MISSION BAY PARK
2013 BATHYMETRY AND
EELGRASS INVENTORY

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Bathymetry was collected in 2013 and is presented in feet Mean Lower Low Water (MLLW). Eelgrass mapping is based on sidescan surveys, groundtruthing and subsequent spot-checking within areas of apparent aberrations.

Eelgrass survey data are accurate to within approximately ±6.6 feet (a composite of the navigational system error and sidescan error). Eelgrass data reflects a particular period in time and are anticipated to be seasonally and stochastically dynamic.

Bathymetric charts and eelgrass maps are for planning purposes only and are not to be used for navigation or project specific purposes. The authors make no representation regarding the accuracy of these maps relative to submerged structures, debris, shoals, or other navigational hazards.

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San Diego, California

BACKGROUND

Mission Bay is a 2,299-acre bay located at the heart of the 4,235-acre Mission Bay Park in San Diego, California. During the 1950-1960's the bay was created to serve as a recreational harbor through dredging and filling of coastal salt marsh and expansive mudflats at the mouth of the San Diego River and diversion of the river flows down a defined channel to the Pacific Ocean. The bay has a convoluted 27-mile long shoreline designed to enhance shoreline access and features of the park environment. While much of the marshland habitat has been lost from the area, new uses and habitats have benefited from the historic changes. In particular, eelgrass (*Zostera marina*) habitat has expanded over much of the bay floor and now provides one of the most abundant and unique resources of the Mission Bay ecosystem.

Since eelgrass is predominantly a sub-tidal resource, it is more difficult to monitor and track changes in this habitat than it is to monitor similar sized terrestrial communities. Aerial imagery has historically underestimated eelgrass distribution and conditions. In 1985, the City of San Diego, working in conjunction with state and federal resource and regulatory agencies, as well as interested environmental and bay user groups, agreed to develop a comprehensive resource management plan for Mission Bay Park. The goal was to better address new projects as well as management and maintenance actions in a comprehensive manner. This was the impetus for the development of the Mission Bay Park Natural Resource Management Plan (City of San Diego 1990). Under this management plan, eelgrass resources are to be regularly inventoried and evaluated relative to management activities or project changes in the bay or watershed.

Eelgrass surveys have been previously conducted along the shoreline of Mission Bay in 1986 (Ecosystems 1986) and the entire bay (Merkel 1988, 1992, 1997, 2001, and 2007). The present 2013 survey is a continuation of this survey program and provides insight into long-term trends in eelgrass habitat, as well as providing insight into more broad-reaching patterns of water quality and environmental change within the Bay.

In addition to the eelgrass survey element of the past years, the 1997, 2007, and 2013 work incorporated a bathymetric mapping component that was included as an adjunct to the eelgrass surveys. The bay bathymetry were not the specific focus of the project, therefore, there are some limitations in the applicability of these data. In general, bathymetry for the open water bay bottom is more accurate than shoreline fringe bathymetry where steep slopes exist. Further, bathymetry in eelgrass beds is typically less accurate than bathymetry outside of eelgrass beds due to the interference of eelgrass with acoustic reflection from the bay bottom. Bathymetric data were developed through the use of single beam sonar and interferometric sidescan sonar acoustic technologies. Ground-truthing of the bathymetry was completed by leadline soundings. The mean high water (MHW) shoreline derived from a 2000 Mission Bay Park survey (Plummer et al. 2001) was used as the present bathymetry.

The results of the eelgrass inventory are presented on the individual charts that follow as Appendix 1. Eelgrass survey results and bathymetry data are presented at a 1:2,400 scale (1 inch = 200 feet). Depths are presented in feet below mean lower low water (MLLW) which is the most commonly reported tide-table datum in the San Diego region and the most meaningful datum to most bay users.

SURVEY METHODS

FIELD SURVEYS

In order to map eelgrass beds and prepare charts throughout the bay, surveys were conducted by Merkel & Associates, Inc. using interferometric sidescan sonar operating at a frequency of 468 kHz and 210 kHz single-beam fathometer. A differential global positioning system (dGPS) navigation system was used to track the position of the survey vessel in the bay.

The interferometric sidescan sonar surveyed at 70-meter swath widths (35 meters each on the starboard and port channels). Parallel survey lines were navigated and spaced at approximately 25 meters separation to allow full overlap of the nadir gap at the centerline of the survey swaths. The survey lines were continued until the entirety of the survey area is captured in the survey record.

The collected information from the interferometric sidescan sonar included high-density bathymetry as well as backscatter data. The bathymetric data result from the timing of the return of a sound pulse reflected off the bottom as it is received at multiple stave locations on the transducer array such that elevational point data are derived at a density of approximately 280 points/m^2 excluding areas of multiple swath overlap. The difference in return time to different sensors allows for triangulation of the position of the acoustically reflective surface. The vertical and horizontal accuracy of the bathymetric data are a function of the accuracy of the vessel positioning and the accuracy of adjustments for velocity of sound and pulse angle (pitch, roll, and heave). The horizontal positioning of the survey vessel will be maintained with a Hemisphere VS111 with an accuracy of less than 60 centimeters, 95% of the time. The rest of the survey system is composed of a SEA SWATHplus-H sonar, Valeport miniSVP sound velocity sensor, and an SMC IMU-108 motion sensor. The system's accuracy potential exceeds the latest International Hydrographic Organization (IHO) standards as set out in IHO Standards for Hydrographic Surveys, Special Publication 44 (IHO 1998). Sidescan and multibeam sonar data are adversely affected by the presence of highly acoustically reflective vegetation such as eelgrass that often results in a false bottom interpretation within the vegetation canopy. For this reason, a single beam survey grade fathometer was operated concurrently with the interferometric sidescan sonar in order to provide a verification of the bottom elevations at the survey track centerline. The single beam fathometer was a SyQuest Hydrobox. The single beam sonar used the same positioning system as the sidescan sonar.

GROUND-TRUTHING

Ground-truthing was accomplished for both eelgrass surveys and bathymetric data collection through a separate survey effort. Following initial data collection, a subsequent survey was conducted to spot check bathymetric data by leadline. The distribution of ground-truthing was non-random and primarily focused on sites identified as having substantial discrepancies existing between the prior surveys and the present survey as well as areas of particular interest to the present effort, such as shallow shoals. Additional ground-truthing efforts were focused around marinas, docks, and other areas where sonagraphic surveys were encumbered by limited open water access.

Eelgrass habitat mapping ground truthing was completed using a variety of tools including diver observations, drop video cameras, and a remotely operated vehicle (ROV) that was navigated through areas to determine presence or absence of eelgrass. Ground-truthing effort was focused of greater complexity in sonar interpretation such as along revetment edges, within marinas where piles and boat hulls can obscure features, or where steep and hard sediment conditions can result in higher reflectivity that masks high reflectivity of eelgrass.

DATA ANALYSIS

EELGRASS MAPPING

Following the completion of the sonagraphic survey, the stored sidescan data were post-processed into a series of geo-rectified mosaic images covering all surveyed areas of Mission Bay. The images imported into ESRI® ArcGIS to delineate eelgrass beds. Once identification and delineation of the eelgrass was completed the data were plotted at a 1:2,400 scale (1"=200'). The entire bay was plotted in sections on a total of 12 D-sized sheets using the California State Plane, Zone 6, NAD 83, feet, coordinate system and adapting the sheet breaks from the prior baywide eelgrass surveys (Ecosystems 1986, Merkel 1988, 1992, 1997, 2001, and 2007).

BATHYMETRIC ANALYSES

Bathymetric data were processed and cleaned of erroneous points within the SWATHplus Grid Processor. Data were subsequently reducing to a single average depth value per square meter and exported as an xyz ascii file format. The file was imported into ESRI® ArcGIS for contouring and spatial presentation and analyses. Additional data used for creation of the final bathymetric grid included Mean High Water (MHW) shoreline points derived from a 2001 survey carried out by Project Design Consultants for the City of San Diego.

Mosaic images of backscatter data were prepared and used to map eelgrass habitat using ESRI ArcGIS. Areas will be delineated where interpretive differences in the intensity and patterns of the backscatter data are noted. The GIS specialist responsible for the mapping will determine areas where calibration will be needed to identify the habitat types that are within the digitized boundaries.

RESULTS

EELGRASS DISTRIBUTION AND ABUNDANCE

There were 979.1 acres of eelgrass within Mission Bay at the time of the summer 2013 surveys (Figure 1). There are two species of eelgrass present in the Bay, common eelgrass (*Zostera marina*) and Pacific eelgrass (*Z. pacifica*), although they were not mapped separately. *Zostera marina* is the most common form of eelgrass within Mission Bay and likely accounts for about 99.7 percent of all eelgrass in the Bay, based on an estimated extent of *Zostera pacifica*. While *Z. marina* is found throughout the Bay, *Z. pacifica* is generally considered to be an open coastal species and is generally found in very sandy sediments at deeper depths and with elevated exposure to both

Figure 1. Eelgrass distribution patterns from summer 2013 surveys

oceanic swell and circulation conditions. Within Mission Bay, this species has only been detected within the Mission Bay Entrance Channel west of West Mission Bay Drive Bridge, and principally west of the entrance to Quivira Basin. It is also found on the bay bottom at the mouth of Mariner's Basin between Mariner's Point and Mission Point. It is estimated that less than 3 acres of *Z. pacifica* occurred in Mission Bay during the 2013 growing season.

The extent of eelgrass is generally greatest within the better-flushed westerly portions of the bay, as illustrated in Figure 1, and in the attached map sheets (Appendix 1). Within the easterly portion of the bay, eelgrass is more extensive within more open waters such as Fiesta Bay that are subject to good tidal and wind driven circulation.

Eelgrass grows to a maximum verifiable depth of over 20 feet within Mission Bay. This occurs within patches of Pacific eelgrass (*Zostera pacifica*) located in the Mission Bay Entrance Channel. However, 99.9 percent of all of the Mission Bay eelgrass occurs within depths of less than 17 feet MLLW, and 99 percent of the eelgrass in Mission Bay occurs between 0 and 14.5 feet MLLW with all of the deeper eelgrass occurring within the southwestern entrance area of the Bay.

BATHYMETRY

Bathymetry of Mission Bay is that of a developed recreational embayment. The 2013 bathymetry of Mission Bay is illustrated in Figure 2 and on the individual chart sheets of Appendix 1. Depths range from intertidal to -30 feet within scour pits at the West Mission Bay Drive Bridge. In general, the Bay has a relatively flat bottom driven by initial design to accommodate shallow to mid-draft recreational vessels. Approximately 60 percent of the Bay occurs between the depths of -12 and -6 feet MLLW. An additional 17 percent of the Bay occurs below -12 feet MLLW. Approximately 9 percent of the Bay area occurs between -6 and -2 feet MLLW. Above -2 feet, intertidal areas total 14 percent of the bay area comprising intertidal beaches, mudflats, and marshes, as well as reveted shoreline.

The distribution of deeper and shallower water typically follows a west to east progression with the Mission Bay Entrance Channel, Quivira Basin, and Mariner's Basin being predominantly deep environments with waters principally being between -15 to -20 feet in depth. From the West Mission Bay Drive Bridge to the east, waters step up to shallower depths generally ranging from -8 to -10 feet. Within this general bathymetric condition, there are several mid-bay borrow sites, and scour holes within areas of concentrated tidal flow that have resulted in greater depths. There are also areas of shallower shoaling, typically associated with areas of scour erosion, and areas of sediment delta formation that are attributable to watershed fluvial inputs.

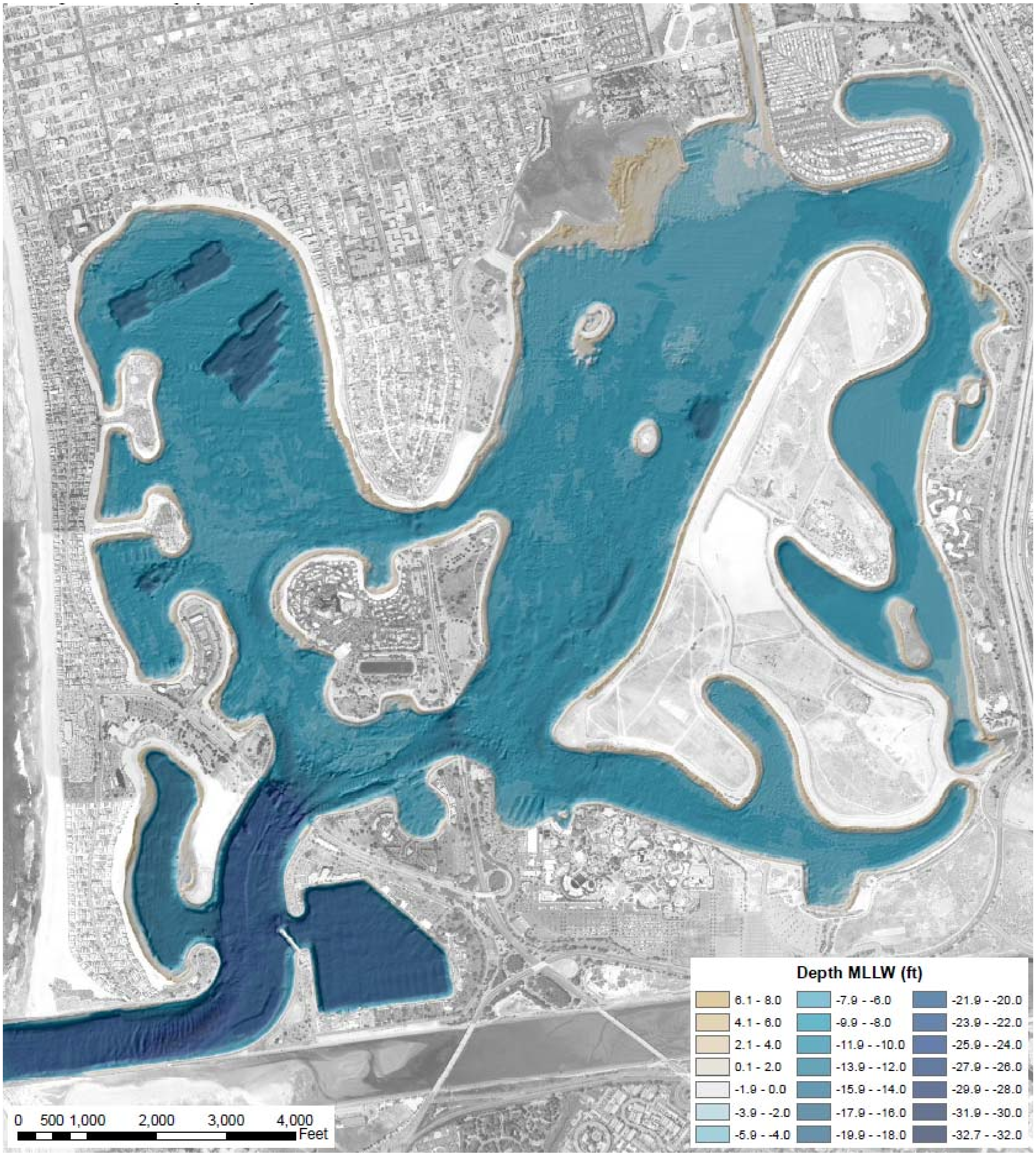

Figure 2. 2013 Mission Bay Bathymetry.

DISCUSSION

EELGRASS RESOURCES

General

Eelgrass is a native marine vascular plant indigenous to the soft-bottom bays and estuaries of the northern hemisphere. The species is found from middle Baja California and the Sea of Cortez to northern Alaska along the west coast of North America and is common in healthy shallow bays and estuaries. Common eelgrass (*Zostera marina*) has a circumglobal distribution within the Northern hemisphere and is geographically widespread along the entire California. However, it is limited in overall abundance due to extremely limited suitable habitat, consisting of clear water shallow protected soft-bottom bays and estuaries.

Eelgrass plays many roles within the coastal bays and estuary ecosystems. It clarifies water through sediment trapping and stabilization. It also provides benefits of nutrient transformation and water oxygenation. Eelgrass serves as a primary producer in a detrital based food-web and is further directly grazed upon by invertebrates, fish, and birds. Eelgrass provides physical structure to the community and supports epiphytic plants and animals that in turn are grazed upon by larval and juvenile fish, other invertebrates and birds. Eelgrass is a nursery area for many commercially and recreationally important finfish and shellfish species, including fish restricted to bays and estuaries as well as oceanic species that enter the coastal areas to breed or spawn.

In 2013 it is estimated that there are less than 12,000 acres of eelgrass statewide (Merkel & Associates 2013). Over 80 percent of this eelgrass is believed to be distributed within four systems, in order of abundance, Humboldt Bay, San Francisco Bay, San Diego Bay, and Mission Bay. While Mission Bay eelgrass in ranks fourth in total area of California behind the much larger bays, it ranks number one of the four for highest percentage of the total water body supporting eelgrass habitat.

Trends in Eelgrass Cover

A comparison of eelgrass coverage and distribution patterns between the 1988, 1992, 1997, 2001, 2007 and the present 2013 surveys indicate an overall eelgrass expansion trend between 1988 (949.3 acres) and 1997 (1,306.6 acres). From 1997 to the 2007 survey, eelgrass fell to the lowest area mapped in the 25-year comprehensive survey record (Figure 3). In 2007, eelgrass covered only 856.0 acres (37%) of the bay bottom. This is only 65.5% of the eelgrass coverage mapped in 2001. During the present 2013 survey, eelgrass rebounded by 123 acres from the 2007 low (Figure 2).

At the present time, eelgrass occupies approximately 43 percent of the Bay, up from the prior 2007 survey period (Table 1). The eelgrass geographic distribution on a macro-scale has not changed significantly from 2007 to 2013; however it should be noted that the most significant declines from 2001 forward have been in the eastern portions of the Bay within De Anza Cove and North Pacific Passage. This is reflected best in the observed eelgrass area decline in Appendix 1 map sheets 1, 4, and 7. Other significant declines that were observed between the 2001 survey and the 2007 survey have substantially recovered. Notably, losses of eelgrass between 2001 and 2007 occurred in the middle and higher density beds of Sail Bay and portions of central Fiesta Bay (Table 1). The 2001 to 2007 losses within these core beds are not as obvious in the summary graph presented as Figure 2. However, by 2013, much of the large losses in the large basin areas had recovered.

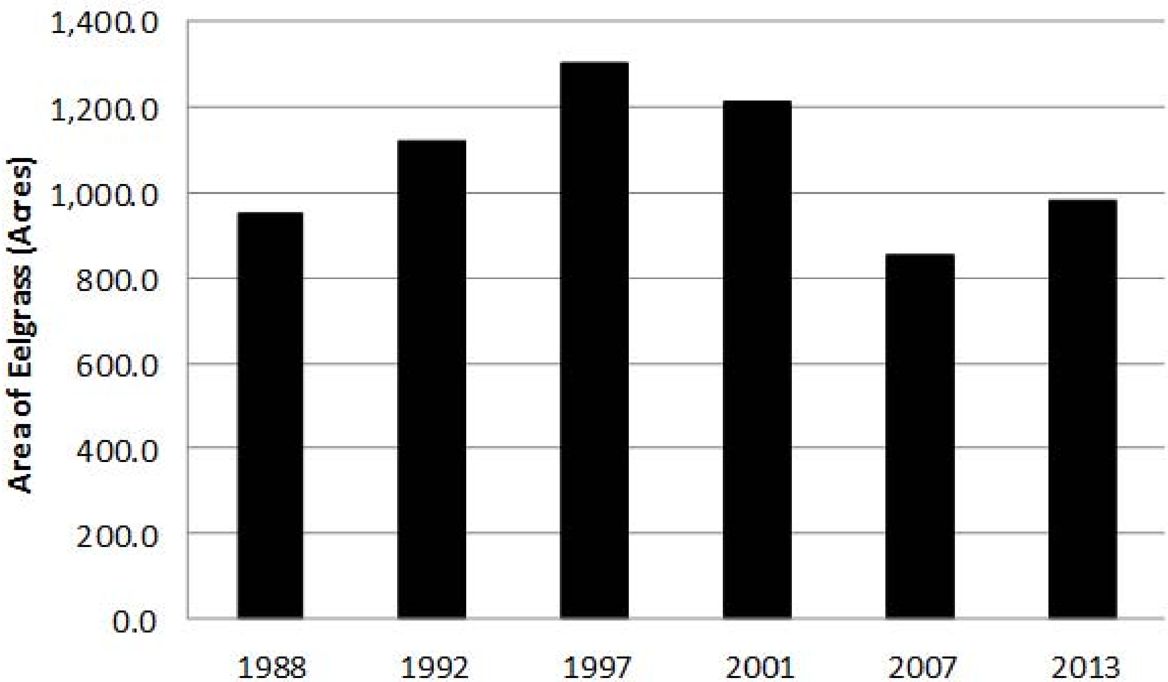

Figure 3. Eelgrass cover changes in between 1988, 1992, 1997, 2002, 2007 and 2013 surveys

Table 1. Eelgrass abundance (acres) for 1988, 1992, 1997, 2001, 2007, and 2013 surveys by survey map sheet

SHEET	TOTAL (ACRES)					
#	1988	1992	1997	2001	2007	2013
1	24.8	25.2	25.4	16.2	4.4	1.4
2	101.5	116.6	118.4	96.9	38.4	104.2
3	69.8	126.5	155.6	146.3	74.9	105.9
4	119.9	124.5	219.6	171.7	64.5	71.0
5	150.0	161.8	159.5	114.7	145.6	146.4
6	228.2	286.4	322.9	301.0	245.0	286.3
7	86.4	102.7	118.2	116.0	23.4	12.1
8	18.2	19.7	17.9	18.9	18.7	20.7
9	101.3	109.6	120.5	139.0	139.4	140.9
10	48.3	47.6	46.7	89.1	100.6	87.8
11	0.9	1.3	2.1	0.6	1.1	2.3
12	0.0	0.0	0.0	0.0	0.0	0.1
TOTAL	**949.3**	**1,121.9**	**1,306.6**	**1,210.4**	**856.0**	**979.1**
% of BAY	**41.3%**	**48.8%**	**56.8%**	**52.6%**	**37.2%**	**42.6%**

Eelgrass as a Means to Monitor Ecosystem Health and Change

In addition to the high intrinsic values of eelgrass as a habitat, it also provides significant value as a tool for examining long-term trends in the eco-system as a result of water quality improvement or deterioration. It has ideal characteristics for use in monitoring system change. Eelgrass is found at the end of the watershed within the coastal bays and estuaries. As a result, overall watershed management effectiveness may be assessed. Eelgrass responds to persistent water quality stresses rather than short duration fluctuations. Eelgrass is adapted to a wide range of tolerances and is capable of "averaging" exposure conditions including temperature, turbidity, seasonal light levels, sedimentation rates, etc., to result in either positive growth or a gradual decline in the resource. As a result, day to day or hour to hour variability such as can be seen with water quality testing is of relatively little consequence to eelgrass. A more biologically meaningful measure of long-term trends in eco-system health can be seen in the response of eelgrass to chronic exposures to the ambient environment. Finally, eelgrass is prolific under suitable environmental conditions and is widely distributed in many coastal bays and estuaries. In effect, eelgrass can be considered a naturally occurring, self-maintaining, pre-deployed, multiple parameter water-quality monitoring instrument -- with ancillary habitat benefits.

The ability for eelgrass to weather short-term stressful environments has been demonstrated on a number of occasions through natural and experimental restriction of resources availability. However, prolonged stresses such as consistent high temperatures or light limitation will result in a decline in eelgrass habitat. Within most sub-tropical and temperate environments, desiccation stresses limit the upper edge of eelgrass growth, and light requirements needed to balance respiration and fuel metabolism (photo-compensation depth) set the lower limits of eelgrass growth in soft bottom embayments. This trend holds true in Mission Bay, and as a result a sharp boundary defines the higher edge of the eelgrass between 0.0 and +1.0 feet MLLW while a less distinct lower boundary is defined by subtle differences in depth and light penetration.

In most of Mission Bay, the bay bottom is relatively flat with the depth ranging from -6 feet MLLW to approximately -12 feet MLLW. A few deeper areas exist within a number of sand borrow pits and marinas, near the mouth of the bay, and beneath bridges where high velocity flows have scoured the bottom. As a result of the relatively featureless bottom topography and a photo compensation depth falling within the narrow depth range defined by the bottom topography, Mission Bay's eelgrass communities are highly sensitive to environmental change of a persistent or frequent nature. For this reason, trends in eelgrass communities within Mission Bay offer an ideal indicator of overall bay health.

Over the past twenty-five years, since the beginning of a concerted effort to monitor change in the eelgrass beds of Mission Bay, periods of significant expansion of the existing beds and periods of eelgrass decline have been observed. The significant increase in eelgrass over the period 1988-1997 suggested an overall improvement of water quality and watershed management practices from the late 1980's through the late 1990's. Earlier records and ancillary observations would suggest this improvement has been occurring since at least the mid-1980's. Prior surveys (Merkel 1988 and 1992) have suggested that this improving trend may have been related to several specific improvements including: 1) fewer or less severe sewage spills that have discharged into Mission Bay; 2) fewer construction projects within the watershed or an increase in effectiveness of construction period best management practices (BMPs); 3) effective storm water interception; or 4) reduced usage or run-off of nitrogen rich fertilizers within the watershed. However, change in eelgrass is not purely a function of watershed inputs and local activities, rather large-scale oceanic influences have been instrumental in structuring coastal eelgrass beds such as those found in Mission Bay.

Between 1997 and 2001, there was an approximately 96-acre decline in eelgrass within Mission Bay. While this decline is reported across a four-year period, there were actually two distinct events that strongly effected Mission Bay eelgrass during the intervening period. Although not comprehensively surveyed during or immediately following the 1997-1998 El Nino Southern Oscillation (ENSO), through spot sampling, eelgrass is known to have substantially declined in relation to the ENSO event. During this period, a rapid decline in eelgrass was observed in all coastal lagoons, bays, and estuaries in southern California. This decline appeared to be unrelated to any activities within the coastal waters or watershed. This decline of the resource was most pronounced at depth and is believed to be related to the rise in sea level during the ENSO and thus a commensurate reduction in light levels on the bay floor. This belief is supported by results of a two-year monitoring program in San Diego Bay that clearly illustrated that during the ENSO canopy light levels declined, while temperatures remained unchanged from those present during non-ENSO years (Merkel & Associates 2000).

In addition to the ENSO event, during the summer months of June through early September 2001 a strong and persistent red-tide dominated along the coast. The red-tide not only blocked light at depth, but also absorbed photosynthetically active radiation (PAR) at the same usable wavelengths and required by eelgrass. As a result, substantial declines in eelgrass were observed in many of the southern California bays and lagoons including Agua Hedionda Lagoon, Batiquitos Lagoon, San Diego Bay, and Mission Bay. These summer declines in eelgrass persisted into October 2001 and could readily account for most, if not all, of the decline observed between the 1997 and 2001 surveys.

During the prior 2007 survey, it was noted that the significant eelgrass decline within Mission Bay from 2001 to 2007 (Figure 3) exhibited characteristics suggestive of a biological agent rather than a physical stressor. This was based on the fact that the principal eelgrass losses were detected in the core eelgrass beds rather than at the upper or lower margins where desiccation and light limitation, respectively, typically restrict eelgrass distribution. Further, losses were greatest within areas that have historically been persistent and which have supported the highest density eelgrass.

Using the bathymetric data collected during the 2007 survey period analyses were completed to evaluate the depth distribution for eelgrass within Mission Bay during 2007. This was completed again in 2013 (Figure 4). These eelgrass depth distributions were compared to the eelgrass depth distribution found in 2001. The data reveal a substantial decline in eelgrass presence within the central portion of the 2001 distribution range occurred in 2007. The decline is so striking as to generate a bimodal depth distribution curve where a unimodal curve would normally be expected. This bimodal distribution curve was further evidence of a third significant controlling factor affecting eelgrass in 2007. This overall depth distribution pattern coupled with the specific spatial patterns of decline strongly suggested a biological control agent was operative, however no direct observational evidence of a pathogen was found at that time. The bimodal depth distribution observed in 2007 continued in 2013 although substantial recovery of eelgrass in the Sail Bay and Fiesta Bay areas has occurred, leaving most of the reduction in eelgrass coverage within the far eastern portions of the Bay, where lower water quality may play a role in reduced recovery rates.

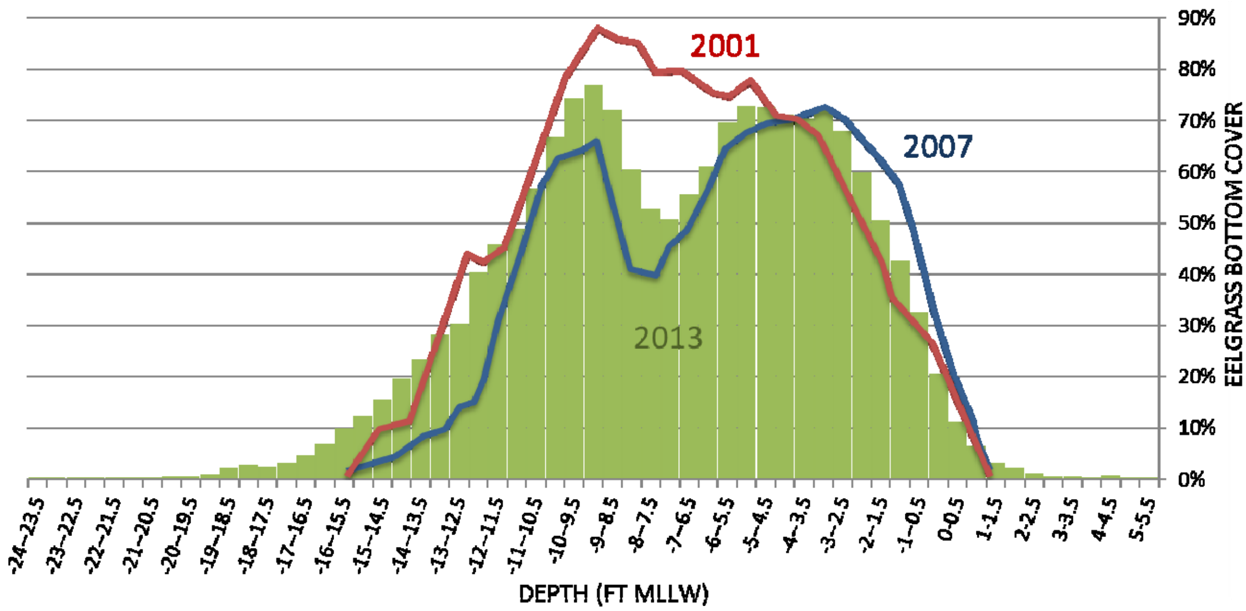

Figure 4. Eelgrass depth distribution as a percentage of available area in half-foot depth bins.

The substantial loss of eelgrass between 2001 and 2007 has been more troubling than changes observed over the prior years. The observed eelgrass decline in the center of the normal distribution range and at the highest densities of eelgrass cover (Figure 4) is suggestive of patterns of disease spread through dense populations, sparing the less dense outliers. Similar anomalous declines in the region's eelgrass beds have been observed in other systems such as San Diego Bay, Agua Hedionda Lagoon, Batiquitos Lagoon, and San Pedro Bay as well.

In 2007, it was premature to conclude with certainty the causative agent in the eelgrass decline was in fact a pathogen, although all evidence pointed in that direction. It was suggested that pattern of decline was consistent with the effects of the contact spread slime mold wasting disease pathogen (*Labyrinthula zosterae*). In 2012, a pathogen was isolated from large die-off areas in San Pedro Bay and Morro Bay. Studies of this pathogen indicated that it spreads by plant-to-plant contact and that it causes tissue rot that severs translocation pathways within the plant tissues resulting in necrosis and ultimate leaf sheading and plant mortality. In 2013, *Labyrinthula* was isolated from floating leaves following a widespread die-off event in Humboldt Bay. While the widespread occurrence of *Labyrinthula* through significant populations of eelgrass on the west Coast has as yet been undocumented, in now appears that many of the systems with major beds of eelgrass have been affected by a pathogen and it appears that the data are converging towards the determination that the same pathogen is affecting beds Statewide.

It has not yet been determined that *L. zosterae* is the pathogen, only that a slime mold of the genus *Labyrinthula* is prevalent in some of the diseased plants. *Labyrinthula* is found naturally at low levels in healthy eelgrass beds and its virulent activity appears to be triggered for reasons that are not fully known. There has been some evidence developed that widespread wasting disease in the eelgrass beds of the North Atlantic during the 1930s was in some manner related to broad scale temperature changes. While no specific information is available relative to disease triggers within California eelgrass, it is likely that broad-scale stressors may have triggered population expansion of the pathogen, changes in pathogen virulence, or weakening of eelgrass making plants more susceptible to infection. More work on the specifics of the disease is needed.

The specific causative agents of eelgrass distribution variability are often times difficult to identify using infrequent comprehensive surveys. Such surveys offer a snapshot view of a habitat that is in a constant state of change that occur both seasonally and interannually. However, the more survey events that are completed the more clear patterns of "normal" distribution become. Figure 5, provides a frequency distribution of eelgrass over six survey seasons (1988, 1992, 1997, 2003, 2007, 2013) spanning the last 25 years. This survey history provides a good view of the distribution of eelgrass during the peak late summer/fall growing season in Mission Bay. Not unexpectedly, the general pattern of eelgrass distribution follows that observed in 2013 relative to the bulk of the eelgrass occurrence. Eelgrass in 2013 displayed a general increase in depth of occurrence from prior years with the most substantial expansion at depth being within the Mission Bay Entrance Channel and near the entrance to Mariner's Basin. While comprising a relatively limited total area, because of the limited area of the Bay that occurs at these deeper depths, eelgrass occupies a surprisingly high proportion of the available habitat in the depth ranges below -14 feet (Figure 4). The 2013 eelgrass distribution map contributes little to an overall expansion of area that has exhibited eelgrass presence for the first time since surveys commenced. However, where such contributions do occur, they are located within the deeper westerly portions of the Bay.

Bathymetry and Erosion/Accretion

Mission Bay is a dynamic low-influx sedimentary environment that is primarily dominated by the effects of tides, wave action, and littoral drift of beach sediments. Principal sediment inputs to the bay include: 1) coastal littoral sand entrainment by flood tides at the Mission Bay Entrance Channel; 2) fluvial sediment inputs from Rose and Tecolote creeks as well as the San Diego River, and; 3) bay beach erosion and littoral transport. Minor sediment inputs are derived from urban storm drains and atmospheric particulate settlement. Sediment outflux from the bay includes sediment flows out the channel to the open coast as well as dredging and shoal reclamation activities. As is typical for most water bodies, deposition and erosion is a function of sediment supply, sediment type, and system energy. Coarse sediment is deposited in higher energy environments than fine sediments and fine sediments often remain in suspension or can be resuspended in higher energy environments prior to settling out in more quiescent areas.

The 2013 bathymetry of Mission Bay is illustrated in the individual map sheets that follow as Appendix 1. An analysis was performed to compare proportional bay depth distribution between the prior 1997 and 2007 surveys and the present 2013 bathymetric mapping Figure 6. Overall, this analysis indicated various minor shifts in bay depths over the past sixteen years. When reviewed in more specific detail, the changes are principally driven by a handful of locations where moderate to major sedimentation has been ongoing. The most visible regions of deposition include Quivira Basin, near the outlets of Rose Creek and Tecolote Creek. Areas of less substantive accretion are noted within the farthest reaches of the bay in both the North and South Pacific Passages, in and around Leisure Lagoon, on the southwest corner of Vacation Island, and between the entrance of Santa Barbara Cove and the northwest corner of Vacation Island.

Figure 5. Frequency distribution of eelgrass over multiple comprehensive surveys (1988, 1992, 1997, 2003, 2007, 2013).

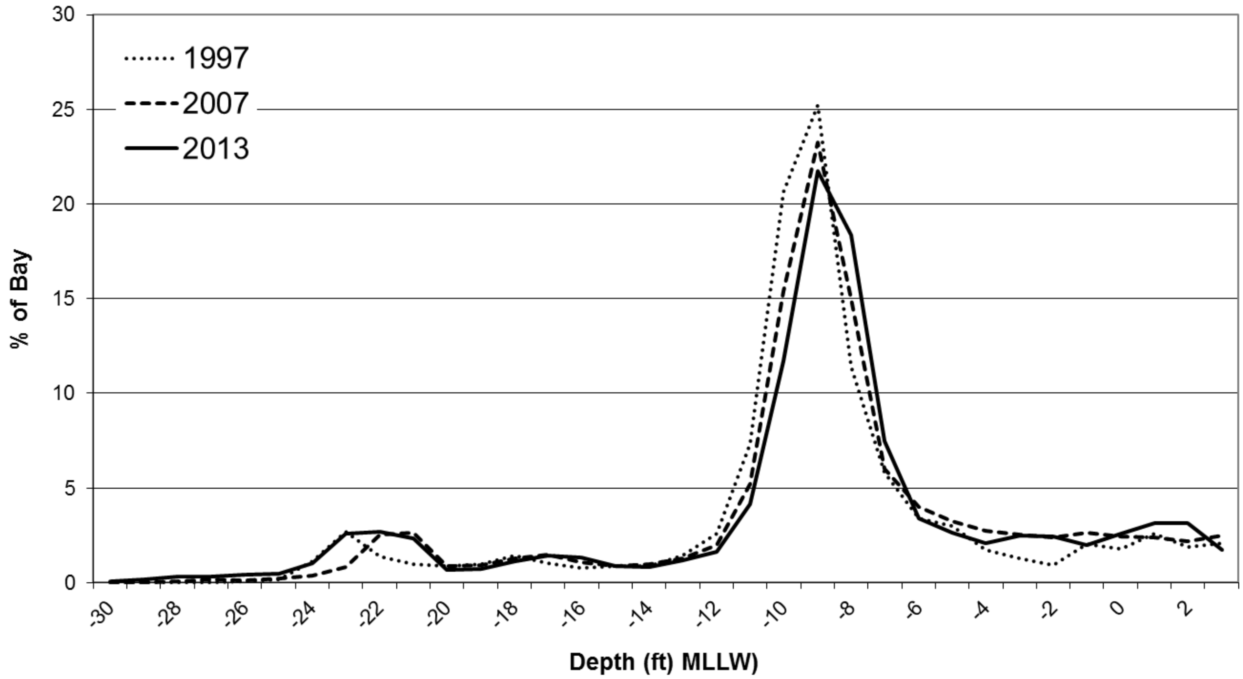

Figure 6. Change in Mission Bay depth distribution as a percentage of the total bay.

The bathymetric analysis reveals far less erosion that appears to be confined to small segments of the Mission Bay channel south of Vacation Island, north of Vacation Island in the Fisherman's Channel between Sail Bay and Fiesta Bay, and immediately inside the entrance of Santa Barbara Cove. There are some notable increases in the percent of bay area at depths in the -20+ to -24 foot MLLW range and a parallel reduction in the extent of bay area in shallower areas. This deepening is the result of federal channel and basin maintenance dredging conducted by the Army Corps of Engineers between the 2007 and 2013 surveys.

The comparison of bathymetric conditions over the sixteen years (1997-2013) reveals little large scale change in the bathymetry of Mission Bay and no surprising areas of sediment accumulation given the bay hydrodynamics and sediment sources. Areas where more substantive changes in bathymetry have occurred include the deeper basins and areas near fluvial inputs. Throughout Quivira Basin there has been 1-2 ft. of deposition from 1997 to 2007 depending upon the area of the basin. In the North and South Pacific Passages, limited water flow and sediment input from Tecolote Creek (North Passage only) has resulted in deposition on the order of 0.5-1.5 ft. over the decade between 1997 and 2007 and relatively little additional change through 2013. Shoaling in the main channel has increased between 2007 and 2013, some of this change likely stems from the channel dredging by the Corps that would have both enhanced water movement in the channel and loosened sands, creating greater capacity for secondary mobility of the material into areas near southwest Vacation Island and along both the southerly and westerly sides of Vacation Island.

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APPENDIX 1. 2013 MISSION BAY PARK EELGRASS INVENTORY AND BATHYMETRIC CHART

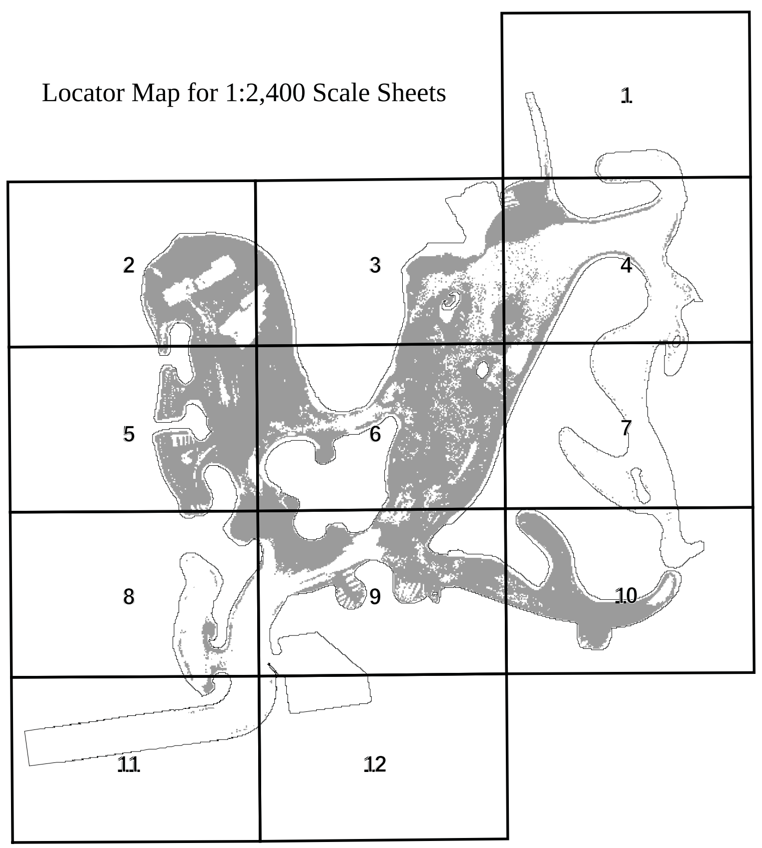
2013
MISSION BAY PARK EELGRASS INVENTORY BATHYMETRIC CHART

SAN DIEGO, CALIFORNIA

Eelgrass *(Zostera marina)*

SHEET LEGEND	SHEET NO.
Title Sheet	1
Composite Bay Map	2
Eelgrass and Bathymetry 2013 -	1
Eelgrass and Bathymetry 2013 -	2
Eelgrass and Bathymetry 2013 -	3
Eelgrass and Bathymetry 2013 -	4
Eelgrass and Bathymetry 2013 -	5
Eelgrass and Bathymetry 2013 -	6
Eelgrass and Bathymetry 2013 -	7
Eelgrass and Bathymetry 2013 -	8
Eelgrass and Bathymetry 2013 -	9
Eelgrass and Bathymetry 2013 -	10
Eelgrass and Bathymetry 2013 -	11
Eelgrass and Bathymetry 2013 -	12

Locator Map for 1:2,400 Scale Sheets



PREPARED FOR:

CITY OF SAN DIEGO
PUBLIC WORKS, E&CP, AEP DIVISION
525 B STREET, SUITE 750
SAN DIEGO, CA 92101
ATTN: JOSEPH DIAB

PREPARED BY:

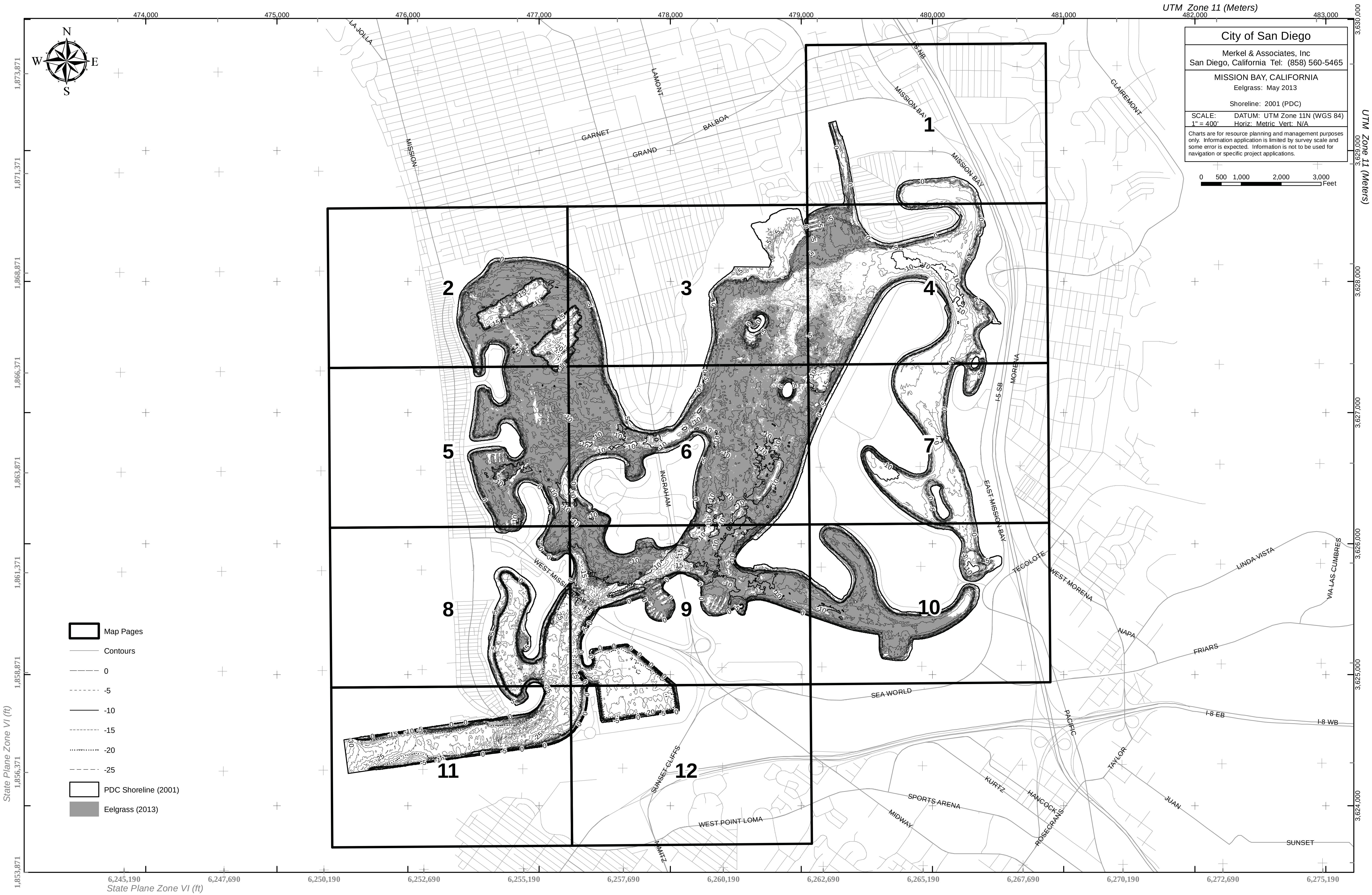
MERKEL & ASSOCIATES, INC.
5434 RUFFIN ROAD
SAN DIEGO, CA 92123
TEL: (858) 560-5465

KEITH W. MERKEL, PROJECT MANAGER

Bathymetry was collected in 2013 and is presented in feet Mean Lower Low Water (MLLW). Eelgrass mapping is based on interferometric sidescan surveys, groundtruthing and subsequent spot-checking within areas of apparent aberrations.

Eelgrass survey data are accurate to within +/- 6 feet (a composite of the navigational system error and sidescan error). Eelgrass data reflects a particular period in time and are anticipated to be seasonally and stochastically dynamic.

Bathymetric charts and eelgrass maps are for planning purposes only and are not to be used for navigation or project specific purposes. The authors make no representation regarding the accuracy of these maps relative to submerged structures, debris, shoals, or other navigational hazards.



UTM Zone 11 (Meters)
City of San Diego
Merkel & Associates, Inc
San Diego, California Tel: (858) 560-5465
MISSION BAY, CALIFORNIA
Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: N/A
Charts are for resource planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.
0 500 1,000 2,000 3,000 Feet
Map Pages
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)
State Plane Zone VI (ft)
1
2
3
4
5
6
7
8
9
10
11
12
LA JOLLA
MISSION
GARNET
GRAND
BALBOA
LAMONT
MISSION BAY
CLAIREMONT
I-5 NB
I-5 SB
MORENA
INGRAHAM
EAST MISSION BAY
WEST MISSION
TECOLOTE
WEST MORENA
LINDA VISTA
VIA LAS CUMBRES
NAPA
FRIARS
SEA WORLD
I-8 EB
I-8 WB
PACIFIC
TAYLOR
JUAN
KURTZ
HANCOCK
ROSECRANS
SPORTS ARENA
MIDWAY
SUNSET
SUNSET CLIFFS
WEST POINT LOMA
NIMITZ


City of San Diego
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Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
Charts are for resource planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.
0 100 200 400 600 Feet
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
479,000
479,250
479,500
479,750
480,000
480,250
480,500
480,750
3,629,750
3,629,500
3,629,250
3,629,000
3,628,750
1,874,412
1,874,012
1,873,612
1,873,212
1,872,812
1,872,412
1,872,012
1,871,612
1,871,212
1,870,812
1,870,412
6,262,596
6,262,996
6,263,396
6,263,796
6,264,196
6,264,596
6,264,996
6,265,396
6,265,796
6,266,196
6,266,596
6,266,996
6,267,396
6,267,796
6,268,196
N
S
E
W
1
GARNET AV
PICO ST
FIGUEROA BL
MAGNOLIA AV
HORNBLEND ST
GRAND AV
FOGG ST
BOND ST
LEE ST
LEE AV
PRIVATE RD
BUNKER HILL ST
REVERE AV
GLENDORA ST
MISSION BAY DR
DEL REY ST
ROSEWOOD ST
I-5 NB OFF RA
BRANDYWINE ST
PAUL JONES AV
ETHAN ALLEN AV
PRINCETON AV
MOULTRIE AV
TRENTON AV
TICONDEROGA ST
SIOUX AV
VIA BELTRAN
SUMTER ST
ZOE ST
BORRESON ST
BAKER ST
I-5 SB
MORENA BL
LLOYD PL
LLOYD ST
BALTIMORE ST
MACTIBBY ST
CRETE ST
CHICAGO ST
AERONCA AV
DONLEY ST
PIPER ST
LLOYD TR
MC GRAW ST
I-5 NB
I-5 SB ON RA
NORTH MISSION BAY DR
DE ANZA RD
DE ANZA BAY DR
NORTHWEST
FUCHSIA DR
ELYSIUM DR
DAFFODIL DR
CAMELIA DR
BEGONIA DR
ASTER DR
GARDENIA DR
HIBISCUS DR
MARINE WY
IRIS DR
JASMINE DR
KERRIA DR
LILAC DR
CIRCLE DR
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)


City of San Diego
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Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
Charts are for resource planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.
0 100 200 400 600 Feet
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
2
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)
GRAND AV
THOMAS AV
REED AV
OLIVER AV
PACIFIC BEACH DR
PARKER PL
LA PALMA ST
OCEAN BL
MISSION BL
OLIVER CT
UNNAMED AL
STRANDWAY
BAYARD ST
CASS ST
DAWES ST
EVERTS ST
EAST BRIARFIELD DR
WEST BRIARFIELD DR
PRIVATE RD
BRAEMAR LN
WAVECREST CT
SANTA RITA PL
ZANZIBAR CT
YORK CT
YARMOUTH CT
WINDEMERE CT
WHITING CT
VERONA CT
VENICE CT
SAN RAFAEL PL
VANITIE CT
TOULON CT
TANGIERS CT
SUNSET CT
SEAGIRT CT
SALEM CT
SAN JOSE PL
ROCKAWAY CT
REDONDO CT
QUEENSTOWN CT
OCEAN FRONT WK
BAYSIDE WK
BAYSIDE LN
SANTA CLARA PL
475,500
475,750
476,000
476,250
476,500
476,750
477,000
477,250
3,628,500
3,628,250
3,628,000
3,627,750
3,627,500
1,870,412
1,870,012
1,869,612
1,869,212
1,868,812
1,868,412
1,868,012
1,867,612
1,867,212
1,866,812
1,866,412
6,250,596
6,250,996
6,251,396
6,251,796
6,252,196
6,252,596
6,252,996
6,253,396
6,253,796
6,254,196
6,254,596
6,254,996
6,255,396
6,255,796
6,256,196


City of San Diego
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MISSION BAY, CALIFORNIA
Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
Charts are for resource planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.
0 100 200 400 600 Feet
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)
3
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
477,250
477,500
477,750
478,000
478,250
478,500
478,750
479,000
3,628,500
3,628,250
3,628,000
3,627,750
3,627,500
1,870,412
1,870,012
1,869,612
1,869,212
1,868,812
1,868,412
1,868,012
1,867,612
1,867,212
1,866,812
1,866,412
6,256,596
6,256,996
6,257,396
6,257,796
6,258,196
6,258,596
6,258,996
6,259,396
6,259,796
6,260,196
6,260,596
6,260,996
6,261,396
6,261,796
6,262,196
OLIVER AV
PACIFIC BEACH DR
CHICO ST
FORTUNA AV
LA PALMA ST
ROOSEVELT AV
GRAHAM ST
LA PLAYA AV
MOORLAND DR
LA MANCHA DR
PRIVATE RD
GRESHAM ST
HAINES ST
RIVIERA DR
INGRAHAM ST
PROMONTORY ST
BUENA VISTA ST
BAYONNE DR
YOSEMITE ST
JEWELL ST
SHASTA ST
KENDALL ST
SEQUOIA ST
LAMONT ST
HONEYCUTT ST
MORRELL ST
CROWN POINT DR
CORONA ORIENTE RD
OLNEY ST


UTM Zone 11 (Meters)
City of San Diego
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Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
Charts are for resource planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.
0 100 200 400 600 Feet
N
S
E
W
4
PRIVATE RD
DE ANZA BAY DR
ROSE CREEK SHORE DR
MARIGOLD DR
NARCISSUS DR
PRIVATE RD
ROSE DR
TULIP DR
NORTH MISSION BAY DR
MC GRAW ST
GESNER ST
I-5 SB ON RA
I-5 NB ON RA
I-5 SB OFF RA
CLAIREMONT DR
I-5 NB OFF RA
INGULF ST
I-5 RA
JELLETT ST
KANE ST
DENVER ST
MORENA BL
EAST MISSION BAY DR
I-5 SB ON RA
I-5 SB
I-5 NB
FIESTA ISLAND RD
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)
State Plane Zone VI (ft)
479,000
479,250
479,500
479,750
480,000
480,250
480,500
480,750
3,628,500
3,628,250
3,628,000
3,627,750
3,627,500
1,870,412
1,870,012
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1,869,212
1,868,812
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1,867,212
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6,263,796
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6,264,596
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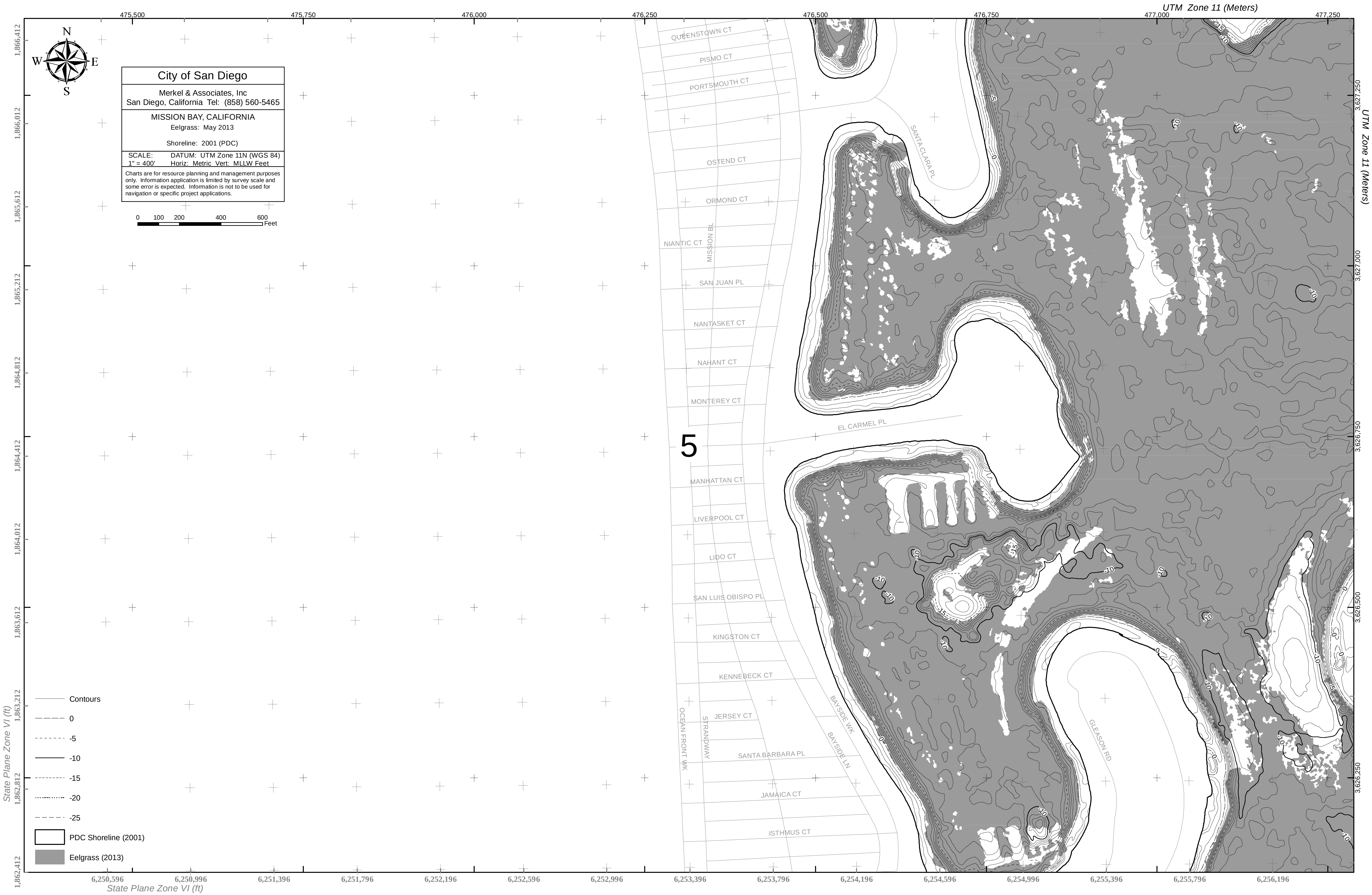
6,267,796
6,268,196


City of San Diego
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MISSION BAY, CALIFORNIA
Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
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Horiz: Metric Vert: MLLW Feet
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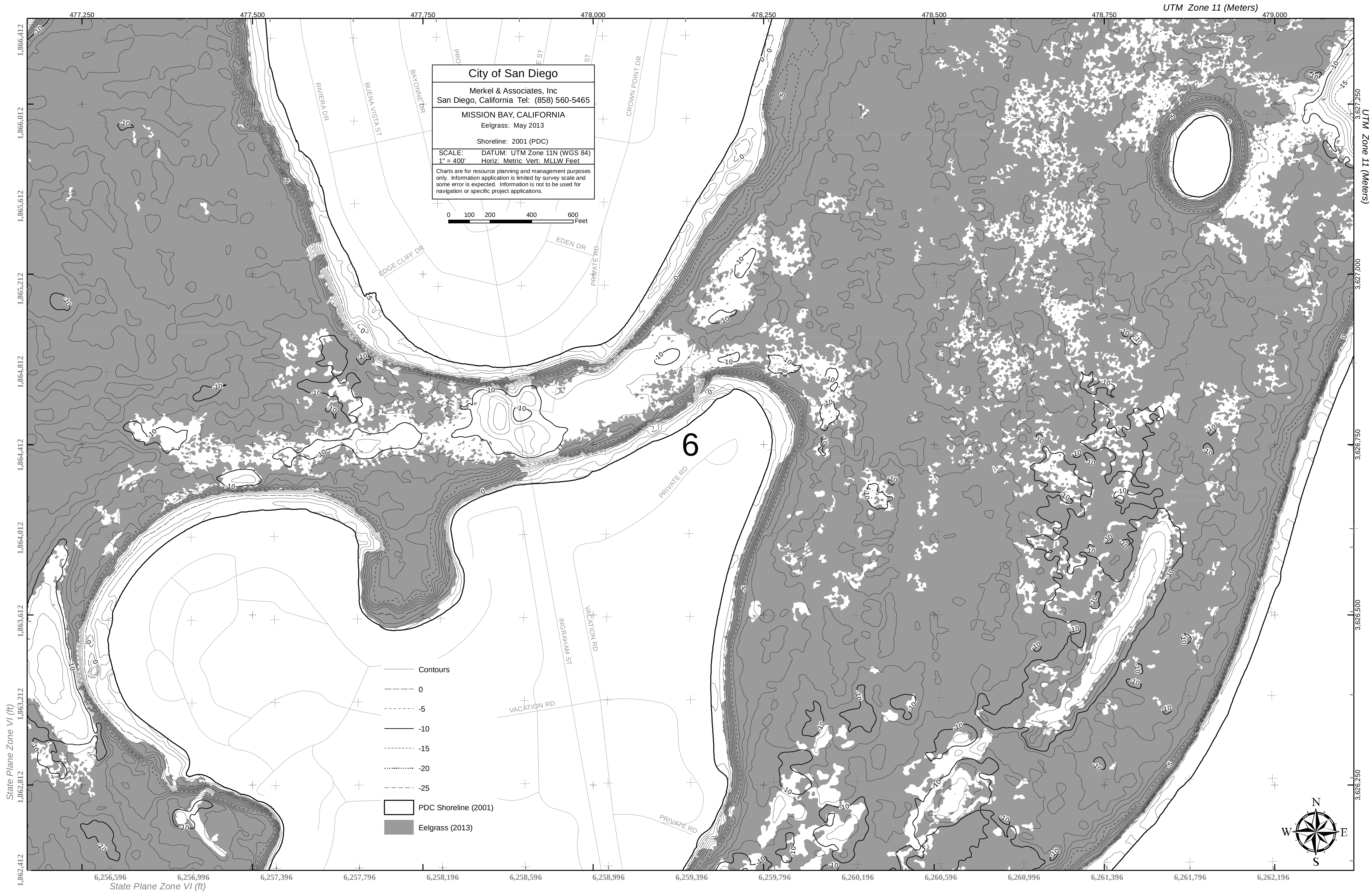
0 100 200 400 600 Feet
N
S
E
W
UTM Zone 11 (Meters)
475,500
475,750
476,000
476,250
476,500
476,750
477,000
477,250
3,627,250
3,627,000
3,626,750
3,626,500
3,626,250
State Plane Zone VI (ft)
1,866,412
1,866,012
1,865,612
1,865,212
1,864,812
1,864,412
1,864,012
1,863,612
1,863,212
1,862,812
1,862,412
6,250,596
6,250,996
6,251,396
6,251,796
6,252,196
6,252,596
6,252,996
6,253,396
6,253,796
6,254,196
6,254,596
6,254,996
6,255,396
6,255,796
6,256,196
5
QUEENSTOWN CT
PISMO CT
PORTSMOUTH CT
OSTEND CT
ORMOND CT
NIANTIC CT
MISSION BL
SAN JUAN PL
NANTASKET CT
NAHANT CT
MONTEREY CT
EL CARMEL PL
SANTA CLARA PL
MANHATTAN CT
LIVERPOOL CT
LIDO CT
SAN LUIS OBISPO PL
KINGSTON CT
KENNEBECK CT
JERSEY CT
SANTA BARBARA PL
JAMAICA CT
ISTHMUS CT
OCEAN FRONT WK
STRANDWAY
BAYSIDE WK
BAYSIDE LN
GLEASON RD
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)


City of San Diego
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MISSION BAY, CALIFORNIA
Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
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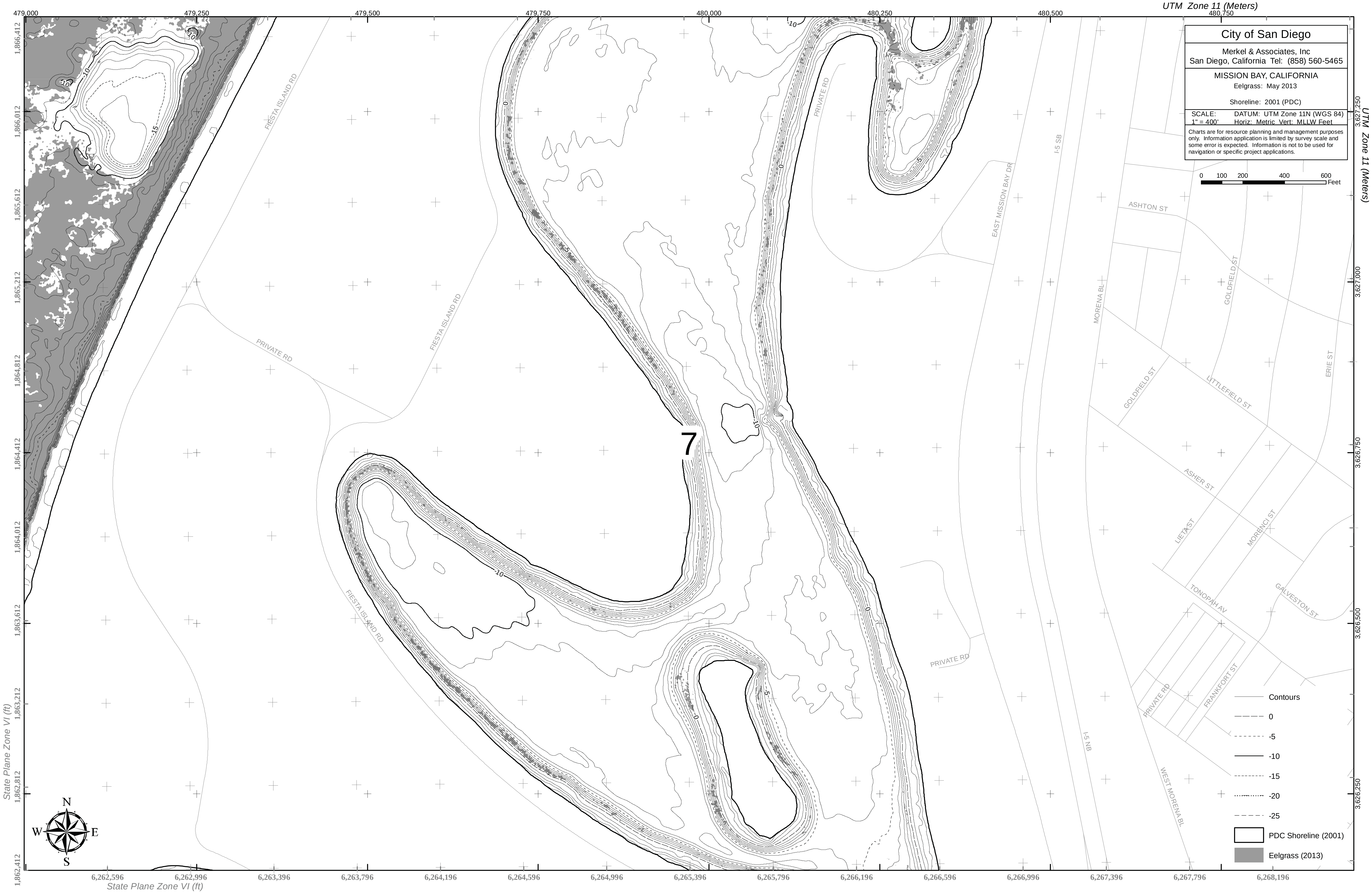
0 100 200 400 600 Feet
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)
6
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
RIVIERA DR
BUENA VISTA ST
BAYONNE DR
CROWN POINT DR
EDGE CLIFF DR
EDEN DR
PRIVATE RD
INGRAHAM ST
VACATION RD
N
S
E
W



UTM Zone 11 (Meters)
479,000
479,250
479,500
479,750
480,000
480,250
480,500
480,750
City of San Diego
Merkel & Associates, Inc
San Diego, California Tel: (858) 560-5465
MISSION BAY, CALIFORNIA
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Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
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0 100 200 400 600 Feet
UTM Zone 11 (Meters)
3,627,250
3,627,000
3,626,750
3,626,500
3,626,250
1,866,412
1,866,012
1,865,612
1,865,212
1,864,812
1,864,412
1,864,012
1,863,612
1,863,212
1,862,812
1,862,412
State Plane Zone VI (ft)
6,262,596
6,262,996
6,263,396
6,263,796
6,264,196
6,264,596
6,264,996
6,265,396
6,265,796
6,266,196
6,266,596
6,266,996
6,267,396
6,267,796
6,268,196
State Plane Zone VI (ft)
FIESTA ISLAND RD
PRIVATE RD
EAST MISSION BAY DR
I-5 SB
I-5 NB
ASHTON ST
MORENA BL
GOLDFIELD ST
ERIE ST
LITTLEFIELD ST
ASHER ST
LIETA ST
MORENCI ST
TONOPAH AV
GALVESTON ST
FRANKFORT ST
WEST MORENA BL
7
N
W
E
S
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)

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DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
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0 100 200 400 600 Feet
N
S
E
W
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
475,500
475,750
476,000
476,250
476,500
476,750
477,000
477,250
6,250,596
6,250,996
6,251,396
6,251,796
6,252,196
6,252,596
6,252,996
6,253,396
6,253,796
6,254,196
6,254,596
6,254,996
6,255,396
6,255,796
6,256,196
1,862,412
1,862,012
1,861,612
1,861,212
1,860,812
1,860,412
1,860,012
1,859,612
1,859,212
1,858,812
1,858,412
3,626,000
3,625,750
3,625,500
3,625,250
3,625,000
8
ISLAND CT
STRANDWAY
MISSION BAY
BAYSIDE LN
VENTURA PL
GLEASON RD
PRIVATE RD
MISSION BL
PRIVATE RD
MARINERS WY
WEST MISSION BAY DR
SAN FERNANDO PL
ENSENADA CT
DOVER CT
DEVON CT
OCEAN FRONT WK
BAYSIDE WK
SAN GABRIEL PL
DEAL CT
CORONADO CT
COHASSET CT
CAPISTRANO PL
BRIGHTON CT
BALBOA CT
AVALON CT
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)


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0 100 200 400 600 Feet
N
S
E
W
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
477,250
477,500
477,750
478,000
478,250
478,500
478,750
479,000
3,625,750
3,625,500
3,625,250
3,625,000
1,862,412
1,862,012
1,861,612
1,861,212
1,860,812
1,860,412
1,860,012
1,859,612
1,859,212
1,858,812
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6,256,596
6,256,996
6,257,396
6,257,796
6,258,196
6,258,596
6,258,996
6,259,396
6,259,796
6,260,196
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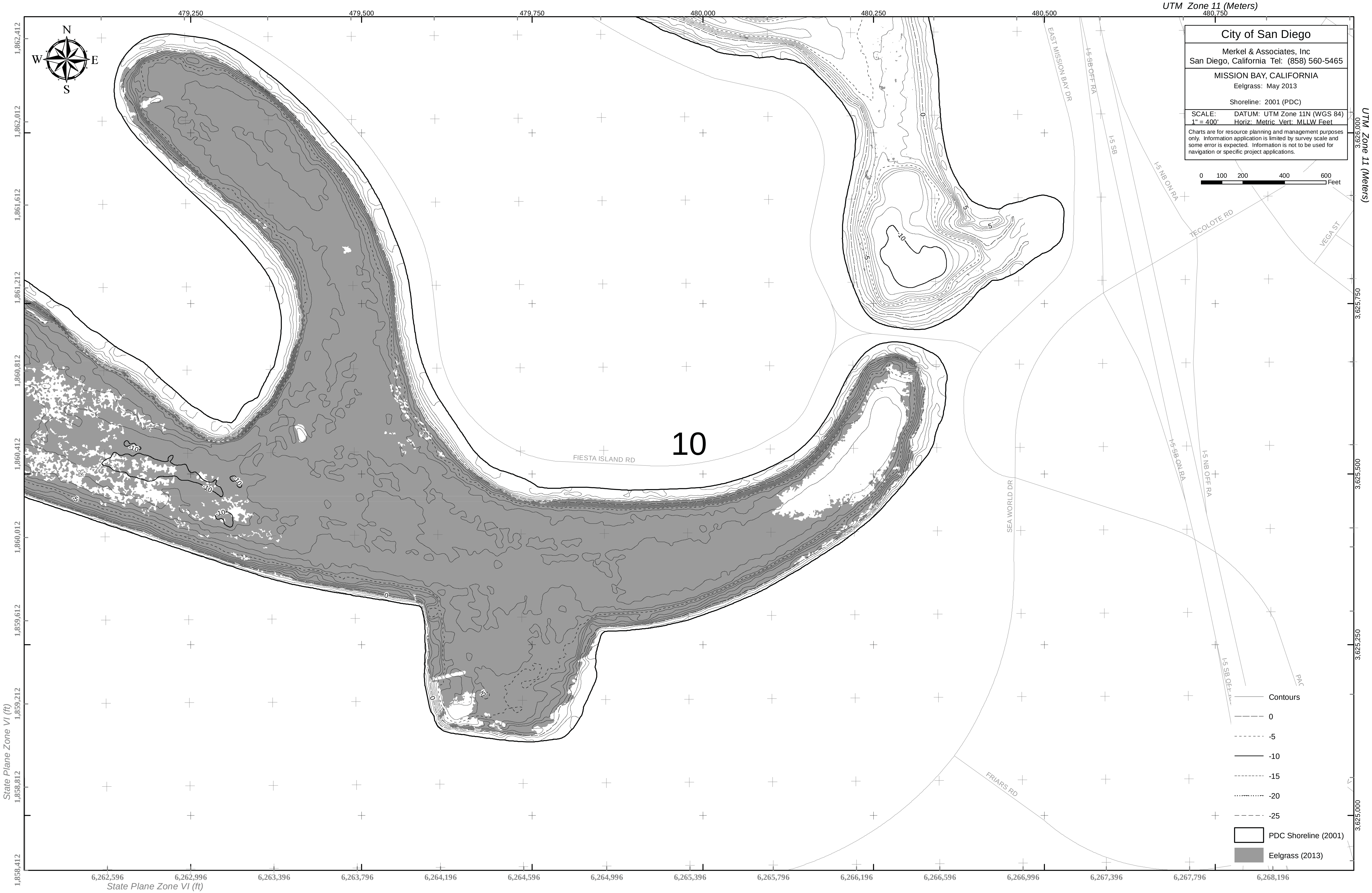
6,260,996
6,261,396
6,261,796
6,262,196
9
PRIVATE RD
INGRAHAM ST
DANA LANDING RD
QUIVIRA ACCESS
WEST MISSION BAY DR
W MISSION BAY DR RA
QUIVIRA RD
INGRAHAM ST RA
SOUTH SHORES RD
SUNSET CLIFFS BL RA
PRIVATE DY
PEREZ COVE WY
SEA WORLD DR
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)


City of San Diego
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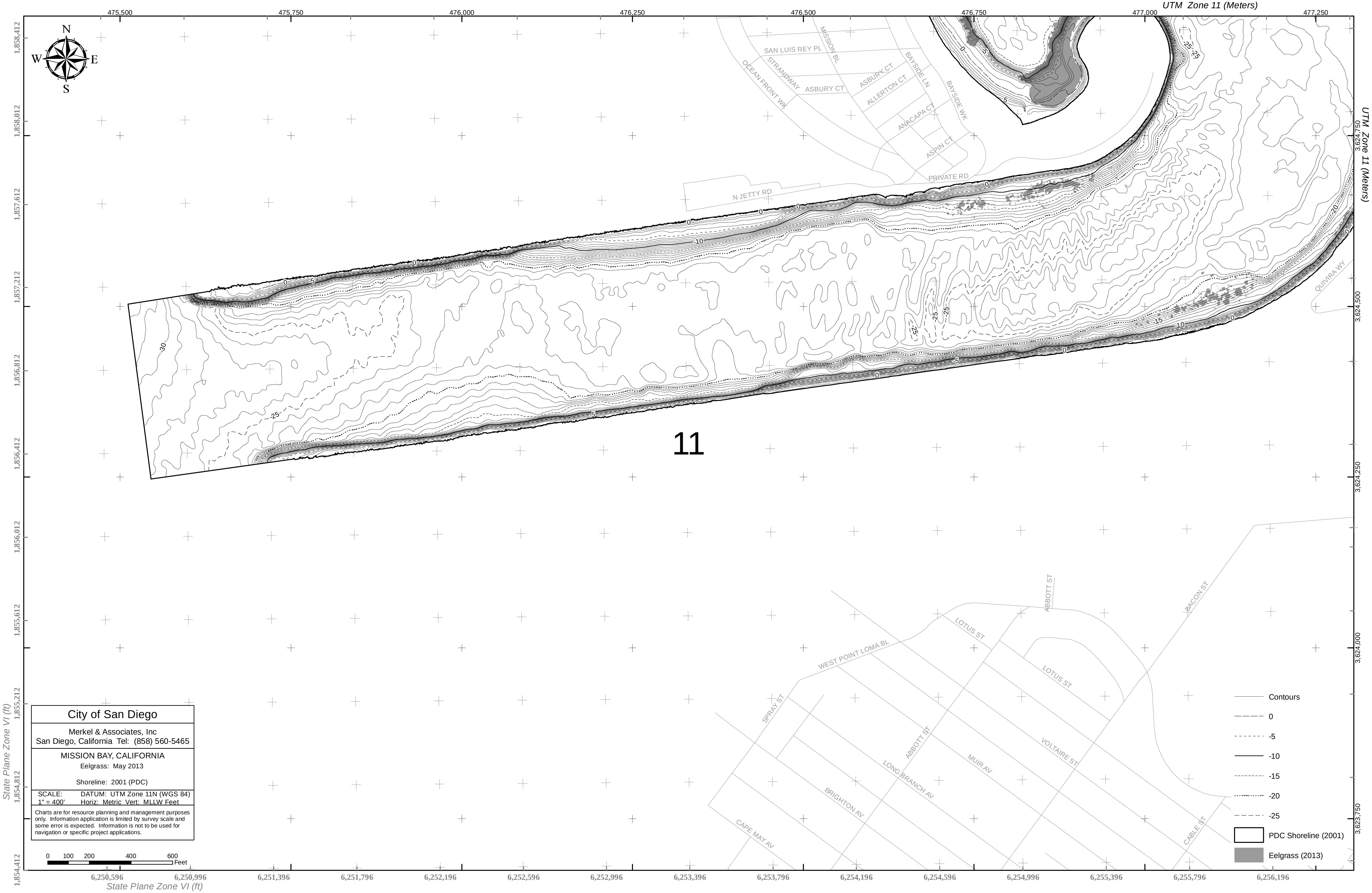
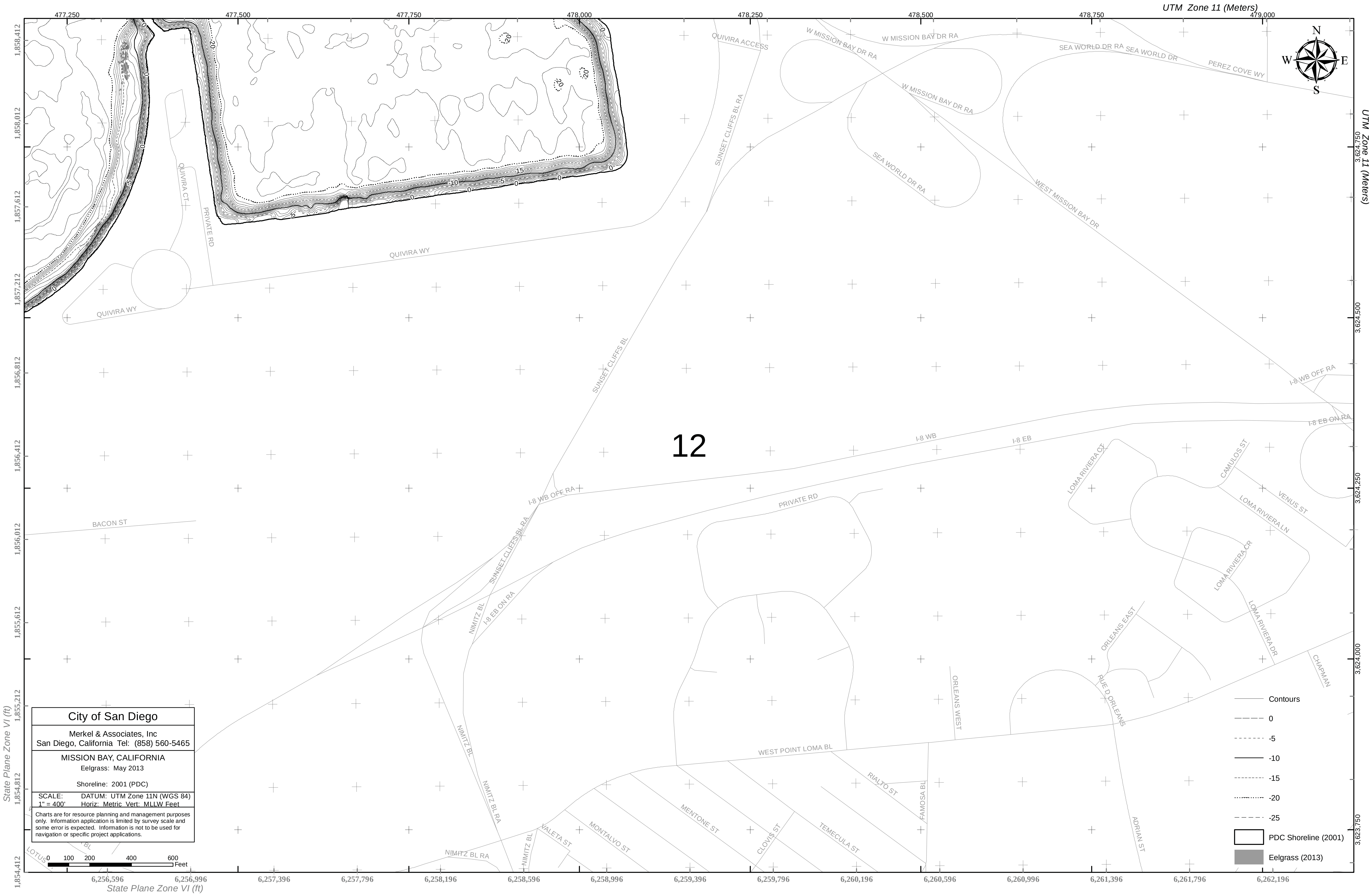
MISSION BAY, CALIFORNIA
Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
Charts are for resource planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.
0 100 200 400 600 Feet
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
N
S
E
W
10
FIESTA ISLAND RD
EAST MISSION BAY DR
I-5 SB OFF RA
I-5 SB
I-5 NB ON RA
TECOLOTE RD
VEGA ST
SEA WORLD DR
I-5 SB ON RA
I-5 NB OFF RA
FRIARS RD
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)



State Plane Zone VI (ft)


City of San Diego
Merkel & Associates, Inc
San Diego, California Tel: (858) 560-5465
MISSION BAY, CALIFORNIA
Eelgrass: May 2013
Shoreline: 2001 (PDC)
SCALE: 1" = 400'
DATUM: UTM Zone 11N (WGS 84)
Horiz: Metric Vert: MLLW Feet
Charts are for resource planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.
0 100 200 400 600 Feet
Contours
0
-5
-10
-15
-20
-25
PDC Shoreline (2001)
Eelgrass (2013)
12
UTM Zone 11 (Meters)
State Plane Zone VI (ft)
N
S
E
W
QUIVIRA ACCESS
W MISSION BAY DR RA
SEA WORLD DR RA
SEA WORLD DR
PEREZ COVE WY
SUNSET CLIFFS BL RA
SUNSET CLIFFS BL
WEST MISSION BAY DR
QUIVIRA CT
PRIVATE RD
QUIVIRA WY
I-8 WB OFF RA
I-8 EB ON RA
I-8 WB
I-8 EB
BACON ST
NIMITZ BL
NIMITZ BL RA
LOMA RIVIERA CT
CAMULOS ST
VENUS ST
LOMA RIVIERA LN
LOMA RIVIERA CR
LOMA RIVIERA DR
ORLEANS EAST
ORLEANS WEST
RUE D ORLEANS
CHAPMAN
WEST POINT LOMA BL
RIALTO ST
FAMOSA BL
MENTONE ST
TEMECULA ST
CLOVIS ST
MONTALVO ST
VALETA ST
ADRIAN ST
LOTUS