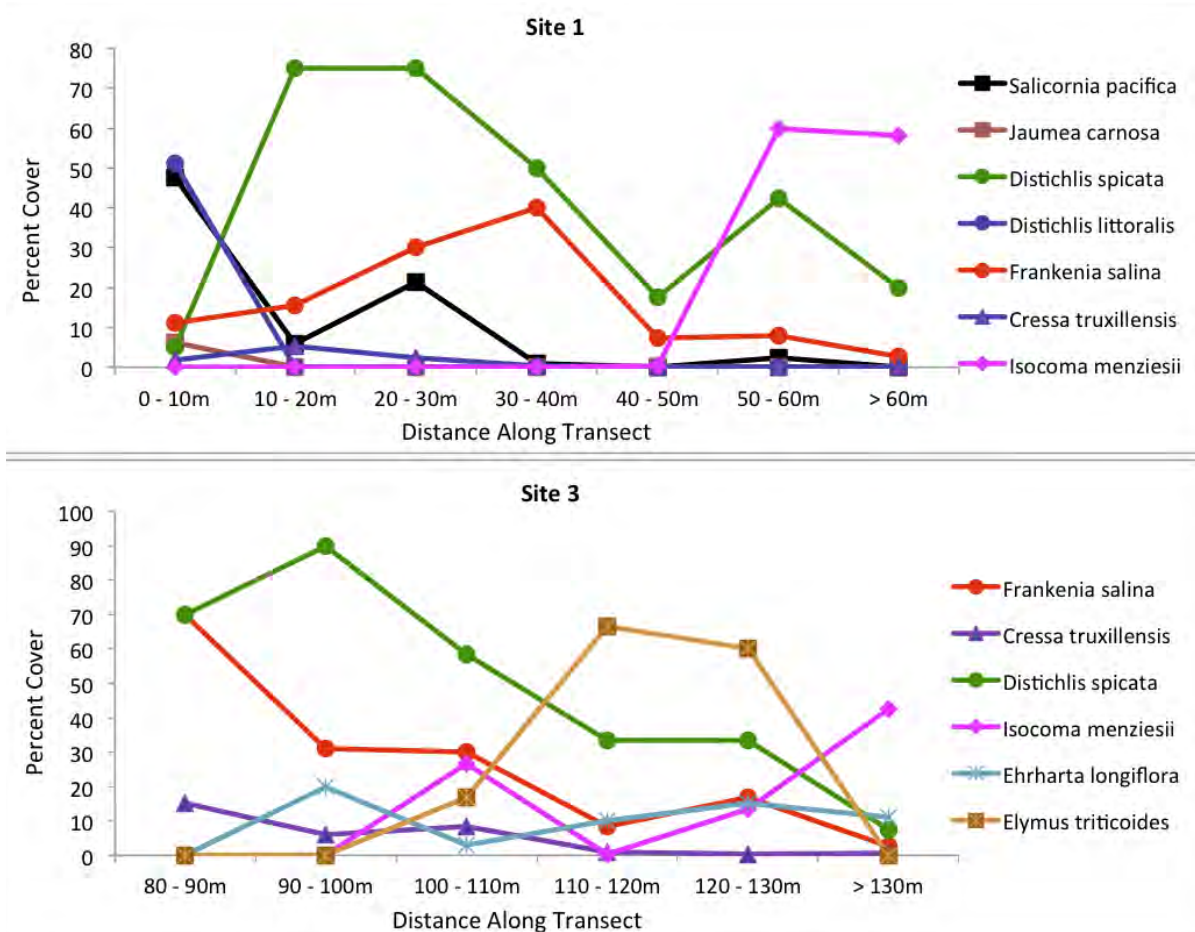


Figure 17 - Data from pilot transects across vegetation zones. Transects begin in the tidal marsh and end in the upland transition zone.

## IV. CONCLUSIONS AND RECOMMENDATIONS

The conditions in Los Peñasquitos Lagoon appear to be fairly typical of recent years. A primary concern remains the closure of the lagoon mouth, which can quickly lead to deteriorated water quality. This last year saw a series of mouth closures and re-openings, each characterized by decreased water quality and subsequent recovery with returned tidal exchange. Mechanical clearing of the mouth occurred in early May 2012, but this had a more limited scope than in previous year. The mouth temporarily closed after this excavation, but re-opened shortly thereafter. Additional excavation conducted at the inlet by California State Parks between June 25-27 proved successful in improving connectivity between the ocean and the Lagoon's channels, as the inlet remained opened through the summer months and into the fall.

The continued discharge of freshwater during the dry season also remains a problem. Several vegetation transects near the back of lagoon continue to indicate a type conversion from salt- to brackish-water habitats. This represents the most apparent long-term biotic change seen in the lagoon. Vegetation surveys should continue in this area to document this conversion.

In recent years, the monitoring program has been shifting to accommodate management needs while preserving core long-term elements. A key change this year was the piloting of the new, cross-elevation SWMP vegetation transects. This will provide the basis for a much expanded effort, which will bring LPL into a national network of sentinel sites. We also began work on the installation of a mouth camera, but persistent telemetry problems have delayed installation. These problems are being addressed through a new telemetry approach, and the mouth camera will be installed in the coming year. In addition, Los Peñasquitos Lagoon has been a focal location in a region-wide assessment of eutrophication in coastal lagoons, and continuing analyses of the results of this work will provide a better picture of both abiotic and biotic responses to nutrient loading. The first peer-reviewed publications are being prepared now.

Consideration of further adaptation of the monitoring program is also warranted. As mentioned in previous years, future directions should include periodic use of the California Rapid Assessment Method (CRAM), after appropriate training of monitoring staff or hiring trained sub-contractors to complete the work. Monitoring efforts should also look to increase the use of continuous water quality monitoring and real-time delivery of this data through telemetry at other locations within the lagoon. Currently there is only one such datalogger, located near the ocean inlet (StationW2), used primarily to show the effects of the ocean inlet on water quality within the western portion of the lagoon. Expanding the use of continuous water quality monitoring and real-time access to the data will greatly improve monitoring efforts and restoration of the lagoon's native habitats through better characterization of water quality and trends, instead of "snap-shots" of water quality provided by one-time sampling efforts. Use of real-time data will also provide quick access to data, which is sometimes required to guide management decisions, and will help avoid loss of data by notifying monitoring and management staff when data loggers are offline, instead of discovering this in the field during retrieval. Continuous monitoring of the downstream segments of the lagoon's three main tributaries will be needed to better quantify freshwater inputs from the watershed, pollutant loading and to better characterize the temporal and spatial dynamics of hypoxic events. Through such efforts, the LPL monitoring program can continue to provide the tools necessary for successful adaptive management of this urban lagoon.

## **V. ACKNOWLEDGEMENTS**

We wish to thank Jade Matrone, Lorena Warner-Lara, Marya Ahmad, and Krista Bergesen for assistance in the field and laboratory, along with the staff of the Torrey Pines State Reserve for their continued cooperation. We thank Mike Hastings, Megan Cooper, the Los Peñasquitos Lagoon Foundation, California Coastal Conservancy, and Southern California Wetlands Recovery Project for facilitating this work.

## VI. REFERENCES and LITERATURE CITED

- Boland, J. 1991. The physical, chemical and biological monitoring of Los Peñasquitos Lagoon; 1990-1991. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Boland, J. 1992. The physical, chemical and biological monitoring of Los Peñasquitos Lagoon; 1991-1992. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Boland, J. 1993. Maintaining an open mouth at Los Peñasquitos Lagoon 1991-1993: review and recommendations. Report prepared for the Los Peñasquitos Lagoon Foundation.
- Carpelan, L.H. 1961. Salinity tolerances of some fishes of a southern California coastal lagoon. *Copeia* 1: 32-39.
- Chapman, J. W., and J. A. Dorman. 1975. Diagnosis, systematics, and notes on *Grandidierella japonica* (Amphipoda: Gammaridea) and its introduction to the Pacific Coast of the United States. *Bulletin of the Southern California Academy of Sciences* 74:104-108.
- Covin, J. 1987. Los Peñasquitos Lagoon vegetation monitoring. Report prepared for the Los Peñasquitos Lagoon Foundation.
- Gibson, D., G.D. Williams, J. Boland 1994. The physical, chemical and biological monitoring of Los Peñasquitos Lagoon; 1993-94. Final report prepared for the Los Peñasquitos Lagoon Foundation. 19 pp + appendices.
- Greer, K.A. 2001. Vegetation type conversion in Los Peñasquitos Lagoon: an examination of the role of watershed urbanization. M.A. Thesis, San Diego State University, San Diego, California, 111 pp.
- Greer, K.A., and D. Stow. 2003. Vegetation type conversion in Los Peñasquitos Lagoon, California: an examination of the role of watershed urbanization. *Environmental Management* 31: 489-503.
- Mudie, P.J., B. Browning, J. Speth. 1974 The natural resources of Los Peñasquitos Lagoon and recommendations for use and development. Coastal Wetlands Series #7, California Dept. Fish and Game.
- Noe, G.B., and J. B. Zedler. 2001a. Variable rainfall limits the germination of upper intertidal marsh plants in southern California. *Estuaries* 24(1):30-40.
- Noe, G.B., and J. B. Zedler. 2001b. Spatio-temporal variation of salt marsh seedling establishment in relation to the abiotic and biotic environment. *Journal of Vegetation Science* 12(1):61-74.
- Nordby, C. 1989. Physical/chemical and Biological Monitoring of Los Peñasquitos Lagoon. Final report prepared for the Los Peñasquitos Lagoon Foundation.

- Nordby, C. 1990. Physical-chemical and Biological Monitoring of Los Peñasquitos Lagoon. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Nordby, C. and J. Covin. 1988. Physical/chemical and Biological Monitoring of Los Peñasquitos Lagoon. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Nordby, C. and J. Zedler. 1991. Responses of fishes and benthos to hydrologic disturbances in Tijuana Estuary and Los Peñasquitos Lagoon, California. *Estuaries* 14: 80-93.
- Oliver, I. and A. J. Beattie. 1993. A possible method for the rapid assessment of biodiversity. *Conservation Biology* 7(3):562-568.
- Purer, E. A. 1942. Plant ecology of the coastal saltmarshlands of San Diego County. *Ecol. Monogr.* 12:82-111.
- Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. Agricultural handbook No. 60. United States Department of Agriculture, Washington, D. C.
- San Diego Association of Governments (SANDAG) 1998. Watersheds of the San Diego Region. Special SANDAG Publication.
- Usui, C.A. 1981. Behavioral, metabolic, and seasonal size comparisons of an introduced gobiid fish, *Acanthogobius flavimanus*, and a native cottid, *Leptocottus armatus*, from upper Newport Bay, California. M.S. Thesis, California State University Fullerton, California, USA.
- Ward, K.M., M. Cordrey and J. West. 2000. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1999-2000. Annual report prepared for the Los Peñasquitos Lagoon Foundation. 46 pp
- Ward, K.M., J. West, and M. Cordrey. 2001. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 2000-2001. Annual report prepared for the Los Peñasquitos Lagoon Foundation. 48 pp.
- West, J., and M. Cordrey. 2002. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 2001-2002. Annual report prepared for the Los Peñasquitos Lagoon Foundation. 38 pp.
- Weston Solutions, Inc. 2009. TMDL Monitoring for Sedimentation/Siltation in Los Peñasquitos Lagoon. Final report prepared in response to Investigation Order R9-2006-076. Prepared for City of Poway, City of Del Mar, City of San Diego, County of San Diego and California Department of Transportation. January 2009.
- White, M.D., and K.A. Greer. 2006. The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Penasquitos Creek, California. *Landscape and Urban Planning*, 74, 125–138.
- Williams, G.D. 1995. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1994-95. Final report prepared for the Los Peñasquitos Lagoon Foundation. 27 pp.



Williams, G.D. 1996. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1995-96. Final report prepared for the Los Peñasquitos Lagoon Foundation. 33 pp.

Williams, G.D. 1997. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1996-97. Final report prepared for the Los Peñasquitos Lagoon Foundation. 39 pp.

Williams, G. D., G. Noe, and J. Desmond. 1998a. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon, 1997-98. Final report prepared for the Los Peñasquitos Lagoon Foundation. 48 pp.

Williams, G.D., J. Desmond, J. Zedler. 1998b. Extension of two nonindigenous fishes, *Acanthogobius flavimanus* and *Poecilia latipinna*, in San Diego Bay marsh habitats. *Cal. Fish and Game*, 84:1-17.

Williams, G. D., J. West, M. Cordrey, and K. Ward. 1999. The physical, chemical, and biological monitoring of Los Peñasquitos Lagoon. Annual report submitted to the Los Peñasquitos Lagoon Foundation. Pacific Estuarine Research Lab, San Diego State University, San Diego, CA.

Williams, G. D., J. M. West, and J. B. Zedler. 2001. Shifts in fish and invertebrate assemblages of two southern California estuaries during the 1997-98 El Niño. *Bulletin of the Southern California Academy of Sciences* 100(3):212-237.

Zedler, J.B. 1991. Invasive exotic plants: threats to coastal ecosystems. p 49-62. In: *Perspectives on the marine environment*. Eds. P.M. Grifman and S.E. Yoder. USC Sea Grant Publication.

Zedler, J.B. (ed.). 2001. *Handbook for Restoring Tidal Wetlands*. CRC Press. Boca Raton, Florida.

Table 2. Plant species found on LPL vegetation transects, 1991-2012.

| <u>Scientific Name</u>   | <u>Common Name</u>                    |
|--|---------------------------------------|
| <b>Saltmarsh Species</b>   |                                       |
| <i>Cressa truxillensis</i>   | alkali weed                           |
| <i>Cuscuta salina</i>  | salt marsh dodder                     |
| <i>Distichlis spicata</i>  | saltgrass                             |
| <i>Frankenia salina</i> ( <i>Frankenia grandifolia</i> )             | alkali heath                          |
| <i>Jaumea carnosa</i>  | fleshy Jaumea                         |
| <i>Limonium californicum</i>   | California sea-lavender               |
| <i>Lasthenia glabrata</i> ssp. <i>coulteri</i>                       | Coulter's goldfields, saltmarsh daisy |
| <i>Distichlis littoralis</i> ( <i>Monanthochloe littoralis</i> )     | shore grass                           |
| <i>Salicornia europaea</i> ( <i>Salicornia depressa</i> )            | annual pickleweed                     |
| <i>Arthrocnemum subterminale</i> ( <i>Salicornia subterminalis</i> ) | perennial glasswort                   |
| <i>Salicornia pacifica</i> ( <i>Sarcocornia pacifica</i> )           | pickleweed                            |
| <i>Spergularia marina</i>  | salt marsh sand-spurry                |
| <b>Transition Species</b>  |                                       |
| <i>Ambrosia</i> sp.  | ragweed                               |
| <i>Atriplex triangularis</i>   | spearscale                            |
| <i>Baccharis salicifolia</i>   | mule fat                              |
| <i>Baccharis sarothroides</i>  | broom baccharis                       |
| <i>Conyza canadensis</i>   | common horseweed                      |
| <i>Eleocharis</i> sp.  | spikerush                             |
| <i>Heliotropium curvassavicum</i>                                    | salt heliotrope                       |
| <i>Isocoma menziesii</i>   | goldenbush                            |
| <i>Juncus acutus</i>   | spiny rush                            |
| <i>Juncus bufonius</i>   | deer weed                             |
| <i>Acmispon glaber</i> ( <i>Lotus scoparius</i> )                    | toad rush                             |
| <i>Pluchea odorata</i>   | salt marsh fleabane                   |
| <i>Pilularia americana</i>   | American pillwort                     |
| <i>Salix</i> sp.   | willow                                |
| <i>Scirpus maritimus</i>   | alkali bulrush                        |
| <i>Typha</i> sp.   | cattail                               |
| <i>Xanthium strumarium</i>   | cocklebur                             |
| <b>Exotic Species</b>  |                                       |
| <i>Brassica nigra</i>  | black mustard                         |
| <i>Bromus hordeaceus</i>   | soft brome                            |
| <i>Cakile maritima</i>   | sea rocket                            |
| <i>Carpobrotus edulis</i>  | hottentot fig                         |
| <i>Chenopodium ambrosioides</i>                                      | Mexican tea                           |
| <i>Cortaderia selloana</i>   | pampas grass                          |
| <i>Cotula coronopifolia</i>  | brass buttons                         |
| <i>Crypsis schoenoides</i>   | swamp/Timothy grass                   |
| <i>Festuca perennis</i> ( <i>Lolium multiflorum</i> )                | Italian ryegrass                      |
| <i>Lythrum</i> sp.   | Hyssop's loosestrife                  |
| <i>Picris echioides</i>  | bristly oxtongue                      |
| <i>Polypogon monspeliensis</i>                                       | rabbit's-foot grass                   |
| <i>Rumex crispus</i>   | curly dock                            |
| <i>Sonchus asper</i>   | prickly sow thistle                   |
| <i>Sonchus oleraceus</i>   | common sow thistle                    |

## **APPENDIX B**

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### Monitoring Methods and Results

# APPENDIX B. MONITORING METHODS

## AND RESULTS

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The 1985 Los Peñasquitos Lagoon Enhancement Plan developed a set of objectives and action items to help guide monitoring efforts within LPL and the watershed. The following presents monitoring results by action item.

### **Action Item #1. Periodically measure the physical and chemical parameters of the lagoon waters, such as water level, salinity, temperature and dissolved oxygen.**

#### **Water Quality**

A monitoring program was developed to gather standard water quality parameters (e.g. DO, salinity, conductivity, pH, temperature, water levels) within lagoon channels. Continuous since 1987, the program provides an account of aquatic health within the lagoon and helps to guide mechanical excavation of the lagoon inlet area and mouth to prevent water quality from becoming lethal to native aquatic species. Sampling locations, frequency, methods and modifications to the monitoring program since 1987 are briefly described below.

Established in 1987, three stations have been used to monitor water quality within Los Peñasquitos Lagoon (Greenwald and Britton 1987). These stations are shown in Figure A-1 and briefly described below:

- **Station W1 (Via Grimaldi, formerly Milligan House)** – Station W1 is located along Carmel Valley Road (at the Via Grimaldi intersection) in the northern arm of the estuary. This station consists of a channel approximately 20 m wide and 1.0 m deep and sediments composed of clay covered with a shallow layer of organic matter.
- **Station W2 (Railroad Trestles)** – Station W2 is located at the large railroad bridge that crosses the main lagoon channel; water quality readings are taken from the catwalk near the middle of the channel, where water depths are approximately 2.0 m.
- **Station W3 (Lagoon Inlet)** – Station W3 is located in one of the channels closest to the lagoon mouth and is most directly exposed to ocean flows and tidal mixing. This site is fairly shallow, with sandy sediments and a highly variable width (8.0 - 40 m) because of its dynamic hydrology.

From 1987 to 1997, all three stations were sampled every two to four weeks, with increased frequency during mouth closure events. Water quality measurements were also made while performing fish and invertebrate sampling. In addition, intensive sampling had been conducted using datalogger deployed at one station from two weeks to 1 month for each sampling period. W2 became a continuous sampling site in 1997 and telemetered in 2008 to provide access to real-time data sets taken in 15-minute intervals. Spatial water quality monitoring has since been conducted (approximately) on a monthly basis at all three stations.

## **Methods**

### ***Continuous Water Sampling***

Intensive water quality sampling was conducted at Station W2, located at the northern-most railroad trestle (Figure A-1) using a YSI model 6600 multi-parameter datalogger installed at a fixed position approximately 0.30 m off the channel bottom. Data from this logger is available in real-time through telemetry (<http://76.12.205.63/main.html#>) along with weather information recorded near W2. The following water quality parameters were measured every 15 minutes by the datalogger at W2:

- Salinity in practical salinity units (psu)
- Water temperature (°Celsius)
- Dissolved Oxygen (DO) in milligrams per liter (mg/L)
- Water level (meters)
- Turbidity in Nephelometric Turbidity Units (NTU)
- pH
- Chlorophyll (µg/L)

### ***Spatial Water Sampling***

Spatial water quality monitoring was conducted at each station along the surface, middle, and bottom of the channel using a YSI 600xlm multi-parameter water quality datalogger connected to a YSI 650 MDS (Multi-parameter Display System). Spatial water quality monitoring measured water temperature, salinity, and DO.

Monthly nutrient and chlorophyll sampling began in April 2011. The water sample is collected at Station W2 and analyzed according to protocols established by National Ocean and Atmospheric Agency (NOAA) and National Estuarine Research Reserve (NERR) protocols. The parameters assessed are orthophosphate, nitrate/nitrite (combined), ammonium, and chlorophyll. Data are compared to samples collected from the Tijuana River Estuary and south San Diego Bay, collected as part of the larger TRNERR effort.

## **Assessment of Success**

Monitoring of physical and chemical parameters of the lagoon waters (e.g. water level, salinity, temperature, and dissolved oxygen) is an invaluable tool for assessing lagoon health, documenting shifts in lagoon environs caused by urban activities (e.g. perennial freshwater inputs from dry weather flows), and identifying idiosyncrasies of aquatic environs within LPL (e.g. areas of stagnant water and/or stratification). Perhaps the longest uninterrupted data set for physical and chemical parameters in lagoon waters in southern California, if not the State, the monitoring program also provides tremendous regional benefits as many monitoring programs in other lagoons are relatively new and lack a historical perspective. Recent efforts have been made to modify the monitoring of physical and chemical parameters of lagoon water to facilitate management decisions at the lagoon, while keeping the scientific value of the data collected intact.

Aside from monitoring ongoing trends of aquatic health within lagoon channels, the continuous water quality monitoring has greatly improved lagoon mouth maintenance and efforts to expand the Lagoon tidal prism through mechanical excavation. Biologic criteria established in lagoon mouth maintenance permits, specifically the program's Coastal Development Permit issued by the California Coastal Commission, sets specific triggers for lagoon mouth openings related to DO and salinity in lagoon waters. Prior to the placement of the permanent data logger at W2, staff biologists responded to lagoon mouth closures by a deploying a datalogger near the inlet to assess water quality parameters for stressful or lethal

levels. A reactive approach, this method proved to be inefficient and relatively unsuccessful in protecting the health of aquatic species. Water quality parameters would often reach lethal levels by the time the inlet was reopened, due in most part to delays caused by scheduling monitoring efforts, reviewing data for accuracy, notifying resource agencies regarding biological criteria, and scheduling lagoon mouth excavation activities. Continuous monitoring of DO and salinity, as well as temperature and lagoon water elevations, allowed LPLF and TRNERR scientists to observe declining trends over time in water quality during inlet closures. This allowed a more proactive approach to meeting biological criteria for lagoon mouth openings, since it could be shown that water quality continued to decline and that restoring the lagoon's tidal prism was essential to avoid fish kills. Continuous monitoring and the proactive approach to restoring the Lagoon's tidal prism during inlet closures was further improved when this datalogger was telemetered in 2008. Providing access to real-time water quality data from this station further improved the ability to establish and validate declining trends in water quality during lagoon mouth closures and improving water quality trends after mechanical excavation of the inlet area. Having this information in real-time improved the ability to determine the need to restore the Lagoon's tidal prism and avoid impacts to aquatic species within the lagoon caused by declining water quality (i.e. DO) since this information could be quickly disseminated to decision makers, including resource agencies, and mechanized excavation equipment secured expeditiously.

Using measures of chlorophyll in tidal wetlands to determine eutrophication from urban runoff is currently under investigation due to confounding factors that may affect data sets and their ability to differentiate between causal factors (e.g. urban runoff), ambient nutrient levels in ocean waters and legacy nutrient loads absorbed into and/or adsorbed onto lagoon sediments.

## **Steps Forward**

Although the water quality parameters now measured allow assessment of estuarine conditions and provide support for management decisions, opportunities exist to provide a more in-depth picture of the health of LPL. In general, expanding the number of monitoring stations within the Lagoon could provide a more complete picture of the Lagoon and its interaction with the watershed and ocean. Currently, water quality is only monitored in the northern edge of the Lagoon. Expanding the monitoring program to other areas within the Lagoon to capture valuable data sets is needed to establish baselines, observe and characterize trends, facilitate management decisions, and guide restoration efforts. A massive sewage spill that occurred in September 2011 due to a failure at the City of San Diego's Pump Station 64 located in Sorrento Valley highlighted the need to expand the current monitoring program, since impacts to aquatic environs caused by rapidly depleted dissolved oxygen could have been better characterized had there been established monitoring stations in the southeastern portion of the Lagoon. Expanding the monitoring program to the southeastern portion of LPL will also better capture ambient and episodic loading from both sub-watersheds (i.e. Los Peñasquitos and Carroll Canyon) that empty into the LPL at this location. Funding the expansion of the monitoring program may be realized through Sediment Total Maximum Daily Load (TMDL) for LPL, which requires lagoon restoration as a compliance target, as well as the countywide bacteria TMDL. Furthermore, mitigating the sewage spill in September 2011 may also provide funding to expand and improve the monitoring program.

Implementing continuous monitoring of water quality parameters on telemetered dataloggers at current and new monitoring stations will greatly improve the ability to capture trends in water quality parameters. Continuous monitoring of water quality parameters helps to avoid data gaps and helps to differentiate between ongoing trends and responses to episodic events, versus aberrations and/or errors in data collection. Real-time delivery of information improves decision making and response times by resource managers, allows incorporation into larger ocean observing system networks (such as the Southern California Coastal Ocean Observing System) and provides early detection of datalogger failures.



Monitoring other constituents, such as fecal indicator bacteria (e.g. coliforms, bacteroides), toxins, pesticides and flow within lagoon channels would also improve efforts to characterize lagoon health, possible pollutant loading and threats to water quality. Adding these constituents to the monitoring program would greatly enhance the ability to determine the effects of legacy impacts (e.g. agriculture, ranching, live sewage discharges) on Lagoon health and the role that urban, commercial and industrial areas, as well as transportation corridors play on Lagoon resources with regard to pollutant loading and its role with regard to impacts to lagoon resources and public health.

## **Action Item #2. Measure biological parameters, including surveys of benthic invertebrates, fish, birds, and vegetation.**

### **Benthic Invertebrates and Fish**

Both surface invertebrates (e.g. small polychaetes, crustaceans) and deep-dwelling invertebrates (e.g. bivalves) were sampled in Los Peñasquitos Lagoon from 1987 to 2009. In 1986 and 1987, Ecological Research Associates (ERA) performed an initial study establishing five fish and invertebrate monitoring sites in the lagoon (Greenwald and Britton 1987) (Figure A-2). From 1988 through 1991 separate sites were being used to monitor fishes and invertebrates. Three of these sites were then selected for continued monitoring efforts to provide a spatial gradient to reflect differences between the “upper” and “lower” lagoon (Nordby and Covin 1988). Two of the station locations were changed in 1992 so that all three sites were located along a gradient in the north arm of the reserve with fish and invertebrate samples being taken at the same locations. Two stations were added in 1996 to better monitor areas, which are heavily influenced by freshwater inputs. These three stations were located along a gradient in the north arm of the reserve and have been monitored continuously up to the 2008/2009 monitoring program.

Prior to 1996, invertebrates were sampled seasonally in spring, summer, fall, and winter. This was reduced to semi-annually, winter and summer only, when densities have been shown to be highest. Beginning in 2001 and continuing to 2008, sampling was again reduced, and sampling now occurs annually during the summer. This decision was based on a scientific assessment of the necessary periodicity of invertebrate sampling, given that processing of benthic samples is labor intensive and costly.

Fishes were sampled seasonally in spring, summer, fall, and winter from 1986 through 1989 and 2002 through the 2008/2009 monitoring period. Between 1990 and 2001 they were sampled semi-annually in the winter and summer only. Seasonal sampling was resumed to enable better emphasis of seasonal differences.

### **Methods**

#### ***Invertebrates***

The baseline study in 1987 utilized Birge-Ekman grab samples with a 218.68 sq cm sample area. Three replicates were made and passed through a 1-mm mesh sieve. Subsequent sampling has utilized cylindrical “clam guns” with a 15-cm diameter (176 cm<sup>2</sup> area) pushed to a depth of 20cm. Between 1988 and 1990, small shallow dwelling organisms (mainly polychaetes and amphipods) and large deep dwelling organisms (mainly bivalves) were determined using the same samples passed through a 1mm mesh sieve. Three samples of three cores each were made at each station for a total of nine cores per station. Easily identified animals were counted and released, while others were preserved and identified

in the lab. Most animals were identified to the species level, although some species were pooled into more broad taxonomic categories.

It was determined that most small organisms could be found within the top 5cm of the surface, so beginning in 1990 shallow organisms were sampled at a depth of 5cm and deeper dwelling organisms at a depth of 20cm. Different mesh sizes were also used to process the samples: 1-mm mesh for shallow organisms and 3-mm mesh for deeper organisms. This resulted in much improved processing efficiency. Until 2004 the number of cores at each station was reduced by combining three cores into each sample at each station for a total of three samples per station. In 2004, the sub-samples were no longer pooled, which allowed calculation of sample variation and improves analytical power, while also allowing direct comparisons to earlier data.

## ***Fish***

At each study site a linear distance of 5 -10 m (depending on the size of the channel) was measured parallel to the channel and blocking nets were deployed to confine all fishes within this area. A bag seine was then swept between the two blocking nets and across the channel to the opposite bank (defining 1 pass). Passes are repeated until the fishes effectively captured by seine approaches zero. The species composition and number of fishes collected are recorded separately for each pass. Sub-samples of at least 30 individuals per species are measured and then released outside the blocking nets. In 2004 the protocol was augmented to include the capture from each blocking net in addition to the seine passes.

## **Assessment of Success**

Monitoring of invertebrates and fish has been suspended since the 2009/2010 monitoring period. It was determined that emerging priorities for the monitoring program (e.g. monitoring eutrophication) should be funded to facilitate regional studies and help to better guide management decisions within LPL and watershed. The monitoring program operates on a relatively fixed annual budget funded through the Lagoon Special Deposit Fund, managed by the State Coastal Conservancy. Annual budgets for the monitoring program are set and adhered to in order to perpetuate this fund as far into the future as possible, while focusing on core needs that monitoring program needs to provide.

## **Steps Forward**

It is anticipated that monitoring for invertebrates and fish could be resumed in the future if program priorities change and/or additional funding is acquired. The importance of invertebrates as a food source to migratory and native birds, including sensitive species, makes this data set valuable, as well as being an indicator species for water quality. Furthermore, tracking the presence and population trends of both native and invasive invertebrate and fish species in LPL could provide both local and regional benefits, especially with regard to LPL's proximity to the two Areas of Special Biological Significance (ASBS), located to the south in La Jolla Cove.

## **Birds**

Bird surveys and census reporting has been conducted by California State Parks, California Department of Fish and Game, docents from the Torrey Pines State Reserve, and other various volunteer organizations (e.g. San Diego Audubon Society). Results from these efforts are not recorded in the annual monitoring reports and can be found separately. Therefore a description of monitoring locations, frequencies, methods and assessments are not included in this appendix.

## Steps Forward

Continuing bird surveys, either directly through TRNERR or in conjunction with California State Parks, would provide a valuable tool in managing LPL and for future restoration efforts. Coastal estuaries and lagoons play a key role for bird species, especially within the Southern California Bight and Pacific Flyway. Furthermore, continued monitoring of sensitive bird species within LPL will help resource agencies and other interested stakeholders assess the health and recovery of these species both locally and regionally, as well as assist in restoration and enhancement efforts of areas within LPL that provide nesting and foraging habitat. Focused surveys of listed species at LPL may also provide additional benefits (e.g. determining specific areas within LPL preferred by Light-Footed Clapper Rail for foraging and nesting), since many of the current survey and census efforts are conducted in several of coastal lagoons and estuaries in southern California.

## Vegetation

Vegetation monitoring was conducted to document the distribution, density, and assemblages of native plants, spatial and temporal changes in species composition, and to determine the magnitude of historic saltmarsh habitat invasion by upland/exotic species.

Vegetation is monitored along established transects in nine areas (Figure A-1). Five of these areas have been monitored since 1987 (Transects 1-5), four since 1990 (Transect 9, Transect 11, and Transect 12) and one since 2001 (Transect 13A and Transect 13B). The locations of Transects 1-8 were chosen based on earlier studies done in the area to allow for long-term comparisons. Transects 6 - 8 were discontinued in 1998 because they could not be relocated (Nordby 1989). In 1990, Transects 9-12, were added to the eastern portion of LPL by J. Boland to better document freshwater invasive species encroaching into native saltmarsh habitat (Boland 1991). In 2000, Transect 10 was no longer accessible due to impassable stands of *Typha* sp. that had expanded to the edge of the creek (Ward et al. 2001). Transect 13 was established in 2001 to replace Transect 10 and to enhance the ability to detect the expansion of exotic species near Carmel Valley due to increased, perennial freshwater inflows from this sub-watershed. Transect 13 is approximately 50 meters west of Transect 9 in the northeastern portion of the lagoon. It was originally 100 meters long and was comprised of two parallel 50 meter transects, Transect 13A and Transect 13B, which ran approximately south (adjacent to channel edge) to north (towards Carmel Valley Road). The exact location of Transect 13A could not be found due coverage by *Typha* sp and was discontinued in 2004.

In March 2008, Transect 14 was established to monitor *Lasthenia glabrata* ssp. *coulteri*, an annual native plant placed on the 1B List (Plants Rare, Threatened, or Endangered in California and Elsewhere) with a threat ranking of 0.1 (seriously threatened in California) by the California Native Plant Society. Transect 14 is located along the eastern portion of the lagoon in an area of expanding freshwater influence and monitored during the springtime.

Aside from monitoring efforts conducted for *L. glabrata* that occurred during spring months, vegetation monitoring for saltmarsh vegetation was initially conducted in the early Fall, to correspond with the end of the growing season. During the 2009/2010, Transect 1 was resampled in March to better quantify non-native annual species that can be missed during fall monitoring efforts. This effort resulted in the identification of nine non-native species along Transect 1, compared to only two non-native species detected during the usual surveys conducted during the Fall.

## Methods

### ***Transects 1-5 and Transects 9, 11, 12 and 13B***

Two (or more) stakes mark the position of each permanent transect, which vary in length from 40 to 665 meters. At five meter intervals along each transect, percent cover, total cover and maximum height of each species were measured within a 0.25 m<sup>2</sup> circular quadrant using the following cover classes:

- Class 1 = < 1% cover
- Class 2 = 1-5% cover
- Class 3 = 6-25% cover
- Class 4 = 26-50% cover
- Class 5 = 51-75% cover
- Class 6 = 76-100% cover.

From 1993 onward an additional class was added to better represent the upper cover classes. Class 6 was modified to include 76 – 95% cover and Class 7 included 96 – 100% cover. Cumulative cover of the individual species can represent values greater than the total percent cover, to account for the fact that plants often overlay each other in a three-dimensional canopy.

Soil salinities were generally taken during surveys along vegetation transects and measured at 10-meter intervals at one transect at each area using a refractometer, a combination of expressed interstitial water, and soil pastes. Prior to 1996, soil salinities were determined in the field. In 1996 the methodology was changed to the sole use of soil pastes to better account for inconsistencies in measuring the salinity of dry and wet soils. Using a 2-cm diameter core, at least three 10-cm deep soil cores were obtained at equally-spaced intervals along each transect. Saturated soil pastes were prepared in the laboratory (Richards 1954). Water was extruded from soil pastes using 10-ml syringes fitted with filter paper and measured salinity with a temperature-compensated refractometer. Recent comparisons show that this method, while consistent across all samples, results in elevated salinity readings relative to field measurements of expressed interstitial waters.

### ***Lasthenia glabrata ssp. coulteri***

Initially the monitoring of the *L. glabrata* was done using three standard methods; the nearest individual method, nearest neighbor method and by direct counts of individuals within 0.10 m<sup>2</sup> quadrants along permanent transects. This methodology was abandoned in 1988 in favor of monitoring discrete patches (Nordby 1989). Until 1995, while walking the margin of each salt panne, a 1-m wide belt transect was run through the margin vegetation every 5 m, and *L. glabrata* presence or absence was noted. From this data, the percent of panne margin containing *L. glabrata* was calculated. Also, a portion of the panne margin where *L. glabrata* was most abundant was chosen and stem densities were estimated per 0.1 m<sup>2</sup>. Currently, there are four zones where *L. glabrata* is monitored (Figure A-3).

From 1995 to 2008, GPS technology was utilized to track changes in *L. glabrata* patch location and size. Although this methodology no longer addresses changes in population densities *per se*, it is a cost-effective conservation tool that provides accurate spatial representations of populations over time. Plant locations and patch perimeters were delineated using pre-survey flagging. Spatial groupings of plants were based on distances to the nearest neighbor, and placed into one of three classes:

- Point [P] = single plant or small group of plants in an area <1 m diameter. Any individual in the group that was >5 m from any and all other plants of the same species outside the group. A Point was indicated by a single GPS point in middle of a group, coded by the letter [P].

- Superpoint [S] = group of plants in an area 1 - 5 m diameter. Any individual in the group was >5 m from any and all other plants of the same species outside the group. A Superpoint was indicated by a single GPS point in middle of a group, coded by the letter [S].
- Polygon [G] = contiguous group of plants (defined as all plants separated by less than 5 m) that cover an area >5 m diameter. A Polygon is indicated by points that trace the outer boundary of a specific area. Any individual in the group was >5 m from any and all other plants outside the group. Polygon points were coded by a letter [G] followed by an assigned number for that polygon (e.g., G1, G2, etc.)

In 2008, Transect 14 was designed to describe the changing vegetation communities associated with the increased freshwater and its potential impacts to *L. glabrata*. It extends 140 meters along a trail between two patches of *L. glabrata*. The presence of *L. glabrata* was recorded at five-meter intervals on either side of the trail. *L. glabrata* was most abundant on the western portion of the transect. In order to better characterize the *L. glabrata* and associated vegetation, percent cover of all species within a 1 meter<sup>2</sup> square quadrat was recorded every five meters along the western portion of the transect.

## Assessment of Success

Monitoring of vegetation transects continuously since 1987 is an invaluable tool for assessing lagoon health with regard to terrestrial habitats and documenting shifts in lagoon habitats caused by urban activities (e.g. perennial freshwater inputs from dry weather flows). Perhaps the longest, uninterrupted data set for lagoon vegetation in southern California, if not the State, the monitoring program also provides tremendous regional benefits as many monitoring programs in other lagoons is relatively new and lack a historical perspective. Recent efforts have been made to augment vegetation monitoring to facilitate management decisions at the lagoon, while keeping the scientific value of the data collected intact. One such effort involves a pilot project designed to survey and map vegetation associations within the entire lagoon to set a baseline for both management and restoration opportunities, with follow up efforts planned to track the evolution of vegetation associations.

## Steps Forward

A goal of the monitoring program should be to increase the use of remotely-sensed imagery and GIS for monitoring work. This will allow better broad-scale assessments of conditions in the estuary and will facilitate communication with other interested parties. In general, resources at the TRNERR and California State Parks would be utilized to facilitate this remote sensing and GIS work. In the immediate future, LPLF plans on using remotely-sensed imagery to delineate the extent of the salt-panne habitat suitable for *L. glabrata* and to map the spatial locations and extent of other important species in the lagoon. Plants of special interest include cattails (*Typha* sp.), arundo (*Arundo donax*), and widgeon grass (*Ruppia maritima*). Preliminary work indicates that *Typha* and perhaps *Arundo* can be mapped from existing imagery. We also will determine the feasibility of monitoring *Ruppia* extents within the reserve using existing remote sensing products (i.e., without having to employ costly overflights dedicated to *Ruppia* monitoring). From this information, we will assess the overall feasibility of increased remote-sensing and GIS work and develop strategies for incorporation of this work into the standard monitoring plan.

Increasing the spatial extent and frequency of vegetation field monitoring, supplemented with remotely-sensed images, could also improve our understanding of vegetation associations within the lagoon in both a static sense (what is there now) and dynamic sense (how are these assemblages evolving), as well as better capturing the presence, distribution and density of non-native annuals, which are better observed during Spring months. This effort has been initiated through the development and partial completion of a pilot project for vegetation association and mapping for LPL in 2011/2012.

## **Action Item #3. Measure runoff and sedimentation originating from the major lagoon tributaries and relate this information to the amount of rainfall.**

### **Runoff and Suspended Sediment**

LPLF coordinated efforts with the United States Geologic Service (USGS) and the City of San Diego to implement this monitoring program. Flow gauges were purchased with funds provided by LPLF and the City of San Diego and installed in Carmel Creek and Carroll Canyon Creek by the USGS (Figure A-3). A stream flow gauge was not installed in Los Peñasquitos Creek, since one was already in operation within this sub-watershed (Figure A-3). Sampling of sediment within each tributary was also performed, occurring within the lower reach of each creek. Arrangements were to be made, presumably between LPLF and USGS, to operate and maintain the gauges and provide monthly reports of stream flow and sediment loads. However, funding was not secured for annual maintenance beyond the first year. This program only lasted approximately 12 – 16 months between 1985 and 1986.

Starting with the 1995/1996 monitoring period of the annual Biological and Physical Monitoring Program, flow from each of the three main tributaries was monitored. Monitoring of flow at the base of Carmel Creek, Los Peñasquitos Creek, and Carroll Canyon Creek continued until the 2010/2011 monitoring period. The monitoring program has been temporarily suspended to revise the methodology to improve data collection and acquire funding to purchase, operate, and maintain permanent flow gauges for each tributary.

### **Methods**

#### ***LPLF and USGS Program***

Flow rates, measured as discharge in cubic feet/second, were measured at each of the three flow gauges installed by USGS every 15 minutes while the stations were operational. Sediment was sampled during or shortly after storm events using grab samples. Grain size analysis was used to determine suspended load, bed load and total sediment load using sieves with differing sized mesh.

#### ***LPL Monitoring Program***

Initially, flows were monitored using the floating object method; a piece of floating material was placed into the stream and the time taken for it to float a known distance was measured. The floating object method was later replaced with a hand-held flow meter, in which measurements are taken at predetermined intervals and depths along a cross section of the stream. The flow meter provides a more accurate measure since it takes into account variations in flow across the stream.



**Table 1. USGS Monitoring Stations in Los Peñasquitos Watershed.**

| Sub Watershed          | USGS Gage # | Latitude  | Longitude  | Drainage Area (miles <sup>2</sup> ) | Begin Date | End Date   | Data           |
|------------------------|-------------|-----------|------------|-------------------------------------|------------|------------|----------------|
| Carmel Valley          | 11023450    | 32°55'48" | 117°14'22" | 1.11                                | 5/01/1985  | 9/30/1985  | Flow, Sediment |
| Los Peñasquitos Canyon | 11023350    | 32°54'23" | 117°12'45" | 57.4                                | 11/12/1985 | 10/25/1986 | Sediment       |
|                        | 11023340    | 32°56'35" | 117°07'15" | 42.1                                | 10/01/1964 | Ongoing    | Flow           |
| Carroll Canyon         | 11023400    | 32°53'45" | 117°13'14" | 15.8                                | 3/01/1985  | 9/30/1986  | Flow, Sediment |

Stream cross-sectional areas were determined through a series of steps that included:

- Depth was measured at every 0.25 m across the width of the channel for all channels not exceeding a width of 2 m. Depth was measured at 0.50 m intervals at all channels greater than 2 m.
- Depending on the channel width, the stream cross-section was divided into a series of 0.25 or 0.50 m–wide columns. These columns were then divided into triangles and rectangles.
- The area of each of these shapes was calculated with their sum representing the total stream cross-sectional area. Water column velocity was quantified in each cross-section using a hand-held current velocity meter. Discharge rates are determined using the equation  $Q = Av$ , where  $Q$  equals discharge,  $A$  is stream cross-sectional area, and  $v$  is the mean water quality velocity.

## Assessment of Success

The LPLF and USGS monitoring program was only successful for approximately 12 – 18 months. Since program funding was only available for one year, as mentioned in the 1985 Enhancement Plan, it is assumed that the program was discontinued due to lack of funding and/or program management and coordination between LPLF and USGS staff. Summary reports were not available for review and might not have been prepared. From the data provided by USGS, it appears that Carmel Creek only flowed in response to rain events, while both Los Peñasquitos Creek and Carroll Creek had measurable flow year round during the monitoring period.

During the 1996/1997 monitoring period, stream flow data documented the perennial nature of all three tributaries due to dry weather flows discharged into the watershed from urban sources (e.g. storm drain outfalls and/or unnatural seepages). However, it is assumed that perennial flows probably existed within each of the tributaries prior to the 1996/1997 monitoring period when flow was not directly monitored. This assumption is based upon observations and indirect measures (e.g. salinity in lagoon channels) performed during earlier monitoring periods that indicated the presence of dry weather flows entering LPL. For example, approximately 3.5 acres in the lower reach of Carmel Valley had been converted from salt marsh to brackish marsh due to freshwater intrusion from 1986 – 1989 (Norby 1990). And, during the 1995/1996 monitoring period, lagoon salinity levels were unusually low during the summer dry season, which followed a wet season with below average rainfall (Williams 1996).

For the 2010/2011 monitoring period, it was determined that flow rates for Carmel Creek, Los Peñasquitos Creek, and Carroll Canyon Creek would no longer be measured. This is due in most part to the need to better characterize the perennial freshwater flows entering LPL from the watershed, beyond the level of presence/absence. It was determined that the current method for stream flow monitoring using hand-held flow meters and sampling on a monthly basis did not capture flow data for specific storms or capture fluctuations in perennial flows, but rather just provided stream flow data specific to the day when flow was measured. Establishing freshwater input trends from each of the three creeks would be better accomplished through the collection of continuous flow data at fixed locations. However, funding is not currently available to set up, operate and maintain these continuous monitoring stations.

## **Steps Forward**

LPLF is working with TRNERR to develop an improved method for measuring freshwater input into LPL from Carmel Creek, Los Peñasquitos Creek, and Carroll Canyon Creek should additional funding become available. This method would involve continuous, telemetered flow monitoring from fixed monitoring stations located within each of the three tributaries. Having continuous flow monitoring data within each tributary would greatly improve the characterization of freshwater input, loading, and sediment transport for each tributary through the development of tools such as hydrographs that capture both peak flows and total runoff volume over time and assist in calibrating hydrologic and loading models used to develop baseline conditions and restoration alternatives.

## **Rainfall**

Monitoring of rainfall data is important to help assess frequency and volumes of storm runoff since LPL is the receiving water body from an approximately 60,000-acre watershed. Measuring rainfall amounts was performed primarily through the use of rainfall data collected at Lindbergh Field, the major airport in San Diego located just north of the downtown area. This is due to the fact that the monitoring program at Lindbergh Field provides the longest continual data set for precipitation in San Diego, which facilitates historic comparisons of both annual and seasonal rainfall amounts.

With advancements in technology, integrating the results from multiple weather stations located throughout the Los Peñasquitos Watershed became possible through weather reporting resources available online, such as [www.wunderground.com](http://www.wunderground.com). In 2009/2010 a weather station was established near Monitoring Station W2 (Labeled “Met” on Figure A-1) to measure parameters such as temperature, wind speed and direction, humidity, atmospheric pressure, rainfall, and light. This information was integrated into the real-time data and a web-based data delivery system developed for Monitoring Station W2.

## **Assessment of Success**

Implementing a weather station within LPL and integrating its data sets with real-time data and a web-based data delivery system developed for Monitoring Station W2 greatly improved the monitoring of weather conditions within the Lagoon and the integration of this data with other efforts conducted as part of the Biological and Physical Monitoring Program. While the monitoring program at Lindbergh Field provides the longest continual set of rainfall data, rainfall measured at Lindbergh Field can differ from rainfall amounts in Los Peñasquitos Lagoon and its watershed. This is due in most part to the localized variability that often characterizes rainfall events in San Diego County. Therefore, using data from the monitoring program at Lindbergh Field can be misleading when applied to monitoring efforts at LPL due to variance in rainfall amounts between downtown San Diego and the Los Peñasquitos Watershed.

## Steps Forward

Integrating information from weather stations located within the upper and lower portions of LPL's three sub-watersheds with the real-time data and a web-based data delivery system developed for Monitoring Station W2 would greatly improve the monitoring of weather conditions throughout the watershed and help determine contributions of each tributary during storm events. This information would be useful in terms of modeling efforts designed to assess loading from each sub-watershed, as well as sediment transport and deposition.

## Sedimentation

Briefly described in the 1985 Enhancement Plan, a program designed to monitor sediment accumulation within LPL in conjunction with monitoring efforts in the watershed for flow rates and sediment was to be implemented in 1985 and continued annually. Benchmarks were to be located in previously documented depositional areas at the Interstate 5 culverts located at Carmel Valley and at the southern end of the Lagoon near Sorrento Valley, where both Carroll Canyon Creek and Los Peñasquitos Creek converge and empty into LPL. However, no record of this effort was found and it is presumed that it did not occur or only occurred for the duration of the runoff and sedimentation efforts for the watershed that occurred between 1985 and 1986.

In 1995, a sediment monitoring program was developed for LPL by Coastal Environments (CE) to measure sediment accumulation in terrestrial areas of the lagoon and within lagoon channels along established transects. A baseline study was conducted in 1995 with subsequent surveys conducted annually.

Fifteen permanent survey transects were established at locations that were determined from a previous study performed by Tekmarine in 1989, discussions with members of LPLF and their Technical Advisory Committee, and field observations conducted during a site visit on October 13, 1995 (Figure A-5). Thirteen of these transects (Transect A1 – Transect J) traverse lagoon channels and were orientated perpendicularly to the adjacent channel. The remaining two transects (Transect L and Transect K) were established in the eastern portion of the Lagoon to measure sediment accretion along the marsh plain and transitional/upland areas. These transects were generally defined by CE in two ways: 1) by a permanent survey pipe installed on one side of the adjacent channel and 2) by visual clues identifying unique landmarks.

## Methods

Survey pipes were installed during the 1995 baseline study, primarily adjacent to existing lagoon channels. Each pipe consisted of 1-inch of galvanized steel, fitted with a 3-inch flange at one end. Each 3-foot long pipe was placed in a hole with the flange positioned at the base of the hole and back-filled. This survey pipe design and method of installation provided a stable reference point. Each hole was excavated to depth of about 2 feet and approximately 1 foot of pipe remained visible at the surface. Where possible, the survey pipes were installed within about 15 feet of the edge of the adjacent lagoon channel.

During surveys, temporary flagging was installed in each survey pipe to assist in locating each pipe and orientations of transect lines were determined with the help of two temporary range markers. A Sokia Set-5A Total Station and Sokia SDR-33 electronic field data logger were used for surveys. A rod holder carrying a prism at the top of a pole with a fixed length then proceeds to traverse the survey transect. Using an infrared beam projected by the total station toward the prism, slant distance and horizontal and

vertical angles are taken and recorded. The datalogger is used to calculate relative coordinates and elevation and to store resulting data. Profile elevations at various points along each transect were determined relative to the elevation of a permanent local benchmark. The total station was positioned at four different locations throughout the Lagoon in order to complete the surveys. Two local benchmarks with known coordinate positions, the coordinates of each new total station position could be determined via triangulation. The accuracy of this method, both horizontally and vertically, is approximately 2 – 3 centimeters. Data collected during the surveys were processed, and all elevations and positions were corrected to National Geodatic Vertical Datum (NGVD 29) and California State Plane Coordinates (NAD 27).

Surveys were conducted on an annual basis, usually during the winter months.

## **Assessment of Success**

The sediment surveys conducted in LPL have provided a useful, low-cost approach to monitoring sediment accretion and erosion within lagoon channels and within the eastern portion of the Lagoon. While more precise techniques exist, they were cost prohibitive given the finite budget set aside for annual monitoring. Expanding the monitoring program would also increase project costs. It was determined that measurements taken between 1995 to 2002 may be inaccurate due to uneven scour around the survey pipes resulting in variable height measurements taken depending on which side of the pipe was being measured. During this period, only one measurement was reported without documenting which side of the pipe was being measured. In order to correct this error, the height of each pipe was measured on all sides with the mean range of values included in the results.

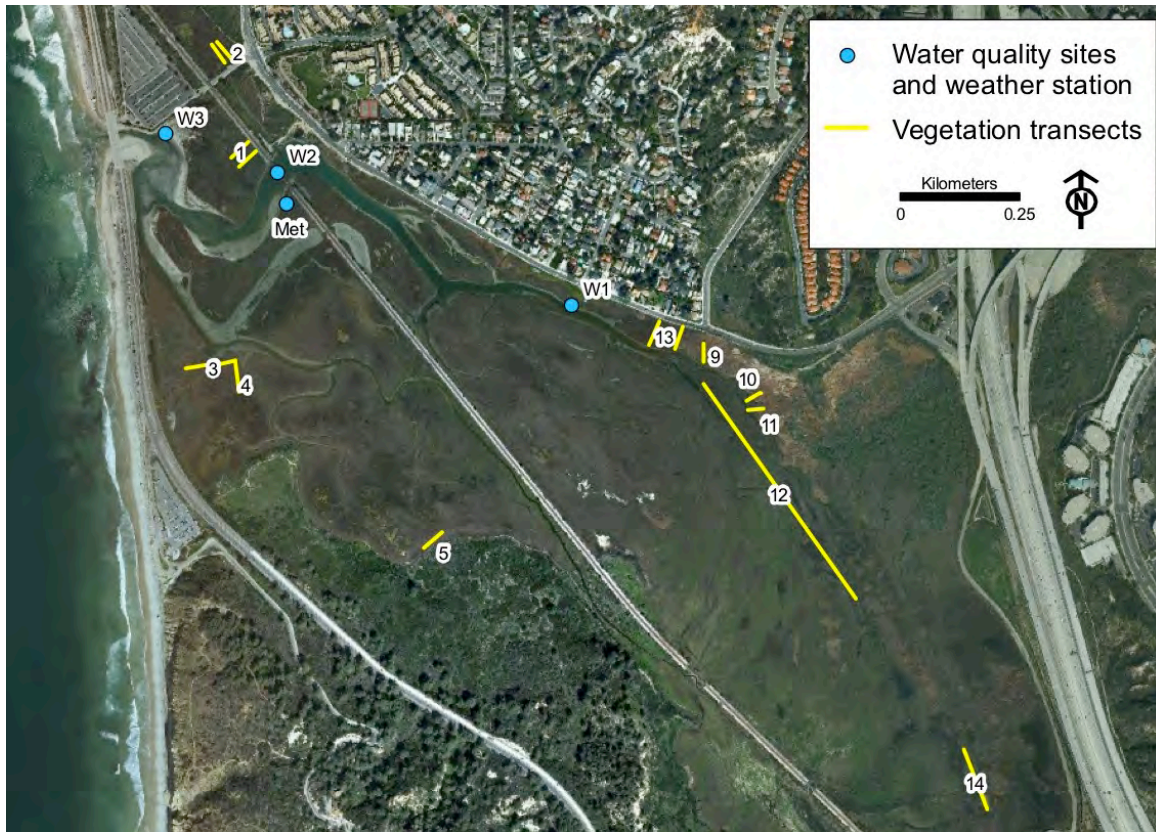
## **Steps Forward**

Annual surveys should be continued using the current methods, unless additional funding can be allocated to improve the program. However, surveys should be conducted prior to each wet season (i.e. before October) to document sedimentation associated with each individual wet season (i.e. October – June).

Additionally, sediment transport rates calculated from flow monitoring in each of the three tributaries would help to determine the impacts of large flow events on erosion and sedimentation within the lagoon and its channels. Expanding the program to other areas in the lagoon plain, transitional areas and upland habitats would improve the characterization of sedimentation processes operating in different areas of the lagoon and the floodplain. Finally, conducting additional studies using sediment coring would help identify annual sedimentation rates that predate the 1995 baseline study and help determine the influence of episodic events and/or human activities (compacted fill or dredge spoils left over from the development of the railway berm and/or the sewage treatment ponds) that helped raise elevations in the eastern lagoon to between +4.5 to +5 ft NGVD over the last 30 to 40 years. Coring has been performed in the Lagoon as part of paleoecological studies, but not extensively within the Lagoon.

# FIGURES

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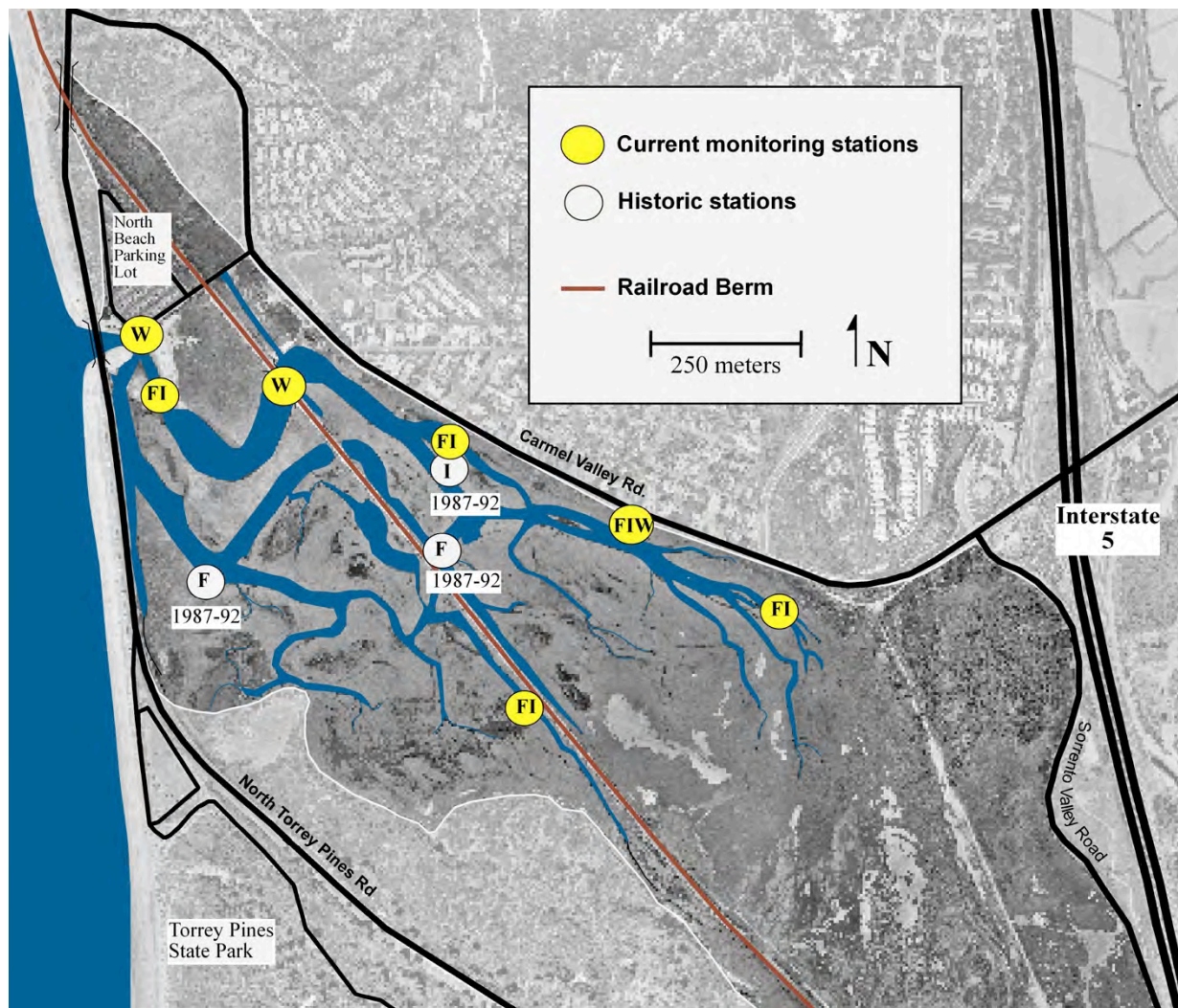


SOURCE: SWIA, 2008

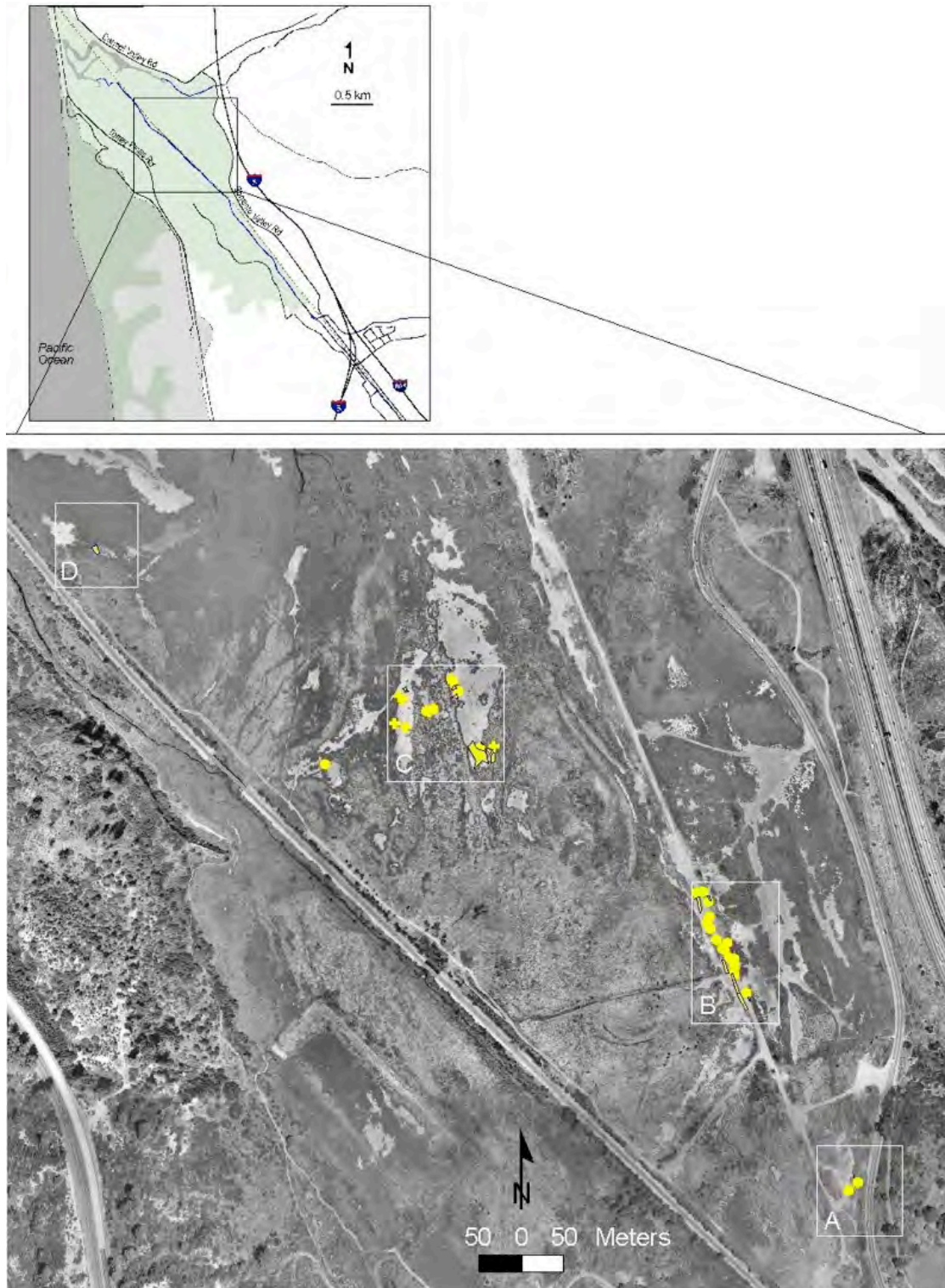
Los Peñasquitos Lagoon . D130136

**Figure B-1**  
Water Quality Sites and  
Vegetation Transects





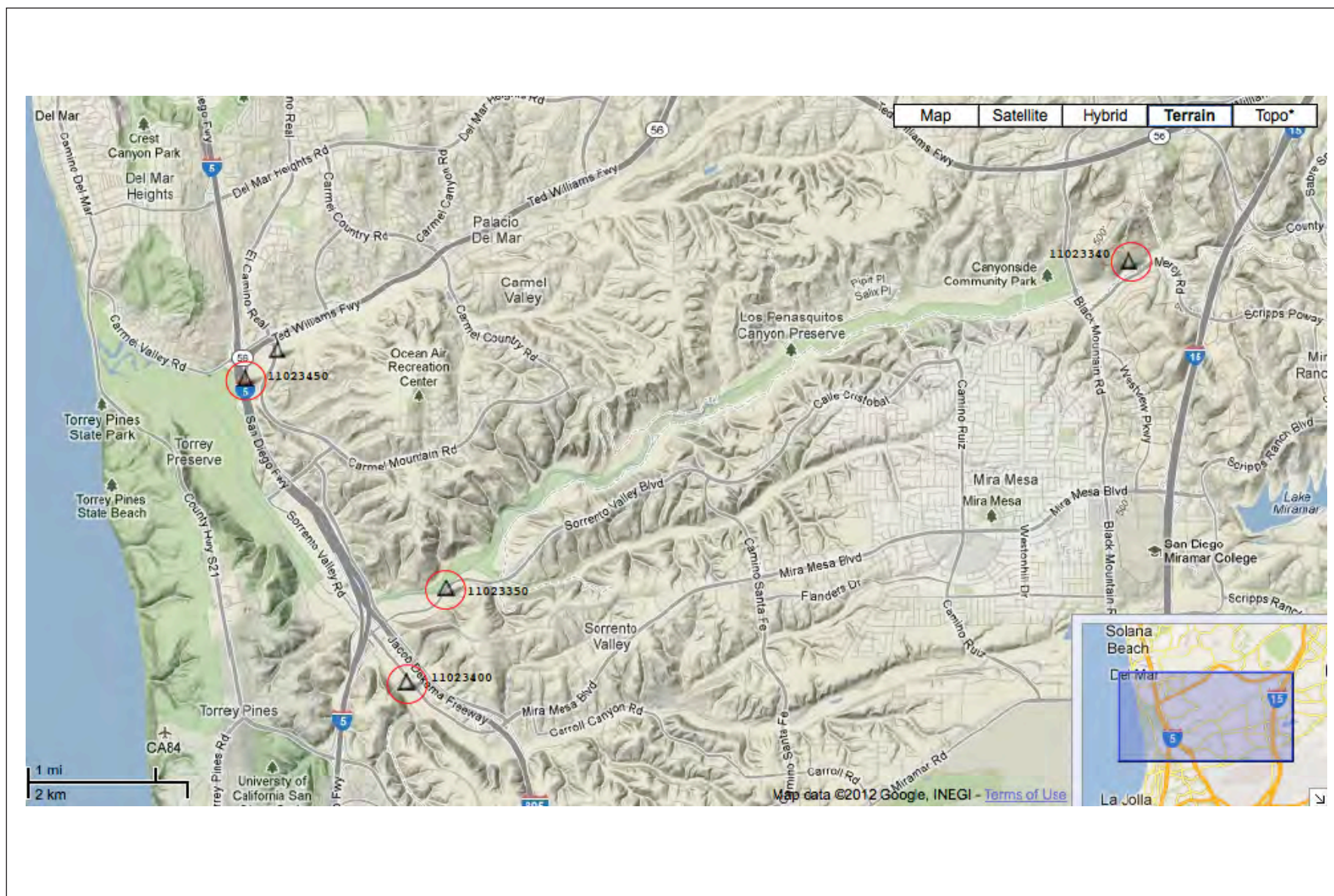
F Fish Stations  
 I Invertebrate Stations  
 W Water Quality Stations



Los Peñasquitos Lagoon . D130136

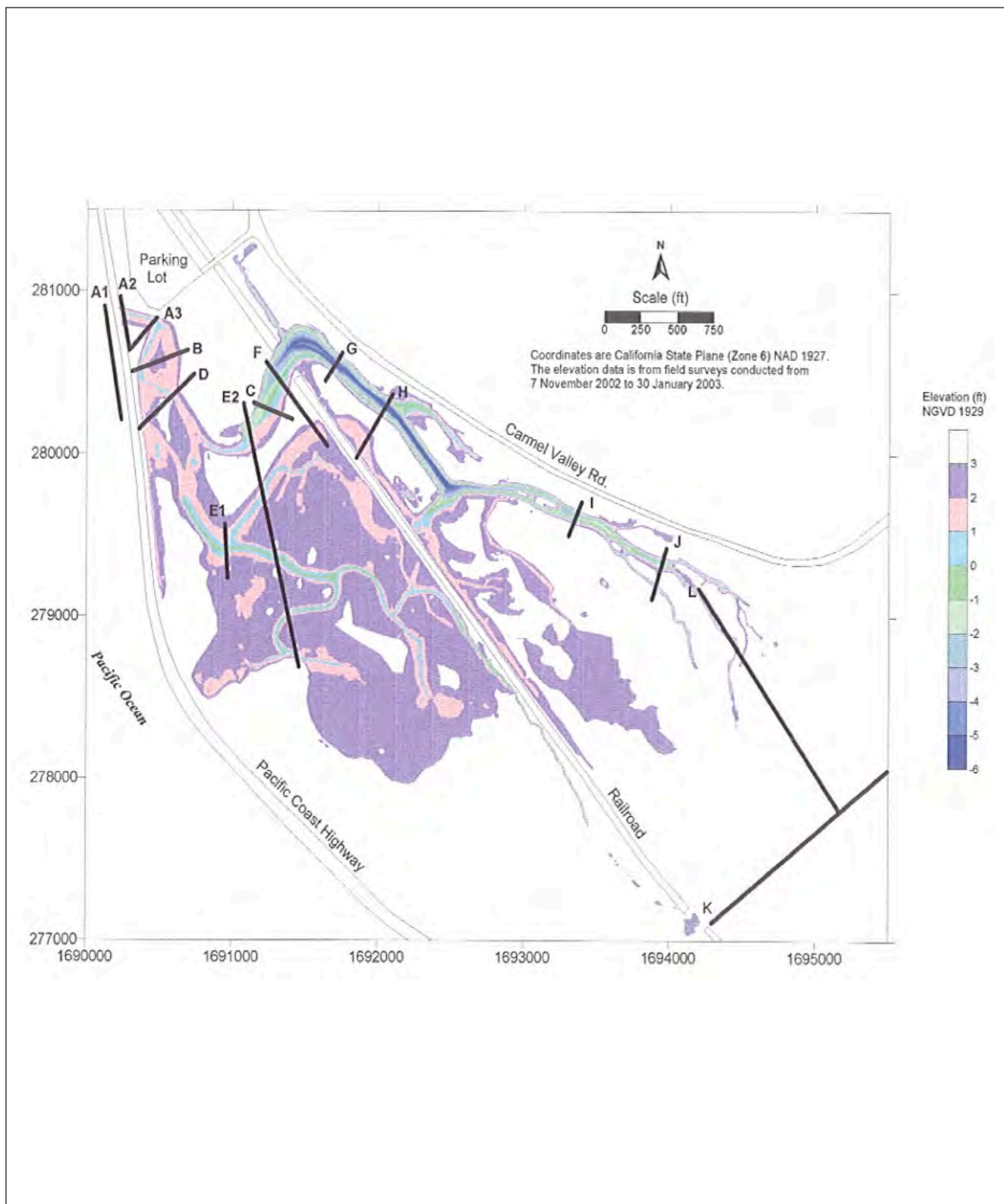
**Figure B-3**  
Current *Lasthenia glabrata*  
Monitoring Areas





Los Peñasquitos Lagoon . D130136

**Figure B-4**  
Locations of USGS Monitoring Stations



SOURCE: Coastal Environments, 2003

Los Peñasquitos Lagoon . D130136

**Figure B-5**  
Sediment Survey Transects

## **APPENDIX C**

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### History of the Lagoon Mouth Openings

## APPENDIX C. HISTORY OF THE LAGOON MOUTH OPENINGS

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In 1997 LPLF commissioned a study that examined the results of the inlet maintenance efforts conducted since 1988 to examine opportunities to adaptively manage the lagoon inlet. This study summarized twelve years of efforts to restore tidal mixing within LPL and provided suggested improvements to the program. This effort was repeated in 2006 after the replacement of the lower bridge in 2005 by the City of San Diego. The 2006 review of the inlet maintenance program was performed in response to modifications of inlet dynamics caused by the design of the new bridge.

From 1985 – 2011, funding for inlet maintenance was provided to LPLF primarily by the City of San Diego and the State Coastal Conservancy. The City of San Diego financed inlet openings at Los Peñasquitos Lagoon from 1988-2005 in response to a settlement in 1987 regarding multiple sewage spills from City's sewage Pump Station 64 (located in Sorrento Valley) that occurred between 1979 - 1986. It is believed the settlement was negotiated with the San Diego Waterboard in 1987 in response to a sewage spill that occurred on November 27, 1986 that released 1.5 million gallons of raw sewage into the Lagoon. The obligation to maintain the inlet was due to expire in 2004 but was extended an additional year by the City to correspond with the replacement of the lower bridge at North Torrey Pines Rd that spans the lagoon inlet. Construction of the bridge was completed in 2005. The average cost for inlet maintenance during this time ranged from \$45,000 to \$60,000.

In 2006, the State Coastal Conservancy assumed funding responsibility for lagoon inlet maintenance, using money from the Lagoon's Special Deposit Fund generated from mitigation payments for development within the coastal zone area adjacent to LPL. Additionally, the Conservancy funded the acquisition of additional permits from the resource agencies since the program had previously operated under a Coastal Development Permit, issued by the Coastal Commission, a Right of Entry Permit, issued by State Parks, and a Regional Permit, issued by Army Corps of Engineers, that had since expired. A Categorical Exemption under CEQA was granted with State Parks acting as the Lead Agency. Permit applications were submitted in 2006 to the appropriate resource agencies and approved in 2007. The program operated under emergency permits during the interim period. The inlet maintenance program currently works under the following environmental documentation:

- CEQA Categorical Exemption – State Parks as Lead Agency.
- Individual Permit – Army Corps of Engineers.
- Section 7 Informal Consultation – U.S. Fish and Wildlife Service.
- Essential Fish Habitat Waiver – National Oceanic and Atmospheric Administration.
- Coastal Development Permit – California Coastal Commission.
- 1602 Streambed Alteration Waiver – California Department of Fish and Game.
- California Endangered Species Act (CESA) Waiver – California Department of Fish and Game.
- 401 Wetland Certification – San Diego Regional Quality Control Water Board.
- Right of Entry Permit – State Parks.

Annual budgets for inlet maintenance funded by the Conservancy ranged from \$70,000 to \$90,000. The increase in price when compared to efforts funded by the City of San Diego was reflective of the need to



remove more sediment from the inlet area after completion of the new bridge in 2005, significant increases to fuel costs that occurred since 2004, and additional efforts required for permit compliance. The Conservancy stopped funding inlet maintenance in 2011, since funding this effort through the Lagoon Special Deposit was no longer viable.

In 2012, inlet maintenance was funded by the County of San Diego's Department of Environmental Health, through their Vector Habitat Remediation Program (VHRP), and State Parks. Funding was provided to reduce breeding habitat for *Culex tarsalis*, a freshwater mosquito linked West Nile Virus (WNV) transmission in San Diego County. *C. tarsalis* breeding habitat is currently present within LPL, due in most part to perennial inputs of freshwater to LPL by dry-weather flows from the watershed. A form of brain encephalitis, WNV affects avian species as well as equine and human populations. Documented cases of WNV have occurred in and around LPL, affecting avian populations primarily, with some cases of human infections occurring in nearby communities. The County provided \$50,000 through its Directed Projects under the VHRP, which was supplemented through in-kind services provided by State Parks.

The different techniques used to open the lagoon mouth over time are described below.

## **1985 Inlet Maintenance Technique**

### **Initial Low-Cost Technique**

To open the lagoon mouth, a ditch was dug from the lagoon to the crest of the beach berm using a bulldozer. A few hours before low tide, the berm was cut through to allow the power of the outflowing lagoon water to erode the sand and cobbles from the channel and to deposit them in the sea or along the beaches. The earthmoving equipment would feed cobbles and sand into the turbulent flow. It was sometimes necessary to use earthmoving equipment for one to two days following the opening in order to remove most of the beach material from the channel area. The process was repeated or modified as necessary to maintain the channel.

### **Moderate-Cost Technique**

In the hope of reducing periodic maintenance costs, the moderate-cost technique involved the use of both a bulldozer and dragline to excavate a channel deeper and wider than the channel created with the initial low-cost technique. It was thought that this method could increase the tidal prism of the lagoon from 3.1 million cubic feet to a maximum of 5.2 million cubic feet and cut through the cobble sill. Furthermore, it was thought that re-opening the channel created by the moderate-cost technique would be easier than the channel created by the initial low-cost technique during inlet closures, due to the removal of a larger volume of cobbles below MSL.

The moderate-cost technique involved first, using a bulldozer to excavate a channel above the tidal range from the shoreline into the deep channel area of the lagoon. Then using a dragline for work within the tidal range, the channel was deepened to -5 feet MSL, with a 40-foot bed width. Excavated material would be disposed of in a way that would avoid significant disruption to marine and wildlife habitats and water circulation. Dredge spoils suitable for beach replenishment were transported to the beach or into suitable longshore currents.

## 1997 Inlet Maintenance Technique

By 1997, two techniques for opening the lagoon mouth and re-establishing tidal mixing had been used, both of which were similar to the techniques outlined in the 1985 Plan. Similar to the low-cost technique, small-scale openings focused on breaching the barrier berm under the lower bridge. Similar to the moderate-cost technique, large-scale openings looked to re-establish a channel from the deep channel to the ocean, which involved considerably more excavation (and cost) than small-scale openings. Seasonality played a key role in terms of which technique to use to re-open the lagoon inlet. While small-scale openings could be performed throughout the year, the study determined that large-scale openings should only be performed between March and June, preferably during periods of spring tides to improve flushing of lagoon waters and equipment access to and within the inlet area both east and west of the lower bridge. Methods for opening the inlet and equipment types were also modified based upon lessons learned during inlet maintenance from 1985 to 1991. The following recommendations were made:

1. During a breaching of the berm, use the force of the water as it pours out of the lagoon to remove some of the sand in the inlet. This can be achieved by breaching the berm a couple of hours before a low low tide. A front loader working in the channel during the breaching should be used to increase the amount of sand removed by the out-flowing water.
2. Cut channel at the south end of the bridge because the flowing water will naturally work its way to the north, with the result that a wide channel is made under the bridge. If the channel is breached at the north end the channel does not widen to the south and the result is a narrow channel.
3. Remove cobble from the inlet wherever and whenever you see it.
4. Dig good “connector channels” between the channel that develops under the bridge during a breaching and the relatively deep channels that are approximately 200 yd. from the bridge. These connector channels should be deep and have no meanders.
5. A large-scale maintenance project requires at least one front loader (International 555 or equivalent) and two self-loading scrapers (637 Caterpillar or equivalent). These machines, working together, will breach the berm, remove cobble and dig a deep channel that leads from the inlet bridge to approximately 200 yards along the two main channels. They will work approximately 5 days.
6. A dredge is not recommended. The inlet is too shallow for a dredge to work efficiently. [This was discovered in spring 1997.]
7. A small-scale maintenance project requires a front loader (International 555 or equivalent) to breach the berm and dig a channel under the bridge. It will work for 2 or 3 days. Note that a front-loader cannot cope with extensive cobble.
8. Describes the details of inlet opening under three lagoon conditions before maintenance occurs
  - a. Lagoon closed, with water level very high,
  - b. Lagoon closed, with water level high, and
  - c. Lagoon closed, with water level low.

## 2006 Inlet Maintenance Technique

In comparison to efforts conducted from 1985 – 2004, Lagoon mouth maintenance efforts after the new bridge was constructed over the inlet in 2005 were modified to focus more on increasing the Lagoon’s tidal prism than on re-opening the lagoon to the ocean through the removal of the sand and cobble barrier berm under the bridge. This came as a response to larger volumes of sand and cobbles that were pushed farther into the Lagoon during storm surges, due to the reduction of bridge support columns (i.e. from 74 to 4), which reduced energy dissipation and subsequent sediment deposition under the bridge span. Improved exchange between the ocean and lagoon seems to have facilitated natural re-openings after the

new bridge was in place. However, large deposits of sediment east of the bridge still reduced the Lagoon's tidal prism, making the mouth more vulnerable to pending closures during summer months when lagoon outflows were not augmented by storm runoff. Aside from increased volume of sediment deposited east of the bridge, the overall spatial extent of the deposited sediment seems to have increased as well. Consequently, inlet maintenance efforts now focused primarily on removing sand and cobbles from the inlet area, east of the bridge, in order to re-establish and improve connectivity between the lagoon main channels and the ocean. Since the lagoon mouth was often open during inlet maintenance efforts, breaching the berm and utilizing outflows to removed sediment was not performed as in the past. Instead, heavy equipment moved into the lagoon on the first day to locate the deep-water mark and, when needed, excavation occurred under the bridge span to improve access for dump trucks.

Since the new bridge, small-scale openings were only performed in 2007 and were driven more to reduce lagoon water levels that were complicating construction efforts along Carmel Valley Road by the City of San Diego in conjunction with restoring lagoon water quality parameters. In other years since 2005, the lagoon inlet re-opened naturally either due to lagoon outflows after rain events or increased water levels within the lagoon caused by a combination of dry weather flows and overwash from high tides and wave activity. While lagoon outflows during these years were successful in breaching the barrier berm that blocked tidal mixing, they were not strong enough to adequately re-establish the channel connecting the Lagoon's main channels to the ocean, aside from the 50-year flood event that occurred on December 23, 2010.

Equipment types and methods were also modified to improve efficiency, reduce associated maintenance costs, reduce the inlets vulnerability to closures during summer months, and provide additional benefits associated with beach disposal of excavated sand and cobbles. A dredge was used in 1997, however it was discovered that the inlet area was too shallow for the dredge to work efficiently. Additionally, the use of self-loading scrapers, sometimes referred to as dirt pans, was discontinued in the late 1990s since it was found that this type of equipment was prone to breakdowns and servicing needs caused by cobbles. Since 2007, the following equipment types have been used when annual budgets allow:

- PC 400 Excavator
- PC 300 Excavator
- WA500 Front Wheel Loader
- 3 Off Road Articulated Rock Trucks

In 2012, the use of an additional front loader was implemented through in-kind services provided by State Parks. The additional front loader was used on Torrey Pines State Beach to knock down disposal piles and re-contour beach profiles in deposition areas.

Since 2007, the inlet maintenance program at LPL now focuses on the following key objectives:

- Insure that the lagoon mouth remained open for the summer by increasing the Lagoon's tidal prism.
- Remove the substantial volume of sand within the project area to prevent it from migrating up the Lagoon's main channel and out of the approved project area.
- Improve tidal mixing within lagoon channels to maintain water quality parameters required for the health of aquatic species.
- Improve draw down times for water impounded in lagoon channels from perennial freshwater inputs from the watershed and along lagoon boundaries.

As in the past, excavation within the Lagoon begins at the deep-water mark and moves toward the ocean over subsequent days, focusing on removing both sand and cobbles. However, the excavated connector channel was increased from 200 yards to approximately 1,000 yards due to additional sediment pushed farther up lagoon channels. Excavation of marine sediments starts at the deep-water mark located between Transect E2 and Transect D (See Figure C-1) and continued through to Transect A1 to restore the Lagoon's tidal prism by re-connecting the Lagoon's main channel with the ocean inlet with an excavated channel of approximately 1,000 linear feet (See Figure C-1). Excavated spoils were stockpiled on site and within the project footprint before being loaded and hauled to Torrey Pines State Beach for disposal. Beach disposal occurred approximately 100-200 yards south of the lagoon inlet, with spoils placed along the base of the coastal bluff and along the water's edge. Spoils placed along the bluffs were re-contoured to mimic natural beach profiles and improve public access and use. Spoils placed along the water's edge were dispersed horizontally within the nearshore environment and lower beach through tidal action, with piles being removed after one complete tidal cycle.

## Assessment of Success

Annual maintenance of the lagoon inlet at LPL and restoration of the tidal prism has provided numerous benefits both within LPL and along Torrey Pines State Beach. Within the Lagoon, water quality (e.g. dissolved oxygen, salinity, pH and temperature) was restored to levels required for the health and survival of aquatic species that include fish species valuable to recreational fisheries (e.g. California halibut and anchovy) and invertebrates that provide a food source to both local and migratory bird species. Restoring the tidal prism also helped to protect the Belding's savannah sparrow (*Passerculus sandwichensis beldingi*), a State-listed endangered species that nests within upper marsh habitat, defined as the area just above tidal influence. During extended inlet closures, rising water levels caused by perennial flows of freshwater from the watershed can inundate the upper marsh, causing nests to be abandoned (Zembel and Hoffman 2010). By lowering levels of freshwater within the Lagoon, the project was also successful in helping protect Nuttall's Lotus (*Lotus nuttallianus*) and Coulter's goldfields (*Laesthenia glabrata ssp coulteri*), two 1B – listed plant species considered by the California Native Plant Society to be rare, threatened or endangered in California. Lowered water levels also restored valuable foraging habitat for two federally endangered birds, the Light-footed Clapper Rail (*Rallus Longirostris Levipes*) and Western Snowy Plover (*Charadrius alexandrinus nivosus*). The inlet maintenance program has also been successful in reducing mosquito-breeding habitat for *C. tarsalis* by restoring the lagoon's ocean inlet and tidal prism, achieved through re-connecting the Lagoon's main channel with the ocean inlet. Project benefits along Torrey Pines State Beach generated by beach disposal of sand excavated from the Lagoon's inlet include the following:

- Covering of exposed riprap located between the Torrey Pines State Beach and public parking spaces along Torrey Pines Road to improve public access and safety.
- Re-contouring of sand placed along the upper beach to mimic the profile of a coastal dune extending from the lower beach to the bluffs to increase the total area of available beach for public use and improved access from Torrey Pine Road.
- Creation of potential spawning habitat for grunion caused by sand placement along portions of the lower beach that had been predominately cobblestones.
- Providing additional protection for Torrey Pines Road from scour during winter storm surges by improving beach profiles along the coastal bluff.
- Improved beach safety along Torrey Pines State Beach through the creation of a beach access ramp for emergency vehicles traveling on Torrey Pines Road.

## Steps Forward

Continued funding for inlet maintenance and restoration of the Lagoon's tidal prism should be a priority for the updated enhancement plan. Annual maintenance will most likely be required to some extent in the future, unless restoration of Lagoon hydrology is successful in reducing inlet closures and maintaining a tidal prism that is conducive to Lagoon health and preventative for closures during the summer months, when water quality is more vulnerable due to increased atmospheric and water temperatures. Securing an ongoing funding source, such as an endowment, should be a priority. Two potential opportunities for securing this type of funding are through a regional lagoon inlet maintenance fund, currently being explored by Caltrans and SANDAG as mitigation for improvements to the north county coastal transportation corridor, or attached to a larger restoration program for the Lagoon, in which maintaining the lagoon's tidal prism will be a key element. In the meantime, potential interim funding opportunities exist through SANDAG's Shoreline Preservation Program, City of San Diego Storm Water Pollution Prevention Program, Caltrans Environmental Enhancement and Mitigation Program (EEMP), and in-kind services from California State Parks.

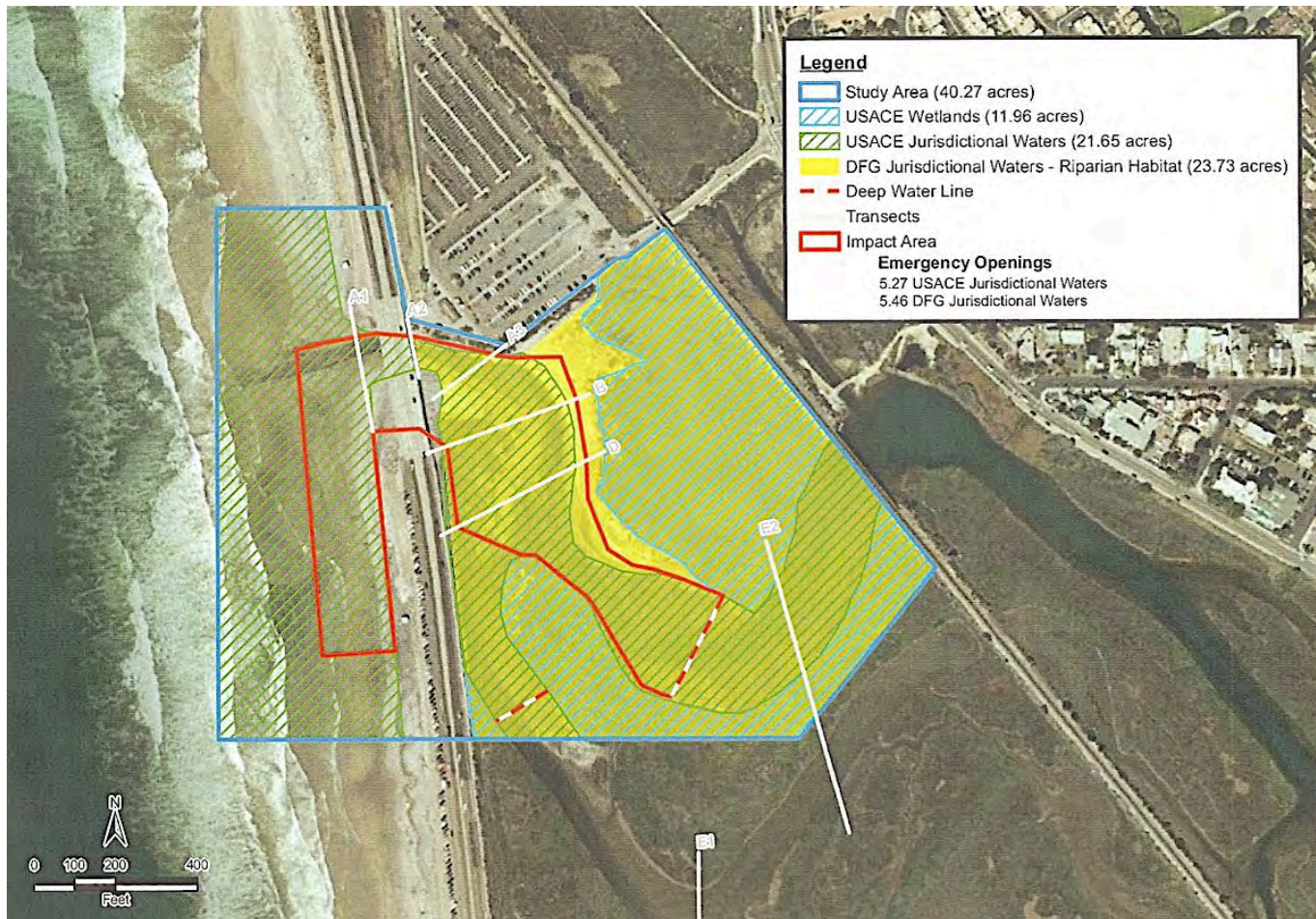
In order to attract funding earmarked for sand replenishment efforts through programs such as SANDAG's Shoreline Preservation Program, it might serve LPLF and State Parks to conduct a pilot project that looks at increasing the total volume of sand removed from LPL and placed on Torrey Pines State Beach. Currently, LPLF and State Parks have been able to place up to 24,000 cubic yards (cy) on Torrey Pines State Beach with proven benefits to public safety, access and use of the beach, protection of North Torrey Pines Road (formerly known as Highway 101) and improvements to potential spawning habitat for grunion. Additional loads of sand could be placed on Torrey Pines State Beach if additional funding was allocated, since current inlet maintenance and beach disposal efforts are constrained by budgetary limits. It is estimated that up to 50,000 cy could be excavated from LPL and placed on Torrey Pines State Beach.

Exploring opportunities to reduce sand and cobble input to LPL from offshore sources might also be explored to reduce future inlet maintenance costs and needs. Placement of an artificial reef offshore of the lagoon inlet might achieve this objective, while increasing marine habitats in an area consisting primarily of sandy bottom. Hardened structures near the lagoon inlet may also be considered, although these structures tend to not be favored by resource agencies due to their impacts to longshore sediment transport that can result in increased erosion down-current of the structures.

# FIGURE

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## **APPENDIX D**

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### Land Acquisition

## APPENDIX D. LAND ACQUISITION

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LPLF, California State Parks, and the State Coastal Conservancy were successful in completing the transfer of the SDGE property (Action 1) and the 20-acre Sorrento Associates property (Action 2) to the State of California. At the time of writing this update, it could not be determined what had happened with the Wyer Property (Action 3). Establishing a protected wildlife link between the Los Peñasquitos Canyon Preserve and the Los Peñasquitos Lagoon area (Action 4), as well as providing an open space link between the Torrey Pines State Reserve Extension and LPL (Action 5), were achieved through the Multiple Species Conservation Program (MSCP), City of San Diego Subarea Plan. Accepting/enforcing easements over prominent bluffs and hillsides around the Lagoon (Action 6) was not achieved and may have not been pursued. A brief description of each action item identified in the 1985 Plan is provided below, along with an assessment of success.

**Action Item #1. Transfer portions of or all of the SDGE property west of Sorrento Valley Road (226 acres) to the State of California as additions to the Torrey Pines State Reserve. Explore with the owners possibilities of fee title acquisition, transfer of development to other properties under the same ownership, donations, or purchase as mitigation for major development proposals that will affect the lagoon.**

In 1966, SDGE purchased the 225-acre property in LPL as part of a 400-acre tract that was the intended site for a nuclear power plant. The 225 acres site was bordered on the west by the current railway berm that bisects LPL, on the north by Carmel Valley Road and on the east by the closed portion of Sorrento Valley Road (See Figure 2-1). This expansive area covered approximately half of the Lagoon's total acreage and included salt marsh, transitional and upland habitats. Acquiring this property was essential for the restoration, enhancement, and long-term protection of LPL and, therefore, was one of the primary objectives of the 1985 Enhancement Plan.

The property was purchased by the State and City of San Diego (City) in 1987 for \$2.25 million and was included as part of the Torrey Pines State Reserve, essentially doubling the size of Lagoon area included in the Reserve. Transfer of the 225-acre property occurred as a result of a long and complicated legal battle between SDGE and the City of San Diego that began in 1974 and settled in 1986. The suit alleged the City had illegally taken the property by rezoning it from industrial to agricultural and then dedicating it as open space, thereby preventing SDGE from gaining economic value from the property. The State Coastal Conservancy became involved in the settlement by proposing the use of \$2 million in State funds to purchase 200 acres of the lagoon and surrounding areas. The City agreed to pay \$250,000 for 25 additional acres near the Lagoon and SDGE retained ownership of 15 acres. ([http://articles.latimes.com/1986-05-28/local/me-8099\\_1\\_city-officials](http://articles.latimes.com/1986-05-28/local/me-8099_1_city-officials))

**Action Item #2. Transfer the Sorrento Associates Property (20 acres) to the State of California as a second addition to the State Reserve. Also explore with the landowners alternative ways of accomplishing the transfer.**

In 1986, the State Coastal Conservancy authorized the purchase of the 20-acre parcel owned by Sorrento Associates. Located in the southeast corner of the Lagoon (see Figure 2-1) and with the City of San Diego limits, this parcel was one of the last remaining undeveloped properties adjacent to LPL. The property was purchased for \$650,000 and remains under State Coastal Conservancy ownership. Although it is not currently included as part of TPSR, it serves as an open space buffer between commercial developments in Sorrento Valley and LPL.

**Action Item #4. Arrange Protection for the Wildlife Link between the Los Peñasquitos Canyon Preserve and the Los Peñasquitos Lagoon Area. Explore with Cal Sorrento the possibilities of fee title acquisition, transfer of development to other properties, donations, partial development and dedication, or land swaps for other property.**

Preserving and protecting the wildlife corridor connecting Los Peñasquitos Canyon Preserve to LPL was achieved through its inclusion in the MSCP, City of San Diego Subarea Plan. The MSCP was designed, in part, to conserve valuable habitats and areas of open space determined as “core areas,” along with habitat linkages that facilitate the movement of wildlife between these core areas. Biological resources within the MSCP are assembled and managed through the establishment of Multi-Habitat Planning Areas (MHPA), which are usually defined as mapped areas and/or quantitative targets for conservation of vegetation communities.

Identified as an important linkage between Los Peñasquitos Canyon and LPL, Los Peñasquitos Creek and its confluence with Carroll Creek fall within MSCP boundaries of protected core areas and are identified as a MHPA for riparian/wetland vegetation communities (see Figure 2-1). This corridor is constrained by the Interstate 5/805-merge overpass and dense vegetation within Los Peñasquitos Creek and its downstream confluence with Carroll Creek in Sorrento Valley. However, monitoring efforts conducted in this area on behalf of the MSCP have observed wildlife movement through this corridor that included coyotes, bobcats and mule deer.

## **Action Item #5. Provide an open space corridor between the Torrey Pines State Reserve Extension and the lagoon area.**

Providing an open space easement between the TPSR Extension and LPL was achieved through its inclusion in the MSCP, City of San Diego Subarea Plan. The corridor between the Extension and LPL designated under the MHPA is located in the southeast corner of the Extension and connects to LPL near the intersection of Portofino Drive and Carmel Valley Road (see Figure 2-1). It's not clear to what extent this corridor is used since wildlife must cross both Portofino Drive and Carmel Valley Road. There does exist a pathway located between residential structures between Via Mar Valle and Camino Del Barco that could, potentially be used as a second wildlife corridor to connect the Extension and LPL. However, it is not clear if this area would be suitable as wildlife corridor given the nearby residential buildings and the need for wildlife to cross over paved roads that include Carmel Valley Road. Furthermore, the portion of LPL that would be accessible to wildlife using this potential corridor is separated from the main portion of the Lagoon by the railway berm and the entrance road to the North Parking Lot.

## **Action Item #6. Accept and enforce open space easements over prominent bluffs and hillsides that form a visual backdrop to Los Peñasquitos Lagoon. The managing agency or group should arrange funding to cover the costs of monitoring and enforcing these easements if it accepts this responsibility. In instances where the City does not accept an easement or requirements for monitoring and enforcement exceed those ordinarily undertaken by the City, the Los Peñasquitos Lagoon Foundation may assume these responsibilities.**

Providing an open space easement over prominent bluffs and hillsides that form the visual backdrop to LPL (Action Item #6) has not been achieved since the 1985 Enhancement Plan. One area in particular that would serve this purpose is a 14.35-acre site located on a bluff behind Pump Station #65 (Figure 2-1). This parcel provides an ideal visual backdrop for the Lagoon and potential overview point for the public. However, this parcel is currently owned by Sorrento Valley Holdings I & II, who are currently proposing its development into the Sorrento Pointe office buildings.

## Steps Forward

In conjunction with StateParks, SCC, City of San Diego, resource agencies, and private landowners, LPLF should continue exploring opportunities to acquire land and/or open space/conservation easements in areas surrounding LPL and TPSR. Establishing long-term funding mechanisms, such as endowments, should be explored before acquiring additional properties and/or easements. Benefits associated with this effort could include:

- Securing visual corridors and backdrops within and around the Lagoon and other areas within TPSR.
- Establishing buffer areas between sensitive habitats and urban areas.
- Improving wildlife corridors between the Lagoon, adjacent areas within TPSR, and outlying MSCP core areas within the watershed and adjacent open space areas.



## **APPENDIX E**

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### Habitat Restoration

## APPENDIX E. HABITAT RESTORATION

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Habitat restoration efforts occur in LPL on both an intermittent and ongoing basis, performed primarily by State Parks and City of San Diego. Some of these efforts included habitat improvements provided by the Plan, while others were performed as mitigation for activities that included the construction of the City of San Diego's Station #65. A brief assessment of the five habitat improvements listed in the Plan are provided below:

### **Action Item #1. Restore sand dune environment adjacent to the North Beach Parking Lot.**

Restoration of the remnant sand dune area adjacent to the North Beach Parking Lot did not occur, other than closing the area from public access since it was considered as potential habitat for the federally listed Western Snowy Plover. This area is vulnerable to scour by both lagoon outflows during large storm events and storm surges from the Pacific Ocean during periods of high wave activity that enter the Lagoon through the ocean inlet. A Rare and Endangered Plant on the California Native Plant Society's 1B.1 List, Nuttall's lotus (*Lotus nuttallianus*) presence in the sand dune area has been historically observed and still exists in the remaining remnant dune areas not affected by scour (Bradshaw 1968). The presence of this endangered plant species would most likely complicate future restoration efforts that involve the placement of large quantities of sand in the upper portion of the remnant dune area, as had been previously suggested in the 1985 Plan. Sand is often placed along the lower portion of this remnant dune area during annual lagoon mouth maintenance efforts. Placed below the protected areas for Western Snowy Plover and Nuttall's lotus, the sand serves as a buffer for this sensitive habitat area from future storm surges and outflows of storm runoff.

### **Action Item #2. Remove encroaching vegetation from historic Least Tern nesting sites along the sewer berm. Also consider covering the site with a layer of sand.**

Historically, least terns have nested in both the east and west end of the lagoon, preferring open, sandy habitat. The last recorded successful fledging of least terns was reported at Los Peñasquitos Lagoon in 1978 (Atwood et al, 1979). Subsequent nesting years were unsuccessful due in most part to predation of the developing chicks and human disturbance (Copper and Webster, 1984). California least terns were last observed in LPL during the spring of 1984, although there was no apparent attempt to nest (Copper and Webster 1984).

The 1985 Enhancement Plan suggested the removal of encroaching vegetation from historic least tern sites located along the sewer berm. Placement of additional sand at these sites was also listed in the Plan as a consideration. Prior to the transfer of the 225-acre SDGE property to the State in 1987, attempts to remove vegetation along the sewer berm were precluded by legal disputes, possibly since the berm was used as an access road by SDGE (Copper and Webster 1984). It is not clear whether SDGE maintained

an easement along the berm after the land transfer, which may have prevented vegetation removal efforts after the land transfer. The berm was later removed in 1997/1998, in an attempt to restore lagoon hydrology between lagoon channels and Carmel Valley. The sewer berm, which had followed the same alignment as the original 1888 railway berm, provided a physical barrier that impeded freshwater flows from Carmel Valley that most likely attributed to the establishment of California least tern nesting habitat through the creation of large, open mud flats and sandy areas just west of the berm. Once this berm was removed, freshwater flows from Carmel Valley were able to push farther west into the Lagoon, resulting in the rapid advancement of brackish marsh and riparian habitats into the Lagoon. The eventual development of an extensive shrub and forested riparian vegetation cover has made much of the east end of LPL unsuitable for nesting. It is not clear whether the nesting habitat for the California least tern occurred naturally in the eastern portion of LPL or if it was of anthropomorphic nature. Paleoecological studies conducted in LPL document the order of magnitude increase in annual sedimentation rates from the watershed since 1820, as well as the newly established bare mud flats that occurred within the Lagoon prior to 1928 (Cole and Wahl 2000). This increase in annual sedimentation deposition within LPL was attributed to human activities in the watershed (e.g. large-scale cattle ranching), which increased erosion rates, and the presence of two railway berms that focused sediment deposition in the eastern half of the Lagoon.

### **Action Item #3. Re-establish cordgrass on an experimental basis in tidal channels once tidal action is restored.**

According to paleoecological and ecological studies conducting in LPL, cordgrass (*Spartina foliosa*) was historically present in LPL (Purer 1942, Cole and Wahl 2000). It is believed the *S. foliosa* became established in LPL between about 2850 and 2600 years before present. Since this species forms the lowest vegetation zone in coastal salt marshes, its establishment in LPL most likely occurred when sedimentation rates were slow relative to sea level rise (McDonald 1977, Cole and Wahl 2000). It is not clear when *S. foliosa* disappeared from LPL, but its presence was last documented within the Lagoon in the 1940s (Purer 1942). It is unlikely that attempts were made to re-establish cordgrass pursuant to the recommendation made by the 1985 Plan, especially since it would have been referenced in one of the annual biological and physical monitoring reports prepared since 1987. Prolonged inlet closures likely complicated restoration efforts to restore *S. foliosa*.

### **Action Item #4. Remove ice plant and other exotic species and establish tidal channels and salt marsh habitat in the areas bounded by Carmel Valley Road, the railroad embankment, and the North Beach Parking Lot access road.**

Commonly referred to as Ice Plant or Hottentot Plant, *Carpobrotus* is a genus of ground-creeping plants with succulent leaves and daisy-like flowers. An invasive species, *Carpobrotus* is often used for ground cover due to its fast growth, resiliency, low height, and resistance to fire. It is not known how *Carpobrotus* was initially introduced to LPL, but it could have occurred as a result of past re-vegetation efforts along Carmel Valley Road. In 2009, State Parks and LPLF received funding through the Southern Wetlands Recovery Program, administered by the State Coastal Conservancy, to remove large sections of *Carpobrotus* along Carmel Valley Road. The project successfully removed approximately 3 acres of this

invasive plant species using low-impact techniques that included covering areas of *Carpobrotus* with black tarps to “cook it” rather than using herbicides. Dead areas of *Carpobrotus* were then removed by hand and transported to the local landfill. State Parks and volunteer staff replaced areas cleared of *Carpobrotus* with native plant species that were hand planted and maintained.

Establishment of tidal channels, outside of efforts conducted as part of the lagoon inlet restoration, has not occurred since the 1985 Plan. This is most likely due to the complicated nature of permitting such activities and the cost prohibitive nature of disposing of excavation spoils. Removal of exotic plant species and restoring salt marsh habitats along the railway embankment has also not occurred since the 1985 Plan. This is most likely due to issues related to access along the railway easement and safety for working crews since the railway line is relatively active with both freight and commuter trains.

Restoration of native plants along the North Beach Parking Lot occurred naturally along the access road that ran parallel to the eastern edge of the parking lot. This sandy road was previously used to access the Lagoon inlet area by heavy equipment that was staged in the North Beach Parking Lot during lagoon mouth maintenance efforts. Since the replacement of the lower bridge above the lagoon inlet in 2004/2005, equipment is now staged along North Torrey Pines Road and access to the lagoon inlet area is gained under the lower bridge. Without the annual disturbance by heavy equipment, native plant species have become re-established along the discontinued access road. Nuttall’s lotus (*Lotus nuttallianus*), a Rare and Endangered Plant on the California Native Plant Society’s 1B.1 List, is one of the native plant species that grow in the previously disturbed area.

## **Action Item #5. Periodically remove illegal dumps and clean up litter around the perimeter of the lagoon.**

Illegal dumps along the perimeter of the Lagoon no longer seem to be an issue with regard to the input of litter into LPL. This is most likely attributed to improved social consciousness with regard to protecting environmental resource and the vigilance of State Parks staff and members of the local community, which includes residents and concerned citizens that frequent the Torrey Pines State Reserve. Litter still enters the Lagoon from storm drains, the ocean inlet, and trash left on nearby streets and urban areas, which is transported into LPL by prevailing winds. State Parks staff and local volunteers help to clean up trash left within the North Beach Parking Lot, along Torrey Pines State Beach, and Carmel Valley Road. Larger trash clean-up efforts have taken place on Torrey Pines State Beach, often lead by environmental groups such as San Diego Coastkeeper.

## **Steps Forward**

Habitat restoration should be a continued priority for LPL, with restoring native salt marsh habitats and removal of exotic species as priorities. While efforts have been successful on small-scale projects, the most likely scenario for large-scale and long-term solutions to habitat restoration will involve restoring hydrology within the watershed and along lagoon boundaries, as well as within the lagoon itself (e.g. reconnecting historic tidal channels). Restored hydrology within the watershed and along lagoon boundaries would include both storm runoff (e.g. peak flows and volume) and dry weather flows associated with activities such as landscape irrigation. Continued lagoon inlet maintenance would be key to any habitat restoration efforts. Examining opportunities to increase the tidal prism should also be considered to improve the volume and spatial extent of tidal mixing and reducing residence times for water within lagoon channels.

Restoring hydrology to a natural state prior to urbanization of the watershed should be considered to facilitate the natural processes that led to LPL's establishment as a coastal salt marsh, in order to reduce associated maintenance costs. However, this may turn out to be unrealistic given what would be required to re-establish natural hydrology, such as the removal of North Torrey Pines Road and associated infrastructure to re-establish the historic location of the lagoon inlet and coastal dunes that existed on Torrey Pines State Beach prior to 1930. Therefore, efforts should also be made to examine restoration alternatives that mimic natural hydrology or, at the very least, establish hydrology that is conducive to restoration and the long-term enhancement and protection of native salt marsh habitats.

Additional efforts to control invasive plant species within LPL should also consider working with Caltrans and municipalities located around the Lagoon and within the watershed to modify plant pallets and hydroseed mixes used to landscape areas graded or disturbed by private or public developments, including capital improvement projects. This would help to reduce the transfer of exotic seed banks to the Lagoon. It is believed that infestation of *Lolium perenne* (English Ryegrass) in LPL was due to its inclusion in hydroseed mixes used in the watershed. Additionally, efforts should be made to examine opportunities to remove exotic plant species already established on surrounding public and private properties. The latter would most likely require community outreach and education with incentives as the driving force, since public funds generally cannot be used to directly enhance private property. Reviewing habitat restoration programs, agreements, and methods used in nearby lagoons, such as San Elijo Lagoon, could provide guidance, especially in matters involving private property.

## **APPENDIX F**

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### Public Access



## APPENDIX F. PUBLIC ACCESS

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For the most part, recommendations provided in the 1985 Plan for improving public access in LPL were not implemented, although some were satisfied indirectly. Educational components (e.g. interpretive displays and informational panel) were implemented to certain degree. A description and assessment of success for each of the nine recommended access improvements are provided below:

### **Action Item #1. Build a Visitor Center in the North Beach Parking Lot with interpretive displays about the marsh and lagoon ecosystem.**

Although a visitor center was never built in the North Beach Parking Lot, interpretive panels were installed near the public restrooms in the parking lot to provide educational information regarding LPL, its environs, and animal species. Additionally, informative panels were installed near the lagoon mouth explaining the need and benefits associated with inlet maintenance. Prohibitive signage was also installed along the border of the lagoon in the North Beach Parking Lot and under the lower bridge to control public access in areas of sensitive habitat.

### **Action Item #2. Build a boardwalk extending south from the North Beach Parking Lot into the restored sand dunes and marsh areas for interpretive purposes.**

This boardwalk was never built and most likely never designed due to the presence of sensitive plant and bird species in this area. Nuttall's lotus (*Lotus nuttallianus*), a Rare and Endangered Plant on the California Native Plant Society's 1B.1 List, has historically occupied this area and persists today even though the area experiences erosion from lagoon outflows during flood events and storm surges entering the Lagoon through the inlet. The dune area is also considered potential nesting habitat for Western Snowy Plover, a federally-listed bird species, and has been roped off to prevent access. The area's vulnerability to erosion would also have reduced alternatives for placement of the boardwalk

### **Action Item #3. Build a pedestrian link between the North Beach Parking Lot and sidewalk of North Torrey Pines Road bridge to provide pedestrian access to the south beach when the lagoon mouth is open.**

The pedestrian link was not developed as part of the 1985 Enhancement Plan. However, it was provided as a design element of the new lower bridge constructed in 2004/2005. Pedestrian access ramps,

compliant with the American with Disabilities Act, were constructed on both the west and east sides of the bridge, north of the inlet to provide safe, public access across the inlet. However, accessing the beach south of the bridge is slightly complicated by coastal bluffs and rip rap. Efforts have been made to place sand in this area during inlet maintenance efforts to improve access points for both pedestrians and emergency vehicles.

#### **Action Item #4. Build a boardwalk from the lagoon mouth along the eastern shoulder of Torrey Pines Road.**

This boardwalk was never constructed as part of the original lower bridge, most likely due to structural weaknesses and dangers posed by falling chunks of cement in the original Highway 101 Bridge, constructed in 1932. As mentioned under Action Item #3, public access across the lagoon mouth was provided by the newly constructed lower bridge that spanned the inlet.

#### **Action Item #5. Build a trail from Flintkote Avenue to North Torrey Pines Road, bypassing the sensitive transitional areas between wetland and upland vegetation. Construct linking trails to North Torrey Pines Road.**

The Marsh Trail skirts the southern edge of the wetland for 1.5 miles connecting North Torrey Pines Road to Flintkote Avenue in Sorrento Valley. It is not clear if this trail was built or simply evolved from foot traffic or as a trail used by larger mammals, such as mule deer. The eastern end of the trail is paved, serving as an access road used by the State Parks, City of San Diego, who maintains a water main that runs across the Lagoon, and SDGE to access power lines.

#### **Action Item #6. Expand and improve the parking lot at the end of Flintkote Avenue and include interpretive facilities.**

The parking lot referred to in this action item is owned by the City of San Diego and used by their Metropolitan Waste Water Division, managed under the City's Public Utilities Department, for equipment and materials staging on an as needed basis. It is not clear whether LPL and/or State Parks approached the City about using this area as a public parking lot.

#### **Action Item #7. Construct and maintain fences and gates at either end of the sewer berm to prevent illegal vehicular entry to the wetland.**

Vehicular access into LPL has been controlled through the implementation of gated entries at access points around the Lagoon. However, the sewer berm was removed in 1997/1998 so this action item is no longer applicable.

**Action Item #8. Develop interpretive displays about sedimentation, freshwater and salt marshes, and riparian habitat in conjunction with the park and ride facility at the intersection of Carmel Valley Road and Sorrento Valley Road. Include a trail or boardwalk skirting the wetland to Portofino Drive to improve pedestrian access.**

Interpretive displays about sedimentation, freshwater and salt marshes, and riparian habitats were not implemented at the park and ride facility at the intersection of Carmel Valley Road and Sorrento Valley Road. Neither was the construction of a boardwalk skirting the wetland to Portofino Drive. The boardwalk most likely was not implemented due to the constrained nature of this area along Carmel Valley Road, which has since impeded the ability to connect a bike trail from Carmel Valley to the North Beach Parking Lot. Placing the boardwalk within the Lagoon would have been difficult as a stand-alone project, due to the need to mitigate impacts to vegetation and sensitive species (e.g. Light-Footed Clapper Rail). Furthermore, it may have been viewed as encroachment into the Lagoon by State Parks, since the Lagoon is a State Preserve with preservation of Lagoon resources a priority over public access.

**Action Item #9. Develop a viewpoint on Sorrento Valley Road at the crest of the hill overlooking the lagoon, if traffic safety considerations can be met. This may be accomplished in conjunction with road improvements or adjacent private development.**

While it is not clear which hill this action item referred to, it is most likely the one located behind City of San Diego Pump Station #65. This action item was never implemented, most likely because this property is privately owned. Currently, this property is planned for development through the construction of office buildings under the name of Sorrento Pointe. In early 2012, a Mitigated Negative Declaration was circulated regarding the proposed Sorrento Pointe development. The value of this property with regard to view corridors and public viewing opportunities was provided through comment letters submitted by groups of interested stakeholders, including LPLF, State Parks, and the Torrey Pines Associations. The final draft of the CEQA Mitigated Negative Declaration for this planned development is still pending.

## **Steps Forward**

Providing public access and educational opportunities are a goal of the updated lagoon enhancement plan. Emphasis will most likely be placed on improving existing areas along the perimeter of the Lagoon, rather than constructing new trails and facilities (e.g. an interpretive center). The closed section of Sorrento Valley Road provides a great potential opportunity for improving public access, viewing platforms, and educational opportunities. Improvements along the Marsh Trail could also be implemented, since people that work in Sorrento Valley often use this trail for recreation. Connecting pedestrian access to LPL from approved trail networks in nearby open space areas (e.g. the Reserve Extension) and bike paths from surrounding areas (e.g. Carmel Valley) should also be considered.

## **APPENDIX G**

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### Sedimentation

# APPENDIX G. SEDIMENTATION

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Several of the action items identified in the 1985 Plan were pursued directly, while others were attained indirectly through programs such as the Total Maximum Daily Load (TMDL) for LPL and the Carmel Valley Restoration and Enhancement Project (CVREP). The following section provides a brief description and assessment of activities pursued under each of the action items identified in the 1985 Plan.

## **Action Item #1. Implement the SANDAG Watershed Management Plan recommendations for improved erosion control ordinances and enforcement and for public education. Publish standards for erosion control and the use of best management practices.**

Prepared for the San Diego Association of Governments (SANDAG) by Boyle Engineering, the Los Peñasquitos Lagoon Watershed Management Plan was developed to provide a comprehensive watershed management plan to prevent increased sedimentation in LPL during development of the watershed. The plan was approved by SANDAG's Board of Directors in 1982 and provided the following:

- A description of engineering methods used to estimate water and sediment runoff for existing and future conditions in the watershed.
- A discussion of potential mitigation measures to reduce the expected sediment increase.
- Recommendations for specific measures to be implemented as the watershed management plan.

Results from the study are briefly summarized below:

- Peak discharges and runoff volumes will increase as a result of development in the watershed.
- Peak discharges for 10-year storms would increase 100 to 200 percent while increases for the 100-year storm will increase by 30 to 40 percent as development "approaches its ultimate stage."
- The concrete-lined flood channel in Sorrento Valley has limited flow capacity, estimated to be 4,000 cubic feet per second.
- The sediment yield from the watershed will increase significantly in the over the next 20 years if proper sediment controls are not implemented. Increases in sediment input will be generated initially by construction activities, but runoff rates from developed areas will result in increased erosion of stream channels. The study projected the following increases in sediment yield from each of the three sub-watersheds:
  - Carmel Valley: 19,000 tons (1980s) to 25,000 tons (future) = ~ 32% increase.
  - Los Peñasquitos Canyon: 34,000 tons (1980s) to 78,000 (future) = ~ 129% increase.
  - Carroll Canyon: 8,000 tons (1980s) to 20,000 ton (future) = ~ 150% increase.
- Siltation and water quality problems in the lagoon would be aggravated by the increased sediment runoff, comprised of both wash load and bed material load.

While the study reviewed several alternatives to mitigate increases in sediment loads to LPL, it concluded that the construction of sediment basins along with non-structural measures would be the most effective. However, sediment basins were not selected in the final version of the plan due to potential issues with project financing; environmental, historic, and archaeological constraints; and the requirement by the Coastal Commission for on-site detention basins as a requirement of development regardless of whether regional sediment basins are constructed. Ultimately, four non-structural measures were selected for inclusion in the approved plan. These measures are described below, along with an assessment of their success:

1. *Improve erosion control ordinances and enforce them.* Specific primarily to grading ordinances for the City of San Diego, City of Poway, and County of San Diego, a number of revisions to erosion control ordinances and enforcement were recommended by the SANDAG plan. The suggested revisions were:
  - Include water quality as a purpose of the ordinances.
  - Add rainy-season provisions to the ordinances, including restrictions on grading during November to March unless authorize by an erosion control plan. Include stabilization measures in place on construction sites by October 15<sup>th</sup>.
  - Required erosion control plans and construction schedules from developers. Increase site inspections by agency staff and coordinate them with construction schedules and rainy-season requirements.
  - Improve the quality of erosion control plans by developing guidelines for such plans and a “best management practices” manual for the area.
  - Improve public awareness of sedimentation problems through public education programs.

The first four suggested revisions have been implemented in the form of a Storm Water Pollution Prevention Plan (SWPPP), a requirement of Construction General Permits issued by municipalities and enforced pursuant to compliance with the Clean Water Act. However, the public education component has not been widely implemented, although the City of San Diego has included it as a component of its Think Blue Campaign, which includes a hotline phone number to report violations, online complaint forms, videos, news and events, public education and outreach, and special projects made accessible to the public through a website (<http://www.sandiego.gov/thinkblue/>).

Erosion control ordinances seem to have proved relatively successful in controlling erosion at construction sites, provided inspections and enforcement are implemented. However, it is not clear to what extent this management plan influenced improvements to erosion control ordinances. Recent revisions in erosion control ordinances that include online posting of inspection results for public review and additional monitoring requirements should improve erosion control at construction sites. However, most of the watershed is already built out, so benefits associated with this improvement in erosion control ordinances and enforcement will most likely only have a site-by-site affect in protecting LPL from sediment.

2. *Open Los Peñasquitos Lagoon to Tidal Action.* Aside from benefits to water quality and habitat, the SANDAG plan highlights the need to open the lagoon mouth to allow movement of sediment through the lagoon and out to the ocean and shoreline. Benefits associated with this recommendation are greatly reduced by the presence of the railway berm that bisects LPL, causing most sediment entering the Lagoon during flooding events to deposit east of the berm even when the lagoon inlet is open.

3. Monitoring Program. The monitoring program suggested by the SANDAG plan would measure the effectiveness of the previous measures and included:
  - Continuous stream gauge stations installed at each major tributary to the lagoon to measure flow and sediment load. And, installation of a gauge upstream of North City West development area, located within Carmel Valley.
  - A benchmark system established to help to measure depth of deposition or scour in the lagoon. Surveying and sediment sampling after significant floods.
  - Water quality monitoring in the lagoon.

Please refer to Appendix A for a description and assessment of monitoring efforts conducted at LPL.

4. Determine the Need for Structural Erosion Control Measures. This measure was included in case the monitoring program demonstrated that erosion control measures, opening the lagoon mouth, and upstream basins recommended by the Coastal Commission or other facilities were not adequately addressing impacts to the Lagoon related to sedimentation. Since this plan was approved in 1982, several efforts have been made to examine, design, and implement structural erosion control measures within the watershed that include erosion control devices (e.g. gabions in Lopez Canyon and the Torrey Pines Reserve Extension) and sediment basins (e.g. the Los Peñasquitos Creek Sediment Basin).

## **Action Item #2. Preserve sediment storage areas identified by Prestegard (1978) in their natural state. Only development that retains the current natural capacity and function of these areas to hold sediment from upstream, or properly mitigates any disruption should be allowed.**

Prestegard's report recommended the preservation of major areas of sediment storage identified during field mapping as a priority to avoid impacts to avoid increased sedimentation in LPL. The report identified sediment storage areas as depositional provinces that included:

- "All of the freshwater and saltwater marsh areas surrounding LPL."
- "Freshwater swamps or alluvial fans at the base of the major tributaries."
- "Unchannelized portions of the major stream, especially Carroll and Carmel Creeks."

For the most part, this action item was unsuccessful since it attempted to regulate development on properties not owned by the State. Development of parcels provides revenue for the local municipalities through permit acquisition and tax revenue. Areas surrounding the Lagoon, within the floodplain of each of the three main tributaries and unchannelized portions of Carmel Creek and Carroll Creek have, for the most part, been developed. This has resulted in the loss of non-tidal salt marsh habitats and channelization of creeks to protect developments from flooding during rain events. Development within Carroll Canyon has constrained the tributary located within this sub-watershed and eliminated the sediment storage capacity in many areas. Gravel and sand mining activities within Carroll Canyon have likely exacerbated sedimentation problems within this sub-watershed. Sedimentation rates have also been exacerbated by storm water management facilities that discharge runoff from urban areas into steep drainages located along canyon walls. Aside from contributing to erosion along canyon walls, increased



peak flows and volumes of storm runoff have incised many of the creek channels, even in areas that had not been channelized to protect adjacent developments.

The City of San Diego purchased land in Los Peñasquitos Canyon for a regional park that evolved into an open space preserve. Additionally, the City converted land along State Route 56 into a river park through the Carmel Valley Restoration and Enhancement Project (CVREP). The benefits afforded by these efforts by the City with regard to sediment storage were greatly reduced since both the lower reaches of Los Peñasquitos Creek and Carmel Creek were channelized. Channelization reduced the ability of these areas to serve as sediment storage areas, since sediment transport rates were no longer abated by the braided stream creek system or a non-channelized flood plain that had previously existed at the base of both of these tributaries.

**Action Item #3. Design in-stream improvements that would decrease erosion and slow downstream sedimentation. Estimate the cost of conserving, restoring, and maintaining stream channels, and identify sediment sources. Re-evaluate the desirability of a facility to remove sediment at the lower end of Carmel Valley. Also re-evaluate the costs, possible financing mechanisms, locations, and environmental effects of sedimentation basins in Carroll Canyon and Los Peñasquitos Canyon.**

In-Stream improvements to decrease erosion and slow downstream sedimentation have not been pursued by LPLF, due in most part to constraints related to property ownership, maintenance complications, and mitigation costs associated with impacts to sensitive species, critical habitat, and waters of the United States. Efforts by the City of San Diego have been made to fulfill this measure, most notably through the Carmel Valley Restoration and Enhancement Project (CVREP) which includes drop structures and other methods used to control sediment transport. It appears that CVREP has been successful in reducing sediment loads to LPL, although this has not been confirmed by monitoring efforts and may be a result of thick vegetation (e.g. *Typha*) that has become established at the base of Carmel Creek serving as a sediment depositional area. A sediment basin was constructed in the lower portion of CVREP, just east of Interstate 5, to capture sediment flows from this tributary before it could reach LPL. It is not clear if this basin is functioning or consistently maintained and is located within an area used as nesting habitat for Light-Footed Clapper Rail, which would greatly complicate maintenance efforts requiring vegetation removal or the use of heavy equipment.

Efforts were initiated in early 2002 by LPLF to address sedimentation from watershed sources through funding provided through Proposition 13 and the State's Non-Point Source Pollution Control Program. Modeling of watershed hydrology, hydraulics, and sediment transport was performed for each of the three sub-watershed, and sediment control alternatives were developed for each tributary. It was determined from these studies that sedimentation impacts affecting LPL were generated primarily in the Los Peñasquitos Canyon and Carroll Canyon. Sediment control alternatives for both of these sub-watersheds involved sediment basins to be located as close to the Lagoon as possible to maximize the interception and retention of sediment from these two sub-watersheds. While a viable site to construct a basin was located along Los Peñasquitos Creek within the lower portion of Los Peñasquitos Canyon, constraints

related to sensitive habitat and/or private property along Carroll Creek in lower Carroll Canyon and Sorrento Valley precluded the ability to construct a basin within this sub-watershed. A sediment source identification map was prepared for Los Peñasquitos Canyon and adjoining Lopez Canyon to facilitate future source identification and control needs.

Since 2008, the City has conducted several studies to identify sediment transport capabilities of each of the Lagoon's three tributaries, sources of sediment within the watershed, and characterization of erosion/deposition trends and processes within the watershed as a response to the Sediment TMDL for LPL. In 2011, a sediment transport and geomorphology study was conducted for Carroll Canyon by ESA PWA on behalf of the City. This study identified key areas within this sub-watershed for sediment management, including stream bank stabilization, streambed maintenance, and detention basins. However, concept designs for these potential measures have not been prepared. LPLF has coordinated efforts with the City to identify and acquire funding through grant opportunities, though none have been successful to date.

## **APPENDIX H**

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### Cultural Setting

## APPENDIX H. CULTURAL SETTING

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### Early Prehistoric Period (Paleoindian Period)

The earliest well documented prehistoric sites in the southern California region show evidence of human presence dating back over 8,000 – 9,000 years ago in the San Diego region. Groups from the early Holocene Epoch, the Early Prehistoric Period, or Paleoindian period, have been referred to locally as the San Dieguito Complex or Tradition (Rogers 1966, Pignolio 2010). People of the San Dieguito Complex were previously thought to have been almost exclusively ‘big game hunters’ (Pourade 1966) and highly mobile in order to follow large mammals. However, more recent evidence suggests that they were also gatherers and, along the coast, exploiters of marine resources (Gallegos 1992). The San Dieguito Complex is generally divided into four “aspects” (major zones of concentration): the Western, Central, Southwestern, and Southeastern Aspects with the San Diego coastal region falling into the Western Aspect (Rogers 1966). The first documented coastal site (i.e. Harris site) in the San Diego region was found along the San Dieguito River, which is located just north of the Los Peñasquitos Watershed.

### Early Archaic Period

During the Early Archaic Period it is believed that the Native Americans had a generalized economy that focused on hunting and gathering (Pignolio 2010) with coastal southern California economies remaining largely based on wild resource use until European contact (Willey and Phillips 1958). Sites dated between approximately 8,000 and 1,500 years before present (BP or prior to 1950) indicate increased use of groundstone artifacts and dart points, along with a mixed core-based tool assemblage that identify a range of adaptations to a more diversified set of plant and animal resources including marine invertebrates in coastal areas (Pignolio 2010). Around 6,000 years BP the lagoons of northern San Diego County supported large populations (Gallegos and Kyle 1988; Pignolio et al. 1993). However, there appears to be a decline in the numbers of sites in northern San Diego County from around 3,000 to 1,500 years BP, which has been attributed to the siltation of the lagoons and the depletion of lagoon resources including shellfish (Gallegos 1992:206, 213; Gallegos and Kyle 1988). The end of the Early Period in present-day San Diego County has been estimated to be around 1,300 years BP (Gallegos 1992:212-213).

### Late Archaic or Late Prehistoric Period

The Late Prehistoric Period (also known as the Late Archaic or Yuman Period) lasted from 1,300 years BP up to European contact. This period has been distinguished from earlier periods by the appearance of small projectile points, ceramics, the introduction of bow and arrow, as well as the practice of cremating the dead (Christenson 1992:217; Gallegos and Kyle 1988). Some researchers believe that the drying up

of the large inland lakes (Lake Cahuilla and others) instigated or contributed to the migration of peoples from the eastern deserts to the western portion of San Diego County (e.g., Pourade 1966:8). Yuman Period sites have been found mainly in the inland portion of the county, with only two percent being located within the coastal strip (Christenson 1992:220). These results may be in part skewed due to the loss of site data because of coastal development prior to the instigation of standard site recording practices (Christenson 1992:220-221). Although Christenson (1992:221, 225-226) concludes that Late Prehistoric people of present-day western San Diego County used a wide variety of environmental settings for settlement and subsistence, maritime resources never became an emphasis, as reported for other groups living along coastal areas of California. However, proof of shoreline and offshore fishing was observed in bone assemblages of fish found in four Early Period sites located near Los Peñasquitos Lagoon that span a period from approximately 7000 to 2800 years BP (Noah 1998).

Torrey Pines State Natural Reserve, including Los Peñasquitos Lagoon, is within the ethnographic territory of the Kumeyaay, formerly referred to as Diegueño, who are direct descendants of the early Yuman hunter-gatherers. Their territory encompassed a large diverse environment that included marine, foothill, mountain, and desert resource zones. The Kumeyaay were mainly hunters and gatherers, making seasonal rounds to take advantage of various resources. However, they had also developed horticultural/agricultural techniques including burning, seed broadcasting, transplanting, and planting (Bean and Lawton 1973; Gee 1972; Luomala 1978; Shippek 1982). Acorns were the single most important food source used by the Kumeyaay and villages were usually located near water sources to facilitate the leaching of tannic acid out of the acorn meal (Pignolio 2010). Seeds from grasses, manzanita, sage, sunflowers, lemonade berry, chia, and other plants were also used along with various wild greens and fruits. Deer, small game, and birds were hunted and fish and marine resources were used as food sources. Hunting implements used by the Kumeyaay included bow and arrow, curved throwing sticks, nets, snares, and fishhooks made of shell or bone (Pignolio 2010).

The Kumeyaay were organized into autonomous bands with a hereditary (patrilineal) clan chief as well as at least one assistant chief (Luomala 1978:597). Each band had a central primary village and a number of outlier homesteads located at small water sources, springs, or at the mouths of secondary creeks (Shippek 1982). They also claimed prescribed territories, but did not own resources except for some minor plants and eagle aeries (Luomala 1976, Spier 1923).

## **Kumeyaay Village of Ystagua (SDI-4609)**

Located within modern-day Sorrento Valley and dating back to 1295 years BP, the Kumeyaay village of Ystagua spans the Late Prehistoric Period up to European Contact. Father Juan Crespí and Miguel Costansó captured early encounters with the Kumeyaay at Ystagua on July 15, 1769 during a Spanish exploration party led by Don Gaspar de Portolá (Carrico 1977). Crespí described the encounter as being friendly and recorded one of the first observations of clay pottery, leading many anthropologists to argue that Native American's manufacturing of pottery occurred prior to Spanish contact (Ibid). Archaeological excavations conducted at Ystagua have yielded extensive grinding technology and faunal collections that include nineteen fish species dominated by Pacific mackerel and sheephead (Noah 1998). Other pelagic fish found at this site included albacore, skipjack, bonito, yellowtail, and barracuda, indicating that residents of Ystagua ventured offshore to kelp beds off of Del Mar and, potentially, further out into open coastal waters (Ibid).

Archaeological evidence indicates that many of the late prehistoric villages moved inland, away from the coastline. This large migration occurred as early as two thousand years before Portolá's arrival and was

most likely due to a drastic decrease in the quantity of shellfish that provided a major food source (Warren 1964). However, Ystagua appears to have been an exception, most likely due to its location near Los Peñasquitos and its three sub-watersheds that provided the Kumeyaay at Ystagua opportunities for both shellfish harvesting along the coast and hunting/gathering opportunities in the nearby coastal canyons (Carrico 1977). Furthermore, natural springs located in Los Peñasquitos Canyon most likely contributed to stability by providing a source of freshwater for both the Kumeyaay and the large mammals they hunted.

## Historic Period

European contact with the Kumeyaay in coastal San Diego began on September 28, 1542, when Juan Rodriguez Cabrillo entered San Diego Harbor and named it San Miguel. A subsequent contact with Spanish explorers occurred later in 1602 when Sebastian Vizcaino sailed into the bay and renamed it San Diego de Alcalá. Kumeyaay culture and society remained stable until the advent of mission system and displacement by Hispanic populations during the eighteenth century (Pignolio 2010). Establishment of the mission system in San Diego was initiated with the building of the Mission San Diego de Alcalá in 1769, located in modern-day Mission Valley just east of Interstate 15. While many of the Kumeyaay initially resisted missionization, the introduction of European diseases greatly reduced the native population during this period and contributed to the breakdown of cultural institutions. De facto Native American control of the southern California region ended several decades later.

The Spanish Period (1769-1821) represents a time of European exploration and settlement that involved dual military and religious contingents based out of the San Diego Presidio and the missions located in San Diego and San Luis Rey. Most of the remaining Kumeyaay during this time period were forced to convert and relocate to the mission, where they were used as a source of labor. The mission system introduced horses, cattle, agricultural goods, and implements from Europe, as well as new construction methods and architectural styles. While Spanish control of the southern California region ended with the separation of Mexico from Spain in 1821, many of the Spanish institutions and laws remained.

The Mexican Period (1821-1848) began with Mexico's independence in 1821. At that time, cowhides were one of the few items in California that could be produced in abundance and shipped long distances (Wade 2009). The first private land grant in San Diego, Rancho Peñasquitos was established in 1823 when Captain Francisco Maria Ruiz, the San Diego Presidio Commandant, was awarded 4,243 acres that included eastern portions of Los Peñasquitos Canyon (Ibid). When the mission system was secularized in 1834, many Native Americans were dispossessed and Mexican settlement was further expanded on lands previous under mission control (Mealey 2010). During this period, Rancho Peñasquitos was expanded by an additional 4,243 acres to the west toward Los Peñasquitos Lagoon that included the remaining portions of Los Peñasquitos Canyon. An early settler of San Diego, Francisco Maria Alvarado, Ruiz's nephew, purchased the Rancho Peñasquitos in 1837 (Wade 2009). The proximity of Rancho Peñasquitos to the main road between San Diego and Yuma most likely helped the rancho to prosper in its early years since it could provide hides, tallow, and beef to both travelers and military personnel during the Mexican-American War (Ibid). Historic reports mention that the United States Army collected over 100 head of cattle from Rancho Peñasquitos in 1846 when General Stephan Watts Kearny chose the rancho as resting place for his Army of West after the Battle of San Pasqual (Ibid). The Mexican Period ended when Mexico ceded California to the United States after the Mexican-American War ended in 1848.

Shortly after the United States took control, gold was discovered in California. This resulted in a rapid influx of American and Europeans that quickly displaced the cultural influences and institutions developed during the Spanish and Mexican Periods. Remaining pockets of de facto Native American control were eliminated by the time of the Garra uprising in the early 1850s (Phillips 1975). While cattle ranching prospered to meet the demands of the growing populations of central and northern California, the prosperity was short-lived and declined after the 1850s due to several factors that included drought, disease and changing land use priorities (farming and homesteads over large ranches) facilitated by the United States control over California (Wade 2009). Few Mexican ranchos remained intact due to land use claim disputes caused by the homestead system that facilitated American settlement within the southern California region (Ibid). Rancho Peñasquitos stayed within the Alvarado family after the Mexican American War, when the United States Congress reassessed and confirmed land ownership in California beginning in 1851 (Ibid). Approval for the land ownership title for Rancho Peñasquitos was granted to the Alvarado family in 1876 by the U.S. Congress and their Board of California Land Commissioners (Ibid). The rancho was sold to Colonel Jacob Taylor in 1888, most likely to offset the debt incurred during negotiations to prove ownership of the land (Ibid). The U.S. Government's establishment of the reservation system between 1877 and 1891 forced the relocation of the Kumeyaay, took away many of their freedoms, and forever changed what remained of their lifestyle (Carrico 1987; Castillo 1978; Shipek 1987).

## Cultural Research at Los Peñasquitos Lagoon and its Watershed

At least 77 archaeological investigations have taken place in the vicinity of Los Peñasquitos Lagoon and the western reaches of its watershed and indicate the presence of prehistoric settlement and historic period occupation (Pignolio 2010). Twenty-six recorded sites have been identified relatively close to Los Peñasquitos Lagoon including Early Period sites in Sorrento Valley (Sites: SDI-1103, SDI-197, SDI-4513) and Carmel Valley (Site: SDI-4615), which span a period of approximately 7000 to 2080 years BP (Pignolio 2010, Noah 1998).

## Marine Resource Use by Native Americans around Los Peñasquitos Lagoon

All four recorded sites near Los Peñasquitos Lagoon (SDI-1103, SDI-197, SDI-4513, SDI-4615) indicate that both the Lagoon and its nearshore environs played a role in the Native American diet consisting, in part, of marine faunal species. SDI-1103 (6310-5020 years BP) is located along the inland edge of Los Peñasquitos Lagoon. Termed the Bank Robber Site, SDI-197 (4590-3820 years BP) is also located on the inland side of the Lagoon approximately 800 meters south of SDI-1103. Located within Sorrento Valley with an estimated age of 5040-2820 years BP, the Rimbach Site (SDI-4513) contained a portion of the ethnohistorically recorded Kumeyaay village of Ystagua (SDI-4609). SDI-4615 (7150-3065 years BP) occupies a low rise on a northern creek bank in Carmel Valley located just over a ½ mile from Los Peñasquitos Lagoon. Faunal assemblages at all four sites indicate a diet that consisted of lagoonal shell species, elasmobranchs (rays and sharks) found in shallow sandy or muddy-bottom areas, and fish species typical of kelp beds, rocky areas, and open waters (Ibid).



It should be noted that the success of harvesting marine resources around Los Peñasquitos Lagoon was most likely shaped, in part, by the transformation of the Lagoon from a deep embayment to brackish marsh and, eventually, to a salt marsh. During the end of a glaciation period and subsequent rise in sea level, Los Peñasquitos Lagoon was transformed into deep-water embayment in 6000 years BP with a rocky coast along the beach (Inman 1983). Around 4000 years BP, sea-level rise slowed and sediment input from the coastal watersheds within the Oceanside Littoral Cell transformed the rocky coastline near Los Peñasquitos Lagoon into sandy beaches (Masters 2005, Masters and Gallegos 1997). As a result, the primary source of coastline fauna available for Native Americans shifted from mollusks to sandy beach species (Ibid). As sea levels stabilized, episodic events associated with El Niño Southern Oscillation (ENSO) continued to facilitate sedimentation within Los Peñasquitos Lagoon, transforming the Lagoon into a brackish marsh by 3600 years BP and salt marsh by 2800 years BP (Cole and Wahl 2000).

# REFERENCES

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- Bean, L. J. and H. W. Lawton  
1973 Some Explanations for the Rise of Cultural Complexity in Native California with Comments on Proto-Agriculture and Agriculture. In *Ballena Press Anthropological Papers* Number 1. Edited by L. J. Bean. Ballena Press, Ramona, California.
- Bevil, A.  
1998b National Register Nomination Form for Torrey Pines Lodge. On file, DPR, SSC, San Diego.
- Breschini, G. S., T. Haversat, J. M. Erlandson  
1996 *California Radiocarbon Dates*. Eighth Edition. Coyote Press, Salinas, California.
- California Department of Parks and Recreation (DPR)  
1984 *San Diego Coastal State Park System General Plan Volume 8 - Torrey Pines State Beach and State Reserve*. State of California Department of Parks and Recreation. On file, DPR, SSC, San Diego.
- Carrico, R. L.  
1987 *Strangers in a Stolen Land: American Indians in San Diego*. Sierra Oaks Publishing Co.  
1977 *Portola's 1769 Expedition and Coastal Native Villages of San Diego County*. Journal of California Anthropology, 4(1). UC Merced
- Castillo, E. D.  
1978 The Impact of Euro-American Exploration and Settlement. In *California*, edited R. F. Heizer, pp. 99-127. Handbook of North American Indians, vol. 8, W. C. Sturtevant, general editor. Smithsonian Institution, Washington D.C.
- Christenson, L. E.  
1992 The Late Prehistoric Yuman Settlement and Subsistence System: Coastal Adaptation. In *Essays on the Prehistory of Maritime California*, edited by T. L. Jones, No. 10, pp. 217-230. Center for Archaeological Research at Davis.
- Cline, L.  
1979 *The Kwaaymii: Reflections on a Lost Culture*. IVC Museum Society, El Centro, California.
- Cole, K. and E. Wahl.  
2000 *A Late Holocene Paleoecological Record from Torrey Pines State Reserve, California*. Quaternary Research. University of Washington. 53:341-451.
- Cook, S. F.  
1978 Historical Demography. In *California*, edited R. F. Heizer, pp. 91-98. Handbook of North American Indians, vol. 8, W. C. Sturtevant, general editor. Smithsonian Institution, Washington D.C.
- Gallegos, D.  
1992 Patterns and Implications of Coastal Settlement in San Diego County: 9000 to 1300 Years Ago. In *Essays on the Prehistory of Maritime California*, edited by T. L. Jones, pp. 205-216. Center for Archaeological Research at Davis, Publication Number 10.
- Gallegos, D. and C. Kyle  
1988 *Five Thousand Years of Maritime Subsistence at Ballast Point Prehistoric Site SDi-48 (W-164), San Diego, California*. Westec Services. Prepared for the Department of the Navy, Western Division Naval Facilities, Engineering Command, San Bruno, California. On file, DPR, SSC, San Diego.
- Gee, P. J.  
1972 An Introduction to the Burning of Vegetation by California Indians. Manuscript on file, DPR, SSC, San Diego

- Gifford, E. W.  
 1931 *The Kamia of Imperial Valley*. Bulletin 97, Smithsonian Institution, Bureau of American Ethnology. United States Government Printing Office, Washington D.C.
- Gifford, E. W. and G. H. Block  
 1990 *Californian Indian Nights*. Reprinted, University of Nebraska Press. Originally published as *Californian Indian Nights Entertainments*, 1930, Arthur H. Clark Company.
- Hubbs, C. L. and T. W. Whitaker  
 1972 *Torrey Pines State Reserve: A Scientific Reserve of the Department of Parks and Recreation, State of California*. The Torrey Pines Association, La Jolla.
- Inman, D  
 1983 Application of coastal dynamics to the reconstruction of paleocoastlines in the vicinity of La Jolla, California. In: Masters, P.M., Flemming, N.C. (Eds.), *Quaternary Coastlines and Marine Archaeology*, Academic Press, London, pp. 1-49.
- Kroeber, A. L.  
 1971 Elements of Culture in Native California. Reprinted in *The California Indians: a Source Book*. Edited by R.F. Heizer and M. A. Whipple. University of California Press, Los Angeles. Originally Published 1922, in University of California Publications in American Archaeology and Ethnology, 13:260-328.  
 1976 *Handbook of the Indians of California*. Reprinted, Dover Publications, New York. Originally published 1925 as Bulletin 78, Smithsonian Institution, Bureau of American Ethnology, Government Printing Office, Washington D.C.
- Kyle, C., A. Schroth, and D. Gallegos.  
 1990 *Early Period Occupation at the Kuebler Ranch Site SDi-8654, Otay Mesa, San Diego County, California*. ERC Environmental and Energy Services Co., San Diego.
- Luomala, K.  
 1978 Tipai-Ipai. In *California*, edited R. F. Heizer, pp. 592-609. Handbook of North American Indians, vol. 8, W. C. Sturtevant, general editor. Smithsonian Institution, Washington D.C.
- Masters, P.  
 2006 *Holocene sand beaches of southern California: ENSO forcing and coastal processes on millennial scales*. Journal of Palaeogeography, Palaeoclimatology, Palaeoecology. Vol 232, pps 73-95
- Masters, P. and D. Gallegos.  
 1997 *Environmental change and coastal adaptations in San Diego County during the Middle Holocene*. In: Erlandson, J.M., Glasgow, M.A. (Eds.), *Archaeology of the California Coast During the Middle Holocene*. Institute of Archeology, University of California Los Angeles, pps 11-21.
- Mealey, Marla and Rachel Ruston  
 2010 Torrey Pines State Nature Reserve ADA Trails and Overlooks Project Archaeological Investigations. California Department of Parks and Recreation, Southern Service Center.
- Noah, A.  
 1998. *Prehistoric Fishing on the San Diego Coast*. PCAS Quarterly, 34(2), Spring
- Pignoli, A, J Aguilar, S. Farmer and N. Brodie.  
 2010 *Archaeological Monitoring, Evaluation, and Data Recovery at Site CA-SDI-19721 for the Los Peñasquitos Creek Sediment Basin Project*. Laguna Environmental. Prepared for the Los Peñasquitos Lagoon Foundation. October 2010.
- Pignoli, A., K. Crawford, and M. Mealey  
 1993 *Historic Properties Inventory of the North County Transit District Maintenance Facility Alternatives, Camp Pendleton, Oceanside, and Carlsbad California*. Ogden Environmental and Energy Services Company. Prepared for Myra L. Frank and Associates, Los Angeles.

Pourade, R. F. (editor)

1966 *Ancient Hunters of the Far West*. The Union Tribune Publishing Company, San Diego.

Rogers, M. J.

1966 The Ancient Hunters-Who Were They? In *Ancient Hunters of the Far West*, edited by R. F. Pourade, pp. 23-110. The Union Tribune Publishing Company, San Diego.

Schaefer, J.

1994 The Challenge of Archaeological Research in the Colorado Desert: Recent Approaches and Discoveries. *Journal of California and Great Basin Anthropology*. 16:60-80.

Shipek, F. C.

1970 *The Autobiography of Delfina Cuero, A Diegueño Indian, as Told to Florence Shipek*. Reprinted. Malki Museum Press. Morongo Indian Reservation, Banning, California. Originally published 1968, Dawson's Book Shop, Los Angeles.

1982 Kumeyaay Socio-Political Structure. In *Journal of California and Great Basin Anthropology* 4(2):296-303.

1987 *Pushed into the Rocks: Southern California Indian Land Tenure, 1769-1986*. University of Nebraska Press.

Wade, S, S. Van Wormer, and H. Thomson

2009 *240 Years of Ranching. Historical Research, Field Surveys, Oral Interviews, Significance Criteria, and Management Recommendations for Ranching Districts and Sites in San Diego Region*. Prepared for California State Parks. September 8, 2009.

Warren, C. N., G. Siegler, and F. Dittmer

1993 Paleoindian and Early Archaic Periods. In *Draft Historic Properties Background Study for the City of San Diego Clean Water Program*, pp. III-1 through III-74. Brian F. Mooney Associates. Prepared for the Clean Water Program for Greater San Diego. On file, DPR, SSC, San Diego.

Warren, C. N.

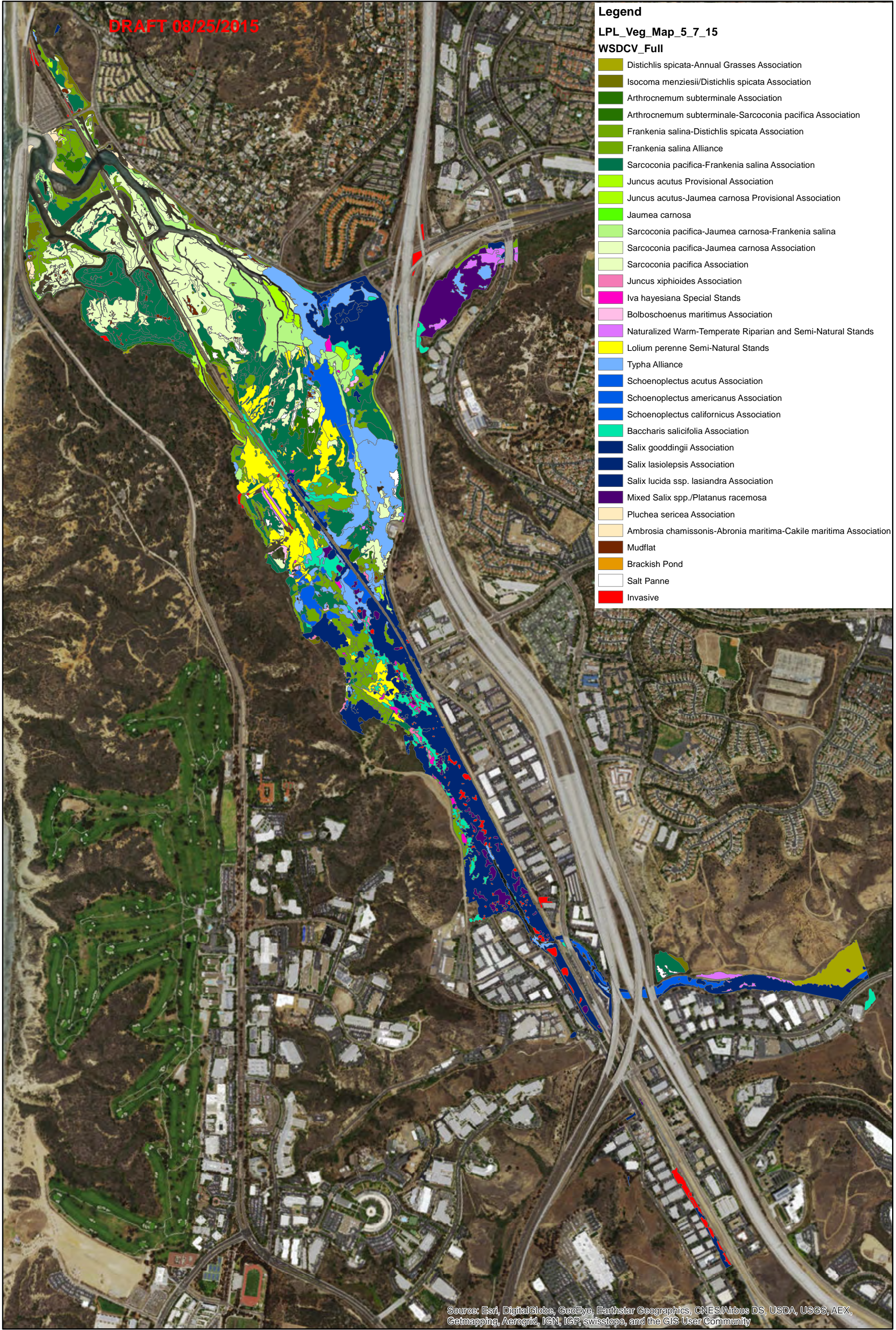
1964 Cultural Change and Continuity of the San Diego Coast. Ph.D. Dissertation, Department of Anthropology, University of California, Los Angeles. University Microfilms, Ann Arbor.

## **APPENDIX I**

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# Los Peñasquitos Marsh Wetland Vegetation Types





**Los Penasquitos Marsh Wetland Vegetation Types**  
**Western San Diego County Vegetation Classification**  
**Torrey Pines State Natural Preserve**

0 500 1,000 2,000 3,000 4,000 5,000 Feet





## **APPENDIX J**

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# Vegetation Types



| FAMILY LATIN     | FAMILY  | Where it Occurs | SPECIES NAME  | COMMON NAME  | Native/Alien | FLOWER  |
|------------------|---|-----------------|---|--|--------------|---------|
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Wetland         | Artemisia palmeri (RE-2)  | Palmer Sagewort, San Diego Sagewort                      | N            | Jul-Sep |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Wetland         | Baccharis salicifolia (B.glutinosa, B. viminea)                                 | Mule Fat   | N            | Jan-Dec |
| CYPERACEAE       | Sedge Family  | Wetland         | Eleocharis macrostachya   | Spike-Rush   | N            | Apr-Nov |
| EUPHORBIACEAE    | Spurge Family                                       | Wetland         | Ricinus communis  | Castor-Bean  | A            | Jan-Dec |
| ANACARDIACEAE    | Sumac Family  | Wetland         | Toxicodendron diversilobum **   | Poison Oak   | N            | Apr-May |
| NYCTAGINACEAE    | Four O'Clock Family                                 | Dune            | Abronia maritima (RE-4)   | Red Sand-Verbena, Seaside Sand-Verbena                   | N            | Feb-Oct |
| NYCTAGINACEAE    | Four O'Clock Family                                 | Dune            | Abronia umbellata ssp. umbellata **   | Beach Sand Verbena                                       | N            | Jan-Dec |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Dune            | Ambrosia chamissonis (A. bipinnatifida)   | Beach Bur  | N            | Jul-Nov |
| CHENOPODIACEAE   | Goosefoot Family                                    | Dune            | Atriplex californica  | California Saltbush                                      | N            | Apr-Nov |
| ONAGRACEAE       | Evening-Primrose Family                             | Dune            | Camissonia cheiranthifolia ssp. suffruticosa                                    | Suncup, Beach Evening-Primrose                           | N            | Apr-Aug |
| FABACEAE         | Pea Family  | Dune            | Lotus nuttallianus (RE-1B)  | Beach Lotus  | N            | Mar-Jun |
| FABACEAE         | Pea Family  | Transition      | Acacia longifolia   | Golden Wattle  | A            | Mar-May |
| AMARANTHACEAE    | Amaranth Family                                     | Transition      | Amaranthus blitoides  | Pigweed, Amaranth  | N            | Jul-Nov |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Amblyopappus pusillus   | Coast Weed, Pineapple Weed                               | N            | Mar-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Ambrosia psilostachya **  | Western Ragweed  | N            | Jul-Nov |
| FABACEAE         | Pea Family  | Transition      | Amorpha fruticosa **  | False Indigo   | N            | May-Jul |
| BORAGINACEAE     | Borage or Forget-Me-Not Family                      | Transition      | Amsinckia menziesii var. intermedia (A. intermedia)                             | Yellow Fiddleneck, Rancher's Fiddleneck, Fireweed        | N            | Mar-Jun |
| PRIMULACEAE      | Primrose Family                                     | Transition      | Anagallis arvensis  | Scarlet Pimpernel  | A            | Mar-Jul |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Anthemis cotula   | Mayweed, Stinkweed, Dog-Fennel                           | A            | Apr-Oct |
| SCROPHULARIACEAE | Figwort or Snapdragon Family                        | Transition      | Antirrhinum nuttallianum  | Purple Snapdragon, Wild Snapdragon, Nuttall's Snapdragon | N            | Mar-Jul |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Artemisia californica   | Coastal Sagebrush, California Sagebrush                  | N            | Aug-Dec |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Artemisia dracunculus   | Dragon Sagewort, (Wild) Tarragon                         | N            | Aug-Oct |
| FABACEAE         | Pea Family  | Transition      | Astragalus trichopodus var. lonchus ** (A. trich. var. leucopsis, A. leucopsis) | Coast Locoweed, Rattleweed, Southern California Locoweed | N            | Feb-Jun |
| CHENOPODIACEAE   | Goosefoot Family                                    | Transition      | Atriplex canescens ssp. canescens   | Four-Wing Saltbush, Wingscale, Shad Scale                | N            | Jun-Aug |
| CHENOPODIACEAE   | Goosefoot Family                                    | Transition      | Atriplex lentiformis ssp. lentiformis **  | Saltbush   | N            | Jul-Oct |
| CHENOPODIACEAE   | Goosefoot Family                                    | Transition      | Atriplex semibaccata  | Australian Saltbush                                      | A            | Apr-Dec |
| POACEAE          | Grass Family  | Transition      | Avena barbata   | Slender Wild Oat   | A            | Mar-Jun |
| POACEAE          | Grass Family  | Transition      | Avena fatua   | Wild Oat   | A            | Apr-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Baccharis emoryi  | Emory Baccharis  | N            | Aug-Dec |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Baccharis pilularis **  | Chaparral Broom, Coyote Brush                            | N            | Aug-Dec |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Baccharis sarathroides  | Broom Baccharis, Desert Broom                            | N            | Jun-Oct |
| CHENOPODIACEAE   | Goosefoot Family                                    | Transition      | Bassia hyssopifolia   | Five-Hook Bassia   | A            | Jul-Oct |
| POACEAE          | Grass Family  | Transition      | Brachypodium distachyon   | Purple False-Brome                                       | A            |         |
| BRASSICACEAE     | Mustard Family                                      | Transition      | Brassica nigra  | Black Mustard  | A            | Apr-Jul |
| POACEAE          | Grass Family  | Transition      | Bromus diandrus   | Common Ripgut Grass, Ripgut Brome                        | A            | Apr-Jun |
| POACEAE          | Grass Family  | Transition      | Bromus hordeaceus (Bromus mollis)   | Soft Chess   | A            | Apr-Jul |
| POACEAE          | Grass Family  | Transition      | Bromus madritensis ssp. rubens (B. rubens)                                      | Foxtail Chess, Red Brome                                 | A            | Mar-Jun |
| BRASSICACEAE     | Mustard Family                                      | Transition      | Cakile maritima   | Sea Rocket   | N            | May-Sep |
| PORTULACACEAE    | Purslane Family                                     | Transition      | Calandrinia ciliata **  | Red Maids  | N            | Feb-May |
| LILIACEAE        | Lily Family   | Transition      | Calochortus splendens   | Splendid Mariposa Lily, Lilac Mariposa Lily              | N            | Apr-Jun |
| CONVULVULACEAE   | Morning-Glory Family                                | Transition      | Calystegia macrostegia ssp. tenuifolia  | Narrow-leaf Morning-Glory                                | N            | Feb-May |
| ONAGRACEAE       | Evening-Primrose Family                             | Transition      | Camissonia bistorta   | Sun-Cup  | N            | Mar-Jun |
| CARYOPHYLLACEAE  | Pink Family   | Transition      | Cardionema ramosissimum   | Tread Lightly, Sand Mat                                  | N            | Apr-Aug |
| AIZOACEAE        | Carpet-Weed Family                                  | Transition      | Carpobrotus edulis (Mesembryanthemum edulis)                                    | Hottentot-Fig, Yellow Ice Plant                          | A            | Apr-Oct |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Centaurea melitensis  | Tocalote, Yellow Star Thistle                            | A            | May-Jun |
| CARYOPHYLLACEAE  | Pink Family   | Transition      | Cerastium glomeratum  | Mouse-Ear Chickweed                                      | A            | Feb-May |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Chaenactis glabriuscula var. orcutii  | Yellow Pincushion Flower                                 | N            | Apr-Jul |
| CHENOPODIACEAE   | Goosefoot Family                                    | Transition      | Chenopodium album   | Lamb's-Quarters, Pigweed                                 | A            | Jun-Oct |
| CHENOPODIACEAE   | Goosefoot Family                                    | Transition      | Chenopodium californicum  | California Chenopody, California Goosefoot               | N            | Mar-Jun |
| CHENOPODIACEAE   | Goosefoot Family                                    | Transition      | Chenopodium murale  | Nettle-Leaved Goosefoot, Wall Goosefoot                  | A            | Jan-Dec |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Chrysanthemum coronarium  | Garland Chrysanthemum, Crown Daisy                       | A            | Apr-Aug |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Cirsium occidentale var. californicum (Cirsium californicum)                    | California Thistle, Bigelow Thistle                      | N            | Apr-Jul |
| CONVULVULACEAE   | Morning-Glory Family                                | Transition      | Convolvulus arvensis  | Common Field Bindweed                                    | A            | May-Oct |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Conyza bonariensis  | Flax-Leaved Fleabane                                     | A            | Jun-Aug |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Conyza canadensis   | Horseweed  | N            | Jun-Sep |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Conyza coulteri   | Coulter's Horseweed                                      |              |         |
| SCROPHULARIACEAE | Figwort or Snapdragon Family                        | Transition      | Cordylanthus rigidus ssp. setigerus   | bristly birds beak                                       | N            |         |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Coreopsis maritima (RE-2)   | Sea Dahlia   | N            | Mar-Jun |
| EUPHORBIACEAE    | Spurge Family                                       | Transition      | Croton californicus **  | California Croton  | N            | Mar-Oct |
| BORAGINACEAE     | Borage or Forget-Me-Not Family                      | Transition      | Cryptantha intermedia   | Nievitass, Forget-Me-Not, Common Cryptantha              | N            | Mar-Jul |
| CUPRESSACEAE     | Cypress Family                                      | Transition      | Cupressus macrocarpa  | Monterey Cypress   | A            | --      |
| CONVULVULACEAE   | Dodder Family [Formerly part of the Colvolvulaceae] | Transition      | Cuscuta californica   | Dodder, Witch's Hair                                     | N            | May-Aug |
| SOLANACEAE       | Nightshade Family                                   | Transition      | Datura wrightii (Datura meteloides)   | Thorn-Apple, Jimson Weed, Tolguacha                      | N            | Apr-Oct |
| APIACEAE         | Carrot Family (Umbelliferae)                        | Transition      | Daucus pusillus   | Rattlesnake Weed   | N            | Apr-Jun |
| BRASSICACEAE     | Mustard Family                                      | Transition      | Descurania pinnata ssp. halictorum  | Western Tansy-Mustard                                    | N            | Mar-Jun |
| LILIACEAE        | Lily Family   | Transition      | Dichelostemma capitatum ssp. capitatum (D. pulchellum, Brodiaea pulchellum)     | Blue Dicks, Wild Hyacinth                                | N            | x       |
| POACEAE          | Grass Family  | Transition      | Dittrichia graveolens   | Dittrichia   | A            | x       |
| POACEAE          | Grass Family  | Transition      | Ehrharta erecta   | erect veldtgrass   | A            |         |
| POACEAE          | Grass Family  | Transition      | Ehrharta longiflora (Not in Jepson)   | annual veldtgrass  | A            | --      |
| POLYGONACEAE     | Buckwheat Family                                    | Transition      | Emex spinosa  | Devil's Thorn  | A            |         |
| ASTERACEAE       | Aster - Daisy - Composite Family                    | Transition      | Encelia californica   | California Encelia, Bush Sunflower                       | N            | Feb-Jun |
| EUPHORBIACEAE    | Spurge Family                                       | Transition      | Eremocarpus setigerus   | Turkey Mullein, Doveweed                                 | N            | May-Oct |
| POLYGONACEAE     | Buckwheat Family                                    | Transition      | Eriogonum elongatum   | Longstem Buckwheat                                       | N            |         |
| POLYGONACEAE     | Buckwheat Family                                    | Transition      | Eriogonum fasciculatum  | California Buckwheat                                     | N            | Mar-Oct |
| POLYGONACEAE     | Buckwheat Family                                    | Transition      | Eriogonum parvifolium   | Seacliff Buckwheat                                       | N            | Mar-Oct |

| FAMILY LATIN     | FAMILY                           | Where it Occurs | SPECIES NAME   | COMMON NAME   | Native/Alien | FLOWER  |
|------------------|----------------------------------|-----------------|--|---|--------------|---------|
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Eriophyllum confertiflorum var. confertiflorum   | Golden Yarrow   | N            | Apr-Aug |
| GENTIANACEAE     | Gentian Family                   | Transition      | Erodium botrys   | Long-Beaked Storksbill or Filaree, Big Heronbill, Clocks      | A            | Mar-May |
| GENTIANACEAE     | Gentian Family                   | Transition      | Erodium cicutarium   | Red-Stem Storksbill, Red-Stem Filaree, White-Stem Filaree     | A            | Feb-May |
| GENTIANACEAE     | Gentian Family                   | Transition      | Erodium moschatum  | White-Stem Storksbill, Green-Stem Filaree, White-Stem Filaree | A            | Feb-May |
| PAPAVERACEAE     | Poppy Family                     | Transition      | Eschscholzia californica **  | California Poppy  | N            | Feb-Sep |
| CACTACEAE        | Cactus Family                    | Transition      | Ferocactus viridescens (RE-2)  | Coast Barrel Cactus   | N            | May-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Filago californica   | California Filago   | N            | Mar-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Filago gallica   | Narrow-Leaf Filago  | A            | Apr-Jun |
| APIACEAE         | Carrot Family (Umbelliferae)     | Transition      | Foeniculum vulgare   | Sweet Fennel  | A            | May-Sep |
| POLEMONIACEAE    | Phlox Family                     | Transition      | Gilia angelensis   | Blue Gilia  | N            | Mar-May |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Gnaphalium californicum  | California Everlasting  | N            | Jan-Jul |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Gnaphalium canescens ssp. beneolens (Gnaphalium beneolens)                             | Fragrant Everlasting, Pearly Everlasting                      | N            | Jul-Nov |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Helianthus annuus **   | Common Sunflower, Kansas Sunflower                            | N            | Feb-Oct |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Hemizonia fasciculata  | Golden Tarweed, Fascicled Tarweed                             | N            | May-Sep |
| URTICACEAE       | Nettle Family                    | Transition      | Hesperocnide tenella   | Western Nettle  | N            | Apr-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Heterotheca grandiflora  | Telegraph Weed  | N            | Jan-Dec |
| BRASSICACEAE     | Mustard Family                   | Transition      | Hirschfeldia incana (Brassica geniculata)  | Mediterranean Mustard, Shortpod Mustard                       | A            | May-Oct |
| POACEAE          | Grass Family                     | Transition      | Hordeum murinum ssp. leporinum (Hordeum leporinum)                                     | Wild Barley, Foxtail Grass                                    | A            | Apr-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Hypochoeris glabra   | Cat's Ear   | A            | Mar-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Isocoma menziesii  | Coast Goldenbush  | N            | Apr-Dec |
| CAPPARACEAE      | Caper Family                     | Transition      | Isomeris arborea **  | Bladderpod  | N            | Jan-Dec |
| POACEAE          | Grass Family                     | Transition      | Lamarckia aurea  | Goldentop   | A            | Feb-May |
| POLYGONACEAE     | Buckwheat Family                 | Transition      | Lastarriaea coriacea (Chorizanthe coriacea)  | Lastarriaea   | N            | Apr-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Lasthenia coronaria  | Southern Goldfields, California Baeria                        | N            | Mar-May |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Lessingia filaginifolia var. filaginifolia (Corethrogyne filag. v. lin (RE-1B) & C. f. | Sand Aster, Del Mar Sand Aster                                | N            | May-Sep |
| POACEAE          | Grass Family                     | Transition      | Leymus condensatus (Elymus condensatus)  | Giant Rye   | N            | Jun-Aug |
| SCROPHULARIACEAE | Figwort or Snapdragon Family     | Transition      | Linaria canadensis **  | Oldfield Toadflax   | N            | Mar-May |
| BRASSICACEAE     | Mustard Family                   | Transition      | Lobularia maritima   | Sweet-Alyssum   | A            | Jan-Dec |
| POACEAE          | Grass Family                     | Transition      | Lolium perenne **  | Perennial Ryegrass, English Ryegrass                          | A            | Apr-May |
| CAPRIFOLIACEAE   | Honeysuckle Family               | Transition      | Lonicera subspicata var. denudata  | Moronel Honeysuckle, Wild Honeysuckle, San Diego              | N            | Apr-Jun |
| FABACEAE         | Pea Family                       | Transition      | Lotus scoparius ssp. scoparius   | Coastal Deerweed  | N            | Mar-Aug |
| FABACEAE         | Pea Family                       | Transition      | Lupinus succulentus  | Arroyo Lupine   | N            | Feb-May |
| MALVACEAE        | Mallow Family                    | Transition      | Malacothamnus fasciculatus **  | Bush Mallow, Mesa False-Mallow                                | N            | Apr-Jul |
| ANACARDIACEAE    | Sumac Family                     | Transition      | Malosma laurina (Rhus laurina)   | Laurel Sumac, California Sumac                                | N            | Jun-Jul |
| LAMIACEAE        | Mint Family                      | Transition      | Marrubium vulgare  | Horehound   | A            | Mar-Jul |
| BRASSICACEAE     | Mustard Family                   | Transition      | Matthiola incana   | Common Stock  | A            | Mar-May |
| FABACEAE         | Pea Family                       | Transition      | Medicago polymorpha  | Bur-Clover  | A            | Mar-Jun |
| POACEAE          | Grass Family                     | Transition      | Melinis repens (Rhynchelytrum repens) (R. roseum)                                      | Natal Grass   | A            | Jun-Sep |
| AIZOACEAE        | Carpet-Weed Family               | Transition      | Mesembryanthemum crystallinum (Gasoul crystallinum)                                    | Crystalline Iceplant, Common Ice Plant                        | A            | Mar-Oct |
| AIZOACEAE        | Carpet-Weed Family               | Transition      | Mesembryanthemum nodiflorum (Gasoul nodiflorum)  | Slender-Leaved Iceplant, Little Ice Plant                     | A            | Apr-Nov |
| MYOPORACEAE      | Myoporum Family                  | Transition      | Myoporum acuminatum  | Boobialla   | A            |         |
| MYOPORACEAE      | Myoporum Family                  | Transition      | Myoporum laetum  | Myoporum  | A            | Jan-Aug |
| POACEAE          | Grass Family                     | Transition      | Nassella lepidia (Stipa lepidia)   | Foothill Needlegrass  | N            | Mar-May |
| POLYGONACEAE     | Buckwheat Family                 | Transition      | Nemacaulis denudata var. denudata (RE-2)   | Coast Woolly-Heads  | N            | Apr-Sep |
| SOLANACEAE       | Nightshade Family                | Transition      | Nicotiana glauca   | Tree Tobacco  | A            | Mar-Oct |
| SOLANACEAE       | Nightshade Family                | Transition      | Nicotiana quadrivalvis (Nicotiana bigelovii var. wallacei)                             | Indian Tobacco, Wild Tobacco                                  | N            | May-Oct |
| FAGACEAE         | Olive Family                     | Transition      | Olea europaea  |   | A            |         |
| CACTACEAE        | Cactus Family                    | Transition      | Opuntia ficus-indica   | Tuna Cactus   | A            |         |
| CACTACEAE        | Cactus Family                    | Transition      | Opuntia littoralis **  | Coast Prickly Pear, Shore Cactus, Mesa Prickly Pear           | N            | May-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Osteospermum fruticosum (Not in Jepson)  | African Daisy   | A            | --      |
| OXALIDACEAE      | Oxalis or Wood-Sorrel Family     | Transition      | Oxalis pes-caprae  | Bermuda Buttercup, Buttercup Sorrel                           | A            | Nov-Mar |
| URTICACEAE       | Nettle Family                    | Transition      | Parietaria hespera   | Western Pellitory   | N            | Feb-Jun |
| POACEAE          | Grass Family                     | Transition      | Pennisetum setaceum  | African Fountain Grass  | A            | Jul-Oct |
| HYDROPHYLLACEAE  | Waterleaf Family                 | Transition      | Phacelia ramosissima var. austrolitoralis  | Branching Phacelia  | N            | May-Aug |
| HYDROPHYLLACEAE  | Waterleaf Family                 | Transition      | Pholistoma racemosum   | White Fiesta-Flower   | N            | Mar-May |
| PINACEAE         | Pine Family                      | Transition      | Pinus torreyana (RE-1B)  | Torrey Pine, Soledad Pine                                     | N            | Jan-Feb |
| PLANTAGINACEAE   | Plantian Family                  | Transition      | Plantago coronopus   | cut-leaf plantain   | A            |         |
| PLANTAGINACEAE   | Plantian Family                  | Transition      | Plantago erecta **   | Dwarf Plantain  | N            | Mar-May |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Pluchea sericea  | Arrowweed   | N            | Mar-Jul |
| FABACEAE         | Pea Family                       | Transition      | Prosopis glandulosa (needs ID)   | honey mesquite  | A            |         |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Pseudognaphalium luteoalbum  | Jersey Cudweed  | A            |         |
| POLYGONACEAE     | Buckwheat Family                 | Transition      | Pterostegia drymarioides   | Threadstem, Granny's Hairnet                                  | N            | Mar-Jul |
| BRASSICACEAE     | Mustard Family                   | Transition      | Raphanus sativus   | Wild Radish   | A            | Feb-Jul |
| ANACARDIACEAE    | Sumac Family                     | Transition      | Rhus integrifolia  | Lemonadeberry   | N            | Feb-May |
| CHENOPODIACEAE   | Goosefoot Family                 | Transition      | Salsola tragus (Salsola iberica, S. kali)  | Russian Thistle, Russian Tumbleweed                           | A            | Jul-Oct |
| LAMIACEAE        | Mint Family                      | Transition      | Salvia apiana  | White Sage  | N            | Apr-Jul |
| LAMIACEAE        | Mint Family                      | Transition      | Salvia mellifera   | Black Sage  | N            | Apr-Jul |
| CAPRIFOLIACEAE   | Honeysuckle Family               | Transition      | Sambucus mexicana  | Elderberry, Desert Elderberry                                 | N            | Mar-Sep |
| ANACARDIACEAE    | Sumac Family                     | Transition      | Schinus molle  | Peruvian Pepper Tree  | A            | Mar-Jun |
| POACEAE          | Grass Family                     | Transition      | Schismus barbatus  | Schismus, Mediterranean Grass                                 | A            | Mar-Apr |
| SCROPHULARIACEAE | Figwort or Snapdragon Family     | Transition      | Scrophularia californica ssp. floribunda   | California Figwort, California Bee-Plant, Bee Plant           | N            | Mar-May |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Senecio californicus   | California Butterweed, California Groundsel                   | N            | Mar-May |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Senecio vulgaris   | Common Butterweed, Common Groundsel                           | A            | Jan-Dec |
| CARYOPHYLLACEAE  | Pink Family                      | Transition      | Silene gallica   | Windmill Pink, French Silene, Common Catchfly                 | A            | Feb-Jun |
| ASTERACEAE       | Aster - Daisy - Composite Family | Transition      | Silybum marianum   | Milk Thistle  | A            | May-Jul |



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|-----------------|---|-----------------|--|--|--------------|---------|
| SIMMONDSIACEAE  | Jojoba Family                                       | Transition      | Simmondsia chinensis   | Goatnut, Jojoba                                    | N            | Mar-May |
| BRASSICACEAE    | Mustard Family                                      | Transition      | Sisymbrium irio  | London Rocket                                      | A            | Jan-Apr |
| BRASSICACEAE    | Mustard Family                                      | Transition      | Sisymbrium orientale   | Sisymbrium, Hare's-Ear Cabbage                     | A            | May     |
| IRIDACEAE       | Iris Family   | Transition      | Sisyrinchium bellum  | California Blue-Eyed Grass                         | N            | Mar-May |
| SOLANACEAE      | Nightshade Family                                   | Transition      | Solanum americanum (Solanum nodiflorum)                                | Little White Nightshade, Small-Flowered Nightshade | A            | Apr-Nov |
| SOLANACEAE      | Nightshade Family                                   | Transition      | Solanum douglasii  | White Nightshade, Douglas' Nightshade              | N            | Jan-Dec |
| SOLANACEAE      | Nightshade Family                                   | Transition      | Solanum xanti **   | Purple Nightshade, Chaparral Nightshade            | N            | May-Jun |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Transition      | Sonchus asper  | Prickly Sowthistle                                 | A            | Jan-Dec |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Transition      | Sonchus oleraceus  | Common Sowthistle                                  | A            | Jan-Dec |
| CARYOPHYLLACEAE | Pink Family   | Transition      | Spergularia bocconii   | Boccone's Sand-Spurry                              | A            | Apr-Sep |
| CARYOPHYLLACEAE | Pink Family   | Transition      | Spergularia marina   | Salt Marsh Sand Spurry                             | N            | Mar-Sep |
| CARYOPHYLLACEAE | Pink Family   | Transition      | Spergularia villosa  | Sand Spurry  | A            | Apr-Jul |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Transition      | Stephanomeria virgata  | Wand Chichory, Wire Lettuce, Twiggy Wreath-Plant   | N            | Jul-Oct |
| AIZOACEAE       | Carpet-Weed Family                                  | Transition      | Tetragonia tetragonioides  | New Zealand Spinach                                | A            | Apr-Sep |
| ZYGOPHYLLACCEAE | Caltrop Family                                      | Transition      | Tribulus terrestris  | Puncture Vine, Caltrop                             | A            | Apr-Oct |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Transition      | Uropappus lindleyi (Microseris linearifolia)                           | Microseris, Silver Puffs                           | N            | Apr-Jun |
| POACEAE         | Grass Family  | Transition      | Vulpia myuros var. myuros (Festuca myuros)                             | Rattail Fescue                                     | A            | Mar-May |
| SAURURACEAE     | Lizard-Tail Family                                  | Wetland         | Anemopsis californica  | Yerba Mansa  | N            | Mar-Sep |
| APIACEAE        | Carrot Family (Umbelliferae)                        | Wetland         | Apiastrum angustifolium  | Wild Celery, Mock Parsley                          | N            | Mar-Apr |
| APIACEAE        | Carrot Family (Umbelliferae)                        | Wetland         | Apium graveolens   | Celery   | A            | May-Jul |
| POACEAE         | Grass Family  | Wetland         | Arundo donax   | Giant Reed   | A            | Mar-Sep |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Aster subulatus var. ligulatus (Aster exilis)                          | Slender Aster                                      | N            | Jul-Oct |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Atremisia douglasiana  | Douglas' Sagewort                                  | N            |         |
| CHENOPODIACEAE  | Goosefoot Family                                    | Wetland         | Atriplex triangularis (Atriplex patula ssp. hastata)                   | Spearscale, Arrow-Leaf Saltbush                    | A            | Jun-Nov |
| CANNABISACEAE   | Hemp Family   | Wetland         | Cannabis sativa  | Marijuana, Hemp                                    | A            | Apr-Jul |
| HYDROPHYLLACEAE |   | Wetland         | Catalpa bignonioides   | Southern Catalpa                                   | A            |         |
| EUPHORBIACEAE   | Spurge Family                                       | Wetland         | Chamaesyce polycarpa (Euphorbia polycarpa var. polycarpa)              | Mat Spurge, Small-seed Sandmat                     | N            | Jan-Dec |
| POACEAE         | Grass Family  | Wetland         | Cortaderia selloana  | Pampas grass                                       | A            |         |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Cotula australis   | Australian Brass-Buttons                           | A            | Jan-May |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Cotula coronopifolia   | African Brass Buttons                              | A            | Mar-Dec |
| CONVULVULACEAE  | Morning-Glory Family                                | Wetland         | Cressa truxillensis **   | Alkali Weed  | N            | May-Oct |
| CONVULVULACEAE  | Dodder Family [Formerly part of the Colvolvulaceae] | Wetland         | Cuscuta salina   | Salt-Marsh Dodder, Salty Dodder                    | N            | May-Sep |
| CYPERACEAE      | Sedge Family  | Wetland         | Cyperus eragrostis   | Umbrella-Sedge                                     | N            | Apr-Nov |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Delairia odorata (Senecio mikanoides)                                  | Cape Ivy   | A            | Dec-Mar |
| POACEAE         | Grass Family  | Wetland         | Distichlis spicata **  | Saltgrass  | N            | Mar-Jul |
| POACEAE         | Grass Family  | Wetland         | Elytrigia pontica  | Tall Wheatgrass                                    | A            | x       |
| ONAGRACEAE      | Evening-Primrose Family                             | Wetland         | Epilobium ciliatum ssp. ciliatum (Epilobium adenocaulon var. parishii) | California Willow-Herb                             | N            | x       |
| MYRTACEAE       | Myrtle Family                                       | Wetland         | Eucalyptus globulus  | Australian Blue gum                                | A            | Dec-May |
| EUPHORBIACEAE   | Spurge Family                                       | Wetland         | Euphorbia peplus   | Petty Spurge                                       | A            | Feb-Aug |
| EUPHORBIACEAE   | Spurge Family                                       | Wetland         | Euphorbia lathyris   | Compass Plant                                      | A            |         |
| FRANKENIACEAE   | Frankenia Family                                    | Wetland         | Frankenia salina (Frankenia grandifolia)                               | Alkali-Heath, Frankenia                            | N            | Jun-Oct |
| GENTIANACEAE    | Gentian Family                                      | Wetland         | Geranium carolinianum  | Wild Geranium, Carolina Geranium                   | A            | Apr-Jun |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Hedypnois cretica  | Crete Hedypnois                                    | A            | Mar-May |
| BORAGINACEAE    | Borage or Forget-Me-Not Family                      | Wetland         | Heliotropium curassavicum (H. curvassavicum ssp. oculatum)             | Chinese Pusley, Salt Heliotrope, Wild Heliotrope   | N            | Mar-Oct |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Iva hayesiana (RE-2)   | Southern Poverty Weed, San Diego Marsh-Elder       | N            | Apr-Sep |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Jaumea carnosa   | Fleshy Jaumea                                      | N            | May-Oct |
| JUNCACEAE       | Rush Family   | Wetland         | Juncus acutus ssp. leopoldii (RE-4) **                                 | Spiny Rush, Spike Rush                             | N            | May-Jun |
| JUNCACEAE       | Rush Family   | Wetland         | Juncus bufonius  | Toad Rush  |              |         |
| JUNCACEAE       | Rush Family   | Wetland         | Juncus mexicanus   | Mexican Rush                                       | N            | May-Aug |
| JUNCACEAE       | Rush Family   | Wetland         | Juncus rugulosus   | Wire Grass, Wrinkled Rush                          | N            | Apr-Jul |
| JUNCACEAE       | Rush Family   | Wetland         | Juncus xiphioides  | Iris-leaf Rush                                     | N            | x       |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Lactuca serriola **  | Wild Lettuce, Prickly Lettuce                      | A            | May-Sep |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Lasthenia glabrata ssp. coulteri (RE-1B)                               | Coulter's Salt Marsh Daisy, Smooth Lasthenia       | N            | Apr-May |
| POACEAE         | Grass Family  | Wetland         | Leymus triticoides   | Beardless Wild Ryegrass                            | N            | Jun-Aug |
| PLUMBAGINACEAE  | Leadwort Family                                     | Wetland         | Limonium californicum **   | Sea-Lavender                                       | N            | Jul-Dec |
| PLUMBAGINACEAE  | Leadwort Family                                     | Wetland         | Limonium perezii   | Marsh-Rosemary, Statice                            | A            | Mar-Sep |
| PLUMBAGINACEAE  | Leadwort Family                                     | Wetland         | Limonium ramosissimum  | Algerian sea-lavender                              | A            |         |
| LYTHRACEAE      | Lythrum Family                                      | Wetland         | Lythrum hyssopifolium  | Hyssop Loosestrife                                 | N            | Apr-Oct |
| MALVACEAE       | Mallow Family                                       | Wetland         | Malvella leprosa (Sida leprosa var. hederacea)                         | Alkali Mallow                                      | N            | May-Oct |
| POACEAE         | Grass Family  | Wetland         | Melica imperfecta  | Melic  | N            | Apr-May |
| FABACEAE        | Pea Family  | Wetland         | Melilotus alba   | White Sweet-Clover                                 | A            | May-Sep |
| FABACEAE        | Pea Family  | Wetland         | Melilotus indica   | Yellow Sweet-Clover                                | A            | Apr-Oct |
| POACEAE         | Grass Family  | Wetland         | Monanthochloe littoralis   | Shoregrass, Salt Cedar                             | N            | May-Jun |
| ONAGRACEAE      | Evening-Primrose Family                             | Wetland         | Oenothera elata ssp. hirsutissima (Oenothera hookeri)                  | Great Marsh Evening-Primrose                       | N            | Jun-Sep |
| POACEAE         | Grass Family  | Wetland         | Parapholis incurva   | Sickle Grass                                       | A            | Apr-Jun |
| ARACACEAE       | Palm Family   | Wetland         | Phoenix canariensis  | Canary Island Date Palm                            | A            | May-Oct |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Picris echioides   | Bristly Ox-Tongue                                  | A            | Jun-Dec |
| PLANTAGINACEAE  | Plantian Family                                     | Wetland         | Plantago arenaria  |  | A            |         |
| PLANTAGINACEAE  | Plantian Family                                     | Wetland         | Plantago major   | Common Plantain, Broadleaf Plantain                | A            | Apr-Sep |
| ASTERACEAE      | Aster - Daisy - Composite Family                    | Wetland         | Pluchea odorata (Pluchea purpurascens)                                 | Marsh Fleabane                                     | N            | Jul-Jan |
| CARYOPHYLLACEAE | Pink Family   | Wetland         | Polycarpon depressum   | California Polycarp                                | N            | Apr-Jun |
| CARYOPHYLLACEAE | Pink Family   | Wetland         | Polycarpon tetraphyllum  | Four-Leaf Polycarp                                 | A            | May-Jul |
| POLYGONACEAE    | Buckwheat Family                                    | Wetland         | Polygonum arenastrum   | Knotweed   | A            | May-Nov |
| POACEAE         | Grass Family  | Wetland         | Polypogon monspeliensis  | Annual Beard Grass, Rabbitfoot Beardgrass          | A            | Apr-Aug |
| POLYGONACEAE    | Buckwheat Family                                    | Wetland         | Rumex crispus  | Curly Dock   | A            | Jan-Dec |

| FAMILY LATIN   | FAMILY                           | Where it Occurs | SPECIES NAME   | COMMON NAME  | Native/Alien | FLOWER  |
|----------------|----------------------------------|-----------------|--|--|--------------|---------|
| POLYGONACEAE   | Buckwheat Family                 | Wetland         | Rumex maritimus  | Maritime Dock  | N            |         |
| POLYGONACEAE   | Buckwheat Family                 | Wetland         | Rumex salicifolius var. salicifolius                                     | Willow-leaf Dock   | N            | May-Sep |
| LEMNACEAE      | Pond Weed Family                 | Wetland         | Ruppia maritima  | Ditch-Grass  | N            | Apr-Jul |
| CHENOPODIACEAE | Goosefoot Family                 | Wetland         | Salicornia europaea  | Annual Slender Pickleweed, Slender Pickleweed or Glasswort | N            | Jul-Nov |
| CHENOPODIACEAE | Goosefoot Family                 | Wetland         | Salicornia subterminalis   | Glasswort  | N            | Apr-Sep |
| CHENOPODIACEAE | Goosefoot Family                 | Wetland         | Salicornia virginica   | Pickleweed, Woody Glasswort                                | N            | Apr-Sep |
| SALICACEAE     | Willow Family                    | Wetland         | Salix exigua   | sand bar willow  | N            |         |
| SALICACEAE     | Willow Family                    | Wetland         | Salix gooddingii **  | Goodding Willow  | N            | Mar-Apr |
| SALICACEAE     | Willow Family                    | Wetland         | Salix lasiolepis **  | Arroyo Willow  | N            | Feb-Apr |
| CYPERACEAE     | Sedge Family                     | Wetland         | Scirpus californicus   | California Bulrush   | N            | Jun-Sep |
| CYPERACEAE     | Sedge Family                     | Wetland         | Scirpus robustus   | Alkali Bulrush   | N            | Apr-Aug |
| LAMIACEAE      | Mint Family                      | Wetland         | Stachys ajugoides var. rigida (S. ajugoides, S. rigida ssp. quercetorum) | Hedge-Nettle   | N            | Apr-Sep |
| CHENOPODIACEAE | Goosefoot Family                 | Wetland         | Suaeda esteroa (S. californica) (RE-4)                                   | California Sea-Blite                                       | N            | Jul-Oct |
| CHENOPODIACEAE | Goosefoot Family                 | Wetland         | Suaeda taxifolia   | Woolly Sea-Blite   | N            |         |
| TAMARICACEAE   | Tamarisk Family                  | Wetland         | Tamarix ramosissima  | Tamarisk   | A            | Apr-Aug |
| APIACEAE       | Carrot Family (Umbelliferae)     | Wetland         | Torilis arvensis   | Japanese Hedge-Parsley                                     | A            | May-Aug |
| TORPAEOLACEAE  | Nasturtium Family                | Wetland         | Tropaeolum majus   | Garden Nasturtium  | A            | Mar-Aug |
| TYPHACEAE      | Cattail Family                   | Wetland         | Typha domingensis  | Southern Cattail, Tule Cattail                             | N            | Jun-Jul |
| TYPHACEAE      | Cattail Family                   | Wetland         | Typha latifolia  | Broad-leaved Cattail, Soft Flag, Tall Cattail              | N            | Jun-Jul |
| URTICACEAE     | Nettle Family                    | Wetland         | Urtica dioica ssp. holosericea (Urtica holosericea)                      | Stinging Nettle, Hoary Nettle                              | N            | Jun-Sep |
| URTICACEAE     | Nettle Family                    | Wetland         | Urtica urens   | Common Nettle  | A            | Jan-Apr |
| VERBENACEAE    | Verbena Family                   | Wetland         | Verbena lasiostachys **  | Western Verbena, Western Vervain                           | A            | May-Sep |
| ARACACEAE      | Palm Family                      | Wetland         | Washingtonia robusta (Not in Jepson)                                     | Mexican Fan Palm   | A            | --      |
| ASTERACEAE     | Aster - Daisy - Composite Family | Wetland         | Xanthium spinosum  | Spiny Clotbur  | N            | Jul-Oct |
| ASTERACEAE     | Aster - Daisy - Composite Family | Wetland         | Xanthium strumarium **   | Cocklebur  | N            | Jul-Oct |

## **APPENDIX K**

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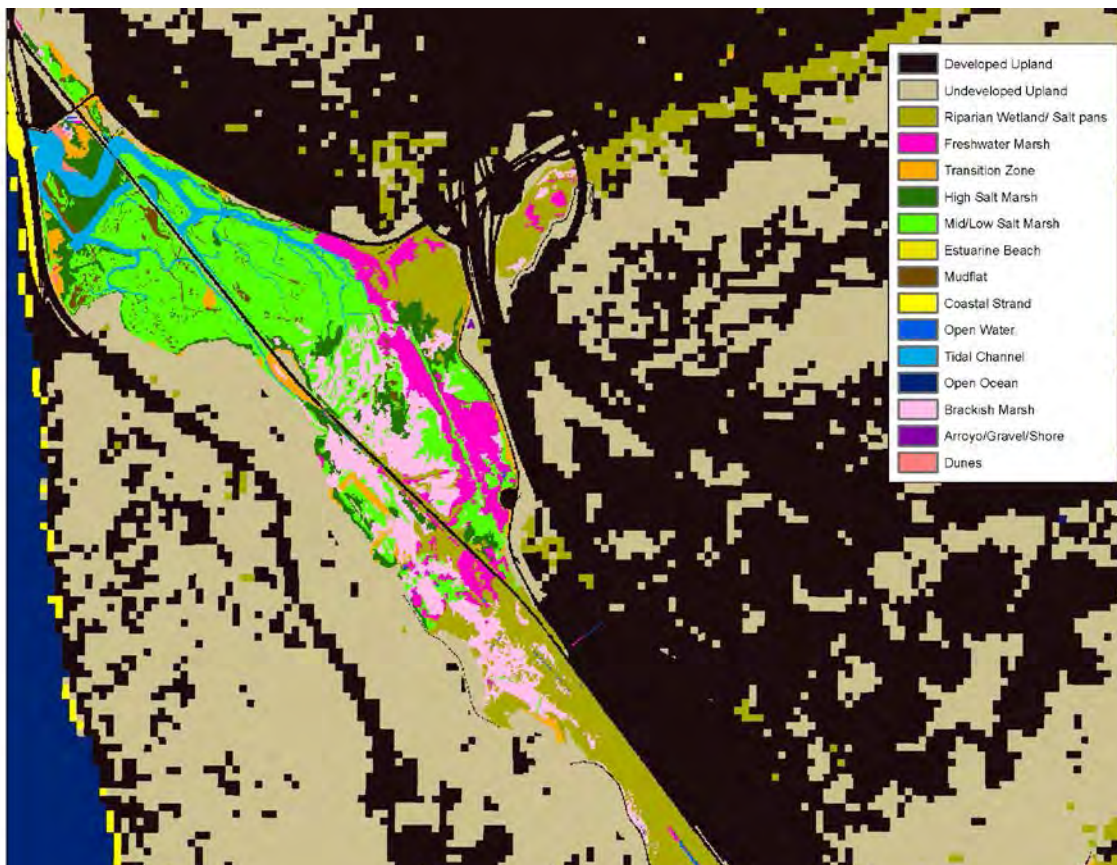
### Baseline Conditions Habitat Projection Modeling

FINAL

# LOS PEÑASQUITOS LAGOON ENHANCEMENT PLAN UPDATE BASELINE CONDITIONS HABITAT PROJECTION MODELING

Prepared for  
Los Peñasquitos Lagoon Foundation

July 2015



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July 2015



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# **Los Peñasquitos Lagoon Enhancement Plan**

## **Baseline Conditions Habitat Projection Modeling**

---

### **1. Model Development**

ESA developed a GIS-based marsh habitat evolution model for Los Peñasquitos Lagoon to estimate the change in acreages of salt marsh, brackish marsh, freshwater marsh, and transition zone habitats over time for future conditions. Inputs to the model include topography, vegetation and habitat data, tides, projected future sea-level rise, areas of freshwater influence, and watershed sediment loading. The model produces maps of habitat types and habitat acreages on decade intervals (i.e., through 2100 for this analysis).

This draft report includes model runs for baseline conditions (current Lagoon habitats and topography, projected sea-level rise, and sedimentation with implementation of the Sediment Total Maximum Daily Load or TMDL), as well as a sensitivity analysis of model parameters to assess the range of likely future habitat acreages under baseline conditions. In the next step of updating the Los Peñasquitos Lagoon Enhancement Plan, proposed restoration actions will be modeled and compared to baseline conditions to inform development of sustainable restoration alternatives and to quantify restoration benefits.

To develop the model, ESA first applied the Sea Levels Affecting Marshes Model (SLAMM), an Environmental Protection Agency (EPA) habitat evolution model, to preliminarily evaluate the effects of sea level rise on Los Peñasquitos Lagoon. SLAMM maps habitat distribution over time in response to sea-level rise, accretion and erosion, and freshwater influence. However, SLAMM does not account for several key processes that are important to Los Peñasquitos Lagoon and Pacific Coast tidal lagoons. SLAMM was developed for marshes with habitat types more typical of embayments or estuaries with open ocean inlets. Los Peñasquitos Lagoon, on the other hand, is characterized as a bar-built estuary in which tidal circulation can be muted or cut off due to sediment deposition within the inlet area. As such, modeling ocean inputs to the bar-built estuaries using SLAMM presents problems since the habitats elevations in lagoons often vary from open estuaries due to the lagoon hydrodynamics. SLAMM also relies on the assumption that freshwater inputs are large and fairly constant year-round, creating habitats such as tidal freshwater marsh. While Los Peñasquitos Lagoon does receive perennial inputs of freshwater from all three of its main tributaries due to land use changes within its watershed, these input volumes are small, and it is the episodic events that bring significant freshwater and sediment into the lagoon. To address these differences, ESA developed a GIS model that recreated some of the features of SLAMM and added in other processes that were important to the system at Los Peñasquitos Lagoon. ESA's GIS model improves upon SLAMM by:

- Creating flexibility to edit the habitat categories to facilitate cross-walks from site-specific vegetation mapping.
- Updating the decision tree to change from one habitat category to another based on biological processes.
- Applying accretion in the model to more accurately represent deposition of sediment transported by tributary creeks during storm events (i.e., deposition of the watershed sediment load or alluvial deposition).
- Creating a structure that allows for different “modules” to be added to or updated in the model. For example, the module that determines areas of freshwater influence can be refined so that changes in freshwater flows can be simulated in conjunction with hydrodynamic modeling as a next step.

The GIS model was first run to recreate and match the outputs of SLAMM at the Lagoon. Once the replication of SLAMM was successfully completed, the model was expanded and improved as described above.

To add flexibility to the habitat categories, ESA’s GIS model allows the user to input habitat types that are specific to the marsh system. For example, SLAMM has a category called “Regularly Flooded Marsh,” which was used to represent mid and low salt marsh in the initial runs for Los Peñasquitos Lagoon. ESA’s GIS model allows users to break out mid and low marsh as separate categories to evaluate how one category changes to the next over time. As another example, Southern California lagoons typically have a transition zone between salt marsh and upland habitats. In SLAMM, upland habitats evolve straight to salt marsh, without any representation of a transition zone. The ESA GIS model converts upland habitats down to transition zone and then down to salt marsh, and has the flexibility to add additional habitats.

Additionally, the habitat decision tree was revised to allow habitats to evolve in the “reverse direction.” For example, salt marsh can now convert to brackish or freshwater marshes (due to freshwater flow) or to upland habitats (due to sedimentation). In SLAMM, salt marsh can only convert to lower elevation habitats and eventually drowns out due to sea level rise.

To apply accretion in a way that more accurately represents watershed sediment loading, ESA developed a module to account for riverine accretion (i.e., alluvial fan deposition). In SLAMM, an area of freshwater influence can be designated and a vertical accretion rate for that area can be chosen. However, as observed at Los Peñasquitos Lagoon, alluvial deposition typically creates an alluvial fan of sediment from the mouth of the river, and not a constant depth of sediment. The module in the ESA GIS model simulates the deposition of a prograding alluvial fan based on the annual sediment load. Not only does this module more accurately represent the physical process of riverine sedimentation, but it also allows for variation in the location of deposition based on changes to the sediment load through time.

The ESA GIS model has been set up in a way to easily allow the addition of modules as they become available. For example, a new module can be developed to represent changes to the area of freshwater influence in response to changes in streamflow. Currently, the ESA GIS model

replicates the SLAMM method for determining freshwater and brackish marsh habitats based on a polygon input defining the area of freshwater influence. In ESA's current model for the Lagoon, the area of freshwater influence is defined by the boundary between the existing salt and brackish/freshwater habitats. This method is sufficient if the freshwater input does not change over time. As a next step to further develop the model, the freshwater influence module could be refined to simulate changes in the area of freshwater influence in response to changes in freshwater flows (e.g., to evaluate Lagoon habitat response to reduced freshwater base flows from the tributary creeks). This module could be developed in conjunction with a hydrodynamic modeling of Lagoon salinity. The development of a hydrodynamic model at a later stage in the project could therefore facilitate revising the existing freshwater module in subsequent phases.

Note that the habitat projection model is focused on long-term habitat changes and processes occurring over a multi-decade time frame. Certain shorter term processes affect habitat evolution, but are accounted for by modeling long-term cumulative processes and habitat change rather than directly representing these shorter term processes. For example, lagoon inlet dynamics and mouth closure affects sediment deposition and freshwater influence on seasonal and interannual time scale. The long-term model captures the net cumulative effect of these processes by using average tides (tidal datums), habitat zonation based on tidal datums, and the sedimentation and freshwater influence modules. The current modeling assumes that the inlet dynamics and ongoing maintenance program will not significantly change in the future and that longer term tidal and deposition processes will therefore not be affected due to changes in inlet processes and maintenance. Coastal sand transport and inlet dynamics are expected to change over time, in response to sea-level rise and regional sand management; however, analyses of these processes is currently outside the scope of this effort. Inlet processes could be analyzed in a subsequent phase, and potential effects on habitat evolution could be accounted for in the habitat projection model by refining the habitat decision tree or adding an inlet module.

Another example of a short-term process that the model analyzes on a longer time-scale, is the episodic sediment delivery from large storms events that Pacific Coast tidal lagoons typically experience. These events, which occur and vary on seasonal and interannual timescales, are not considered directly in the model. Rather, the model uses average decadal sediment loads to account for the overall cumulative amount of sediment that enters the lagoon in the long-term.

## **2. Conceptual Model of Los Peñasquitos Lagoon**

The habitat projection model is based on the conceptual model that Los Peñasquitos Lagoon habitats change over the long-term in response to multiple processes, including tides, accretion, freshwater inflow, ecology, and sea-level rise. These processes are described below, along with the history of how they have changed over time at the Lagoon. Together, these processes and history provide the conceptual basis or framework (conceptual model) for the habitat projection model.

## 2.1 Lagoon Processes

### 2.1.1 Tides

Salt marsh and intertidal habitats establish within zones corresponding to tidal inundation. Tides and tidal inundation within the Lagoon are therefore important processes affecting habitats within the Lagoon. Lagoon tides are driven by ocean tides that propagate through the Lagoon inlet and channels, which affect tidal heights in the Lagoon relative to tidal heights in the ocean (e.g, through tidal muting or damping).

The San Diego coast experiences mixed semidiurnal tides, with two high and two low tides of unequal heights each day. In addition, the tides exhibit strong spring-neap tide variability; spring tides exhibit the greatest difference between high and low tides while neap tides show a smaller than average range. The spring-neap tides also vary on an annual cycle, with the highest spring tides occurring in June-July and December-January and the weakest neap tides occurring in March-April and September-October. Tidal datums for the La Jolla tide gage, which is just downcoast of the lagoon and measures the ocean tides, are summarized in Table 1 (NOAA Tides and Currents).

**TABLE 1**  
**NOAA TIDAL DATUMS FOR THE LA JOLLA TIDE GAGE**

| Tidal Datum                              |      | ft MLLW | ft NAVD |
|--|------|---------|---------|
| Highest Astronomical Tide                | HAT  | 7.14    | 6.95    |
| Mean Higher High Water                   | MHHW | 5.33    | 5.14    |
| Mean High Water                          | MHW  | 4.60    | 4.41    |
| Mean Tide Level                          | MTL  | 2.75    | 2.56    |
| Mean Sea Level                           | MSL  | 2.73    | 2.54    |
| National Geodetic Vertical Datum of 1929 | NGVD | 2.30    | 2.11    |
| Mean Low Water                           | MLW  | 0.91    | 0.71    |
| North American Vertical Datum of 1988    | NAVD | 0.19    | 0       |
| Mean Lower Low Water                     | MLLW | 0       | -0.19   |

When Los Peñasquitos Lagoon is open to the ocean, tides propagate through the mouth of the Lagoon back into the channels. However, tides within the Lagoon are usually constricted by flow through the Lagoon inlet and the inlet dimensions. After inlet maintenance occurs and sand is removed to enlarge the inlet, low tides can drain to below mean sea level (MSL), but as sand fills in the mouth, water cannot drain out on low tide and only high tides enter the lagoon. Figure 1 shows the tides within the lagoon at the bridge gage (Figure 2) while the mouth is open and during a closure event.

Tide data within the lagoon was collected by Coastal Environments (2003) from January 2002 through December 2003 and by the Tijuana River National Estuarine Research Reserve (TRNERR) from September 2013 through May 2014. The locations of the sensors in the more



recent TRNERR data collection effort are shown in Figure 2 and the water surface elevations for all of the gages are shown in Figure 3.

All five gages show low tide muting below 2.19 ft NAVD, because of the sand bar at the lagoon mouth and channel elevations during this period, which were at about MSL (Figure 3). The north gage shows the most muted tides (1.27 ft tide range), as flows are limited by culverts that go under the McGonigle Road, which are heavily occluded with debris and mud. The bridge and west gage shows the largest tide ranges (2.9 ft) since they are closest to the lagoon mouth. Table 2 presents the tidal datums calculated for the five gages with the NOAA La Jolla gage for comparison. Note that ESA performed spot elevation surveys at the Bridge gage to confirm the vertical datum of the Bridge Gage data, but did not do so for the other gages (North Gage, West Gage, East Gage, and South Gage) that were more recently deployed within the Lagoon. The difference between tidal datums (e.g., MHHW) at the Bridge Gage and other gages within the Lagoon may be due to inaccuracies in how the other gages were surveyed into the vertical datum rather than actual differences in high tide elevations. The other gages should therefore only be used to assess the tidal range at those locations and not tidal datums.

**TABLE 2**  
**TIDAL DATUMS WITHIN THE LOS PEÑASQUITOS LAGOON**  
(values in feet NAVD)

| Tidal Datum        | La Jolla <sup>1</sup><br>(Published) | La Jolla <sup>2</sup><br>(Calculated) | Bridge Gage <sup>3</sup> | North Gage <sup>34</sup> | West Gage <sup>34</sup> | East Gage <sup>34</sup> | South Gage <sup>34</sup> |
|--------------------|--------------------------------------|---------------------------------------|--------------------------|--------------------------|-------------------------|-------------------------|--------------------------|
| MHHW               | 5.14                                 | 5.39                                  | 5.27                     | 5.50                     | 5.55                    | 5.64                    | 5.58                     |
| MHW                | 4.41                                 | 4.69                                  | 4.67                     | 5.33                     | 4.88                    | 5.08                    | 5.03                     |
| MTL                | 2.56                                 | 2.80                                  | 3.60                     | 4.78                     | 3.79                    | 4.27                    | 4.21                     |
| MSL                | 2.54                                 | 2.80                                  | 3.73                     | 4.61                     | 4.02                    | 4.27                    | 4.25                     |
| MLW                | 0.72                                 | 0.91                                  | 2.53                     | 4.24                     | 2.70                    | 3.46                    | 3.38                     |
| MLLW               | -0.19                                | 0.08                                  | 2.39                     | 4.22                     | 2.64                    | 3.44                    | 3.35                     |
| Diurnal Tide Range | 5.3                                  | 5.3                                   | 2.9                      | 1.3                      | 2.9                     | 2.2                     | 2.2                      |

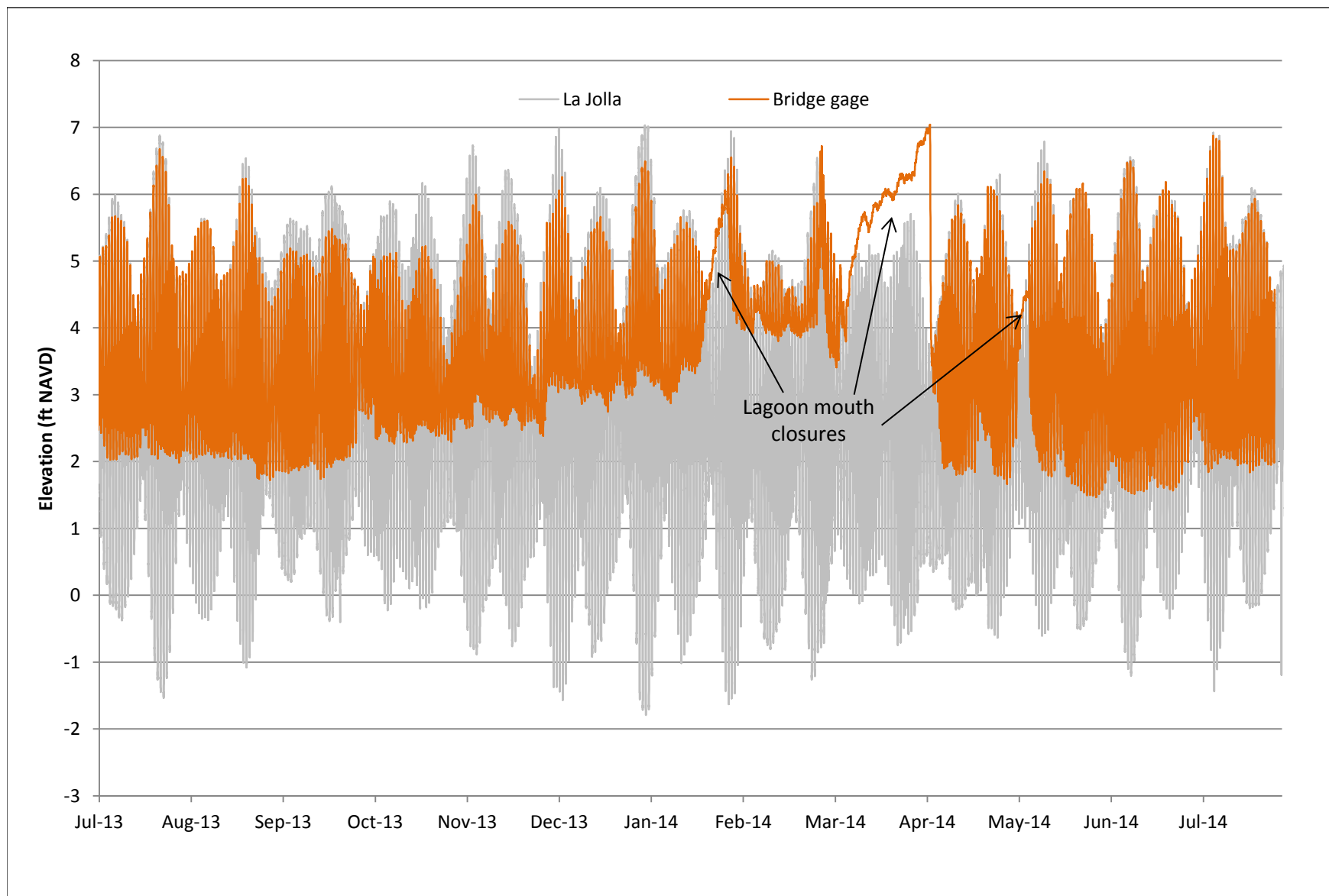
1. La Jolla datums from NOAA Tides and Currents (2014).

2. Datums calculated for the La Jolla gage for the same time period as the gages in the lagoon (September 2013 - May 2014).

3. Data from TRNERR

4. Gages were not surveyed by ESA and therefore should only be used to assess the tidal range, Datums are approximate.

Comparison of the La Jolla and Bridge Gage show that the mean higher high water (MHHW) and mean high water (MHW) datums are similar during the period analyzed (September 2013 – May 2014) when the Lagoon inlet is open and not very constrained.



Source: TRNERR



Los Peñasquitos. D130136

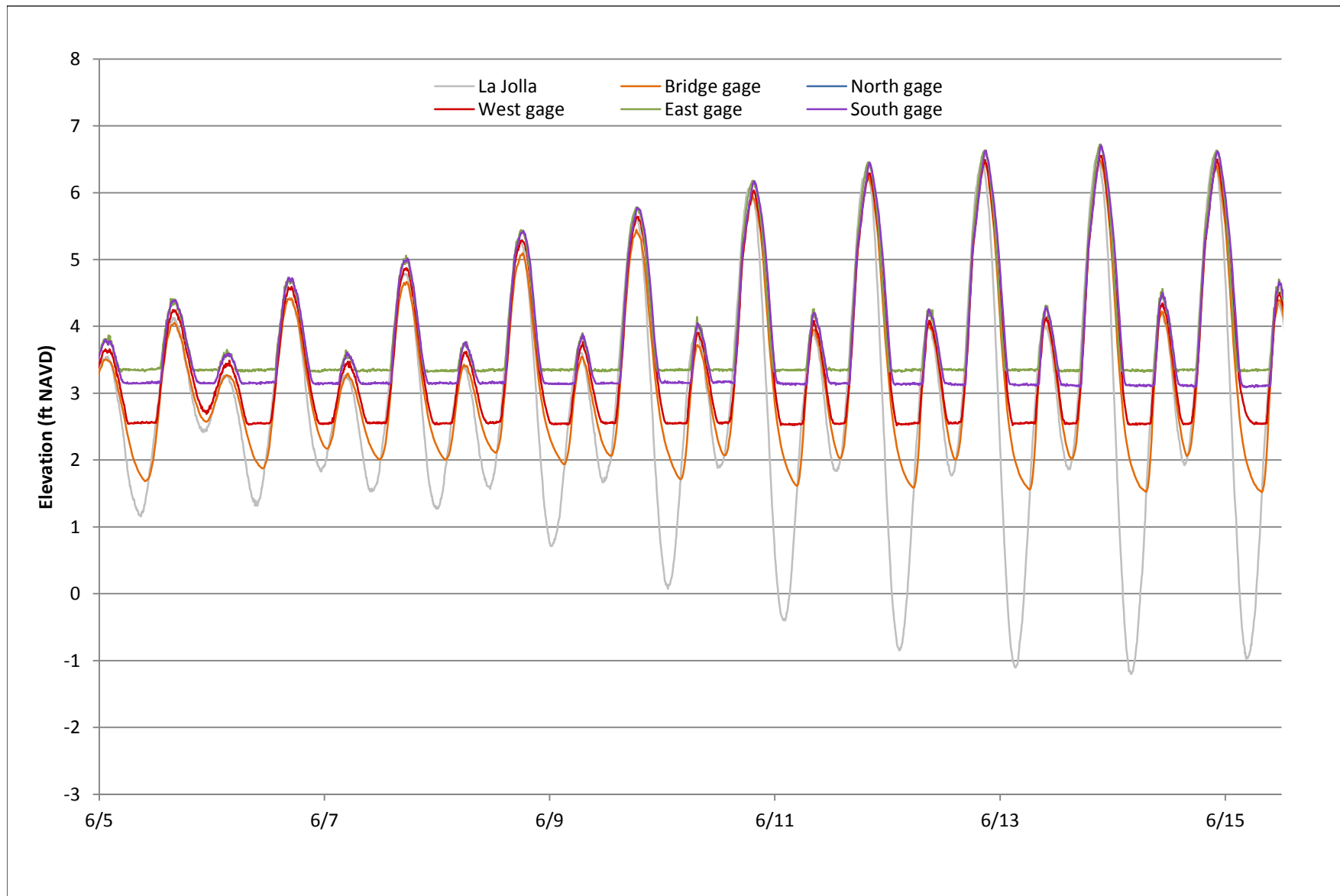
**Figure 1**

Tide Time Series  
July 2013 to July 2014









Source: TRNERR



Los Peñasquitos. D130136

**Figure 3**

Tide Time Series  
June 5-15, 2014

## 2.1.2 Topography and Accretion

The elevation of an area determines the frequency of tidal inundation and salinity, which then influences the type of vegetation that will establish. If the topography changes due to accretion (or restoration/grading), the habitat types can change in response. The Lagoon receives sediment from its watershed and tributary creeks. Sediment carried by creek flows during storm events is deposited within the Lagoon. As evidenced by the topography of the Lagoon and observed habitat change, a portion of the watershed sediment load carried by creeks is deposited in alluvial fans extended from the creek mouths (fluvial or alluvial fan deposition). Finer-grained suspended sediment is deposited across the marsh surface when storm water fills and inundates the Lagoon and by subsequent tidal inundation. Salt marsh or tidal accretion results from suspended sediment deposition due to storm events and tidal inundation, as well as from the accumulation of plant biomass over time. Estimates of fluvial and tidal accretion are discussed further below. Note that some portion of the watershed sediment load is also exported through the Lagoon to the ocean by storm flows.

### ***Fluvial Accretion***

In 2009, a total maximum daily load (TMDL) was developed for sediment loading in the lagoon (Weston 2009). The watershed sediment load was estimated for the TMDL by modeling the current and historic sediment loads using data on catchments, streams, soil characteristics, irrigation, land use, and meteorological conditions. Current (2000) and historic (mid-1970s) land uses were modeled using the same meteorological conditions from a critical wet period to determine the change over time. Table 3 presents these values.

**TABLE 3  
SEDIMENT LOADS BASED ON TMDL**

|      | <b>Current Load (2000)<br/>(cy/yr)</b> | <b>Historic Load (mid-1970s)<br/>(cy/yr)</b> | <b>Required Load<br/>Reduction</b> |
|------|--|--|------------------------------------|
| TMDL | 7,620                                  | 2,550  | 67% or 2,520 cy/yr                 |

SOURCE: Tetra Tech 2010.

Monitoring and additional studies performed in conjunction with the TMDL show that Carroll Canyon Creek contributes the majority of the sediment load to the Lagoon (Weston 2009 and ESA PWA 2011). Land use change, including urbanization of the watershed, has modified the hydrology and geomorphology of all three tributaries to Los Peñasquitos Lagoon. In the case of Carroll Canyon, commercial and light-industry are the primary land uses, which results in large expanses of hardscape. Storm water is collected on these impervious surfaces and directed toward the Municipal Separate Storm Sewer System (MS4), generating increased peak flows that are discharged from outfalls often located along canyon walls or within steep, incised drainages. As a result, large amounts of sediment are being produced where erosion and mass wasting of channel banks occur. Field surveys conducted in 2009 indicate that the primary sources of sediment within Carroll Canyon include canyon walls and drainages that receive direct discharges from MS4 outfalls, as well as creek channel bed and banks (Weston 2009).

Field mapping and sediment transport modeling performed by ESA PWA in 2011 support these findings. In addition to increased peak flows from MS4 discharges, a mile-long cement channel located within Sorrento Valley also contributes to elevated rates of sediment transport to Los Peñasquitos Lagoon from Carroll Canyon. During a preliminary monitoring program for the Lagoon's Sediment TMDL, hydrographs generated for Carroll Creek showed the flashy nature of this sub-watershed, as opposed to hydrographs that showed gradual increases and a decline in discharge rates for Los Peñasquitos Creek (Weston 2009).

The pattern and volume of fluvial sediment deposition in the Lagoon are due to both the sediment load, the portion of the sediment load that enters the Lagoon from the creeks, deposition of coarser and finer grained sediment as storm flows spread out over the Lagoon, and the amount of sediment that is deposited versus exported to the ocean (i.e., sediment trapping efficiency). The pattern and volume of deposition observed in the topography provides empirical information on the net deposition. The existing topography of the Lagoon indicates two sloping fans of sediment: one extending from Carmel Creek and another extending from the confluence of Los Peñasquitos Creek and Carroll Canyon Creek. It should be noted that the sediment fan from Los Peñasquitos Creek and Carroll Canyon Creek extends into the Lagoon in a northward trajectory facilitated by two railway bridges that create gaps in the earthen railway berm rather than a northwest trajectory that would most likely occur if the railway berm was not present.

### ***Tidal Accretion***

Suspended sediment from storm flows or resuspension of sediment by tidal flows is deposited across the salt marsh and intertidal habitats when they are inundated by sediment-laden tidal water. As the tidal waters rise and fall, areas that are low with respect to the tidal range are covered with sediment-laden water for a longer period of time and accrete at a faster rate than higher elevations. At the higher end of the tidal range, the frequency and duration of flooding by high tides is diminished so that the rate of sediment accumulation is less. This provides an inverse relationship between sediment accretion and elevation. The maximum accretion rate occurs at low elevations (below mean lower low water, MLLW) and little to no tidal accretion occurs above MHHW. Figure 4 shows a linear relationship between sedimentation rate and elevation based on this conceptual model and used for the habitat projection modeling.

### **2.1.3 Freshwater Inflow**

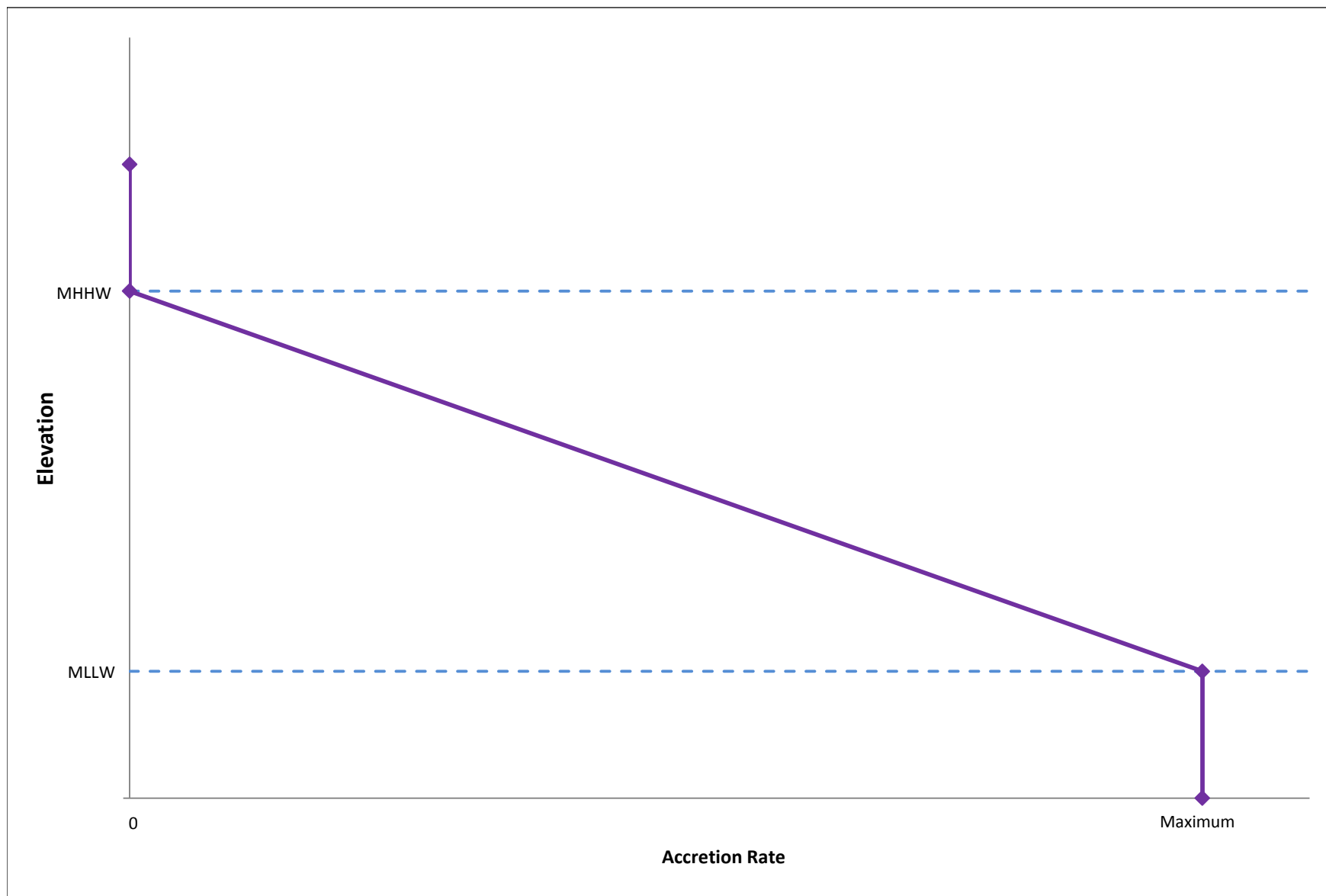
Riparian, freshwater marsh, and brackish marsh habitats form in areas influenced by freshwater inflows. These areas of freshwater influence are either inundated solely by freshwater or are characterized by tidal mixing of ocean water and freshwater inflows, creating brackish salinities. The influence of freshwater determines what type of vegetation can establish in that area. If the extent of freshwater influence increases, the extent of riparian, freshwater marsh, and brackish marsh habitats will increase. Conversely, if the area of freshwater influence is reduced, the extent of freshwater habitats will be reduced. The area or extent of freshwater influence can be inferred from the extent of existing freshwater habitats, correlated to freshwater inflows, and/or quantified through monitoring and modeling of freshwater inflows and salinity gradients.

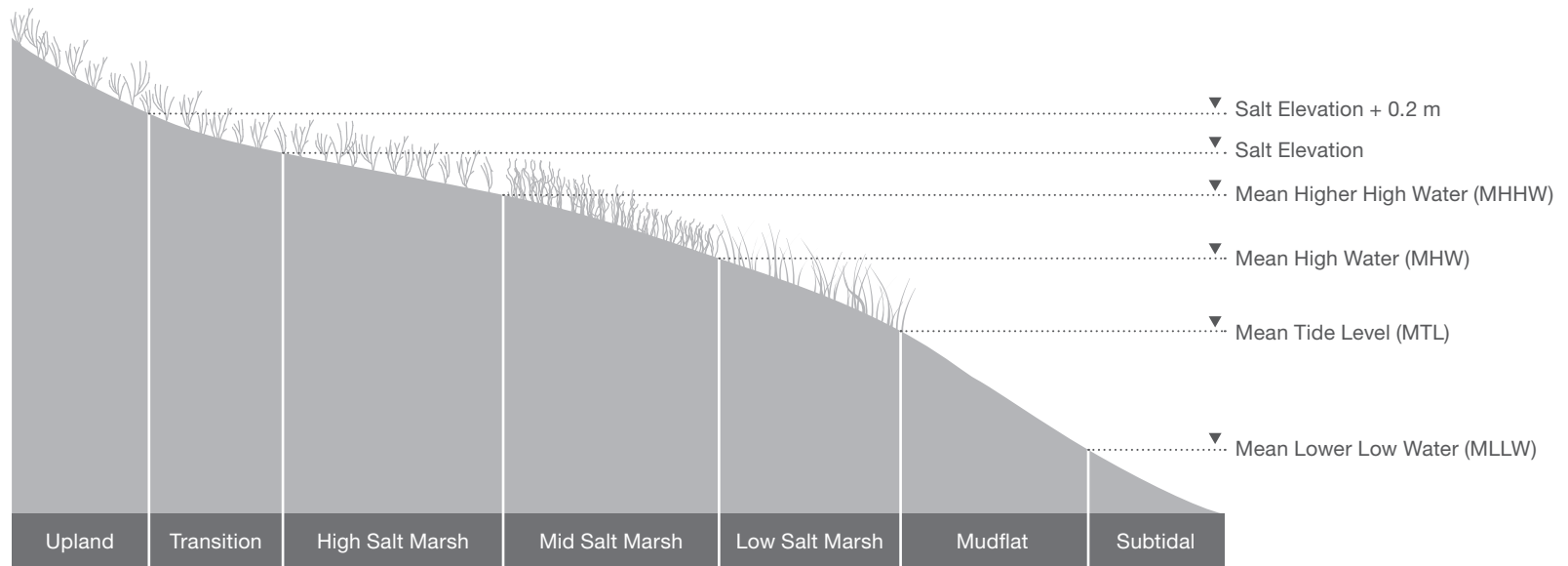


## 2.1.4 Habitat Zones

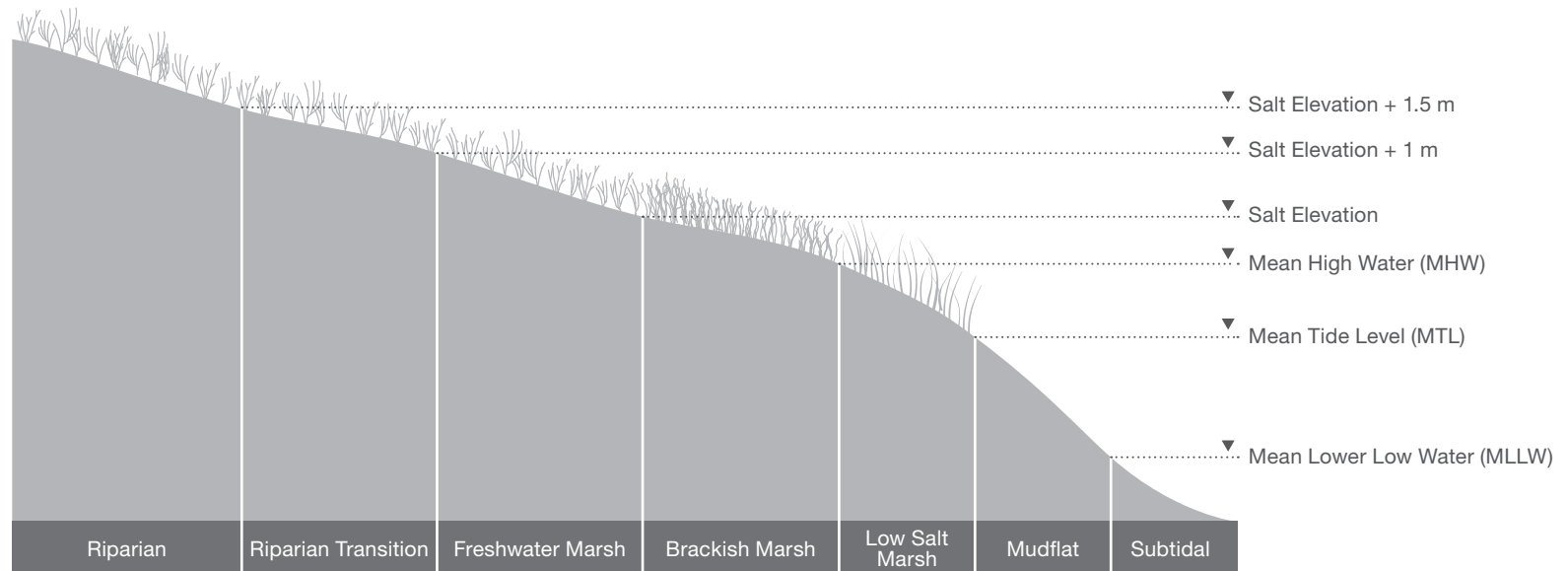
Lagoon habitat zones can be defined for different areas based on the elevation of the area relative to tidal datums (i.e., as a surrogate for the frequency of tidal inundation) and whether the area is within the zone of freshwater influence. The model uses an additional datum called the “salt elevation,” which is based on the extent of existing salt marsh (6.56 ft NAVD) and is just below the highest astronomical tide (HAT, 6.95 ft NAVD). Remnant salt marsh exists above this elevation as a byproduct of lagoon mouth closures, however most of these areas have been lost to development and habitat conversion. Figure 5 shows the different elevation-based habitat zones for areas outside and within the area of freshwater influence used in the habitat projection model. When there is no freshwater in the area, the upland species establish at the highest elevations, followed by transition, salt marsh, mudflat, and lastly, subtidal habitat. When a freshwater influence is present, riparian species establish at the highest elevations, followed by riparian transition, freshwater marsh, brackish marsh, low salt marsh, mudflat, and subtidal habitat. Below MHW, the tides have a strong enough influence that salt marsh can establish even in the presence of freshwater.

The area of freshwater influence and salt elevation can be inferred from existing Lagoon habitats and topography, and the conceptual habitat zone scheme can be compared and validated against existing Lagoon habitats. Existing habitats in the lower half of the Lagoon are composed of salt marsh and the upper half is a mix of salt marsh, brackish marsh, and freshwater marsh. Riparian habitat appears near the mouths of each creek. Beach habitat appears along the coast, with some transition zone and dunes just inside the lagoon. Section 5.1 includes a quantitative comparison of the modeled habitat zones and existing habitats.





Habitat Zones Outside of Freshwater Influence



Habitat Zones Within Area of Freshwater Influence

### 2.1.5 Sea-level Rise

Sea-level rise is expected to be a major driver of habitat evolution at Los Peñasquitos Lagoon. Since most vegetation establishes in areas based on the local tidal inundation and salinity, habitats will evolve when the tides rise.

The State of California Sea-Level Rise Guidance Document (CO-CAT, 2013) provides guidance for California projects in planning for sea-level rise. The document recommends using the estimates provided by the National Research Council's (NRC) report on *Sea-Level Rise for the Coasts of California, Oregon, and Washington* (2012) as a starting place to select values. These predictions for Los Angeles (the closest predictions to San Diego) are:

- 2 to 12" of sea-level rise by 2030
- 5 to 24" of sea-level rise by 2050
- 17 to 66" of sea-level rise by 2100

With climate change, extreme high water levels may change more than mean sea levels due to alterations in the occurrence of strong winds and low pressures. However, this has not been extensively studied for the project area, so it is not included in this conceptual model.

## 2.2 Historic Changes to the Lagoon

The processes described above have caused habitat conversion and will continue to cause habitat change in the future. The following description of historic habitat change resulting from the above processes informs the conceptual model for how habitats will continue to change in the future in response to these processes.

In the late 1800s, Los Peñasquitos Lagoon was mostly salt marsh with an extensive salt pan in the middle, which fluctuated in size from year to year (SFEI 2014; Figure 6). Land use changes within Los Peñasquitos Canyon began in 1832 with the advent of cattle ranching. Land within the canyon was cleared for cattle grazing, which allowed for more sediment erosion during storm events (Cole and Wahl 2000). Urban development increased rapidly from 1966-1999 and undeveloped land decreased from 87% to 57% of the watershed area (White and Greer 2006). As of 2000, 46% of the watershed was classified as impervious (Tetra Tech 2010). Flood plains located at the bottom of each sub-watershed, which had served as natural deposition zones for sediment during storm events, were greatly constrained and, in some locations, lost to development. In addition, all three tributaries were channelized through the lower portions of the watershed, facilitating increased peak flows and sediment transport to Los Peñasquitos Lagoon. As a result, sediment that would normally drop out before reaching the Lagoon now entered, some times in the form of large sediment plumes that raised elevations in these areas above tidal influence. Since 1996, the Lagoon has received year round freshwater inputs as all three tributaries became perennial as a byproduct of urbanization of the watershed. Increased sediment deposition within Los Peñasquitos Lagoon coupled with year round freshwater intrusion has converted salt marsh habitat in the upper lagoon to a mix of brackish marsh, freshwater marsh, and riparian habitats.

### 2.2.1 Hydromodification

Increased impervious surfaces are often related to urban development, especially with regard to commercial and industrial land use. Termed “hardscape”, these areas prevent infiltration of storm water into the ground, and instead, direct these flows to the MS4 where they are consolidated and released through storm outfalls. As a result, MS4 discharges scour drainages and exposed cliffs, and reach streams and creeks more rapidly. This means that the peak (and total) flow in a creek is greater and occurs more rapidly than under un-developed conditions (with fewer impervious surfaces). This modification to the stream hydrograph is referred to as hydromodification (hydromod). Hydromod can cause significant erosion in natural drainages and canyon walls that receive discharges, as well as within creek beds, banks, and floodways as the geomorphology shifts to transport the larger flow. The higher peak flows possess greater energy, which can mobilize greater amounts and sizes of sediment.

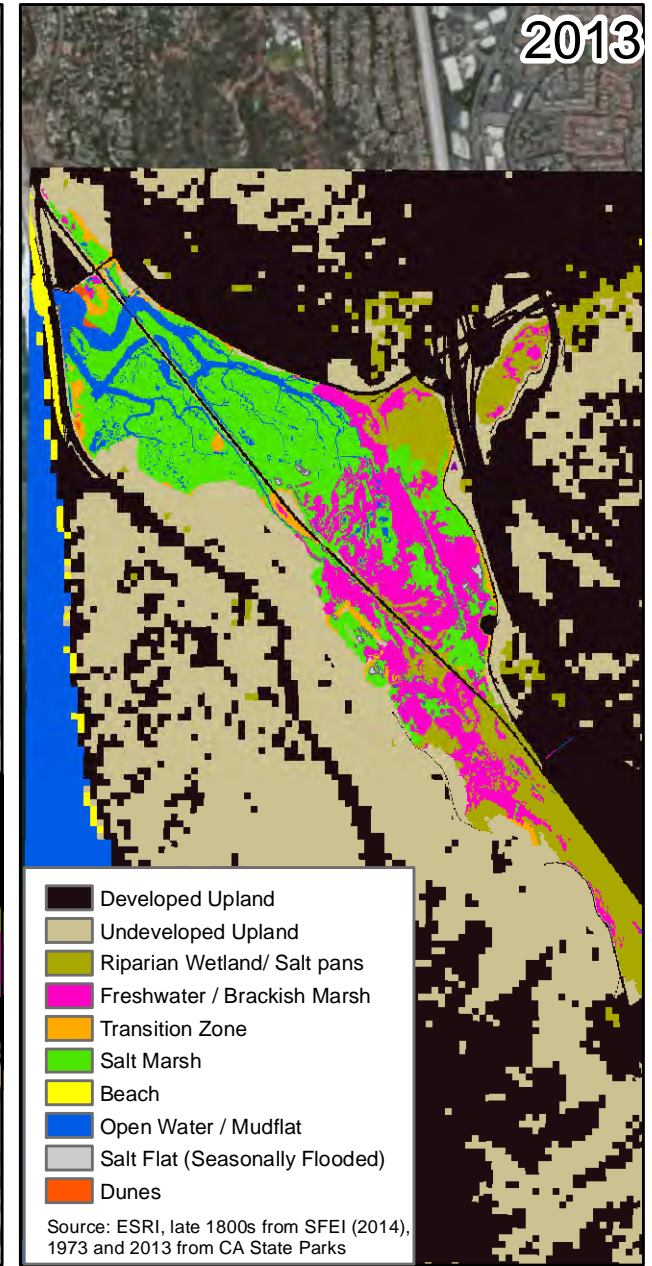
### 2.2.2 Increased Sedimentation

Sedimentation rates in Los Peñasquitos Lagoon likely increased by an order of magnitude from 0.27 mm/yr pre-settlement to 3.5 mm/yr post-settlement due to hydromod affects associated with ranching and grazing (Cole and Wahl 2000). By the 1900s, the sedimentation rate reached 4.3 mm/yr (Cole and Wahl 2000). The amount of sediment that entered the lagoon built up the areas near the creek mouths, and raised these areas out of the tidal range. Extensive urban development starting in the 1960s dramatically increased hydromod and sediment loading. Between 1968 and 1985, approximately 6.1 ft of sediment accumulated at the mouth of Carmel Creek, according to survey data (LPLF and SCC 1985).

### 2.2.3 Increased Freshwater Inflow

Increased freshwater inputs from urban sources have greatly impacted the health of Los Peñasquitos Lagoon, impairing water quality, facilitating vector breeding habitat, and causing loss of native salt marsh through habitat conversion. From 1950 to the early 1970s, the Lagoon received daily discharges of untreated sewage from three separate treatment plants. The Callan Treatment plant pumped 50,000 US gallons (190,000 L) per day during the 1950s; the Sorrento plant produced 500,000 US gallons (1,900,000 L) per day starting in 1962; and the Pomerado Waste Water Treatment Plant pumped treated sewage into the lagoon from 1962 to 1972. Eventually these discharges ceased with the construction of pump stations that sent sewage to treatment plant, which then discharged treated effluent into the Pacific Ocean via outfalls located offshore. Following the build out of the watershed, including Carmel Valley, all three tributaries to Los Peñasquitos Lagoon became perennial with year round input to the Lagoon occurring from 1995 to the present day. Between 1966 and 2000, the area of riparian vegetation in the Lagoon doubled (White and Greer 2006). Sediment deposition in salt marsh areas raised areas above the tidal range, and with the increased year-round freshwater flow from the watershed, these areas converted to riparian, freshwater, or brackish marsh. Figure 6 illustrates this change over time. The re-issued municipal separate storm sewer system (MS4) permit (SDRWQCB, 2013) prohibits the discharge of non-storm flows through the MS4 system. The City of San Diego is moving forward with control measures to address these non-storm flows in accordance with the re-issued MS4 permit.







### 3. Model Inputs

The GIS model was run with the following inputs to look at habitat evolution at Los Peñasquitos under baseline conditions and to test the sensitivity of the model to different model parameters. Subsequent model runs will be conducted to evaluate enhancement alternatives, which can be compared to habitats projected under baseline conditions to quantify enhancement benefits over time.

#### 3.1 Topography and Bathymetry

Topography is used in the model as input to the habitat evolution decision tree (see Section 3.2). Figure 7 presents the existing topography of the Lagoon and presents the four sources that were used. Off the coast, the USACE Southern California Bathymetry LiDAR (2009) was used for bathymetric data, while the Scripps Southern California LiDAR (2009) provided more detailed data along the shore and into the lagoon mouth. The rest of the lagoon was covered with the California Coastal Conservancy Coastal LiDAR Project Digital Elevation Model (DEM; 2009-2011). The remaining area within the model boundary was covered with the California IFSAR DEM (2002-2003), which is lower resolution than the other data sets.

The resulting topography/bathymetry was converted to 5 m cells provide a spatial resolution that is consistent with the vegetation mapping and maintains reasonable model run times.

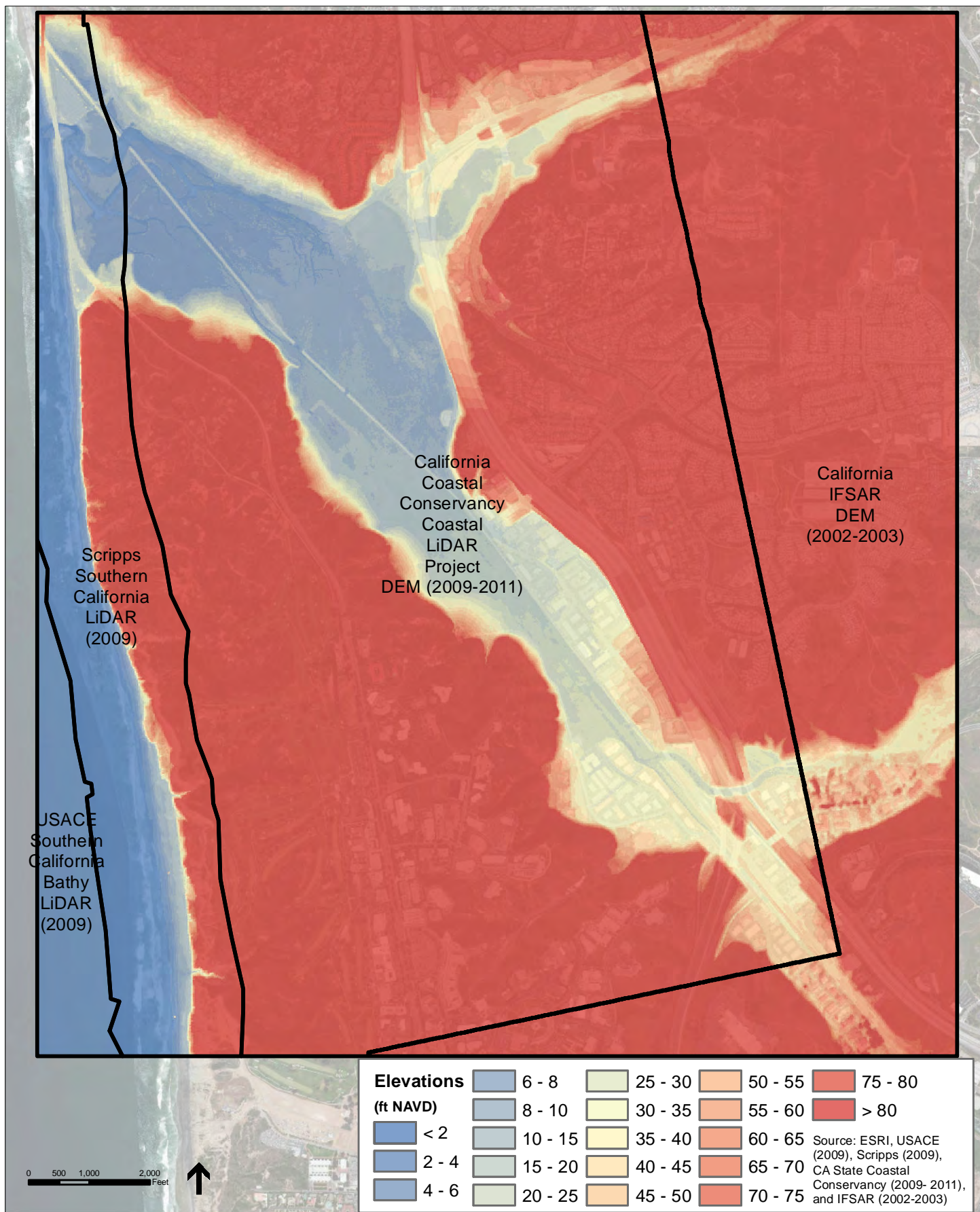
#### 3.2 Vegetation Mapping

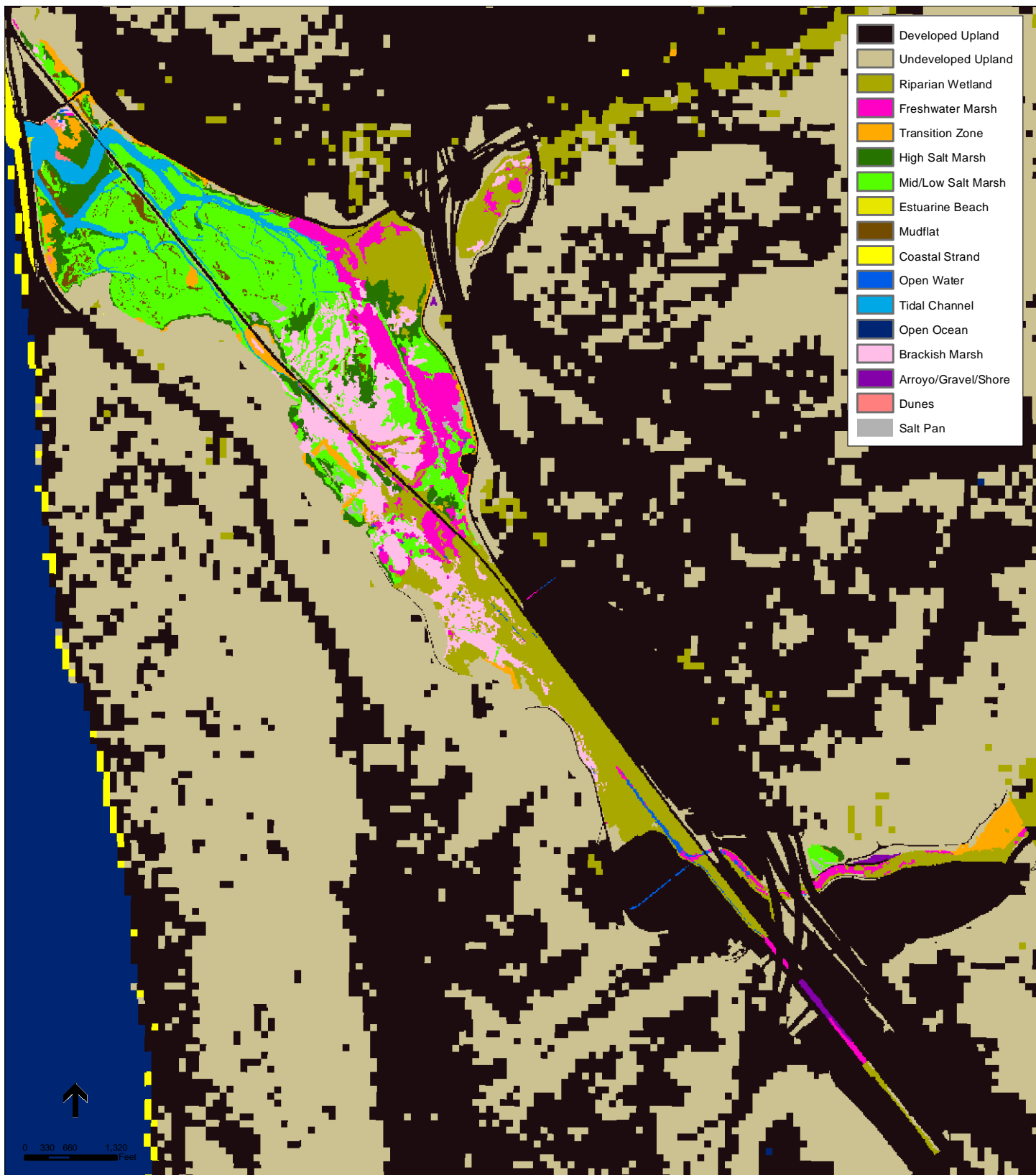
To evaluate how habitats will evolve over time, existing conditions vegetation mapping is needed. State Parks delineated vegetation boundaries on an aerial image flown by Lenska in the winter of 2013. Vegetation polygons were delineated at a scale of 1:600. Additional data used to assist with the delineation of vegetation boundaries included:

- 2013 LiDAR vegetation height data from Coastal Conservancy
- 2009-2011 California Coastal Conservancy Coastal LiDAR DEM
- 2011 Bing Imagery
- Oblique Imagery from Google Maps and Bing Maps
- Images from ArcGIS

Dominant species cover was estimated in the field and categorized using the Vegetation Classification Manual for Western San Diego County (VCMWSD) (AECOM/CDFG 2011) for approximately 30% of the vegetation. Figure 8 shows the vegetation map. Field data for the entire site is expected for future runs of the model.

Vegetation was categorized into habitat types according to the habitat cross-walk presented in Appendix A. The cross-walk was developed based on inundation frequency, salinity preferences, and expected evolution under sea-level rise for each vegetation type. The habitat evolution decision tree is presented in Figure 9. Note that salt pans were not included in the model, but could be added as a post-processing step if desired.

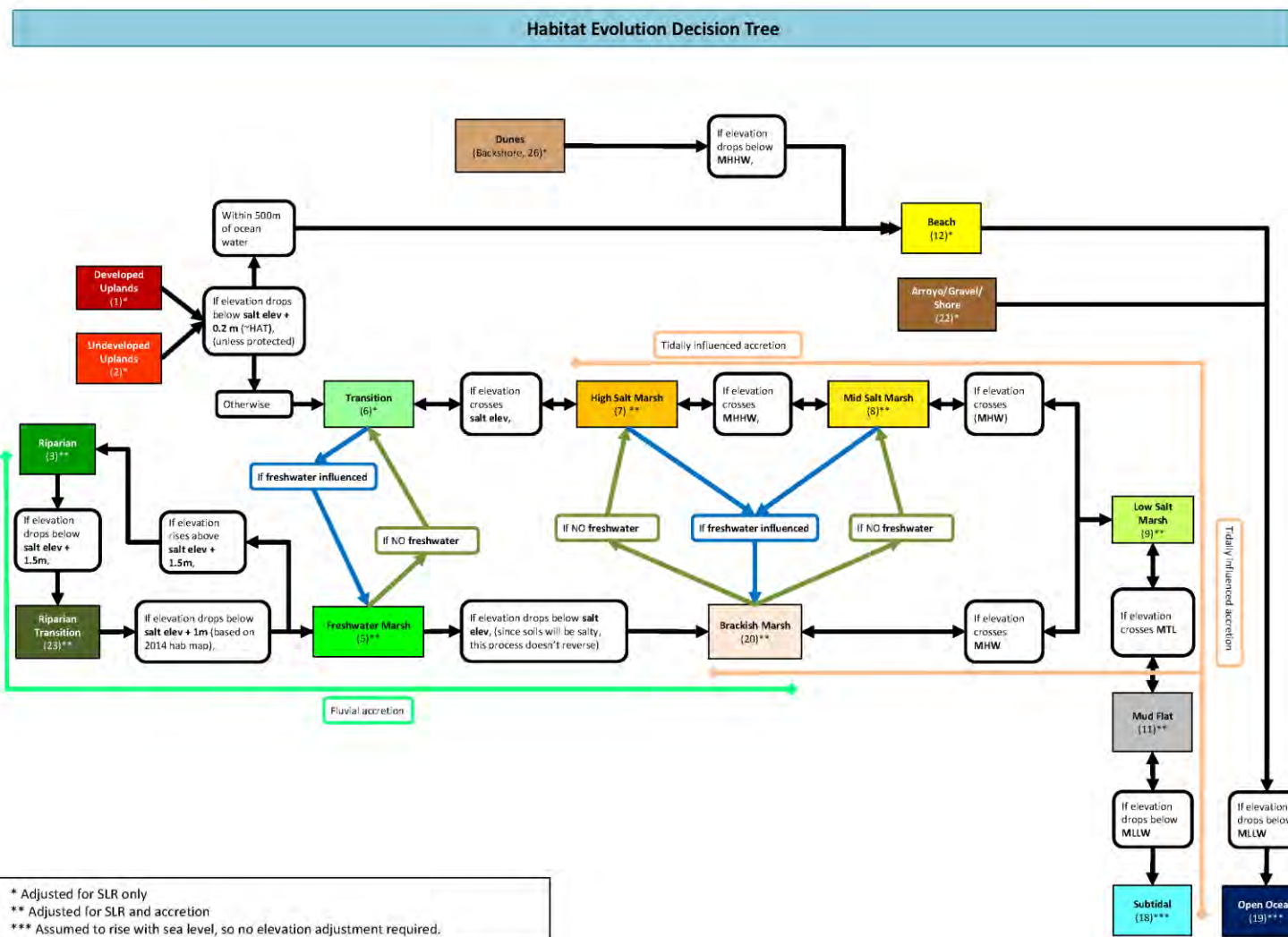




G:\130136\_LosPenasquitos\vegmap.mxd

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community Lagoon vegetation mapping by State Parks 2014. Upland mapping from NOAA 2006.

Los Penaquitos. D130136  
**Figure 8**  
 2013 Vegetation Map



Los Peñasquitos Lagoon. D130136

**Figure 9**  
Habitat Evolution Decision Tree

## 3.3 Tidal Water Levels

### 3.3.1 Tidal Datums

Tidal datums are used within the model as an input to the habitat evolution decision tree (see Section 3.2). For example, MLLW is the boundary between open water and mudflat or beach, because it indicates the elevation at which land is always inundated (during an average day). If land is below MLLW, it is assumed to be open water; if land is just above, it is either mudflat or beach.

The model uses the tidal datums from the bridge gage, since low tide at the other gages within the lagoon is limited by the channel depth, and the bridge gage is in a deeper channel (Table 4). An additional “salt elevation” datum is used to set the limit between high salt marsh and transition zone, and brackish marsh and freshwater marsh. The salt elevation is set to 6.56 ft NAVD (2.0 m NAVD) at Los Peñasquitos, based on the existing transition between habitats.

**TABLE 4**  
**TIDAL DATUMS USED IN THE MODEL**  
(values in feet NAVD)

| Tidal Datum    | Bridge Gage <sup>1</sup> |
|----------------|--------------------------|
| Salt Elevation | 6.56 (2 m)               |
| MHHW           | 5.27                     |
| MHW            | 4.67                     |
| MTL            | 3.60                     |
| MSL            | 3.73                     |
| MLW            | 2.53                     |
| MLLW           | 2.39                     |

1. Data from TRNERR

### 3.3.2 Sea-Level Rise

In the model, sea-level rise is added to each datum by decade. To test the sensitivity of the model to sea-level rise predictions, the model was run with low, projected, and high rates of sea-level rise from the NRC (2012). Table 5 provides the different scenarios by decade.



**TABLE 5**  
**SEA-LEVEL RISE SCENARIOS**  
(values in inches from 2000)

| Year | Low Scenario | Projected Scenario | High Scenario |
|------|--------------|--------------------|---------------|
| 2010 | 0.4          | 1.3                | 3.3           |
| 2020 | 1.1          | 3.1                | 7.4           |
| 2030 | 2.1          | 5.3                | 12.1          |
| 2040 | 3.4          | 8.2                | 17.6          |
| 2050 | 4.9          | 11.6               | 23.9          |
| 2060 | 6.8          | 15.5               | 30.9          |
| 2070 | 8.9          | 20.0               | 38.6          |
| 2080 | 11.3         | 25.1               | 47.0          |
| 2090 | 14.0         | 30.7               | 56.1          |
| 2100 | 17.0         | 36.9               | 66.0          |

## 3.4 Sedimentation

### 3.4.1 Fluvial Accretion

The model uses a decadal sediment load to build a fan or partial cone of sediment that advances out from the creek mouth to raise the topography. A volume of sediment is calculated from the total sediment load from the previous decades. The shape of a cone is calculated based on this volume and a constant slope (based on the slope of the existing sediment fans). Due to the sloping fan, the extent of the fan increases as sediment is added to the fan and the toe or edge of the fan advances outward. Smaller amounts of sediment result in a fan that remains close to the mouth, while larger sediment volumes extend further out into the lagoon. The cone is then added on to the existing topography.

Two conceptual loading curves were developed to test a range of possible sedimentation in the Lagoon. One curve was based on the loads estimated in the TMDL (Table 3). The first curve used the current, historic, and required loads from the TMDL and interpolated in between (Figure 10).

A second curve was developed based on the sedimentation surveys of LPLF and SCC, which provide a higher estimate of the sediment load for the purpose of testing model sensitivity. The second conceptual curve assumes that the 1960s-1980s represented the time when the sediment load from the watershed was the greatest (i.e. the peak decadal load), because most of the watershed development occurred during this period (White and Greer 2006) and this period therefore likely represents the period when hydromod effects and sediment loading were the greatest. To calculate the peak load, the volume of the fan of sediment from the Carmel Creek mouth was estimated. Using the depth of the fan (6.1 ft) and dividing the volume by the time it took to accumulate (17 yr between surveys in 1968 and 1985; LPLF and SCC 1985), a sediment load of 6,710 cy/year was calculated for Carmel Creek. A total load was estimated using the size of the watersheds to scale the sediment loads for Carroll Canyon and Los Peñasquitos Creeks



(Table 6). The TMDL proposes a 67% reduction of sedimentation by 2030, so a reduced load of 117,300 cy/decade was used for the second curve. Figure 10 shows this curve.

The second curve based on sediment surveys is a rough upper-end estimate of modeled sediment loads. This curve may overestimate the peak load if the fan was entirely deposited during a couple of large storm events during the 1983 El Niño, which was an exceptional event. However, the purpose of this curve is to test the model's sensitivity to the sediment loading parameter using a different set of data than was used for the TMDL model, which is based on land use runoff coefficients. While Carroll Canyon has been shown to be contributing significant sediment to the lagoon (ESA PWA 2011), the other two canyons have been found to be more stable under present day conditions (Weston 2009 and ESA PWA 2011). The second curve provides an upper-end estimate for sensitivity analyses.

**TABLE 6  
PEAK SEDIMENT LOADS BASED ON SEDIMENT SURVEYS**

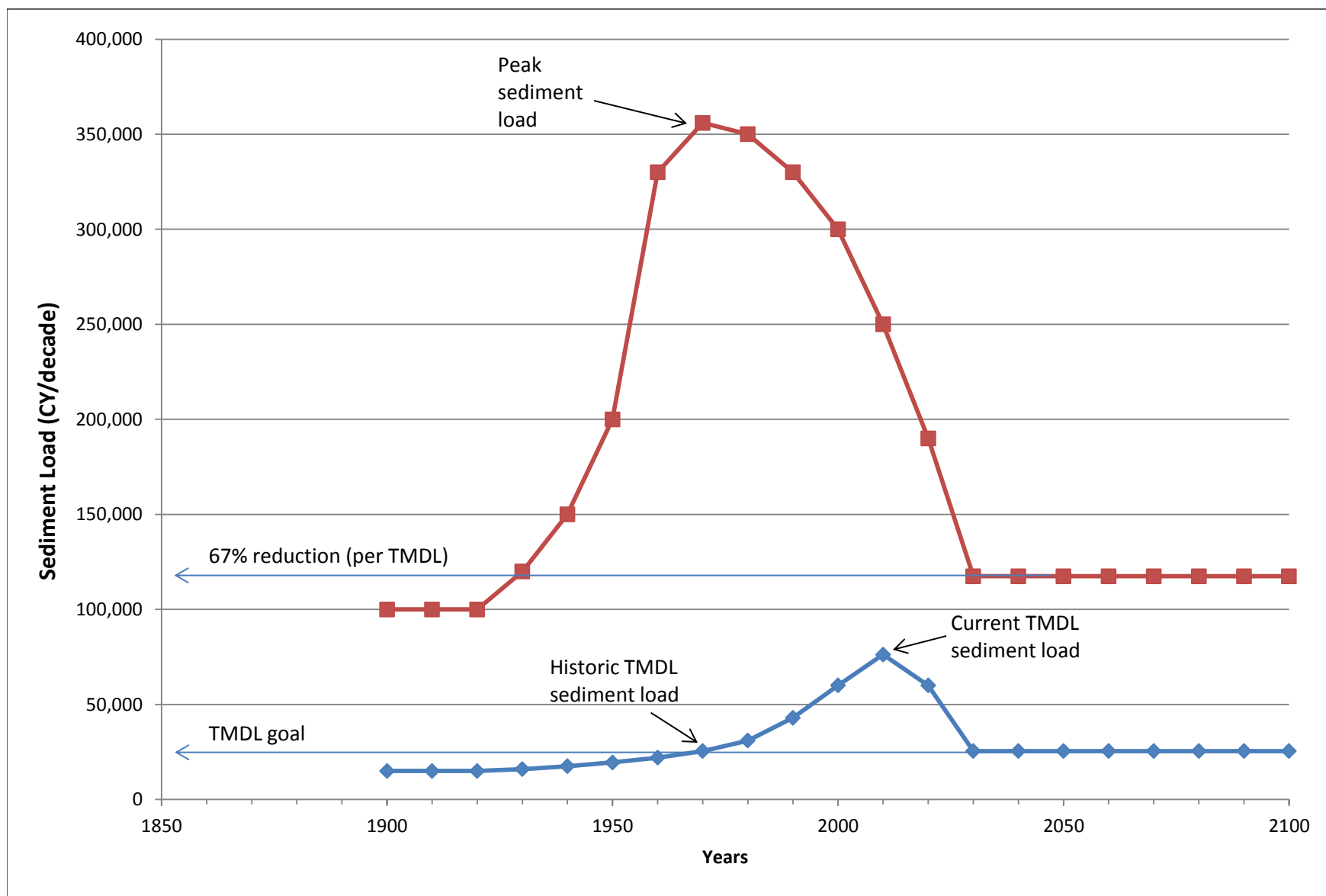
| <b>Creek</b>      | <b>Watershed Area<br/>(ac)</b> | <b>Sediment Load<br/>(cy/yr)</b> | <b>Sediment Load<br/>(cy/decade)</b> | <b>Percent of Total<br/>Load</b> |
|-------------------|--------------------------------|----------------------------------|--------------------------------------|----------------------------------|
| Carmel            | 11,180                         | 6,710                            | 67,100                               | 19%                              |
| Los Peñasquitos   | 37,028                         | 22,240                           | 222,400                              | 63%                              |
| Carroll Canyon    | 11,004                         | 6,610                            | 66,100                               | 19%                              |
| <b>Total Load</b> |                                | <b>35,560</b>                    | <b>355,600</b>                       |                                  |

### 3.4.2 Tidal Accretion

In the model, tidal accretion is applied to all areas below MHHW as described in the conceptual model (Section 0). The maximum rate of tidal accretion was set to 4.6 mm/yr based on the current estimated rate found by Cole and Wahl from a sediment core taken in the marsh (1999).

## 3.5 Freshwater Inflow

The model defines the area of year-round freshwater influences based on a freshwater influence polygon. For existing conditions, this polygon was defined by the extent of brackish and freshwater marsh in the Lagoon (Figure 11). To test the sensitivity to the freshwater inflow, the model was run with the freshwater influence polygon based on existing conditions and for a reduced extent of freshwater influence (Figure 11). A future version of this model may incorporate hydrodynamic modeling of Lagoon salinities for existing conditions and future conditions with reduced freshwater flow to quantify the reduction in freshwater influence corresponding to reductions in freshwater inflows.







## 4. Model Runs

Table 7 presents the scenarios that were run in the GIS model to test the model sensitivity. Low, mid, and high rates of sea-level rise were evaluated with sediment loading curves based on the TMDL (representing a lower or “low” sediment loading estimate) and sedimentation surveys (representing a higher or “high” sediment loading estimate). A reduced area of freshwater influence was evaluated for high rates of sea-level rise and the high sediment loading curve to illustrate the effect of reducing freshwater influence in the model.

**TABLE 7  
RUN CATALOG**

| Run   | Sea-Level Rise | Sediment Load Curve | Freshwater Influence |
|-------|----------------|---------------------|----------------------|
| Run 1 | Low            | Sediment Surveys    | Existing             |
| Run 2 | Mid            | Sediment Surveys    | Existing             |
| Run 3 | High           | Sediment Surveys    | Existing             |
| Run 4 | High           | TMDL                | Existing             |
| Run 5 | High           | Sediment Surveys    | Reduced              |

## 5. Results

The runs in Table 7 allowed for comparisons between different sea-level rise scenarios, sediment load curves, and areas of freshwater input. Below, Section 5.1 presents the model “validation” of existing habitat types. Sections 5.2- 5.4 present the results for sensitivity runs on sea-level rise, sediment loads, and areas of freshwater influence respectively.

### 5.1 Model “Validation”

The model was compared to existing vegetation to check the model assumptions for the habitat evolution decision tree. Current topography and existing tidal datums were input to the model with no sea-level rise to model the existing conditions (2010) and to validate the model. Table 8 presents habitat acreages from the 2010 mapped vegetation and from the 2010 modeled habitats. Figure 12 shows the mapped vegetation compared to the modeled habitats.



**TABLE 8**  
**HABITAT ACREAGES FOR MAPPED VS MODELED**

| Run                           | 2010<br>Mapped<br>Vegetation | 2010<br>Modeled<br>Vegetation | Difference | Notes  |
|-------------------------------|------------------------------|-------------------------------|------------|--|
| Developed Upland              | 2550.9                       | 2550.9                        | 0.0        |  |
| Undeveloped Upland            | 2360.8                       | 2357.3                        | -3.5       |  |
| Riparian Wetland              | 212.1                        | 212.1                         | 0.0        |  |
| Riparian Transition Zone (TZ) | 0.0                          | 22.9                          | 22.9       | Category not mapped in vegetation mapping.   |
| Freshwater Marsh              | 56.5                         | 23.6                          | -32.9      | The model categorized some FW Marsh as Riparian TZ based on elevation.   |
| Brackish Marsh                | 82.1                         | 148.4                         | 66.3       | The model assumes remnant Mid Marsh in FW areas will convert to Brackish Marsh based on elevation and freshwater influence                                 |
| Transition Zone (TZ)          | 26.5                         | 61.5                          | 35.1       | The model categorizes some Mid Marsh as TZ due to the high elevations where the Mid Marsh is occurring   |
| High Salt Marsh               | 45.2                         | 117.8                         | 72.6       | The model categorizes some Mid Marsh as High Marsh due to the high elevations where the Mid Marsh is occurring   |
| Mid Salt Marsh                | 166.7                        | 9.3                           | -157.4     | The model categorizes some Mid Marsh as High Marsh, TZ, or Brackish Marsh due to the high elevations where the Mid Marsh is occurring and the FW influence |
| Low Salt Marsh                | 0.0                          | 5.9                           | 5.9        |  |
| Mudflat                       | 11.8                         | 0.4                           | -11.4      | The model assumes mudflat at higher elevations will vegetate and become Salt Marsh or Brackish Marsh   |
| Subtidal                      | 39.5                         | 40.0                          | 0.5        |  |
| Dunes                         | 1.1                          | 1.1                           | 0.0        |  |
| Beach                         | 22.6                         | 18.0                          | -4.6       |  |
| Arroyo/Gravel/Shore           | 2.9                          | 2.9                           | 0.0        |  |
| Open Ocean                    | 415.7                        | 422.1                         | 6.5        |  |

When the mapped vegetation is input to the model, some habitats change, since actual vegetation does not always follow the rules of the model. Discussion of some of these habitat shifts is presented below.

- **Mudflat.** Higher elevation unvegetated areas within the marsh that were mapped as mudflat are classified as salt or brackish marsh by the model decision tree, which is equivalent to assuming these areas will become vegetated marsh.
- **Mid Salt Marsh.** Because the mid salt marsh habitat at Los Peñasquitos occurs above MHHW (possibly due to marshplain deposition during storm events), the model classifies this mid marsh habitat as high salt marsh and transition zone. Additionally, some salt marsh is present in the back of the marsh where most of the area has converted to brackish and freshwater marsh. The model classifies these remnant habitats as brackish

marsh based on the area of freshwater influence and habitat decision tree. Over time, these remnant marsh areas are, in fact, likely to convert to brackish and freshwater marsh due to the increased sedimentation and freshwater flow and the ongoing process of habitat conversion.

- **High Salt Marsh/Transition Zone.** As mentioned above, the model classifies mid salt marsh as high salt marsh and transition zone based on the higher elevations where mid salt marsh occurs.
- **Brackish Marsh.** As explained for mid salt marsh, the model classifies areas of remnant salt marsh as brackish marsh where there is freshwater influence.
- **Freshwater Marsh.** Some freshwater marsh is classified as riparian transition (which was not mapped), because of the elevation at which the habitat occurs.
- **Riparian Transition Zone.** This habitat type was not mapped in the vegetation mapping, but the model categorizes the upper elevation freshwater marsh as riparian transition zone.

## 5.2 Sea-Level Rise Curves

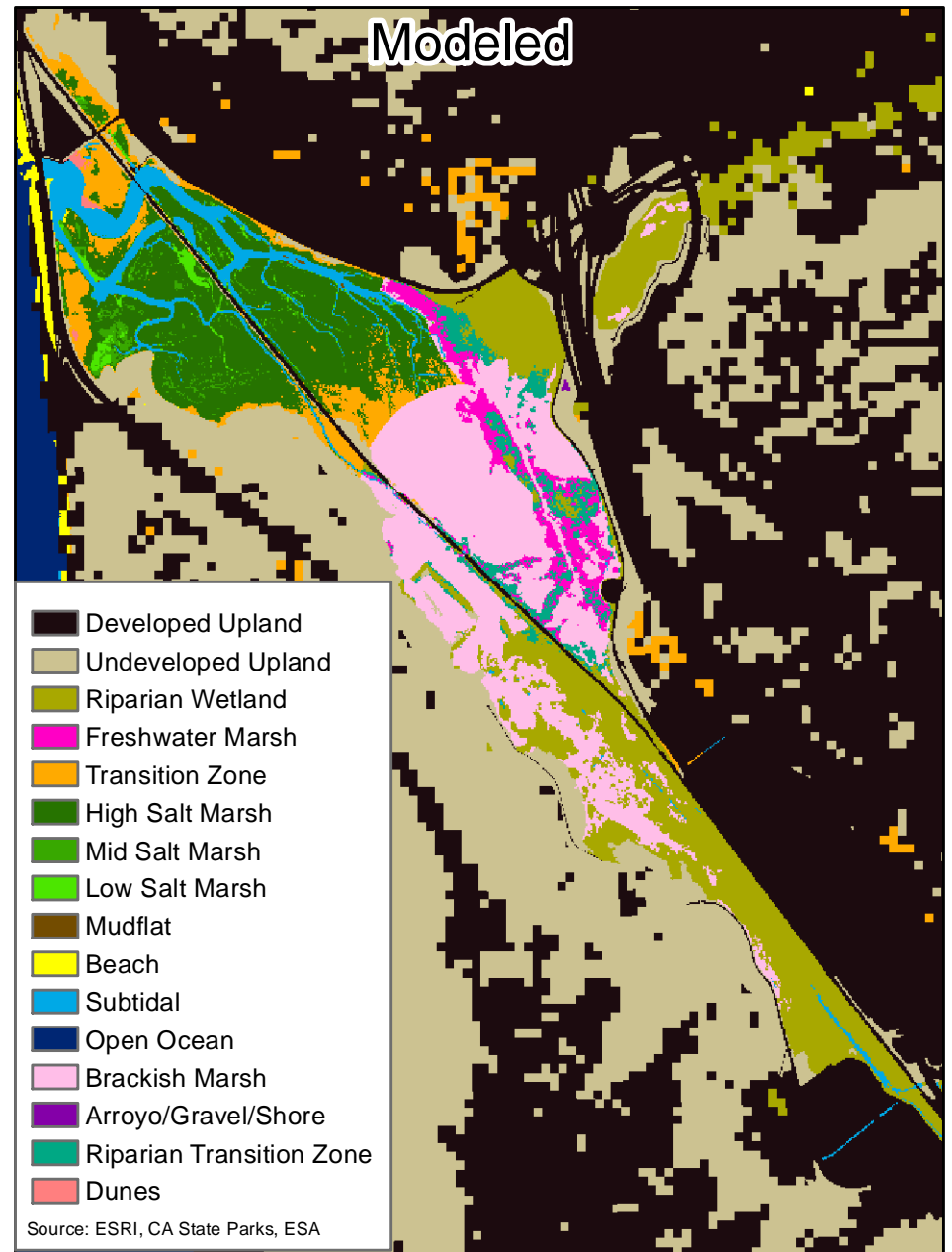
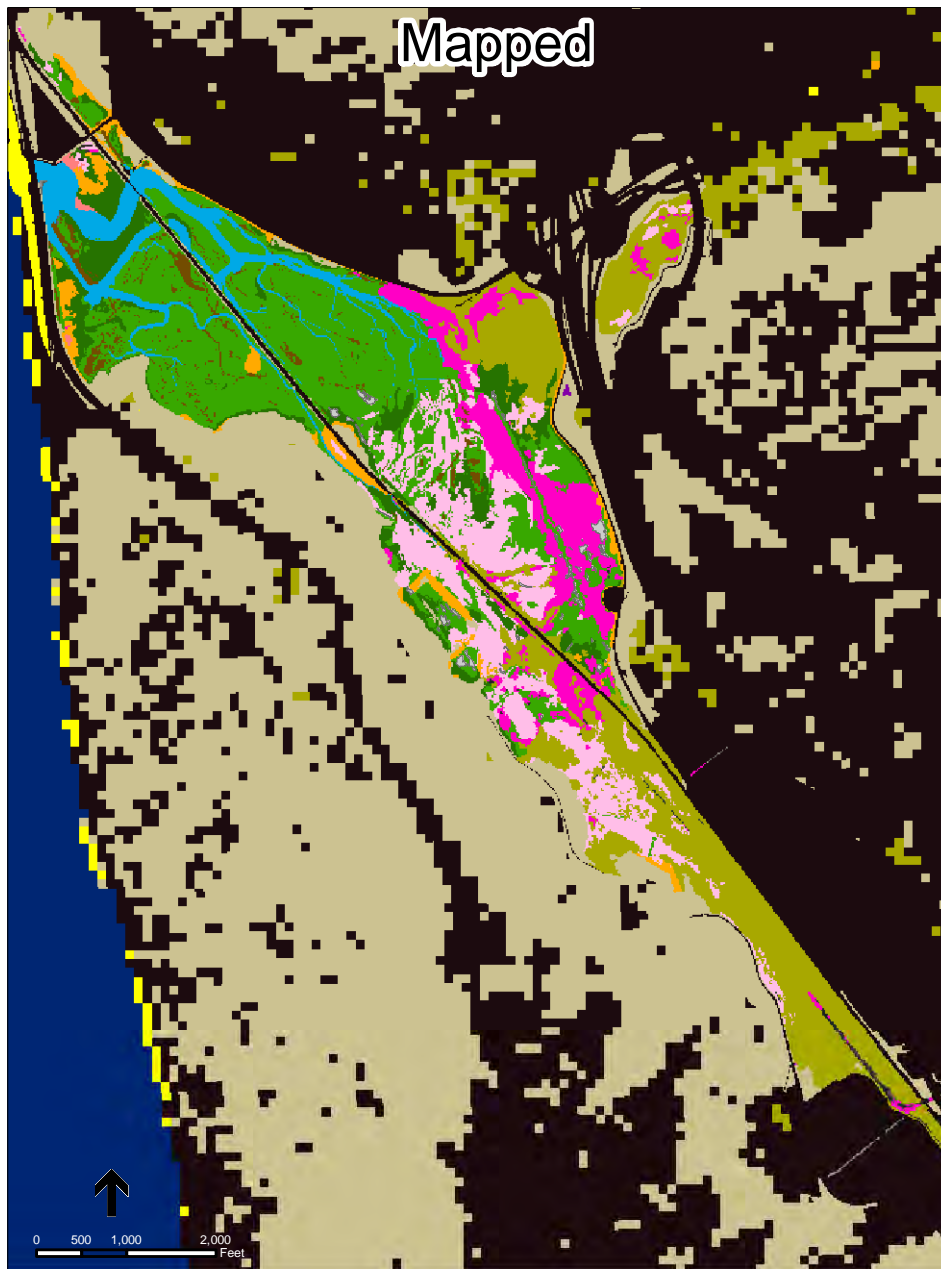
Table 9 presents the habitat acreages for low (run 1), mid (run 2), and high (run 3) rates of sea-level rise at 2100, as well as the difference between these habitat acreages and the 2010 modeled habitats. With higher rates of sea-level rise, higher elevation habitats convert to lower habitat types. For example, under the mid and high scenarios, there is a loss of riparian wetland, riparian transition zone, freshwater marsh, transition zone, and high salt marsh. Mid salt marsh increases except under high sea-level rise where there is a slight loss of habitat. Low salt marsh and mudflat increase under all scenarios. Figure 13 shows the 2100 habitat maps for low, mid, and high sea-level rise. (See Appendix C for habitat maps of each decade between 2020 and 2100)

Figure 14 through Figure 16 show the evolution of habitats over time for low, mid, and high rates of sea-level rise. Under low sea-level rise, the total amount of salt marsh stays about the same over time. With mid sea-level rise, the salt marsh increases at the expense of the transition zone, but the freshwater habitats are not affected very much. However, under high sea-level rise, the area of salt marsh decreases and the area of freshwater habitats decrease as mudflat and subtidal habitats progress up slope.

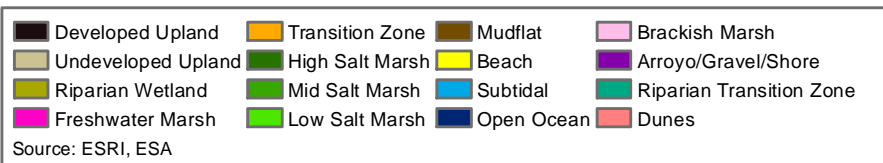
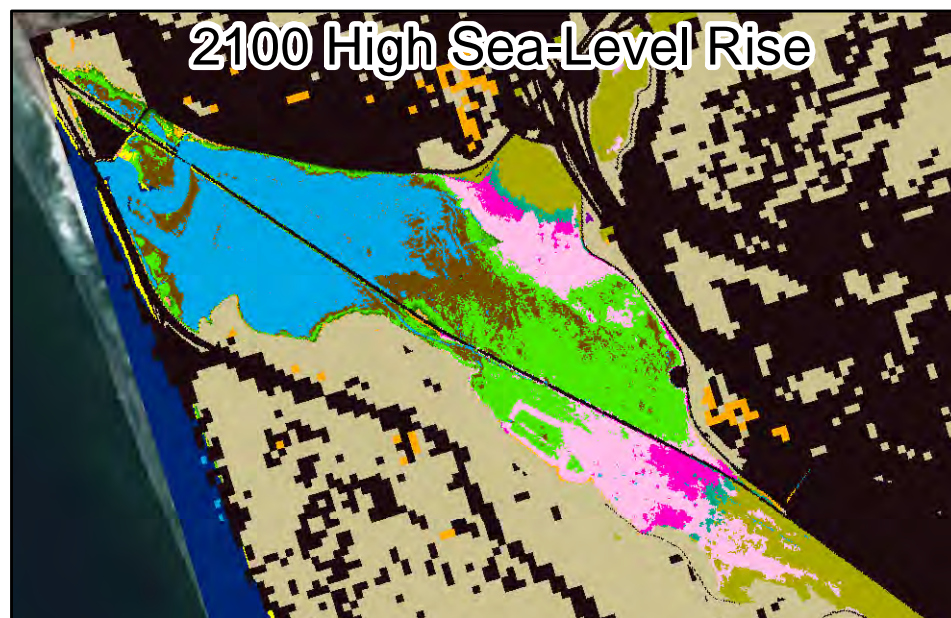
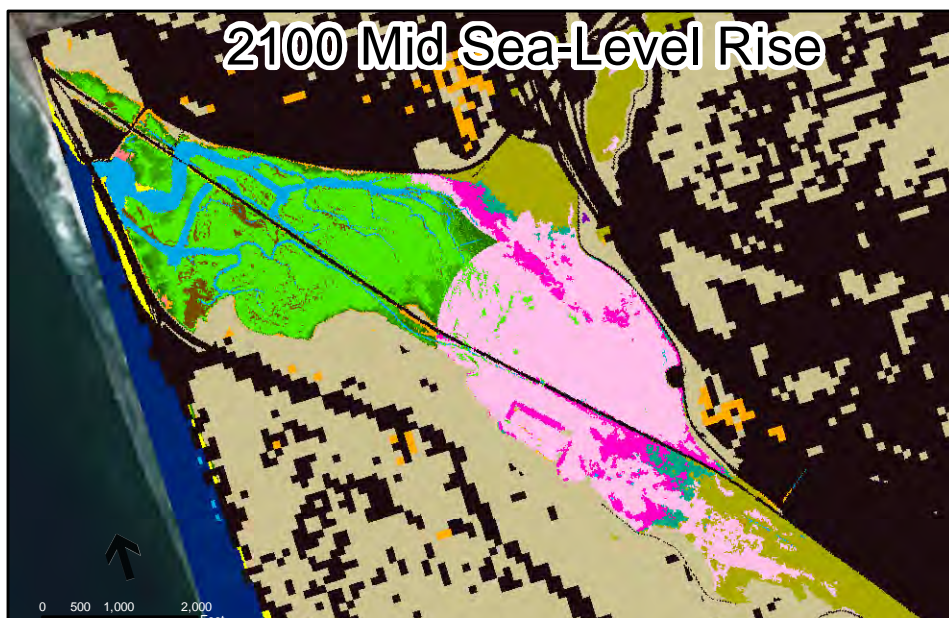
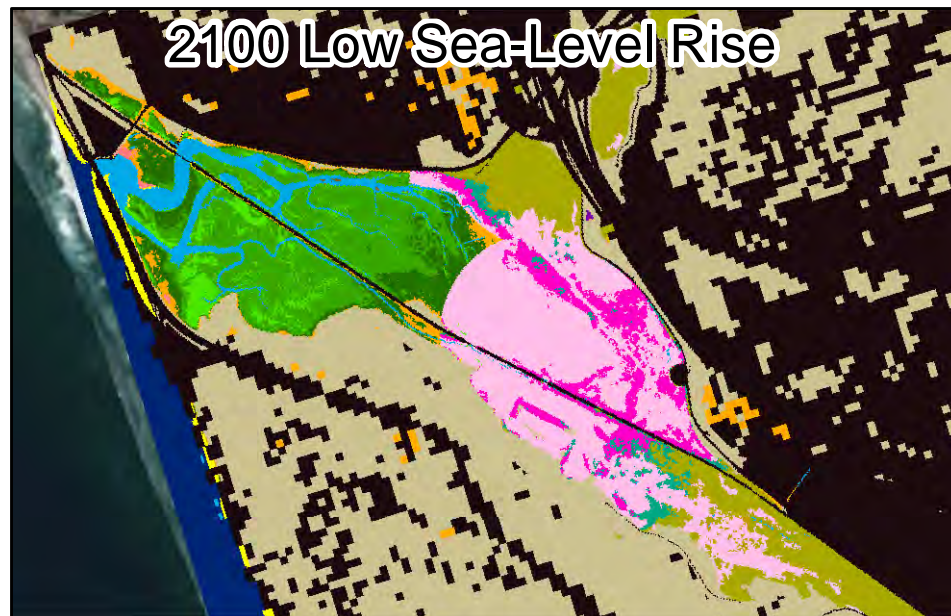
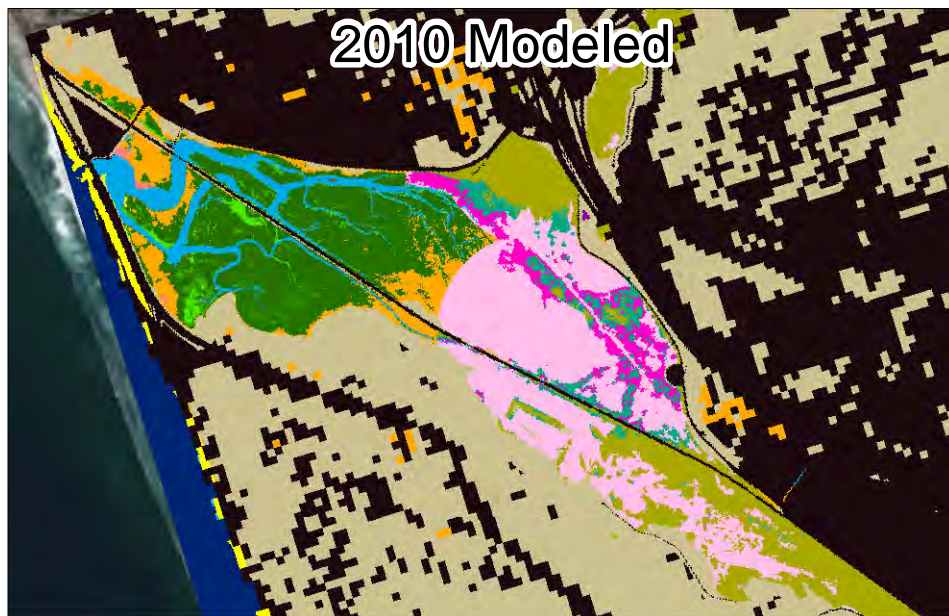


**TABLE 9**  
**HABITAT ACREAGES FOR SEA-LEVEL RISE**

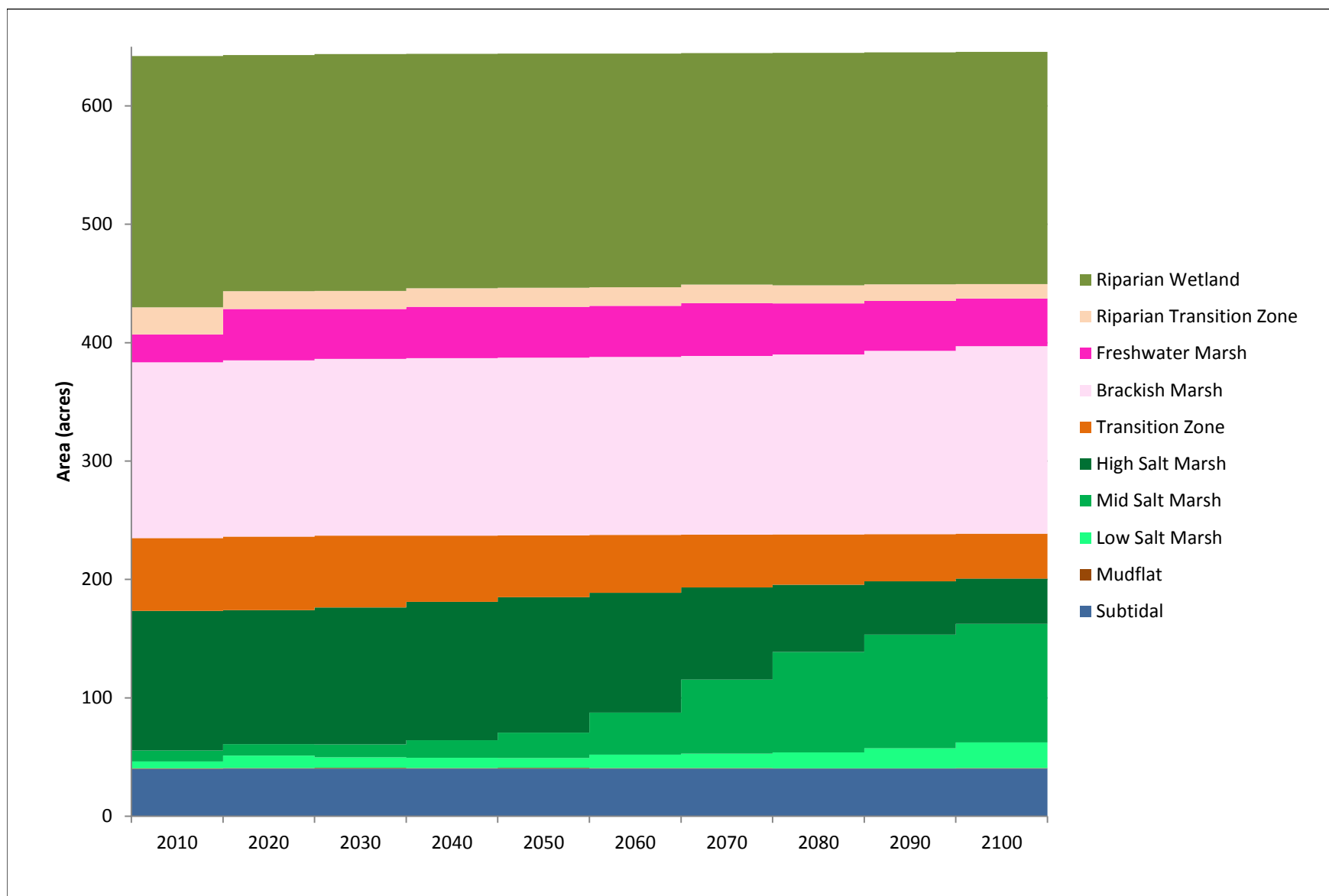
| Run                      | Modeled<br>Acreage in 2010 | Acreage in 2100 |        |        | Acreage difference 2100-2010 |        |        |
|--------------------------|----------------------------|-----------------|--------|--------|------------------------------|--------|--------|
|                          |                            | Low             | Mid    | High   | Low                          | Mid    | High   |
| Developed Upland         | 2550.9                     | 2550.9          | 2550.9 | 2550.9 | 0.0                          | 0.0    | 0.0    |
| Undeveloped Upland       | 2357.3                     | 2337.4          | 2331.9 | 2322.7 | -19.9                        | -25.4  | -34.6  |
| Riparian Wetland         | 212.1                      | 196.1           | 186.2  | 175.7  | -16.0                        | -25.9  | -36.4  |
| Riparian Transition Zone | 22.9                       | 12.2            | 9.8    | 7.5    | -10.8                        | -13.1  | -15.4  |
| Freshwater Marsh         | 23.6                       | 40.2            | 29.6   | 18.0   | 16.6                         | 6.0    | -5.6   |
| Brackish Marsh           | 148.4                      | 158.4           | 177.9  | 91.1   | 10.0                         | 29.5   | -57.2  |
| Transition Zone          | 61.5                       | 38.0            | 30.6   | 27.9   | -23.5                        | -31.0  | -33.7  |
| High Salt Marsh          | 117.8                      | 38.0            | 11.4   | 5.0    | -79.8                        | -106.4 | -112.9 |
| Mid Salt Marsh           | 9.3                        | 100.2           | 19.6   | 4.3    | 90.9                         | 10.3   | -5.0   |
| Low Salt Marsh           | 5.9                        | 21.7            | 130.1  | 109.3  | 15.8                         | 124.3  | 103.5  |
| Mudflat                  | 0.4                        | 0.3             | 13.7   | 60.0   | 0.0                          | 13.3   | 59.6   |
| Subtidal                 | 40.0                       | 40.3            | 42.0   | 160.3  | 0.3                          | 2.0    | 120.2  |
| Dunes                    | 1.1                        | 1.0             | 0.7    | 0.2    | -0.1                         | -0.4   | -0.9   |
| Beach                    | 18.0                       | 12.6            | 8.7    | 6.4    | -5.3                         | -9.3   | -11.6  |
| Arroyo/Gravel/Shore      | 2.9                        | 2.9             | 2.9    | 2.9    | 0.0                          | 0.0    | 0.0    |
| Open Ocean               | 422.1                      | 413.5           | 417.8  | 421.7  | -8.6                         | -4.3   | -0.5   |







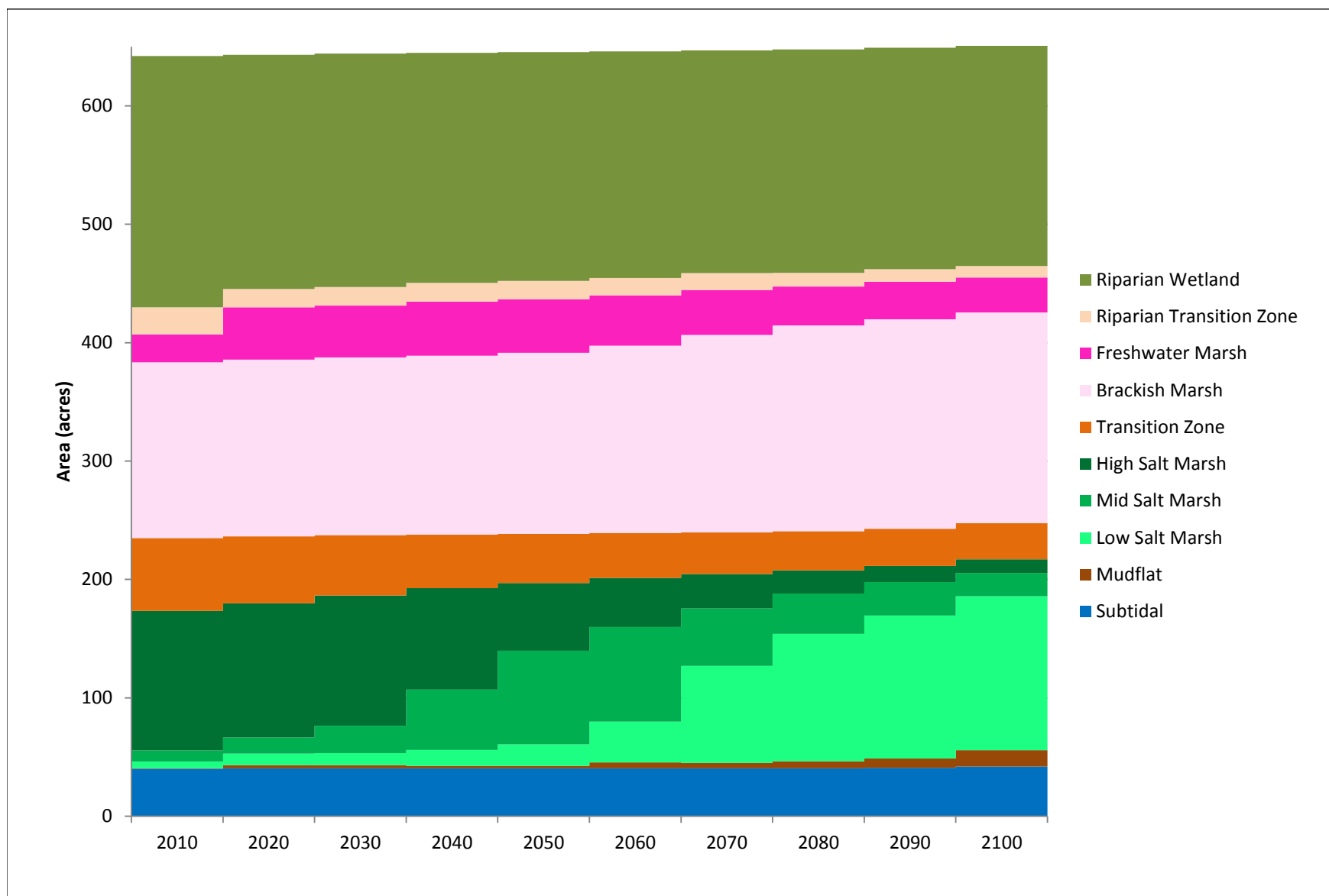
Los Peñasquitos Lagoon. D130136  
**Figure 13**  
 2010 Modeled Vegetation versus  
 Various Amounts of Sea-Level Rise



Los Peñasquitos Lagoon. D130136

**Figure 14**

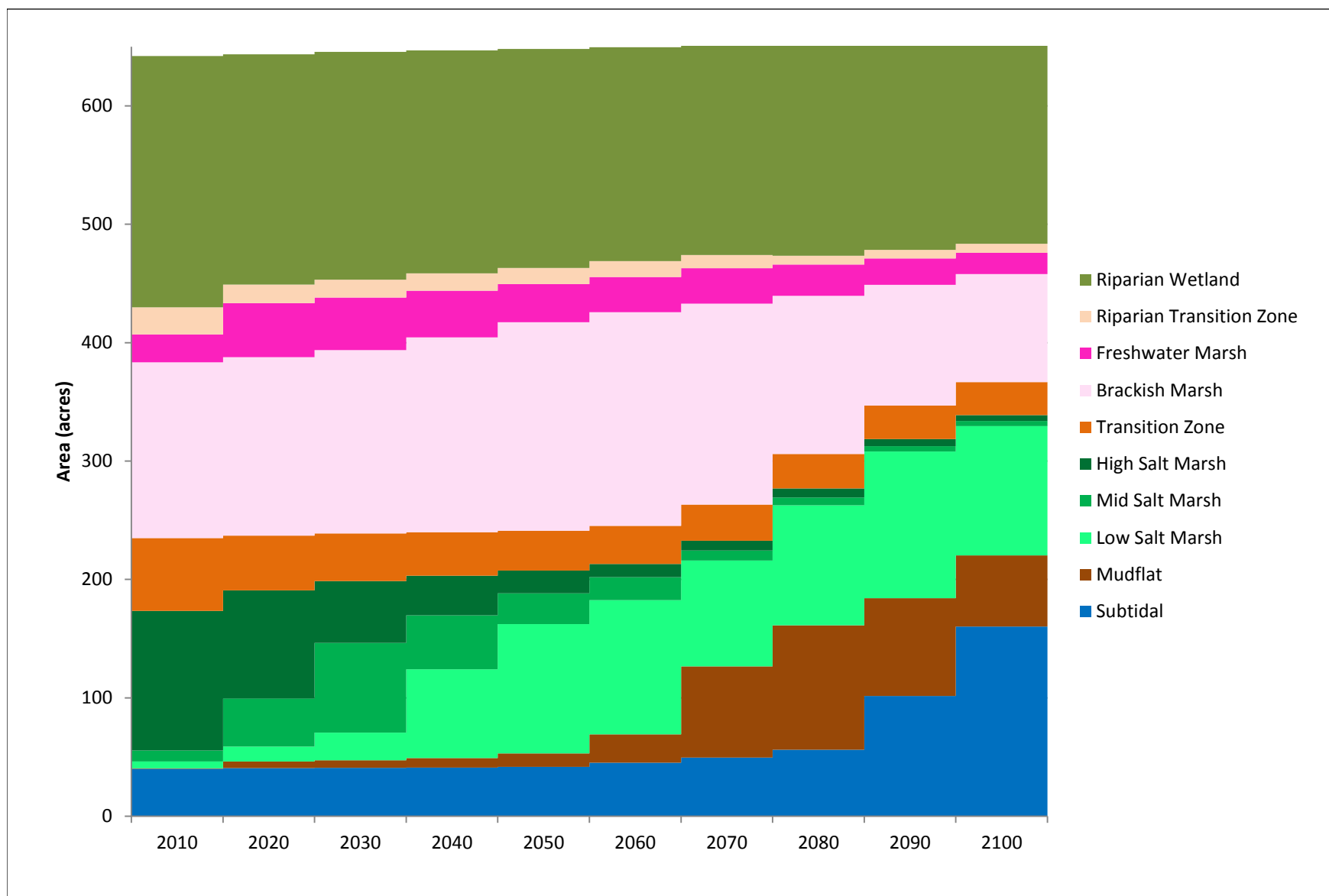
Run 1 Habitats Over Time  
(Low Sea-Level Rise)



Los Peñasquitos Lagoon. D130136

**Figure 15**

Run 2 Habitats Over Time  
(Mid Sea-Level Rise)



Los Peñasquitos Lagoon. D130136

**Figure 16**

Run 3 Habitats Over Time  
(High Sea-Level Rise)

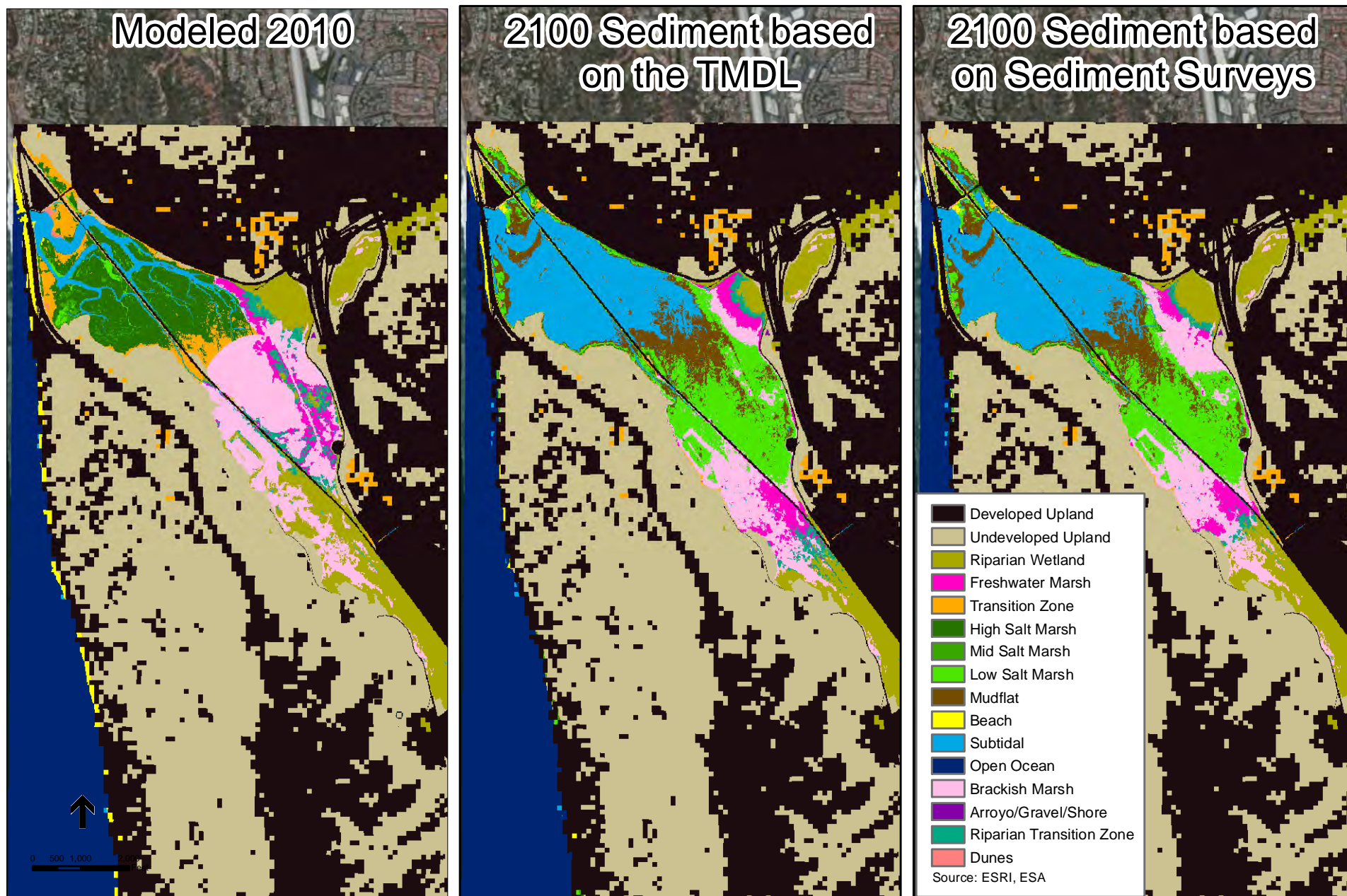


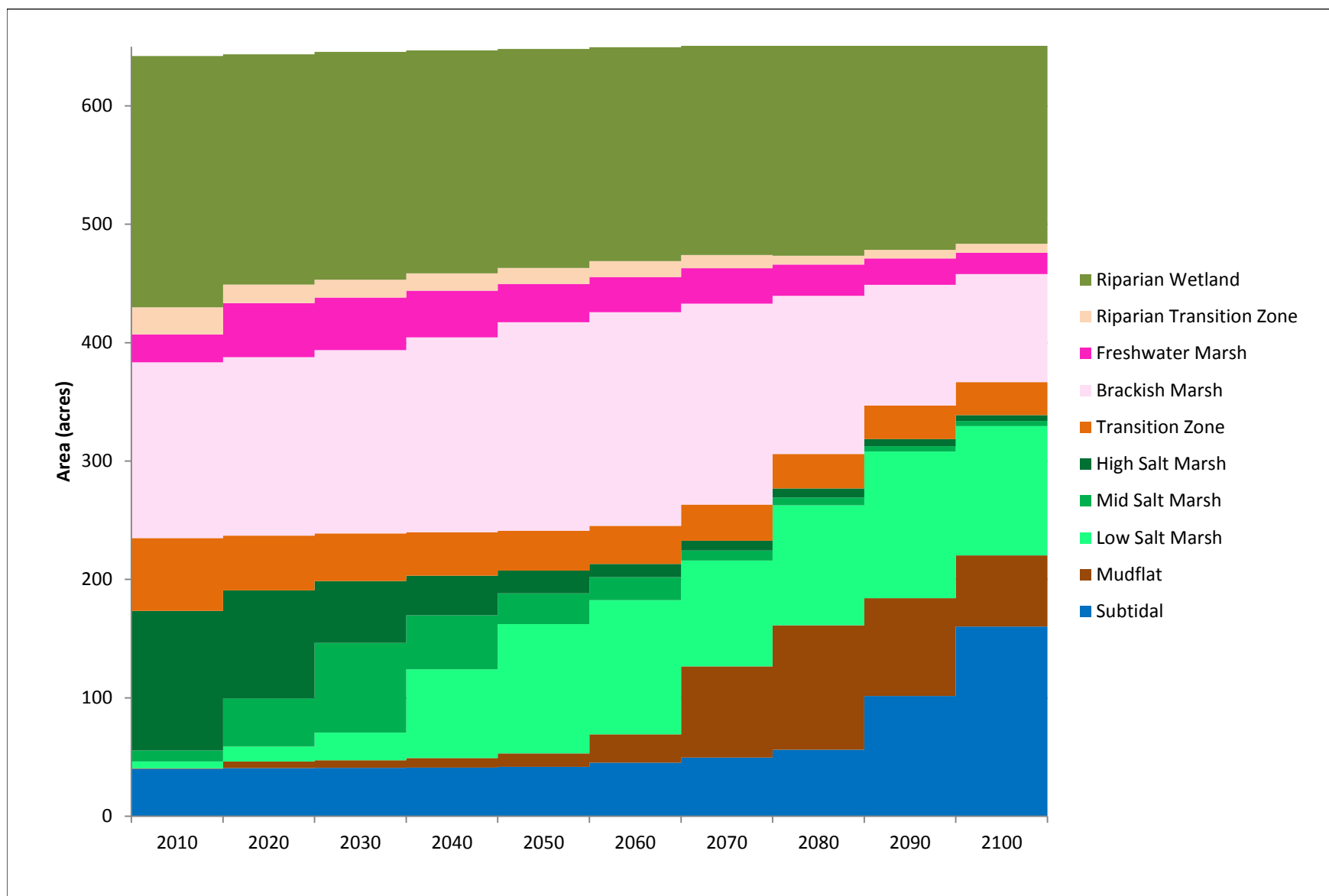
## 5.3 Sediment Load Curves

Table 10 compares the habitat acreage at 2100 for the modeled upper-end sediment loading (based on the sediment survey data; run 3) and the sediment loading, based on the TMDL (run 4). With less sediment, the habitats convert from riparian and brackish marsh to low salt marsh. However, the difference in sediment loading curves has a fairly minor effect on the habitat distribution under baseline or “no enhancement” conditions. This is because areas above tidal inundation are maintained above tidal elevations even with sea-level rise under both sediment loading scenarios. Figure 17 shows the 2100 habitat maps under the two sediment loading curves (predicted TMDL loads – run 4 and sediment surveys – run 3) compared to the 2010 modeled habitats. Figure 18 and Figure 19 show the habitat evolution over time for the run 3 and run 4 sediment loading curve respectively.

**TABLE 10**  
**HABITAT ACREAGES FOR SEDIMENT LOADING CURVES**

| Run                      | Modeled Acreage<br>in 2010 | Acreage in 2100         |                 | Difference<br>(Run 4 –Run 3) |
|--------------------------|----------------------------|-------------------------|-----------------|------------------------------|
|                          |                            | Run 3<br>(Sed. Surveys) | Run 4<br>(TMDL) |                              |
| Developed Upland         | 2550.9                     | 2550.9                  | 2550.9          | 0.0                          |
| Undeveloped Upland       | 2357.3                     | 2326.3                  | 2322.7          | 3.6                          |
| Riparian Wetland         | 212.1                      | 156.1                   | 175.7           | -19.6                        |
| Riparian Transition Zone | 22.9                       | 12.3                    | 7.5             | 4.8                          |
| Freshwater Marsh         | 23.6                       | 25.6                    | 18.0            | 7.6                          |
| Brackish Marsh           | 148.4                      | 77.3                    | 91.1            | -13.9                        |
| Transition Zone          | 61.5                       | 28.3                    | 27.9            | 0.4                          |
| High Salt Marsh          | 117.8                      | 4.6                     | 5.0             | -0.4                         |
| Mid Salt Marsh           | 9.3                        | 3.8                     | 4.3             | -0.5                         |
| Low Salt Marsh           | 5.9                        | 118.7                   | 109.3           | 9.4                          |
| Mudflat                  | 0.4                        | 69.3                    | 60.0            | 9.3                          |
| Subtidal                 | 40.0                       | 164.3                   | 160.3           | 4.1                          |
| Dunes                    | 1.1                        | 0.2                     | 0.2             | 0.0                          |
| Beach                    | 18.0                       | 6.6                     | 6.4             | 0.3                          |
| Arroyo/Gravel/Shore      | 2.9                        | 2.9                     | 2.9             | 0.0                          |
| Open Ocean               | 422.1                      | 427.7                   | 421.7           | 6.0                          |

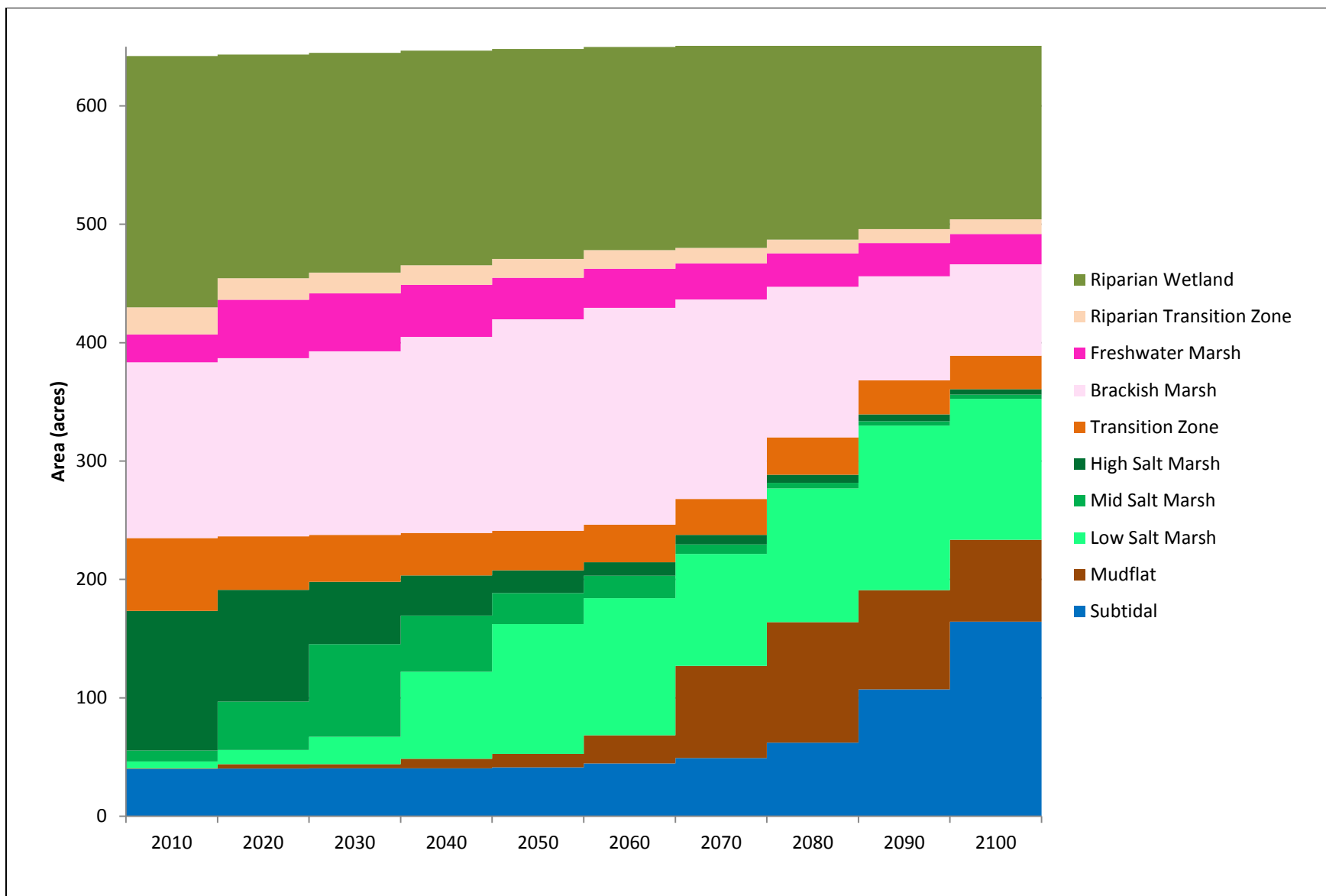




Los Peñasquitos Lagoon. D130136

**Figure 18**

Run 3 Habitats Over Time  
(Sediment Loading based on Sediment Surveys)



Los Peñasquitos Lagoon. D130136

**Figure 19**

Run 4 Habitats Over Time  
(Sediment Loading based on the TMDL)

## 5.4 Area of Freshwater Influence

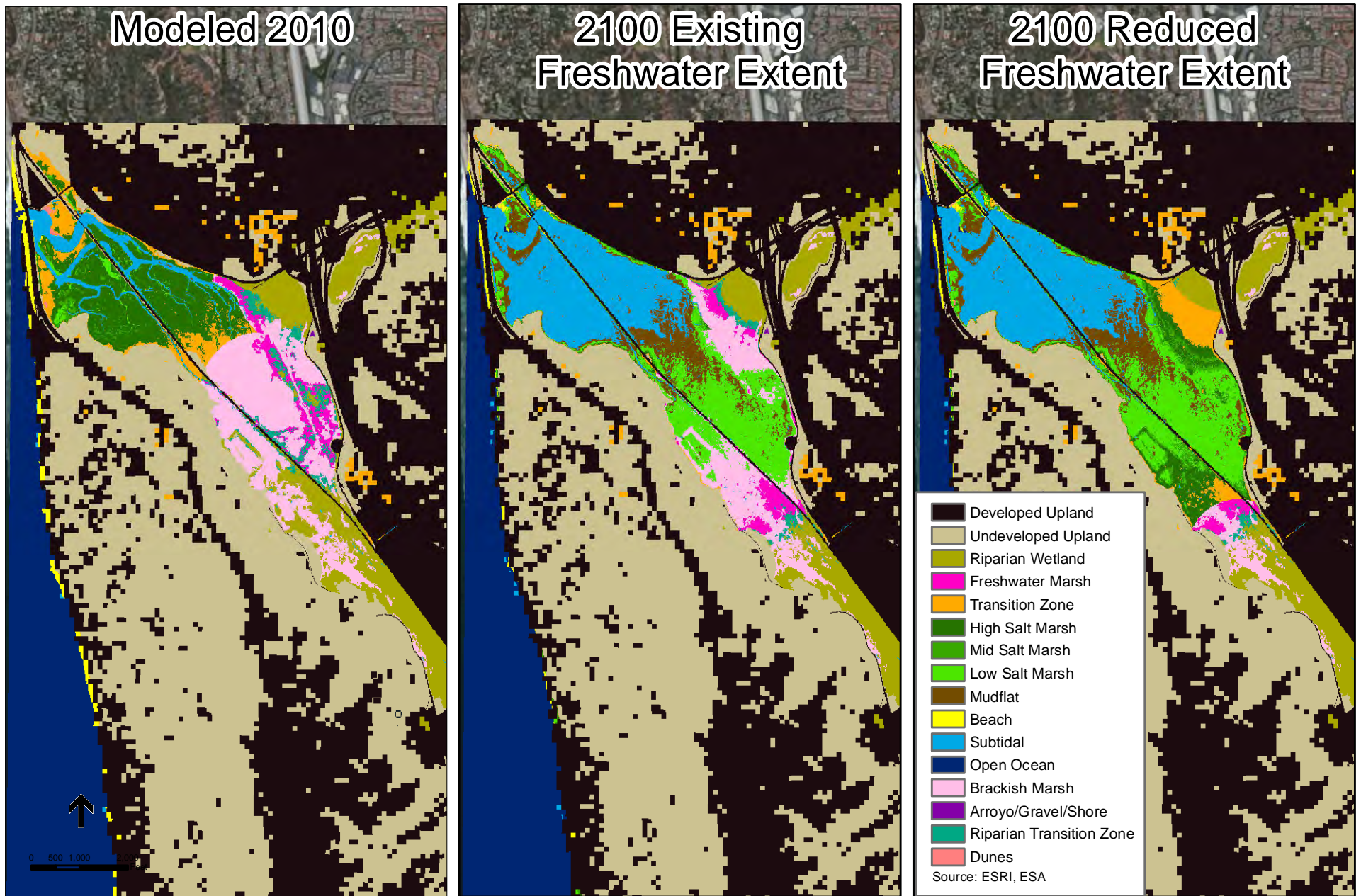
Table 11 provides the habitat acreage for run 3, which uses the existing extent of freshwater influence, and run 5, which has a reduced extent. With less freshwater, the habitats convert from freshwater influenced habitats (riparian, freshwater, brackish) to salt marsh habitats (high, mid, low salt marsh). Figure 20 shows the habitat maps with the existing and reduced areas of freshwater influences.

**TABLE 11  
HABITAT ACREAGES FOR AREA OF FRESHWATER INFLUENCE AND SEDIMENT LOAD  
SCENARIOS**

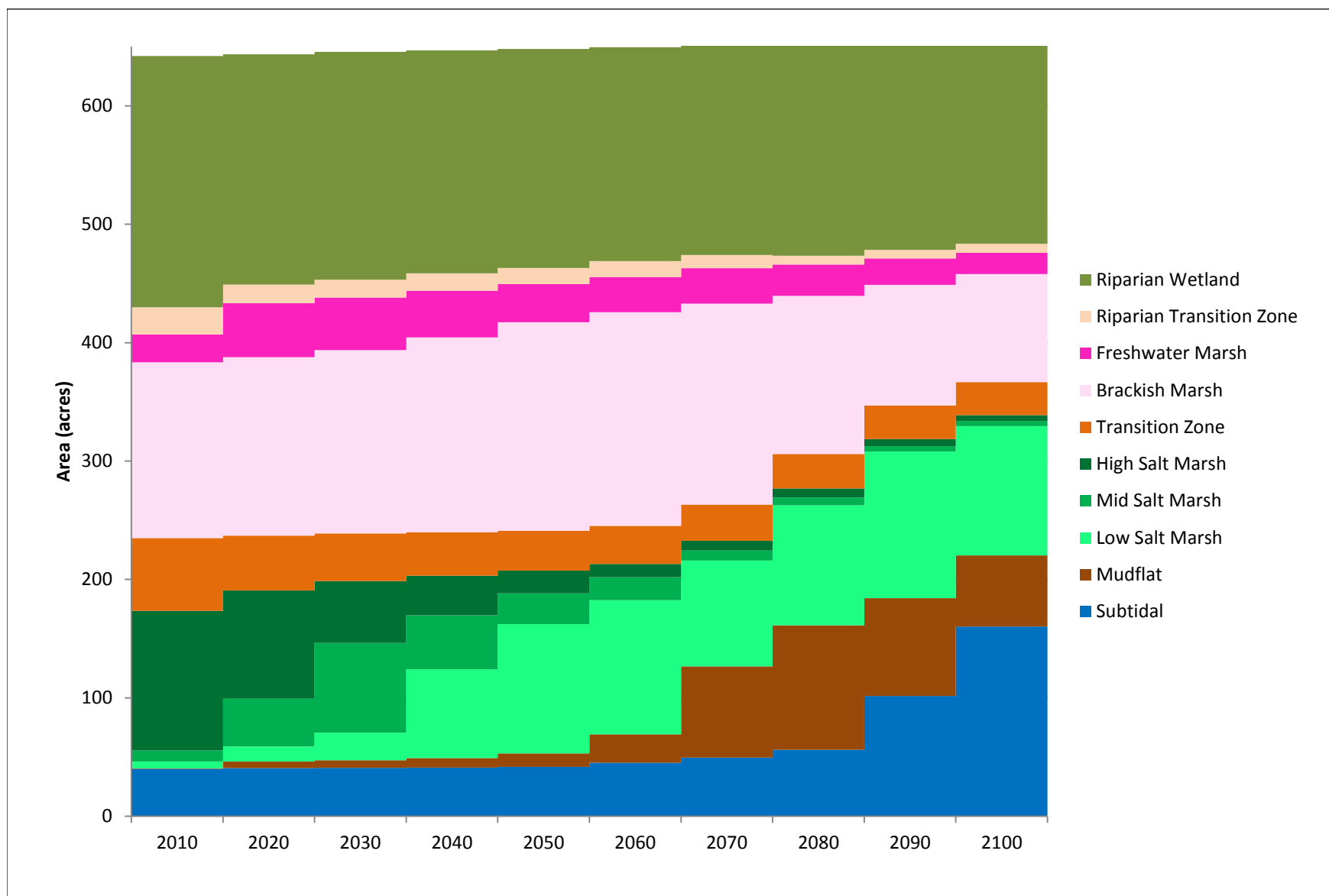
| Run                      | Modeled Acreage<br>in 2010 | Acreage in 2100 |         | Difference<br>(Reduced –<br>Existing) |
|--------------------------|----------------------------|-----------------|---------|---------------------------------------|
|                          |                            | Existing        | Reduced |                                       |
| Developed Upland         | 2550.9                     | 2550.9          | 2550.9  | 0.0                                   |
| Undeveloped Upland       | 2357.3                     | 2322.7          | 2322.7  | 0.0                                   |
| Riparian Wetland         | 212.1                      | 175.7           | 167.8   | -7.9                                  |
| Riparian Transition Zone | 22.9                       | 7.5             | 3.5     | -4.1                                  |
| Freshwater Marsh         | 23.6                       | 18.0            | 0.0     | -18.0                                 |
| Brackish Marsh           | 148.4                      | 91.1            | 26.6    | -64.6                                 |
| Transition Zone          | 61.5                       | 27.9            | 57.5    | 29.7                                  |
| High Salt Marsh          | 117.8                      | 5.0             | 40.1    | 35.1                                  |
| Mid Salt Marsh           | 9.3                        | 4.3             | 23.4    | 19.1                                  |
| Low Salt Marsh           | 5.9                        | 109.3           | 112.6   | 3.3                                   |
| Mudflat                  | 0.4                        | 60.0            | 60.0    | 0.0                                   |
| Subtidal                 | 40.0                       | 160.3           | 160.3   | 0.0                                   |
| Dunes                    | 1.1                        | 0.2             | 0.2     | 0.0                                   |
| Beach                    | 18.0                       | 6.4             | 6.4     | 0.0                                   |
| Arroyo/Gravel/Shore      | 2.9                        | 2.9             | 2.9     | 0.0                                   |
| Open Ocean               | 422.1                      | 421.7           | 421.7   | 0.0                                   |

Reducing the freshwater inflow allows salt marsh habitats to move upslope with sea level rise. Figure 21 and Figure 22, which show the habitats over time for the existing and reduced freshwater extents, illustrates how under reduced freshwater, the salt marsh acreage remains about the same over time, even when mudflat and subtidal habitats increase.





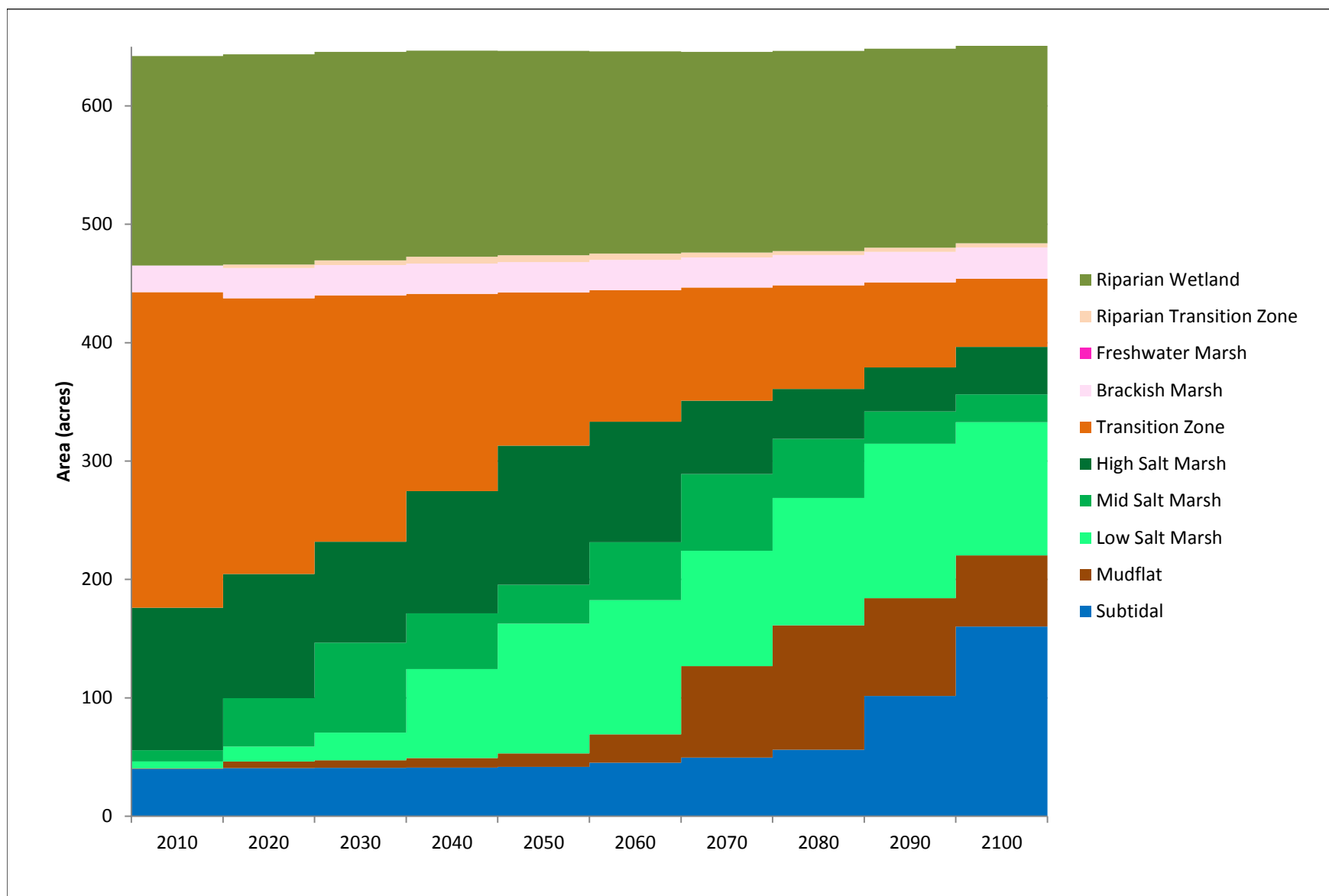




Los Peñasquitos Lagoon. D130136

**Figure 21**

Run 3 Habitats Over Time  
(Existing Freshwater Extent)



Los Peñasquitos Lagoon. D130136  
**Figure 22**  
 Run 5 Habitats Over Time  
 (Reduced Freshwater Extent)

## 6. Discussion

The GIS model provides a look into the future at the different habitat types that may occupy Los Peñasquitos Lagoon. It can model different levels of sea-level rise, sediment loading curves, and extents of freshwater input. The results presented here look at the base conditions at Los Peñasquitos and predict or project future conditions without any restoration in the Lagoon. It is expected that discussions with the project team will lead to a revised list of runs to evaluate future scenarios.

### 6.1 Model Calibration

The current model setup captures many of the habitat categories very well with a few exceptions:

- **New habitat categories.** Riparian transition zone was added into the habitat decision tree to account for areas that would be transitioning between riparian and freshwater marsh habitats. This category could be eliminated if it is determined unnecessary for the analysis at Los Peñasquitos.
- **The model assumes vegetation has fully responded to physical processes.** As freshwater increased in the lagoon, brackish and freshwater marsh species have established in areas that were previously salt marsh. However, some remnant salt marsh remains. The model assumes this salt marsh will convert to brackish and freshwater marsh, which is likely, given the physical factors. However, the model does not account for the time this will take.

Similarly, unvegetated areas in the marsh are assumed to vegetate in the model. If it is assumed that some small portion of the marsh will always remain unvegetated, the results could be post-processed to include a certain percent of each marsh type as unvegetated mudflat or salt pan.

- **Salt marsh elevations in the lagoon are higher relative to tidal datums than reflected in the model.** Most of the salt marsh at Los Peñasquitos Lagoon was mapped as mid marsh species and is at elevations above MHHW. This may be a result of inundation and sediment deposition during storm events, when Lagoon water levels are elevated above tide levels by storm flows. It could also be an artifact of extended inlet closures, which would also raise Lagoon water levels above tide levels. The habitat evolution tree could be adjusted to account for these higher elevations, if desired.

### 6.2 Sea-Level Rise

As expected, the different sea-level rise curves provided different results. Under low sea-level rise, salt marsh acreage actually increases as it shifts from transition zone and high marsh to a larger area of mid marsh. Under mid sea-level rise, most of the salt marsh converts to low salt marsh. There is an overall loss of salt marsh under the high sea-level rise, as habitat converts to mudflat and subtidal. Since rates of sea-level rise still remain uncertain, future model runs should include multiple scenarios.

## 6.3 Sediment Load

The model suggests that the continued change of habitats under baseline conditions (without Lagoon restoration) is not sensitive to the sediment load, although both scenarios assumed a decrease in sediment load over time due to the TMDL. Since large fans already exist in the topography near the creek mouths, the additional sediment is expected to spread out over the fan and further increase the elevation of the fan, with only a slight increase in the extent of the fan. However, sediment loading should still be considered in future model runs that involve restoration that changes the existing topography. For example, restoration alternatives that remove alluvial sediment to restore salt marsh would need to consider the impact of re-deposition of alluvial sediment and conversion of restored marsh to brackish and other habitat types. The incoming sediment load could become a more important process in the model, since low sediment might not affect the marsh, but high sediment could raise the ground out of marshplain elevations once again. It's recommended that future runs include a range of sediment loads to account for this as sedimentation could still be a significant consideration in enhancement planning.

## 6.4 Freshwater Influence

The extent of freshwater has the largest influence on the habitats found in 2100. It is important to note that the reduced polygon was chosen to represent a lower end of freshwater influence and is not based on some percent reduction in freshwater flow rates. However, the model results show the importance of freshwater influence on habitat conversions. Without a reduction in freshwater inflow or a way to limit the marsh area that is influenced by freshwater, salt marsh cannot be restored until elevations drop below MHW. Under future restoration alternatives, continued dry-weather freshwater flows will likely impact any restored areas.

The freshwater module of the model should be refined as more data becomes available, so that the extent of freshwater influence can be connected to freshwater inflow. A hydrodynamic model will be required to model freshwater flows and salinity.

## 7. References

- AECOM, California Department of Fish and Game, and Conservation Biology Institute. First Edition. 2011. *Vegetation Classification Manual for Western San Diego County*.
- Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT). 2013. State of California Sea-Level Rise Guidance Document. March 2013.
- Coastal Environments. 2003. *Report #9. Monitoring Program for the Los Peñasquitos, Lagoon Hydrodynamics*. Final report prepared for the Los Peñasquitos Lagoon Foundation.
- Cole, K. and E. Wahl. 2000. *A Late Holocene Paleoeological Record from Torrey Pines State Reserve, California*. Quaternary Research. University of Washington. 53:341-451.
- ESA PWA. 2011. *Los Peñasquitos Watershed Geomorphic and Sediment Transport Assessment*. A report prepared for the Storm Water Department of the City of San Diego.
- Federal Emergency Management Agency. San Diego, CA. 2012. *Flood Insurance Study*. Flood Insurance Study Number 06073CV001C.
- Los Peñasquitos Lagoon Foundation and State Coastal Conservancy. 1985. Los Peñasquitos Lagoon Enhancement Plan and Program.
- National Oceanic and Atmospheric Administration. 2014. Tide Predictions. San Diego, CA Tidal Data Daily View, Station Id: 9410170.
- National Research Council. 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington*. June 2012.
- San Diego Regional Water Quality Control Board. 2013. National Pollutant Discharge Elimination System (NPDES) Permit and Waste Discharge Requirements for Discharged from the Municipal Separate Storm Sewer Systems (MS4s) Draining the Watersheds within the San Diego Region. May 8, 2013.
- San Francisco Estuary Institute. September 2014. *Northern San Diego County Lagoons Historical Ecology Investigation*.
- Tetra Tech. 2010. Los Peñasquitos Lagoon Sediment/Siltation TMDL, Attachment 1, Technical Support Document to the Staff Report for the Sediment TMDL for Los Peñasquitos Lagoon. Prepared for the City of San Diego, Storm Water Department and US EPA. October 20, 2010.
- Tijuana River National Estuarine Research Reserve (TRNERR). 2012. *The Physical, Chemical, and Biological Monitoring of Los Peñasquitos Lagoon*.
- U.S. Fish and Wildlife Service, Division of Habitat and Resource Conservation. Version 2.0. Arlington, VA. 2011. *Sea Level Affecting Marshes Model (SLAMM)*.
- Weston Solutions, Inc. 2009. *Los Peñasquitos Lagoon TMDL – Watershed Phase I Sediment Source Identification Study for the Los Peñasquitos Watershed*. Final Report prepared for the City of San Diego.

White, M and K. Greer. 2006. *The Effects of Watershed Urbanization on the Stream Hydrology and Riparian Vegetation of Los Peñasquitos Creek, California*. Landscape and Urban Planning 74 (2006) 125-138.



## 8. List of Preparers

This report was prepared by the following ESA staff:

Lindsey Sheehan, P.E.

Nick Garrity, P.E.

David Pohl, P.E.

# Appendix A

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## Vegetation Cross-Walk

### **Developed Uplands**

Concrete, Asphalt, Structures, Irrigated Landscaping, Gravel or Frequently Maintained Dirt Roads

### **Undeveloped Uplands**

Native upland vegetation

Non-native upland vegetation (not landscaping)

Dirt Lots/Ruderal Vegetation

### **Riparian Wetlands**

Tree or Shrub dominated riparian vegetation

VCMWSD Types: *Baccharis salicifolia* classification, *Salix goodingii* Association, *Salix lasiolepis* Association, *Iva hayesiana* Special Stands.

Also Included are Non-native stands of *Arundo donax*, *Cortedaria selloana*, *Tamarix* spp., *Washingtonia filifera*, *Catalpa bignonioides*, etc.

### **Freshwater Marsh**

Freshwater Herbaceous vegetation mostly tall, perennial monocots.

VCMWSD Types: *Typha* Alliance, *Shoenoplectus acutus* Association, *Shoenoplectus americanus* Association, *Schoenoplectus californicus* Alliance, Natural Warm-Temperate Riparian and Wetland Semi-Natural Stands, *Juncus xiphioides* Association

### **Transition Zone**

Wetland to Upland transition areas usually mix of facultative wetland and upland species. There is relatively little of this habitat mapped at LPL maybe because of the large urban edge on the northeastern edge and the steep land on the southwest.

VCMWSD Types: *Isocoma menziesii*-*Distichlis spicata*, *Distichlis spicata*-Annual Grass Association. Also *Distichlis spicata*-Annual Grass Association with *Carpobrotus edulis*, *Pluchea serecia* Association.

### **High Salt Marsh**

Usually not inundated. *Frankenia salina* usually dominant, *Distichlis spicata* present

VCMWSD Types: *Frankenia salina*-*Distichlis spicata* Association, *Frankenia salina* Alliance, *Arthrocnemum subterminale*-*Sarcoconia pacifica* Association, *Arthrocnemum subterminale*-Association

### **Brackish Marsh**

A difficult type to delineate class that indicates type conversion from Salt Marsh to Brackish or freshwater types both native and non-native. Largest extent is from Saltmarsh being invaded by *Lolium perenne*. Usually has *Frankenia salina* and *Sarcocornia pacifica* present.

VCMWSD Types: *Lolium perenne* Semi-Natural Stands, *Bolboschoenus maritimus* Association, *Anemopsis californica* Alliance, *Juncus acutus* Provisional Association \*(90% *Juncus* sp).

### **Mid Salt Marsh**

We made this one up. Seems distinctive between mudflat, and all *Sarcocornia pacifica* and the High Saltmarsh types.

VCMWSD Types: *Sarcocornia pacifica*-*Frankenia salina* Association

### **Mid/Low Salt Marsh**

Lowest vegetated Marsh usually dominated by *Sarcocornia pacifica* or *Jumea carnos*. Outside of tidal areas occurs in low spots that are impounded (maybe evaporated) freshwater areas

VCMWSD Types: *Sarcocornia pacifica* Association, *Juncus acutus*-*Jaumea carnos* Provisional Association

### **Tidal Channel**

Interpreted from 2013 high tide photo. Dark Water. Probably not exposed during average low tide

### **Mud Flat**

Interpreted from 2013 high tide photo and 2011 Mid-Tide photo. Brown Colored Water. Probably exposed during average low tide.

### **Brackish Pond**

Shallow pond that is inundated for much of the year and does not support emergent freshwater vegetation. Surrounded by Brackish Marsh or non-tidal Saltmarsh

### **Salt Pan**

Shallow pond that is dry for much of the year and does not support emergent freshwater vegetation. Surrounded by saltmarsh vegetation supports

### **Open Water**

Unvegetated freshwater

### **Dunes**

Vegetated Sand Dunes

VCMWSD Types: *Ambrosia chamissonis*-*Abronia maritima*-*Cakile maritima* Association

### **Coastal Strand**

Unvegetated Sandy Areas

## **Appendix B**

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### **Habitat Acreage Tables**

### Run 1 - Low Sea-Level Rise

[illegible]



## Run 2 - Mid Sea-Level Rise

|                          | 2010   | 2010   | 2020   | 2030   | 2040   | 2050   | 2060   | 2070   | 2080   | 2090   | 2100   |
|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Developed Upland         | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 |
| Undeveloped Upland       | 2360.8 | 2357.3 | 2354.0 | 2345.5 | 2344.7 | 2344.2 | 2337.0 | 2336.1 | 2335.2 | 2333.9 | 2331.9 |
| Riparian Wetland         | 212.1  | 212.1  | 197.8  | 197.2  | 194.3  | 193.2  | 191.3  | 188.0  | 188.7  | 186.9  | 186.2  |
| Freshwater Marsh         | 56.5   | 23.6   | 44.2   | 43.7   | 45.5   | 45.2   | 42.4   | 37.9   | 33.0   | 31.7   | 29.6   |
| Transition Zone          | 26.5   | 61.5   | 56.5   | 51.0   | 45.2   | 41.3   | 38.0   | 35.1   | 33.0   | 31.5   | 30.6   |
| High Salt Marsh          | 45.2   | 117.8  | 113.2  | 110.0  | 85.6   | 57.2   | 41.4   | 29.2   | 19.6   | 13.6   | 11.4   |
| Mid Salt Marsh           | 166.7  | 9.3    | 13.7   | 23.1   | 51.1   | 79.1   | 79.9   | 48.5   | 34.0   | 28.3   | 19.6   |
| Low Salt Marsh           | 0.0    | 5.9    | 9.8    | 10.1   | 13.4   | 18.2   | 34.5   | 82.0   | 107.5  | 120.7  | 130.1  |
| Mudflat                  | 11.8   | 0.4    | 2.7    | 2.8    | 2.1    | 2.1    | 4.9    | 4.4    | 6.0    | 7.9    | 13.7   |
| Beach                    | 22.6   | 18.0   | 15.0   | 15.4   | 13.5   | 13.4   | 13.3   | 11.8   | 10.7   | 9.6    | 8.7    |
| Subtidal                 | 39.5   | 40.0   | 40.4   | 40.4   | 40.4   | 40.5   | 40.5   | 40.6   | 40.6   | 41.0   | 42.0   |
| Open Ocean               | 415.7  | 422.1  | 418.4  | 417.6  | 413.5  | 413.6  | 412.9  | 414.5  | 415.5  | 416.8  | 417.8  |
| Brackish Marsh           | 82.1   | 148.4  | 149.3  | 150.0  | 151.0  | 153.0  | 158.2  | 166.9  | 173.8  | 176.9  | 177.9  |
| Arroyo/Gravel/Shore      | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    |
| Riparian Transition Zone | 0.0    | 22.9   | 15.4   | 15.6   | 15.9   | 15.4   | 14.7   | 14.2   | 11.5   | 10.6   | 9.8    |
| Dunes                    | 1.1    | 1.1    | 1.0    | 1.0    | 1.0    | 1.0    | 1.0    | 1.0    | 0.9    | 0.8    | 0.7    |

**Run 3- High Sea-Level Rise, High Sediment Loading, Existing Freshwater Extent**

|                          | 2010   | 2010   | 2020   | 2030   | 2040   | 2050   | 2060   | 2070   | 2080   | 2090   | 2100   |
|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Developed Upland         | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 |
| Undeveloped Upland       | 2360.8 | 2357.3 | 2353.4 | 2344.1 | 2342.7 | 2341.4 | 2333.0 | 2330.6 | 2328.7 | 2326.0 | 2322.7 |
| Riparian Wetland         | 212.1  | 212.1  | 194.4  | 192.3  | 188.2  | 185.0  | 180.6  | 177.8  | 180.3  | 177.9  | 175.7  |
| Freshwater Marsh         | 56.5   | 23.6   | 45.7   | 44.3   | 39.5   | 32.3   | 29.7   | 29.9   | 26.5   | 22.5   | 18.0   |
| Transition Zone          | 26.5   | 61.5   | 46.0   | 40.2   | 36.7   | 33.6   | 32.3   | 30.7   | 29.2   | 28.3   | 27.9   |
| High Salt Marsh          | 45.2   | 117.8  | 91.4   | 52.2   | 33.5   | 19.3   | 11.1   | 8.2    | 7.6    | 6.1    | 5.0    |
| Mid Salt Marsh           | 166.7  | 9.3    | 40.5   | 75.7   | 45.5   | 26.0   | 19.4   | 8.6    | 6.6    | 4.6    | 4.3    |
| Low Salt Marsh           | 0.0    | 5.9    | 12.7   | 23.4   | 75.1   | 109.2  | 113.4  | 89.2   | 101.4  | 123.9  | 109.3  |
| Mudflat                  | 11.8   | 0.4    | 5.5    | 6.2    | 8.0    | 11.3   | 23.9   | 77.1   | 105.1  | 82.5   | 60.0   |
| Beach                    | 22.6   | 18.0   | 13.4   | 13.8   | 10.9   | 10.7   | 10.8   | 9.1    | 8.2    | 7.3    | 6.4    |
| Subtidal                 | 39.5   | 40.0   | 40.8   | 41.0   | 41.1   | 41.8   | 45.3   | 49.6   | 56.1   | 101.6  | 160.3  |
| Open Ocean               | 415.7  | 422.1  | 420.1  | 419.3  | 416.3  | 416.5  | 415.9  | 418.0  | 419.1  | 420.4  | 421.7  |
| Brackish Marsh           | 82.1   | 148.4  | 150.8  | 155.0  | 164.6  | 176.0  | 180.5  | 169.7  | 133.5  | 101.8  | 91.1   |
| Arroyo/Gravel/Shore      | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    |
| Riparian Transition Zone | 0.0    | 22.9   | 15.7   | 15.1   | 14.6   | 13.6   | 13.5   | 11.0   | 7.3    | 7.1    | 7.5    |
| Dunes                    | 1.1    | 1.1    | 1.0    | 1.0    | 0.9    | 0.9    | 0.8    | 0.7    | 0.4    | 0.3    | 0.2    |

#### Run 4- Low Sediment Loading

|                          | 2010   | 2010   | 2020   | 2030   | 2040   | 2050   | 2060   | 2070   | 2080   | 2090   | 2100   |
|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Developed Upland         | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 |
| Undeveloped Upland       | 2360.8 | 2357.3 | 2354.1 | 2352.4 | 2350.4 | 2348.9 | 2345.1 | 2341.4 | 2331.6 | 2329.2 | 2326.3 |
| Riparian Wetland         | 212.1  | 212.1  | 188.8  | 185.5  | 181.1  | 177.2  | 171.5  | 171.6  | 168.5  | 161.7  | 156.1  |
| Freshwater Marsh         | 56.5   | 23.6   | 49.4   | 49.0   | 43.9   | 35.3   | 33.0   | 30.4   | 28.3   | 28.0   | 25.6   |
| Transition Zone          | 26.5   | 61.5   | 45.3   | 39.7   | 36.1   | 33.4   | 31.7   | 30.2   | 31.6   | 28.9   | 28.3   |
| High Salt Marsh          | 45.2   | 117.8  | 94.4   | 52.6   | 33.8   | 19.3   | 11.3   | 8.2    | 6.8    | 5.7    | 4.6    |
| Mid Salt Marsh           | 166.7  | 9.3    | 40.8   | 78.3   | 47.5   | 26.2   | 18.9   | 7.9    | 4.8    | 3.7    | 3.8    |
| Low Salt Marsh           | 0.0    | 5.9    | 11.9   | 23.0   | 73.6   | 109.6  | 115.9  | 94.6   | 113.0  | 139.0  | 118.7  |
| Mudflat                  | 11.8   | 0.4    | 3.7    | 3.7    | 7.9    | 11.4   | 23.6   | 77.8   | 101.7  | 83.8   | 69.3   |
| Beach                    | 22.6   | 18.0   | 15.3   | 13.9   | 10.3   | 10.1   | 9.2    | 8.1    | 9.1    | 7.4    | 6.6    |
| Subtidal                 | 39.5   | 40.0   | 40.4   | 40.4   | 40.5   | 41.2   | 44.7   | 49.2   | 62.2   | 107.2  | 164.3  |
| Open Ocean               | 415.7  | 422.1  | 424.1  | 425.6  | 423.2  | 423.4  | 423.8  | 424.3  | 424.5  | 426.6  | 427.7  |
| Brackish Marsh           | 82.1   | 148.4  | 150.4  | 154.9  | 165.6  | 178.5  | 183.2  | 168.6  | 127.1  | 87.9   | 77.3   |
| Arroyo/Gravel/Shore      | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    |
| Riparian Transition Zone | 0.0    | 22.9   | 18.1   | 17.7   | 16.5   | 15.8   | 15.8   | 13.1   | 11.5   | 11.7   | 12.3   |
| Dunes                    | 1.1    | 1.1    | 1.0    | 1.0    | 0.9    | 0.9    | 0.8    | 0.7    | 0.3    | 0.3    | 0.2    |

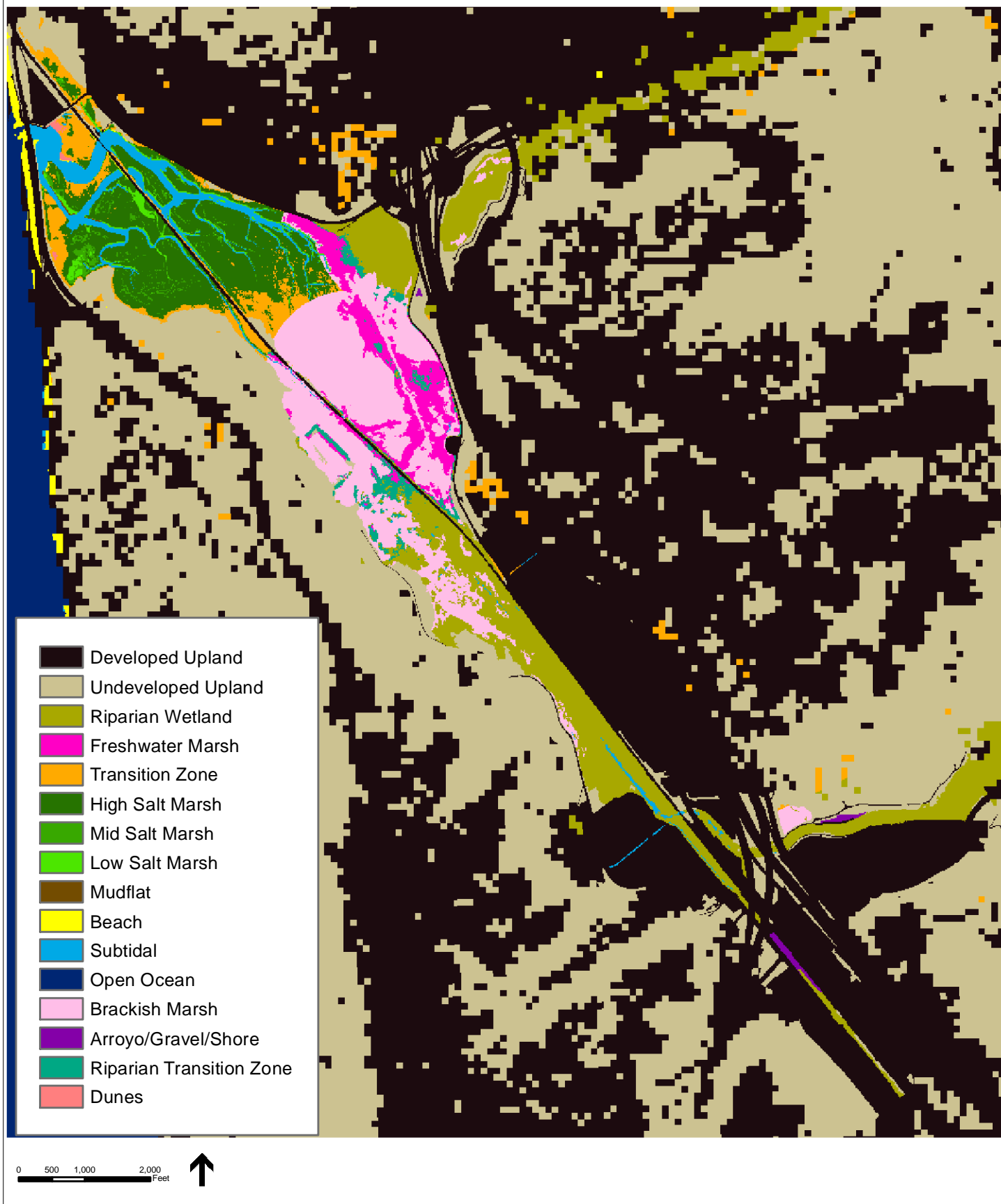
**Run 5- Reduced Freshwater Extent**

|                          | 2010   | 2010   | 2020   | 2030   | 2040   | 2050   | 2060   | 2070   | 2080   | 2090   | 2100   |
|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Developed Upland         | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 | 2550.9 |
| Undeveloped Upland       | 2360.8 | 2357.3 | 2353.4 | 2344.1 | 2342.7 | 2341.4 | 2333.0 | 2330.6 | 2328.7 | 2326.0 | 2322.7 |
| Riparian Wetland         | 212.1  | 176.7  | 177.6  | 176.0  | 174.1  | 172.5  | 170.6  | 169.4  | 169.0  | 168.1  | 167.8  |
| Freshwater Marsh         | 56.5   | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| Transition Zone          | 26.5   | 266.5  | 232.8  | 208.1  | 166.5  | 129.4  | 111.0  | 95.4   | 87.4   | 71.9   | 57.5   |
| High Salt Marsh          | 45.2   | 120.4  | 105.1  | 85.2   | 103.2  | 117.5  | 101.9  | 62.0   | 42.3   | 37.1   | 40.1   |
| Mid Salt Marsh           | 166.7  | 9.4    | 40.7   | 76.0   | 47.2   | 32.9   | 48.9   | 64.8   | 50.0   | 27.3   | 23.4   |
| Low Salt Marsh           | 0.0    | 5.9    | 12.7   | 23.4   | 75.1   | 109.5  | 113.4  | 97.5   | 107.5  | 130.5  | 112.6  |
| Mudflat                  | 11.8   | 0.4    | 5.5    | 6.2    | 8.0    | 11.4   | 23.9   | 77.2   | 105.1  | 82.5   | 60.0   |
| Beach                    | 22.6   | 18.0   | 13.4   | 13.8   | 10.9   | 10.7   | 10.8   | 9.1    | 8.2    | 7.3    | 6.4    |
| Subtidal                 | 39.5   | 40.0   | 40.8   | 41.0   | 41.1   | 41.8   | 45.3   | 49.6   | 56.1   | 101.6  | 160.3  |
| Open Ocean               | 415.7  | 422.1  | 420.1  | 419.3  | 416.3  | 416.5  | 415.9  | 418.0  | 419.1  | 420.4  | 421.7  |
| Brackish Marsh           | 82.1   | 22.6   | 25.6   | 25.6   | 25.6   | 25.6   | 25.6   | 25.6   | 25.6   | 25.7   | 26.6   |
| Arroyo/Gravel/Shore      | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    | 2.9    |
| Riparian Transition Zone |        | 0.0    | 2.8    | 4.0    | 5.8    | 5.9    | 5.4    | 4.1    | 3.4    | 3.5    | 3.5    |
| Dunes                    | 0.0    | 1.1    | 1.0    | 1.0    | 0.9    | 0.9    | 0.8    | 0.7    | 0.4    | 0.3    | 0.2    |

## **Appendix C**

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### **Habitat Maps**

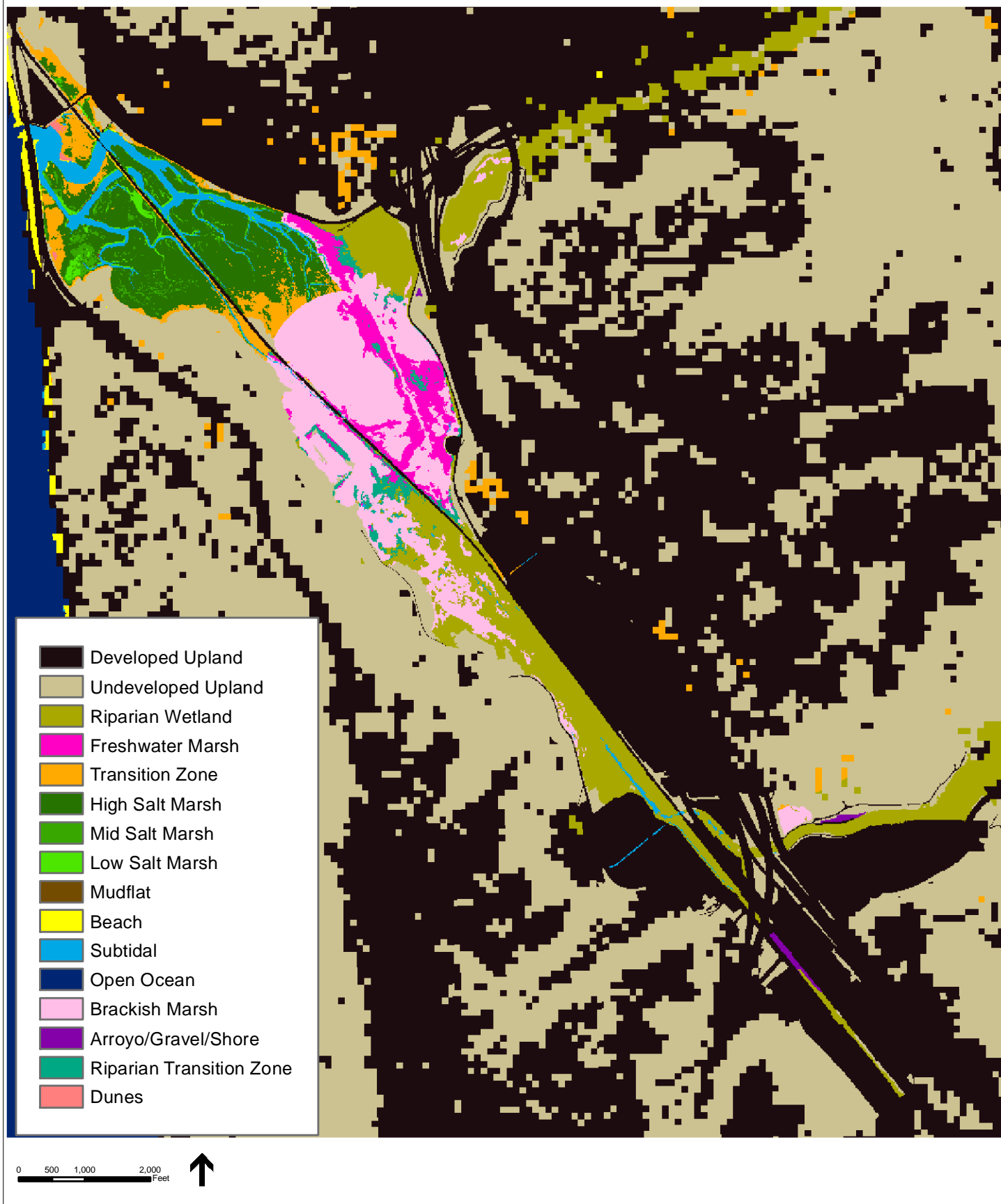


Los Peñasquitos Lagoon, D130136

**Figure 1**

Run 1, 2020 Habitats

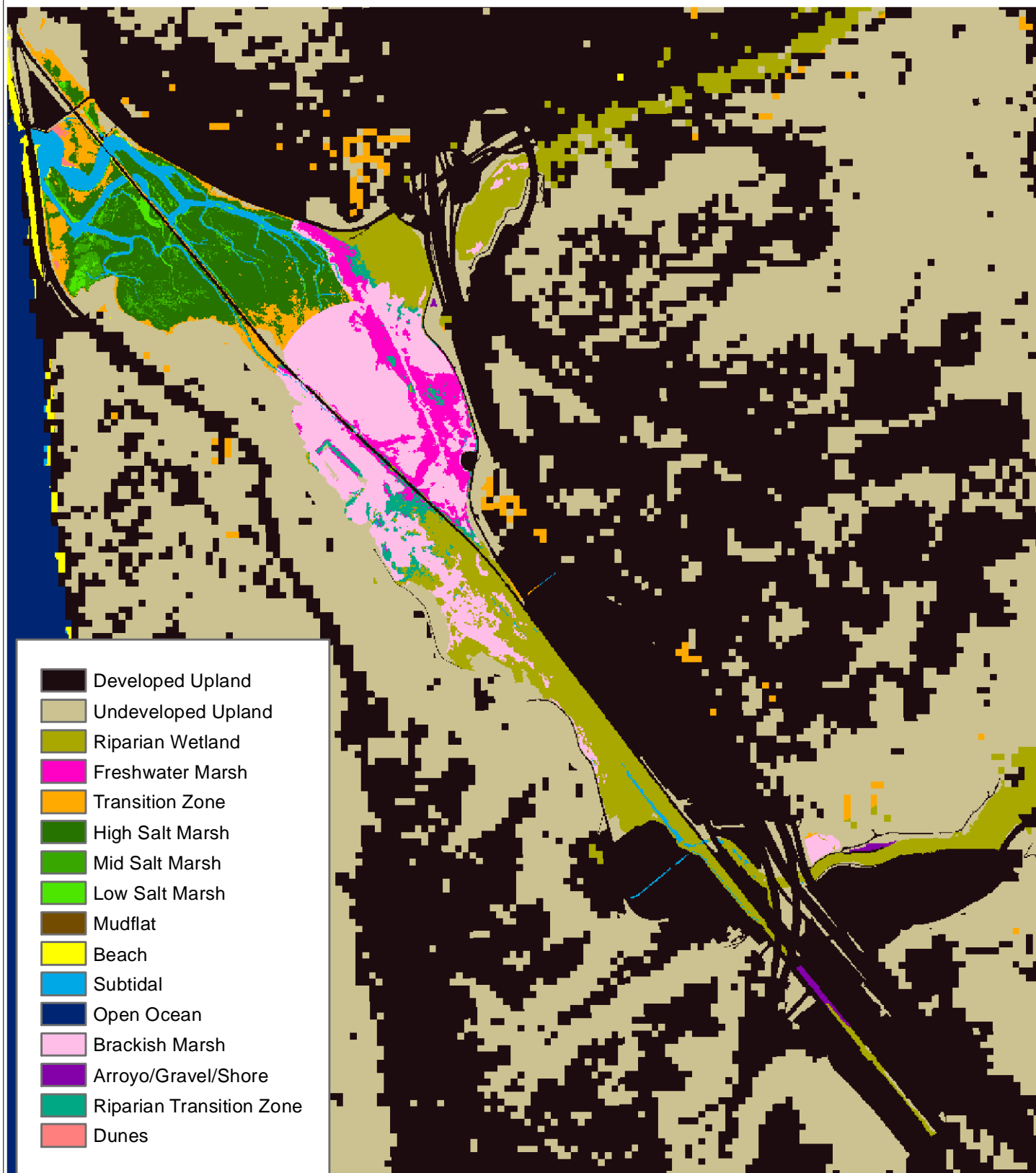


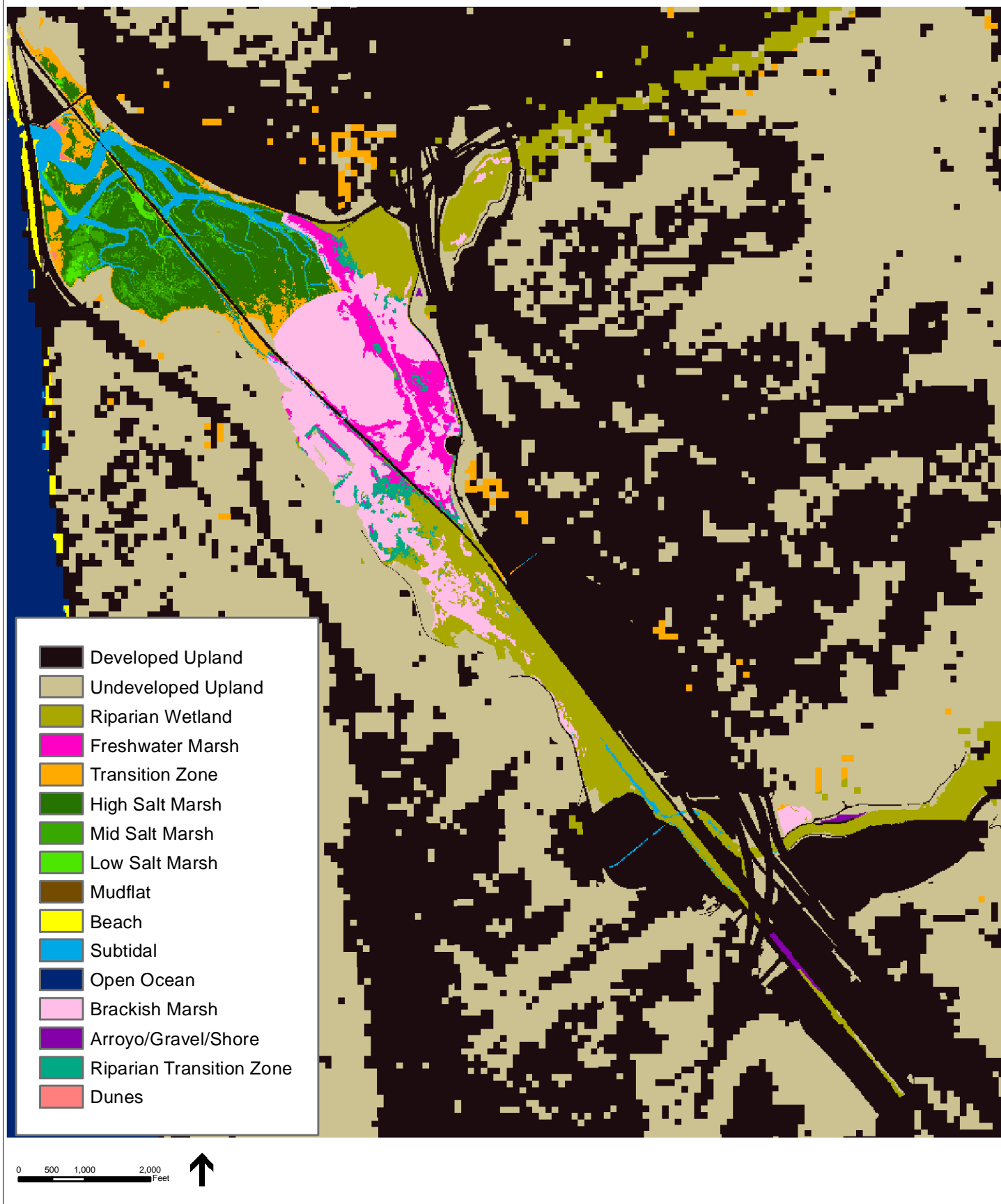


Los Peñasquitos Lagoon, D130136

**Figure 2**

Run 1, 2030 Habitats

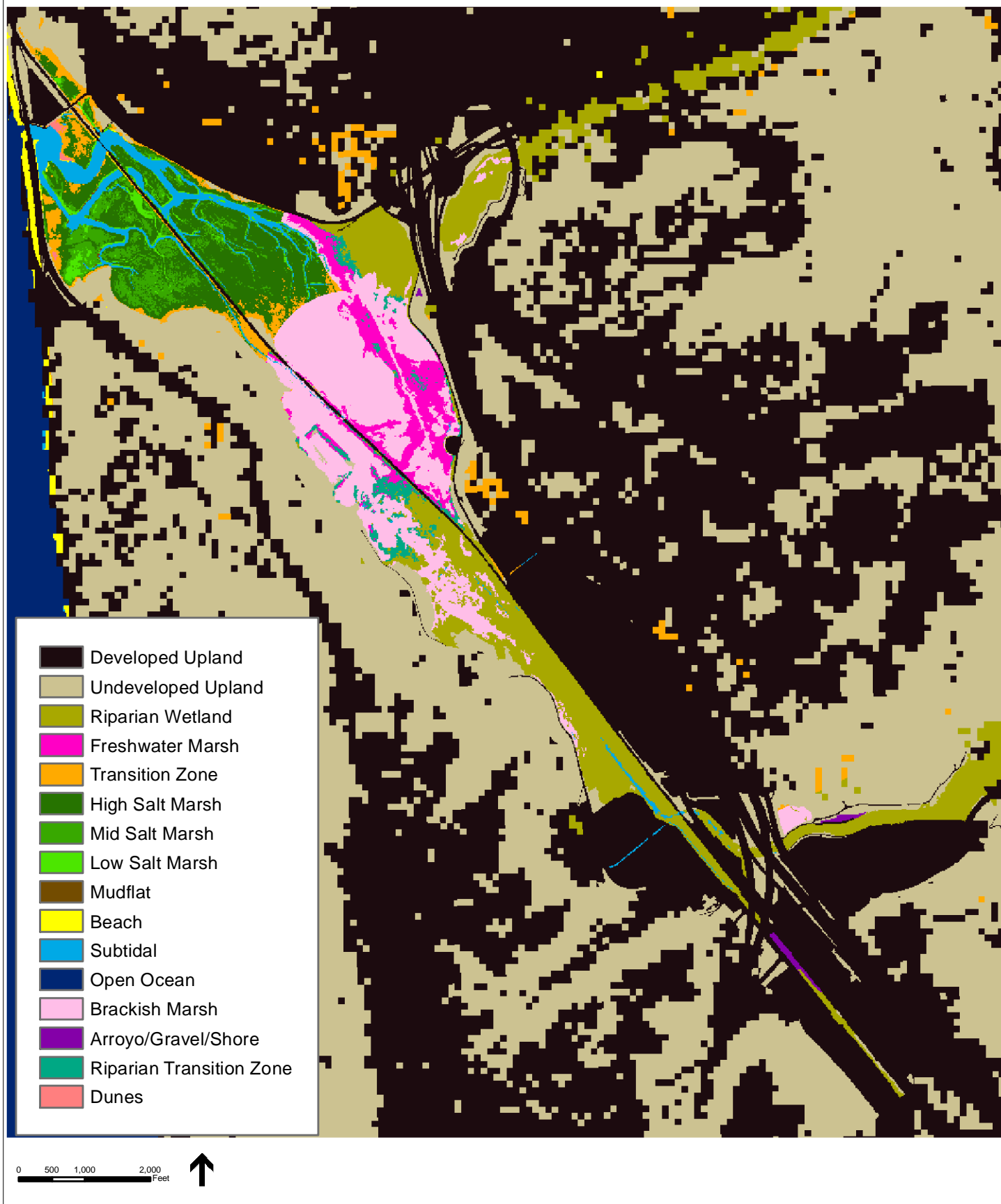




Los Peñasquitos Lagoon, D130136

**Figure 4**

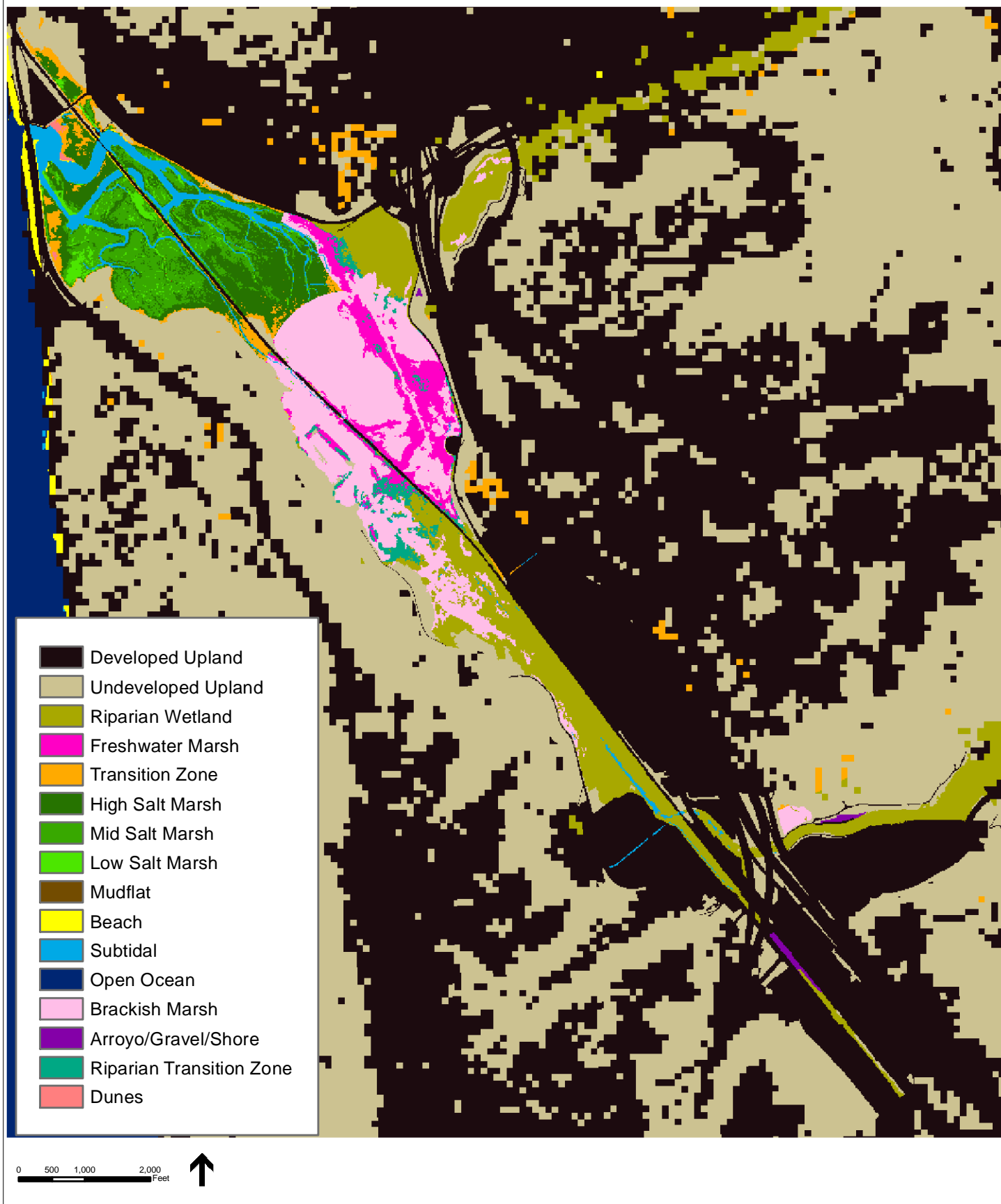
Run 1, 2050 Habitats

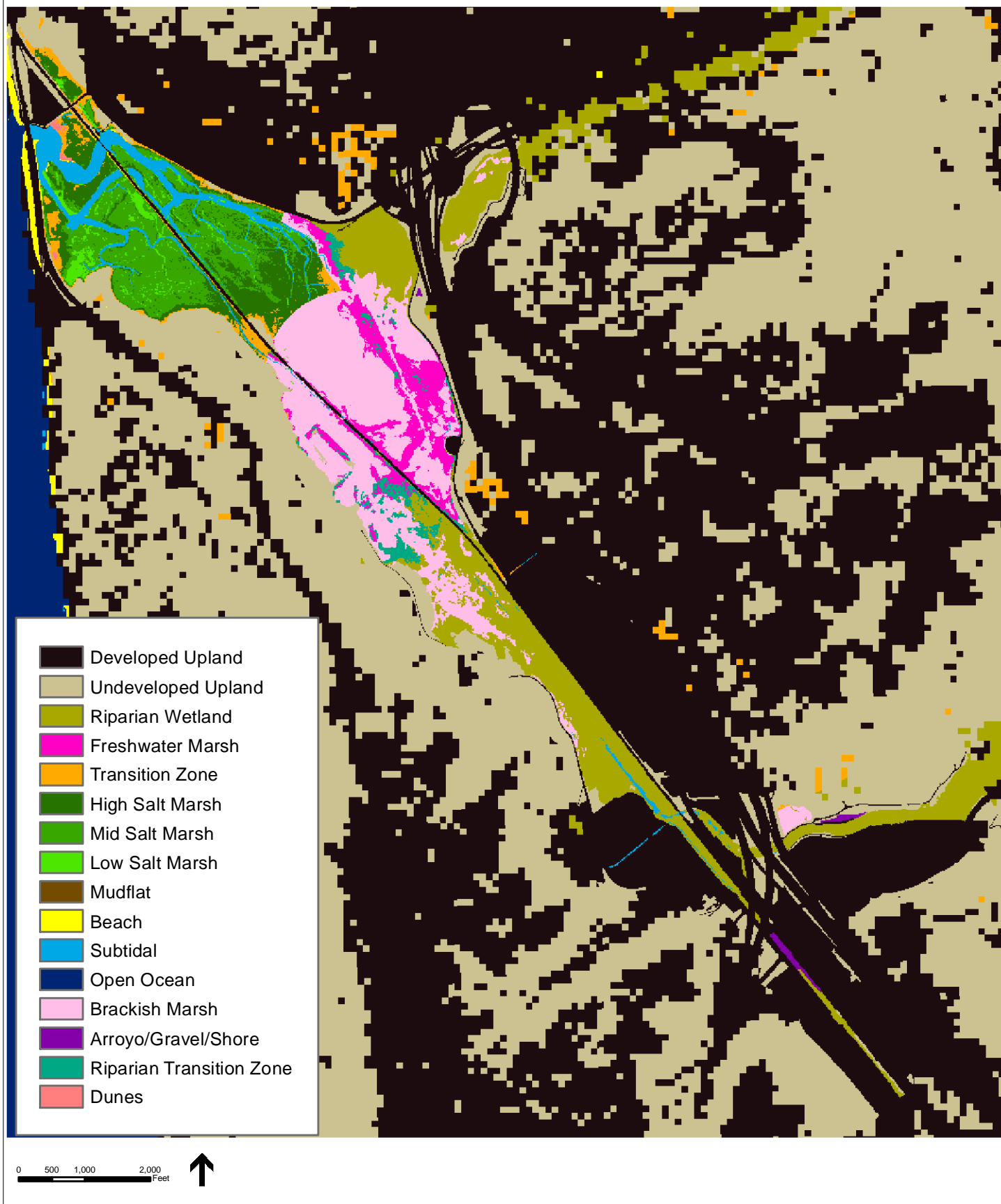


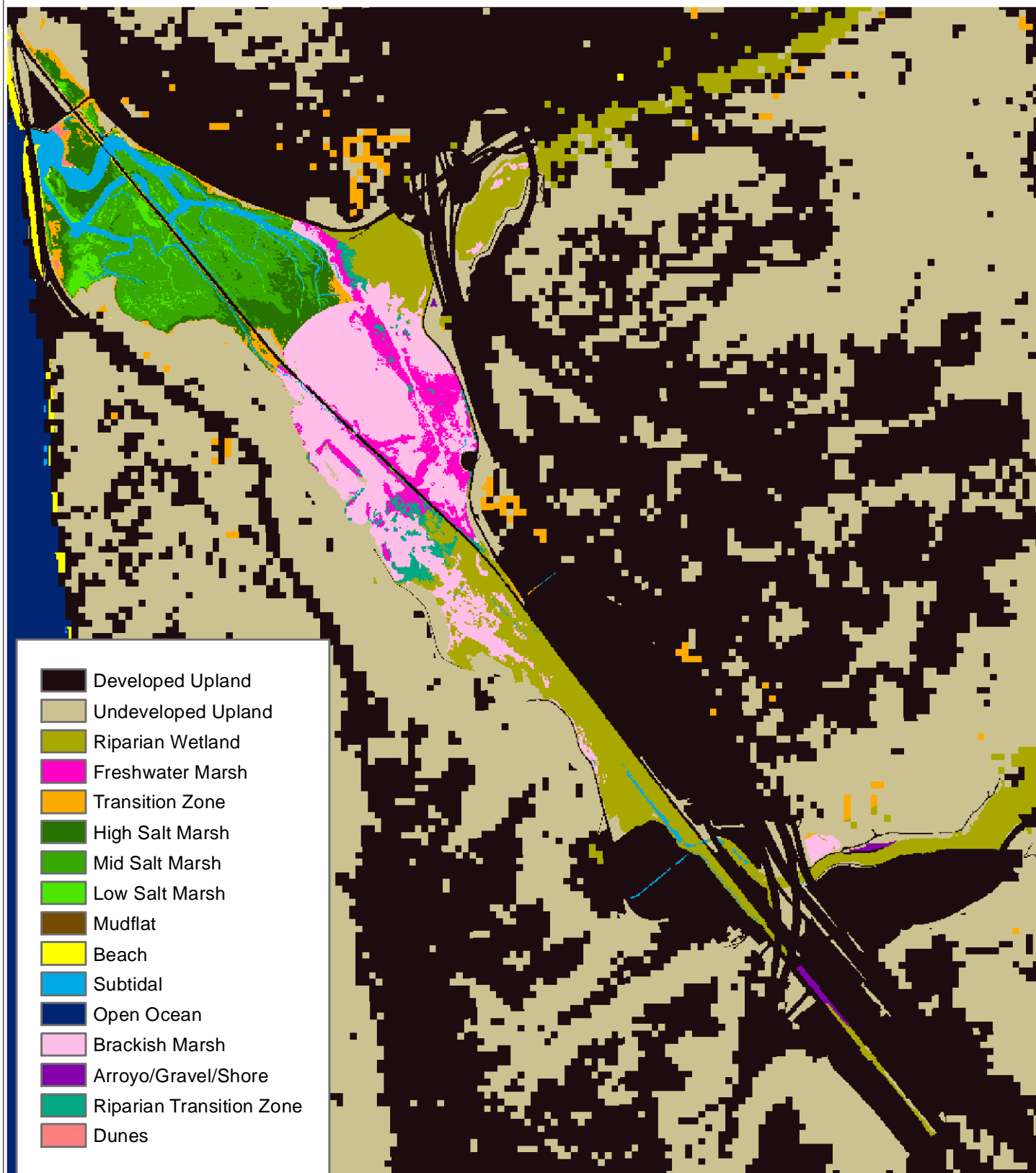
Los Peñasquitos Lagoon, D130136

**Figure 5**

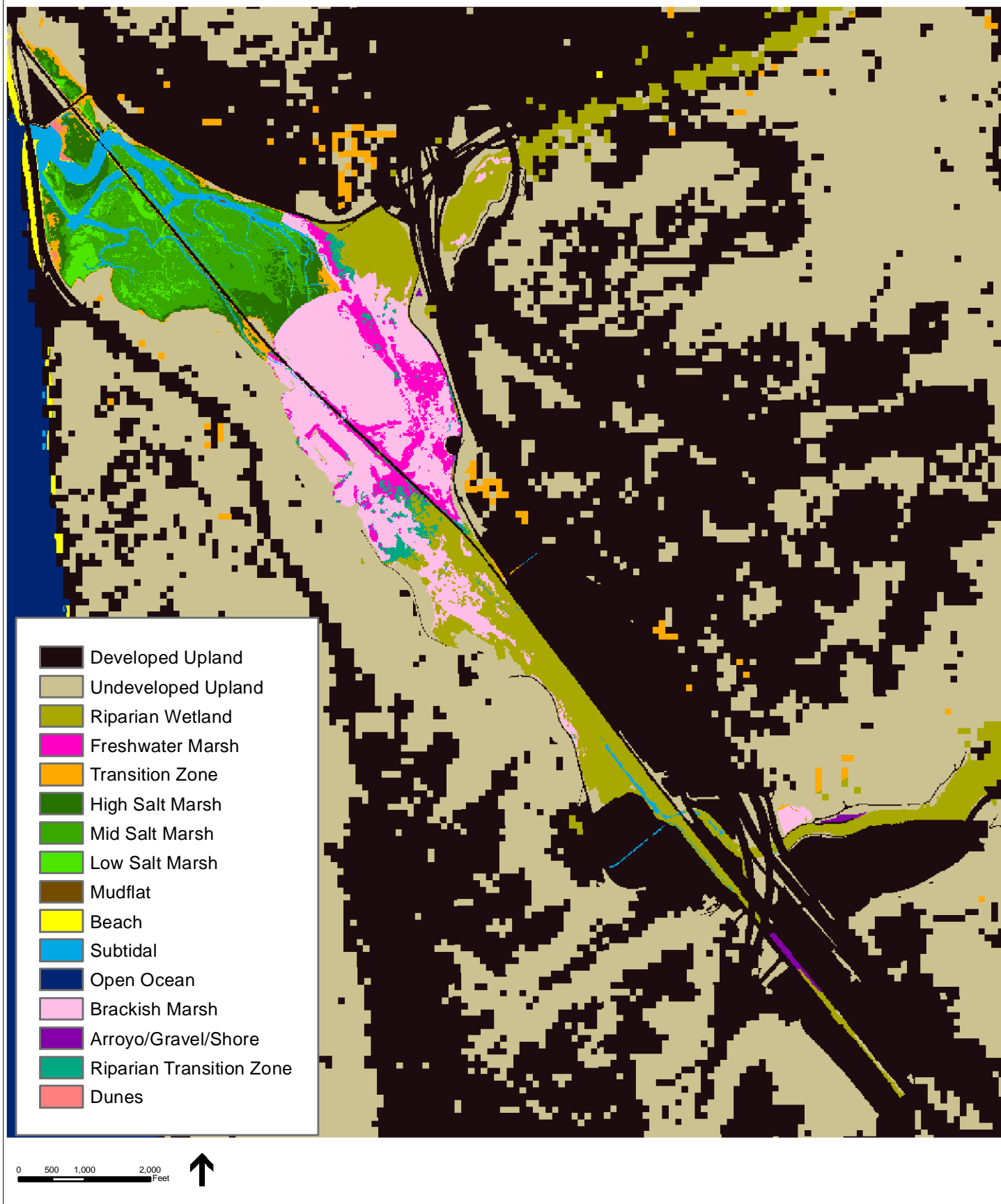
Run 1, 2060 Habitats







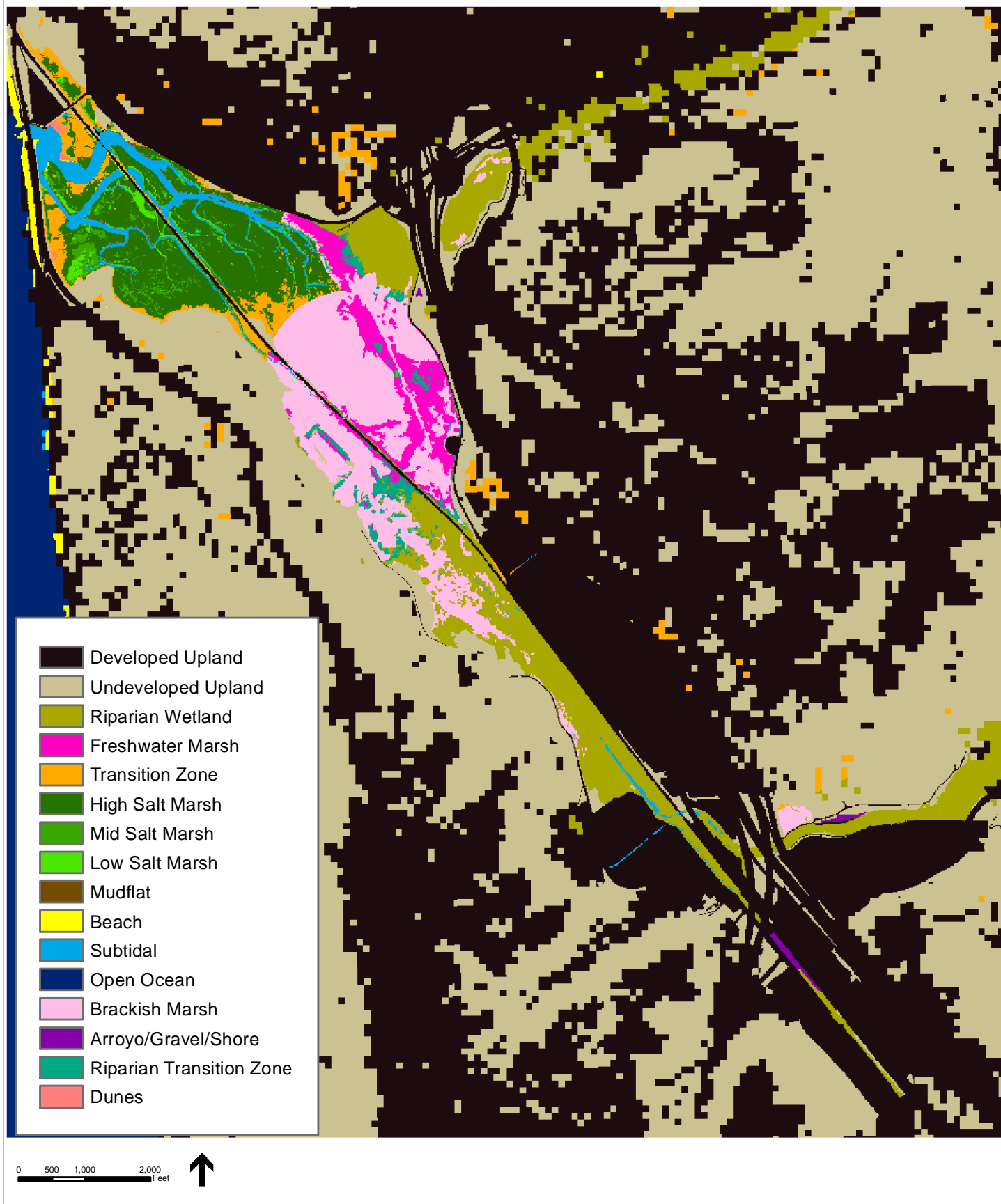


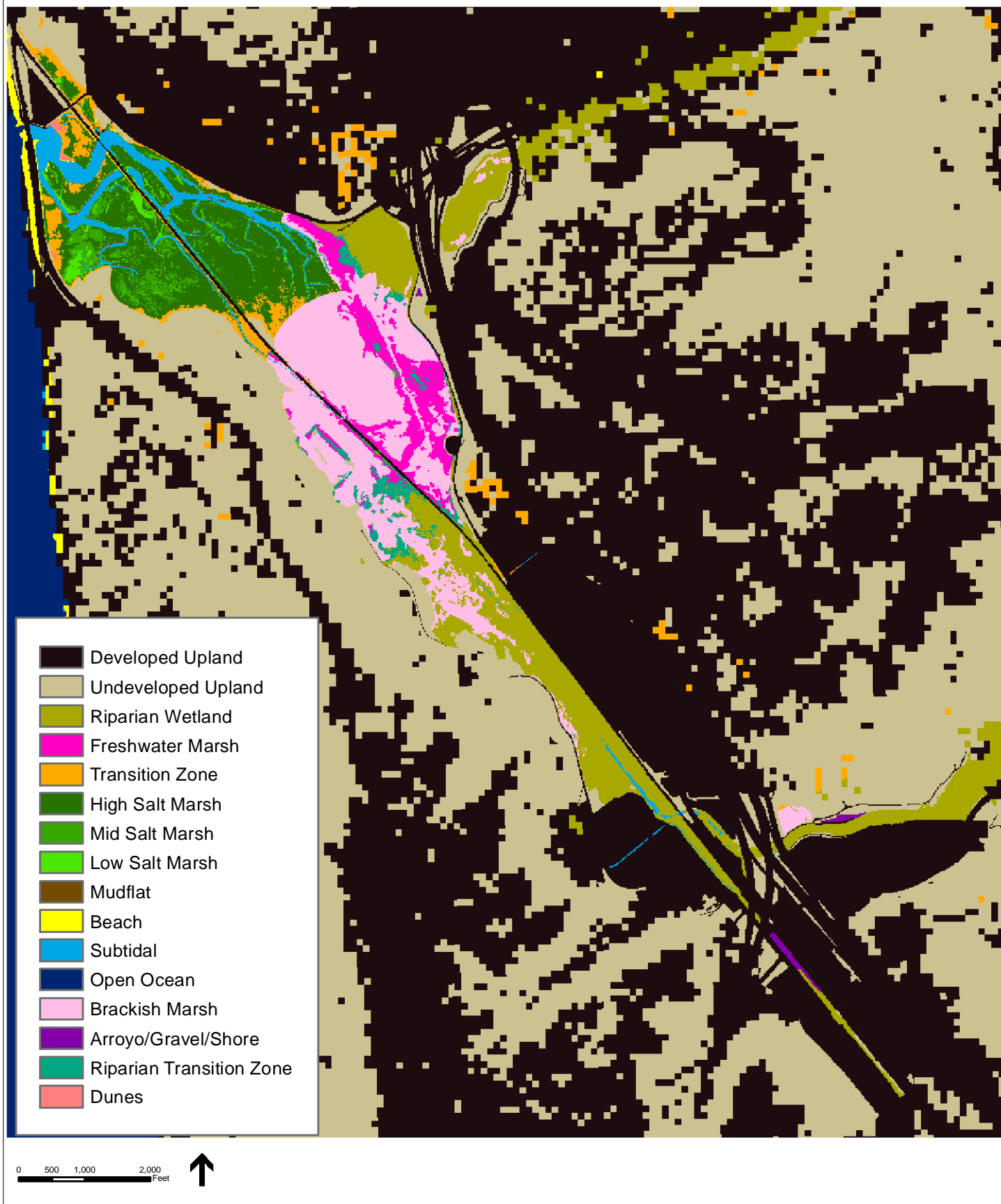


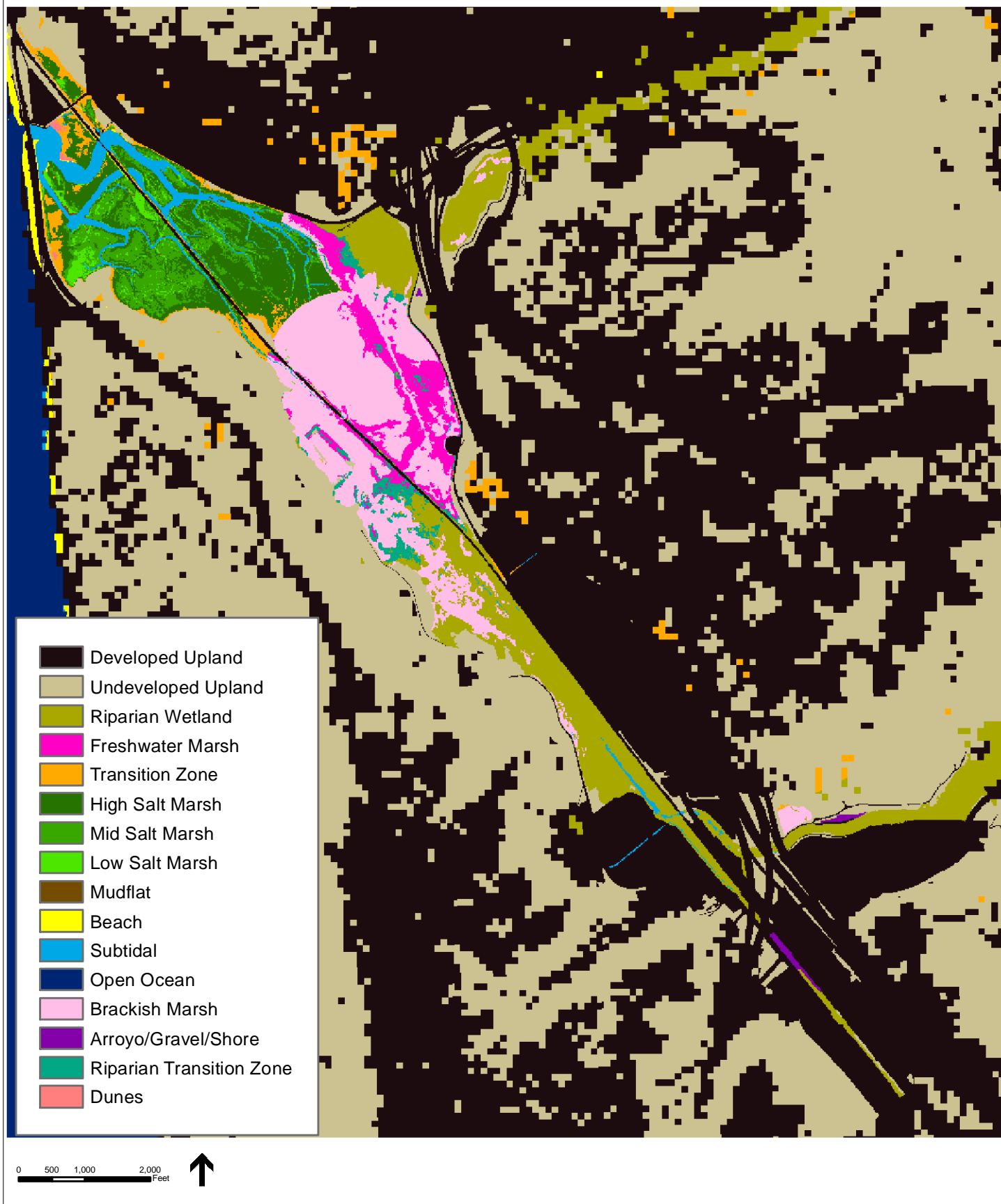
Los Peñasquitos Lagoon, D130136

**Figure 9**

Run 1, 2100 Habitats



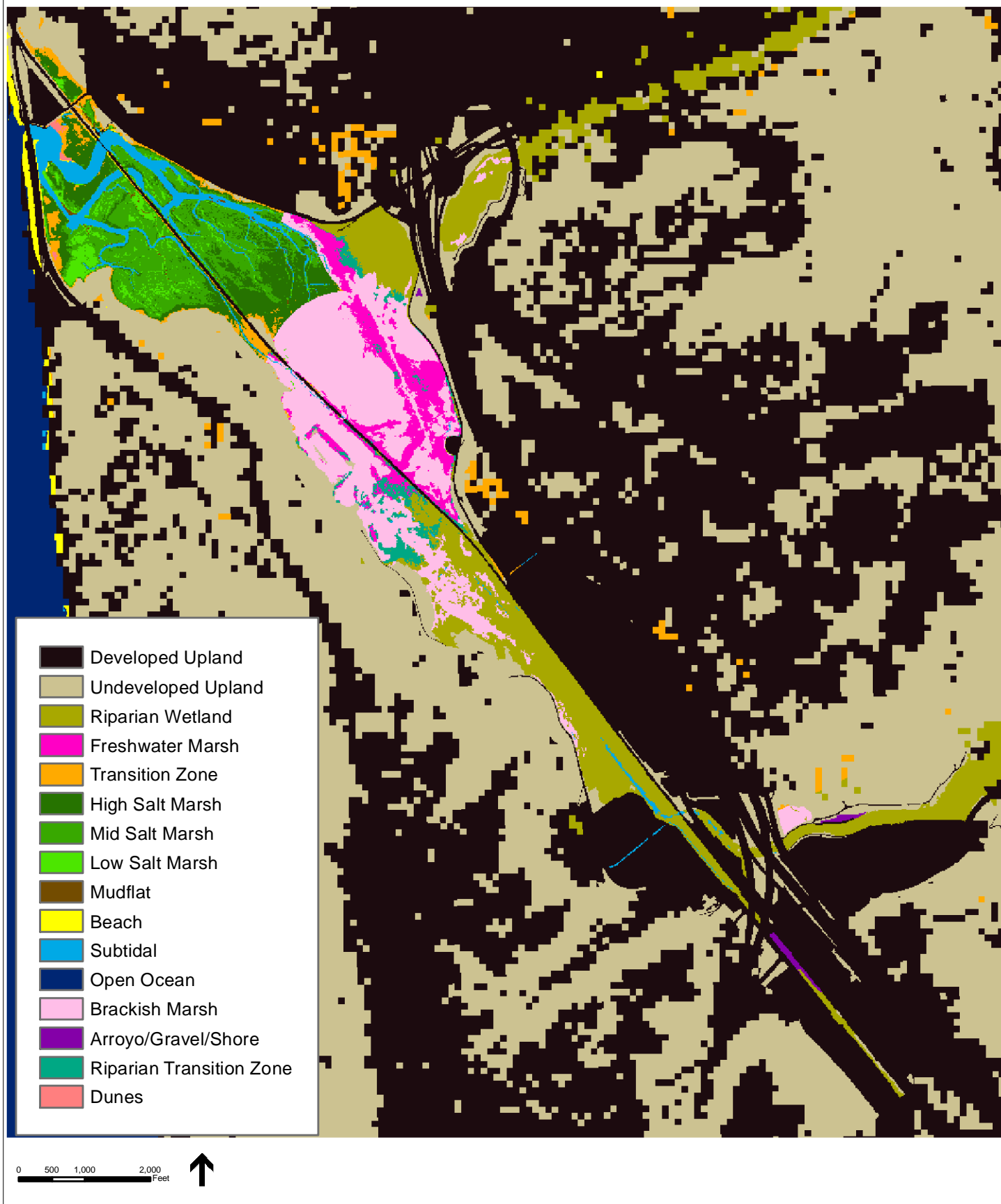


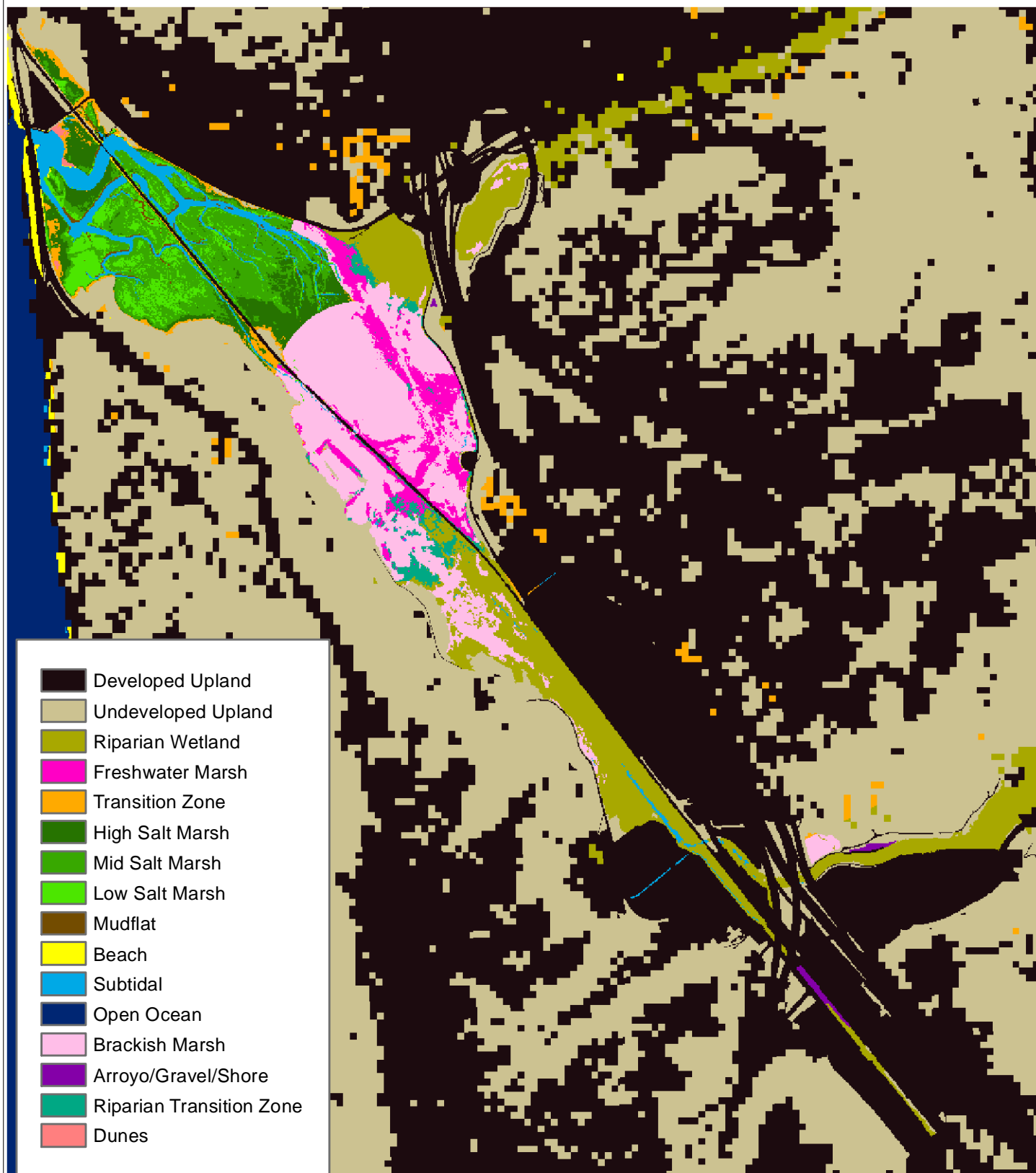


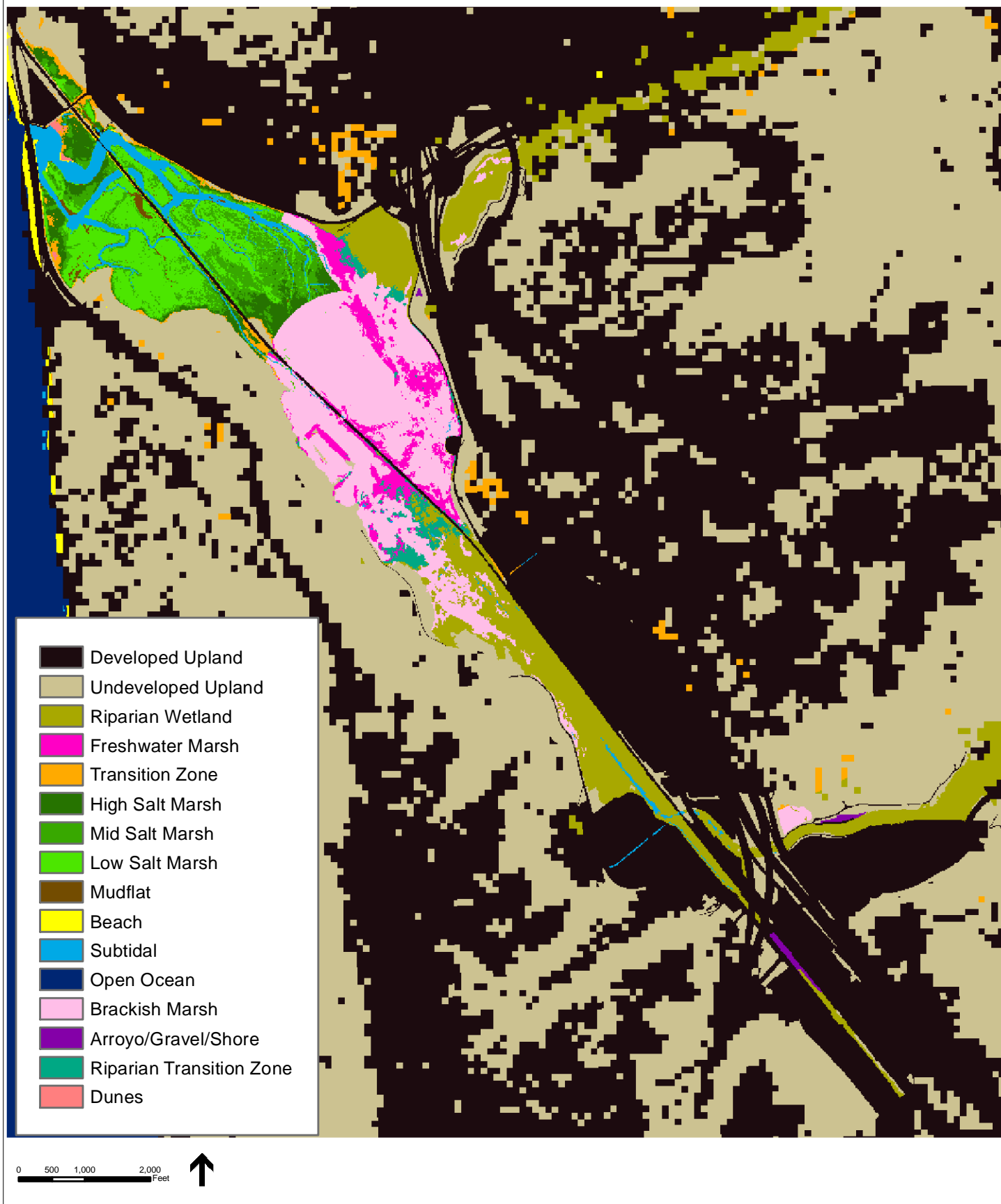
Los Peñasquitos Lagoon. D130136

**Figure 12**

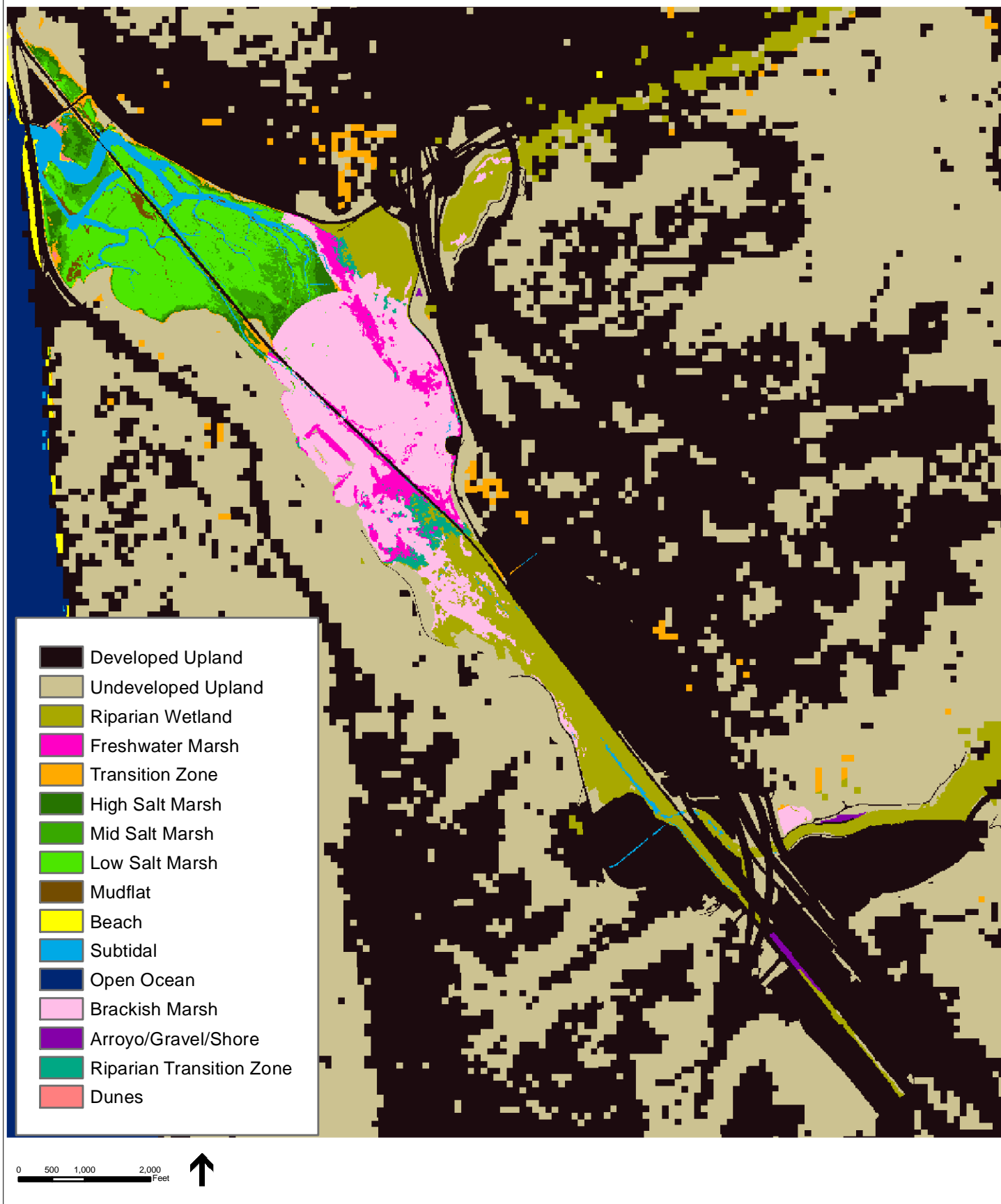
Run 2, 2040 Habitats

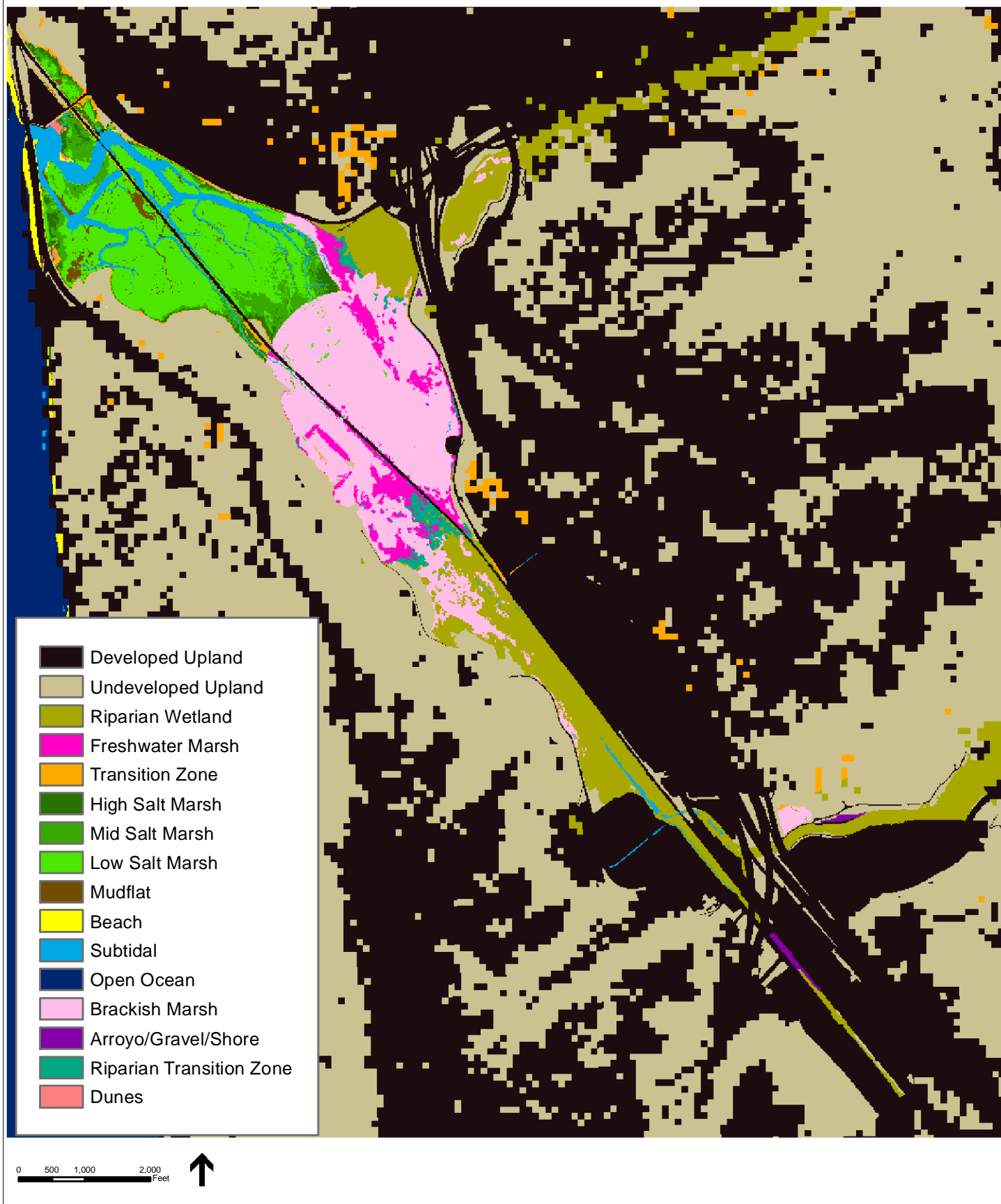


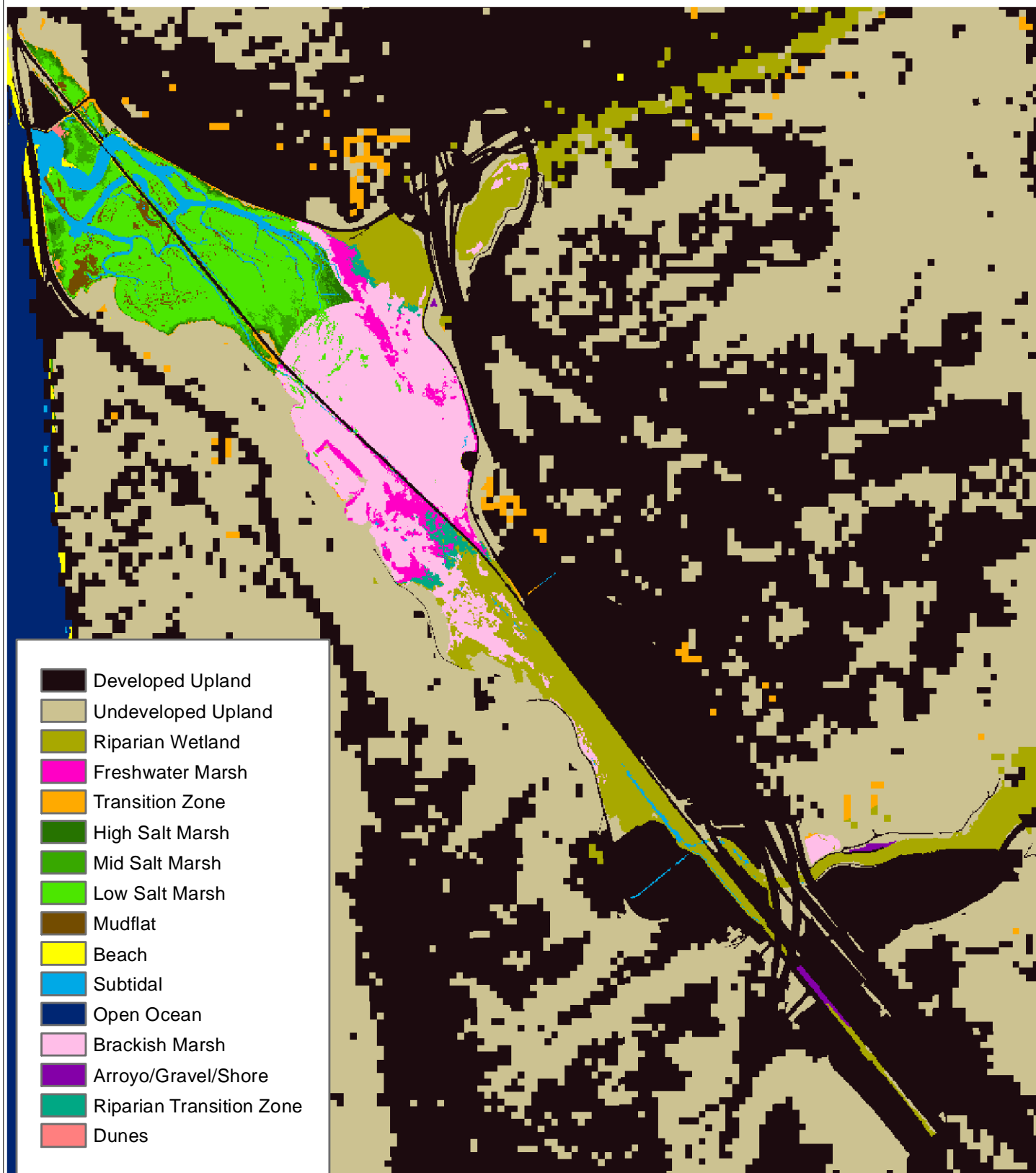


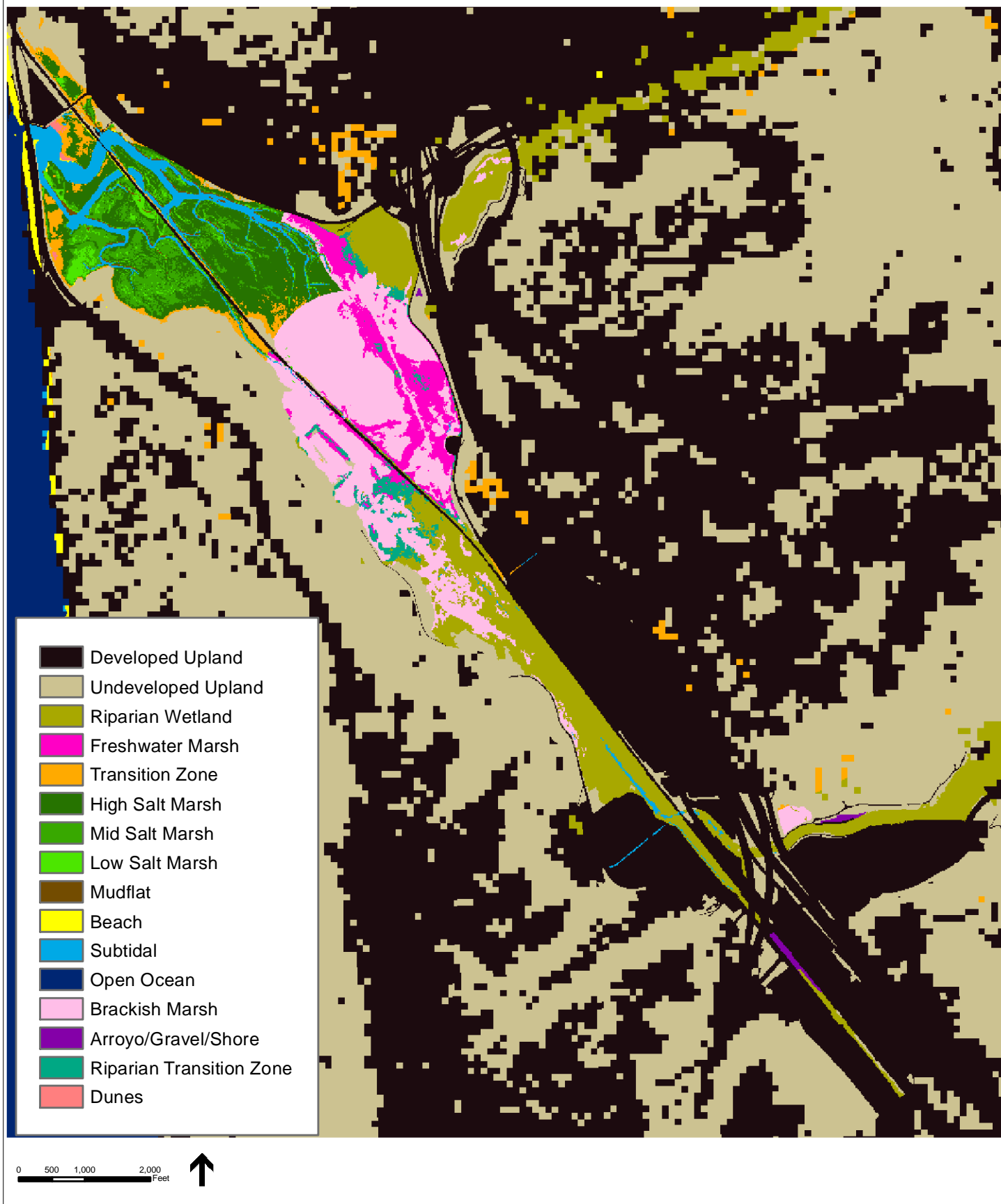








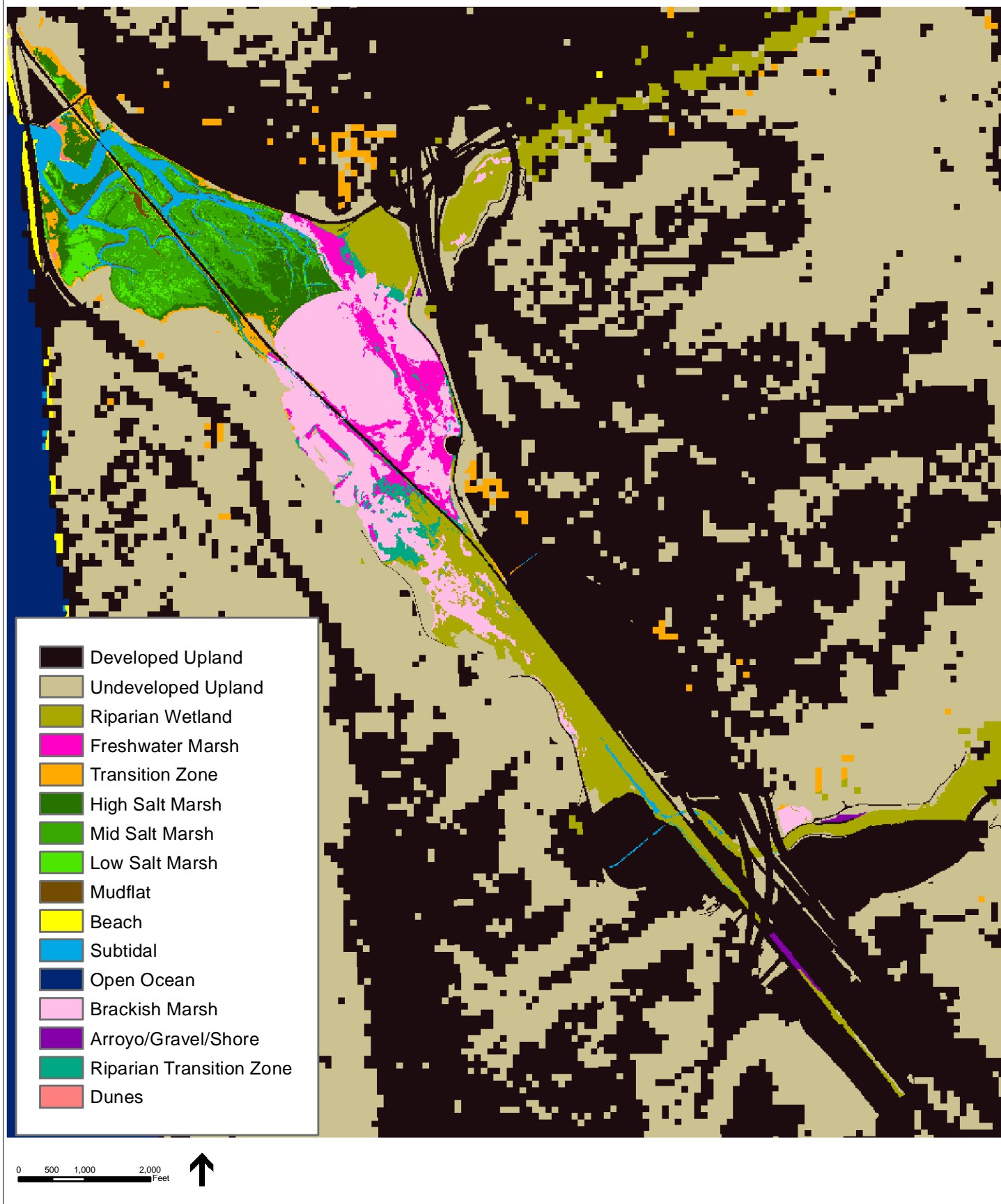




Los Peñasquitos Lagoon. D130136

**Figure 19**

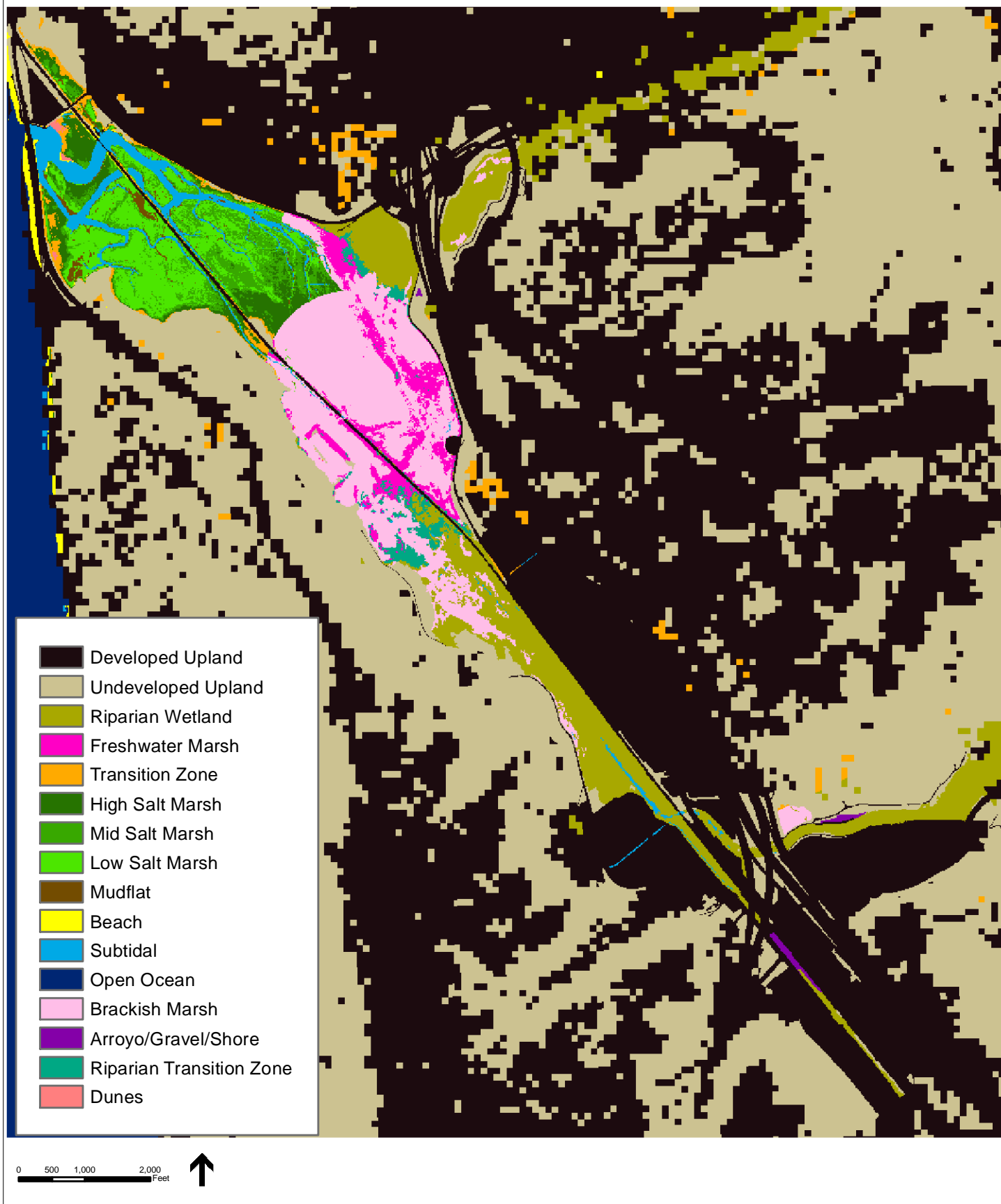
Run 3, 2020 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 20**

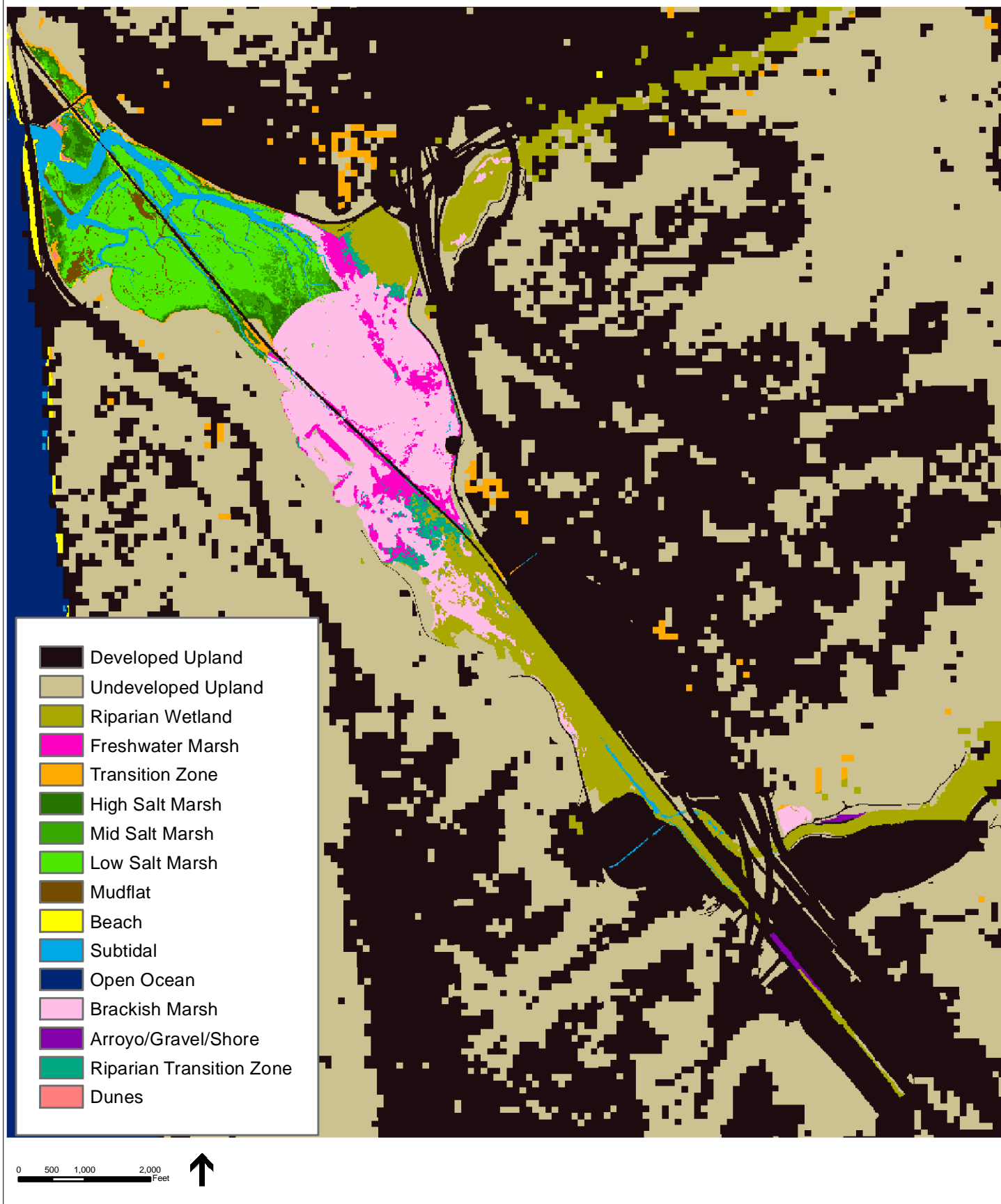
Run 3, 2030 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 21**

Run 3, 2040 Habitats

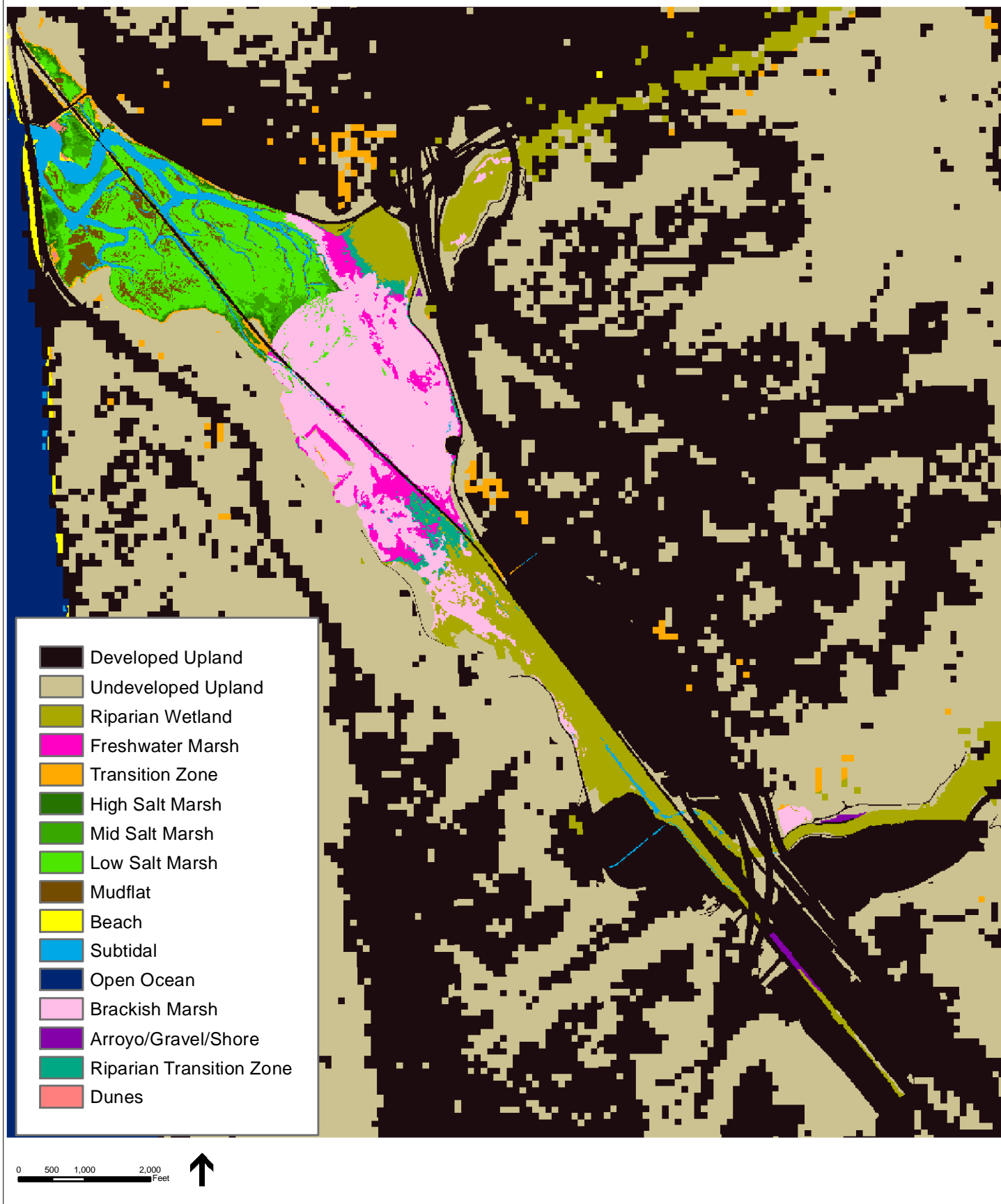


Los Peñasquitos Lagoon. D130136

**Figure 22**

Run 3, 2050 Habitats

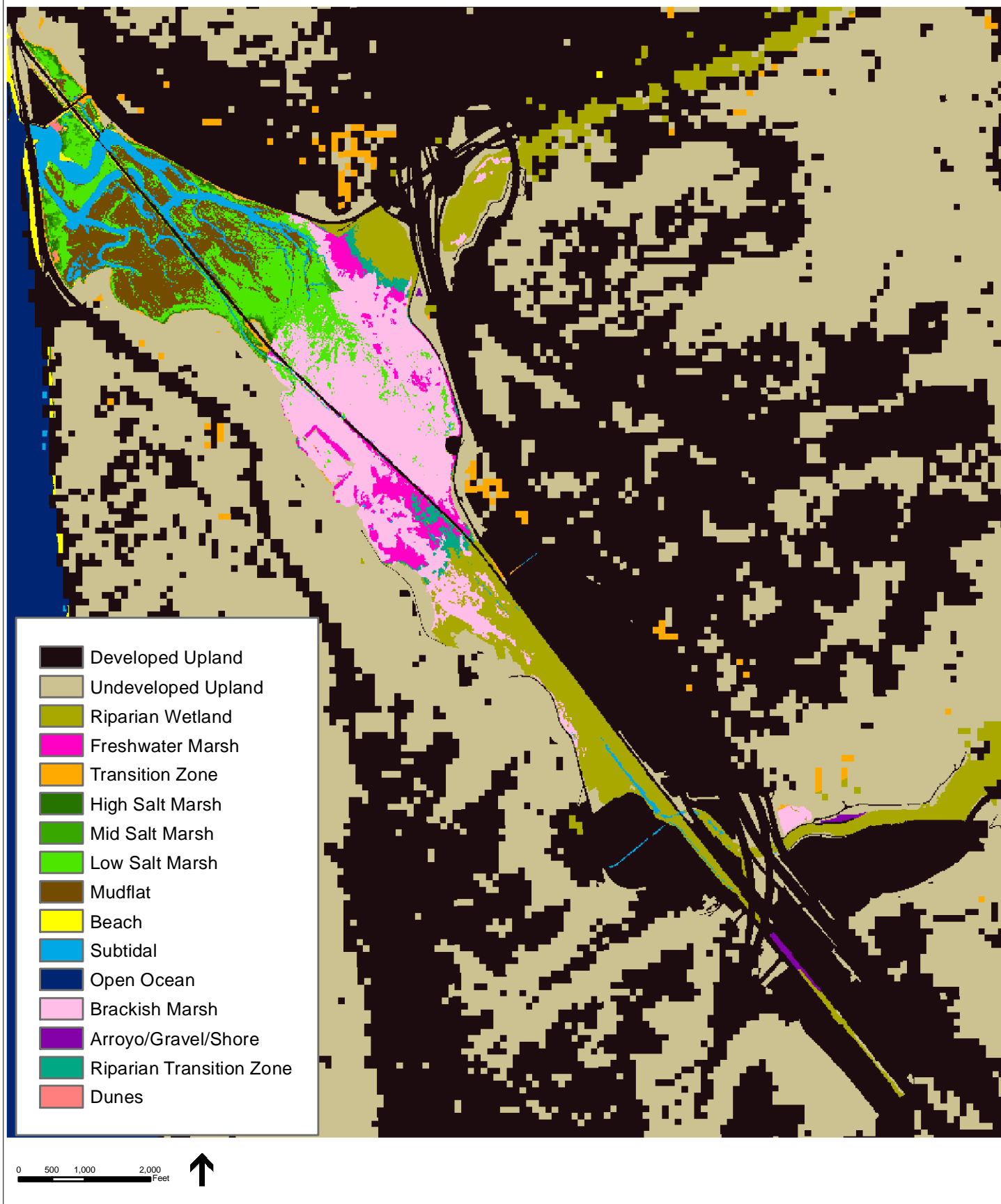




Los Peñasquitos Lagoon. D130136

**Figure 23**

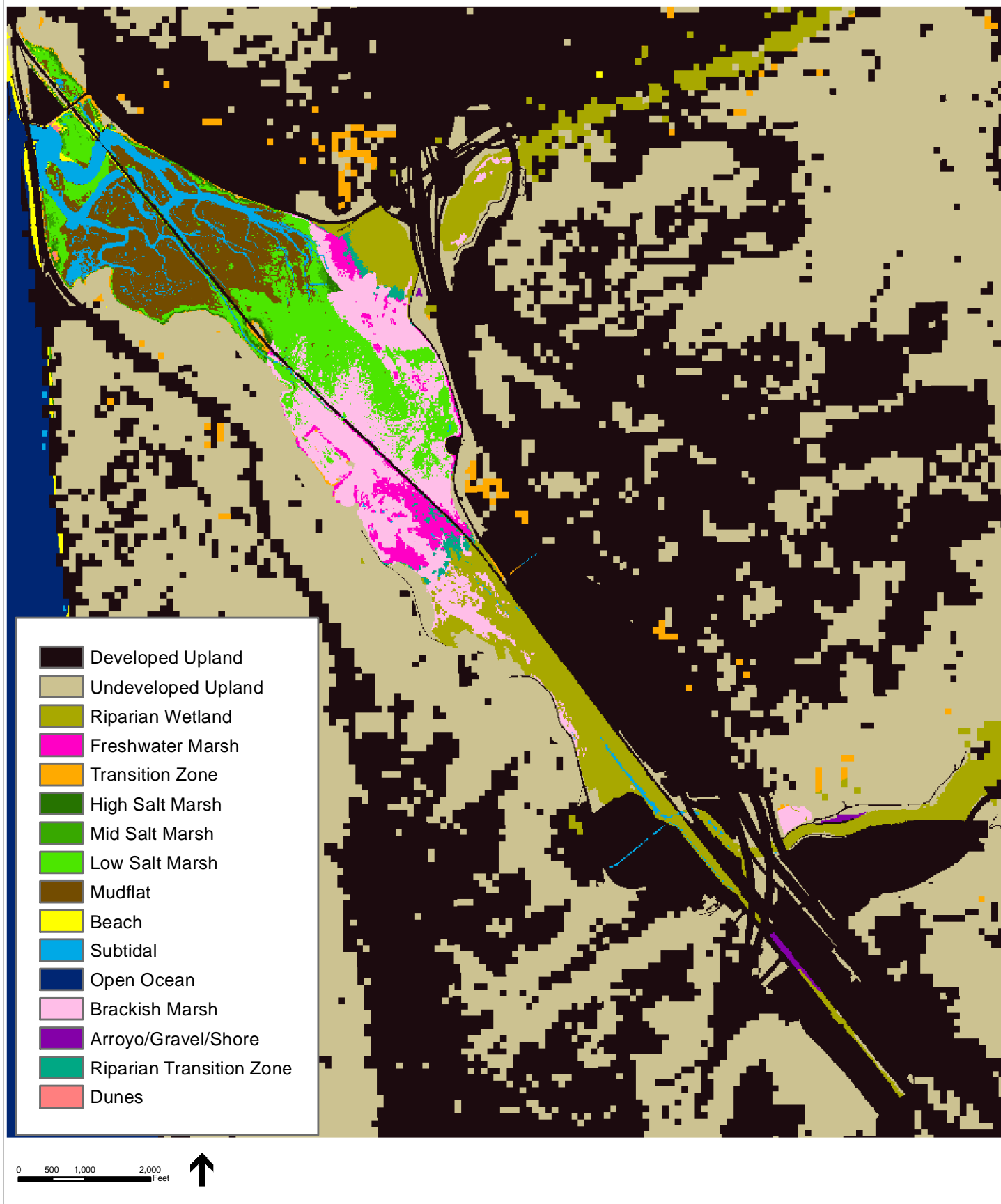
Run 3, 2060 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 24**

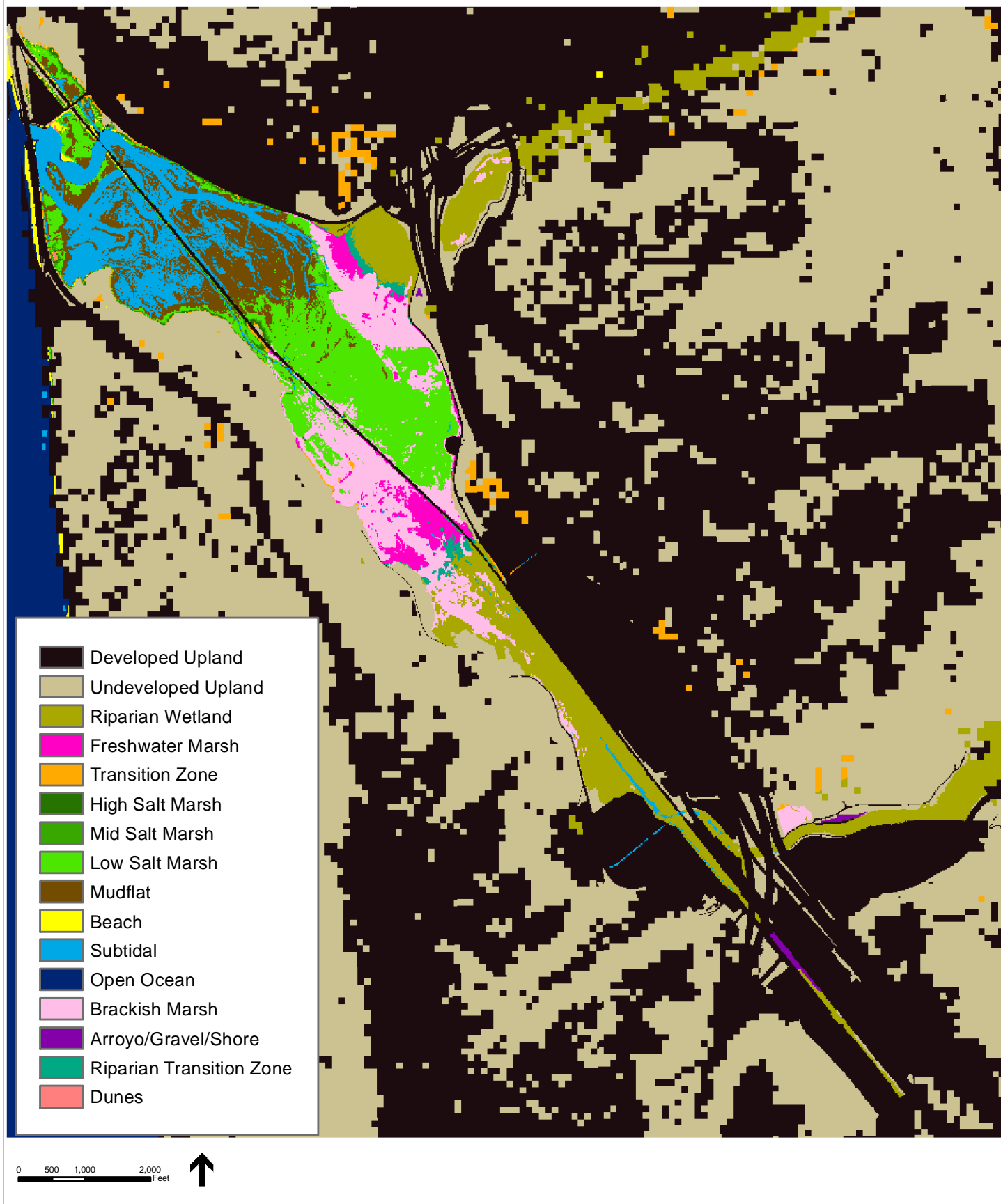
Run 3, 2070 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 25**

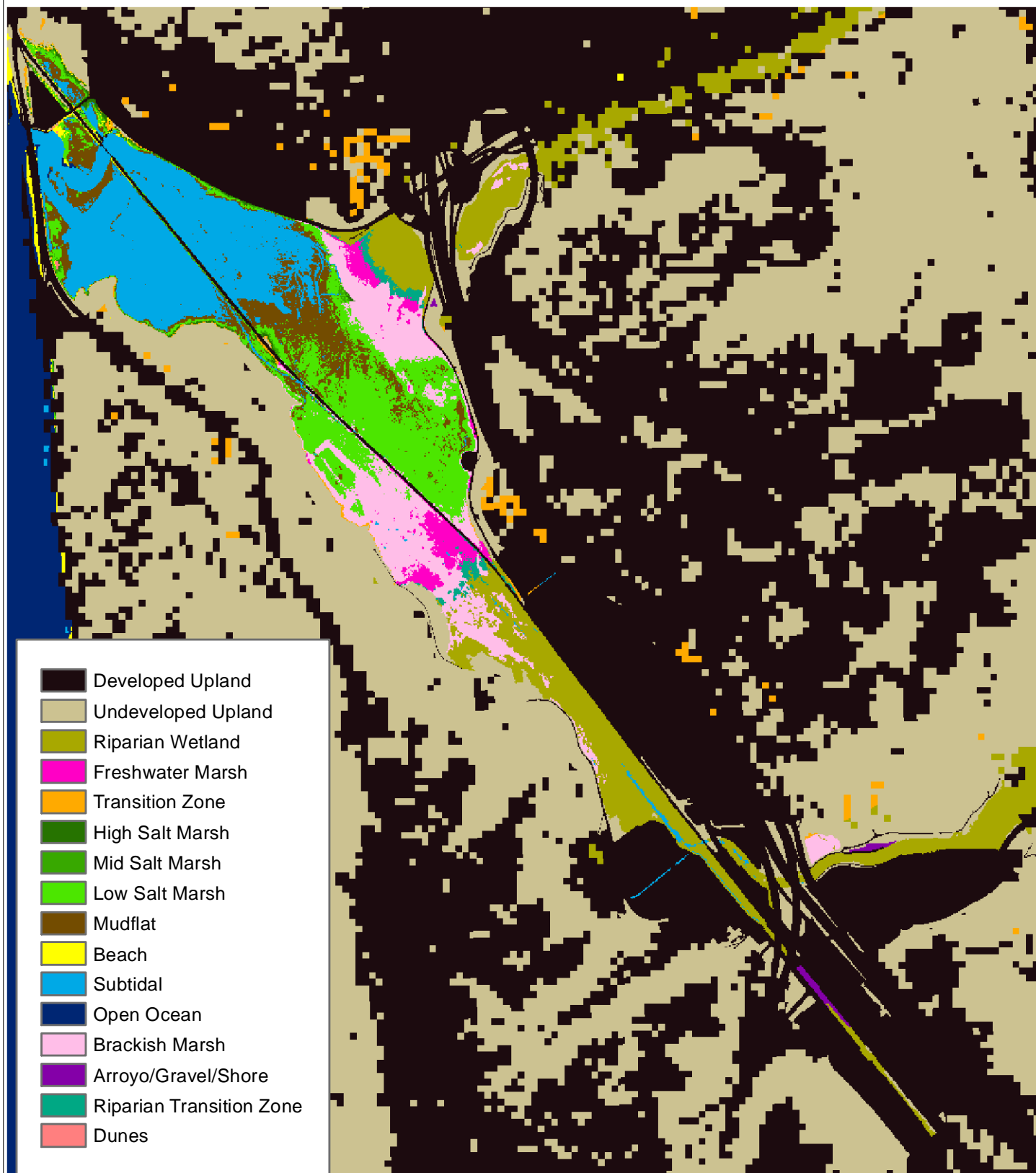
Run 3, 2080 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 26**

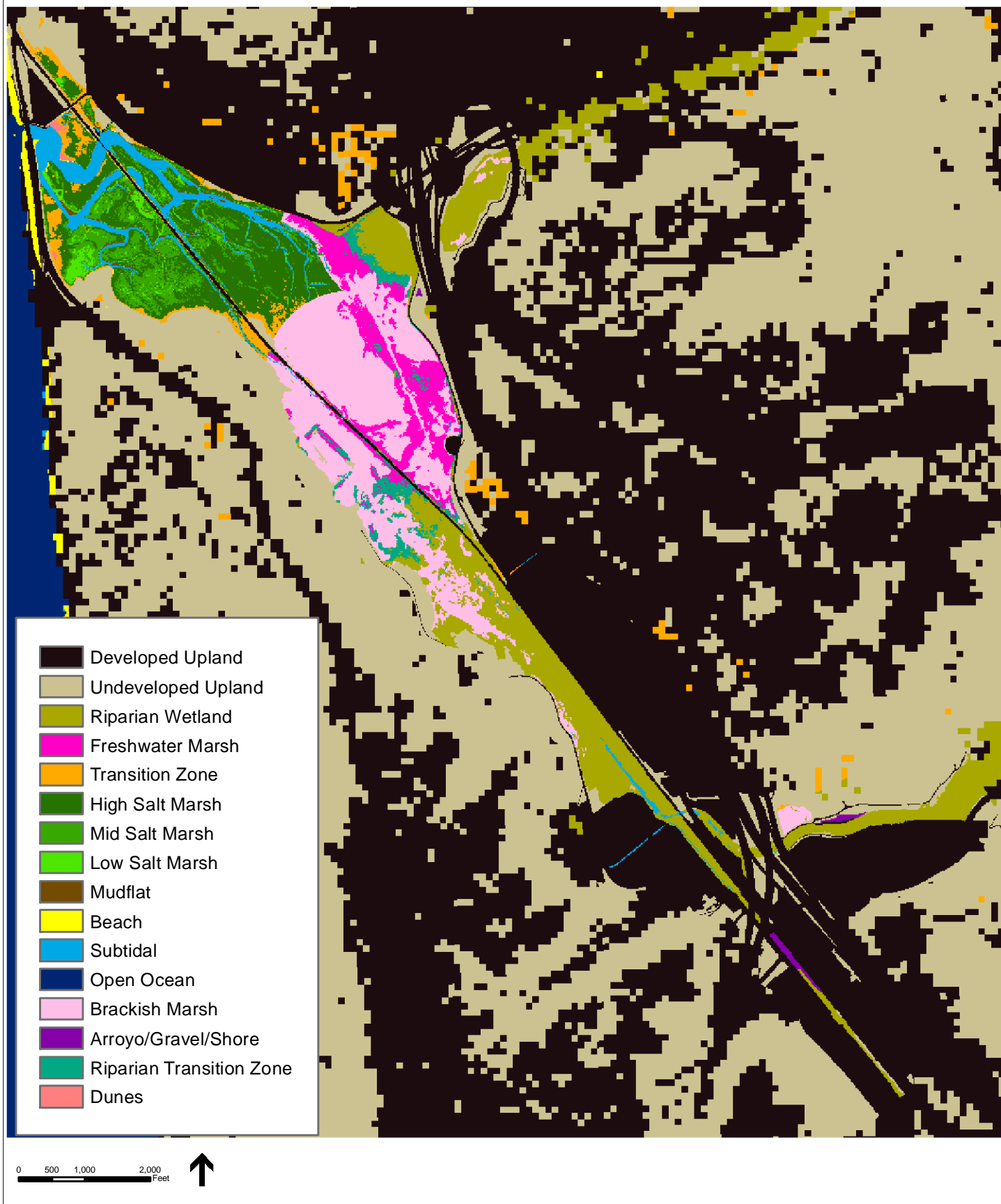
Run 3, 2090 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 27**

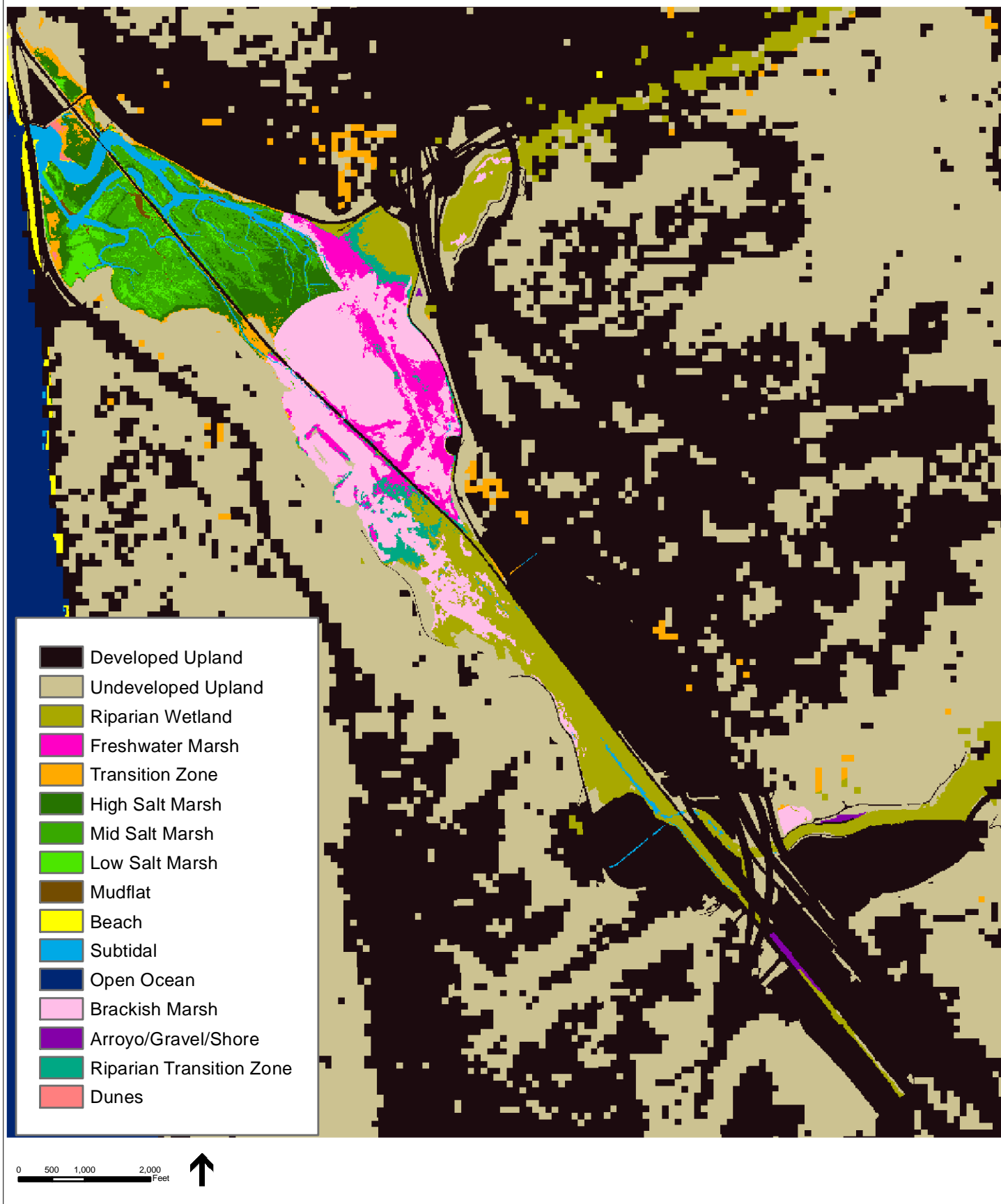
Run 3, 2100 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 28**

Run 4, 2020 Habitats

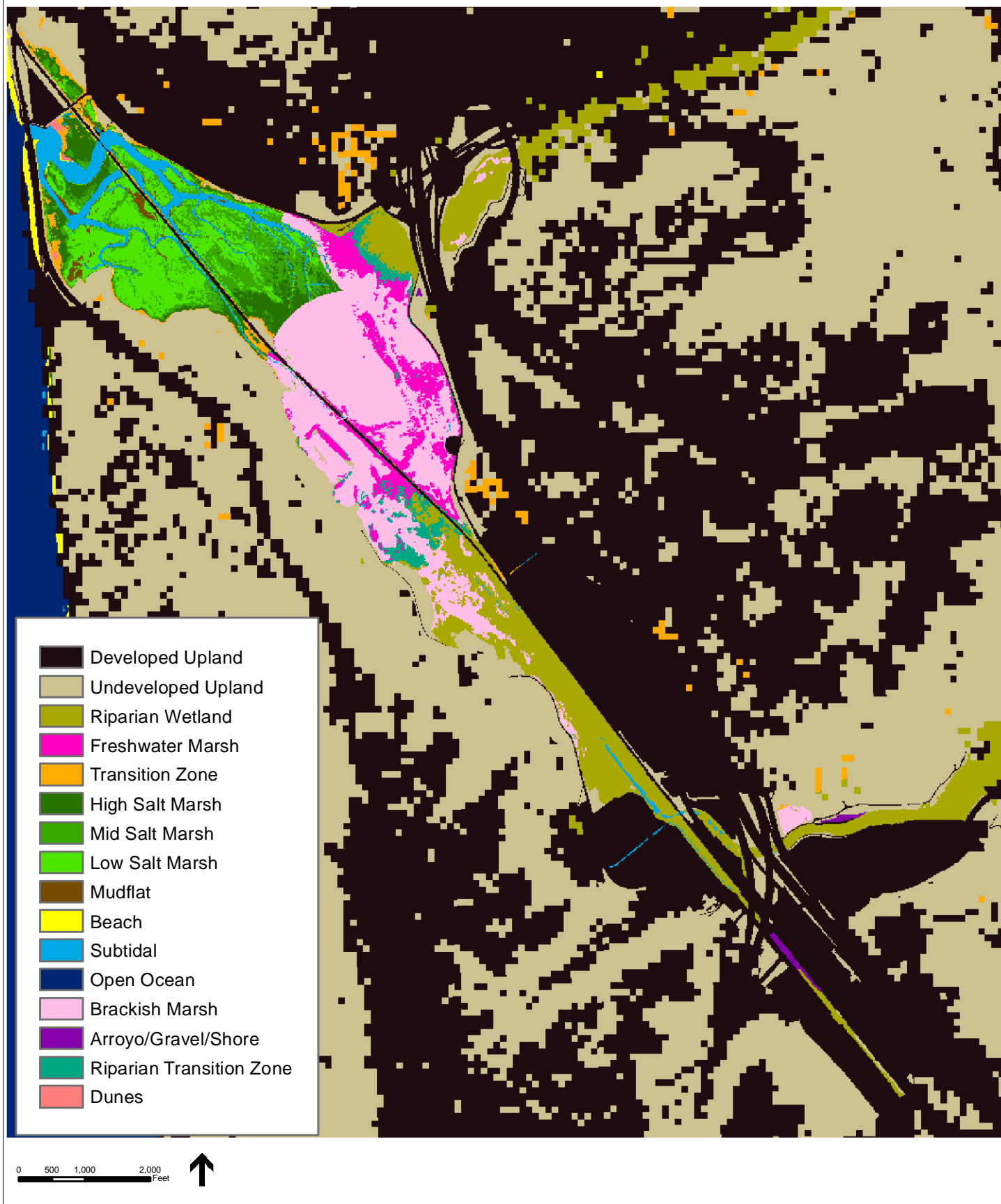


Los Peñasquitos Lagoon. D130136

**Figure 29**

Run 4, 2030 Habitats

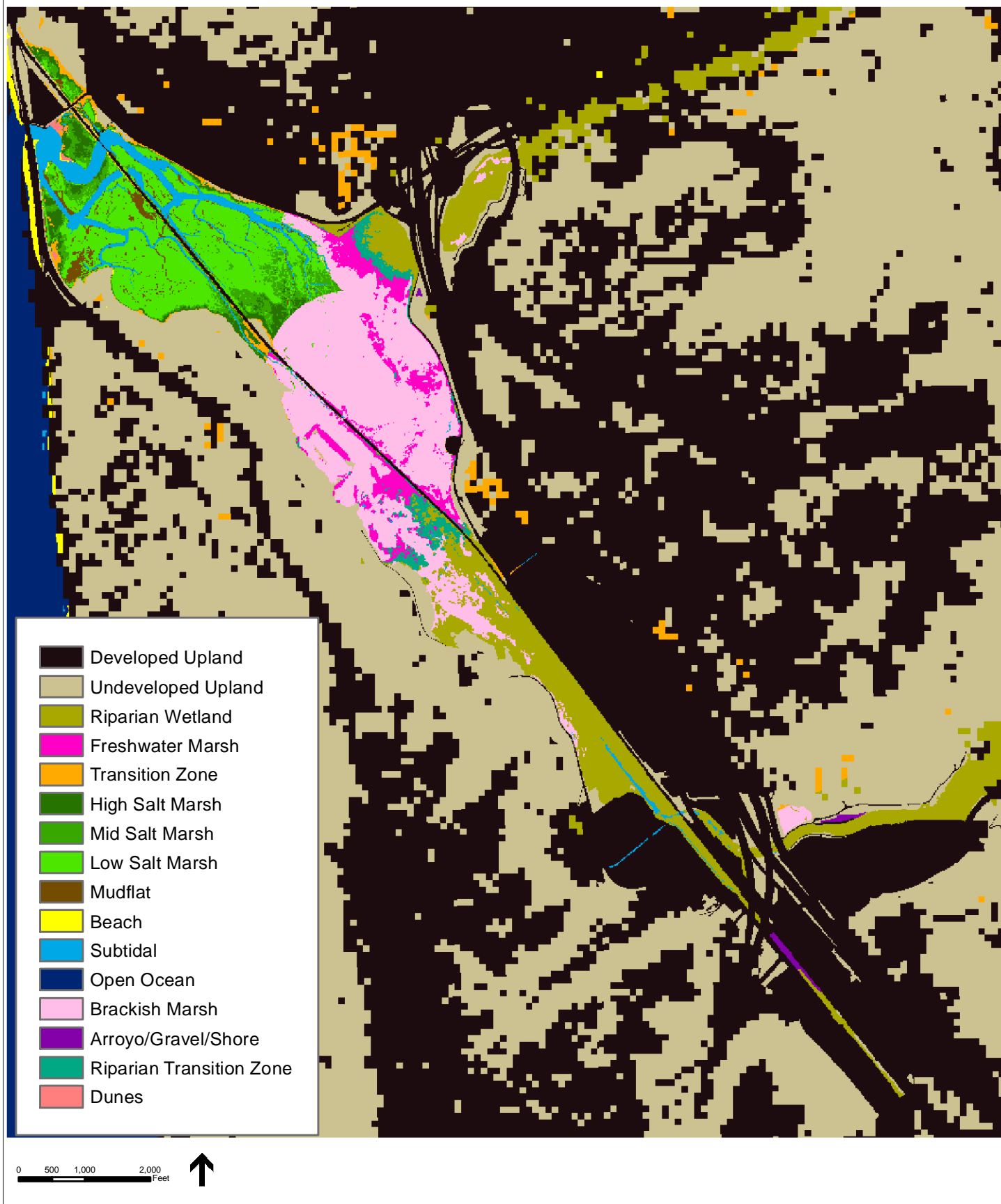




Los Peñasquitos Lagoon. D130136

**Figure 30**

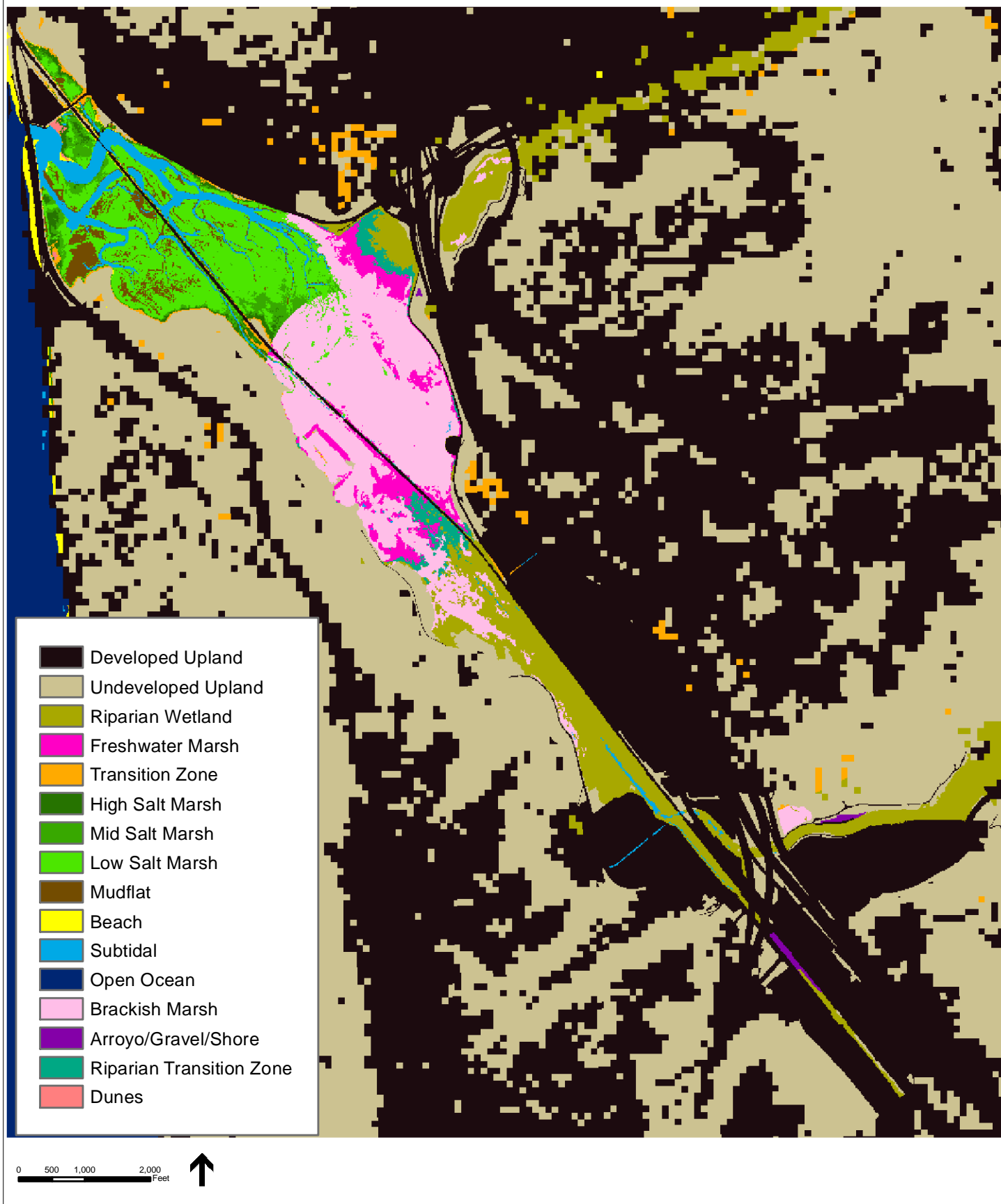
Run 4, 2040 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 31**

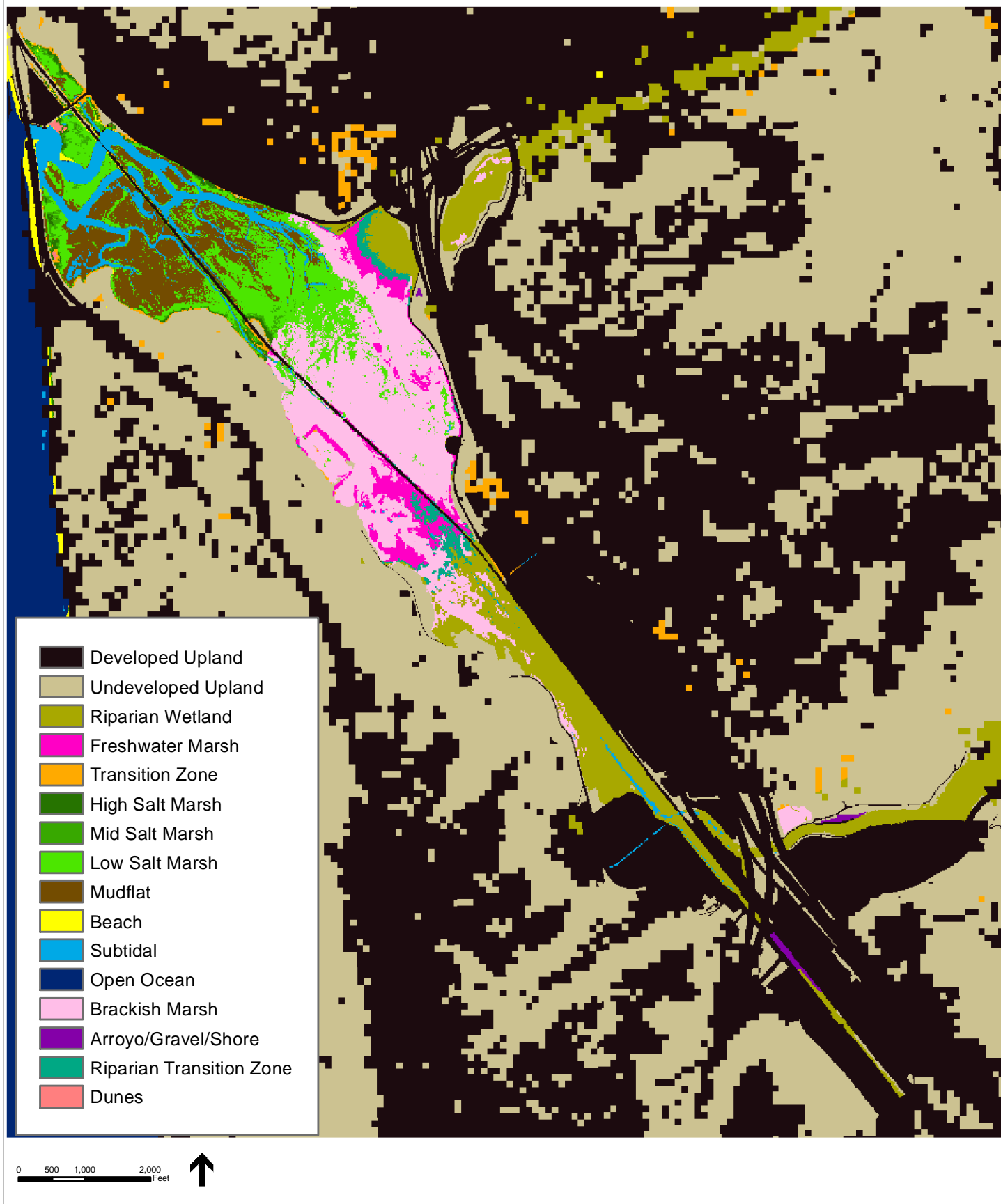
Run 4, 2050 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 32**

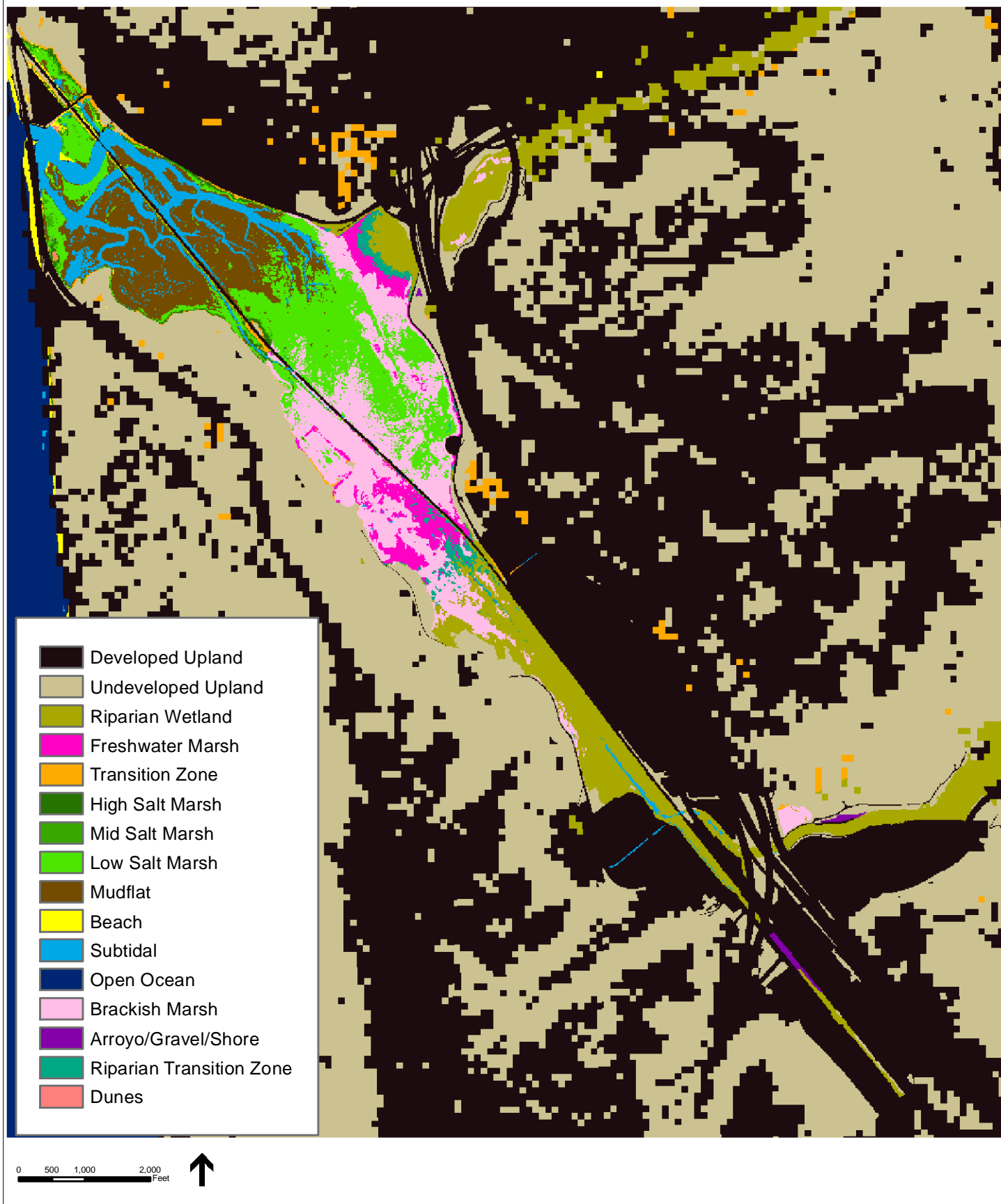
Run 4, 2060 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 33**

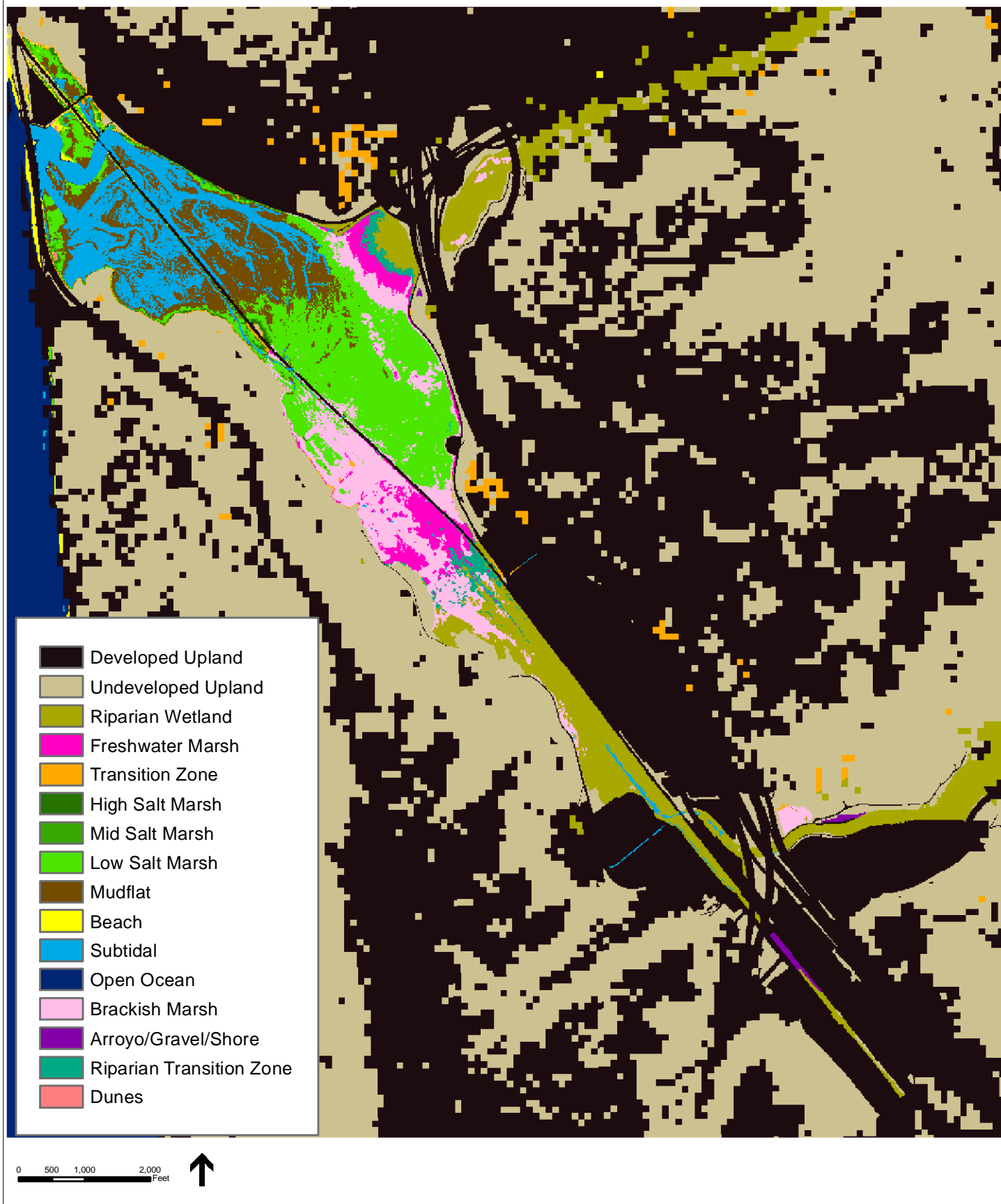
Run 4, 2070 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 34**

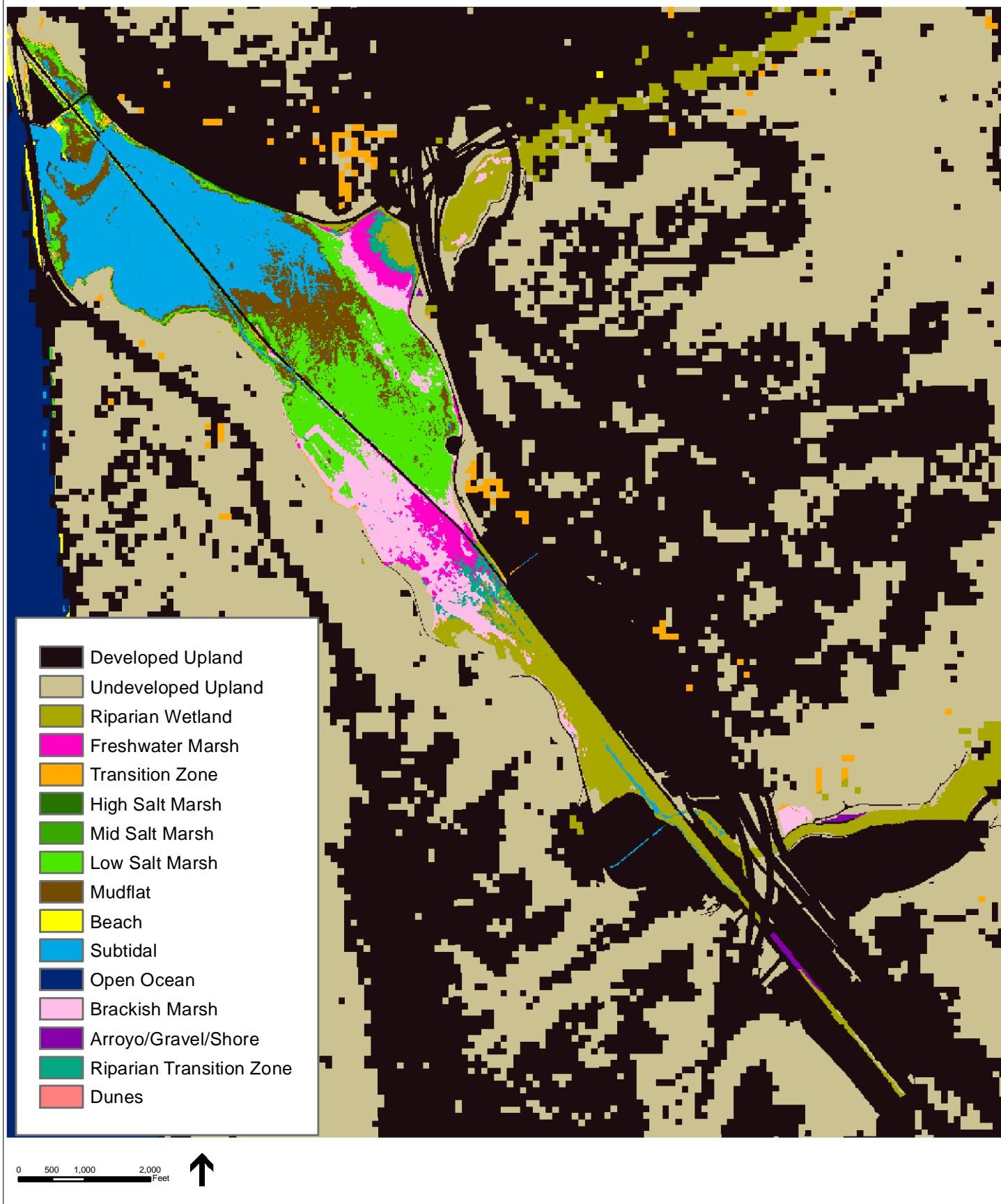
Run 4, 2080 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 35**

Run 4, 2090 Habitats

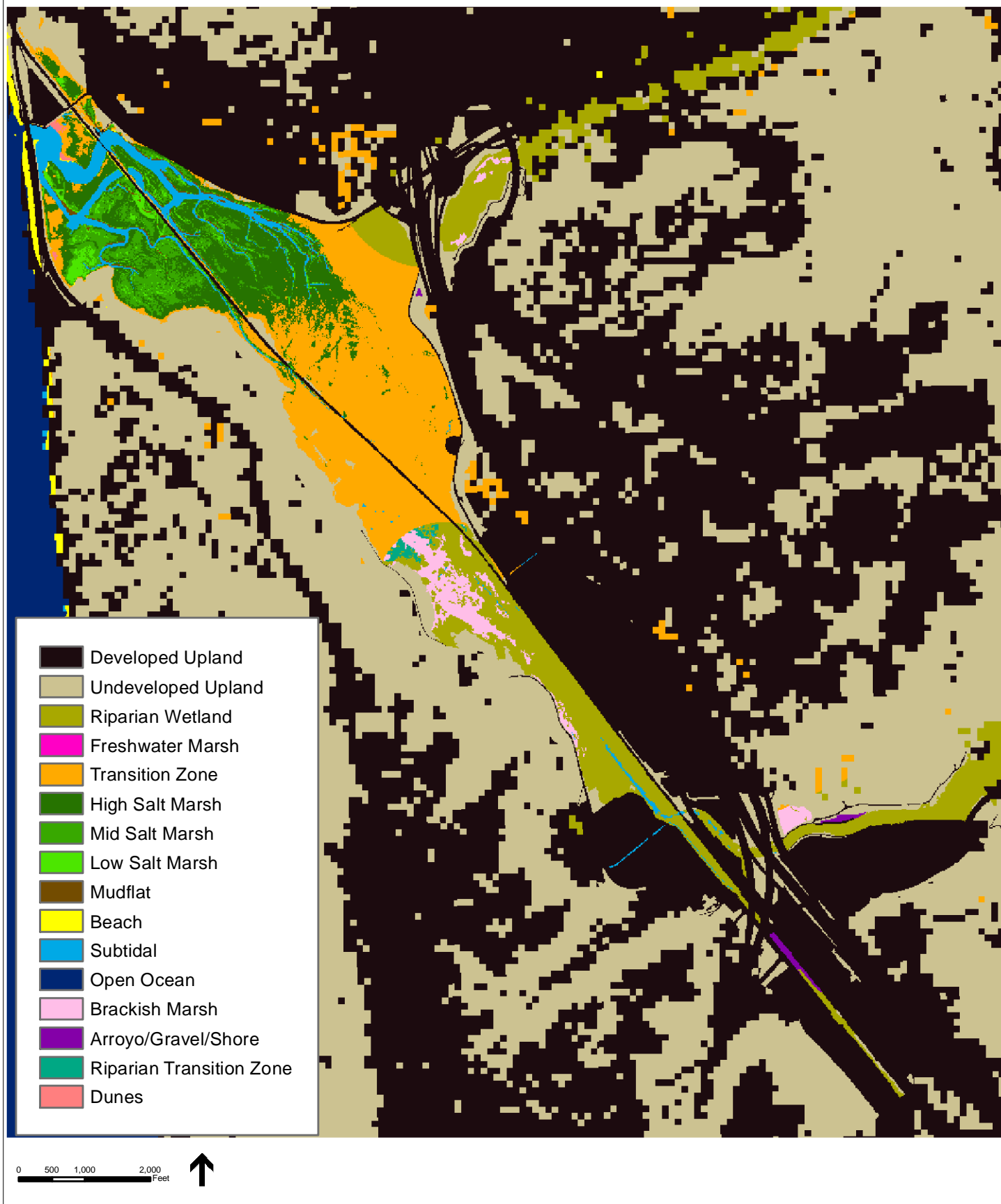


Los Peñasquitos Lagoon. D130136

**Figure 36**

Run 4, 2100 Habitats

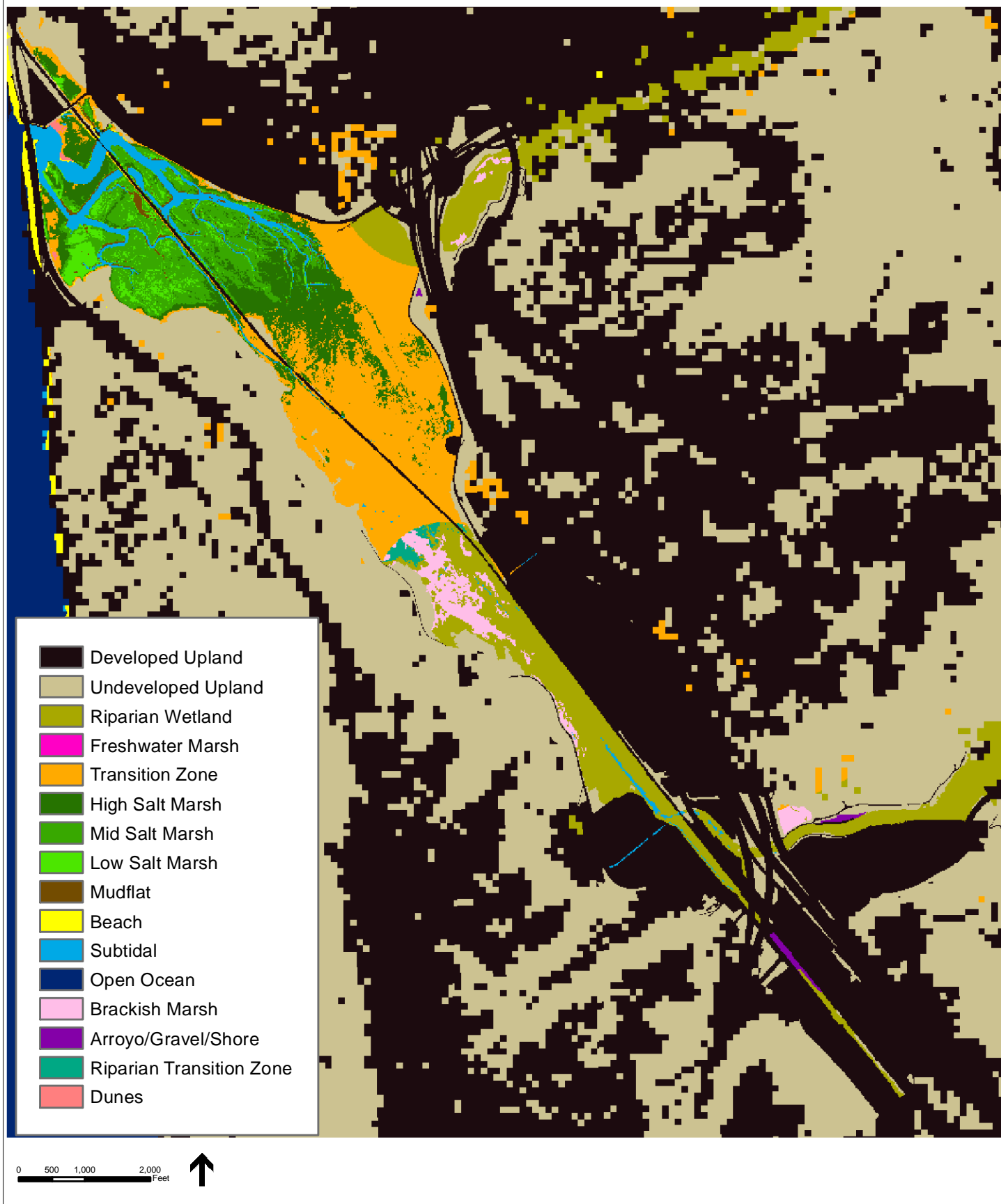




Los Peñasquitos Lagoon. D130136

**Figure 37**

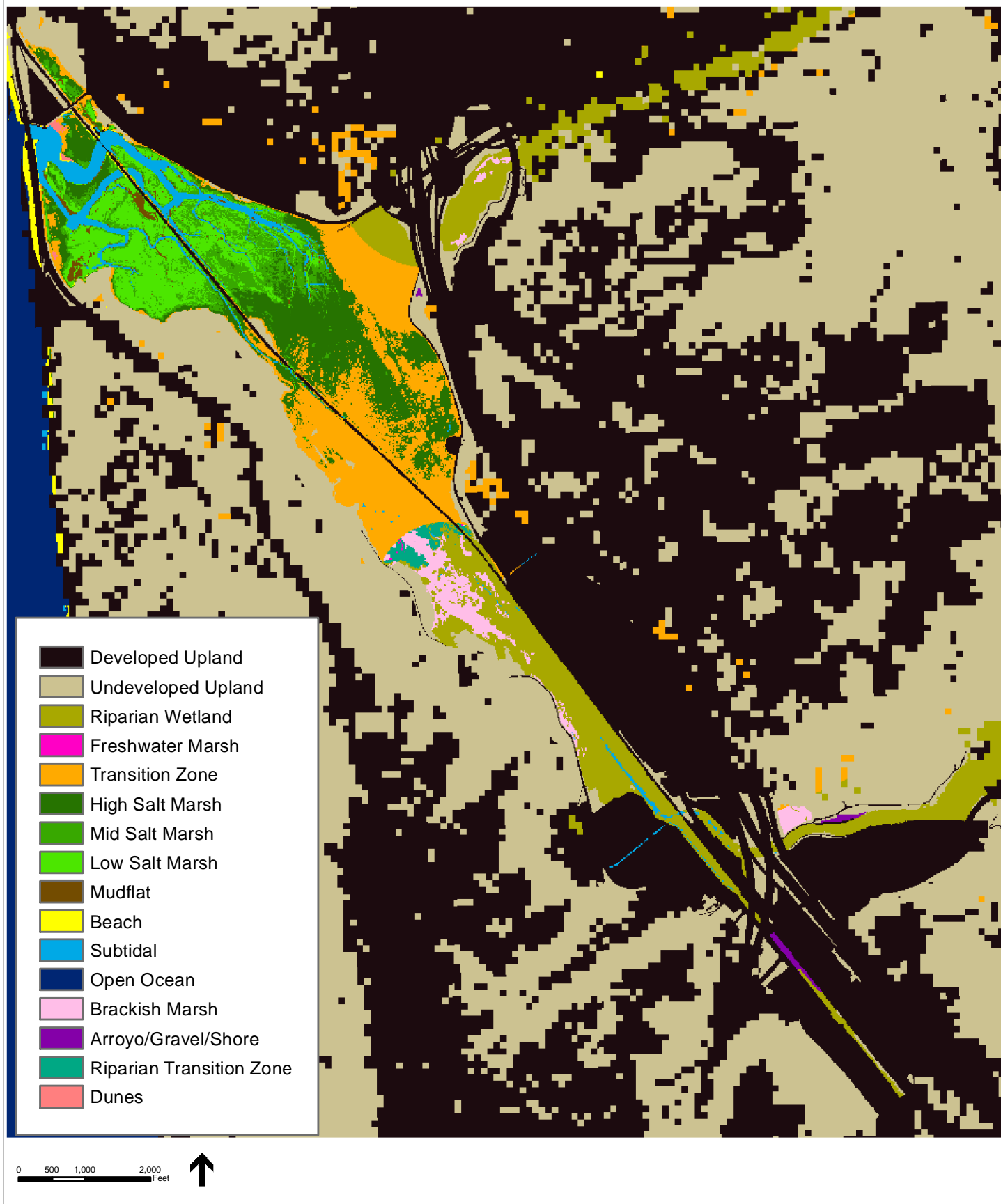
Run 5, 2020 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 38**

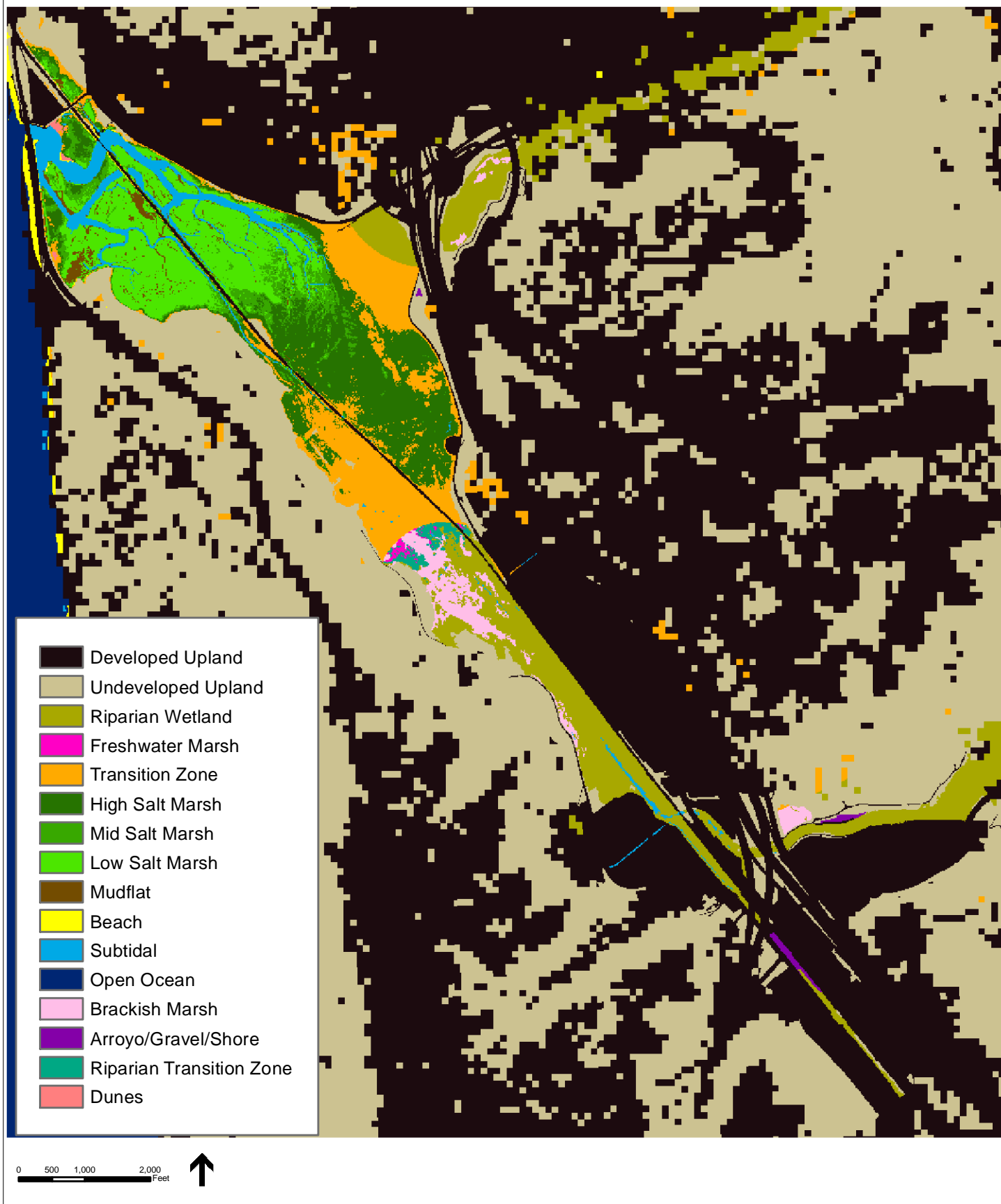
Run 5, 2030 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 39**

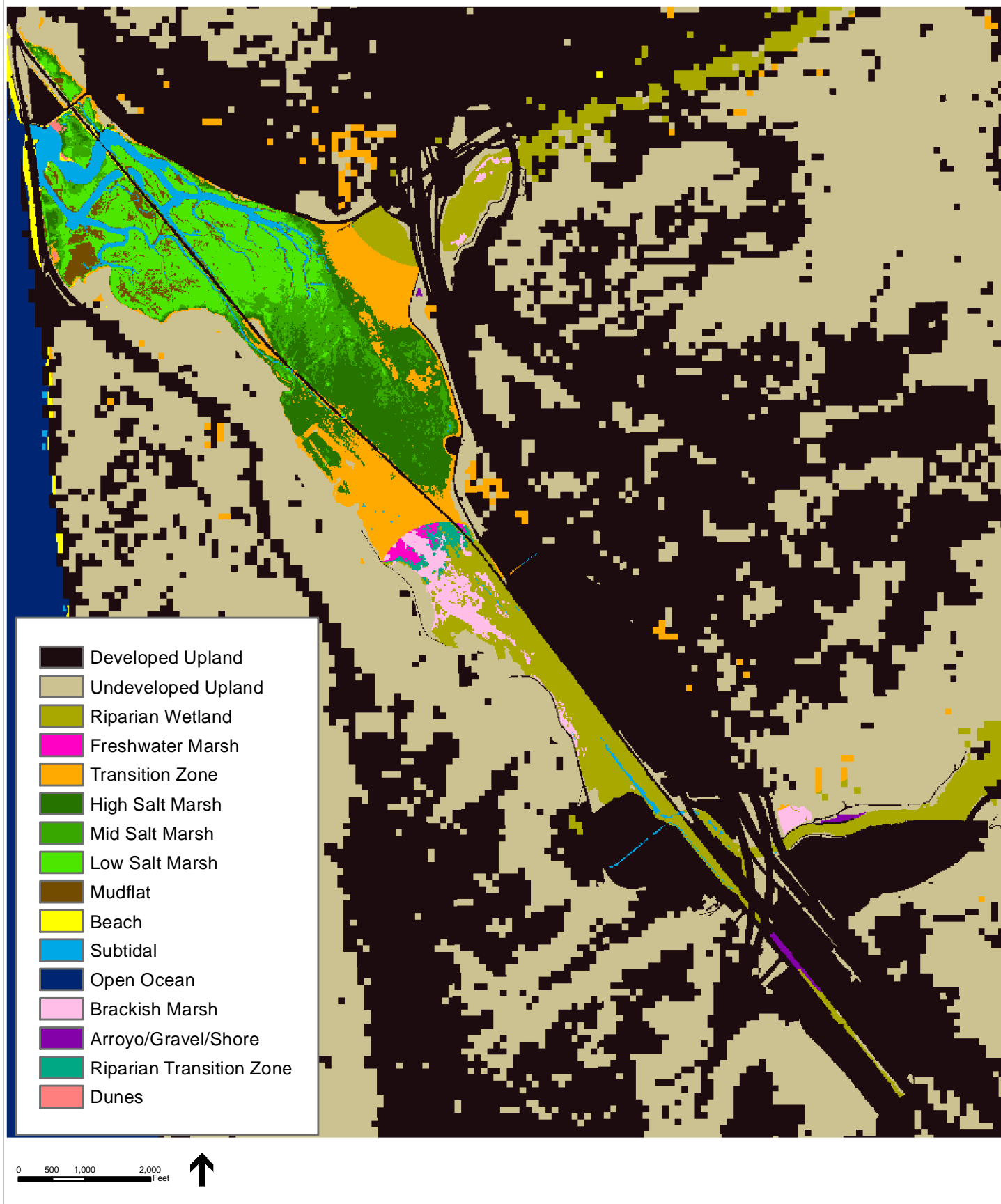
Run 5, 2040 Habitats

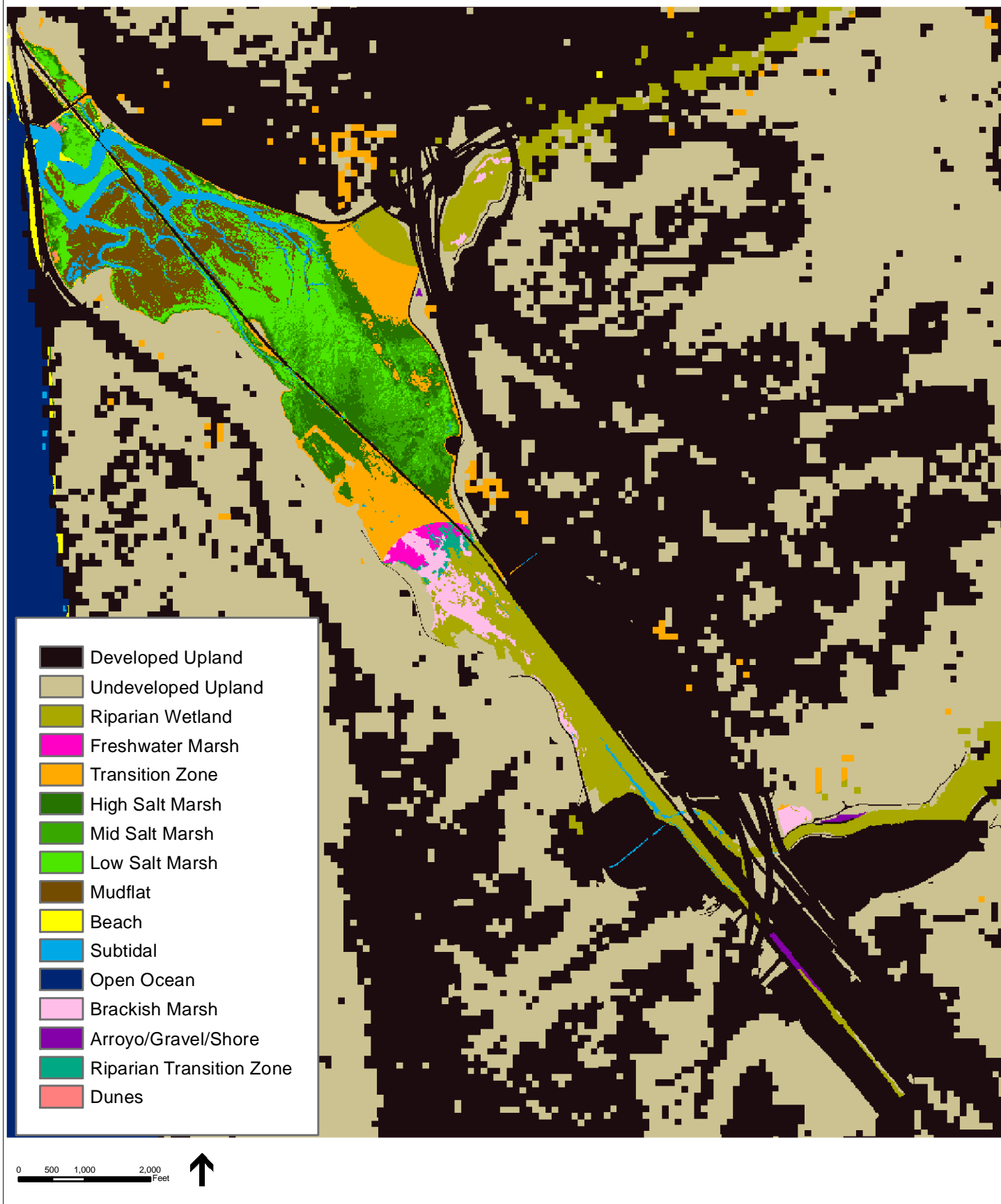


Los Peñasquitos Lagoon. D130136

**Figure 40**

Run 5, 2050 Habitats

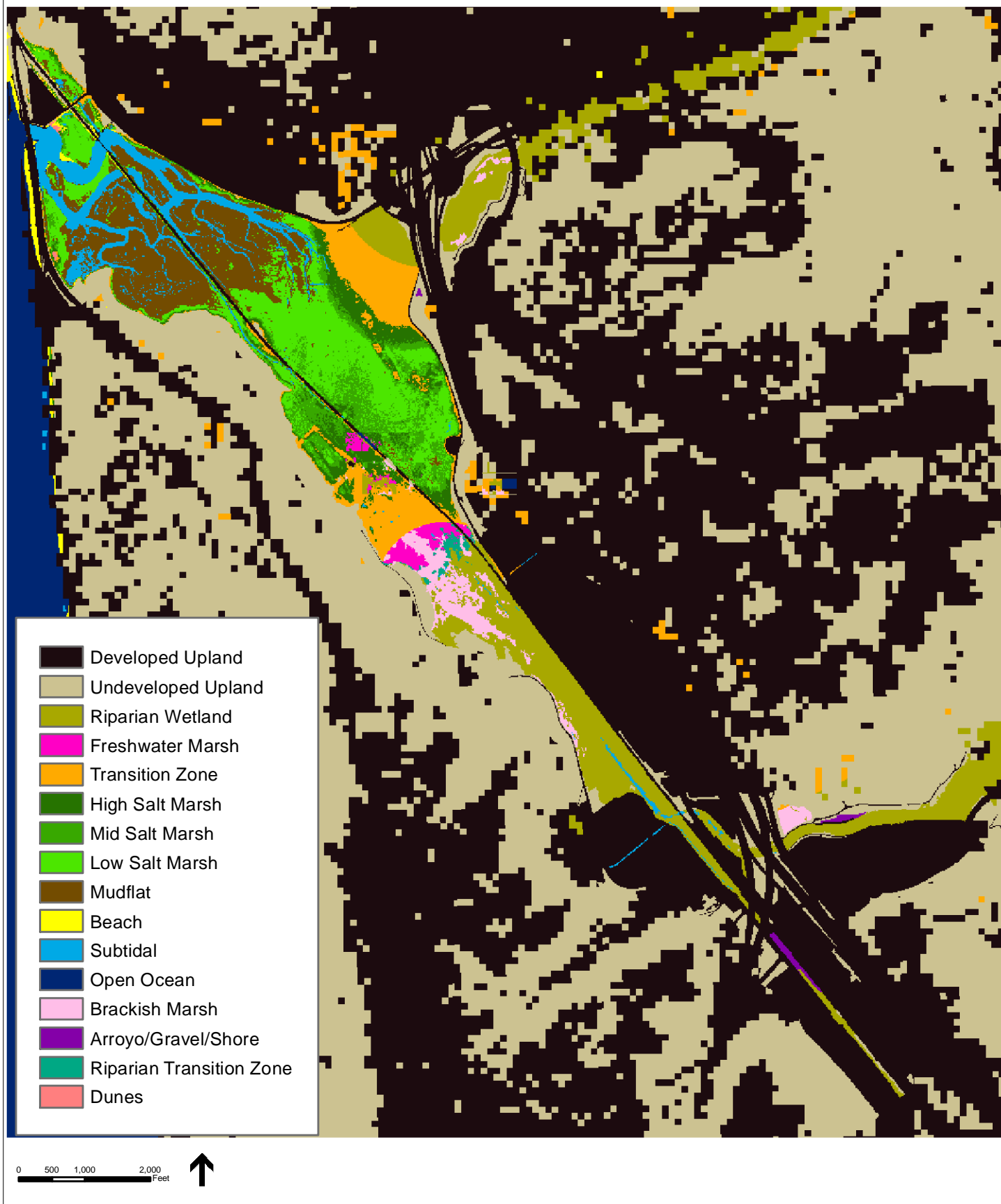




Los Peñasquitos Lagoon. D130136

**Figure 42**

Run 5, 2070 Habitats

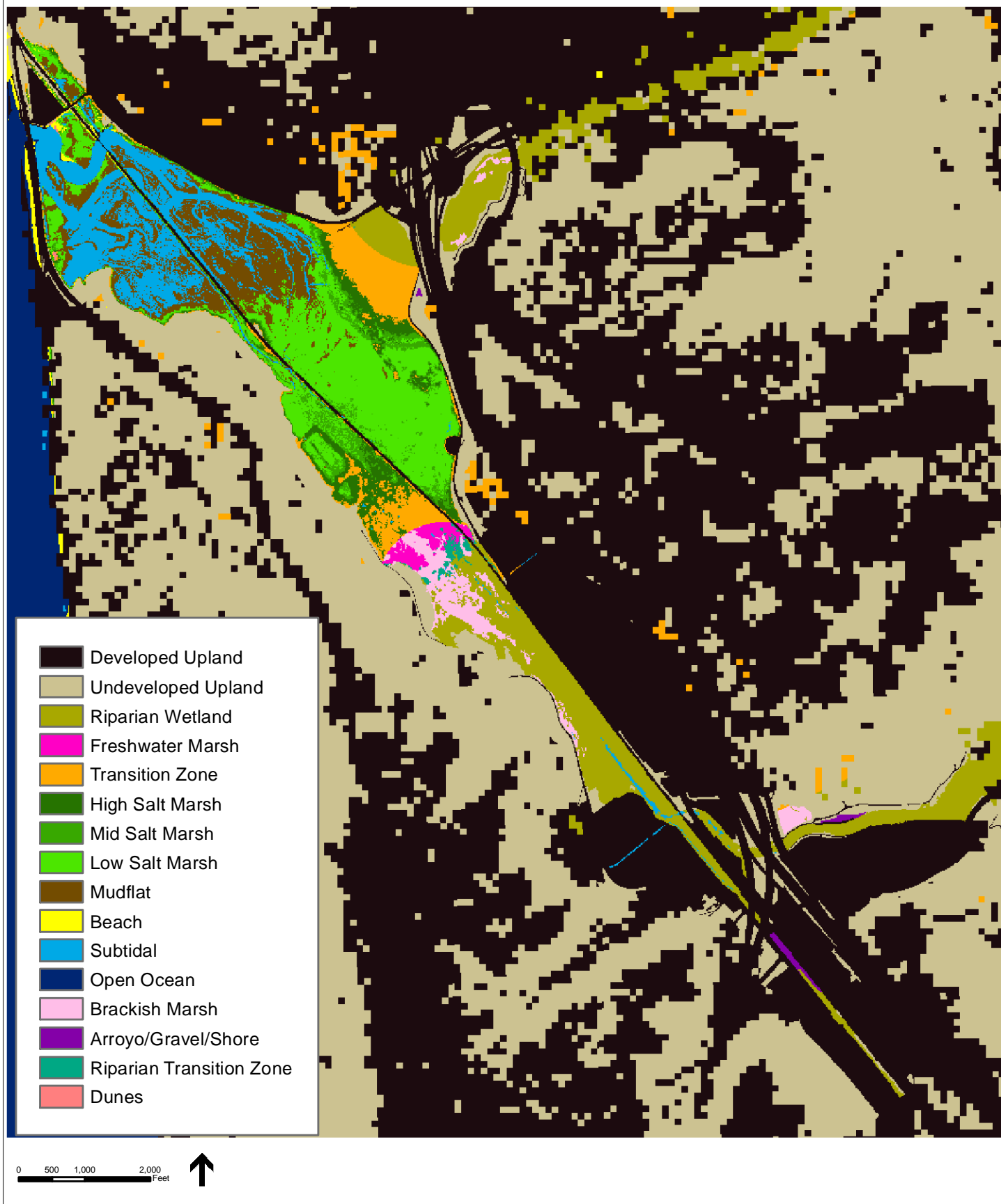


Los Peñasquitos Lagoon. D130136

**Figure 43**

Run 5, 2080 Habitats

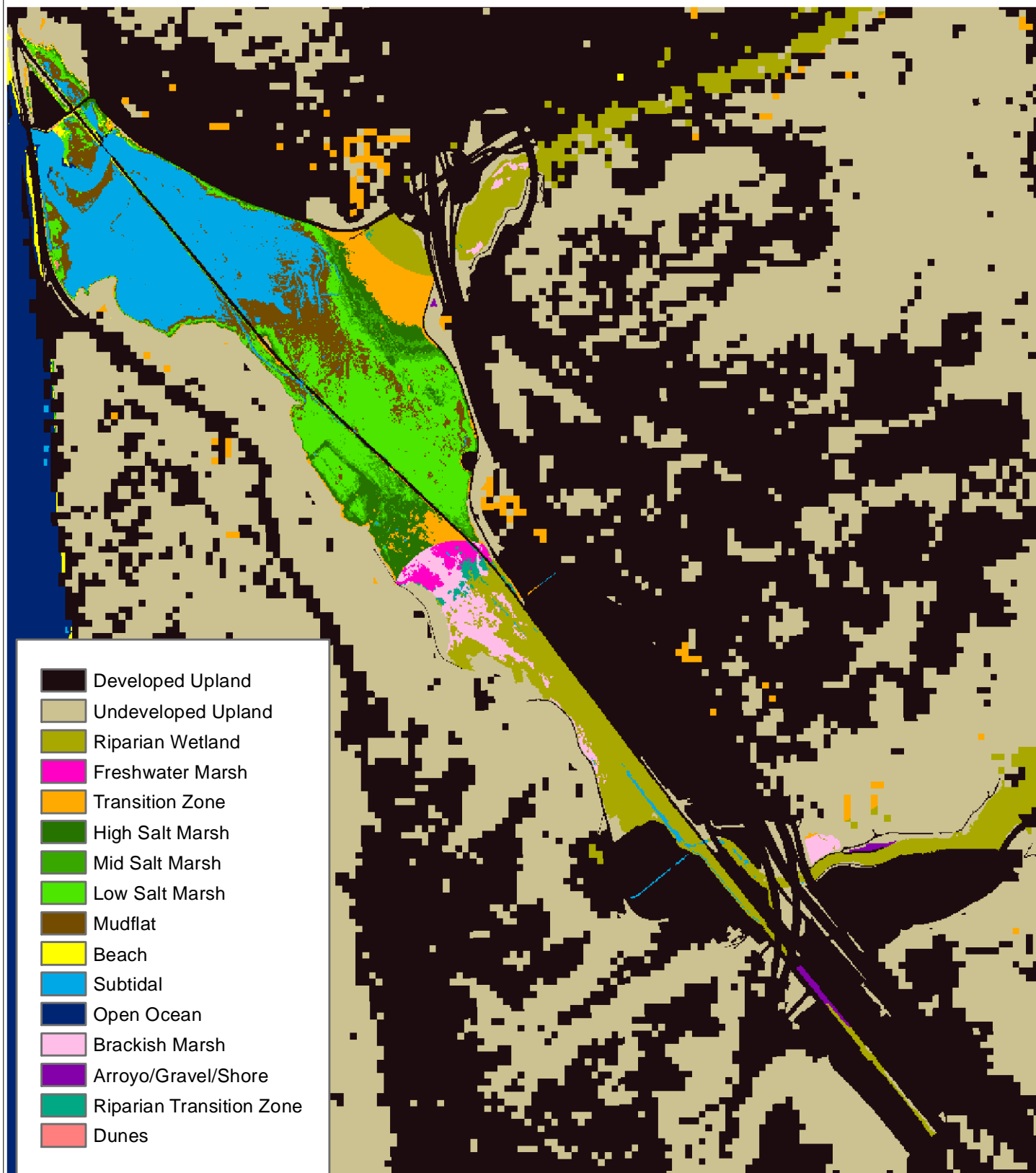




Los Peñasquitos Lagoon. D130136

**Figure 44**

Run 5, 2090 Habitats



Los Peñasquitos Lagoon. D130136

**Figure 45**

Run 5, 2100 Habitats

## Appendix D

### Freshwater Inflow Data

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## Appendix D. Freshwater Inflow Data

### Los Peñasquitos Creek

The United States Geological Survey (USGS) maintains a long term flow gage (11023340) in the upper watershed of Los Peñasquitos Creek. Daily discharge is available for 1964 through now. Additional streamflow data were collected at the base of the creek between 2007 and 2008 as part of the Los Peñasquitos TMDL monitoring study (Weston 2009). Weston created transformations to calculate flows based on the USGS gage data (Table 1). Under base flow conditions, the downstream gage showed slightly large flows than the USGS gage. However, under storm events, the downstream gage showed noticeably smaller flows (even smaller than would be expected with infiltration upstream), which may indicate that the streamflows are underestimated. FEMA (2012) estimated a slightly larger flow under the 10-year event, but an order of magnitude more than Weston for the 50-yr event (Table 2).

The average base flow for Los Peñasquitos Creek is 2.06 cfs (Weston, 2009). During storms, the creek's response to rainfall is delayed when compared to the other two creeks, likely due to dense vegetation and a dam upstream that may restrict flow.

### Carmel Creek

The USGS maintained a streamflow gage on Carmel Creek between 1985 and 1986. Greer and Stow (2003) took streamflow measurements at the same location between 1999 and 2000 and observed an order of magnitude increase in dry season flows. Table 1 shows the return period flows as calculated from the USGS gage with the Weston (2009) transformation. FEMA estimates are slightly higher (Table 2).

### Carroll Canyon Creek

Table 1 provides the return event flows for Carroll Canyon Creek based on the Weston (2009) transformations. The FEMA estimates are slightly lower for the 10- and 50-year events (Table 2). Because the watershed has become so urbanized, flows are quick to respond to rainfall events and result in larger peaks, as water runs directly off the impervious surfaces and into the channel.

**Table 1.**

**Los Peñasquitos Watershed Runoff Flow Conditions – USGS and Weston (2009)**

| Return Period (year) | Upper Los Peñasquitos Streamflow <sup>1</sup> (cfs) | Lower Los Peñasquitos Streamflow <sup>2</sup> (cfs) | Carmel Creek Streamflow <sup>2</sup> (cfs) | Carroll Canyon Creek Streamflow <sup>2</sup> (cfs) |
|----------------------|---|---|--|--|
| 50                   | 5,730   | 4,151   | 1,349                                      | 6,398  |
| 10                   | 4,560   | 3,304   | 1,073                                      | 5,091  |
| 5                    | 3,110   | 2,253   | 732  | 3,472  |
| 1                    | 49  | 36  | 12   | 55   |

1. Calculated from USGS gage #11023340.

2. Calculated using Weston 2009 transformations.

**Table 2.**

**Los Peñasquitos Watershed Runoff Flow Conditions – FEMA FIS**

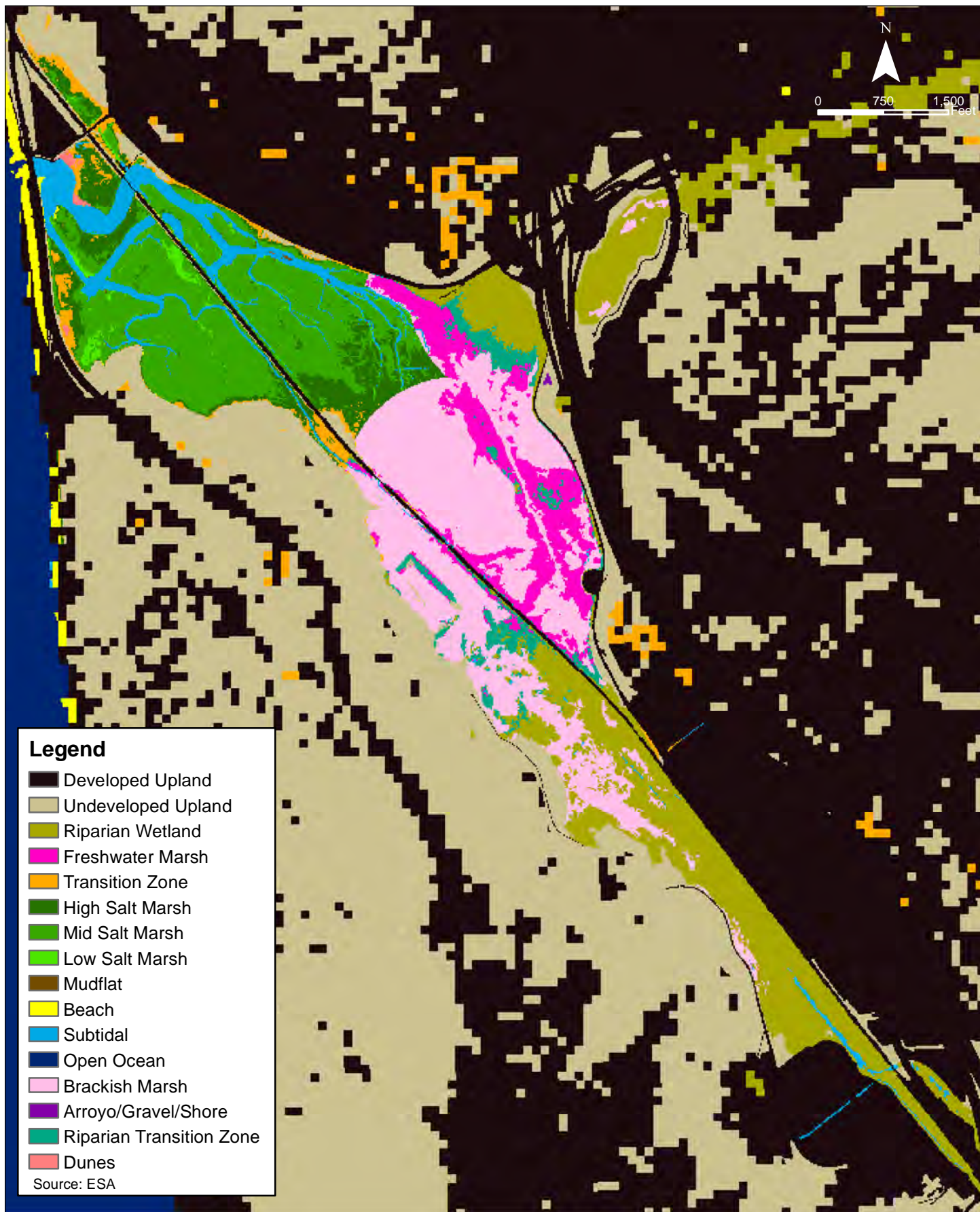
| Return Period<br>(year) | Los Peñasquitos Creek<br>(Above Soledad Canyon) (cfs) | Carmel Creek (above<br>Soledad Canyon) (cfs) | Carroll Canyon Creek (at<br>ATSF Railway) (cfs) |
|-------------------------|---|--|---|
| 500                     | 37,600  | 21,300                                       | 18,700  |
| 100                     | 16,800  | 9,800  | 6,700   |
| 50                      | 11,300  | 6,500  | 4,500   |
| 10                      | 3,700   | 2,100  | 1,500   |

Flow at all three creeks has been measured monthly since 1995 for the Los Peñasquitos Lagoon Monitoring, and provides snapshots of flow conditions (TRNERR 2012).

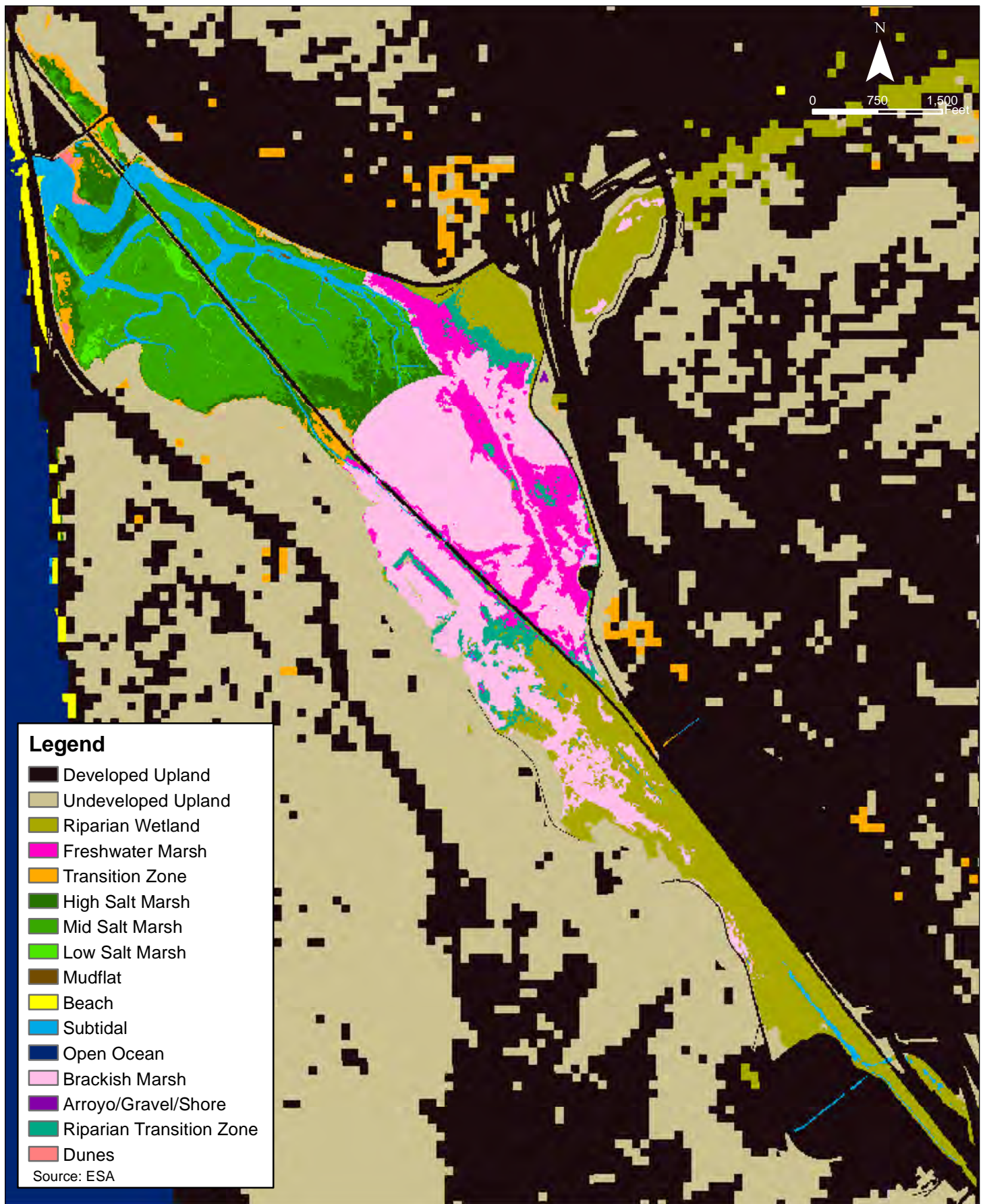
## **APPENDIX L**

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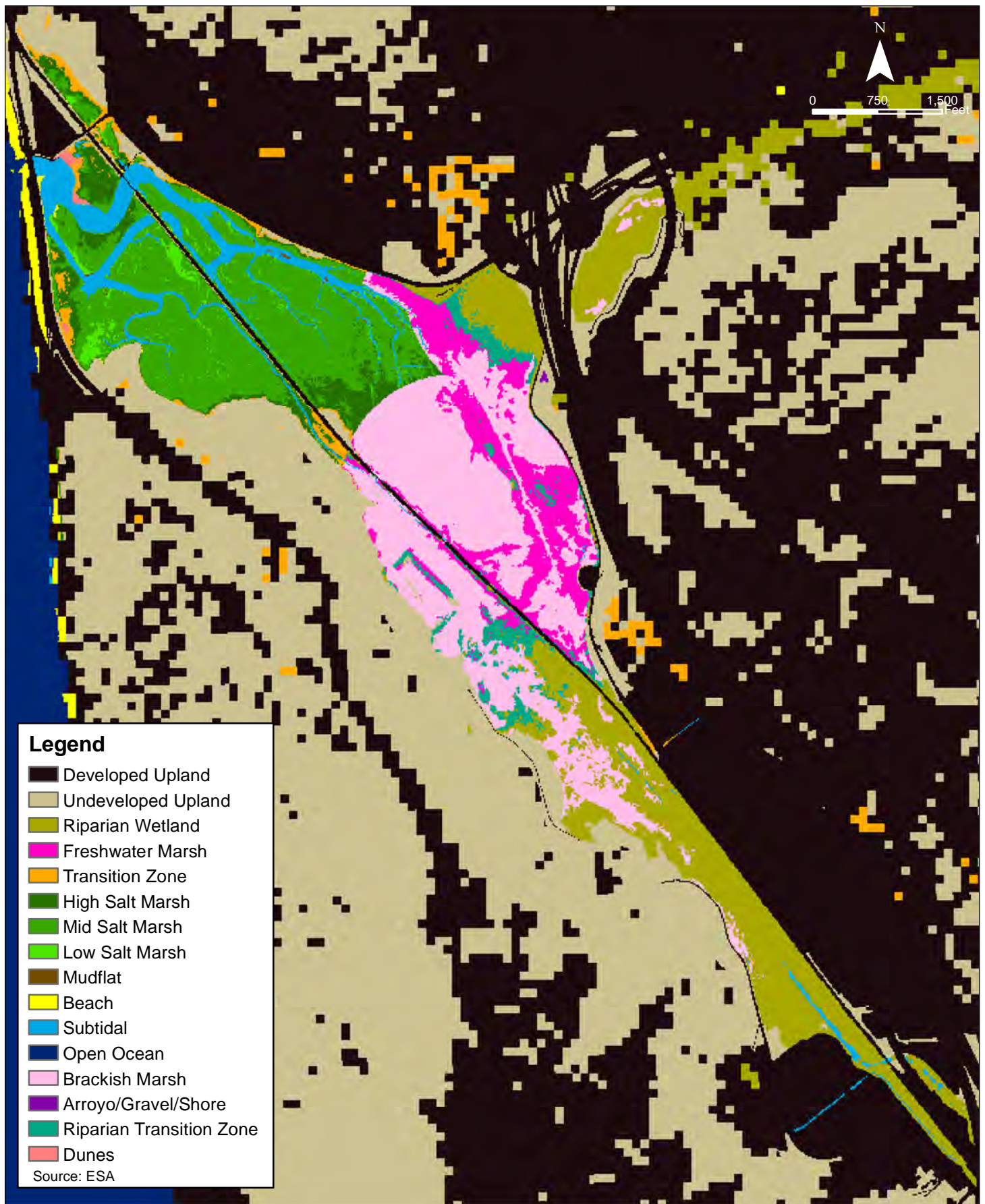
### Baseline Habitats, 2010



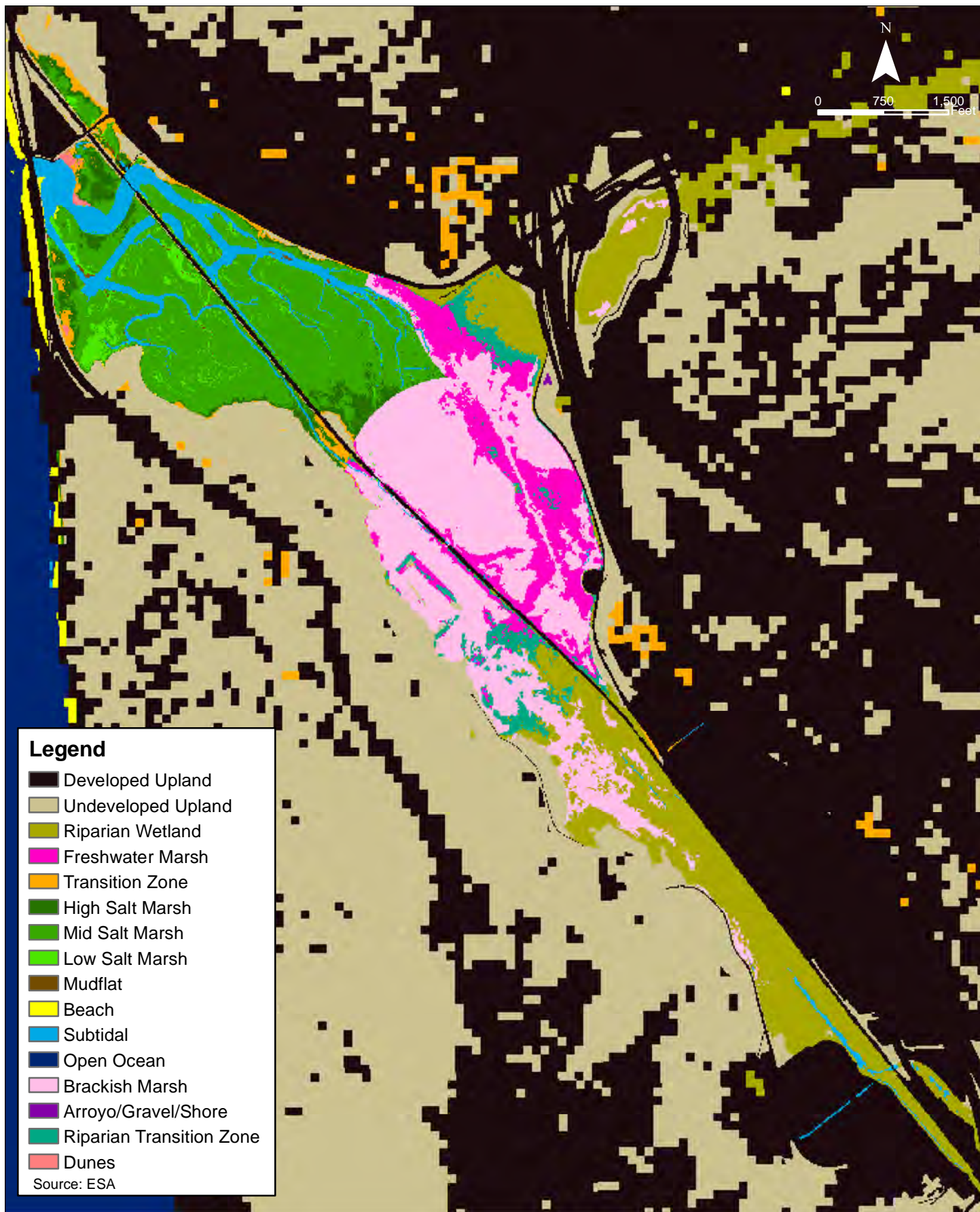




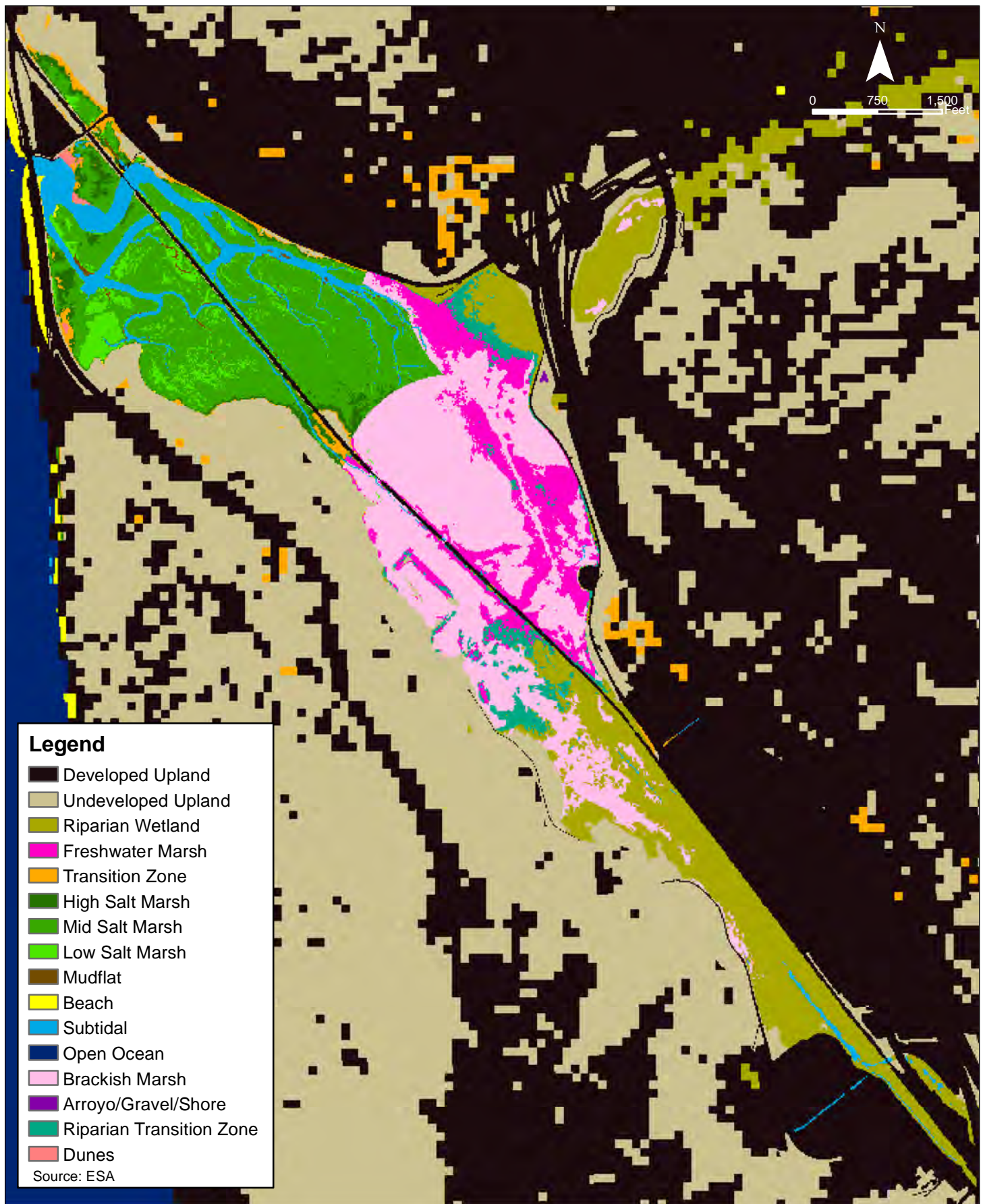




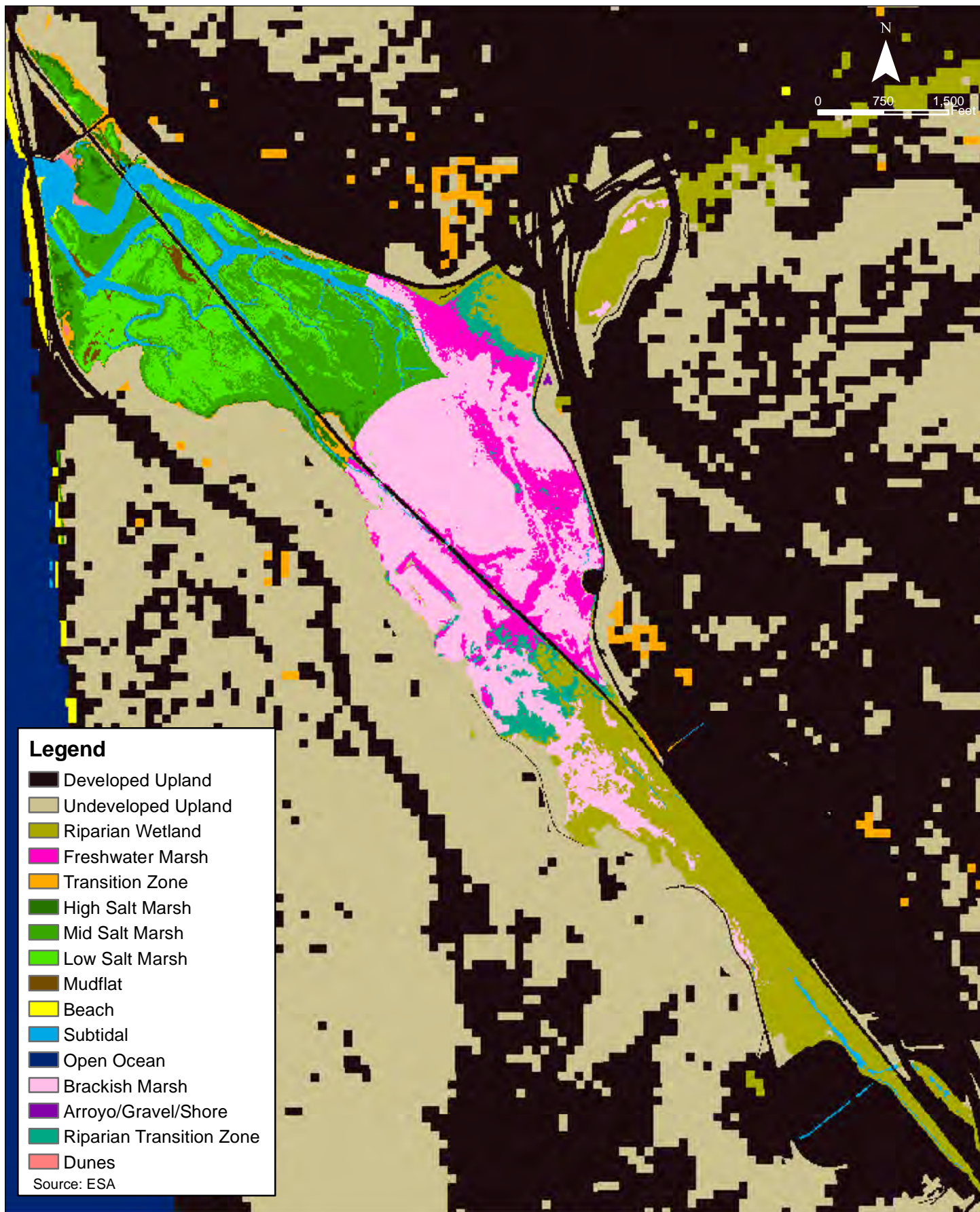




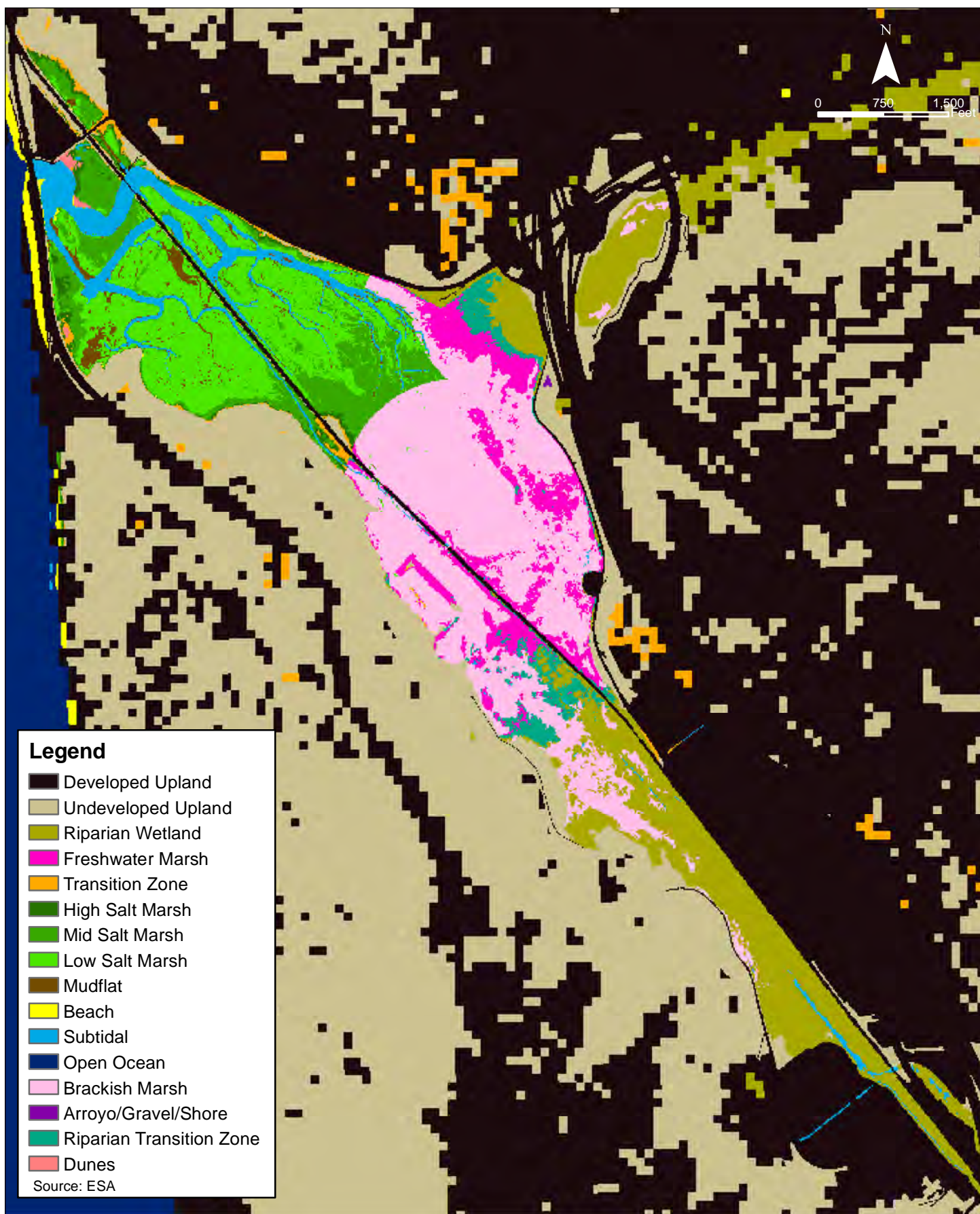




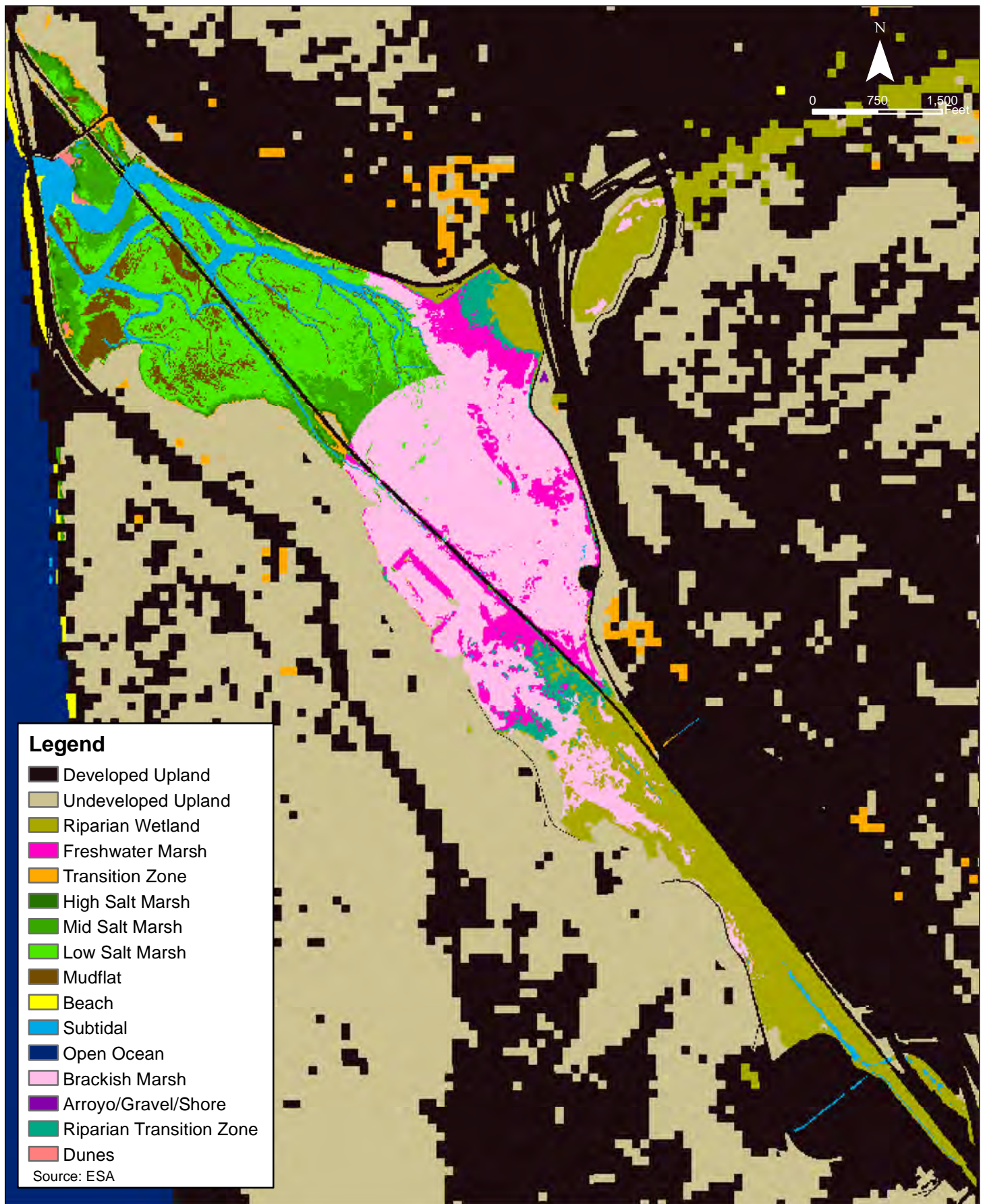




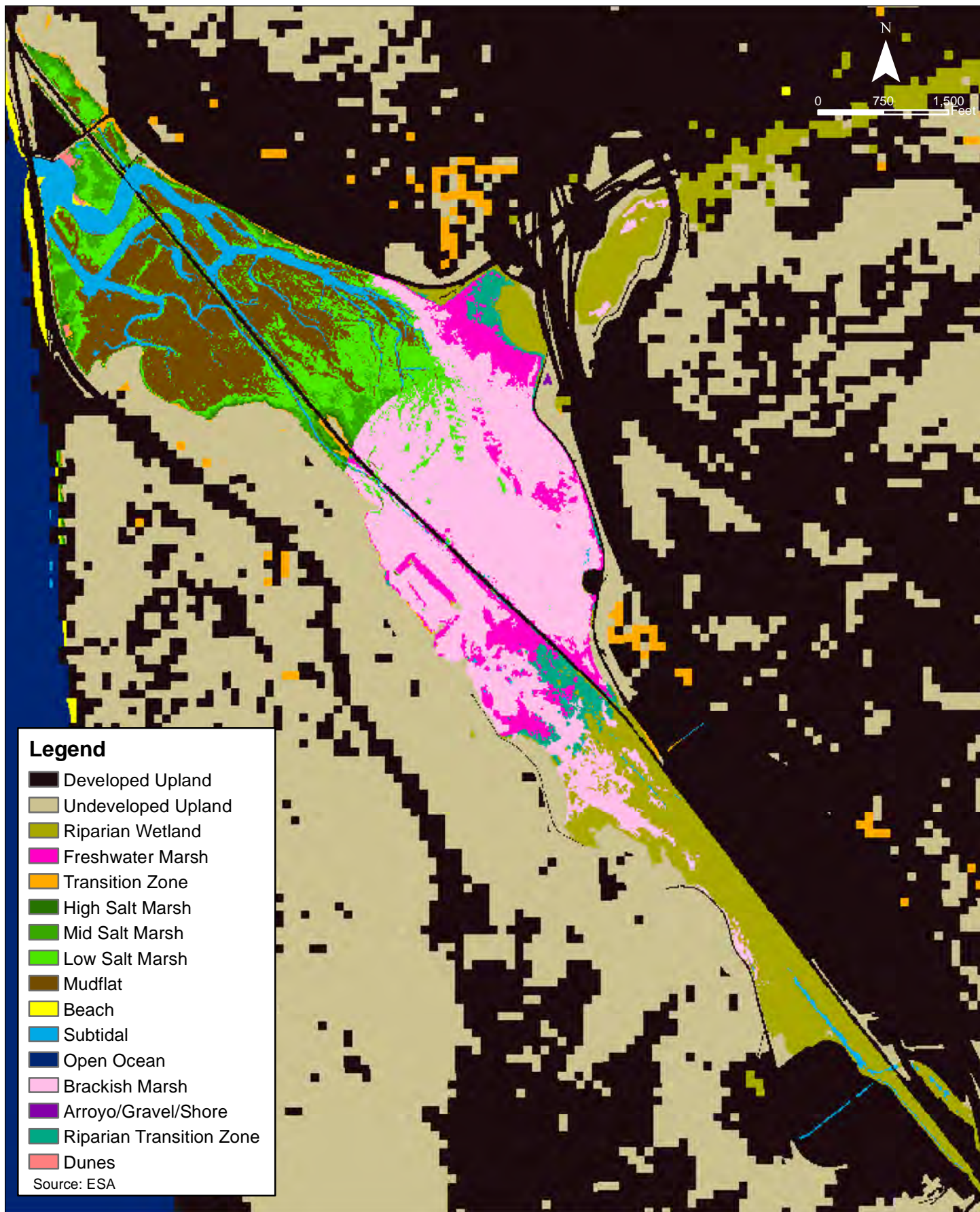




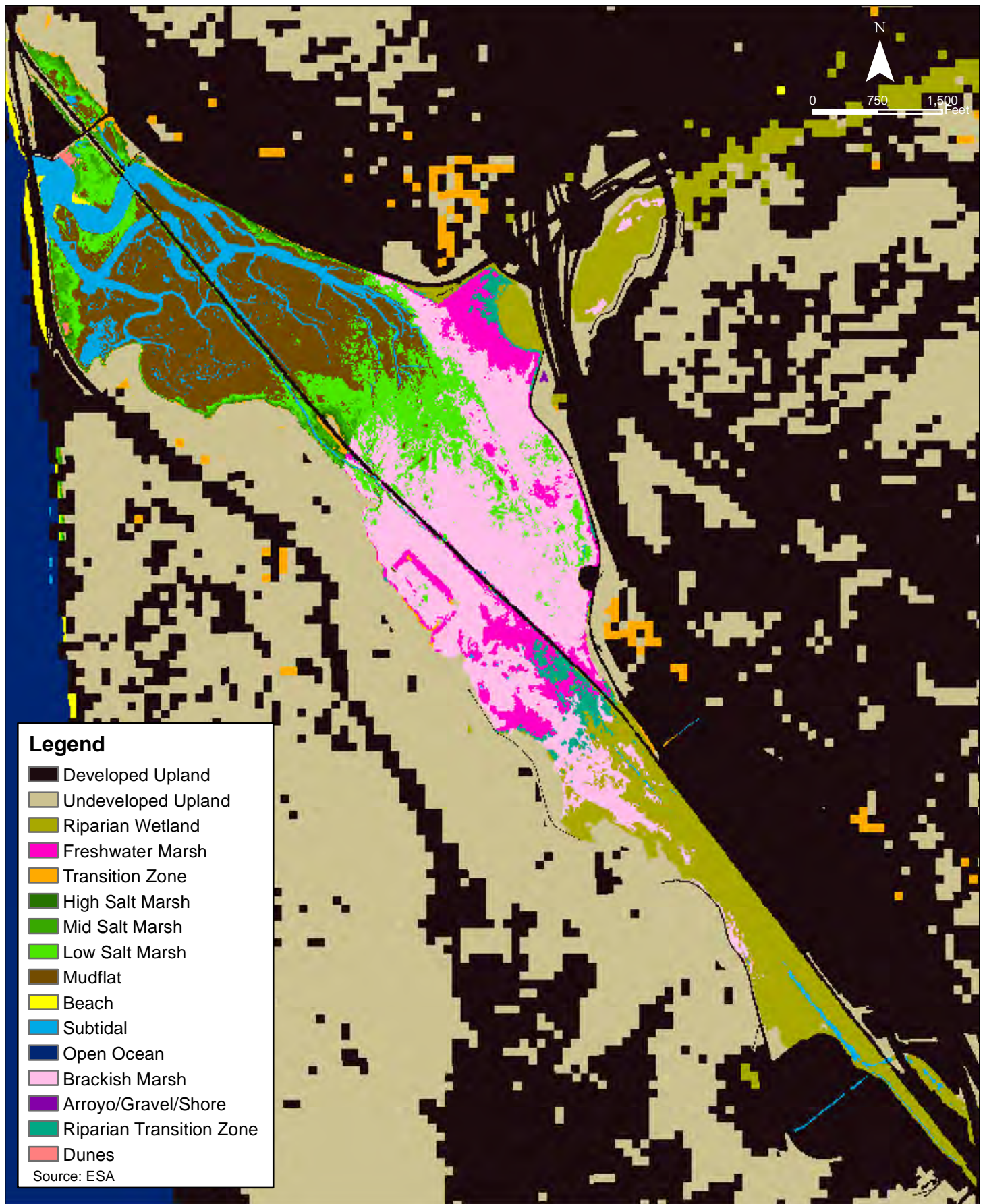




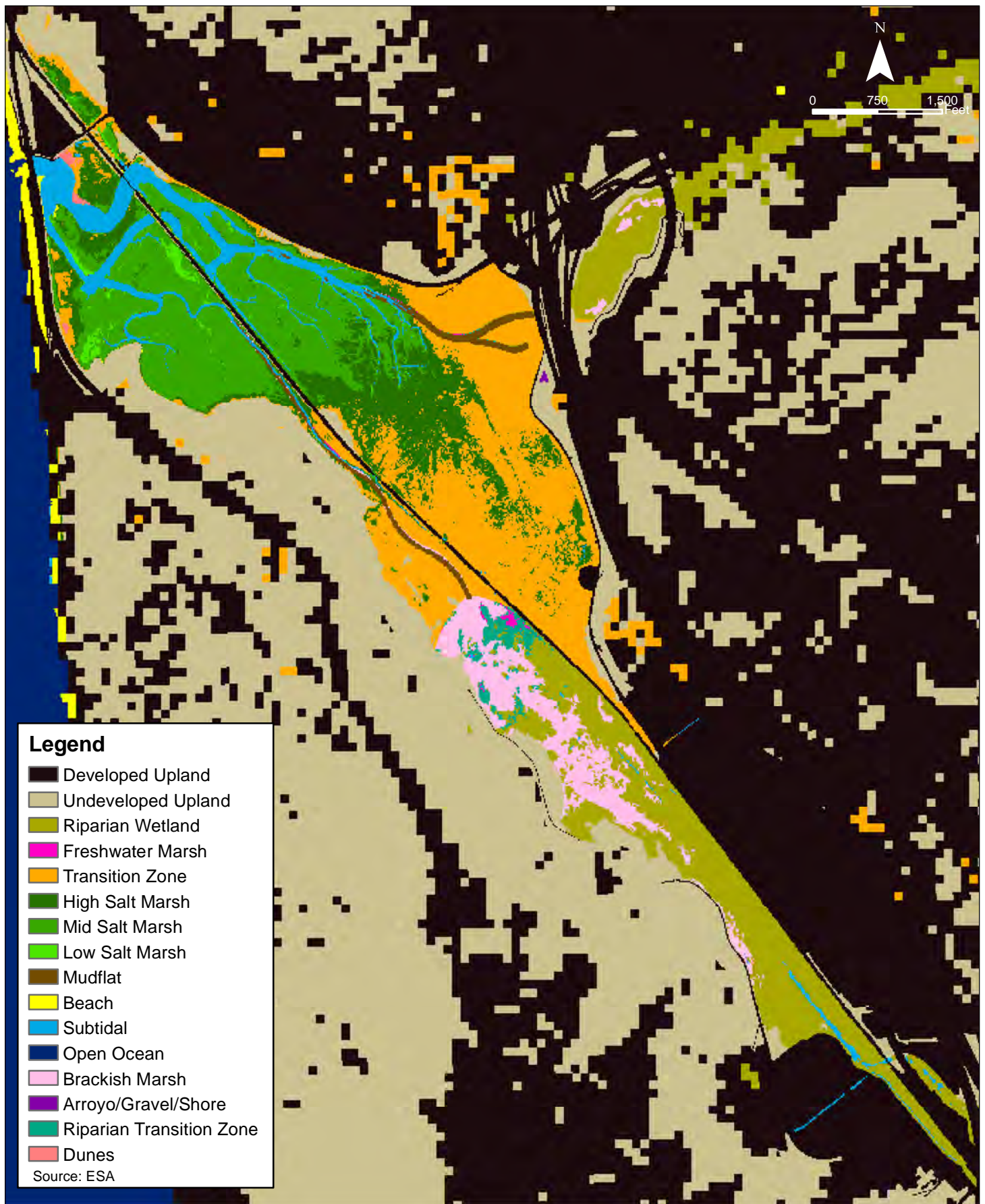




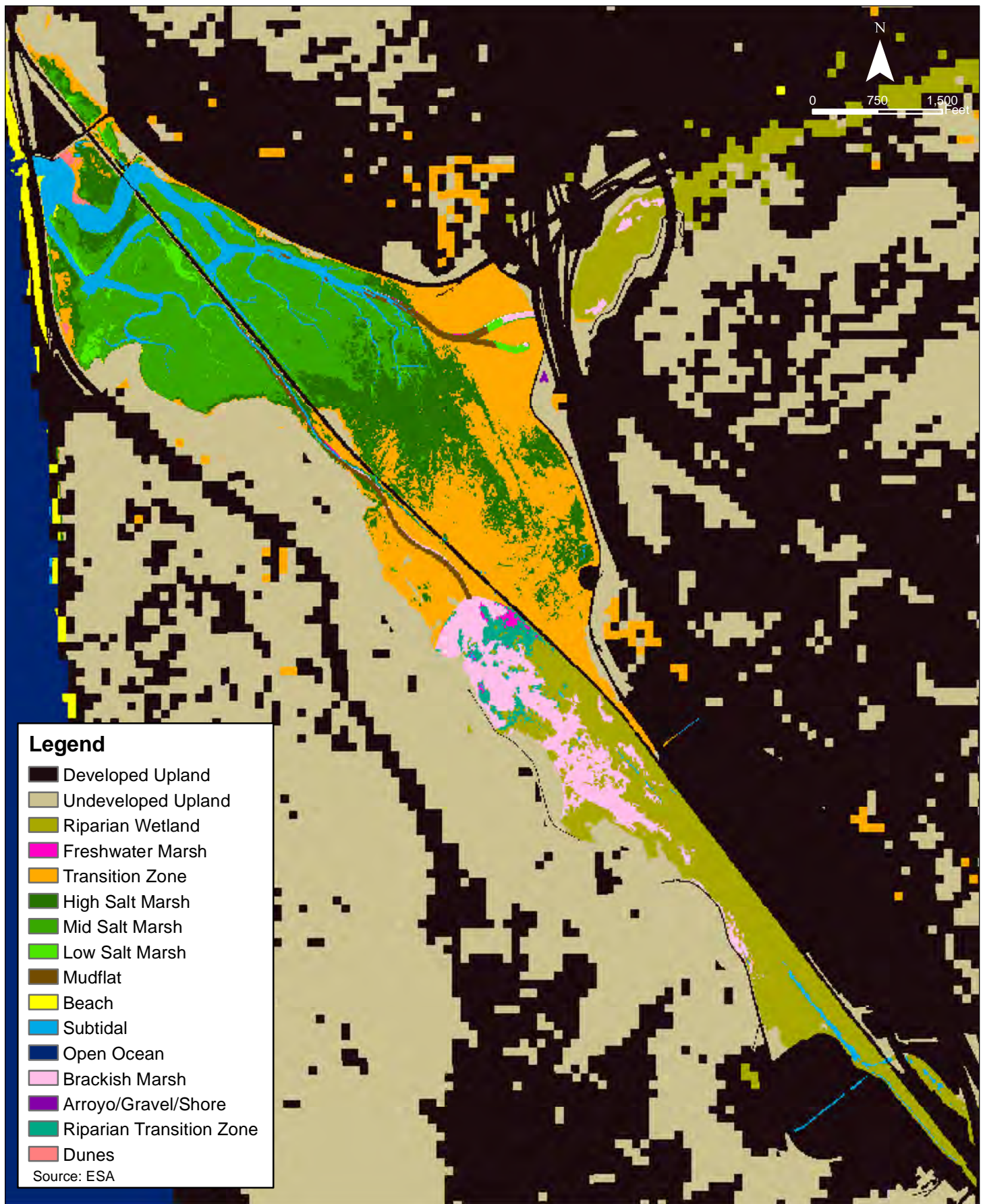




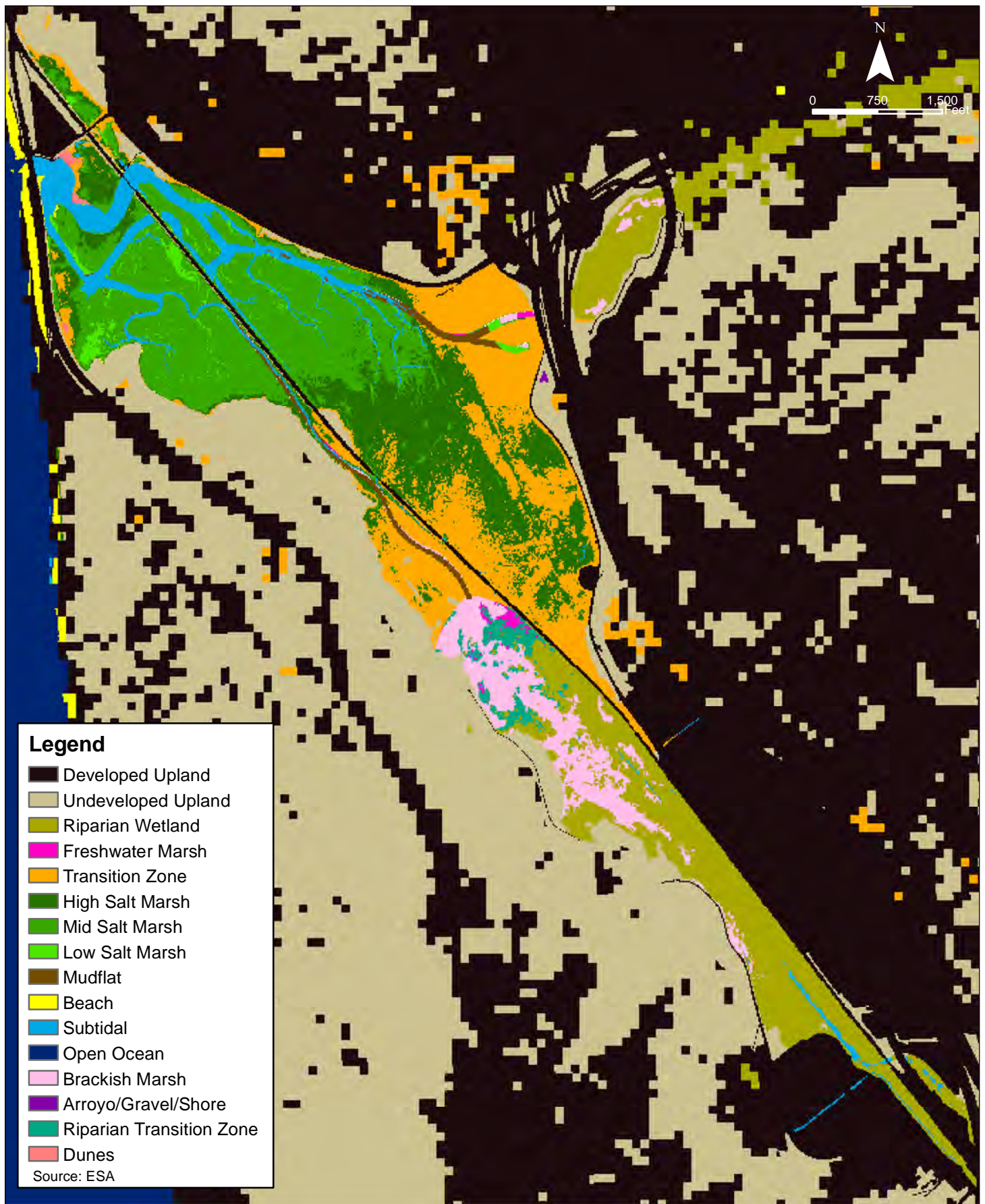




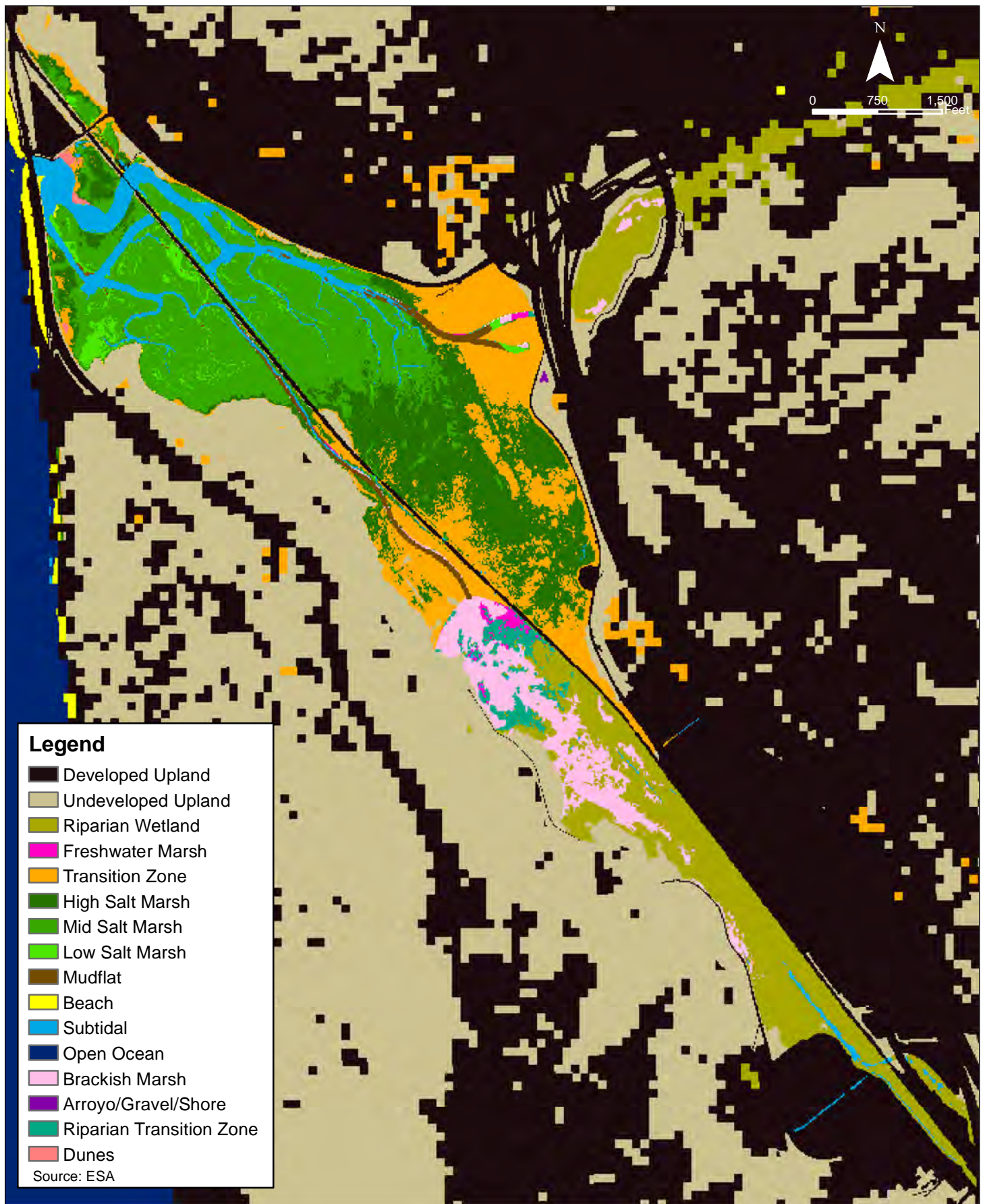




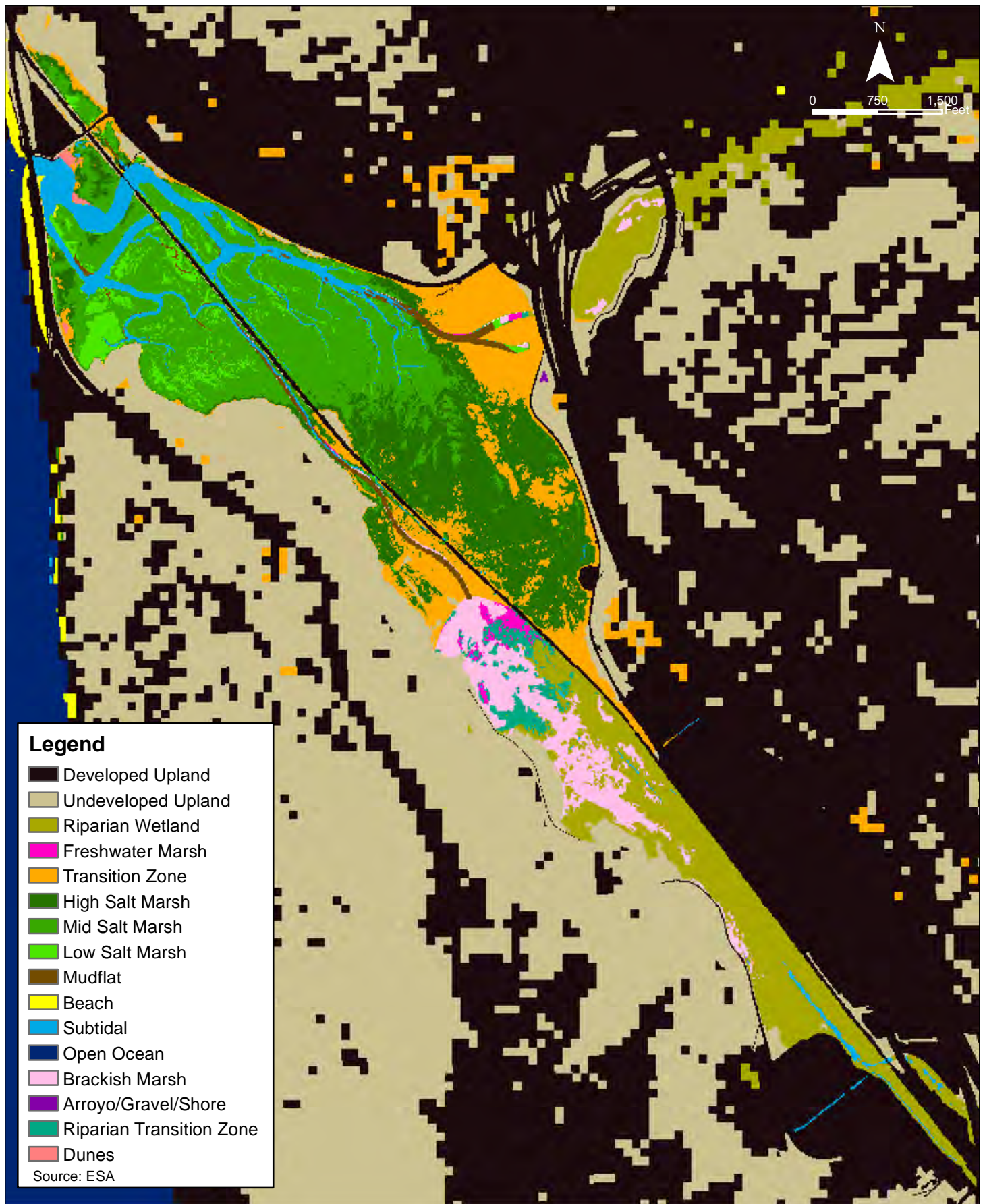










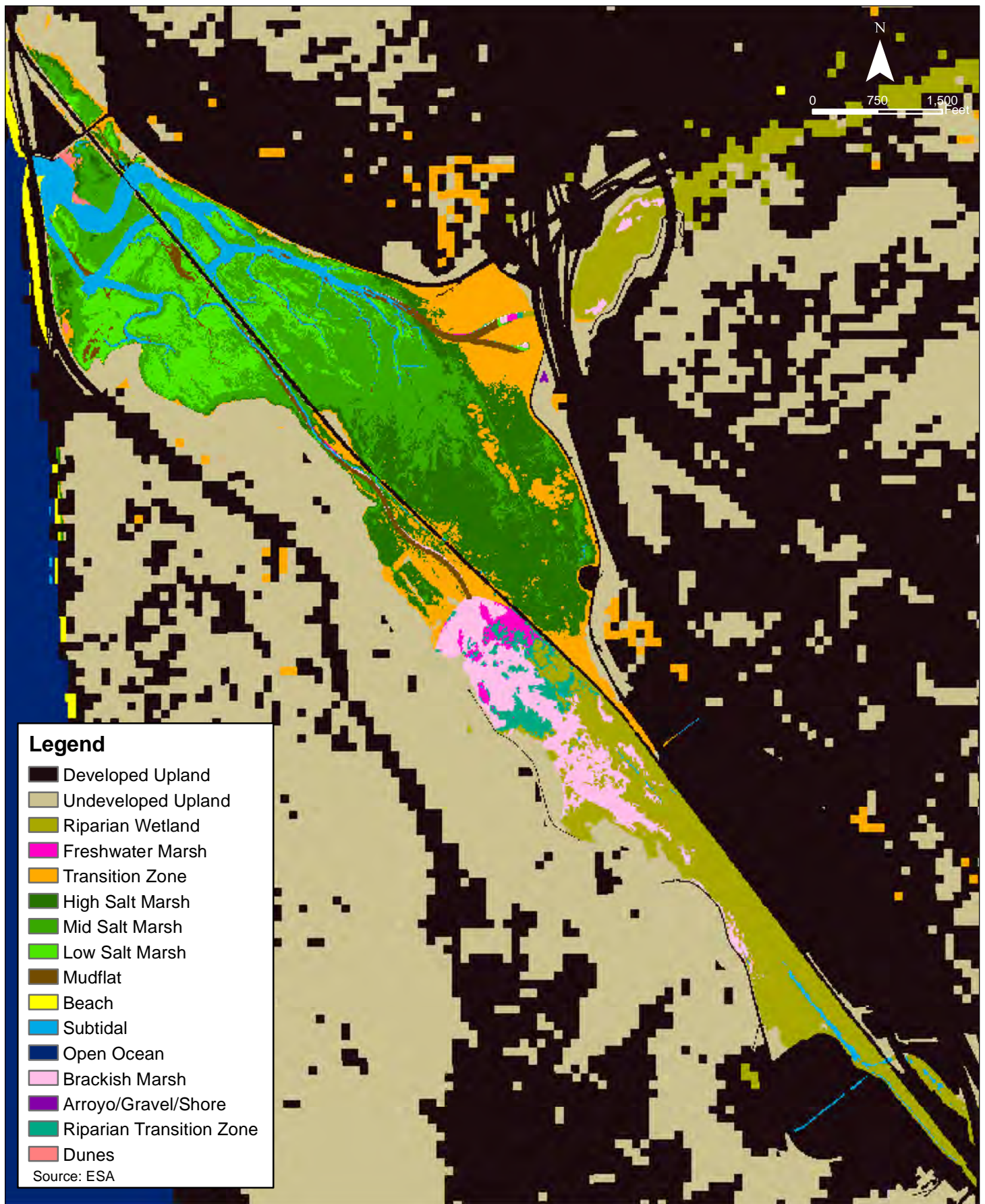


Los Peñasquitos Lagoon, D130136

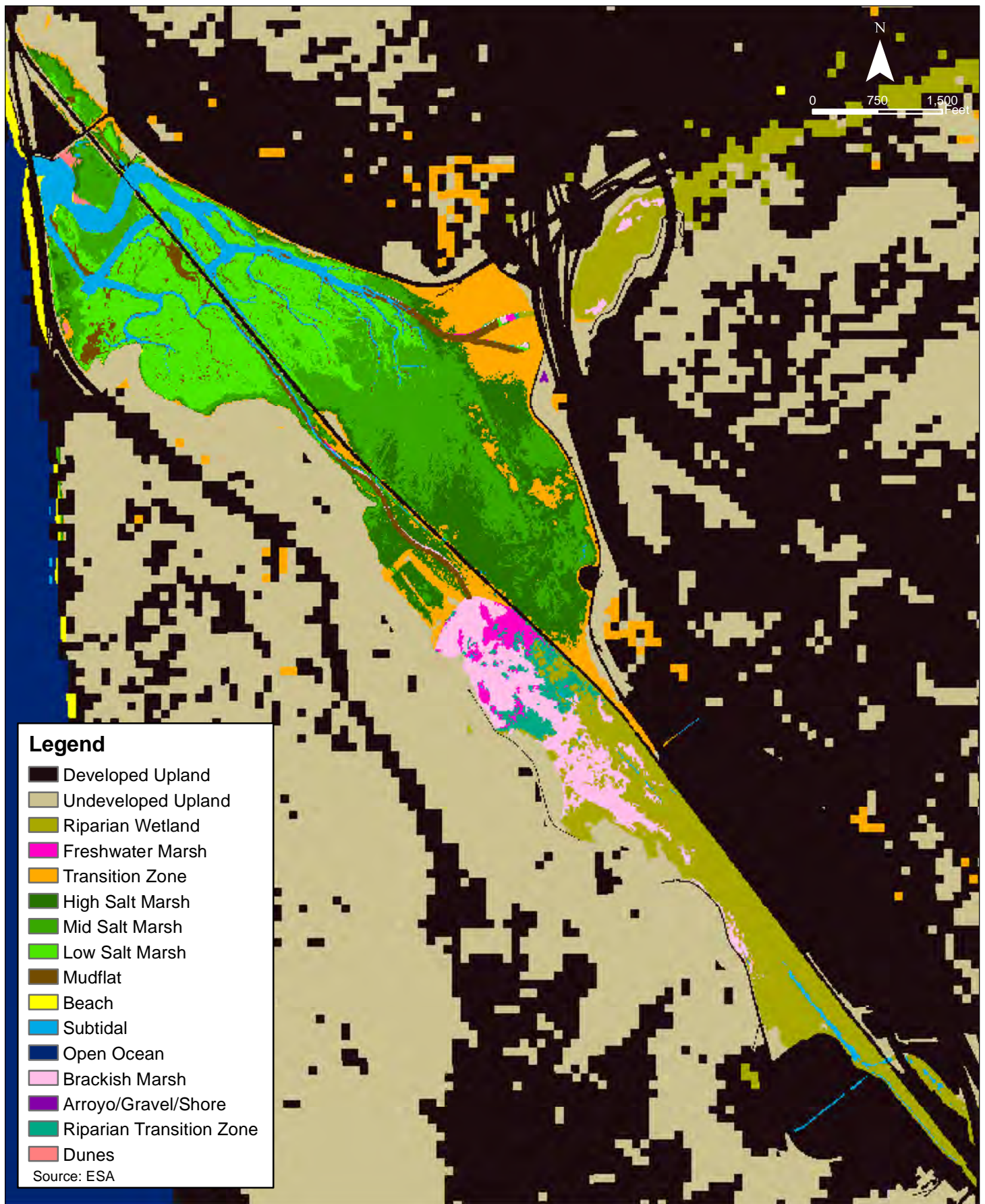
**Figure L-15**

Restoration with Channel Improvements, 2050







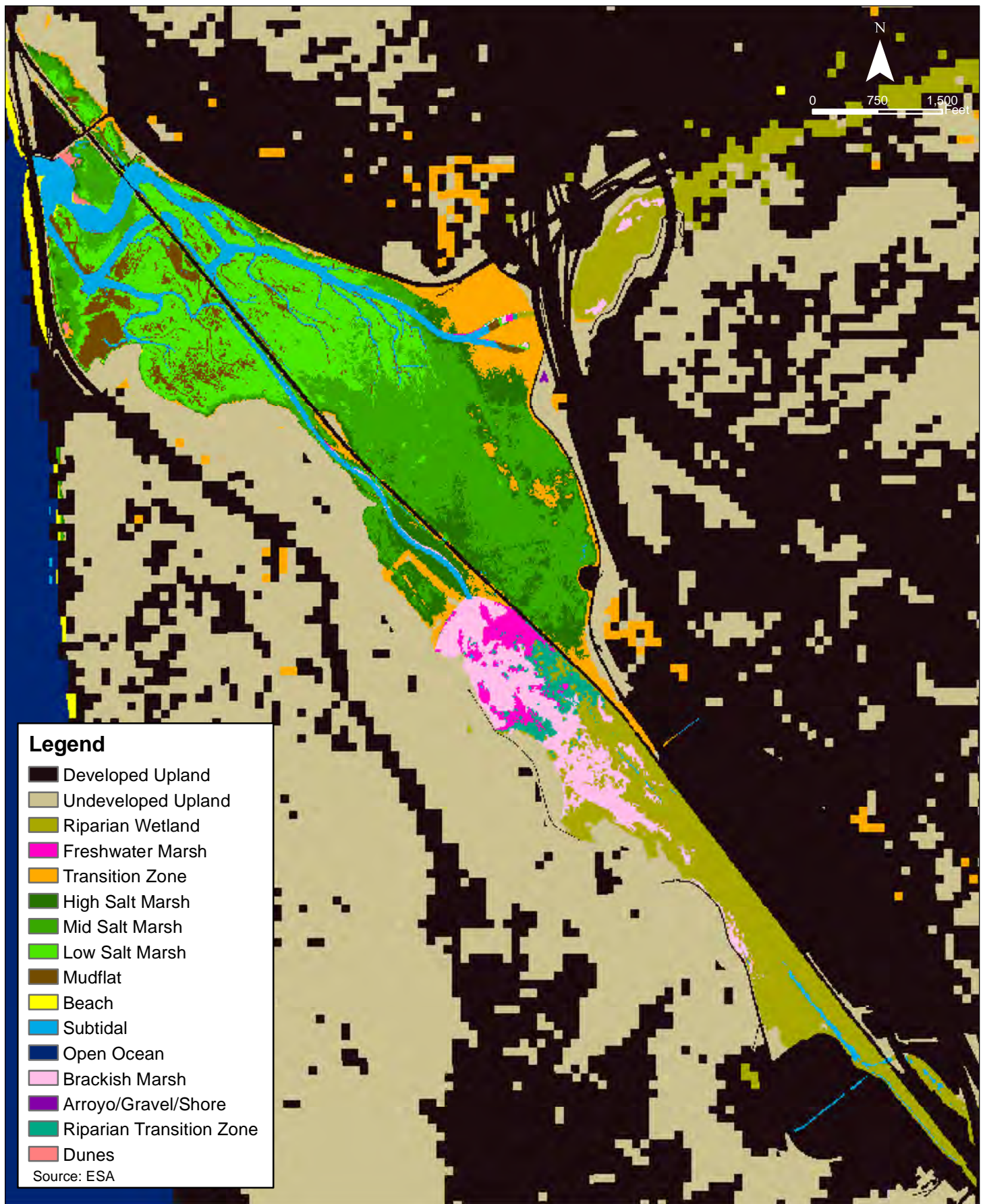


Los Peñasquitos Lagoon. D130136

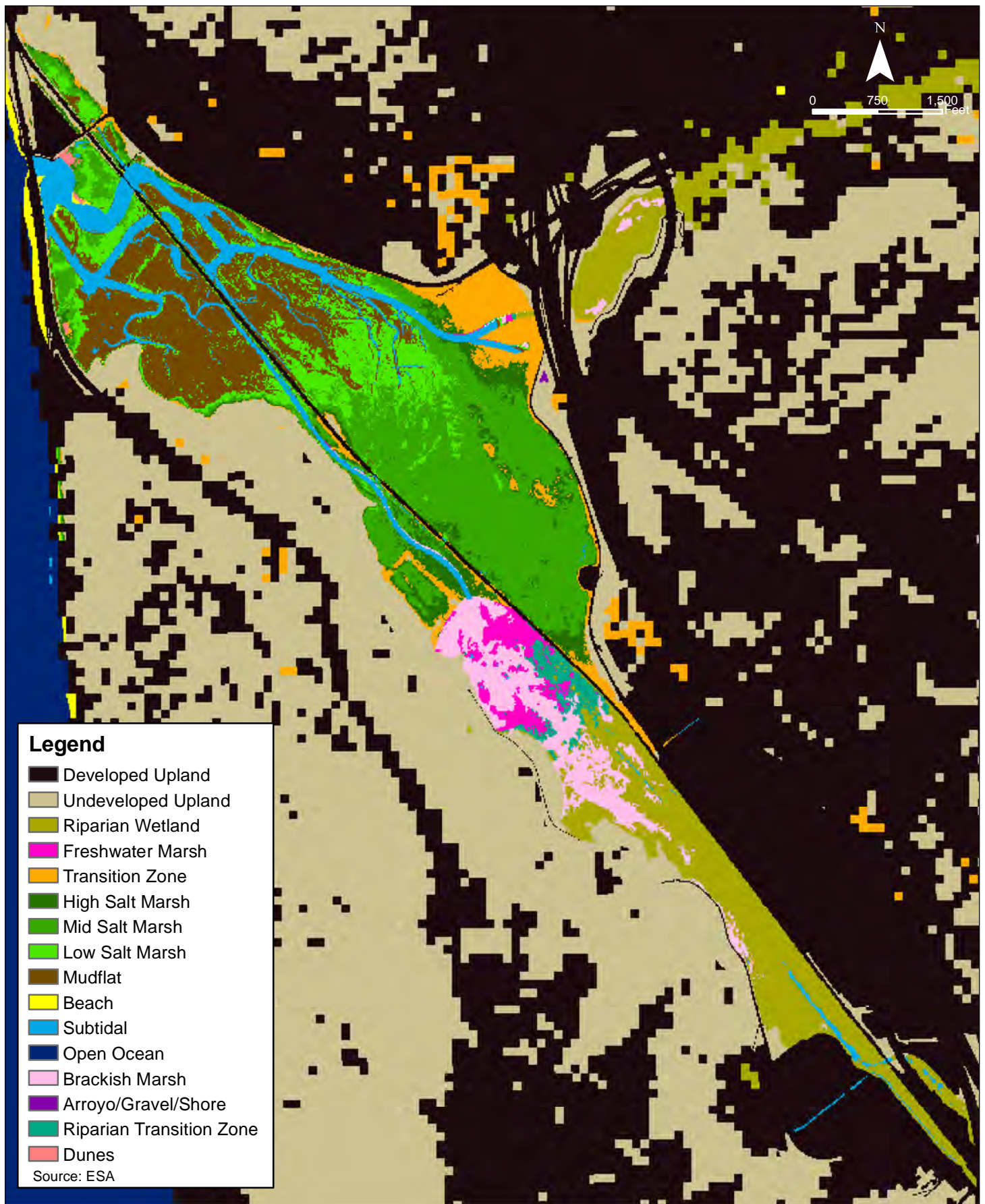
**Figure L-17**

Restoration with Channel Improvements, 2070

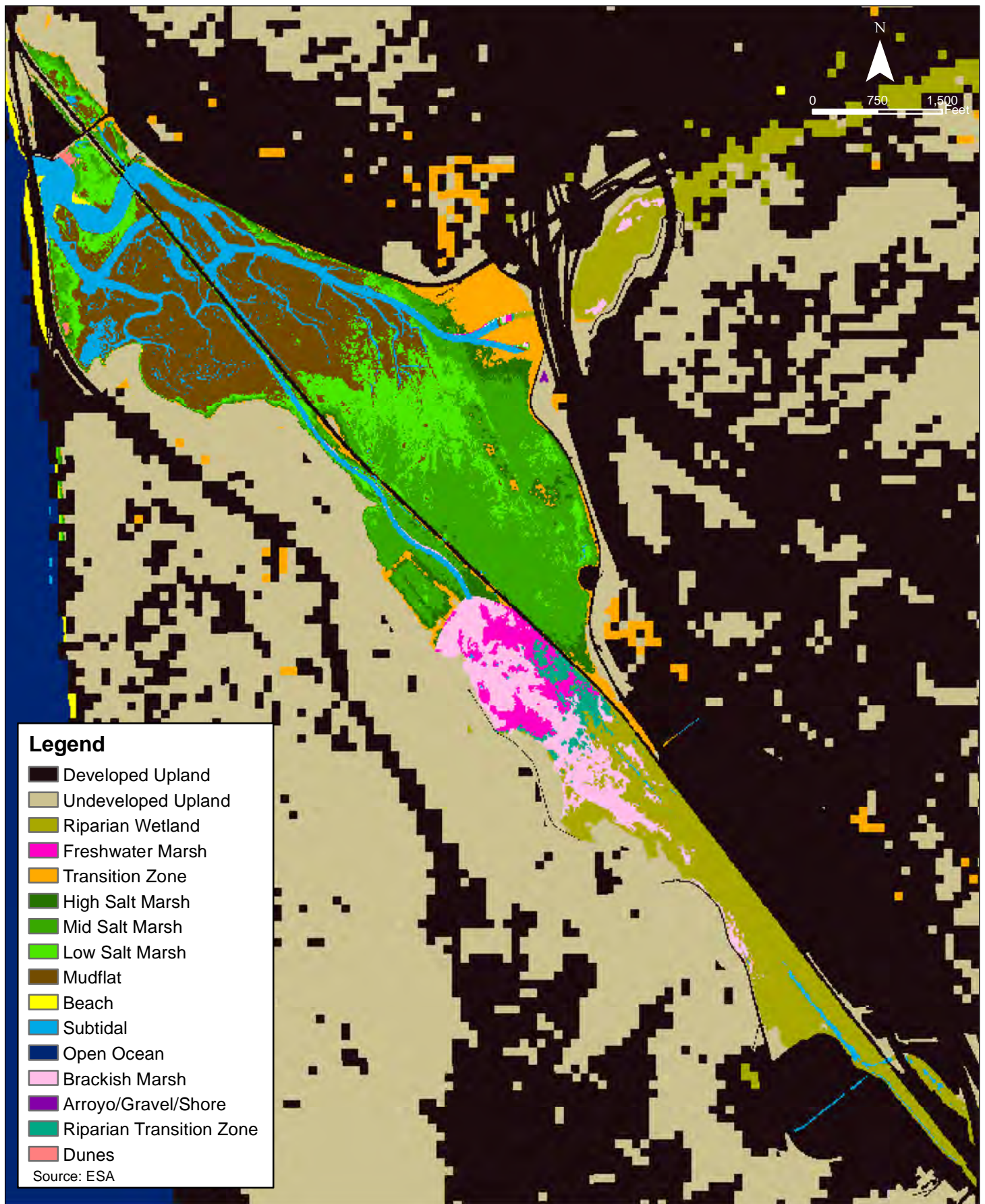










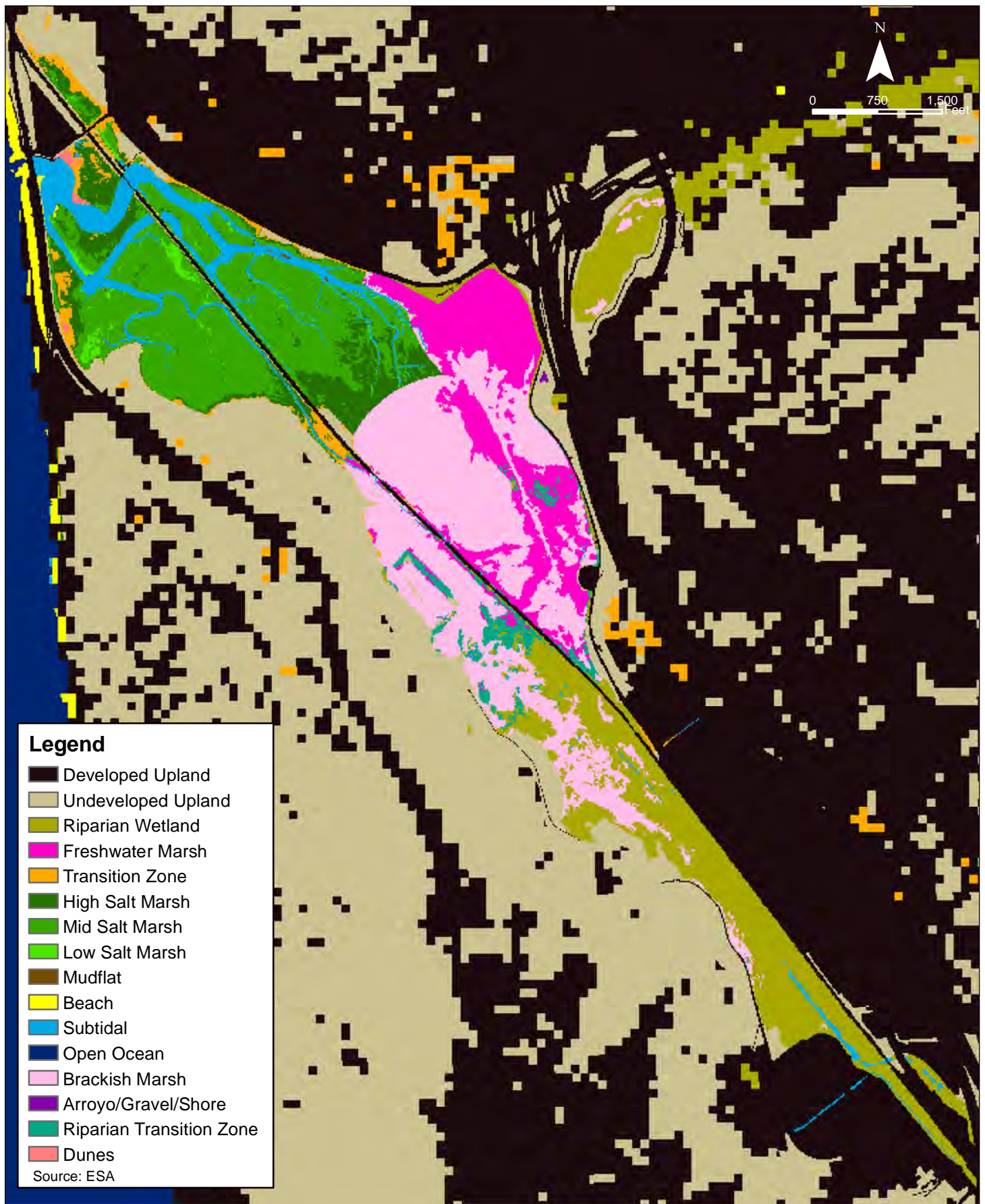


Los Peñasquitos Lagoon. D130136

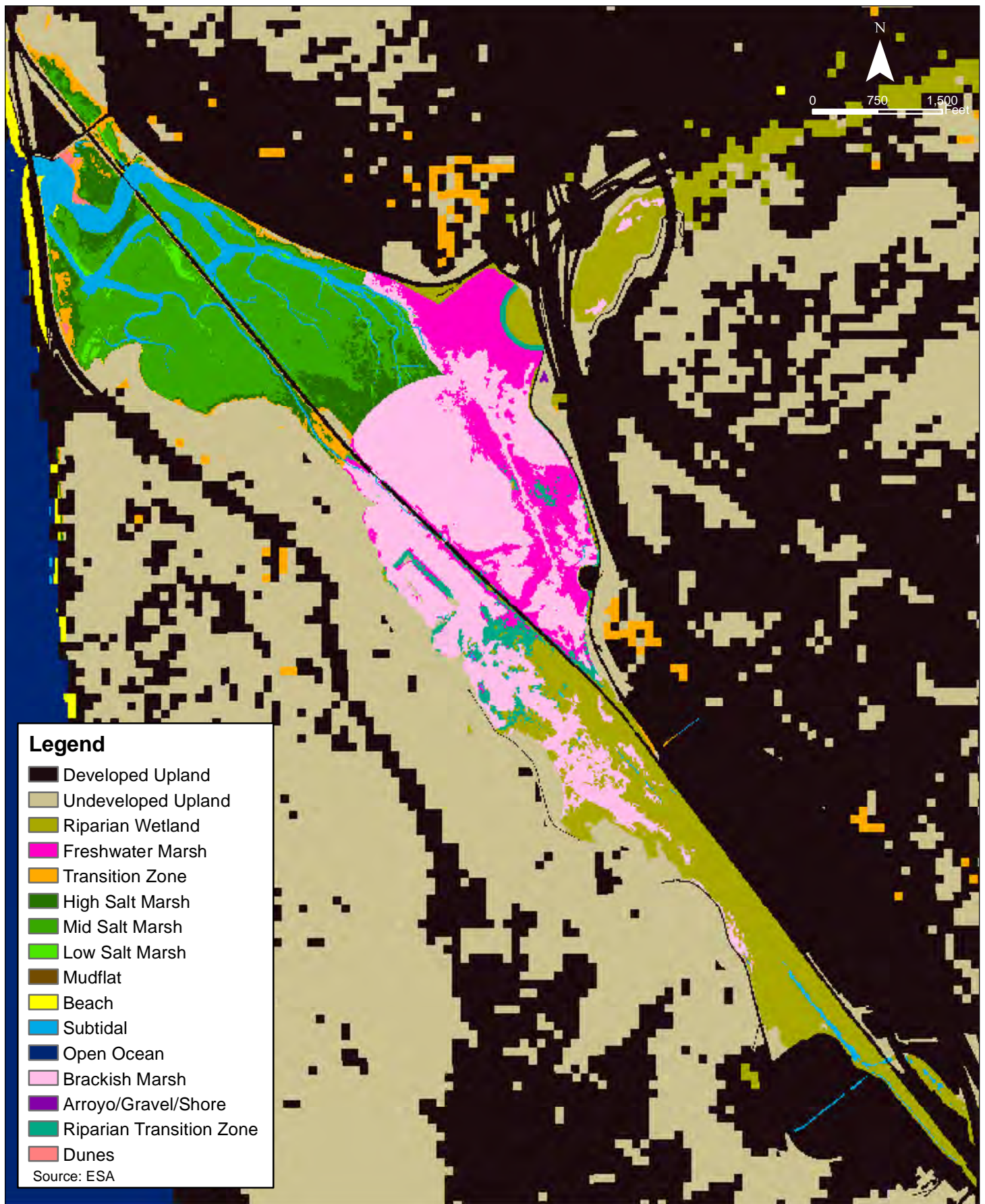
**Figure L-20**

Restoration with Channel Improvements, 2100

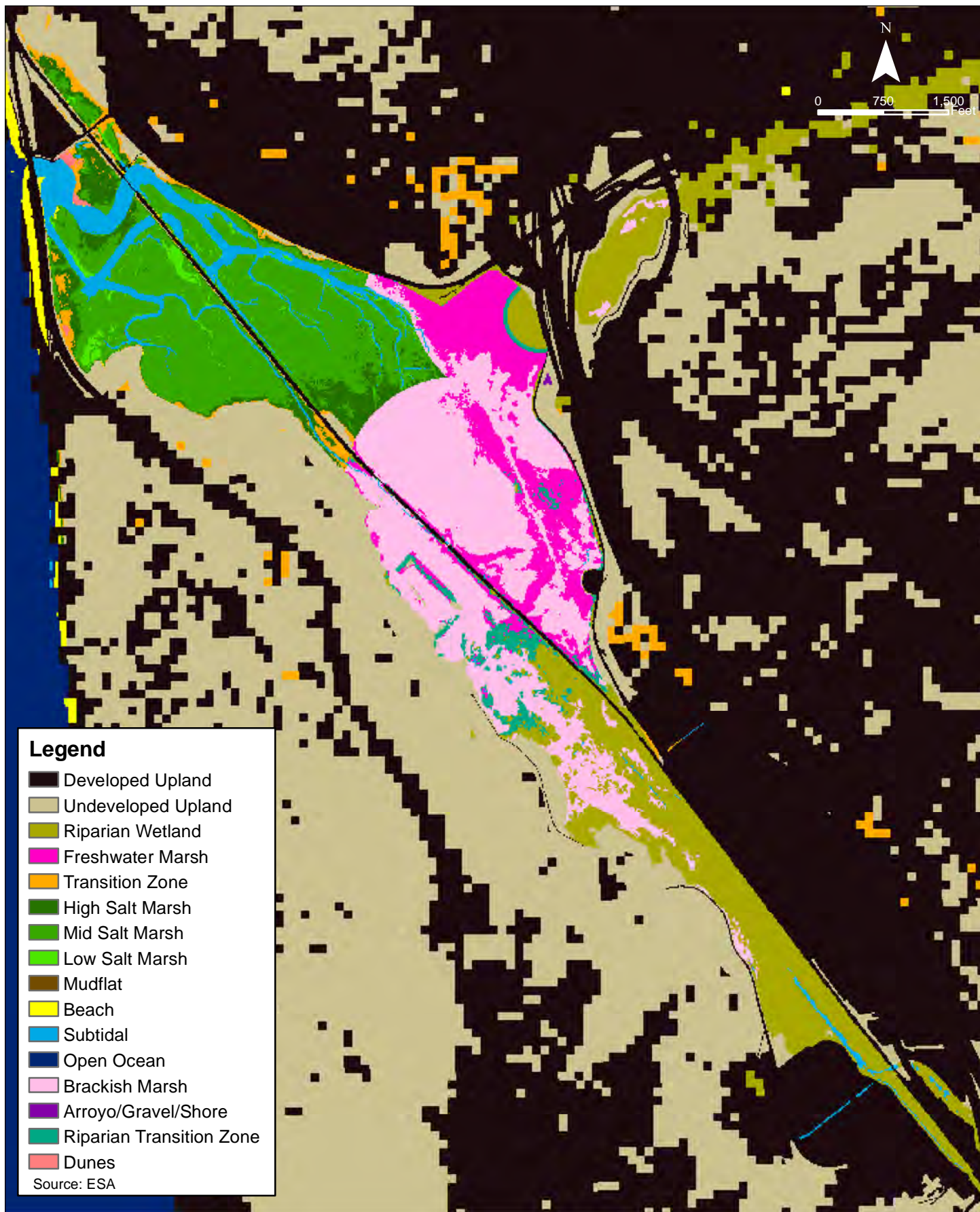




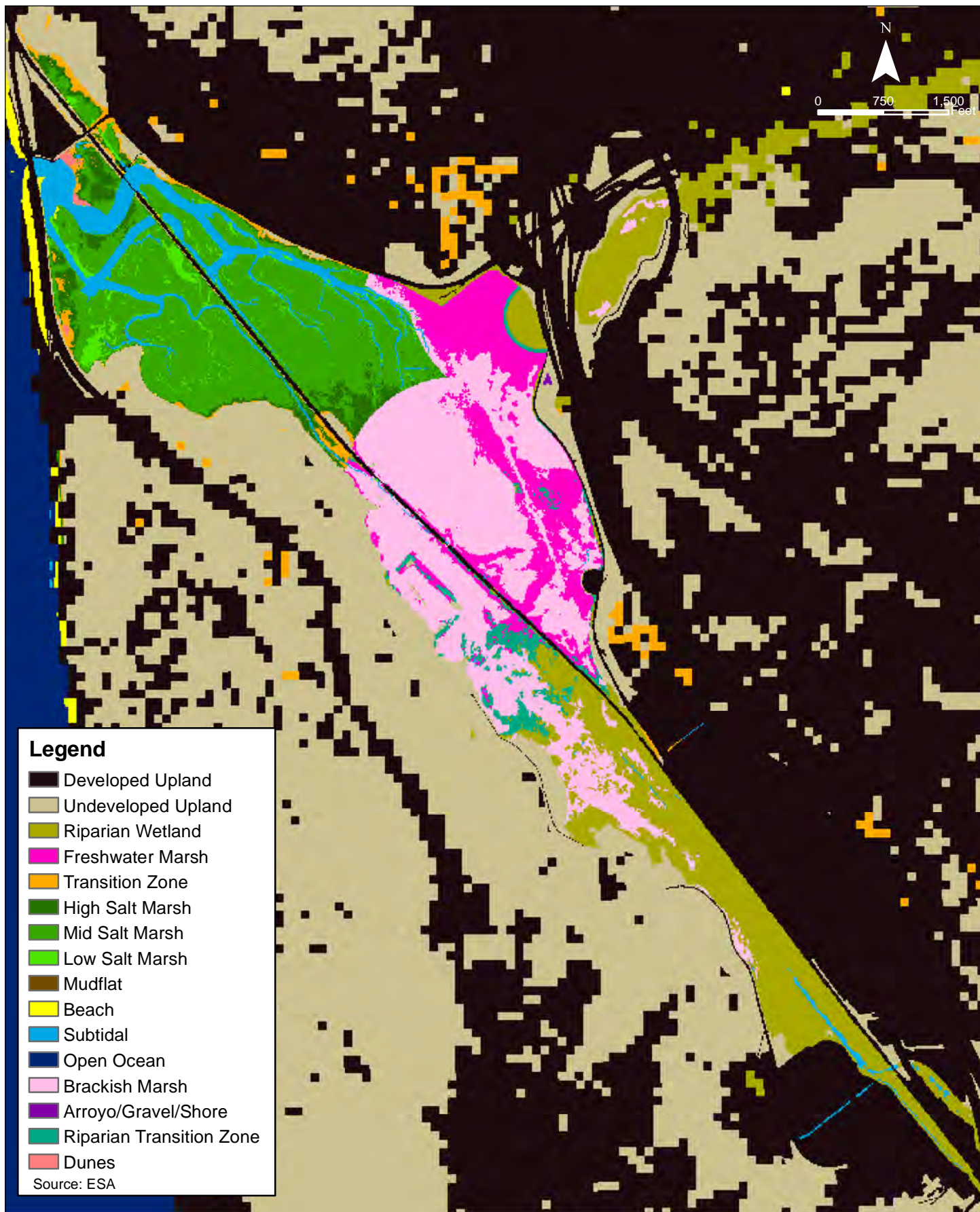




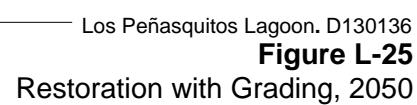




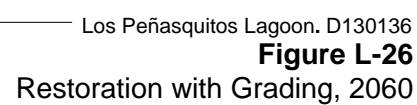




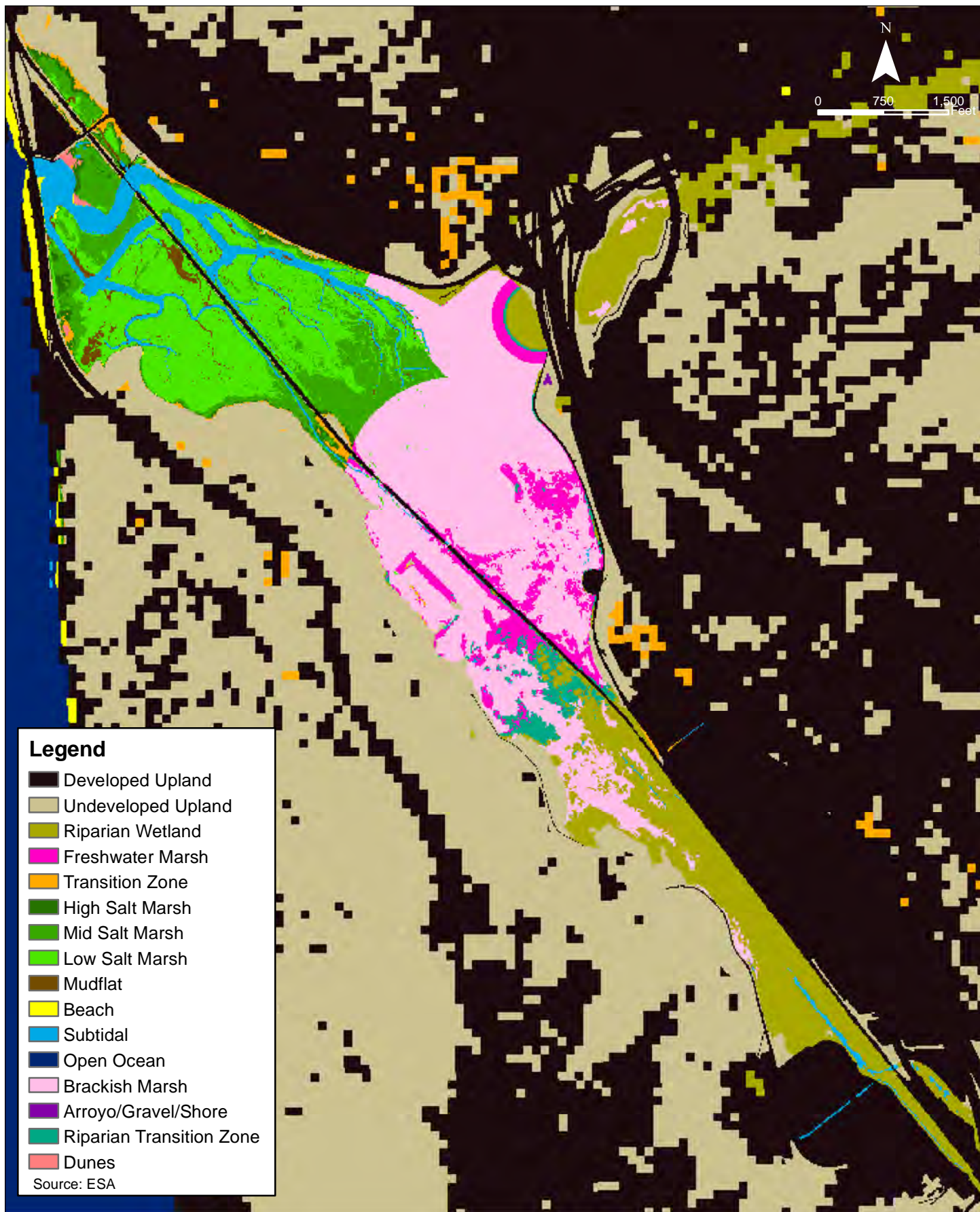




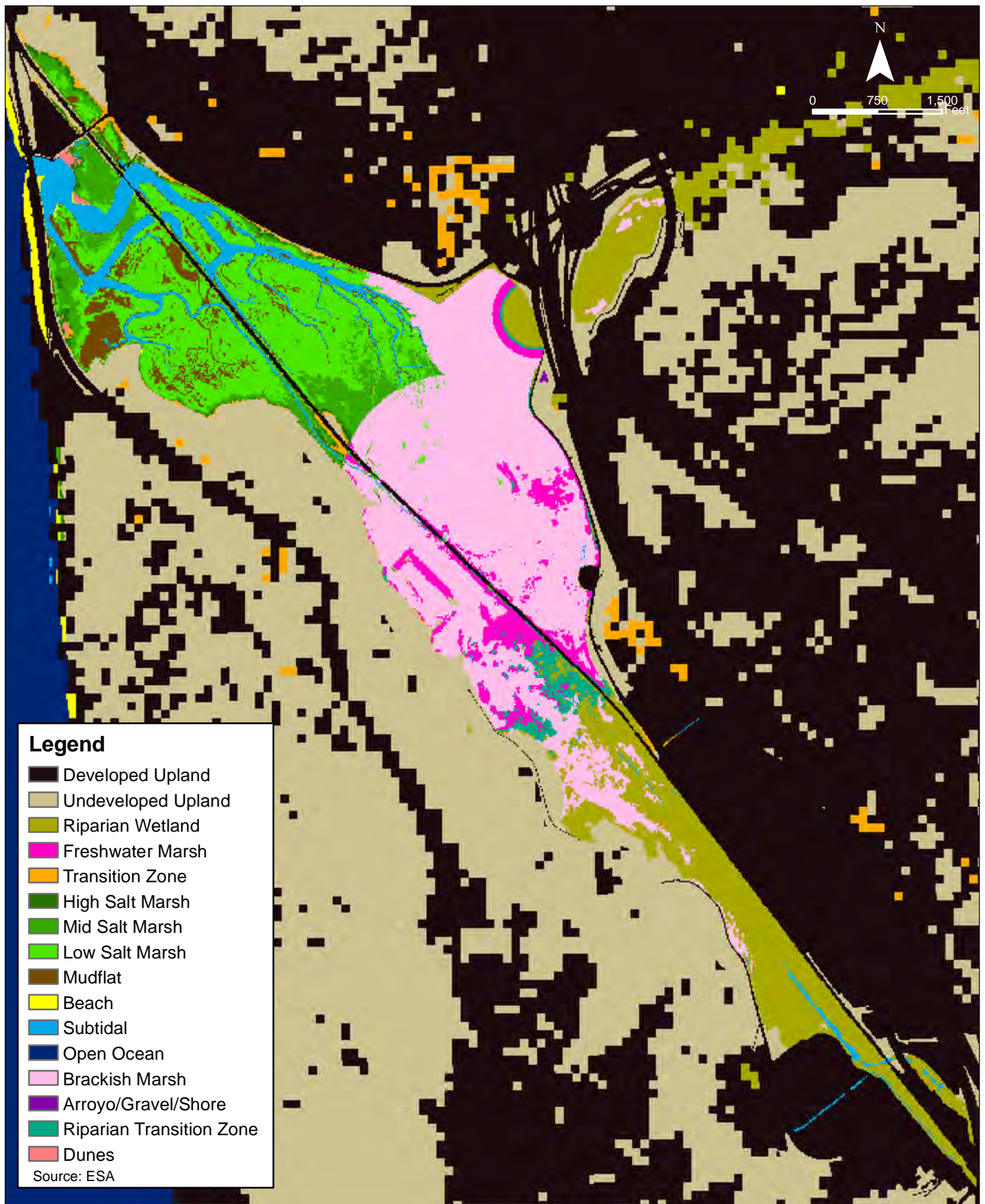




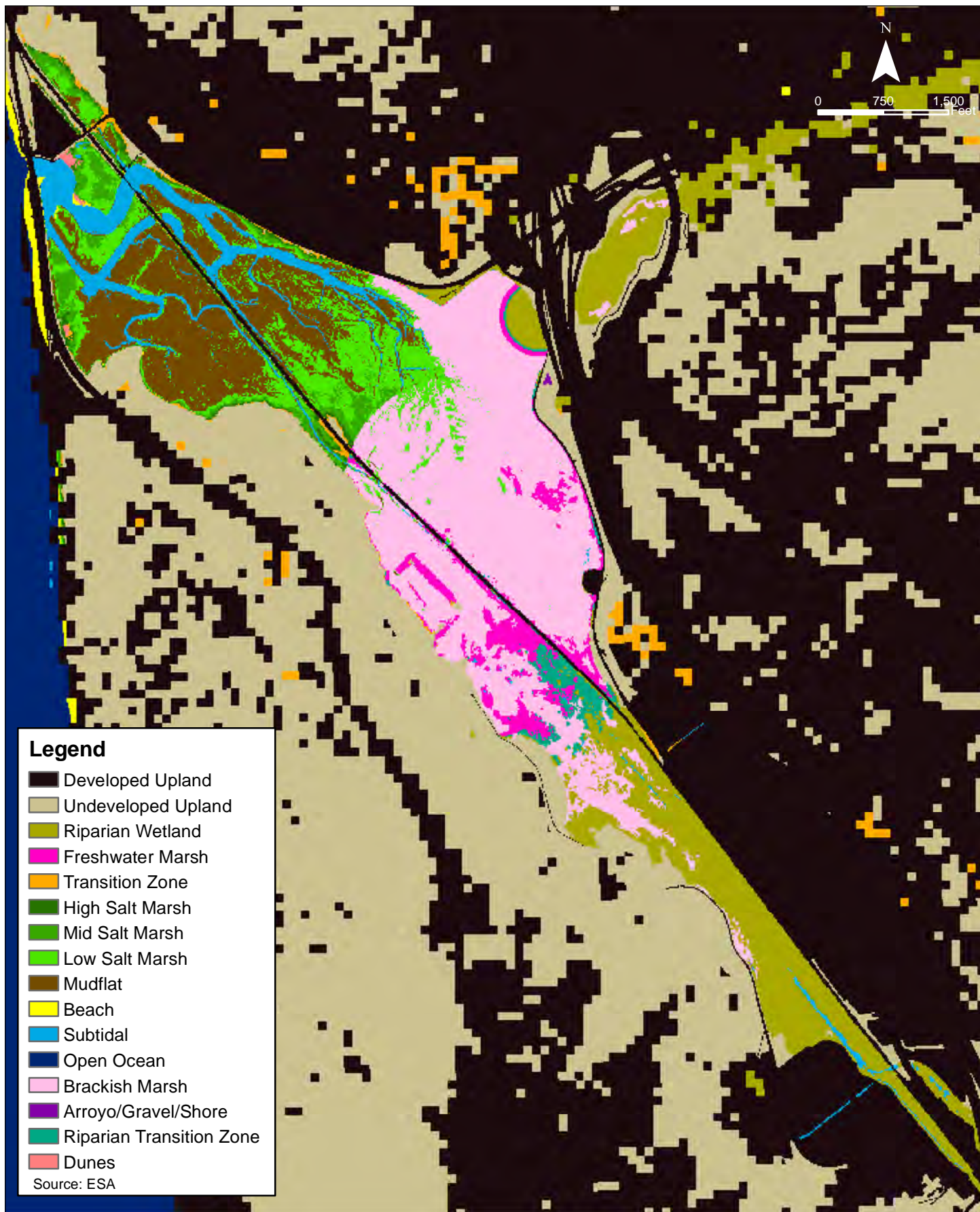




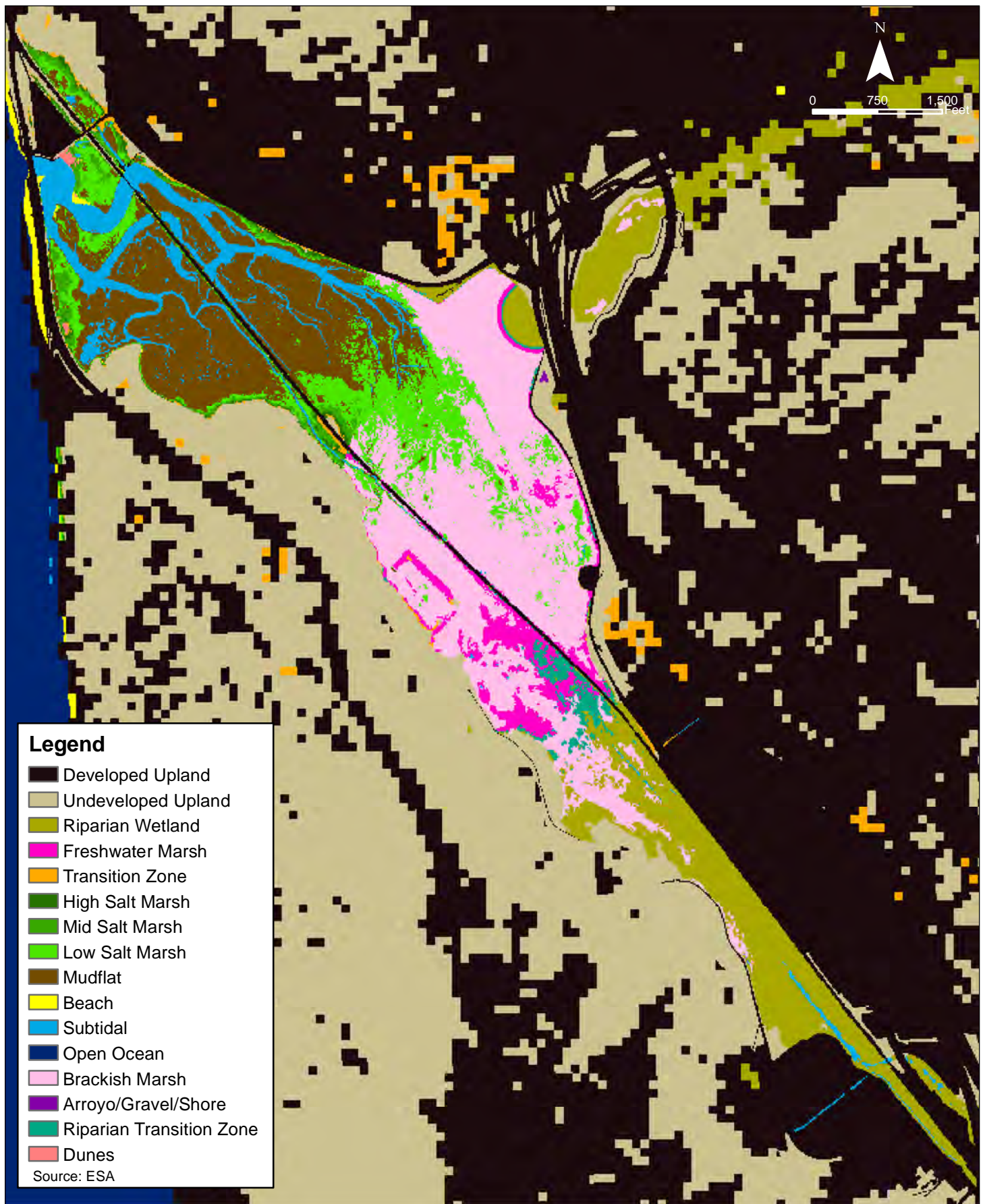




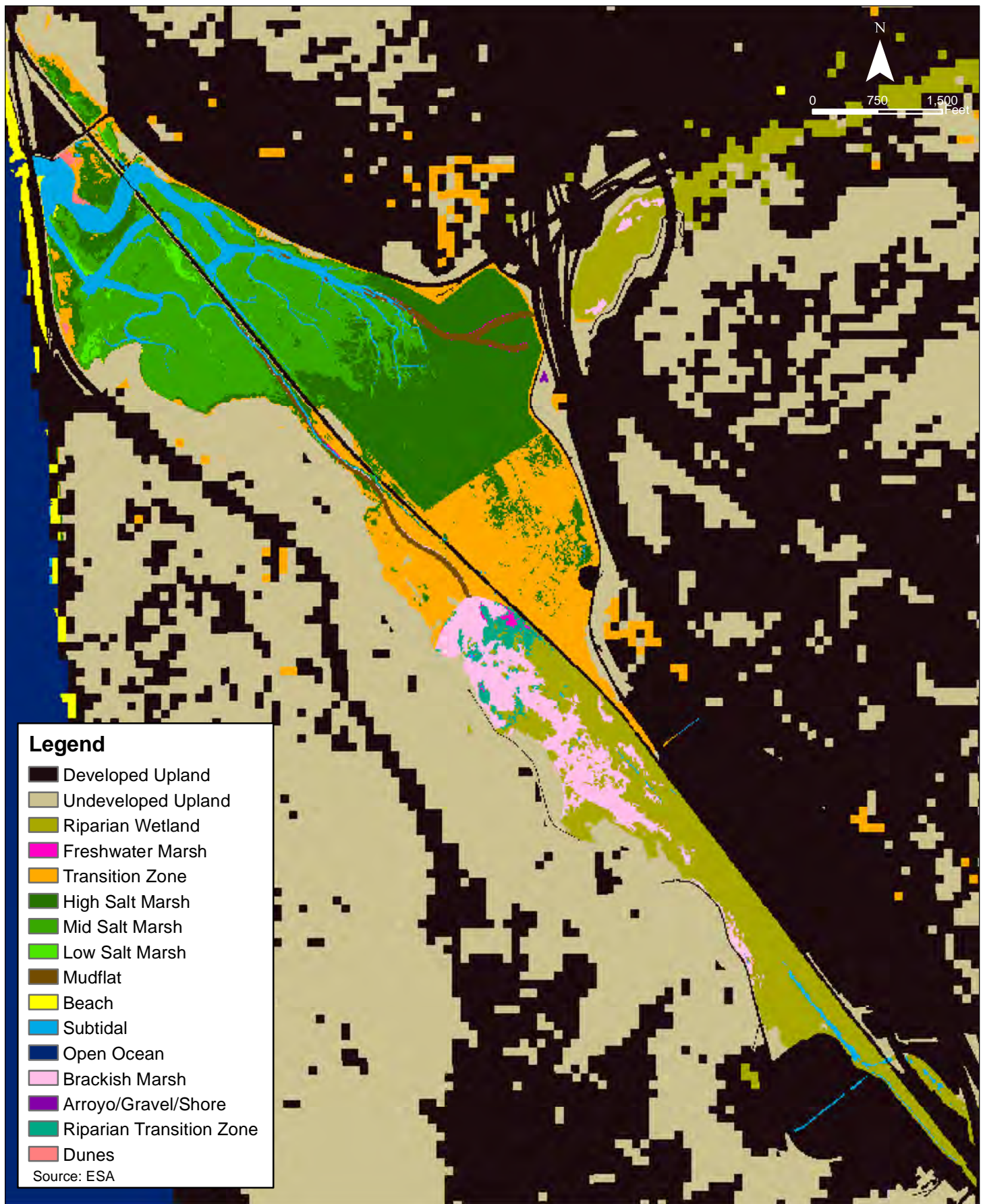










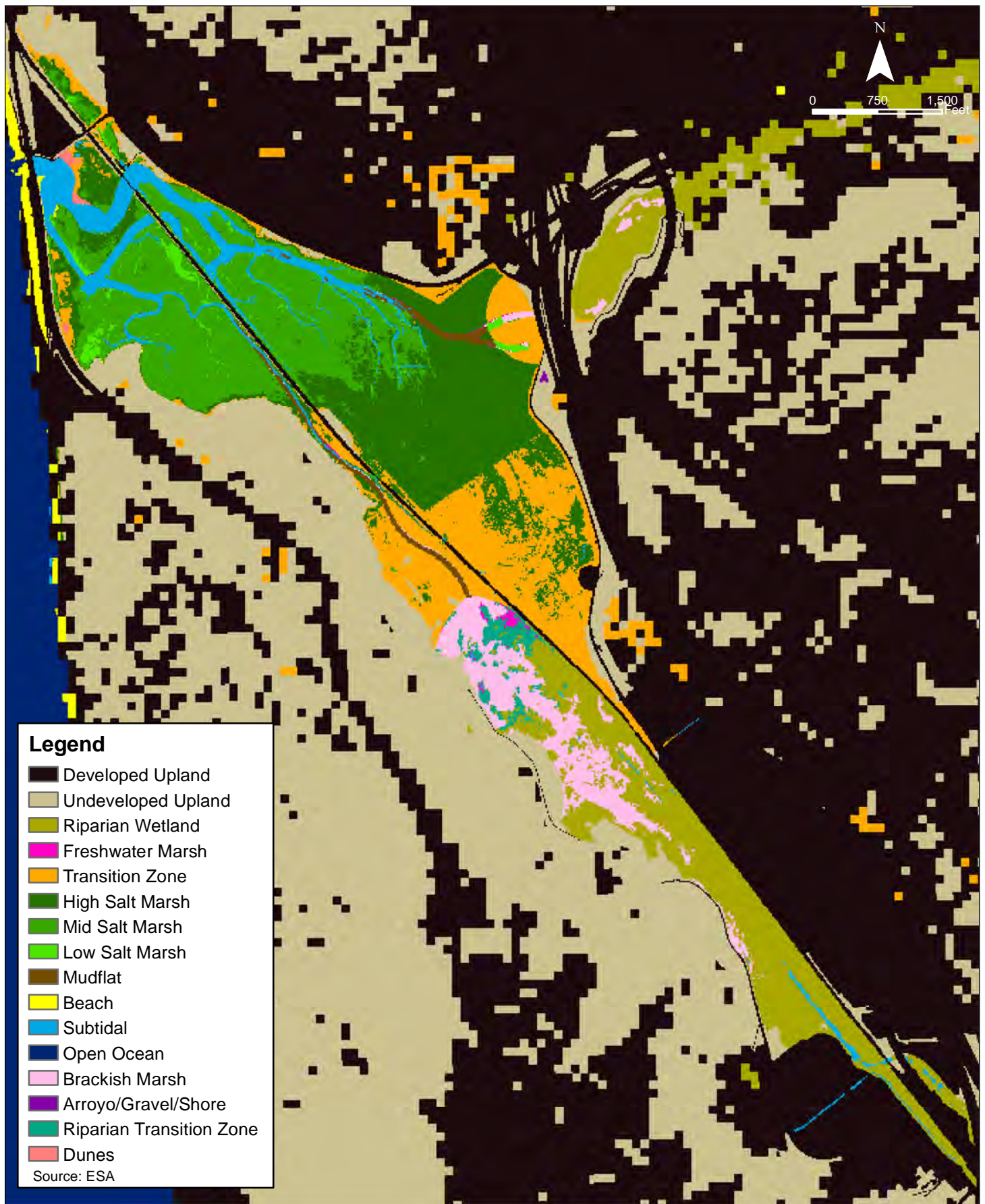


Los Peñasquitos Lagoon, D130136

**Figure L-31**

Restoration with Grading and Channel Improvements, 2010



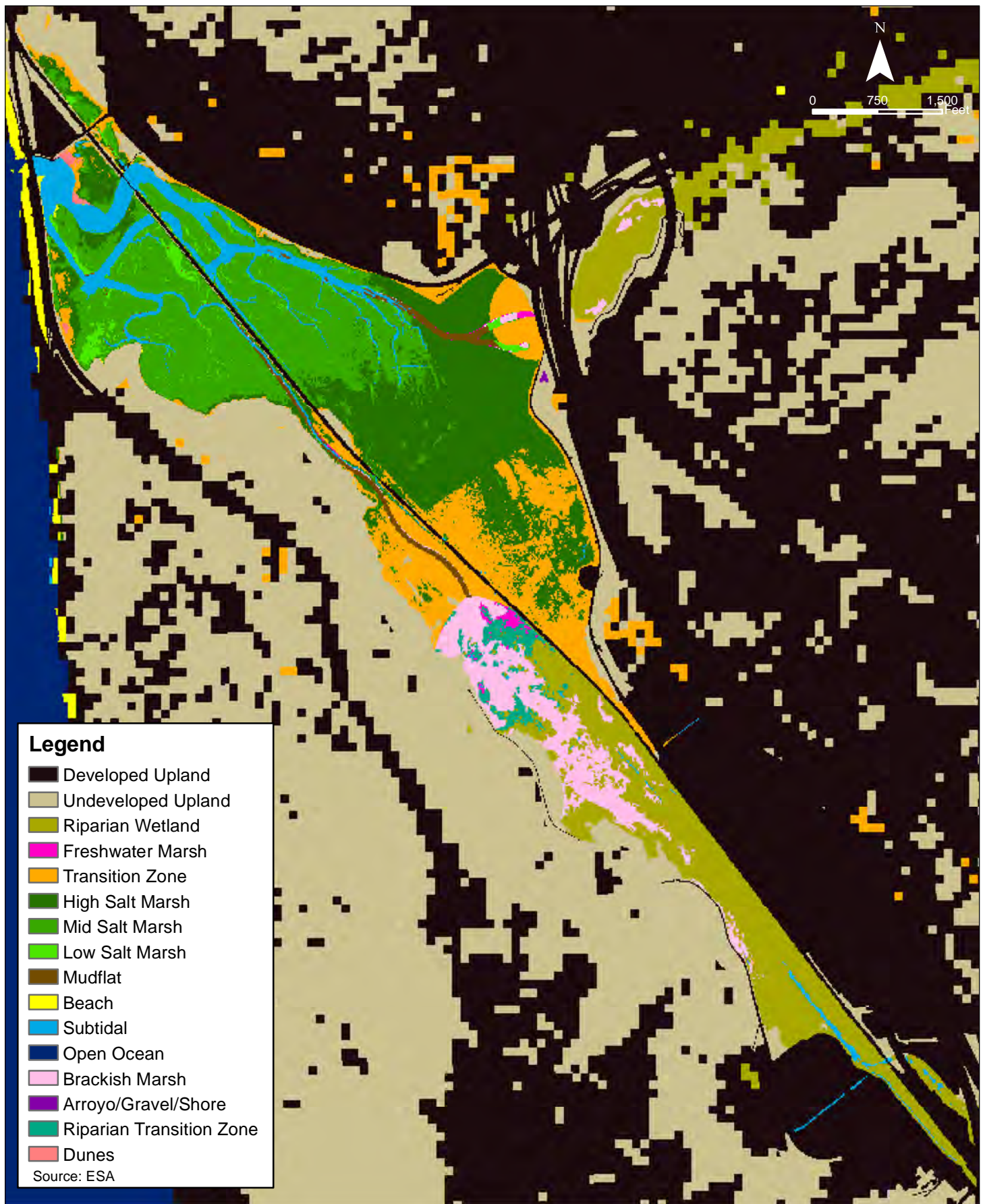


Los Peñasquitos Lagoon, D130136

**Figure L-32**

Restoration with Grading and Channel Improvements, 2020



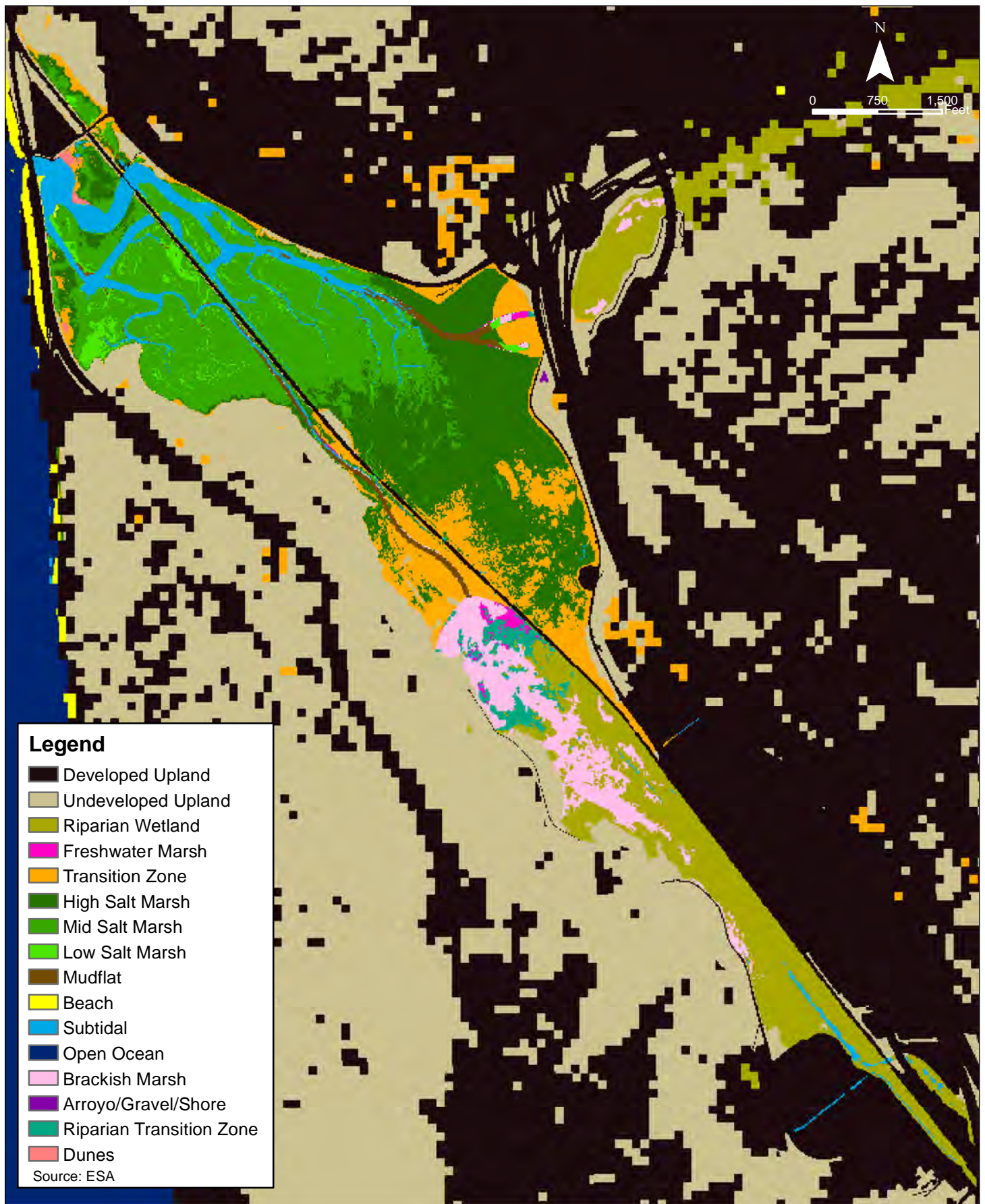


Los Peñasquitos Lagoon, D130136

**Figure L-33**

Restoration with Grading and Channel Improvements, 2030



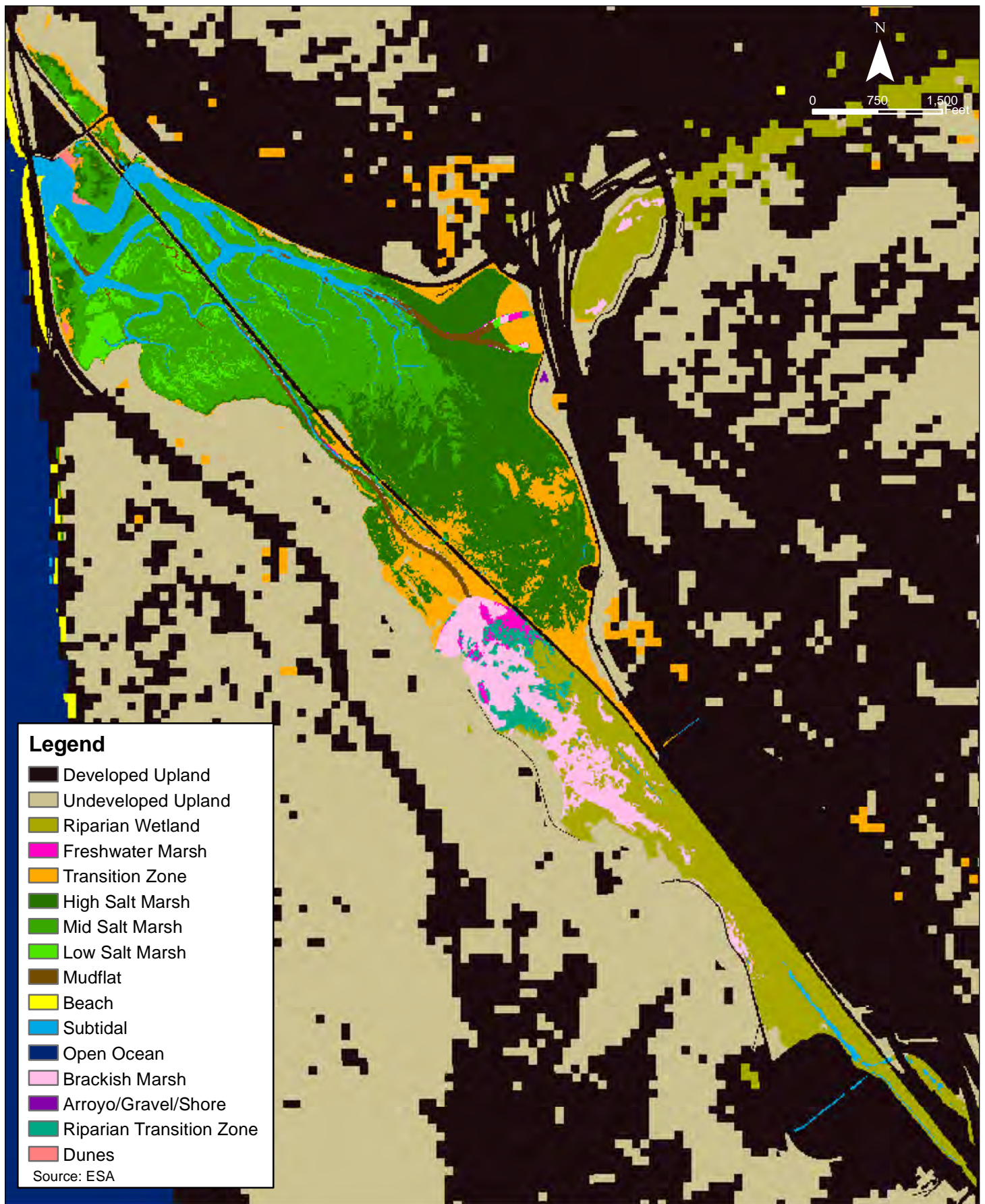


Los Peñasquitos Lagoon, D130136

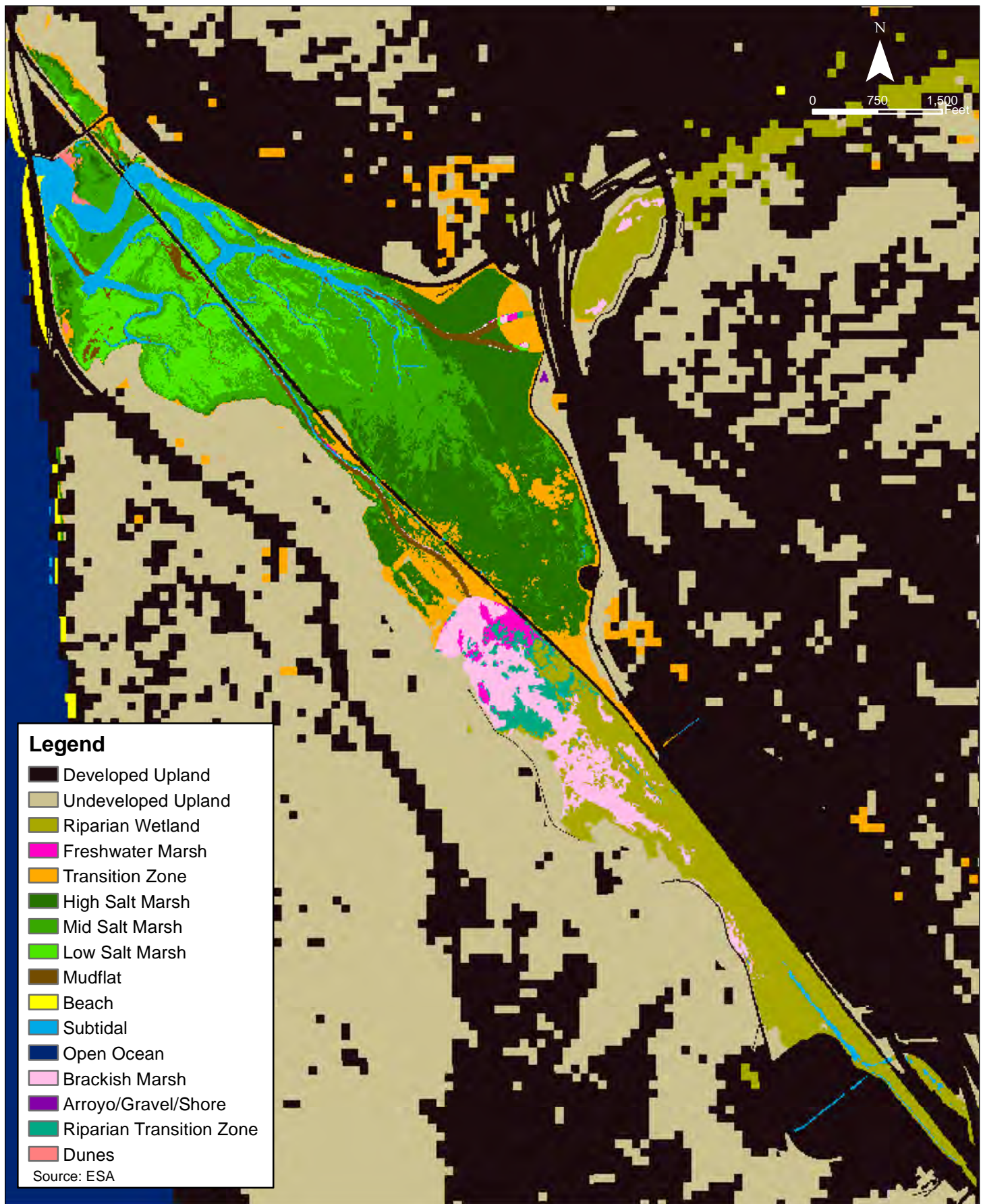
**Figure L-34**

Restoration with Grading and Channel Improvements, 2040







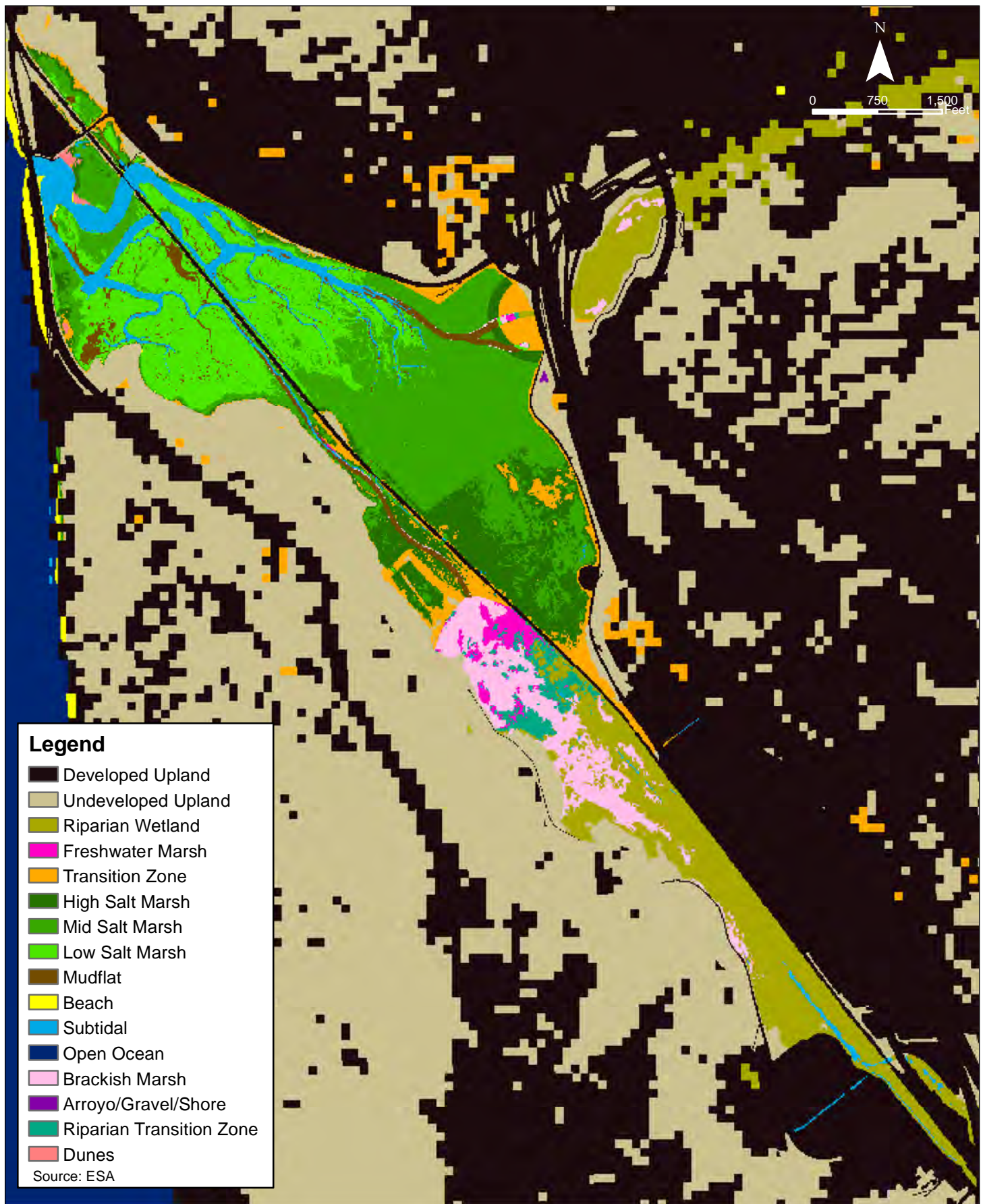


Los Peñasquitos Lagoon, D130136

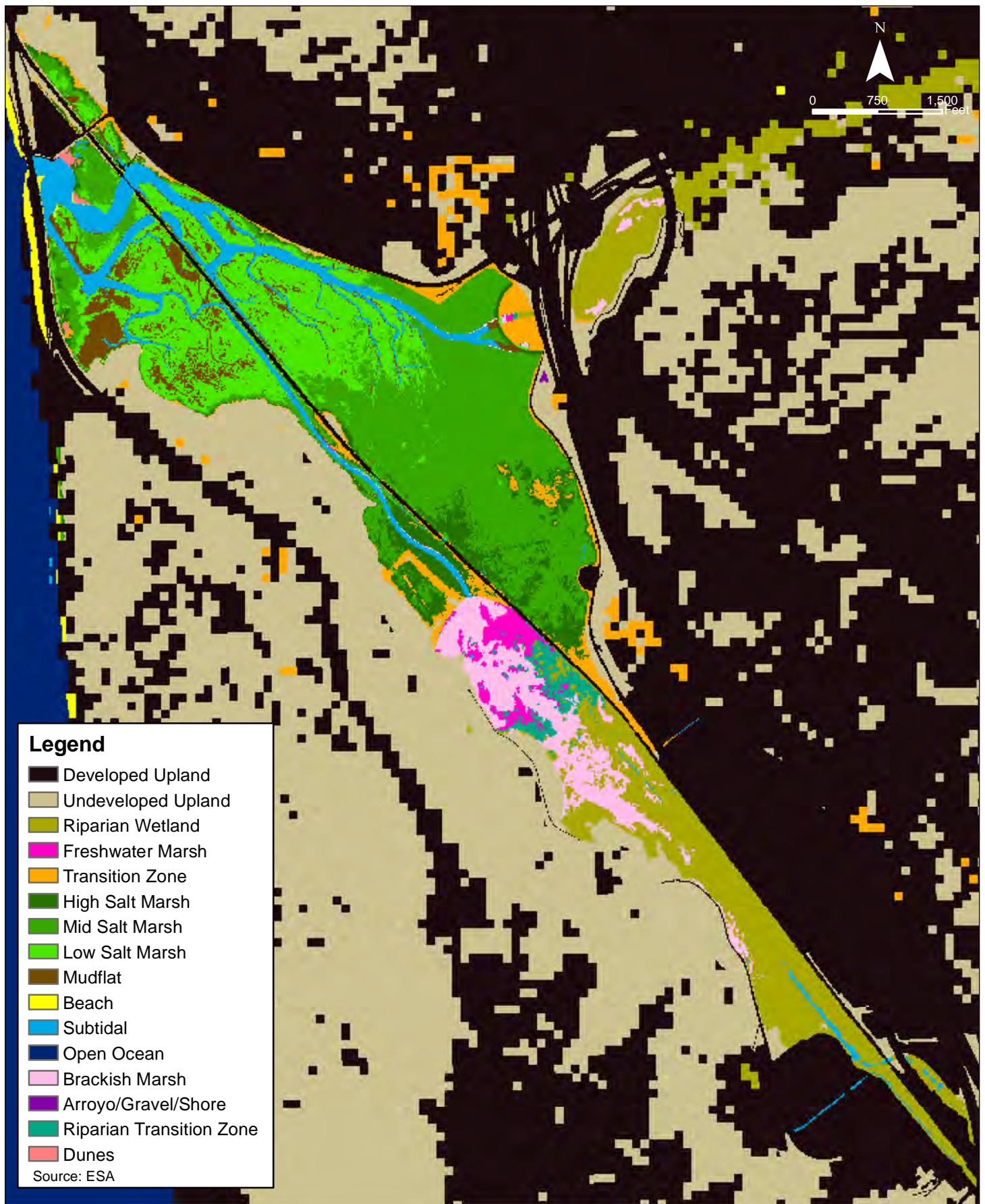
**Figure L-36**

Restoration with Grading and Channel Improvements, 2060







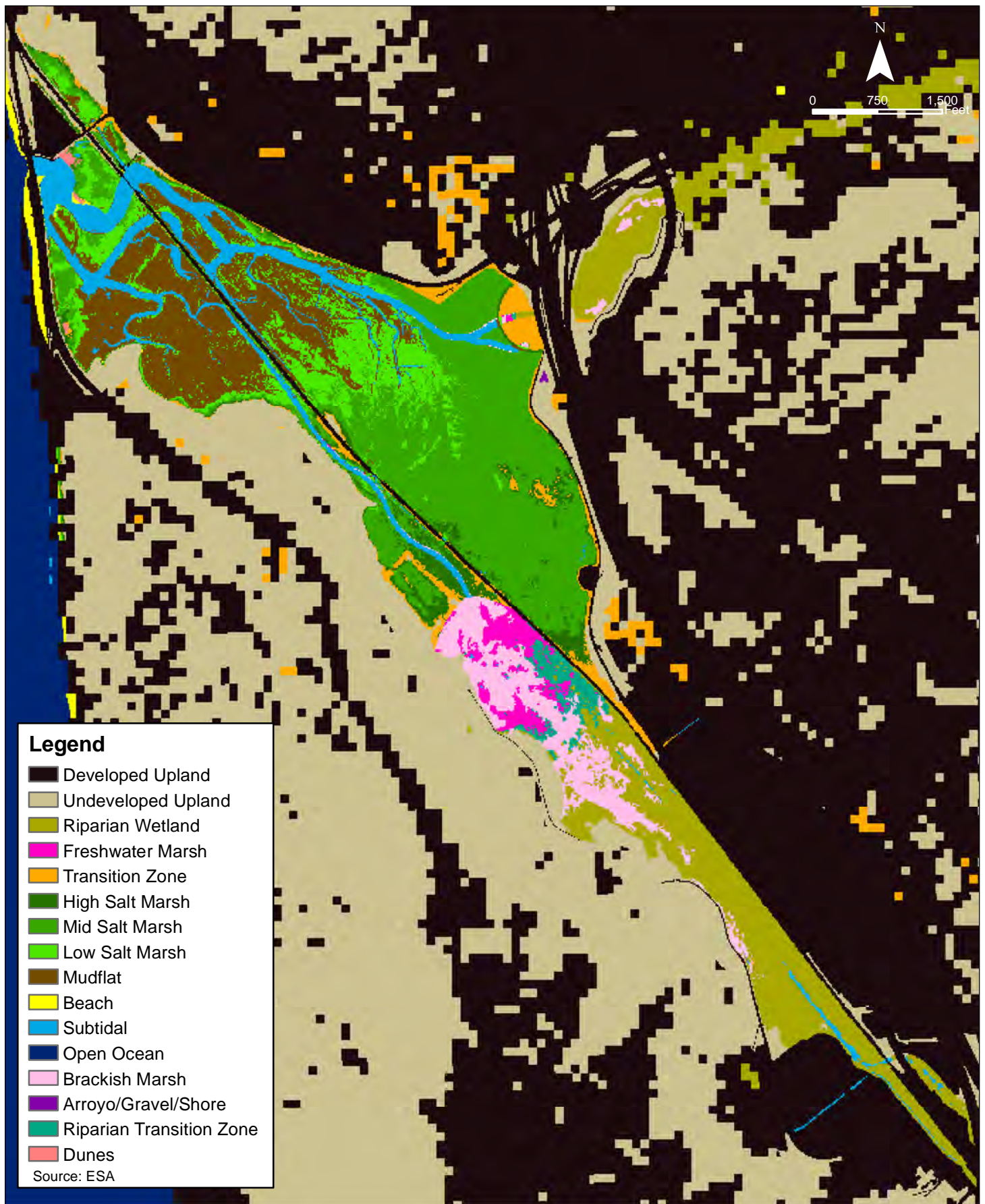


Los Peñasquitos Lagoon, D130136

**Figure L-38**

Restoration with Grading and Channel Improvements, 2080





Los Peñasquitos Lagoon, D130136

**Figure L-39**

Restoration with Grading and Channel Improvements, 2090



