

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 m³) 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.

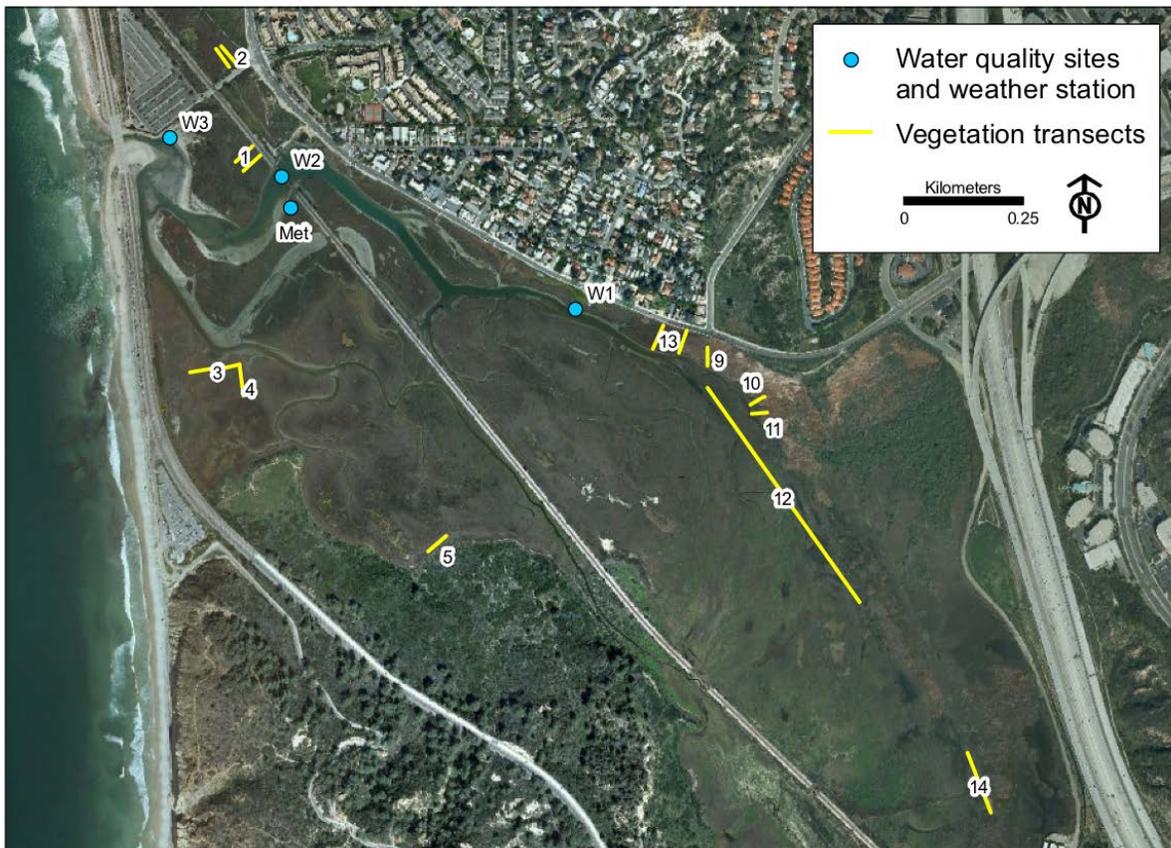


Figure 4 - Water Quality Sampling Stations and Vegetation Transects within Los Peñasquitos Lagoon.

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.

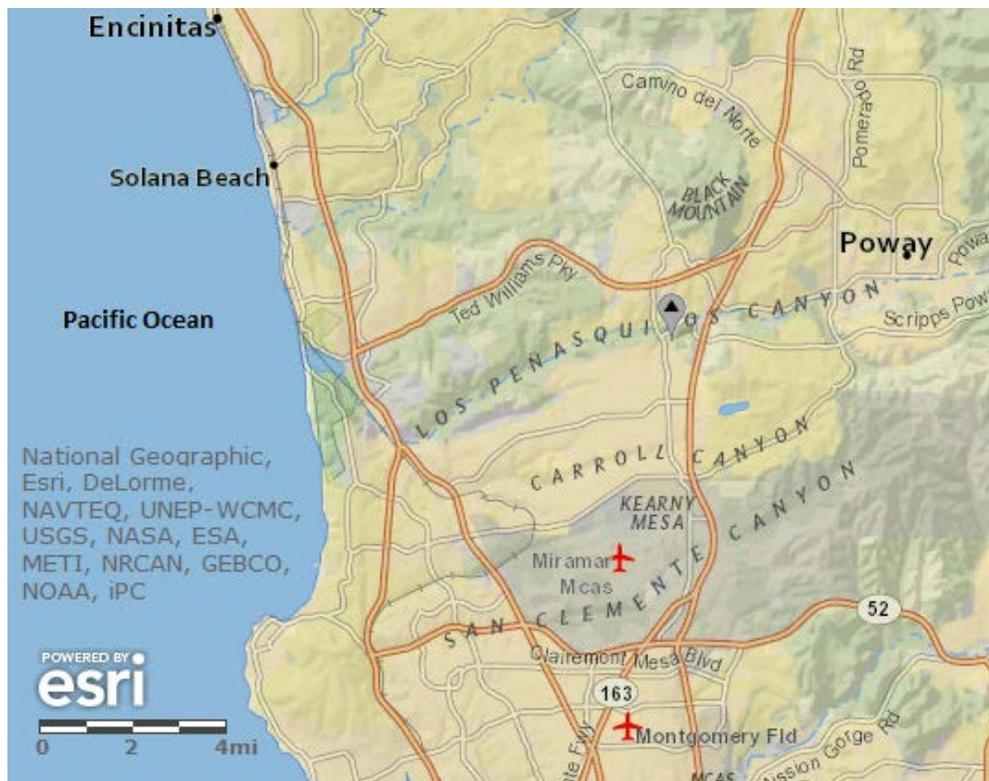


Figure 5 - Location of USGS Gauge 11023340 (grey symbol) in Los Peñasquitos Canyon. Graphic modified from http://nwis.waterdata.usgs.gov/nwis/nwismap/?site_no=11023340&agency_cd=USGS.

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 ($\mu\text{g/L}$)

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 ($\mu\text{g/L}$).

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 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.

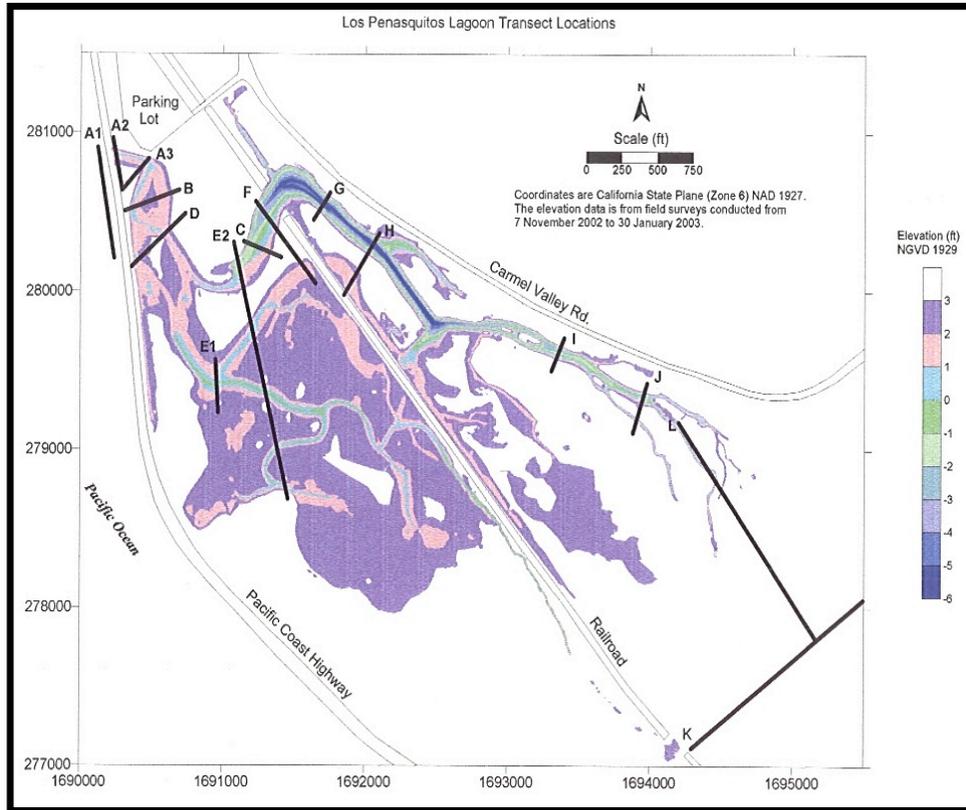


Figure 6 – Locations of accretion/erosion transects.

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-m² 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 1m² 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 1m² 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.

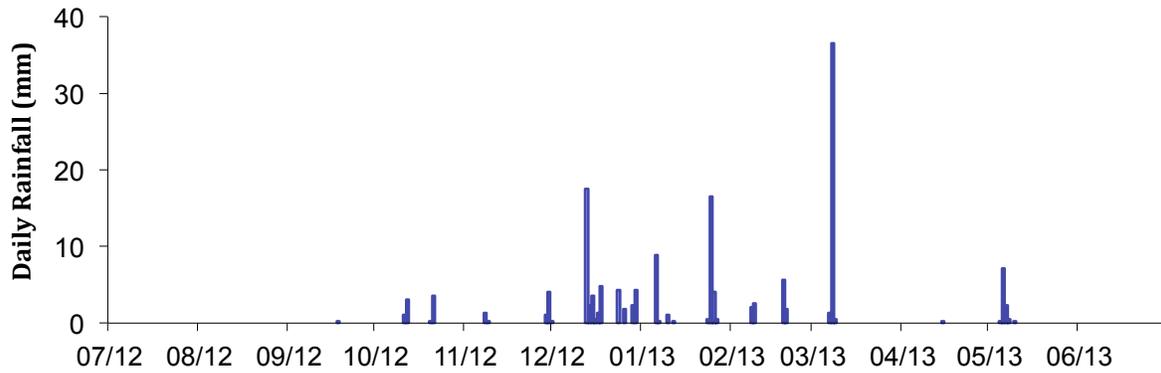


Figure 7 - Daily rainfall as measured at the LPL weather station.

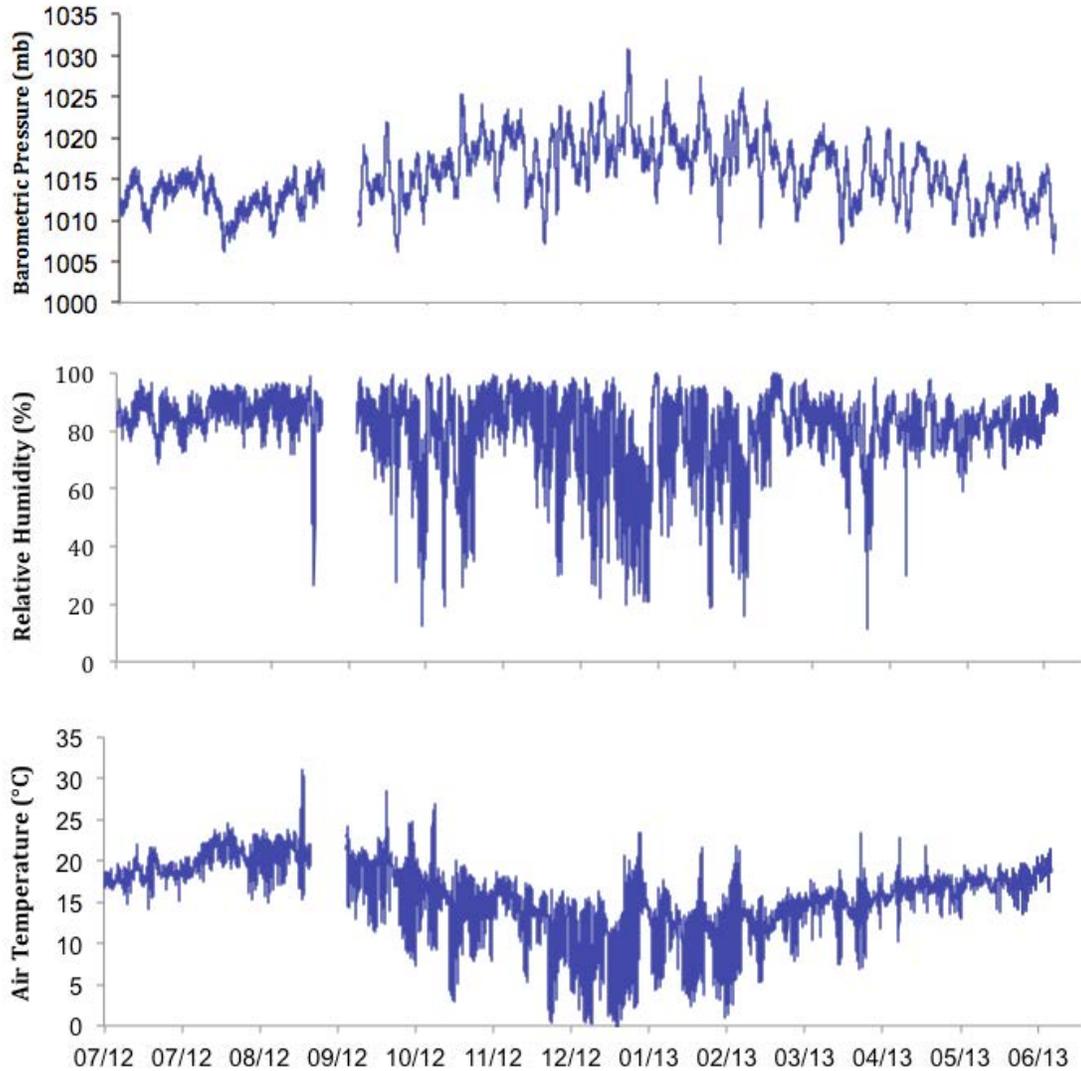


Figure 8 - Barometric pressure, humidity, and air temperature as measured at the LPL weather station.

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 f³/s) compared to peaks in previous years (Figure 10).

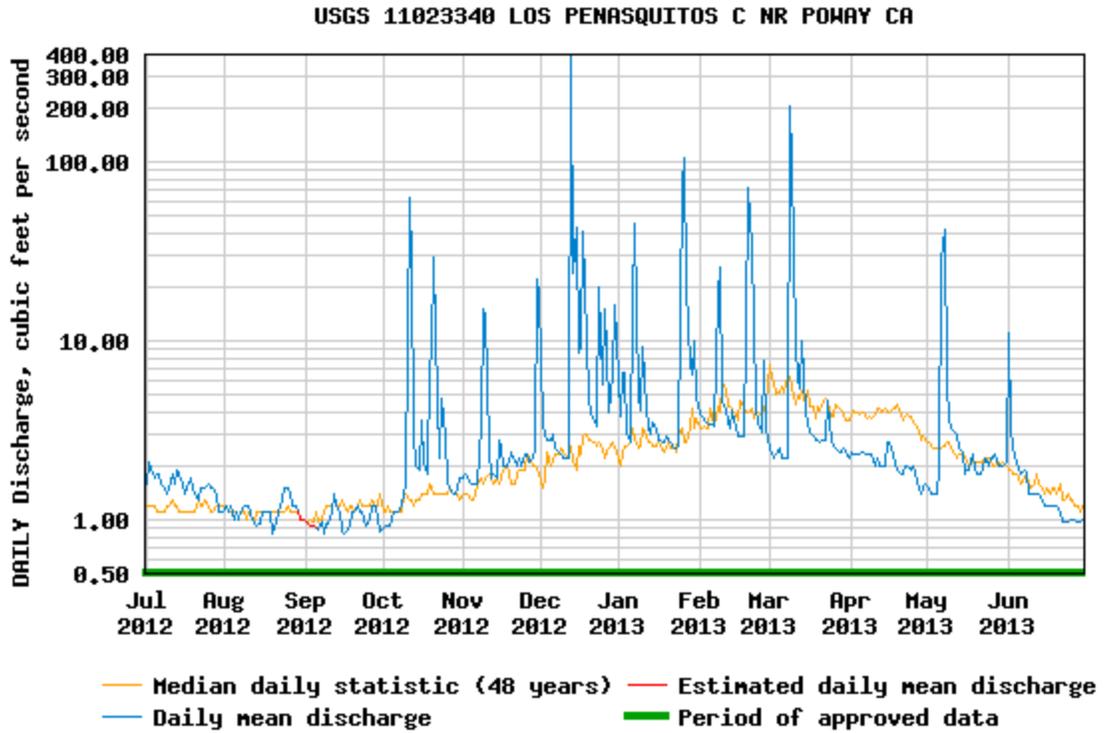


Figure 9 - USGS Gauge 11023340 Flow Rates for Los Peñasquitos Creek. Graphic by USGS.

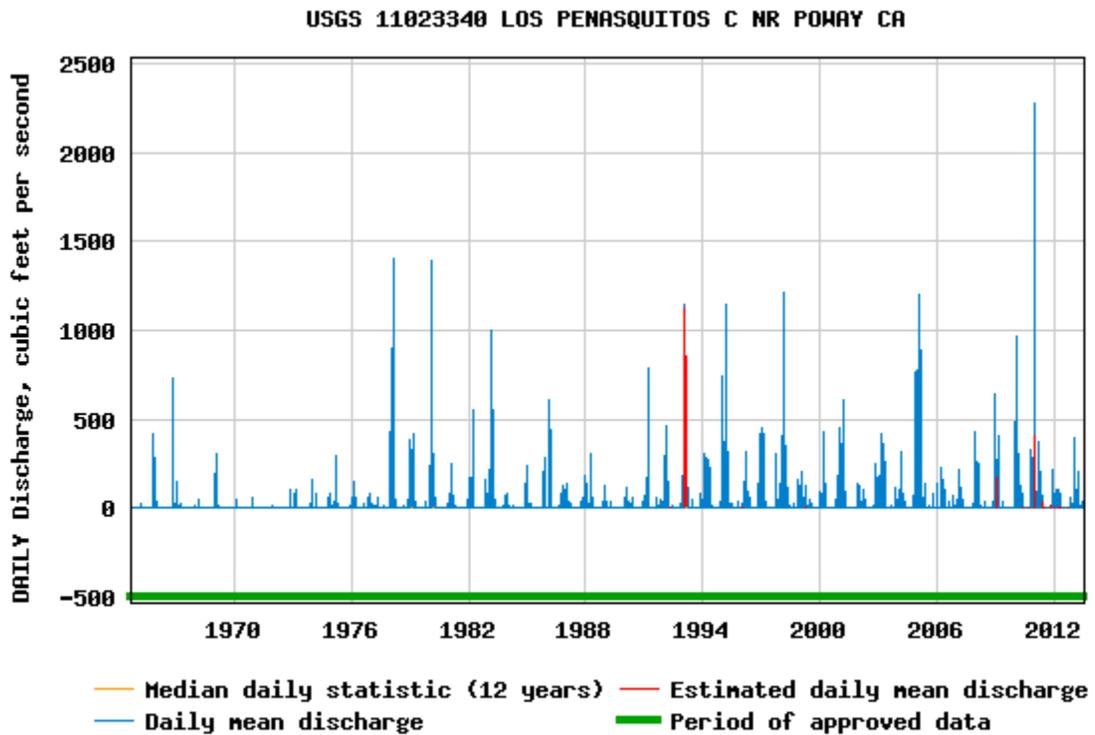


Figure 10 - Long term record for USGS Gauge 11023340 on Los Peñasquitos Creek. Graphic by USGS.

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 18th.

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 18th, shortly after discovering the mouth was completely closed, through May 13th, immediately following the first mechanical opening of the mouth.

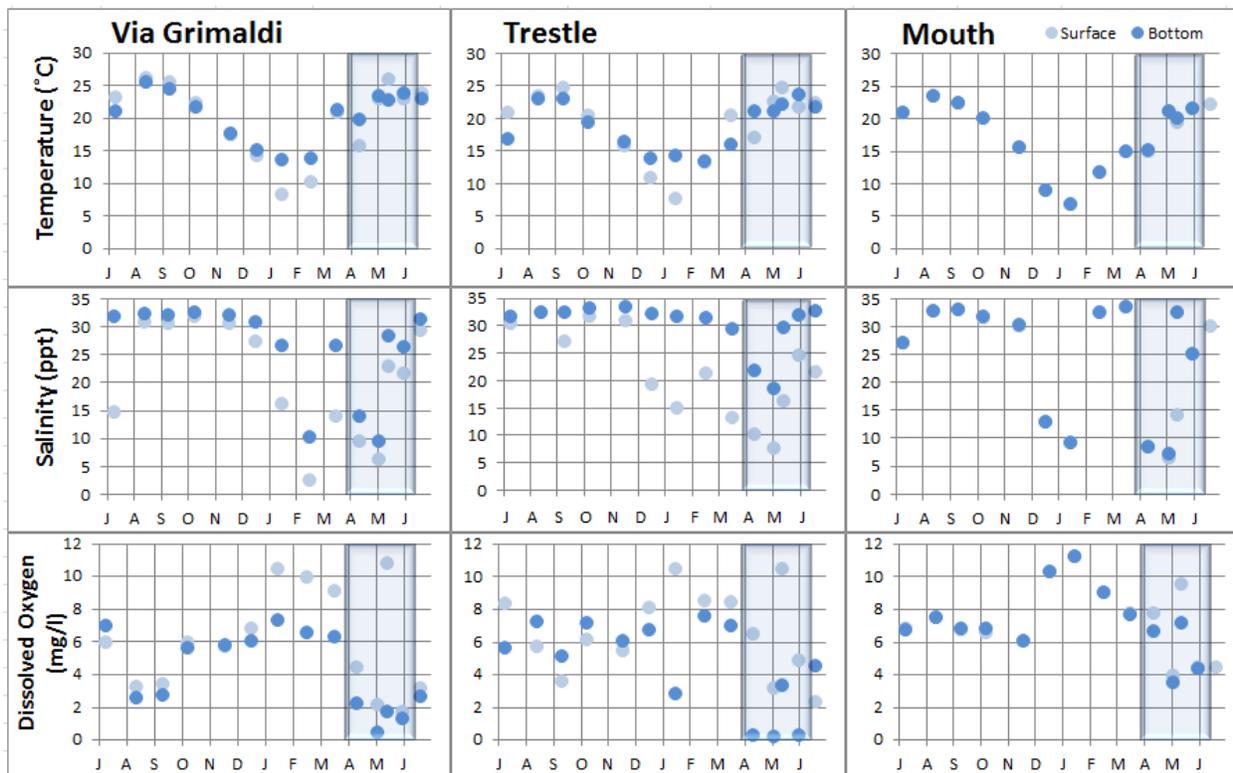


Figure 11 - Spatial water quality data, July 2012 – June 2013. Shaded areas indicate periods of mouth closure.

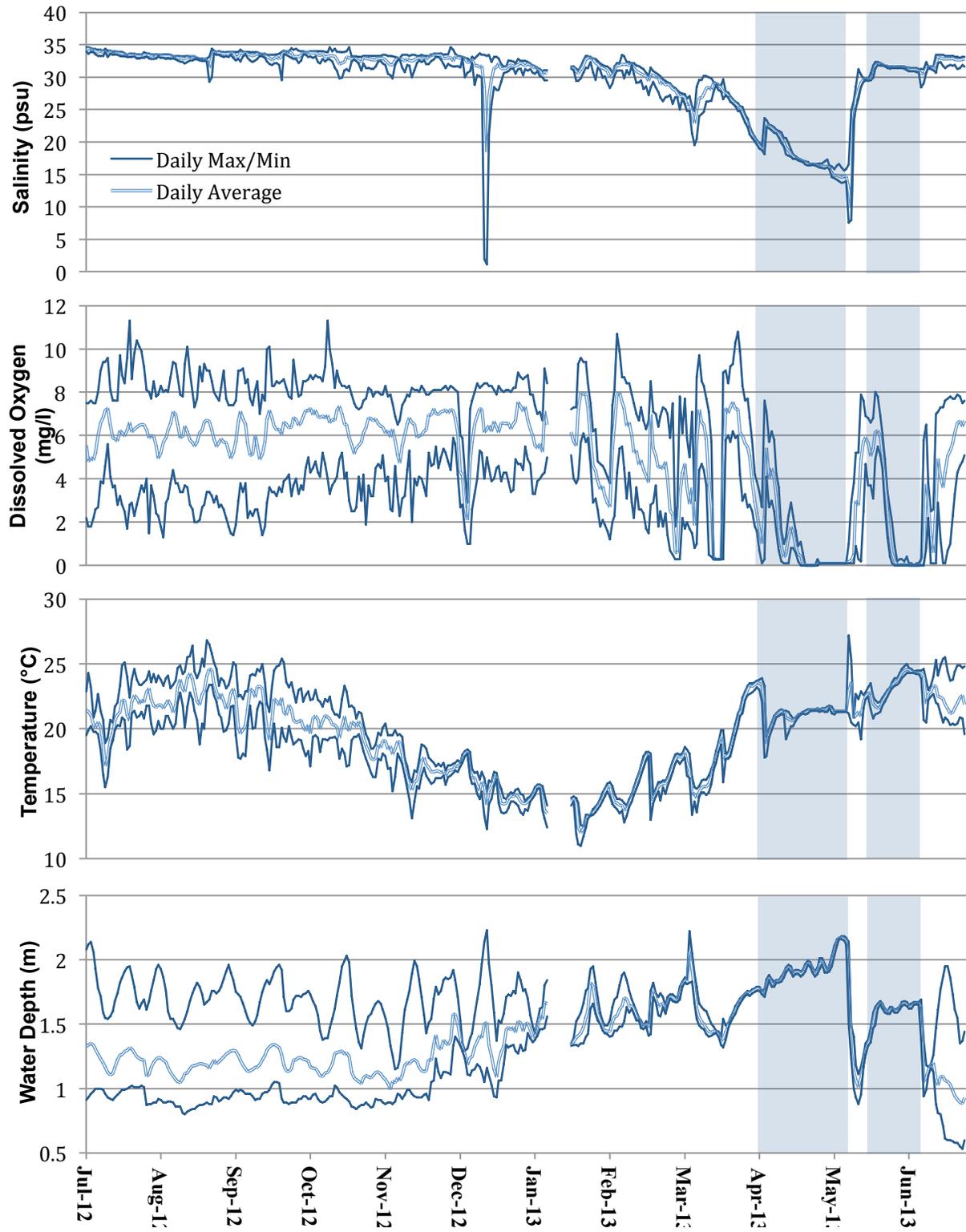


Figure 12 - Water quality data from the data logger at station W2. Data are presented as daily means, maximums, and minimums. Shaded regions indicate the presence and estimated duration of a lagoon inlet closure. Gaps indicate periods when the data logger was inoperative (Jan 8-18) or individual probes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

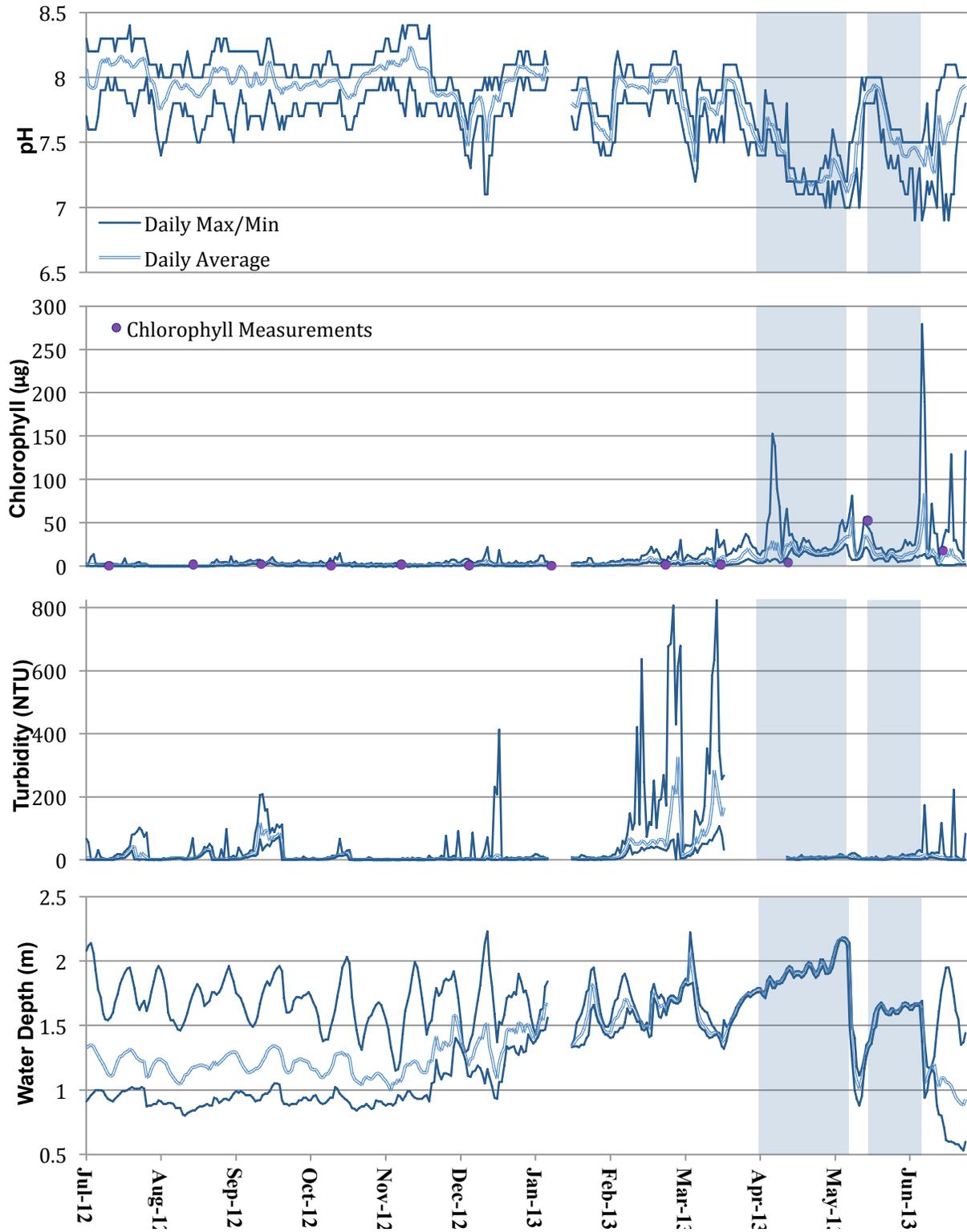


Figure 12, continued - Water quality data from the data logger at station W2. Data are presented as daily means, maximums, and minimums. Shaded regions indicate the presence and estimated duration of a lagoon inlet closure. Gaps indicate periods when the data logger was inoperative (Jan 8-18) or individual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

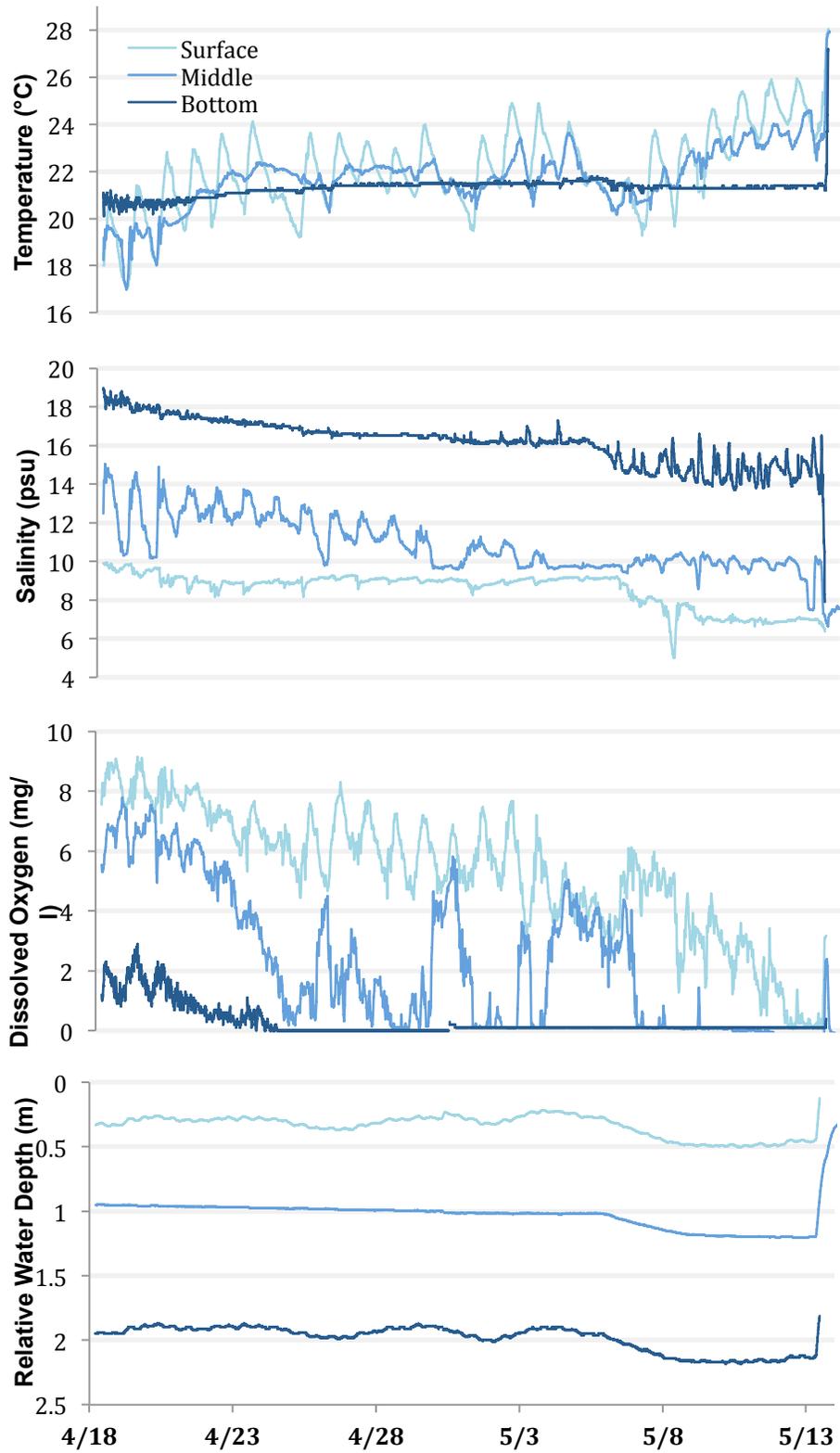


Figure 13 – Data from the 3 data loggers deployed during the mouth closure to assess water quality parameters vertically in the water column at Station W2.

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.

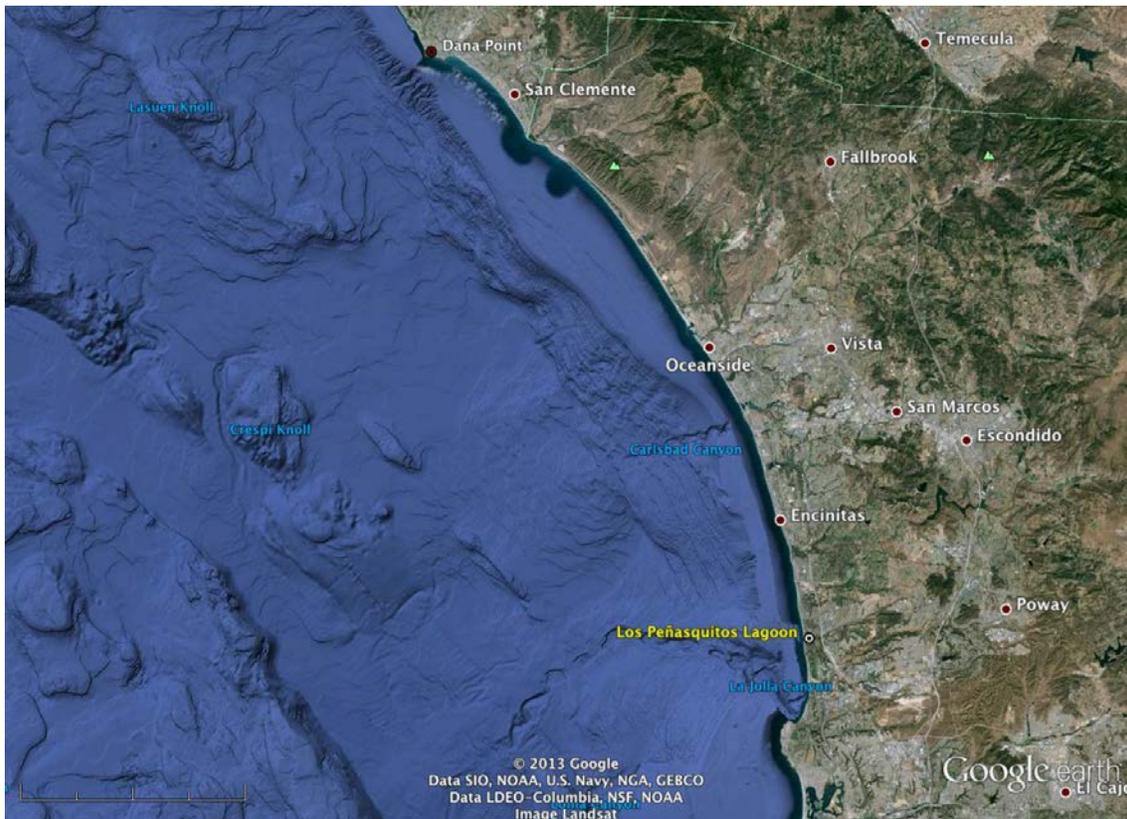


Figure 14a – Oceanside Littoral Cell – Dana Point to La Jolla

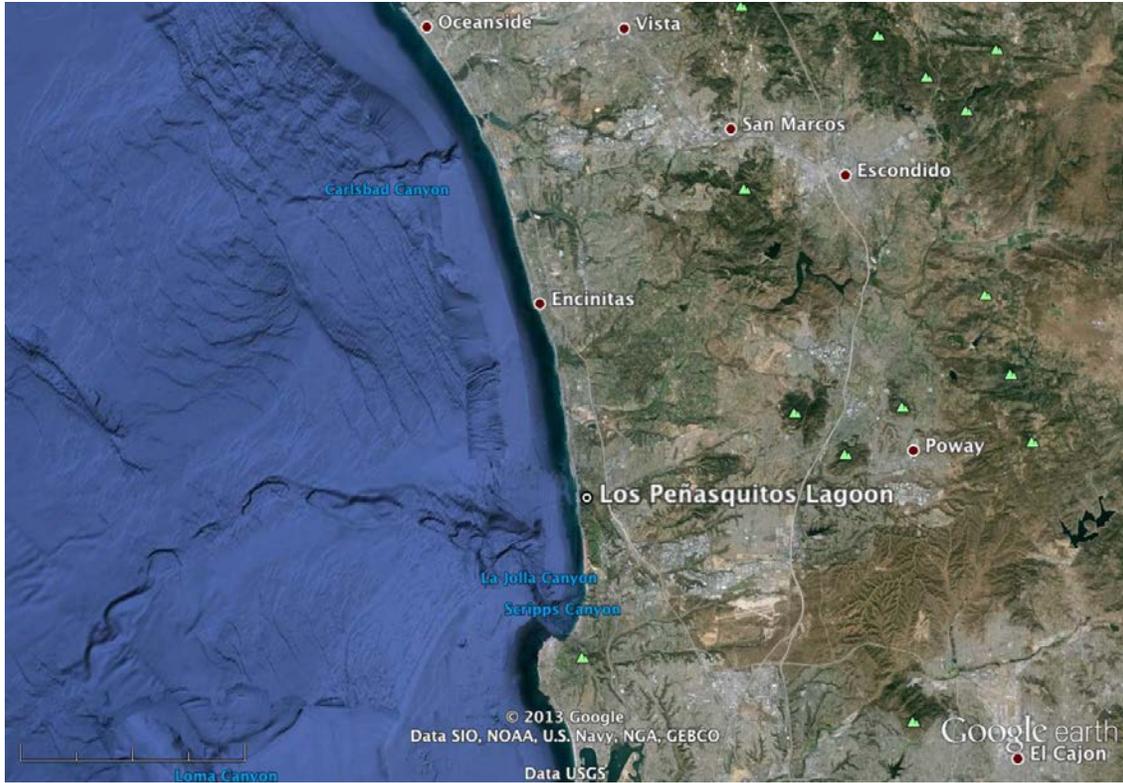


Figure 14b – Oceanside Littoral Cell – Oceanside to La Jolla

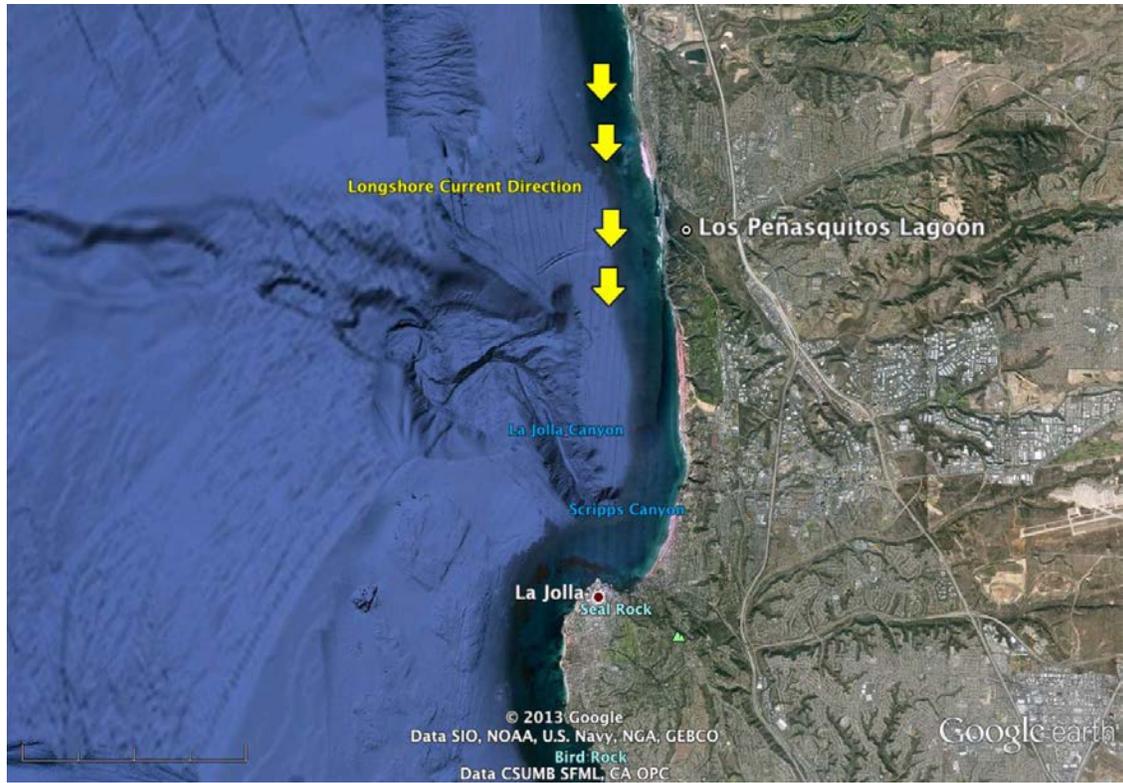


Figure 14c – Oceanside Littoral Cell – Los Peñasquitos Lagoon

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 6th, which show no significant channel (figure 15b). Thanks to a large storm during December 12th-14th, 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 23rd (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 13th -17th. 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 7th, it was confirmed that the mouth was indeed closed. Another reopening event began on June 12th. 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.

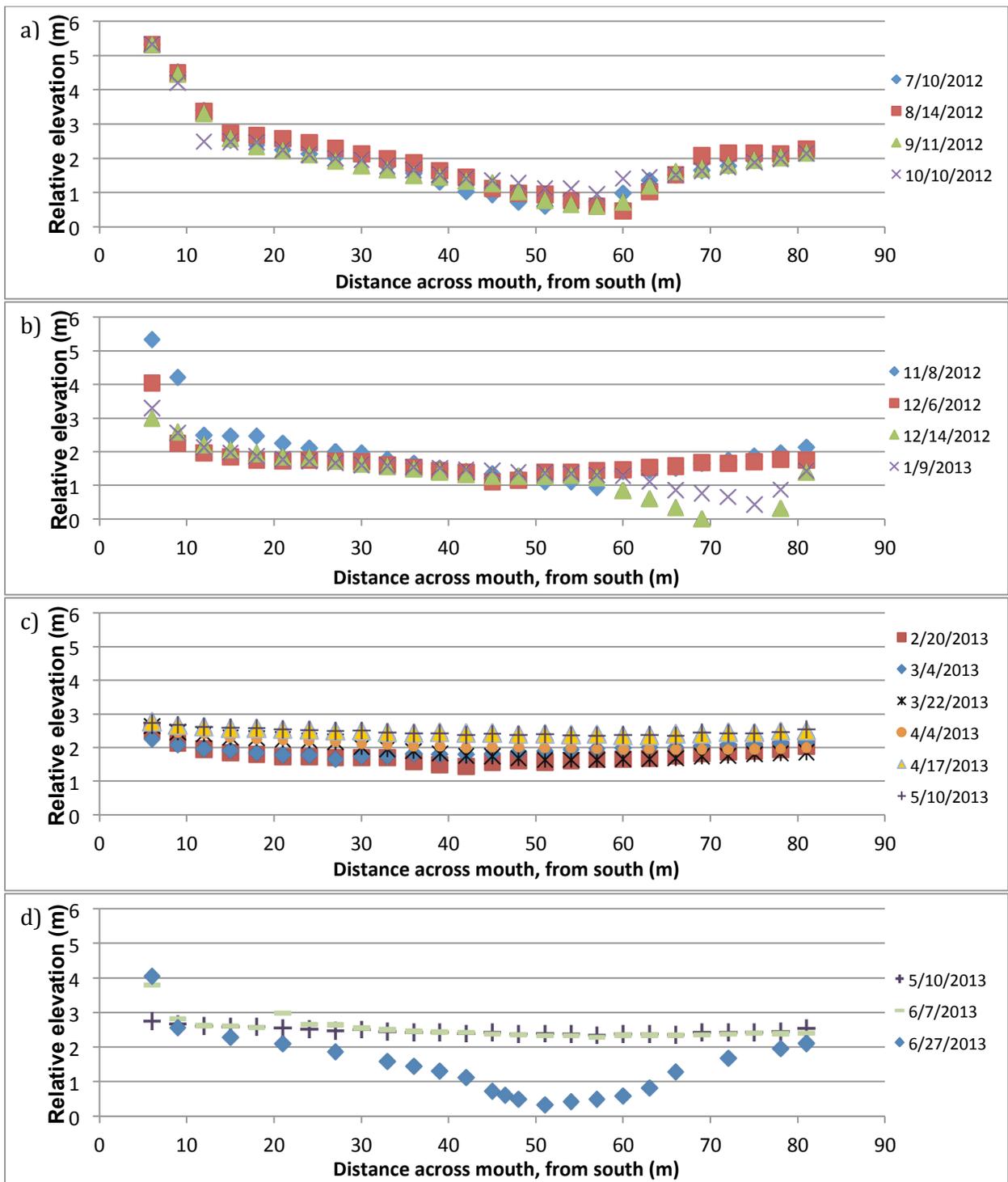


Figure 15 - Relative elevations at lagoon mouth, see text (above).



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 23rd and remained closed until it was mechanically breached on May 14th. 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.

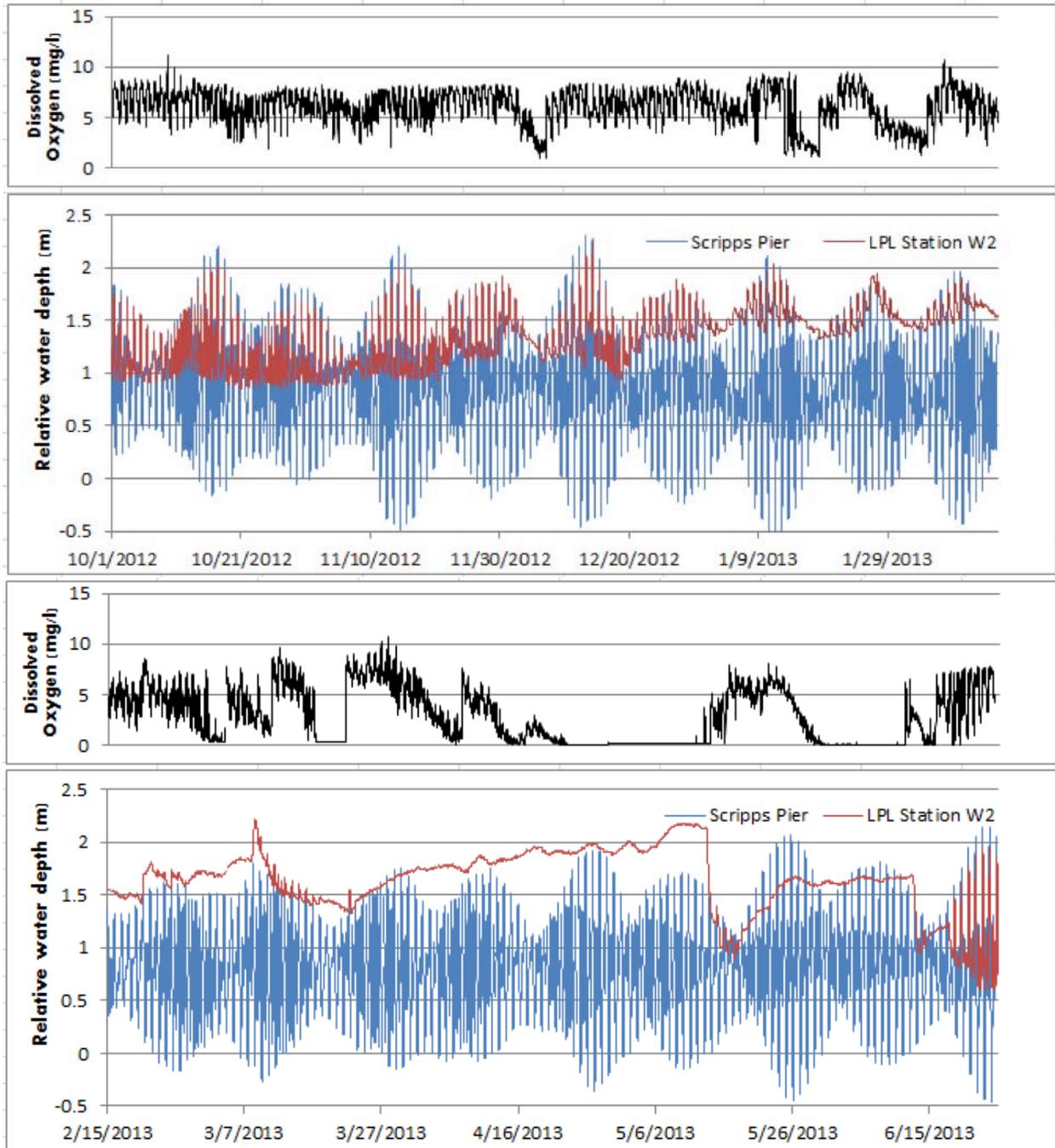


Figure 17 - 15-minute water depth and dissolved oxygen (DO) data from LPL Station W2 and 6-minute water depth from Scripps Pier for periods of intermittent mouth closures and re-openings.

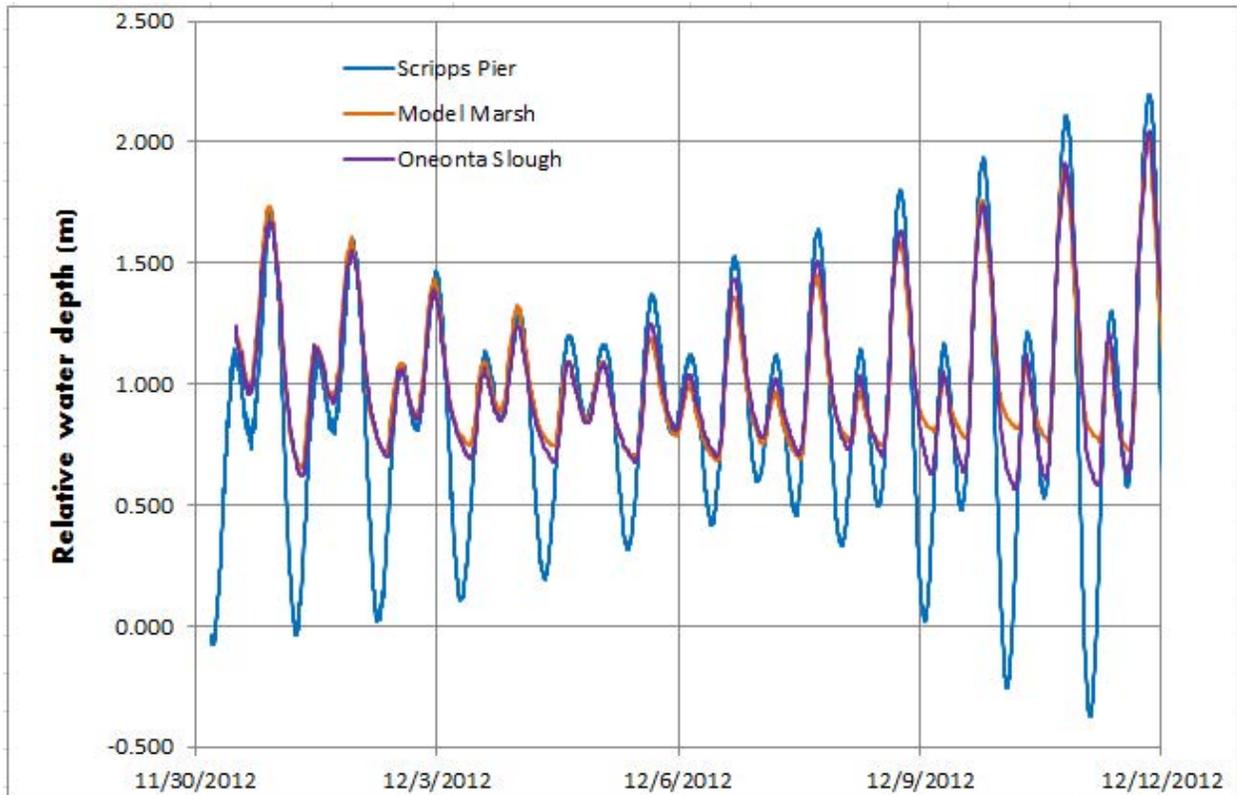


Figure 18 - 15-minute water depth data from two sites at the Tijuana River Estuary and 6-minute water depth from Scripps Pier for an irrelevant time period to show normal tidal influence at these sites. Oneonta Slough and Model Marsh are two sites being monitored for water quality in the northern arm 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 ~ 470nm) 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).

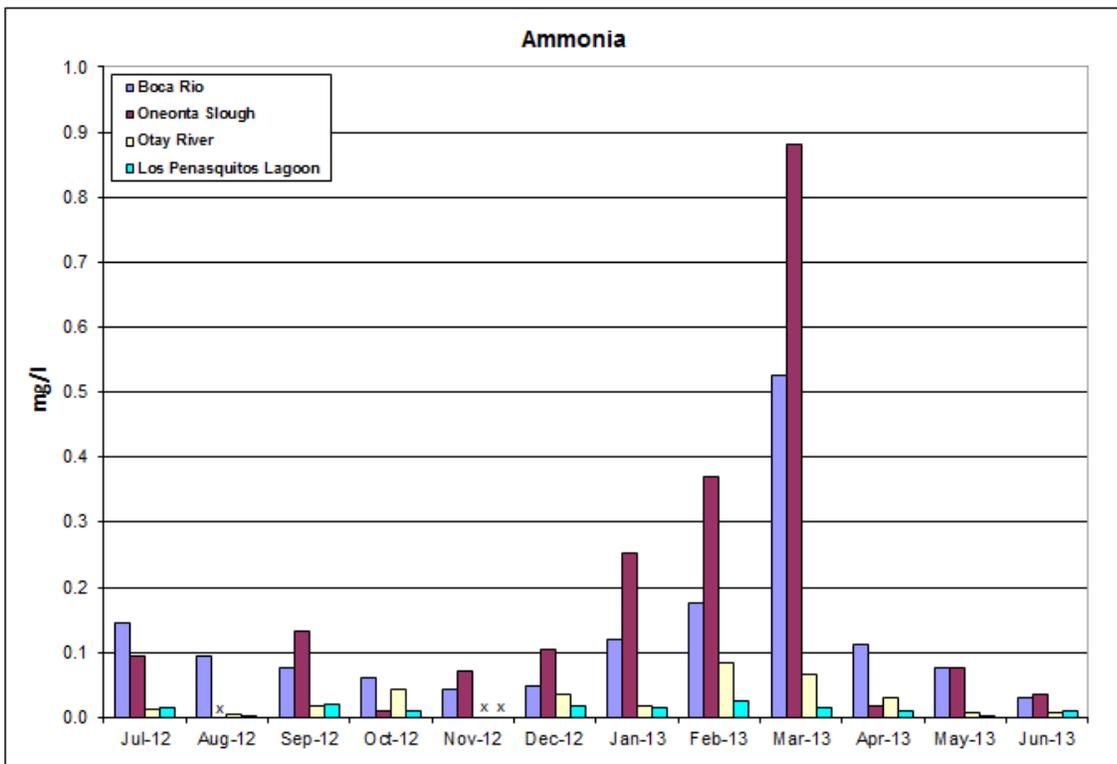
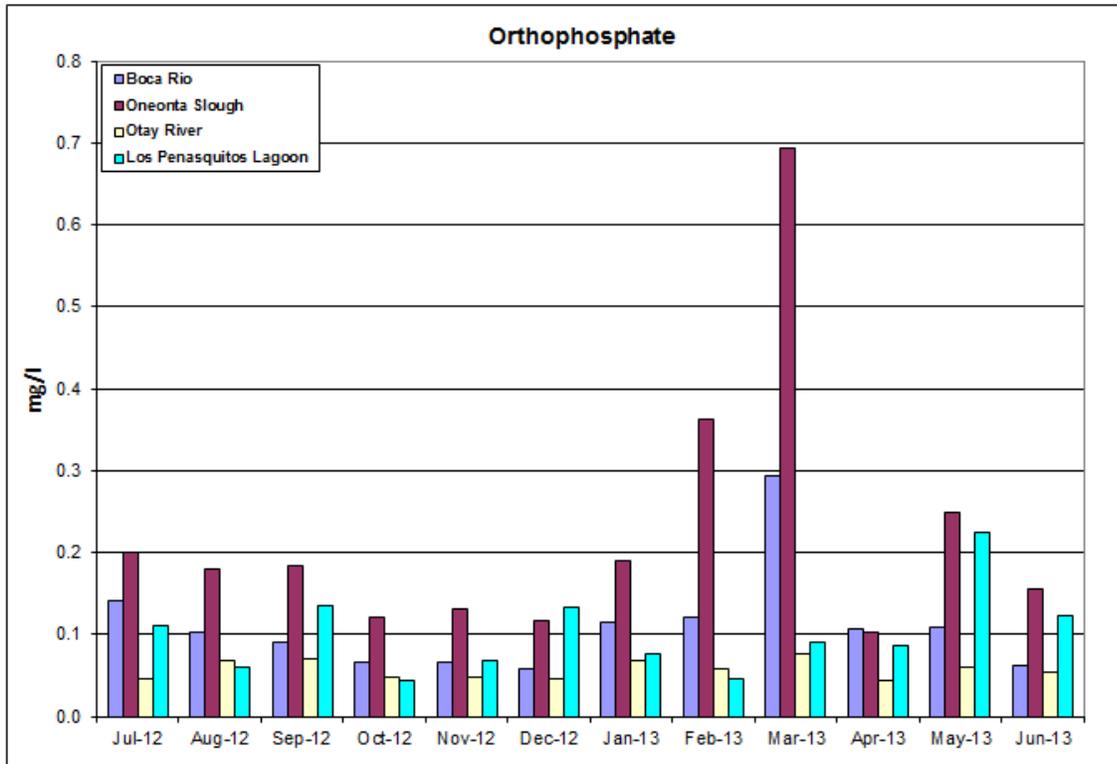


Figure 19 - Monthly nutrient data for two Tijuana Estuary sites (Boca Rio and Oneonta Slough), a San Diego Bay site (Otay River), and Los Peñasquitos Lagoon. “x” indicates no data.

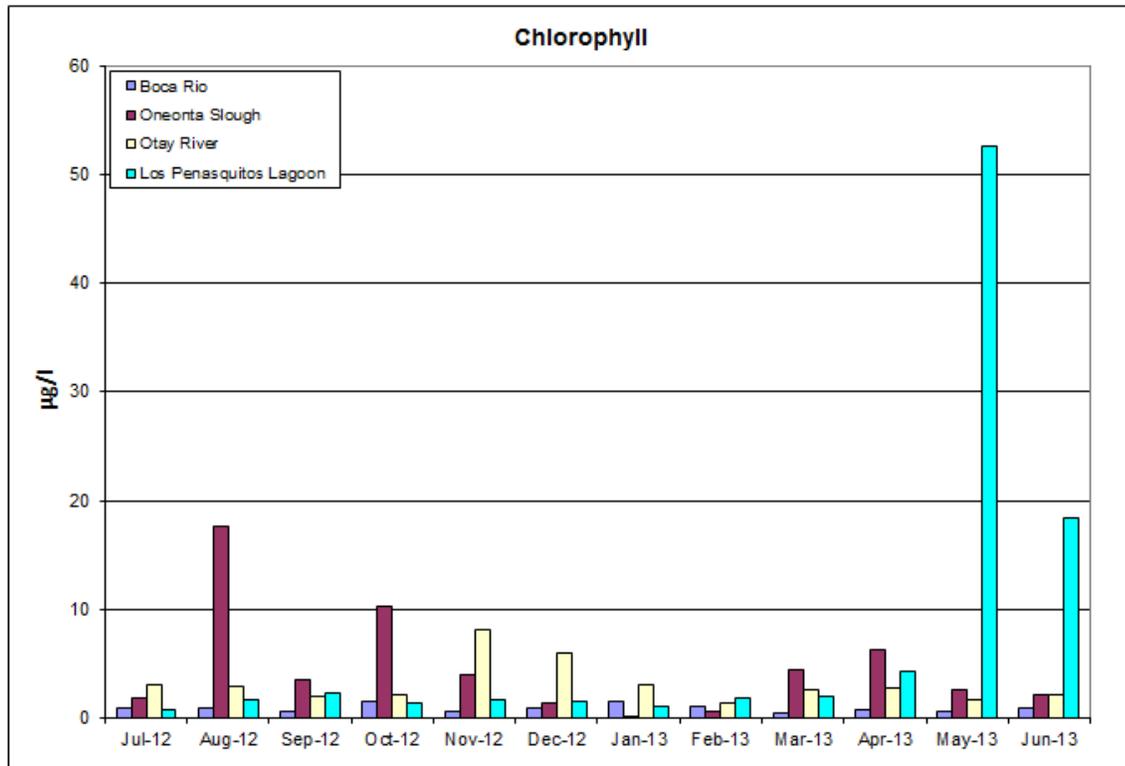
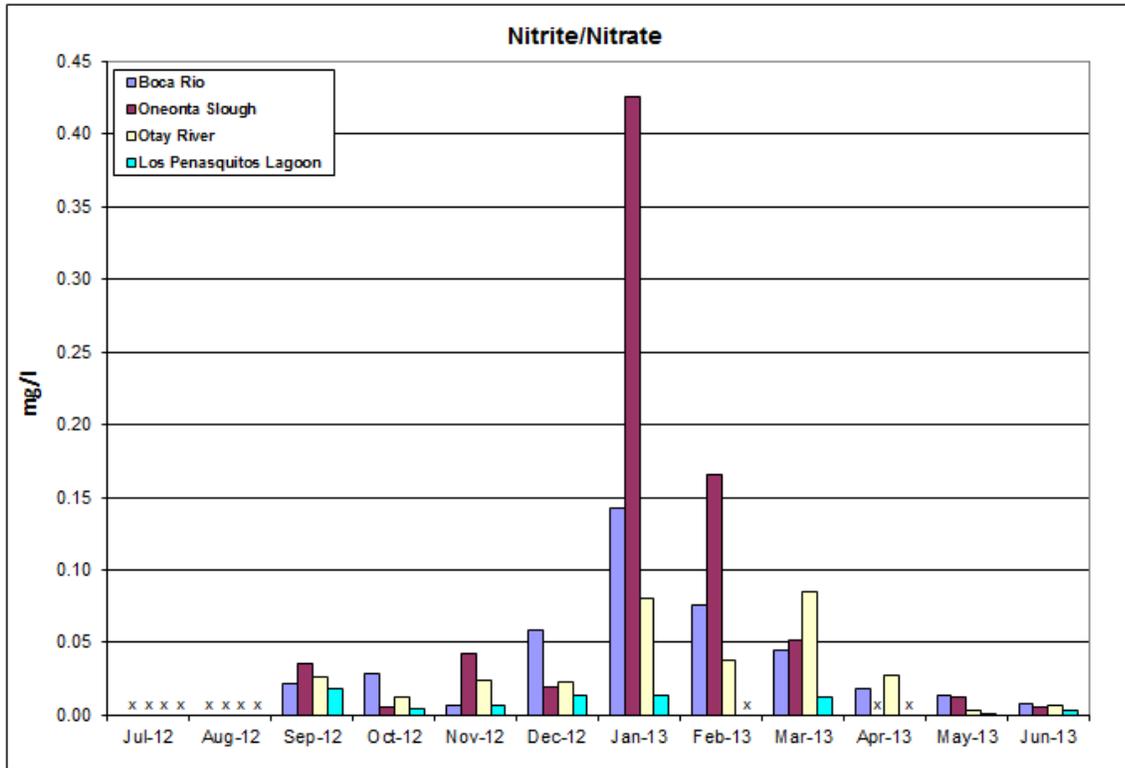


Figure 19, continued - Monthly nutrient data for two Tijuana Estuary sites (Boca Rio and Oneonta Slough), a San Diego Bay site (Otay River), and Los Peñasquitos Lagoon. “x” indicates no data.

VEGETATION

^{SS} = Saltmarsh Species

^{SSOP} = Saltmarsh Species, Obligate Parasite

^{ES} = Exotic Species

^{TSA} = Transitional Species, Alkali

^{TSB} = Transitional Species, Brackish

^{TSR} = 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*)^{SS} – 32.3%



Fleshy Jaumea (*Jaumea carnosa*)^{SS} – 29.2%



Alkali heath (*Frankenia salina*)^{SS} – 19.0%



Saltgrass (*Distichlis spicata*)^{SS} – 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*)^{SSOP} – 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*)^{ES}.

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*)^{SS} – 25%

Saltgrass (*Distichlis spicata*)^{SS} – 23%

Pickleweed (*Salicornia pacifica*)^{SS} – 22%

Iceplant/hottentot fig (*Carpobrotus edulis*)^{ES} – 16%

Ragweed (*Ambrosia* sp.)^{TSA} – 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*^{ES} 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*^{SS} has remained the dominant saltmarsh species since the removal effort in 1996. Exotic species found included rabbitfoot grass (*Polypogon monspeliensis*)^{ES}, dock (*Rumex sp.*)^{ES}, sow thistle (*Sonchus sp.*)^{ES}, wild radish (*Raphanus sativus*)^{ES}, and Italian ryegrass (*Festuca perrennis*)^{ES}, 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*)^{TSA} – 32%

Survey indicated that 12% was completely or partially dead

Saltgrass (*Distichlis spicata*)^{SS} – 22% (-1% from 1991 survey)

Survey indicated that 9% was completely or partially dead

Pickleweed (*Salicornia pacifica*)^{SS} – 11% (-11% from 1991 survey)

Alkali heath (*Frankenia salina*)^{SS} – 8% (-17% from 1991 survey)

Perennial glasswort (*Arthrocnemum subterminalis*)^{SS} – 4%

Alkali weed (*Cressa truxillensis*)^{SS} – < 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*)^{SS} – 46%

Pickleweed (*Salicornia pacifica*)^{SS} – 31%

Alkali heath (*Frankenia salina*)^{SS} – 19%

Saltgrass (*Distichlis spicata*)^{SS} – 18%

Alkali weed (*Cressa truxillensis*)^{SS} – 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*^{SS}, *J. carnosa*^{SS}, *F. salina*^{SS}, *D. spicata*^{SS}, and *C. truxillensis*^{SS} have been present at this site since 1991. The obligate parasite, Saltmarsh dodder (*Cuscuta salina*)^{SSOP} was not found on this transect prior to 1995, but has been found

annually since then. *S. pacifica*^{SS} was the dominant species in 2012 with a percent cover of 54% as opposed to *J. carnosus*^{SS}, which was the dominant 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*)^{SS} – 54% (+23% from 1991 survey)

Alkali heath (*Frankenia salina*)^{SS} – 19% (same % as in 1991 survey)

Alkali weed (*Cressa truxillensis*)^{SS} – 10% (-4% from 1991 survey)

Fleshy Jaumea (*Jaumea carnosus*)^{SS} – 9% (-37% from 1991 survey)

Saltmarsh dodder (*Cuscuta salina*)^{OPSS} – 8%

Survey indicated that 3% was completely or partially dead

Saltgrass (*Distichlis spicata*)^{SS} – 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*^{SS} and *F. salina*^{SS} 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*)^{SS} – 56%

Alkali heath (*Frankenia salina*)^{SS} – 28%

Saltgrass (*Distichlis spicata*)^{SS} – 20%

From 1991-2002, three species have shared dominance at this site: *S. pacifica*^{SS}, *D. spicata*^{SS} and *F. salina*^{SS}. Since then, *F. salina*^{SS} has become the dominant species (65%) followed by *S. pacifica*^{SS} (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*)^{SS} – 65% (+37% from 1991 survey)

Pickleweed (*Salicornia pacifica*)^{SS} – 36% (-20% from 1991 survey)

Saltgrass (*Distichlis spicata*)^{SS} – 13% (-7% from 1991 survey)

Survey indicated that 3% was completely or partially dead

Saltmarsh dodder (*Cuscuta salina*)^{SSOP} – > 2%

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

Alkali weed (*Cressa truxillensis*)^{SS} – > 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*)^{SS} – 38%

Alkali heath (*Frankenia salina*)^{SS} – 27 %

From the time monitoring began in 1991 until 2001, two species, *S. pacifica*^{SS} and *F. salina*^{SS}, have dominated along the transect. In 2012, a small amount of saltmarsh dodder (*Cuscuta salina*)^{SSOP} was found and *S. pacifica*^{SS} and *F. salina*^{SS} 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*)^{SS} – 54% (+16% from 1991 survey)

Alkali heath (*Frankenia salina*)^{SS} – 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*)^{SS} – 44%

Pickleweed (*Salicornia pacifica*)^{SS} – 39%

Shoregrass (*Distichlis littoralis*)^{SS} – 34%

Saltgrass (*Distichlis spicata*)^{SS} – 10%.

From 1991 to 1998, *S. pacifica*^{SS} 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*^{SS} 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*)^{SS} – 69% (+30% since 1991 survey)

Alkali heath (*Frankenia salina*)^{SS} – 22% (-22% since 1991 survey)

Shoregrass (*Distichlis littoralis*)^{SS} – 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*)^{SS} with some Cattails (*Typha* sp.)^{TSB}:

Pickleweed (*Salicornia pacifica*)^{SS} – 81%

Cattails (*Typha* sp.)^{TSB} – 20%

Typha sp.^{TSB} cover has increased in recent years to 39% in 2012, though it dropped from 69% in 2011. *S. pacifica*^{SS} has decreased along the transect over the past 13 years to 3% cover. *J. carnosa*^{SS} 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.^{TSB} 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*)^{SS} – 68%

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

Saltmarsh dodder (*Cuscuta salina*)^{SSOP} – 9%

Survey indicated that 8% was completely or partially dead

Pickleweed (*Salicornia pacifica*)^{SS} – 3% (-78% since 1991 survey)

Salt marsh fleabane (*Pluchea odorata*)^{SS} – 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*^{SS} and *F. salina*^{SS}, 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*)^{SS} – 64%

Pickleweed (*Salicornia pacifica*)^{SS} – 36%

Spearscale (*Atriplex prostrata*)^{TSA} – 16%

Curly dock (*Rumex crispus*)^{ES} – 2%

Cattail (*Typha* sp.)^{TSB} – 1%

By 1999, the eastern portion of the transect resembled a brackish marsh/riparian community dominated primarily by Cattail (*Typha* sp.)^{TSB} and Willow (*Salix* sp.)^{TSR}. *Typha* sp.^{TSB} had also reached the edge of the creek. Assuming that *Typha* sp.^{TSB} 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.)^{TSB} and Willow (*Salix* sp.)^{TSR}. The use of aerial photography and remote sensing data is needed to more accurately document the spread of Cattail (*Typha* sp.)^{TSB} and Willow (*Salix* sp.)^{TSR}. 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. carnos*^{SS} (100%) was the dominant species in 2012. *C. salina*^{SS}, *D. spicata*^{SS}, *F. salina*^{SS}, *S. pacifica*^{SS}, and *A. prostrata*^{ES} 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*^{SS} and *F. salina*^{SS} 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. carnos*^{SS}, 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.^{TSB}. The last two of the original sections were not sampled in 2012, as *Typha* sp.^{TSB} 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 carnos*)^{SS} – 49%

Pickleweed (*Salicornia pacifica*)^{SS} – 30% (-33% from 1991 survey)

Alkali heath (*Frankenia salina*)^{SS} – 17% (+2% from 1991 survey)

Unidentifiable dead grasses – 16%

Saltmarsh dodder (*Cuscuta salina*)^{SSOP} – > 2%

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

Spearscale (*Atriplex prostrata*)^{ES} – 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.^{T_{SB}} 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.^{T_{SB}} and was discontinued in 2004. In 2011, 13A was again located and surveyed. In 2001, *S. pacifica*^{SS} overwhelmingly dominated Transect 13B with ~85% cover. The transects in 2012 indicated that coverage by *S. pacifica*^{SS} 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*)^{SS} – 89%

Alkali heath (*Frankenia salina*)^{SS} – 7%

Shoregrass (*Distichlis littoralis*)^{SS} – 7%

Pickleweed (*Salicornia pacifica*)^{SS} – 4% (-81% from 2001 survey)

Spiny rush (*Juncus acutus*)^{T_{SA}} – 2%

Toad rush (*Juncus balticus*)^{T_{SA}} – 1%

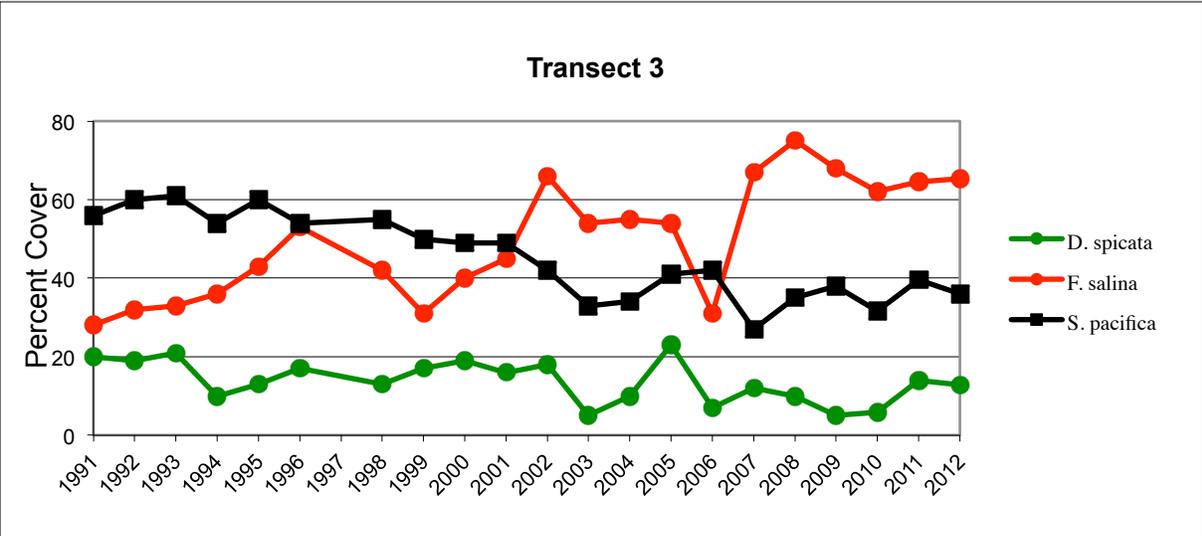
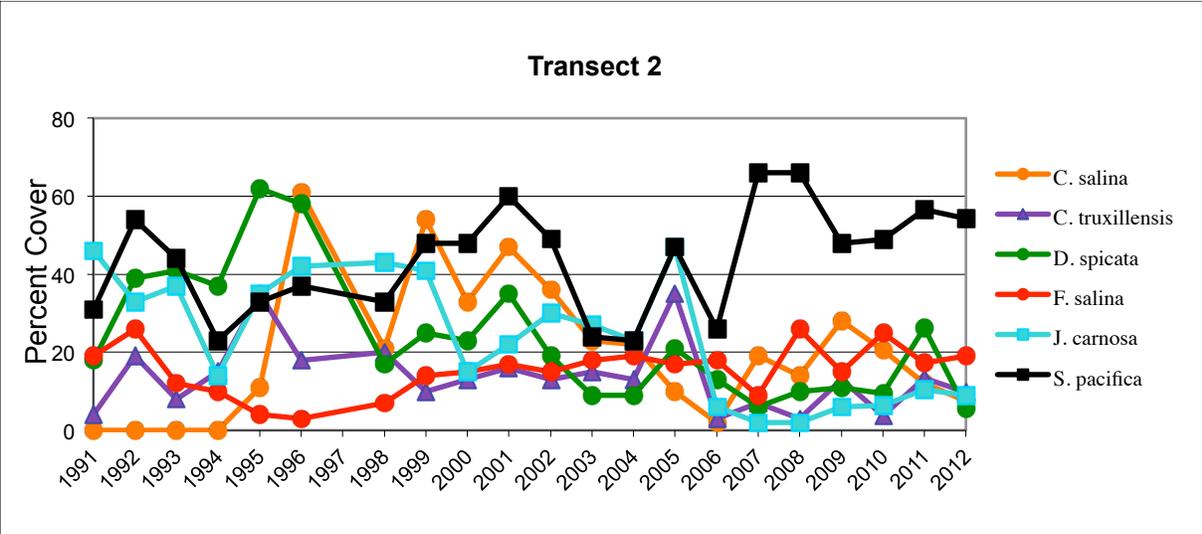
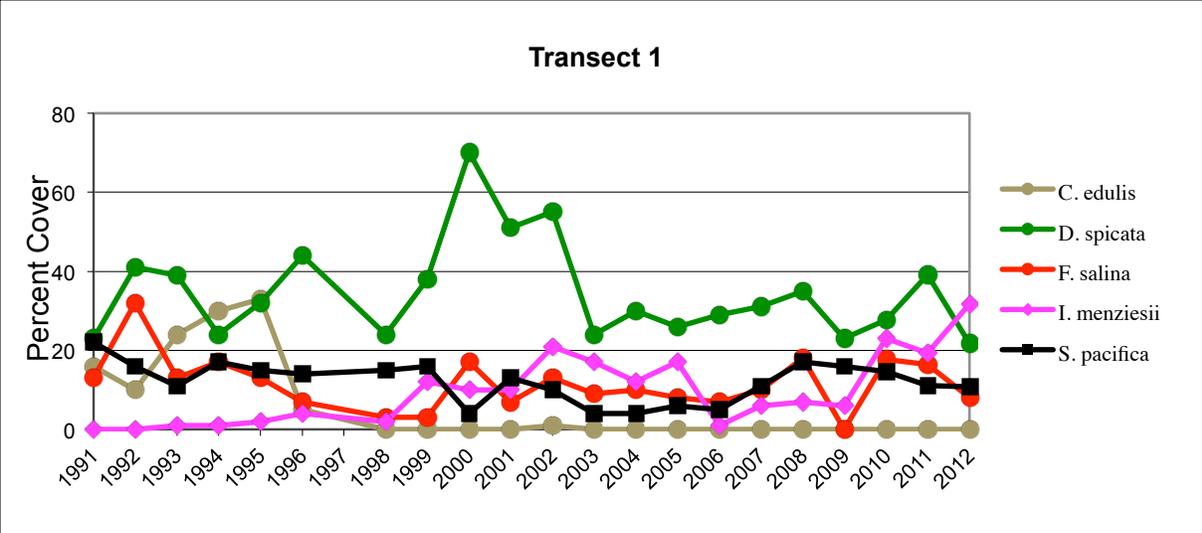


Figure 20 - Long-term vegetation data for dominant species for transects 1 – 5, 9, and 11 – 13, displaying % cover from 1991 – 2012.

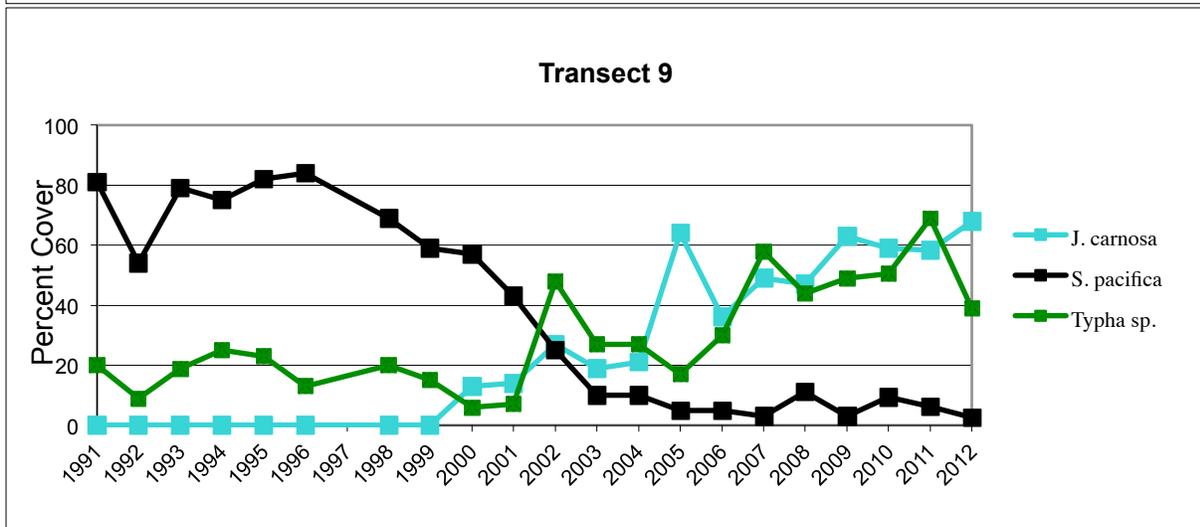
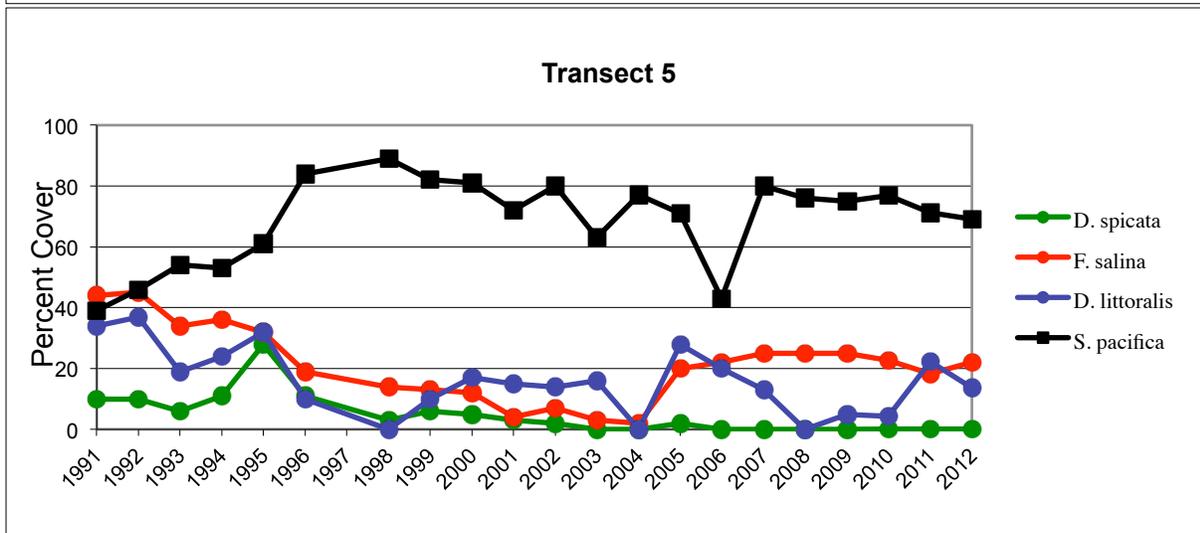
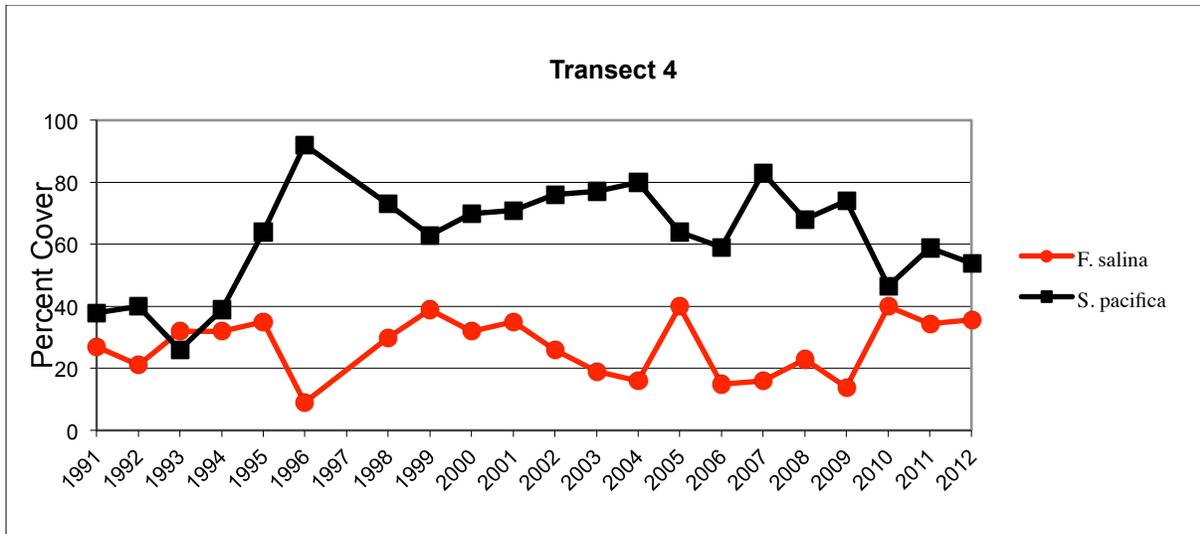


Figure 20, continued - Long-term vegetation data for dominant species for transects 1 – 5, 9, and 11 – 13, displaying % cover from 1991 – 2012.

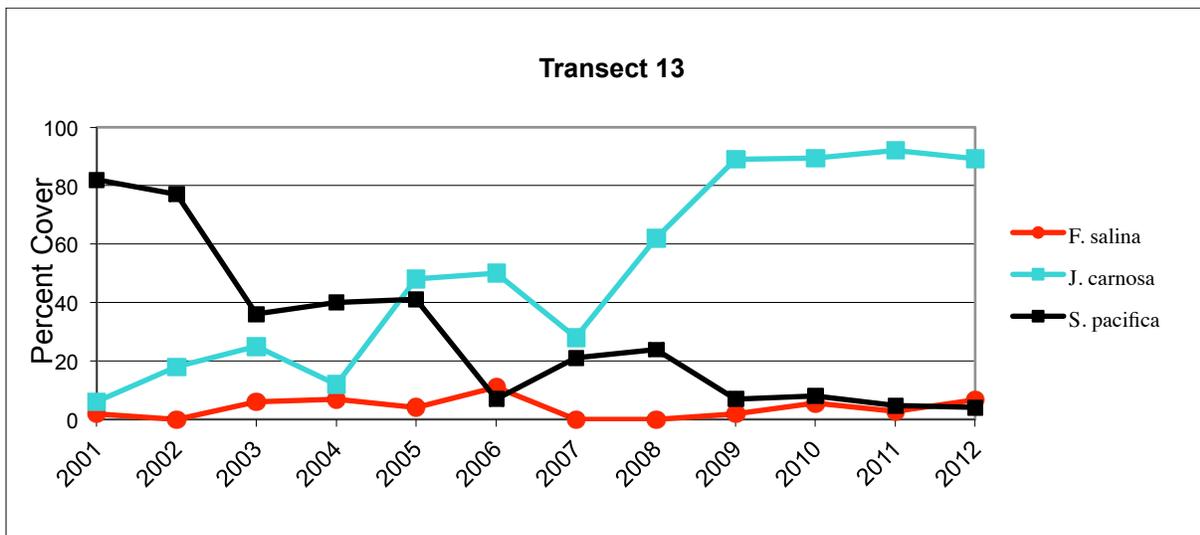
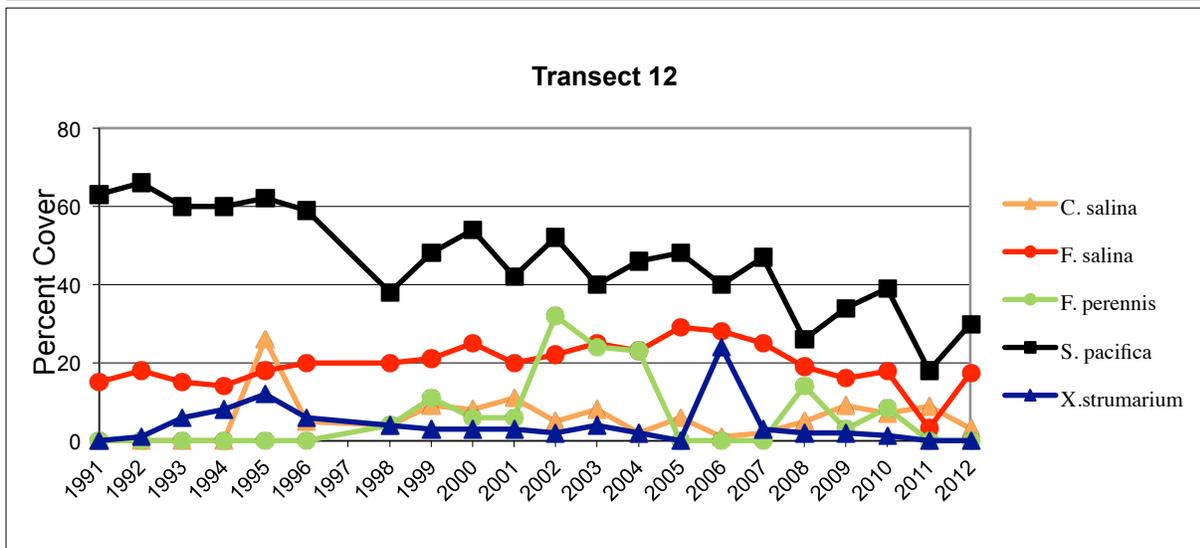
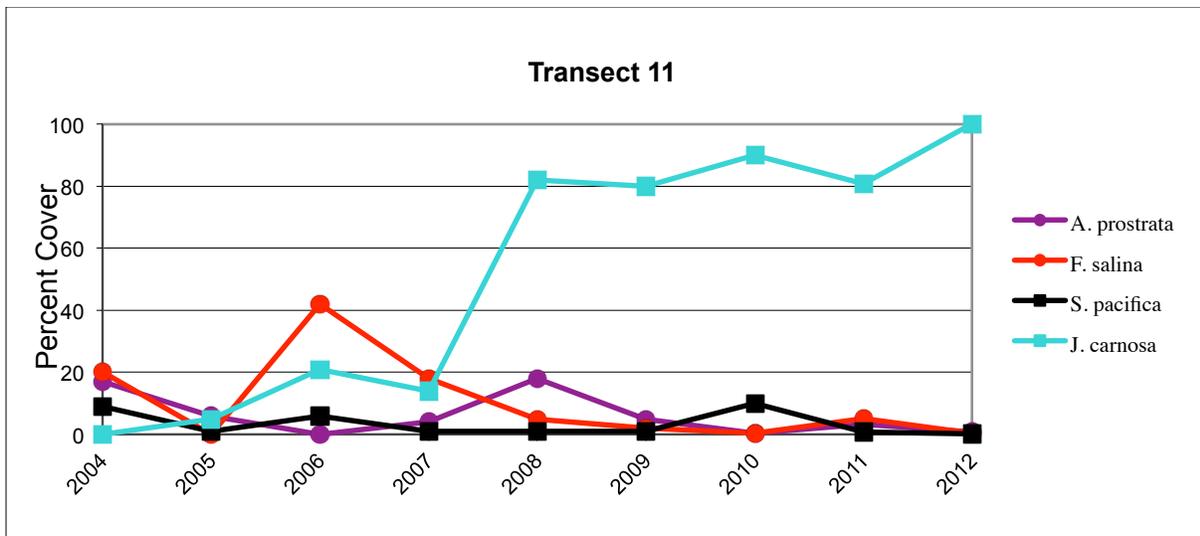


Figure 20, continued - Long-term vegetation data for dominant species for transects 1 – 5, 9, and 11 – 13, displaying % cover from 1991 – 2012, continued.

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*^{SS} 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*)^{SS} – 45%

Alkali heath (*Frankenia salina*)^{SS} – 6%

Saltgrass (*Distichlis spicata*)^{SS} – 21%

Shoregrass (*Distichlis littoralis*)^{SS} – 2%

Curved Sicklegrass (*Parapholis incurva*)^{ES} – 4%

Brass Buttons (*Cotula coronopifolia*)^{ES} – 8%

Fleshy Jaumea (*Jaumea carnosa*)^{SS} – 2%

Perennial glasswort (*Arthrocnemum subterminale*)^{SS} – 4%

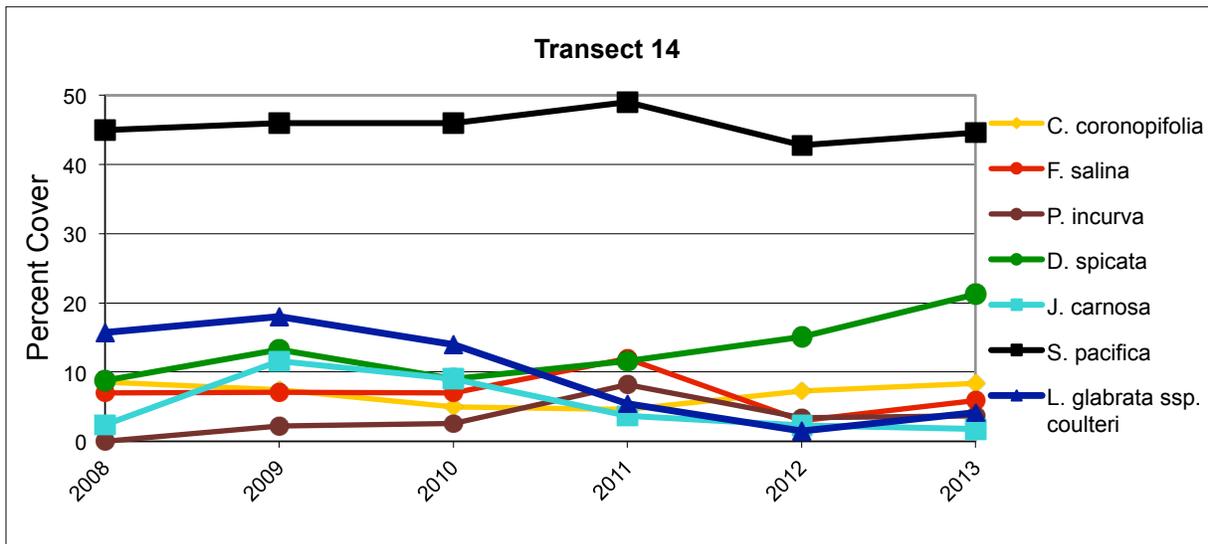


Figure 21 - Long-term data for spring vegetation transect 14, displaying % cover of *Lasthenia glabrata* ssp. *coulteri* and other dominant species.

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
Saltmarsh species	Mean % cover of individual species									
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
Transitional species										
Atriplex californica	< .1									
Atriplex californica*			1							
Baccharus 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		
Exotic species										
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.

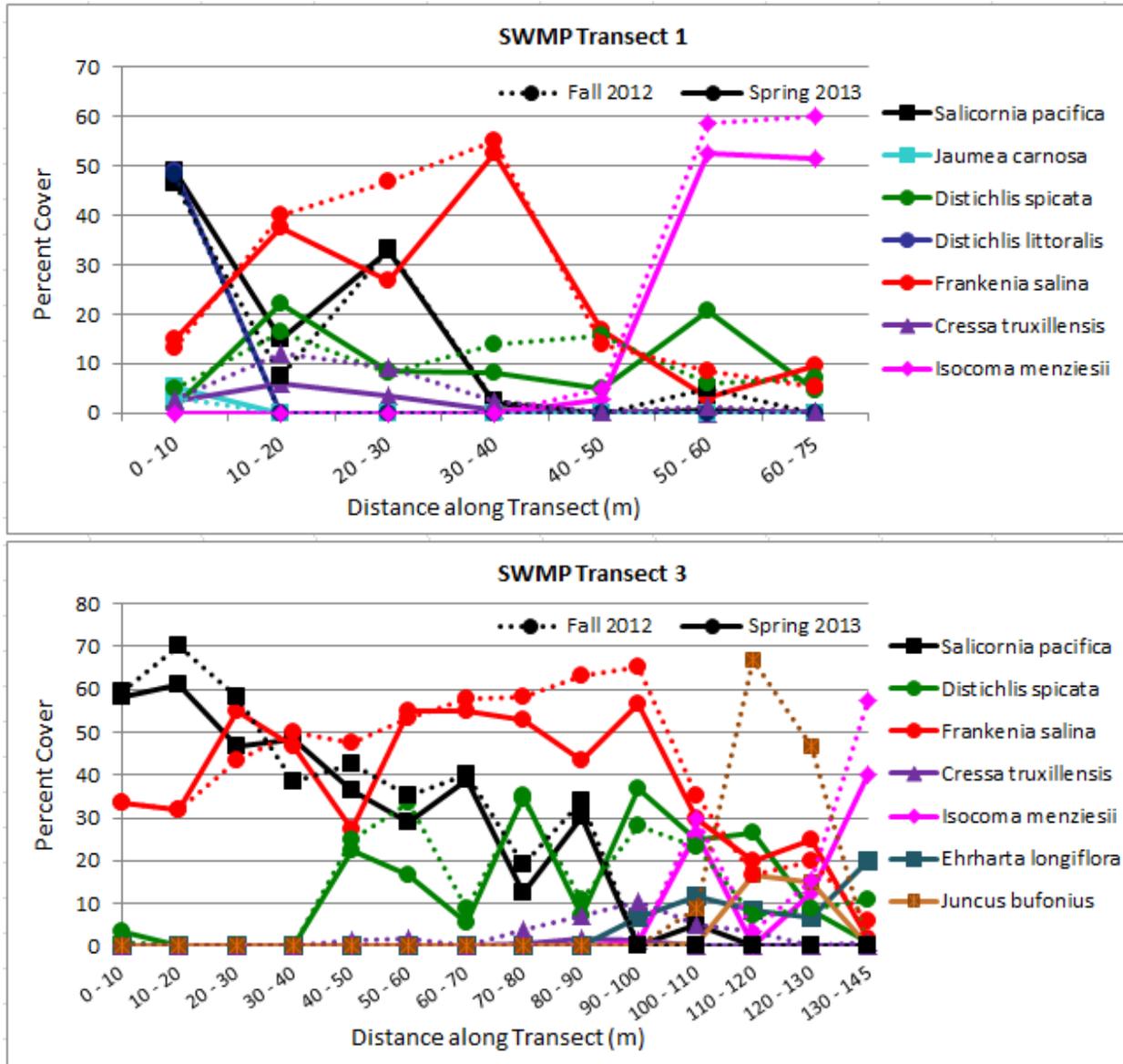


Figure 22 - Data from transects across vegetation zones. Transects begin in the tidal marsh and end in the upland transition zone. *Ehrharta longiflora* was not identified in the fall, however, there was significant cover (16%) of dead grass that was unidentifiable in those quadrats where it was present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

Transect #	FALL 2012		SPRING 2013	
	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
Saltmarsh species	Mean % cover of individual species			
Amblyopappus pusillus	< 1		< 1	
Arthrocnemum subterminale	4		3	
Cressa truxillensis	1	1	< 1	< 1
Cressa truxillensis*	2	1	< 1	< .1
Cuscuta salina	< 1	< 1	< 1	< 1
Cuscuta salina*	2	1	< 1	
Distichlis spicata	5	12	5	14
Distichlis spicata*	4	2	3	
Distichlis littoralis	9		9	
Frankenia salina	22	42	20	39
Frankenia salina*		< 1		
Jaumea carnosa	< 1	< 1	1	2
Limonium californicum	< .1		< 1	
Salicornia pacifica	15	29	16	27
Transitional species				
Ambrosia psilostachya	< 1	< .1	< 1	< 1
Atriplex californica	< .1	< 1	< 1	< 1
Baccharus pilularis				< 1
Cylindropuntia prolifera		< .1		< .1
Elymus triticoides			< .1	< 1
Galium sp.				< .1
Isocoma menziesii	7	6	6	5
Isocoma menziesii*	13	< .1	11	< 1
Juncus balticus		2		2
Juncus balticus*		6		4
Lepidium virginicum			< .1	
Pseudognaphalium biolettii			< 1	
Pterostegia drymarioides			12	< .1
Pterostegia drymarioides*	7			
Exotic species				
Anagallis arvensis			< 1	
Atriplex prostrata	< .1	< 1		< .1
Bromus sp.				< 1
Carpobrotus edulis			< .1	
Ehrharta longiflora			3	3
Erodium cicutarium				< .1
Lactuca serriola			< .1	
Melilotus indicus			< .1	
Oxalis pes-caprae			< 1	
Parapholis incurva			< 1	
Polypogon monspeliensis*	< 1			
Raphanus sativus	< 1		< 1	
Rumex sp.	< 1		< 1	
Sonchus 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> [†]
<u>Saltmarsh Species</u>		
<i>Amblyopappus pusillus</i>	dwarf coastweed / pineapple weed	
<i>Arthrocnemum subterminale</i> (<i>Salicornia subterminalis</i>)	Parish's glasswort	
<i>Cressa truxillensis</i>	alkali weed	
<i>Cuscuta salina</i>	salt marsh dodder	
<i>Distichlis littoralis</i> (<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> (<i>Salicornia europaea</i>)	glasswort	
<i>Salicornia pacifica</i> (<i>Salicornia virginica</i> , <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 horseweed	
<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 var. menziesii</i>	Menzie's / Coast goldenbush	
<i>Juncus acutus ssp. Leopoldii</i>	Leopold's rush / southwestern spiny rush	4.2 - Uncommon in California; .2: Fairly endangered in California
<i>Juncus balticus ssp. 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> (<i>Lolium multiflorum</i>)	Italian ryegrass
<i>Helminthotheca echioides</i> (<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

[†] 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 13th, 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 13th was not successful in keeping the inlet open. When crews arrived at the inlet on May 14th, 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 (Station W2), 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.

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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), 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.

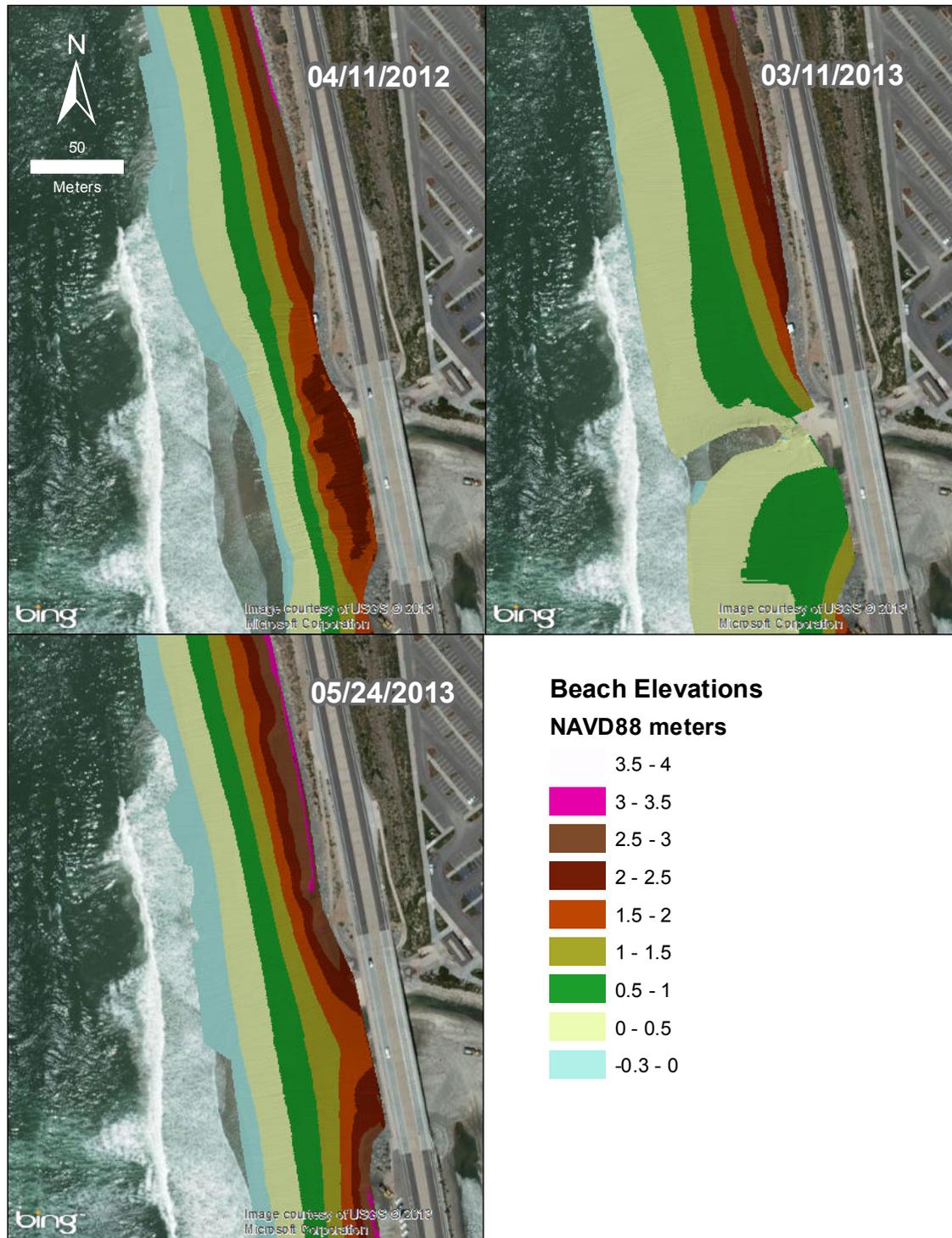
RBSP II

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.



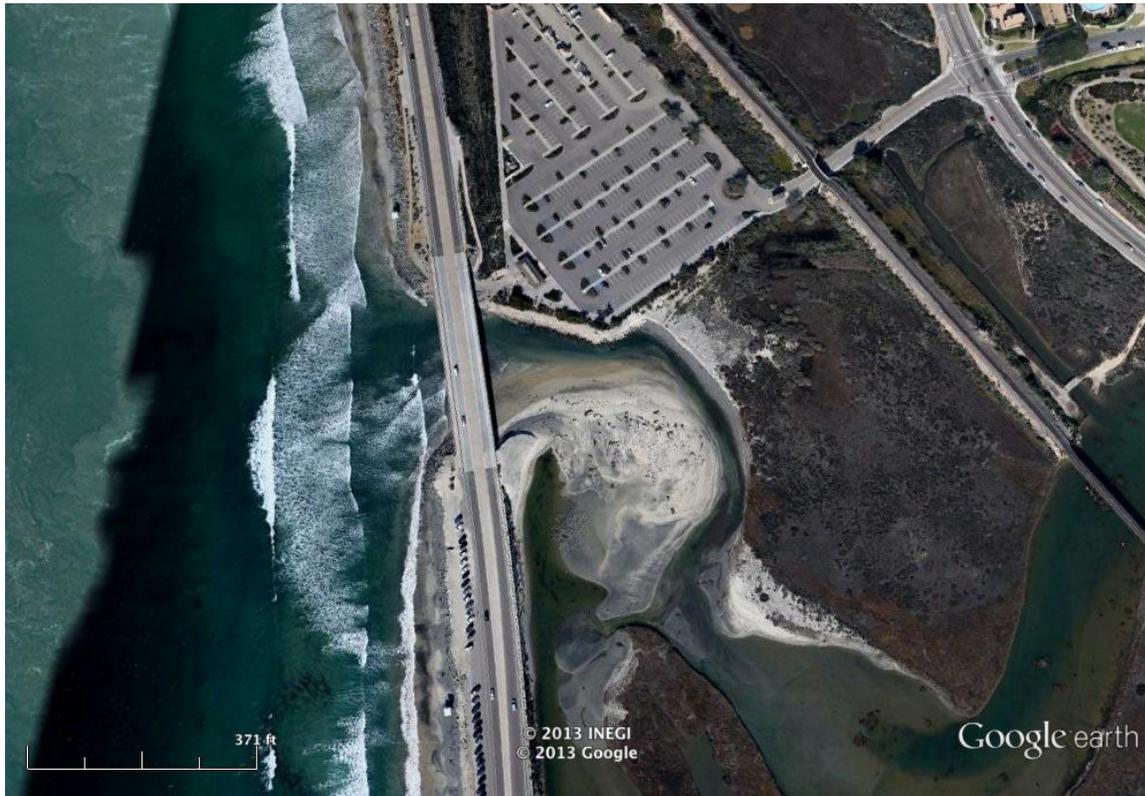
View of Beach Profile, Northern Edge of Los Peñasquitos Lagoon Inlet. May 15, 2013



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.