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ORMOND BEACH WETLAND RESTORATION FEASIBILITY PLAN: HYDROLOGIC AND GEOMORPHIC CONDITIONS REPORT

Prepared for

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1. INTRODUCTION

The California State Coastal Conservancy (SCC), in cooperation with other state, federal and local agencies, is in the process of developing a comprehensive plan to enhance, restore and manage the natural resources of the greater Ormond Beach area. Although many of the ecologic values of the site have degraded due to human-induced changes to the landscape, the existing coastal wetlands are a significant resource for several wildlife and plant species. As part of the larger Ormond Beach Wetland Restoration Feasibility Plan, this report summarizes the hydrologic and geomorphic conditions within the planning area that will be useful to identifying restoration opportunities and constraints based on physical processes.

Ormond Beach is located on the south central coast of California, 60 miles north of Los Angeles and 50 miles south of Santa Barbara (Figure 1). Historically, the area supported a complex ecosystem that extended along the coastal edge of the Oxnard Plain between Point Hueneme and Point Mugu. Substantial modifications to the landscape and physical processes that maintained the natural habitats coincided with agricultural and industrial development during the 20th century. Currently, the project area includes approximately 1,500 acres of coastal lagoon, beach and dune, seasonal wetland, agricultural fields and industrial land (Figure 2).

The following sections describe the physical processes that affect the study area and shape the coastal habitats. Section 2 contains a list of conclusions based on our understanding of the physical setting, which is described more fully in subsequent sections. Historical conditions and the changes to the landscape are summarized in Sections 3 and 4, respectively. Section 5 includes a discussion of the existing geomorphic and hydrologic conditions. Likely future changes to these processes and the role of infrequent extreme events are described in Section 6.

2. CONCLUSIONS

The active physical processes that control the site hydrology and shape the landscape affect the feasibility of creating, restoring and maintaining coastal habitats at Ormond Beach. We have developed the conclusions listed below from our review of readily available data, hydrologic and geomorphic principles and our understanding of site conditions.

- The natural coastal habitats at Ormond Beach have been altered by several land use changes and modifications of the hydrologic and geomorphic processes. Historically, this project area was part of a wetland complex that extended from Point Hueneme through Mugu Lagoon and was supported by muted tidal exchange with Mugu Lagoon, high groundwater elevations, and freshwater discharges from the Oxnard Plain. Historic Lagoons were probably connected to the ocean for brief periods of time when the beach berm was breached. These habitats have been directly affected by development of agricultural fields, updrift ports and heavy industry facilities; construction of drainage channels that have diverted freshwater flows and sediment sources away from the wetlands have indirectly affected the historic habitats.

- The size of beach and dune habitat within the project site is dependent upon continued mechanical sand bypassing at the Channel Islands and Port Hueneme Harbors, which delivers about 850,000 yd^3 per year on average. These operations mitigate the effects of jetties at the ports, which have diverted the littoral stream offshore into deeper water and increased offshore losses.

- Ground elevations over the majority of project site are substantially above mean higher high water. Only about 130 acres of the duck ponds and less than 50 acres of the other parcels lie within the reach of the tides. Consequently, creation of large portions of tidal marsh habitat will require a substantial amount of excavation.

- Based on observations at other coastal systems, we estimate that on the order of 1,500 acre-feet of tidal prism will be required to maintain a continually open inlet at Ormond Beach. Smaller wetland sizes are likely to experience intermittent closures. A tidal prism of about 200 acre-feet would probably be sufficient to produce seasonally open tidal inlets, similar to the coastal lagoons that occurred historically at Ormond Beach. Connectivity between the coastal wetlands and ocean could potentially be maintained by construction of coastal structures (e.g., groins) or intervention (i.e., mechanical breaching). Climatic variability, uncertainties regarding the actual rate of littoral drift, and the complexities of sediment dynamics prevent a precise evaluation of inlet closure potential.

- The climate in the study area is semi-arid, with less than 20 inches of rain on average each year and approximately 60 inches per year of evaporation. Therefore, substantial seasonal fluctuations in water levels are expected unless wetlands have a steady supply of groundwater, regular tidal inundation, or receive diversions from agricultural, industrial and residential discharges. For example, based on a net evaporation rate of 40 inches/yr, approximately 5,000 acre-feet of water would be required each year to maintain a constant water level across a 1,500-acre wetland. About 1,200 acre-feet would be required for a 350-acre wetland.

- An impermeable clay bed approximately 30 feet below the surface maintains a semi-perched watertable, the surface of which varies from a few feet of the ground elevations during winter months to up to ten feet below the ground surface during late summer and fall. In some areas, the water in this semi-perched zone creates ephemeral pools after large rainfall events. This semi-perched groundwater could potentially be used to maintain brackish or freshwater wetlands, although the quality of this water needs to be assessed.

3. HISTORICAL GEOMORPHIC CONDITIONS

3.1 PHYSICAL LANDSCAPE

Ormond Beach lies along the coastal edge of the Oxnard Plain, an extensive low-lying alluvial fan between the Santa Ynez and Santa Monica Mountains built by ancient sediments deposited from the Santa Clara River. Formations of this and other watershed basins along the east-west trending Transverse Ranges of southern California predominately consist of geologically young and easily eroded sediments. This region is known for its high sediment yields, which Inman and Jenkins (1999) attribute to the lithology and complexity of the regional tectonics. Freshwater drainages along the Oxnard Plain include the Ventura and Santa Clara Rivers to the northwest, Calleguas Creek to the southeast and minor discharges in between.

The stretch of coast along the project area is located at the southeastern end of the Santa Barbara Littoral Cell, which extends from Point Conception on the west to Point Mugu on the southeast (Figure 3). The western section of the cell generally consists of narrow and thin sand beaches backed by vertical bluffs. The section southeast of the Ventura and Santa Clara Rivers contains wider sand beaches and is backed by the Oxnard Plain. These differences in beach width reflect the general direction of longshore transport (to the southeast) and the location of dominant source fluvial sediment (the Santa Clara River). Two submarine canyons, the Hueneme and Mugu Submarine Canyons, lie at the northwest and southeast boundaries of Ormond Beach, respectively, and coincide with distinct changes in the planform shape of the shoreline. Offshore of the project area is the approximately 20-mile wide Santa Barbara Channel and the northern chain of the Santa Barbara Channel Islands.

Prior to urbanization, the early coast surveys depict a rich complex landscape of sandy beaches, open-water lagoons and estuaries, a series of linear dune ridges, brackish and seasonal freshwater marshes, and grass and transitional uplands. These surveys from the 1850s show a sandy shoreline with a continuous strip of low dunes about 200-300 feet wide along the area that would be come known as Ormond Beach (Thompson, 1994). Behind this dune complex coastal grasslands extended across the low-lying Oxnard Plain, which was drained by a series of channels – the largest of which would later become the Hueneme/Bubbling Springs and Oxnard Industrial Drains – that terminated at back-dune brackish open-water water and wetlands. Mugu Lagoon is the only water body shown in the 1850s maps with a continually open tidal inlet. Examination of these 19th century coastal survey maps reveals a series of parallel dune ridges, presumably built during early stillstands, suggesting that the shoreline along the Oxnard Plain has been accreting over the past 5,000 years (Thompson, 1994).

Before substantial development had occurred on the Oxnard Plain, groundwater flowed naturally from inland recharged areas to the nearshore portions of the Hueneme and Mugu Submarine Canyons (UWCD 2002). This flow occurred through a series of lower and upper aquifer systems, as well as a shallower zone of semi-perched groundwater. Historic accounts of pervasive artesian conditions near the upper portions of the aquifers suggest infiltration of streamflow; percolation of direct precipitation on the valley floor; and compaction of fine-grain beds produced a substantial amount of groundwater.

3.2 PHYSICAL PROCESSES

Ormond Beach is thus contained in a littoral cell that, while being supplied by fluvial sources, is delimited by two large sediment sinks in the form of submarine canyons. Within the littoral cell, longshore transport generally occurs southeasterly according to prevailing wave climate, shoreline orientation and sheltering by the Santa Barbara Channel Islands and Point Conception. The actual amount of material that is available for building beaches along Ormond Beach, and further down drift, is therefore dependant upon sediment supply from the Santa Clara and Ventura River systems, the trapping efficiency of the submarine canyons and the management of coastal sediments in the vicinity of updrift port facilities.

Shoreward progradation of the Oxnard Plain halted once the shoreline reached the Hueneme and Mugu Submarine Canyons, at which time excess coastal-building sediment began to be captured and diverted beyond the continental shelf. As sediment bypassing across the head of the Hueneme Submarine Canyon began to equilibrate with the southeasterly longshore transport of beach sands, the shoreline position of Ormond Beach began to stabilize. Re-orientation of the coastline and the point-bight planform alignment at both Point Hueneme and Point Mugu reflect the changing balance between sediment supply and wave conditions as part of the sediment load is transferred from the littoral stream to submarine canyons and lost offshore (Thompson, 1994).

The historic broad sandy beaches along the coastal edge of the Oxnard Plain provided a source of sediment for wind-blown transport and the development of interior dune fields. Although these interior dune fields probably acted as sediment sinks during average or calm conditions, beach sands stored in these geomorphic features could be mobilized and transported shoreward during extremely erosive coastal storms.

Relatively high rates of littoral transport along the sandy beaches prevented regular tidal connection between the lagoons along the greater Ormond Beach area, and, based on the early coast surveys, Mugu Lagoon appears to have been the only body of water large enough to maintain a continually open inlet. The beach barriers of the lagoons northwest of Mugu Lagoon were probably only breached during unusually high runoff events and closed after a relatively short period of time. Wave runnup and overtopping of the beach barrier may have also supplied back-barrier lagoons with marine water.

4. CHANGES FROM HISTORICAL TO PRESENT CONDITIONS

4.1 ALTERATIONS TO THE HYDROLOGIC SYSTEM

Since the 20th century, alterations to freshwater drainages, agricultural production and urbanization have substantially modified the coastal landscape of the Ormond Beach area. In general, the historic coastal wetlands and lagoons that were once hydrologically connected to surface runoff and groundwater sources have diminished in size and become fragmented through a series of hydrologic modifications or directly modified by changes in land use.

The salt and brackish lagoons depicted on the early coastal survey maps of the 1850s remained largely undisturbed until the beginning of the 20th century, although some development had begun on the coastal grasslands that would become Port Hueneme. By the late 1930s, agricultural development and diversions of local freshwater discharges began to substantially modify the wetlands around the Ormond Beach area. It was at this time that an agricultural ditch, referred to as the Old Oxnard Drain or East Hueneme Drain, was constructed parallel to the shoreline to divert surface water and high groundwater flows from the agricultural lands immediately north of Ormond Beach to Mugu Lagoon. As freshwater sources were diverted, the historic brackish and salt marshes began to dry and diminish in size (McClelland 1985).

Hydrologic modifications continued with urbanization and expansion of agricultural lands. By 1945, much of the channelized Oxnard Industrial Drain and Hueneme Drain (also known as Bubbling Springs Drain) directed flows from the lands north and east of Ormond Beach to the East Hueneme Drain, which had been enlarged for flood control purposes (Impact Sciences 1996; McClelland 1985). Further modifications to the natural drainage patterns include construction of the J Street Drain in 1960 and the installation of the Hueneme Pump Station, which was required to lift water from the Hueneme Drain to the J Street Drain (Impact Sciences 1996). These primary local drainages, along with Oxnard Drainage Ditch #3 which conveys surface flows around the southern edge of the Southland Sod property, are shown in Figure 4. Other minor drainages occur on the site but are of less significance to surface hydrology.

Accumulation of wind-blown sand in the East Hueneme Drain east of the Oxnard Industrial Drain gradually reduced the conveyance of this channel and discharge into Mugu Lagoon. By 1961 discharges were routed behind the beach barrier at North Ormond Beach via breaks in the East Hueneme Drain, where water accumulated until breaches conveyed flow directly to the ocean (Impact Sciences 1996). In order to manage the elevations of water impounded at the newly formed J Street Lagoon, the Ventura County Flood Control District began to mechanically breach the beach barrier about this time. Regular mechanical breaching continued, with approximately four to six breaches per year, until the practice was stopped in 1992 in response to concerns of adverse effects to foraging habitat for sea and shorebirds (Impact Sciences 1996).

Changes to groundwater elevations followed widespread development of irrigated farmland on the Oxnard Plain, and the landward flow was first observed in the late 1930s. Following a period of wet years during which the direction of these flows reversed, seawater intrusion intensified from the late

1940s through the 1980s as development continued (UWCD 2002). In addition to changes in groundwater elevation and seawater intrusion due to overdraft, improperly constructed wells have lead to poor quality water from the semi-perched zone to flow downward and contaminate the lower aquifer system. Elevated chlorine levels across the Oxnard Plain have also been attributed to the dewatering of salt-laden marine clays, which is a result of a decrease in pressure in the aquifers caused by regional pumping (UWCD 2002). Since the mid 1980s, facilities have been built to increase the amount of recharge to the aquifers, and monitoring over the past nine years shows that seawater intrusion near Port Hueneme has been reversed.

4.2 ALTERATIONS TO THE LITTORAL SYSTEM

In addition to the hydrologic and land use changes described above, alterations to the natural coastal processes were occurring during the 20^{th} century within the study area. The most notable changes included the construction of port facilities updrift of Ormond Beach at Port Hueneme and the Channel Islands Harbors. The shoreline at Ormond Beach, which remained relatively stable before natural littoral processes were altered, has changed substantially in response to construction of these port facilities and initiation of mechanical sand bypassing. These changes reveal the influence the net longshore transport and management practices at the updrift harbors have on the amount of sand delivered to Ormond Beach.

The shoreline in the vicinity of Ormond Beach remained relatively unchanged from the conditions depicted in the 1850s surveys until the construction of the jetties off of Point Hueneme in 1939, which interrupted the southward flux of littoral sediments by increasing the amount of material lost to the Hueneme Submarine Canyon. This suggests a balance between sediment availability, natural bypassing at the head of the Hueneme Submarine Canyon and storage upon the downdrift beaches. During the two decades following construction of facilities at Port Hueneme, and before the onset of mechanical bypassing of littoral sediment, downdrift beaches lost between 600 and 1,000 feet of width (City of Port Hueneme, 1997).

Construction of the offshore breakwater at the Channel Islands Harbor in 1960 further altered the natural longshore transport of beach sands by trapping material updrift of its jetties. However, it was at this time that dredging and piping of sediment across the Hueneme Submarine Canyon was initiated to mitigate the diminished supply of coastal material at Ormond Beach and other areas downdrift of the ports. Since the onset of mechanical bypassing, the shoreline has accreted substantially (Wiegel, 1994). The volume of sand bypassed through pumping has diminished gradually, from an annual average of about 1.2 million yd^3 initially to a current rate of approximately 850,000 yd^3 although the exact volume varies during each of the biennial dredging events.

These observations demonstrate the relationship of updrift sediment supply, beach nourishment management practices and the resulting fluctuations of morphology at Ormond Beach and other downdrift locations.

4.3 SUMMARY OF LANDSCAPE CHANGES

Over the last century, there have been significant changes to the active physical processes in the greater Ormond Beach area. In addition to modification of the natural earth-shaping geomorphic process, direct changes in land uses in the project area have affected the landscape. Examination of historic records reveals three general alterations that have affected the coastal landscape and need to be considered when developing restoration, enhancement and management plans for the project area.

- Residential, agricultural and industrial developments have altered the topography and directly impacted coastal habitats. Substantial changes in land use at the project site included construction of the Ormond Beach Power Generating Station, expansion of industrial uses along Perkins Road and development of the Halaco disposal site in the 1970s (McClelland 1985). These land use and habitat changes are clear from a comparison between the early coast surveys and recent aerial photography (Figure 5). Because the Halaco disposal site was developed immediately to the south of the Oxnard Industrial drain, the facility has largely fixed the downstream location of this drainage.

- Construction of jetties at the Channel Islands and Port Hueneme Harbors has altered the natural movement littoral sediment along the coast by focusing sediment transport pathways into deeper water, increasing offshore losses and accumulating material along updrift beaches. As a consequence, the sustainability of Ormond Beach and other downdrift sites relies upon continued operation of mechanical bypassing systems at these port facilities, particularly at the Channel Islands Harbor.

- Channelization of the major freshwater creeks and rivers, as well as urbanization and agricultural production, has modified the hydrologic characteristics of the local watersheds. The result has been more managed hydrographs (i.e., modified frequency and duration of runoff events) and diminished supply of freshwater to historic back-barrier wetlands and lagoons. Along with direct modification to historic wetlands through changed land uses, natural habitats have reduced in size due to construction of agricultural ditches and flood conveyance facilities that have drained the historic wetlands.

- Pumping for agricultural irrigation and other uses has reduced the elevation of groundwater below the Oxnard Plain and led to salinity intrusion at the heads of the Hueneme and Mugu Submarine Canyons, although some of the intrusion near the Hueneme Submarine Canyon has been reversed in recent years. Lowering of groundwater elevations has lead to a deterioration of water quality and land subsidence; salt that has entered the aquifers as result of rapid intrusion during dry periods and has remained in the system.

5. EXISTING SITE CONDITIONS

5.1 PHYSICAL SITE DESCRIPTION

5.1.1 Topography

As discussed above, the greater Ormond Beach area occupies the coastal margin of the gently sloping Oxnard Plain. Towill, Inc collected LIDAR topographic data over the project site in April 2001, as shown in Figure 6. Most of this area consists of level or nearly level areas of the alluvial plain, except for the low-lying areas of the J Street Lagoon where freshwater discharges and direct rainfall accumulate when the inlet through the beach barrier is closed. Development has altered the elevations in much of the area relative to those observed in the 1850s.

The LIDAR topographic data were used to construct the elevation-area curves shown in Figure 7. These hypsometric curves reveal that ground surface elevations across the majority of the project area lie above the reach of the tides. Specifically, only about 50 acres of the land acquired by the SCC in the South Ormond Beach area are below mean higher high water (MHHW). The distribution of elevation by parcel shows that the Southland Sod and SCC areas will likely require the least amount of excavation to lower significant acreages to elevations suitable for tidal inundation. Comparison between the elevations of the project area and the duck clubs is presented in Figure 8, and reveal that typical elevations in the game preserves are approximately two feet below those in other parcels.

5.1.2 Geology & Soils

Inman and Jenkins (1999) have attributed the large sediment yields of the coastal watersheds within the Transverse Ranges to their composition – relatively young and unconsolidated sediments – and the structural complexity of the region, which includes slip faults, thrust faults and overturned beds. These high yields are reflected in the relatively large annual net yield per area of the three major sources of material to the Santa Barbara Littoral Cell: the Santa Clara River, the Ventura River and Calleguas Creek.

As shown in Figure 9, the soils found at the project area consist of poorly drained loamy sands to silty clay loams level found along moderately sloping or nearly level soils of the alluvial fan. These soils consist of an associate of the Camarillo, Hueneme and Pacheco series. WRA (2000) sampled soils at South Ormond Beach and found that soils generally consisted of sand or clay. Sandy soils typically occurred higher in the dunes, whereas clay soils and layers were found at lower elevations. JSA (1994) also collected soil samples at South Ormond Beach and found variation of soil texture with depth, which they attributed to the episodic deposition in the alluvial plain. Surface textures in these South Ormond Beach samples varied from loamy sands to sandy loam. Finer subsurface textures, found at depths between 16 to 28 inches, ranged from sandy clay loam to silty clay. Below the layers of fine textured soils, JSA (1994) reported coarse sand beginning at depths of 32 to 54 inches. Along the margin of the South Ormond Beach wetland and the coastal dunes, wind-blown sand was found blended into the fluvial-deposited material (JSA 1994). Soil mapping by the USDA (1970) suggest that similar soil characteristics occur in other areas of the project site.

5.2 HYDROLOGIC PROCESSES

5.2.1 Surface Water Hydrology

Surface water hydrology at Ormond Beach is affected by freshwater discharges, groundwater, intermittent tidal exchange and direct rainfall. Southeast of the Reliant Ormond Beach Generating Station, Oxnard Drainage Ditch #3 receives some tidal water from leaking flap gates connected to Mugu Lagoon. The paragraphs below describe the three drains that contribute most of the freshwater to Ormond Beach: The Oxnard Industrial Drain, the J Street Drain and the Hueneme Drain. Also included in this section is a description of tidal exchange through Oxnard Drainage Ditch #3.

The descriptions of the three freshwater drainages rely largely upon information reported by Impact Sciences (1996) and Kennedy/Jenks (1999). The discussion of tidal exchange is based upon measurements collected by PWA (2000) and simplified numerical modeling in order to demonstrate basic concepts of tidal inundation and exchange in the J Street Lagoon. Typical and event discharges along the three major drainages are summarized below in Table 1.

5.2.1.1 The Oxnard Industrial Drain

The Oxnard Industrial Drain conveys runoff from industrial and agricultural areas on the east side of the City of Oxnard. The Rice Drain is tributary to the Oxnard Industrial Drain, which has a total watershed area of 5,935 acres – the largest of the three tributaries of the J Street Lagoon. This channel is lined along its entire length, expect for the section that begins approximately 500 ft downstream of Hueneme Road. Flows from the Oxnard Industrial Drain are discharged into the J Street Lagoon. Flows from all three of these drains are frequently impounded at the J Street Lagoon and behind a beach barrier that prevents a direct tidal connect to the ocean. While the inlet is closed, water surface elevations in the lagoon are controlled by seepage across the sandy beach berm and evaporation.

A remnant of the Oxnard Drain, the Oxnard Drainage Ditch #3, is located on the ocean side of the Halaco Disposal Site, although much of the channel is filled with wind-blown sand. A ‘leaky’ tide gate at the terminus of the remnant canal east of the Oxnard Industrial Drain allows for muted tidal action to pickleweed marsh, open water and salt panne areas on the Metropolitan Water District of Southern California and City of Oxnard Community Development (MWD/OCD) property. PWA (2000) measured similar fluctuations in water surface elevation immediately upstream and downstream of the tide gate along Oxnard Drainage Ditch #3, although elevations on the upstream side of the gate were higher – presumably due to freshwater runoff or tidal ‘pumping’ from Mugu Lagoon.

5.2.1.2 The J Street Drain

Stormwater and urban runoff from approximately 1,340 acres of residential areas in the central Oxnard are routed through the J Street Drain and directly into the J Street Lagoon. The entire length of the channel upstream of the Hueneme Pump Station is lined with concrete. The J Street Drain was constructed in 1960 to alleviate flood hazards.

5.2.1.3 The Hueneme Drain

The Hueneme Drain, also referred to as the Bubbling Springs Drain, is fed by a natural spring (Bubbling Springs) and urban runoff from 610 acres within the City of Port Hueneme. Although the channel bottom is soft, its banks are lined with rip-rap or grouted rip-rap. Due to differences in invert elevations, the Hueneme Pump Station lifts water from the terminus of this channel near the downstream end of J Street Drain. The freshwater introduced to the surface via Bubbling Springs has a greater influence on surface hydrology during the summer and fall months when precipitation and runoff is absent.

Table 1. Flows in The Oxnard Industrial, J Street and Hueneme Drains

	Typical (MGD)	**10-year (cfs)**	**50-year (cfs)**
Oxnard Industrial Drain	4	2,798	4,115
J Street Drain	1*	1,049	1,542
Hueneme Drain	1	251	369

* Pro-rated based on typical flows in Oxnard Industrial Drain and based on watershed.

5.2.1.4 The J-Street Lagoon

Flows from the Hueneme Drain / Bubbling Springs (via the Hueneme Pump Station), the J-Street Drain, and the Oxnard Industrial Drain all discharge into the J-Street Lagoon. This lagoon extends along an approximately one-half mile reach of Ormond Beach, from the terminus of the J-Street Drain at its furthest up-coast extent to immediately adjacent to the Halaco site at its furthest down-coast extent. As discussed in Section 5.3.3, the J-Street Lagoon is periodically open to the ocean and subject to muted tidal action.

5.2.1.5 Tidal Exchange

Table 2 summarizes the tidal datums and observed extreme water levels at the Santa Monica water level station maintained by the Center for Operational Oceanographic Products and Services (CO-OPS). This station was chosen due to its proximity to the project site, and its tidal datums are expected to be representative of the Ormond Beach area. Tides along this coastline are semi-diurnal, with two sets of unequal highs and lows each day.

Based on the data presented in Table 2, the expected average daily tide range for an unconstrained tidal lagoon at Ormond Beach is 5.4 ft. However, modeling results for inlet widths at Ormond Beach show significant attenuation of water surface fluctuations within the J Street Lagoon at low tides. These preliminary findings are consistent with observations at other small coastal lagoon where the elevation of the thalweg of the inlet channel is relatively high compared to the tides along the open coast. For very small coastal lagoons, the constrained flows through the inlet may produce a diurnal (i.e., once-a-day) fluctuation of water within the lagoon if ocean water only fills the site during higher high tides.

Table 2. Tidal Datums at Santa Monica, California

Datum	Elevation (ft MLLW)	Elevation (ft NAVD88)
Highest Observed Water Level (11/30/1982)	8.50	8.31
Mean Higher High Water (MHHW)	5.42	5.23
Mean High Water (MHW)	4.69	4.50
Mean Tide Level (MSL)	2.81	2.62
Mean Low Water (MLW)	0.93	0.74
North American Vertical Datum (NAVD88)	0.19	0.00
Mean Lower Low Water (MLLW)	0.00	-0.19
Lowest Observed Water Level (12/17/1933)	-2.84	-2.65

Source: Center for Operational Oceanographic Products and Services. Tidal epoch is 1984-2001.

Tidal attenuation due to inlet geometry will affect the amount of tidal prism mobilized and reduce the ability of scour to naturally maintain an open connection to the ocean. This has important implications for wetland design, because a constrained inlet will modify the hydroperiod and exchange of nutrients, sediments and other matter. Using tidal prism versus cross-sectional area relationships for small coastal inlets (Hughes, 2002), we estimated approximate sizes of the inlet at the J Street Lagoon and used a one-dimensional model to simulate tidal flows. Based on the results presented in Table 3, we estimate that approximately 15 to 17 acre-feet of water are transported through the inlet when it is subject to tidal action. This estimate accounts for the typical flow in the Hueneme, J Street and Oxnard Industrial Drain summarized in Table 1 and the effective tidal prism.

Table 3. Estimated Inlet Geometry of the J Street Lagoon

Estimated Tidal Prism (acre-feet)	Estimated Inlet Area at Throat (ft^2 below MSL)	Estimated Inlet Throat Width (ft at MSL)	Estimated Inlet Throat Depth (ft below MSL)
15	48	33	1.5
17	58	37	1.6

Source: Inlet Area estimated from Hughes (2002). Throat depth and width computed from assumed aspect ratio (width:depth) of 23.

5.2.2 Fluvial Sediment Supply

Wind blown beach and dune sand is deposited in the existing wetlands, although the amounts are unknown. Sediment delivery via the three primary drainages – The Hueneme, J Street and Oxnard Industrial Drains – is unknown due to the lack of sediment data along the local tributaries to the project area. However, the delivery of fluvial sediments appears to be small due to urbanization and the fact that the wetlands are cut off from the sediment load of the drainage and flood control channels.

The much larger sediment sources in the region – Ventura River, Santa Clara River, and Calleguas Creek – all discharge sediment into the tidal waters farther north or south of Ormond Beach. Bed particle sizes within the Santa Clara watershed range from fine sand to coarse gravel (Simons, Li and Associates 1983). Much of the delivery by these sources occurs during brief, episodic discharge events, with 50% of the suspended sediment discharge occurring during only 0.1% of the time (Warrick and Milliman, 2003). Willis and Griggs (2002) have estimated that the Santa Clara River, Ventura River and Calleguas Creek discharge approximately 1.63, 0.215 and 0.649 million yd^3 of sand and gravel per year. However, El Niño/Southern Oscillation (ENSO) climate patterns produce variations on multi-decadal time scales (Inman and Jenkins, 1999), with ENSO years generally resulting in higher rates of precipitation and sediment delivery to the ocean. Larger variations occur on an inter-annual basis due to exceptionally dry years or large, infrequent flooding events.

Despite the potential for delivery of high volumes of sediment from these rivers, particularly the Santa Clara, much of this sediment is lost from the littoral drift. Hyperpycnal flows (river effluent density greater than ocean water density) result when sediment concentrations exceed 40 g/L, and represent an important mechanism for sediment delivery to the seabed, accounting for approximately 75% of the cumulative discharge of the Santa Clara River over the past 50 years (Warrick and Milliman, 2003). Warrick et al. (2004) estimate that 90% of the suspended sediment discharged from the river is removed from the surface plume within 1 km of the river mouth, where it is transported offshore within the bottom meter of the water column by bottom nephloid layers and as fluid-mud. It is believed that hyperpycnal plumes may be responsible for transporting large quantities of sediment offshore beyond the littoral cells, resulting in a long-term loss of potential sediment supply to downdrift beaches.

5.2.3 Groundwater

The Oxnard Plain is underlain by a complex aquifer system that has been the primary source of freshwater supplies since the 19th century (Hanson, 1994; Hanson et al., 2003). The aquifer system is bound along mountain fronts by impermeable consolidated bedrock. Offshore, the aquifers outcrop along the edge of the submarine shelf, which provides a hydraulic connection with the ocean (Hanson et al., 2003). Natural recharge occurs through infiltration of streamflow from major rivers, tributaries and the numerous arroyos that drain the mountains and contributes water to the aquifer. Landward flow from the ocean, storage in coarse-grained beds and compaction of the fine-grain beds also contribute sources of water to the aquifer.

The steady increase in demand for water in the area has lead to subsidence, seawater intrusion, groundwater contamination, and inter-aquifer flow. Based on volumes reported by UWCD (2003), 72,000 acre-feet of groundwater were pumped during 2002 from the Oxnard Aquifer and a portion of the Pleasant Valley basin that lies within the boundary of the district. The majority of this water was extracted from the Lower Aquifer System. Much of the groundwater in the Oxnard Plain has been affected by seawater intrusion and the collapse of marine sediment within the aquifer (Kennedy/Jenks Consultants, 1999; UWCD, 2001). Intrusion of seawater into the Oxnard Aquifer of the Upper Aquifer System extended about a mile inland from the coast at Port Hueneme and Mugu Lagoon. Lateral seawater intrusion in areas adjacent to the Hueneme and Mugu Canyons has lessened since 1995, with intrusions in to the coastal edges of the aquifer of Point Hueneme apparently in reversal due to construction of several new facilities designed to increase recharge (UWCD, 2001). These include the Freeman Diversion (1991), the Pumping Through Pipeline (1986) and the Noble spreading basins (1995).

Sources of water to the regional ground-water flow system are natural and artificial recharge, coastal landward flow from the ocean (seawater intrusion), storage in the coarse-grained beds, and water from compaction of fine-grained beds. Most natural recharge occurs through infiltration (losses) of streamflow within the major rivers and tributaries and the numerous arroyos that drain the mountain fronts of the basin. Artificial recharge is a major source of ground-water replenishment. Hanson et al. (2003) estimate that during 1984-93, the average rate of artificial recharge at the spreading grounds was about 54,400 acre-ft/yr, 13 percent less than the estimated natural recharge rate for streamflow infiltration within the major rivers and tributaries. Estimated recharge from infiltration of irrigation return flow on the valley floors averaged about 51,000 acre-ft/yr, and treated sewage effluent averaged about 9,000 acre-ft/yr.

Under natural conditions, the largest discharge from the groundwater system was outflow as coastal seaward flow and evapotranspiration, although pumpage from thousands of water-supply wells has diminished these outflows and is now the largest outflow from the groundwater flow system. Hanson et al. (2003) estimate the total average pumpage between 1984-93 at about 247,000 acre-ft/yr; of which about 146,000 acre-ft/yr was from the Fox Canyon Groundwater Management Agency (FGMA) subareas and 101,000 acre-ft/yr from the non-FGMA subareas. Of the total 1984-93 pumpage, 46 percent was contributed by natural recharge, 22 percent was contributed by artificial recharge from diverted streamflow, 20 percent was contributed by irrigation return flow, 4 percent was contributed from sewage-effluent infiltration, 6 percent was contributed from storage depletion, and 2 percent was contributed from coastal landward flow (seawater intrusion). Hanson et al. (2003) modeled future ground-water conditions based on proposed water-supply projects for the Santa Clara-Calleguas ground-water basin. These proposed projects all assume a reduced pumpage in the FGMA areas which resulted in a reduction but not an elimination of storage depletion and related seawater intrusion and subsidence.

A shallow clay lens across the plain, approximately 30 feet below grade, prevents deep penetration of the shallow aquifer (Impact Science, 1996). These shallow water tables required the import of fill in order to create soil conditions suitable for agricultural, industrial and residential development. Water in this near-surface zone comes from agricultural return flows and precipitation, and is not used for irrigation or drinking. Results of water quality data from two wells near the Oxnard Industrial Drain at Hueneme Round describe high concentrations of total dissolved solids (Kennedy/Jenks Consultants, 1999). Water levels within the semi-perched zone fluctuate from a few feet below the surface at the end of the rainy season to about ten feet below the surface by late fall.

Annual rain for the region (recorded at gauge #245 at Santa Paula) is low, measured to be 17.42 inches per year, on average. This figure is considerably lower that the local rates of evaporation, 59.31 inches (UWCD, 2002). Consequently, water is, on net, lost from the soil surface to the atmosphere and thus rainfall is not a significant contributor to the long-term quantity of water in the semi-perched zone. The elevation of the water in the semi-perched zone can vary rapidly, however, in response to seasonal and short-term rain events. In 2000, PWA found indications of rainwater influence during the winter season while monitoring groundwater surface elevations at South Ormond Beach between the beach berm and Oxnard Ditch (PWA, 2000). These data indicate a strong correlation to precipitation and show fluctuation of water elevations at the interior piezometers from 1.5 feet below grade in late August 1999 to about 0.5 feet above the ground surface in April 2000. Measurements of groundwater elevations closer to the sandy beach berm show less seasonal fluctuation but also responded to relatively low levels of rainfall.

5.3 COASTAL PROCESSES

5.3.1 Wave Climate

Ormond Beach is located within the Southern California Bight, an area that includes several offshore islands, submarine canyons and a narrow continental shelf (Figure 3). Major coastal features that affect the local wave climate are Point Conception, the northern chain of the Santa Barbara Channel Islands and, to a lesser extent, the two submarine canyons that bound the coastal edge of the greater Ormond Beach area. In general, this stretch of coastline is subject to energetic winter waves and more calm conditions during the summer months.

Wave exposure at Ormond Beach is primarily limited to two directional sectors: one from the west that lies within the Santa Barbara Channel; and a second that lies to the south between Anacapa Island and Point Mugu. Data from the Anacapa Passage and Point Dume directional wave buoys were used to characterize wave conditions from these two sectors. Wave rose plots developed by the Coastal Data Information Program (http://cdip.ucsd.edu/) are presented in Figure 10 and Figure 11 for data collected at the Anacapa Passage and Point Dume buoys, respectively. Sheltering by the northern chain of the Santa Barbara Channel Islands and Point Conception accounts for the nearly unidirectional and westerly waves measured by the Anacapa Passage buoy. Waves recorded at the Point Dume buoy are more broadly distributed and show exposure from the west to south, although the largest and most frequent waves arrive from due west.

Mean monthly values of the significant wave heights (the average of the highest one-third waves) measured at the Anacapa Passage and Point Dume buoys are presented in Figure 12 and show the expected seasonality. The largest waves were observed during the winter months, with a steady decline in wave height through the summer months and the smallest waves recorded from July to October. The same seasonal trend of energetic winter waves and less energetic summer conditions is apparent in the wave power graphs presented in Figure 13. Wave power is a more appropriate indicator of longshore sand transport since it is a measure of the rate at which wave energy available to move sand arrives at the coast.

In the past, the Coastal Data Information Program maintained the Channel Islands, Port Hueneme and Point Mugu nearshore buoys. Historic data from all three of these buoys show similar seasonal trends and wave heights, suggesting that measurements collected by the Anacapa Passage and Point Dume buoys are representative of conditions at Ormond Beach.

5.3.2 Longshore Sediment Delivery

As described above, Ormond Beach lies at the southeastern end of the Santa Barbara Littoral Cell, which is primarily fed by fluvial dischargers from the Santa Clara River, Ventura River and Calleguas Creek. The Santa Clara River is the largest contributor of fluvial material to the littoral cell, feeding approximately 65% of all sediment transported down-coast (Stillwater Sciences, 2005). From the mouth of this river, much of the fine-grain alluvium is lost offshore, while coarse-grain material is transported to the southeast along with existing beach sands and input from sources farther upcoast (Wiegel, 1994). Most of the littoral sediment is moved toward the southeast, with only minor reversals, and leads to an almost unidirectional transport of beach sands at the project site (Moffatt & Nichol, 1986). Stillwater Sciences (2005) describe sediment dynamics at the mouth of the Santa Clara River and the effects of high fluvial flows on inlet breaching and delivery of fluvial sediments to the nearshore, the majority of which is in the form of hyperpycnal flows.

In between Point Conception and Point Mugu, there are four harbors that intercept the natural longshore transport of sand. Of these four harbors, the Channel Islands Harbor and the Port Hueneme Harbor are in closest proximity to Ormond Beach and have the greatest effect on the amount of sand delivered to the project area. These facilities consist of two jetties at Port Hueneme that extend almost to the head of the submarine canyon, and a pair of jetties and detached shore parallel breakwater at the Channel Islands Harbor.

Currently, sand that accumulates on the updrift sides of the jetties is mechanically bypassed and placed on downdrift beaches to reduce the loss of beach width observed in the first decades following construction of the facilities at Port Hueneme. Material dredged from the Channel Islands Harbor is pumped downdrift to Silver Strand and Hueneme Beaches on a biennial basis. Port Hueneme conducts maintenance dredging every 5-7 years and disposes of the sand at local beaches in order to keep the sand within the littoral system. Quantities from past bypassing activities are summarized in Table 4. Because the current biennial average of sand bypassing at the Channel Islands Harbor is 1.7 x 10^6 yd^3, the annual amount of sand that enters the Ormond Beach area between Hueneme and Mugu Canyon is approximately 850,000 yd^3. The volume of sand dredged at Port Hueneme is smaller and occurs less frequently.

Table 4. Historical Dredging Records for Ventura, Channel Islands and Port Hueneme Harbors

Harbor	Dredging History (years)	Dredging Volumes (yd^3)	Disposal Locations
Ventura	1964-1987 (a)	640,000 (annual average)	McGrath State Beach, South Beach, and Nearshore
	1990-1994 (b)	360,000 (annual average)	
	1995-2004 (c)	486,300 (annual average)	
Channel Islands	1960-1987 (a)	1.2 x 10^6 (annual average)	Hueneme Beach, Silver Strand Beach and Ormond Beach
	1984-1993 (b)	1.5 x 10^6 (biennial average)	
	1994-2002 (c)	1.7 x 10^6 (biennial average)	
Port Hueneme	1983 and 1989 (b)	Total of 515,000	Silver Strand Beach and Hueneme Beach
	1999 (c)	Total of 68,333	

a. From Wiegel, 1994
b. From Impact Sciences, 1996
c. From Army Corps of Engineers (Los Angeles District) 2004

5.3.3 Beach Morphology and Processes

PWA conducted fieldwork on July 28th, 2004 to survey the beach profile at Ormond Beach. A plan view showing the location of the profiles is shown in Figure 14 and the profiles are shown in Figure 15. The profiles extend in the seaward direction out to the approximate water surface elevation (WSE) and extend in the landward direction to the J Street Lagoon. For these three measured cross sections, the average beach face slope (measured from the top of the berm to the water surface elevation) is 1:15 and the average height of the berm crest is 12.5 feet (NAVD 88).

The measured beach profiles at Ormond Beach show a typical berm-type profile that is characteristic of summer conditions. Due to a decrease in wave heights during the summer months there is a net shoreward movement of sand in the landward direction that causes beach accretion. These high berm elevations prevent an open connection to the ocean and cause discharges to collect in the J Street Lagoon. In the winter months, when the average wave heights increase due to offshore and local storms, the beach face and the berm will experience erosion as sand is transported in the offshore direction. Typically this net movement of sand creates a bar in the nearshore. Due to erosion of the berm and an increase in stormwater discharges, water surface elevations relative to the beach berm diminish in the winter. If the water level in the lagoon reaches a critical elevation relative to the height of the berm crest, a breach will form between the ocean and the lagoon.

A 'natural' breach across the beach barrier can occur in two different ways (Kraus et al., 2002). The first involves beach scour once surface flow is initiated after a critical water surface elevation is reached. Increases of lagoon water surface elevations can occur through either collection of freshwater discharges behind the beach barrier or wave runup and overtopping. The second process through which natural breaching occurs involves seepage across a narrow beach barrier. Seepage of water through porous sediment due to differences in water elevations between the lagoon and ocean can saturate the sediment and create a sediment-water mixture. If the sediment-water mixture becomes unstable, large volumes of the mixture can be transported rapidly and can create an opening between the lagoon and the ocean. Natural breaching at Ormond Beach during the winter months could occur by either one of these physical mechanisms.

5.3.4 Inlet Feasibility Analysis

The stability of a coastal inlet largely depends on the balance of the wave and tidal power. Wave-driven beach sands deposited into the mouth of a tidal inlet reduce the ability of the inlet to remain open, while tidal flows can cause scour, removing beach sands from the inlet and maintaining its size and location. Freshwater discharges, such as those from the Hueneme, J Street and Oxnard Industrial Drains, add to the scouring effect of tidal currents. In general, inlets tend to remain open if the scouring effect of the tides is sufficiently strong relative to the incident wave power.

Inlet closure is event driven, and for small coastal lagoons largely depends on the joint probability of energetic waves co-incident with weak neap tides. Analysis of the frequency and duration of inlet dynamics will be important in assessing future estuarine processes and habitat conditions at Ormond Beach; although such a detailed study requires a time series of instantaneous nearshore wave power and is beyond the scope of this report. Therefore, we have presented estimates of existing and historic conditions at Ormond Beach along with 27 other coastal lagoons along the west coast in Figure 16. Johnson (1973) used the ratio of annualized wave power and the potential mean diurnal tidal prism to establish a general characterization of inlet stability. Based on the size of the historic lagoons along the Ormond Beach area depicted in the early coast surveys from the 1850s and a mean diurnal tide range of 5.4 feet, we estimate that the historic lagoons at Ormond Beach had a maximum potential tidal prism of approximately 160 acre-feet (7×10^6 ft^3). The existing tidal prism of the J Street Lagoon, which we estimate to be approximately 20 acre-feet, is clearly too small to maintain an inlet given the wave exposure – a finding that is consist with the observed inlet dynamics. Based on the data presented in Figure 16, we estimate that approximately 1,500 acre-feet are required to maintain an "always open" inlet at Ormond Beach. Less tidal prism, on the order of 200 or 300 acre-feet, would be required to create an intermittingly open inlet. The frequency and duration of inlet closures, and the resulting wetland functions and ecological values, would vary for intermediate wetland sizes. Also, note that the amount of tidal damping across a new ocean inlet must be considered when translating the minimum tidal prism into a minimum footprint for the new tidal lagoon (i.e., each acre of the new tidal lagoon is not expected to 5.42 acre-feet of tidal prism).

The preliminary assessment of inlet stability above demonstrates the difficulty in creating a continuously open tidal inlet without the use of coastal structures, such as a short groin, to provide local wave sheltering.

5.4 IMPLICATIONS FOR HABITATS OF KEY SPECIES

WRA has prepared a list of key plant and wildlife species, along with the associated habitat requirements, for the project area (Appendix A). The existing conditions and physical processes described above present opportunities and constraints for enhancement and restoration of these coastal habitats. Implications of the physical setting for habitats of key species include the following:

- <u>Tidal inlet stability</u>. Creating a continually open inlet at the project site without the use of coastal structures, such as groins, would be challenging due to the amount of tidal scour required to offset wave-driven deposition at the mouth of the inlet. Based on the inlet dynamics of other coastal lagoons and the wave exposure at Ormond Beach, we estimate that a tidal prism on the order of 1,500 acre-feet would be required to maintain an open inlet. Under extreme events, when energetic coastal waves deposit unusually large amounts of sand at the mouth of the inlet, even a wetland of 1,500 acre-feet could close. The ability of maintaining an open inlet will affect habitat for species dependent on densely vegetated and regularly drained tidal marshes. Scour along the inlet and its ability to remain open could be enhanced by increasing the amount of freshwater flows towards the lagoon, although the delivery would have to be substantial and continue throughout the dry season.

- <u>Intermittent or reduced tidal exchange</u>. Tidal wetlands smaller than the minimum size required to maintain a continually open inlet would lead to intermittent closures and result in rapid changes in salinity and water levels by either flooding the marshes as water backs up or by drying out mudflats as evaporation proceeds. Brackish or freshwater conditions could result if there is a significant freshwater inflow from local drainages during the winter, while hypersaline conditions could prevail in the summer when evaporation is high. The net result is a loss of species diversity as only a few plants and animals are able to handle the extreme conditions associated with these processes. Lagoons that are not fully closed but subject to a substantial amount of tidal muting (commonly due to a relatively high sill along the thalweg of the entrance channel) may undergo similar decreases in species diversity since the net result is reduced tidal influence.

- <u>Freshwater delivery to coastal wetlands</u>. Stormwater and runoff presently collect behind the beach barrier at Ormond Beach to form the J Street Lagoon, which provides low-salinity habitat for certain species. However, the aerial extent of this shallow lagoon habitat is limited. Grading gently sloping areas around the coastal margin could potentially increase the amount of shallow brackish habitat.

- Availability of fluvial sediments and beach sands. While the supply of sands is expected to be sufficient to maintain beach and dune habitat, as well as develop sandy flood shoals and tidal flats, the availability of fine-grain cohesive sediments is negligible due to low concentrations of suspended sediments in oceanic waters, development in the watersheds and the fact that most of the local drainages have been channelized. This suggests low rates of inorganic sedimentation and that the extent of vegetated salt marsh will largely depend on the graded elevations in areas chosen for excavation.

  Wide and sandy beaches in the study area are expected to persist as long as bypassing operations at updrift port facilities are maintained, providing a supply of coarse-grain material to build sparsely vegetated habitat for some key wildlife and plant species.

- Perched groundwater. The relatively shallow groundwater elevations of the semi-perched zone provide an opportunity to create fresh or brackish marsh habitat where existing ground surface elevations prohibit tidal inundation. This potentially affects a substantial portion of the project area, although the high rates of evaporation (59 inches/yr) relative to precipitation (15 inches/yr) and the observed changes in groundwater elevation (more than 1.5 feet) could affect species abundance and diversity, particularly in those areas lacking other hydrologic sources. Low-lying areas not supplied with groundwater are likely to dry out in the summer and fall, creating sparsely vegetated playas with saline soils.

6. EXTREME EVENTS AND FUTURE CHANGES IN PHYSICAL PROCESSES

6.1 EFFECTS OF EXTREME EVENTS

Infrequent and large-magnitude events have the potential to substantially affect the morphology of the project site. This could occur through either extreme fluvial or coastal processes.

6.1.1 Infrequent Storm Events and Fluvial Processes

During the 1969 flood, the storm-generated transport of fluvial sediment along the Santa Clara River, the largest source of material to the Santa Barbara Littoral Cell, more than doubled the total transport of material during the previous 25 years (Inman and Jenkins, 1999). During this time, approximately 13 million yd^3 of sediment was delivered to the offshore delta (Noble Consultants, 1989). Such rapid inputs into the littoral cell may cause year-to-year shoreline variation, although its long-term position will be controlled by the average delivery of beach sands and prevailing wave climate.

Under natural conditions, large flood events along the Santa Clara River would deliver sediments across the Oxnard Plain and build the alluvial fan as water overflowed the channel banks. With the construction of flood control facilities, natural delivery of fluvial sediments during flood events no longer occurs except in the most extreme events and cannot be relied upon as a source for marsh-building sediment.

6.1.2 Coastal Storms

Although largely protected by the Channel Islands, the beach profile at Ormond Beach will respond rapidly to winter coastal storms, which typically lower the beach profile by moving sand from the shoreface to offshore bars. Some of this material may be lost offshore if cross-shore transport is strong enough, although less energetic summer waves typically re-build the shoreface and beach barrier gradually. Restoration of interior dunes may mitigate adverse effects of extremely erosive coastal storms because these features store beach sands away from the influence of typical waves.

With a typically lower beach berm elevation, the likelihood of breaching a closed lagoon increases. Runoff and stormwater discharges further increase the chances of natural breaching, along with storm surge along the coast that may lead to periodic overtopping of the beach berm during higher high tides. Continued overtopping may induce breaching by increasing water levels inside the closed lagoon above the beach berm, or by scouring due to the surface flow across the beach berm.

6.2 SEA-LEVEL RISE

Local relative sea level is a combination of global (eustatic) ocean volume change components and regional to local (isostatic) components such as tectonic uplift or subsidence. Relative sea-level rise, which is a combination of eustatic and isostatic effects, has implications for restoration and management of coastal resources, because increased water surface elevations will affect flood hazards, shoreline erosion rates, and habitats along the shoreline.

Globally, sea-level elevations have increased on the order of 1 to 2 mm/yr over the past few thousand years (Lambeck and Bard, 2000). Over the past 150 years, these rates have increased and are expected to continue to increase. The expected value for the rate of sea level rise is about 3 mm/yr over the next 50 years and about 5 mm/yr over the subsequent 50 years (IPCC 2001). Because of uncertainty in carbon emissions and global climate response, significant uncertainty remains for these predicted rates.

Gornitz et al. (1997) analyzed data from long-term tide gages along the west coast of the U.S. and estimated the average rate of sea-level rise to be between 1.39 and 1.48 mm/yr. This value implies the prevalence of global sea-level rise, although land subsidence probably also contributes relative changes in sea-level at Ormond Beach. Hanson (1994) has reported subsidence in the area of Port Hueneme to be 1.2 mm/yr from 1939 and 1978, presumably due to extraction of groundwater and oil and gas exploration. The rates of subsidence increase significantly farther inland, where declines in groundwater elevations and oilfield pressure are greatest.

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9. FIGURES

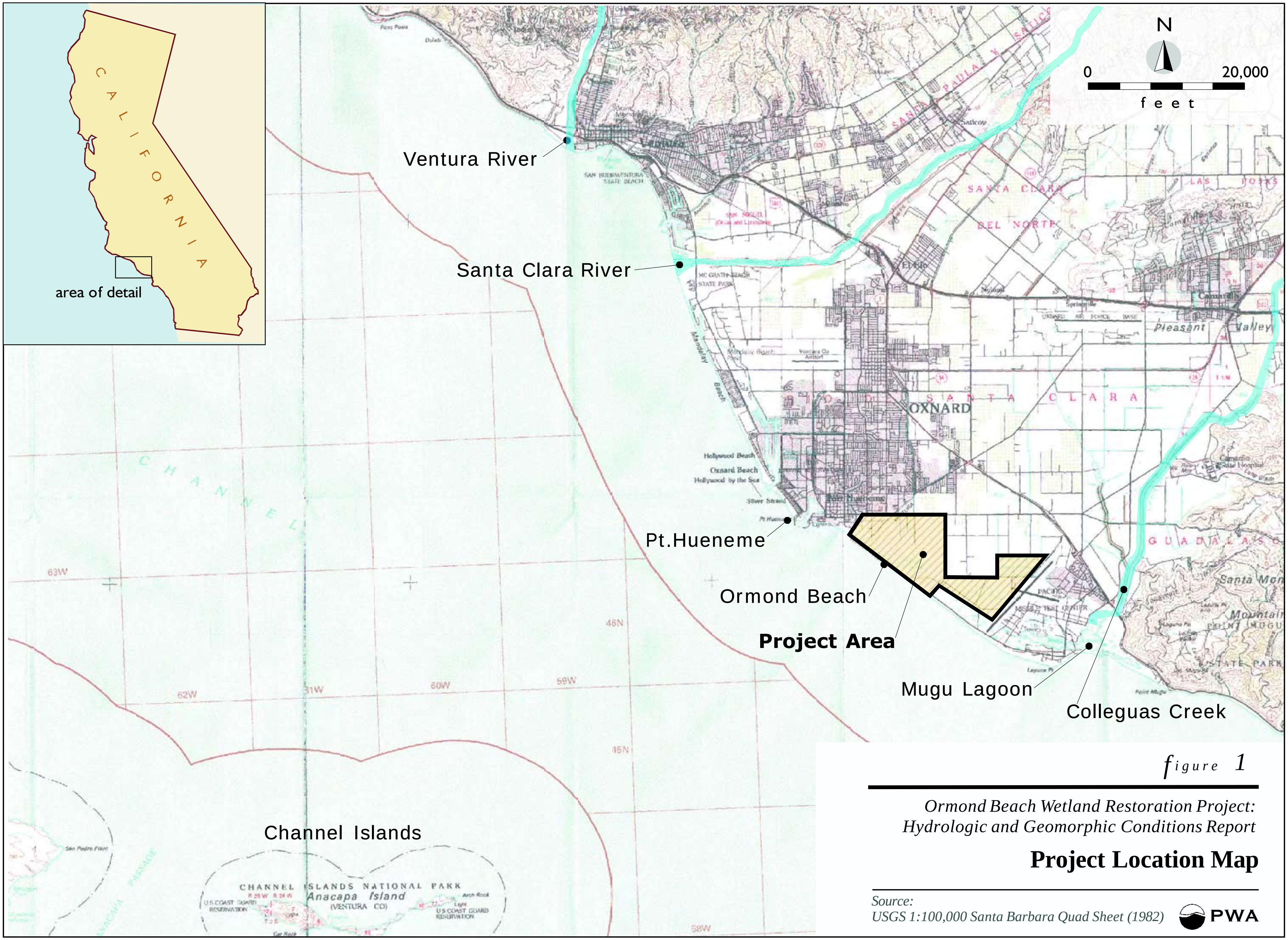

figure 1

Ormond Beach Wetland Restoration Project: Hydrologic and Geomorphic Conditions Report

Project Location Map

Source:
USGS 1:100,000 Santa Barbara Quad Sheet (1982)

PWA

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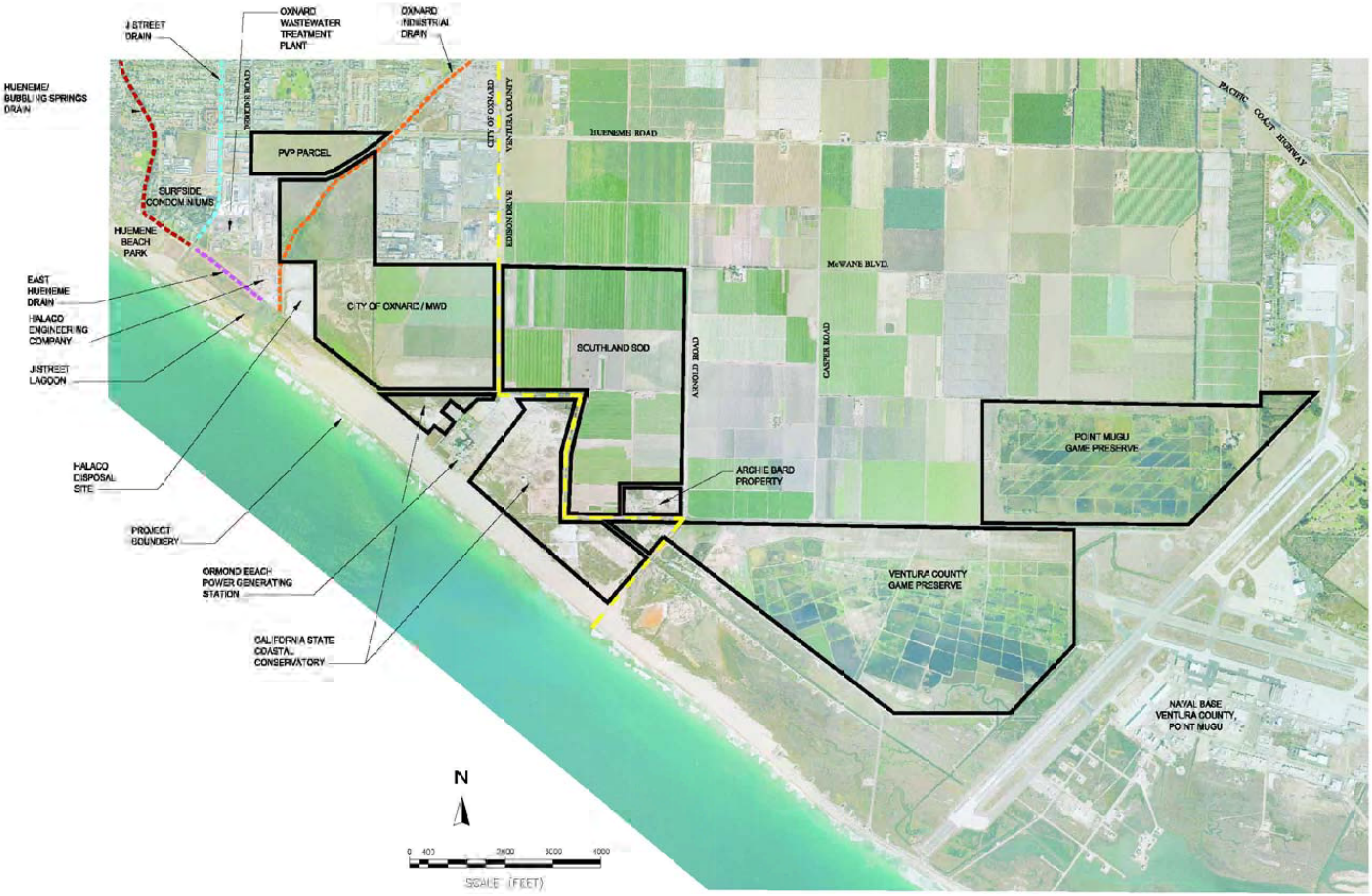

figure 2

Ormond Beach Wetland Restoration Project: Hydrologic and Geomorphic Conditions Report

Project Site Plan

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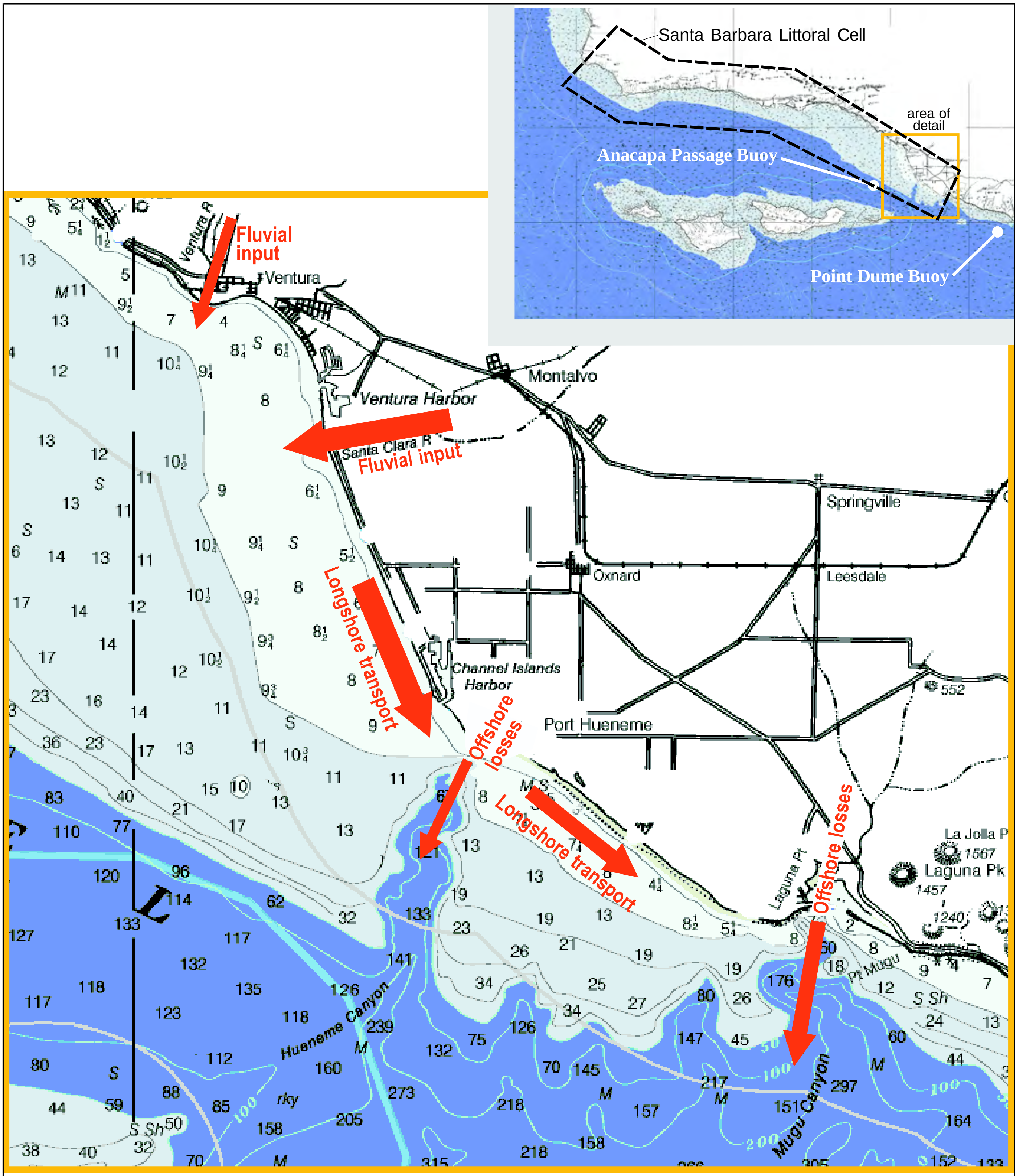

figure 3

Ormond Beach Wetland Restoration Project: Hydrologic and Geomorphic Conditions Report

Map of Littoral System and Buoy Location

1738/Littoral.cdr

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figure 4

Ormond Beach Wetland Restoration Project:
Hydrologic and Geomorphic Conditions Report

Local Drainages

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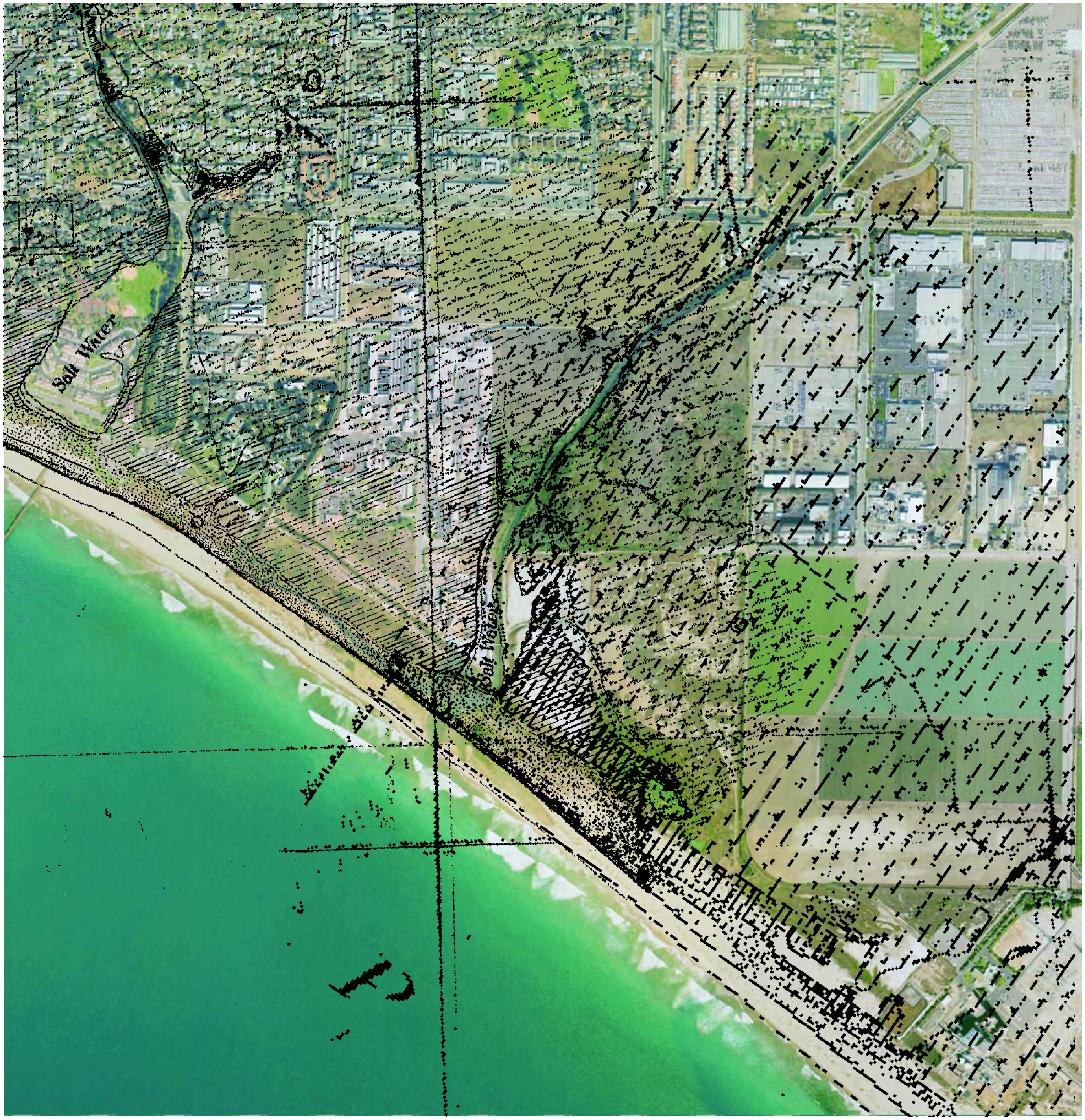

figure 5

Source:
1855 U.S. Coast Survey
2003 aerial photograph

Ormond Beach Wetland Restoration Project:
Hydrologic and Geomorphic Conditions Report

Historic Habitat and Present Day Land Use

1738/hist-overlay2.cdr

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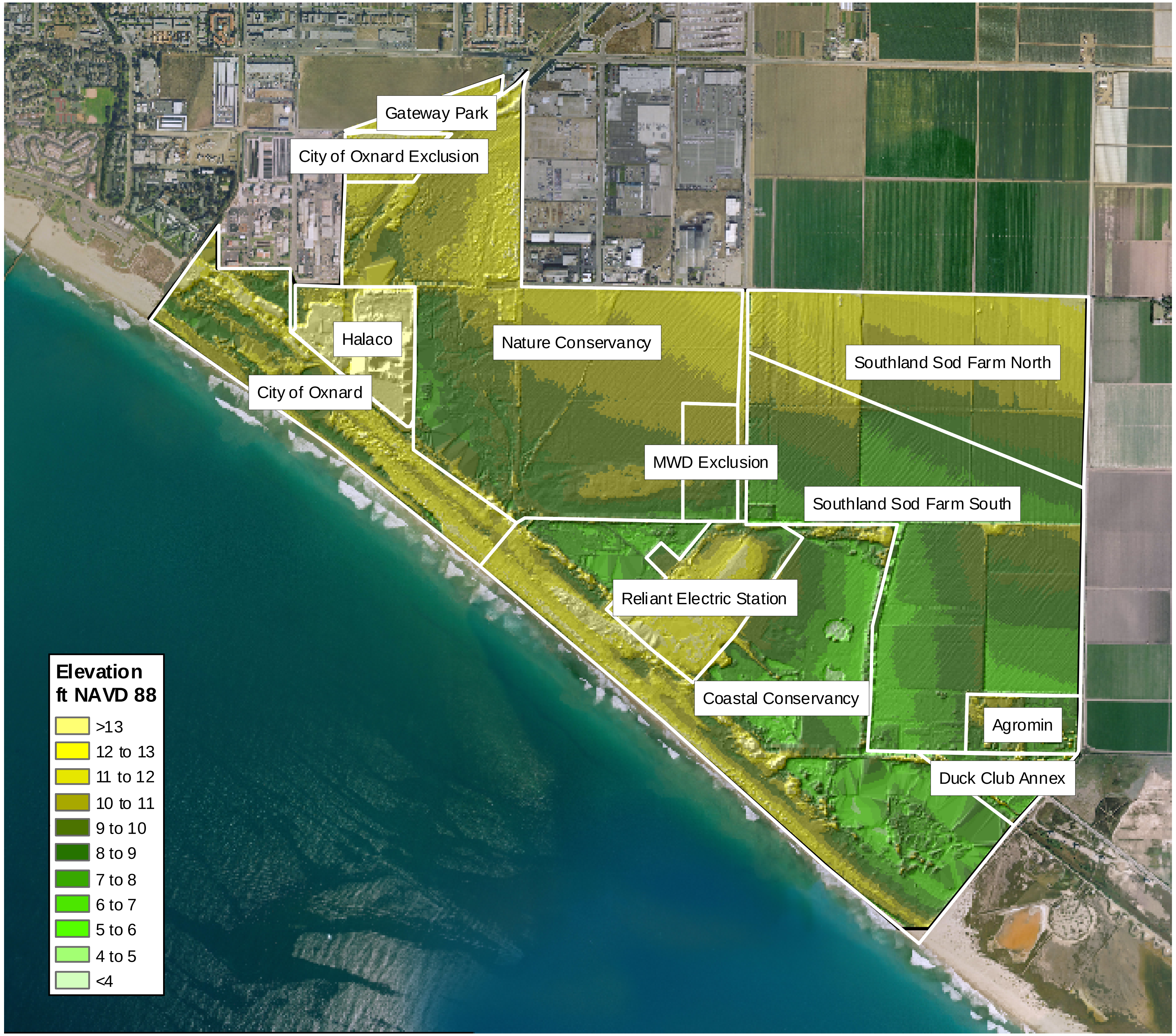

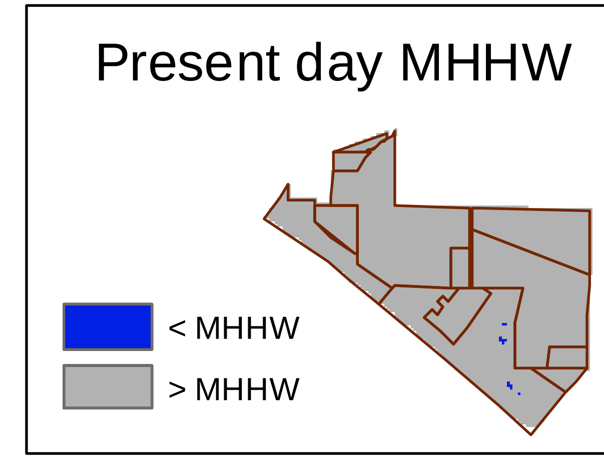

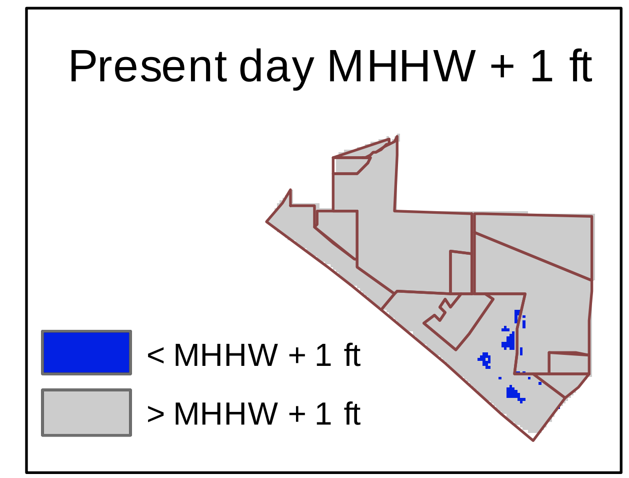

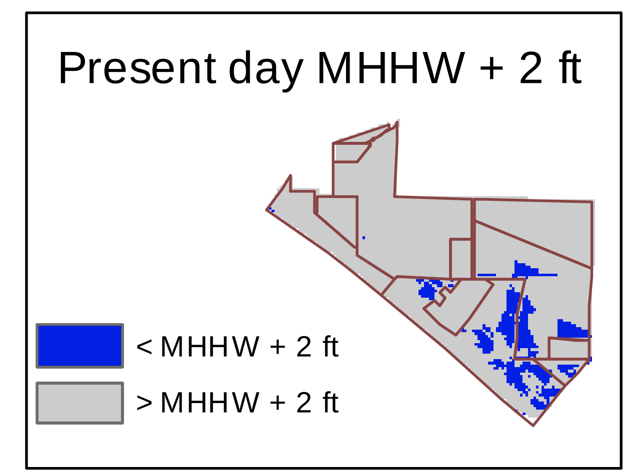

Source: Topography from LiDAR survey by Towill (2001)

Notes: The property boundaries depicted in this figure are for general planning purposes only. They have not been surveyed and may not coincide exactly with parcel-specific legal boundaries.

Feet

0 2,750 5,500 11,000

Ormond Beach Wetland Restoration Feasibility Study

Existing Site Topography

PWA Ref # - 1738.9

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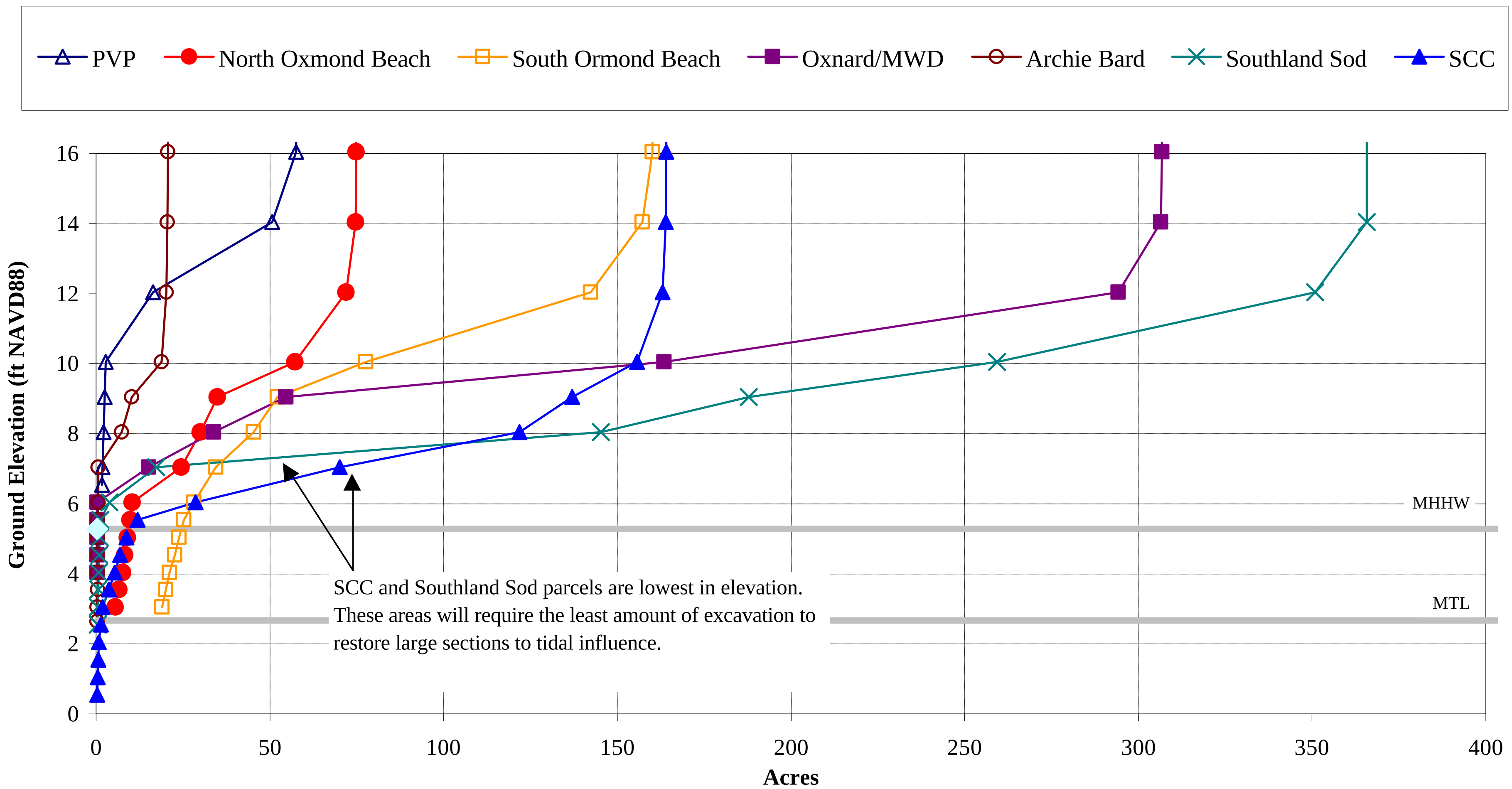


Notes: Mean Higher High Water (MHHW) is 5.23 ft NAVD88, based on published tidal datums at Santa Monica (CO-OPS).

Source: Topography from LIDAR survy by Towill (2001).

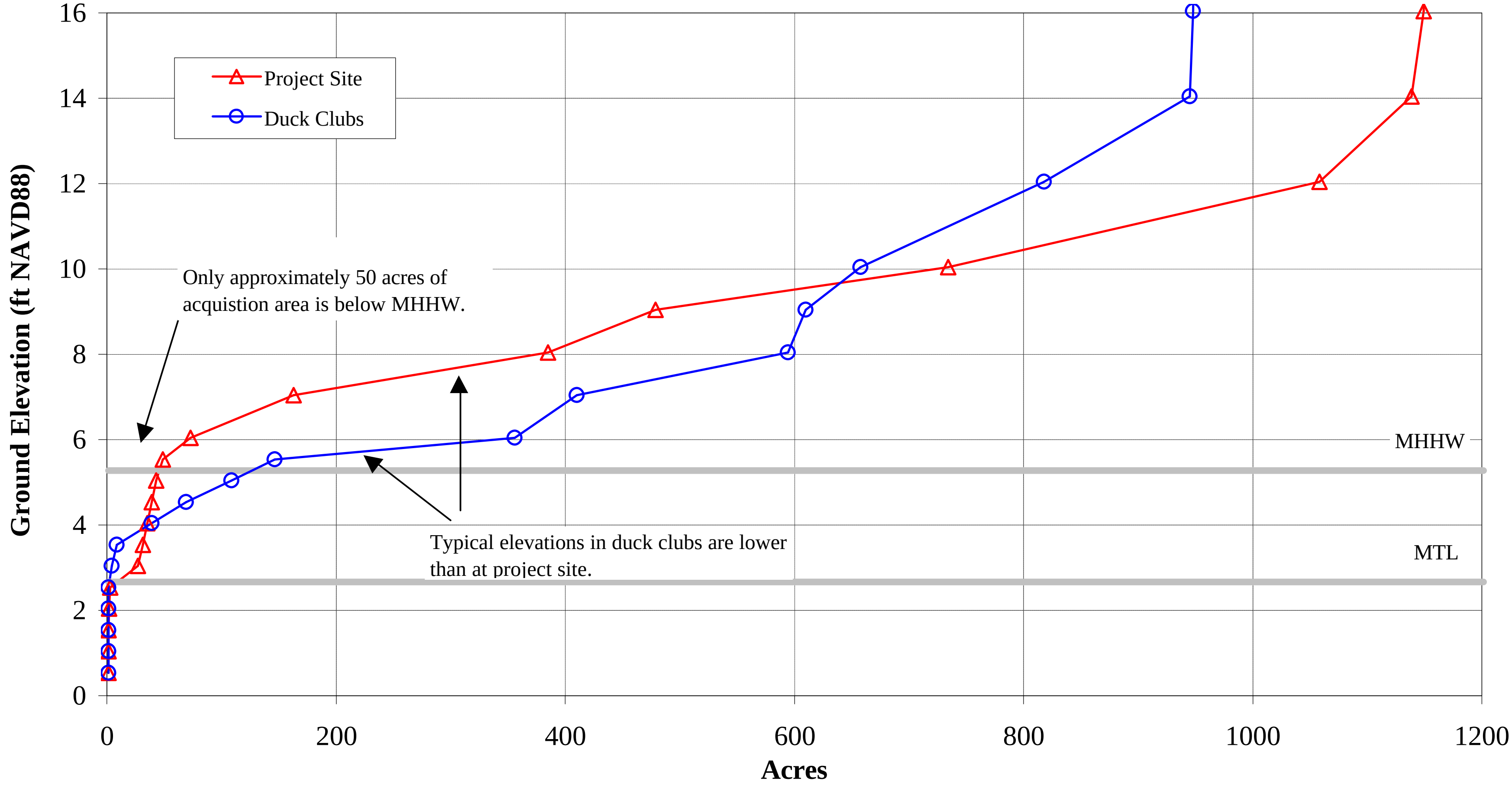
figure 6

Ormond Beach Wetland Restoratoin Feasibility Study: Hydrologic and Geomorphic Conditions Report

Site Hypsometry by Parcel

PWA REF 1738-04

PWA



Notes: Mean Higher High Water (MHHW) is 5.23 ft NAVD88, based on published tidal datums at Santa Monica (CO-OPS).

Source: Topography from LIDAR survy by Towill (2001).

figure 7

Ormond Beach Wetland Restoration Feasibility Study:
Hydrologic and Geomorphic Conditions Report

Hypsometry of Project Site

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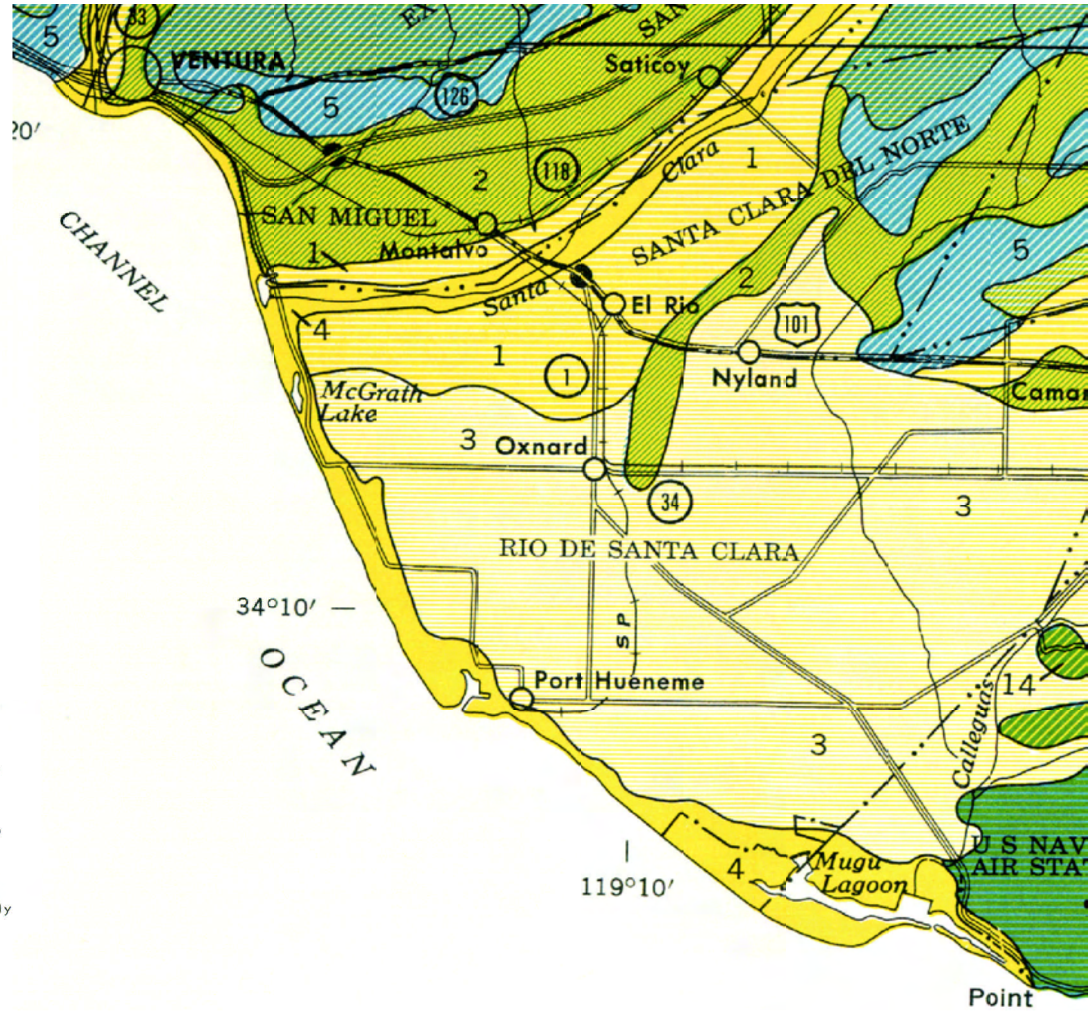
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

UNIVERSITY OF CALIFORNIA
AGRICULTURAL EXPERIMENT STATION

GENERAL SOIL MAP

VENTURA AREA, CALIFORNIA



SOIL ASSOCIATIONS

LEVEL TO MODERATELY SLOPING, EXCESSIVELY DRAINED TO POORLY DRAINED SOILS OF THE ALLUVIAL FANS, PLAINS, AND BASINS.

1	Pico-Metz-Anacapa association: Level to moderately sloping, very deep, well-drained sandy loams and very deep, somewhat excessively drained loamy sands.
2	Mocho-Sorrento-Garretson association: Level to moderately sloping, very deep, well-drained loams to silty clay loams.
3	Camarillo-Hueneme-Pacheco association: Level and nearly level, very deep, poorly drained loamy sands to silty clay loams.
4	Riverwash-Sandy alluvial land-Coastal beaches association: Level to gently sloping, excessively drained to poorly drained, stratified sandy, gravelly, and cobbly material.

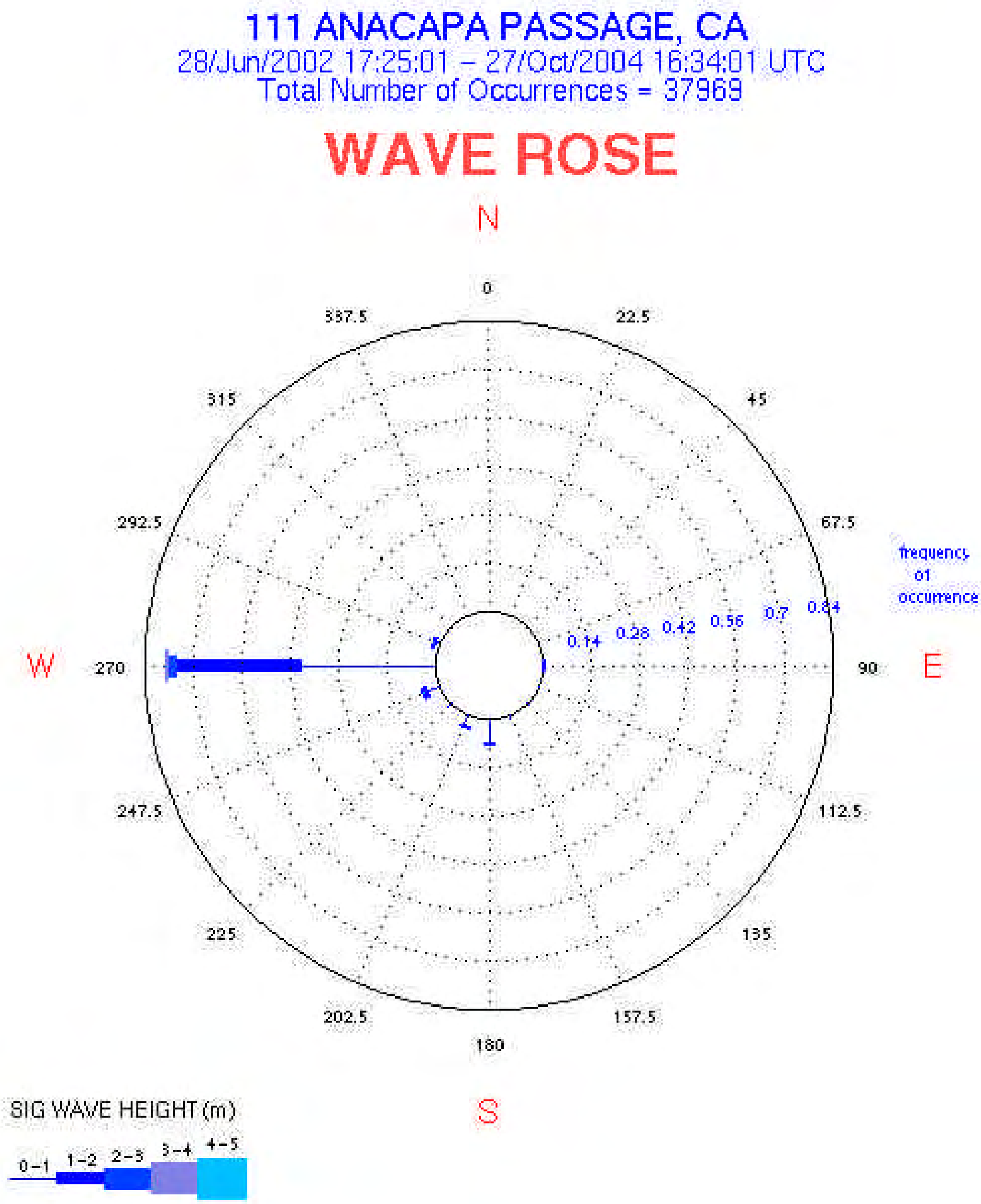
figure 8

Ormond Beach Wetland Restoration Project:
Hydrologic and Geomorphic Conditions Report

General Soil Map

1738/soils.cdr

PWA



The length of each petal (or segment of a petal) defines the frequency of occurrence. There are sixteen direction sectors and each sector covers 22.5°.

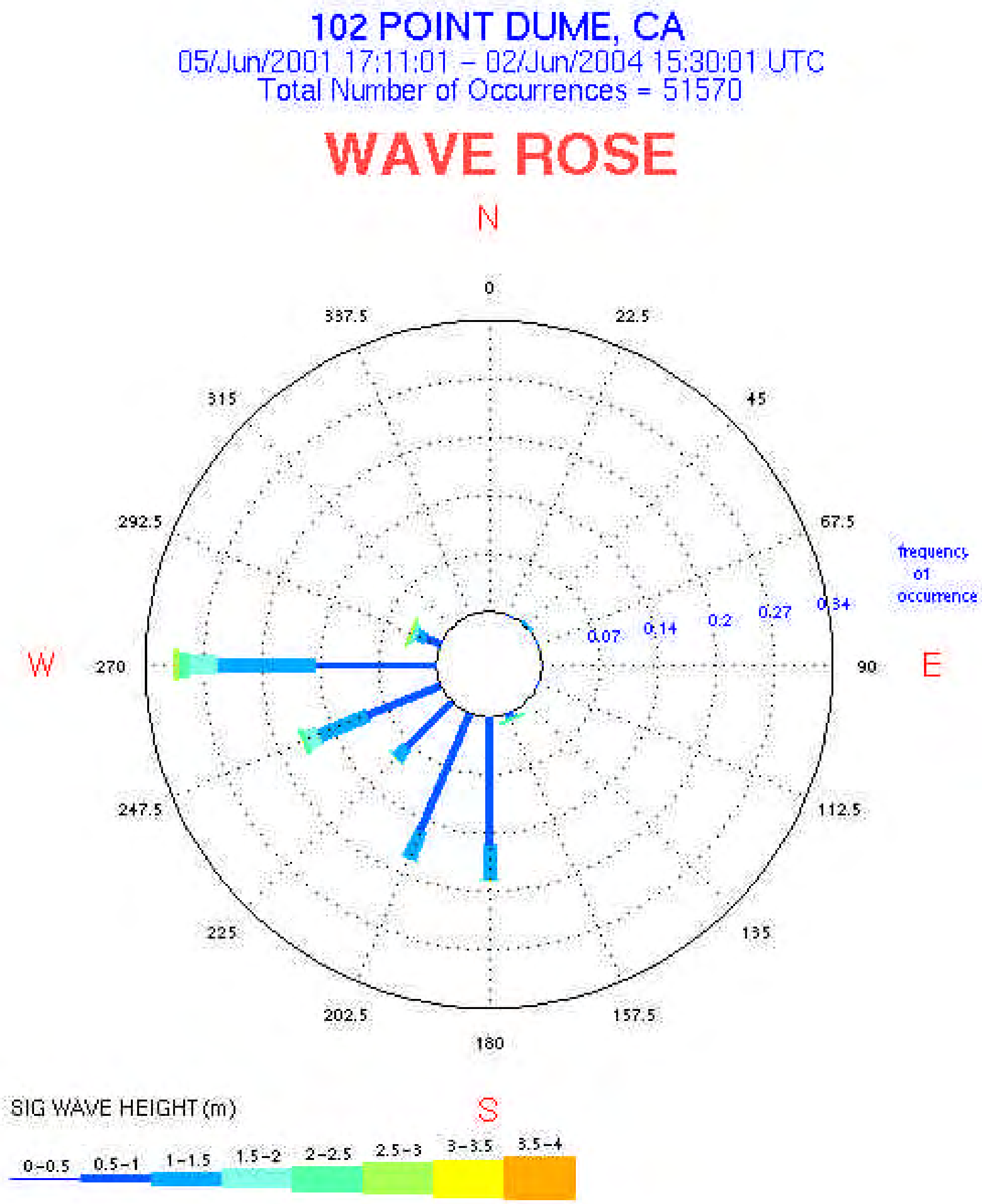
figure **9**

Ormond Beach Wetland Restoration Project: Hydrologic and Geomorphic Conditions Report

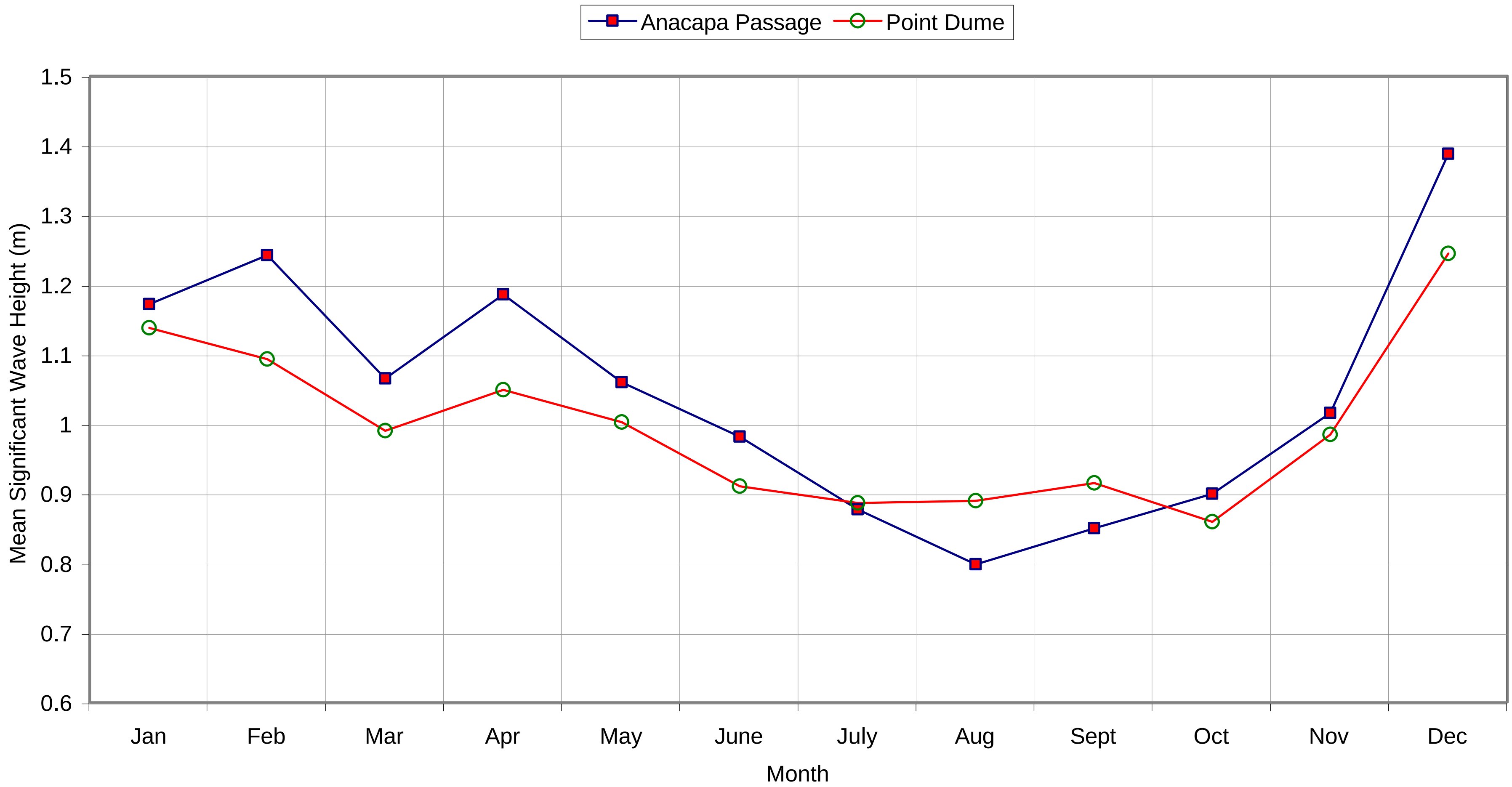
Wave Rose for Anacapa Passage

PWA Ref# 17384-04

PWA



The length of each petal (or segment of a petal) defines the frequency of occurrence. There are sixteen direction sectors and each sector covers 22.5°.	*figure* **10** *Ormond Beach Wetland Restoration Project: Hydrologic and Geomorphic Conditions Report*
	Wave Rose for Point Dume
	PWA Ref# 17384-04



Notes: Significant wave height is average of highest 1/3rd waves.
Source: CDIP

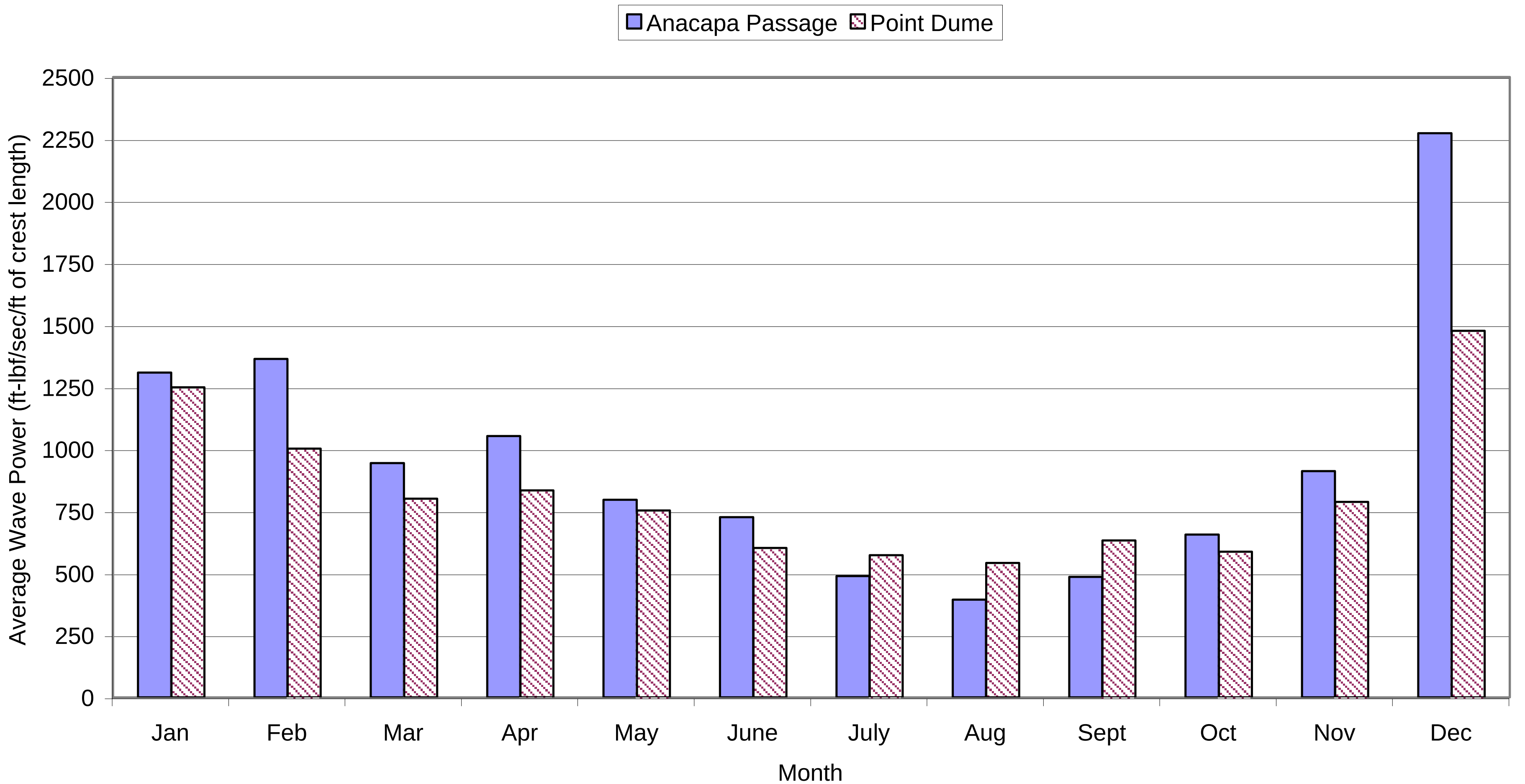
figure 11

Ormond Beach Wetland Restoration Feasibility Study:
Hydrologic and Geomorphic Conditions Report

Monthly Mean Wave Heights at Offshore Buoys

PWA REF 1738-04

PWA



Source: CDIP

figure 12

Ormond Beach Wetland Restoration Feasibility Study:
Hydrologic and Geomorphic Conditions Report

Average Wave Power at Offshore Buoys

PWA REF 1738-04

PWA

figure **13**

Ormond Beach Wetland Restoration Feasibility Study: Hydrologic and Geomorphic Conditions Report

Plan View of Ormond Beach Profiles

Notes:
Cross sections field surveyed on July 28, 2004.
Aerial photo from April 2001.

PWA#1738.00

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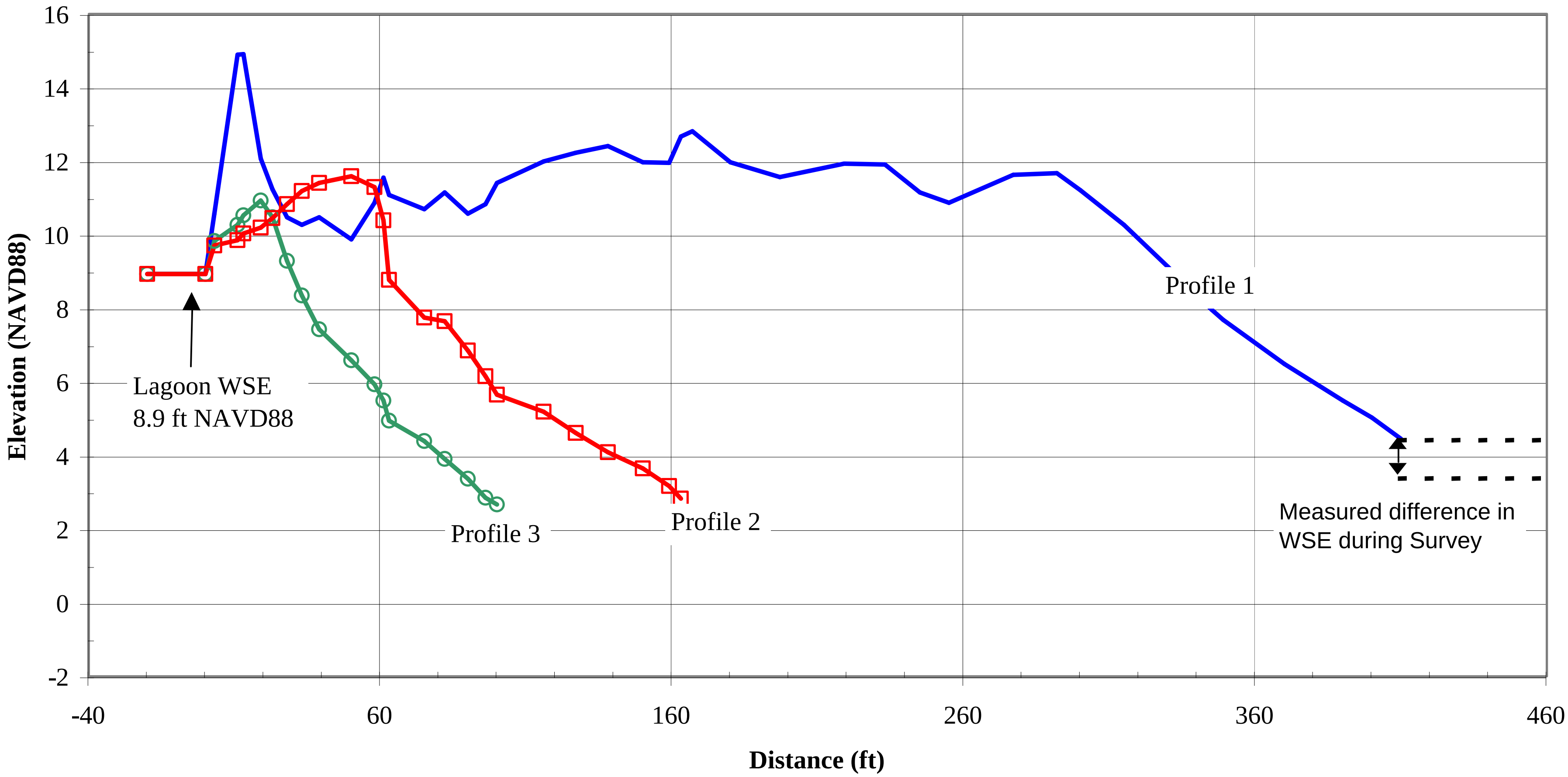


Source: PWA survey 7/28/2004

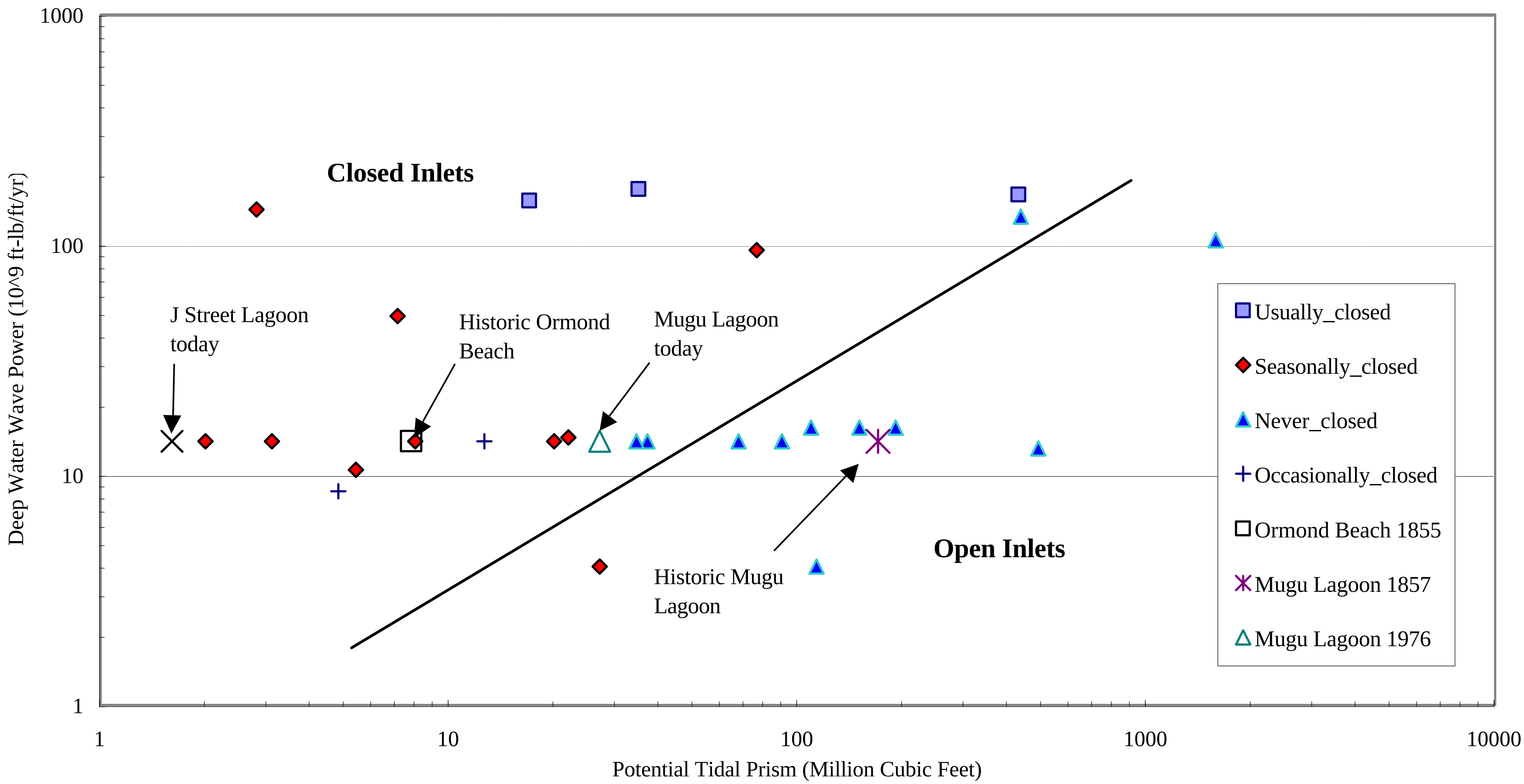
figure 14

Ormond Beach Wetland Restoration Feasibility Study:
Hydrologic and Geomorphic Conditions Report

Ormond Beach Profiles

PWA REF 1738-04

PWA



Notes
Source

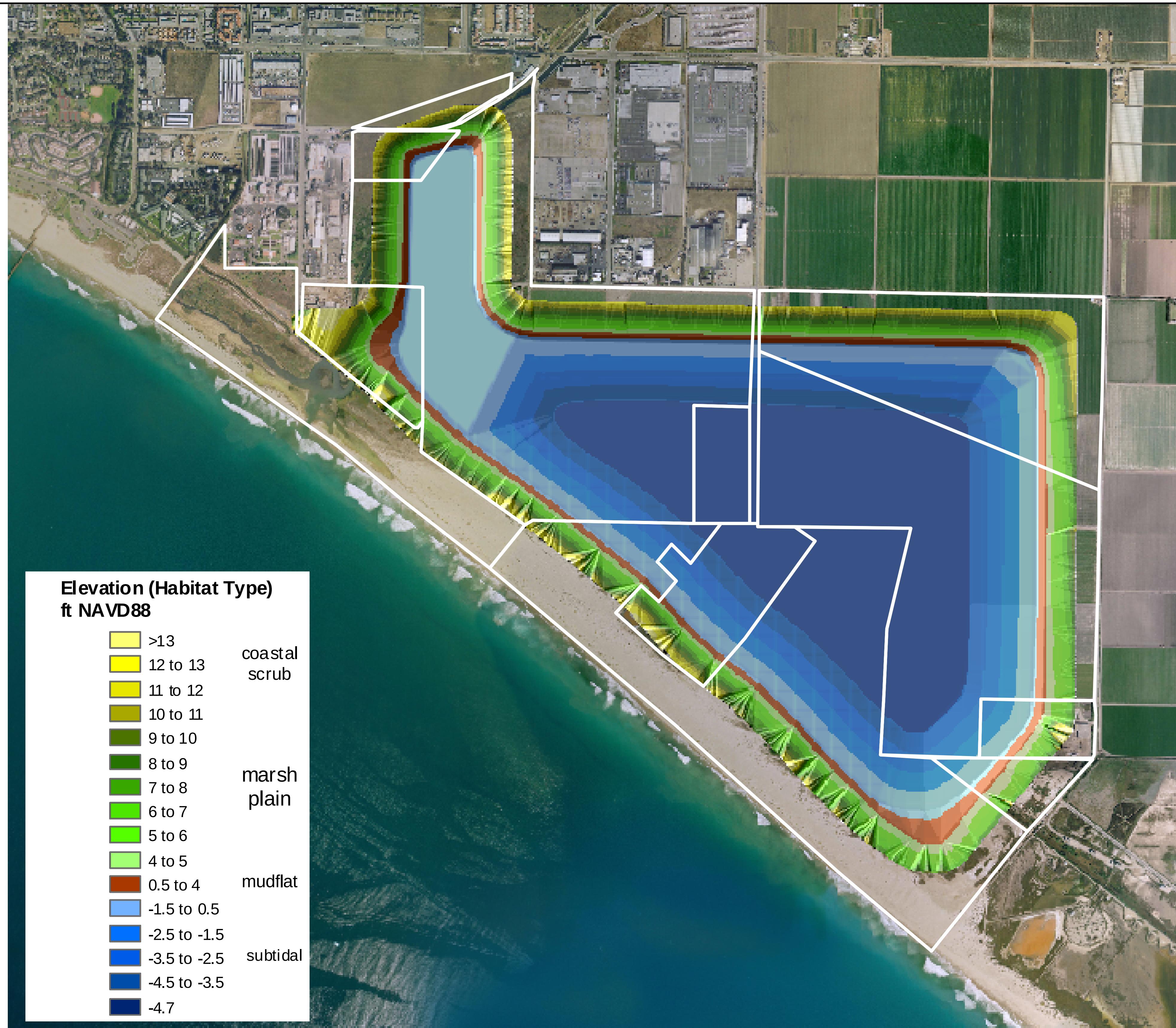
figure 15

Ormond Beach Wetland Restoration Feasibility Study:
Hydrologic and Geomorphic Conditions Report

Inlet Stability of Coastal Lagoons

PWA Ref 1738-04

PWA



Notes: Preliminary lagoon topography for discussion purposes only

Ormond Beach Wetland Restoration Feasibility Study

Proposed Unconstrained Tidal Lagoon

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Appendix A

Habitat Requirements for Key Species

(Prepared by WRA)

SPECIES	HABITAT REQUIREMENTS
Plants	
red sand-verbena *Abronia maritima*	This species occurs optimally on semi-stabilized dunes which are subject to salt spray. This species cannot tolerate freshwater or drought conditions. Red-sand verbena has been documented within the coastal foredune habitat in the southern region of the Study Area (Jones and Stokes Associates, Inc. 1998).
Ventura marsh milk-vetch *Astragalus pynostachyus var lanosissimus*	The only putatively natural population of this species is within Oxnard, Ventura County, California. The remaining population has been composed of 30-50 reproductive plants per year, but as many as 300 vegetative plants have been observed during years with above normal precipitation and cool summers. Ventura marsh milk-vetch has been documented on well-drained soils of open sites in coastal habitats, often on bluffs or flats near bodies of brackish water or with a relatively high water table, in association with *Baccharis pilularis, Malosma laurina*, and *Toxicodendron diversilobum*. Historic records, and the location of the single known natural population suggests that this species may survive where summer fog ameliorates the otherwise hot summers. Survivorship of experimental populations was highest at sites with high water tables providing fresh or brackish water, as compared to salt water from nearby salt marshes. An experimental population has been planted within the transitional habitat adjacent to the diked coastal salt marsh habitat located to the southwest of the Reliant Ormond Beach Generating Station.
southern tarplant *Centromadia parryi ssp. australis*	This species occurs in valley and foothill grasslands, alkaline soils, and peripheral salt marsh habitats. At the Del Mar locale the soils are mapped as Chino silt loam and the salt marsh vegetation is found only yards away. At Newport Back Bay this tarplant grows in mesic grasslands with an ocean influence; most of the surrounding vegetation here consists of invasive non-native weeds.
Orcutt's pincushion *Chaenactis glabriuscula var. orcuttiana*	Ecological studies of this species' habitat requirements are lacking; however, it is known to occur within open, dry sand dunes adjacent to the ocean.

salt marsh bird's-beak *Cordylanthus maritimus ssp. maritimus*	This species was once a common plant of the upper marsh. This annual species germinates best after seeds have had a cold treatment and is densest in or near open habitats. Salt marsh bird's-beak is rarely discovered very far from the highest high tide elevations, usually on the upper ecotonal edge with the surrounding habitat (coastal scrub, housing developments). Salt marsh bird's beak was observed growing at the saltmarsh/coastal foredune interface within the Study Area. Additionally, several patches were observed in managed duckponds dominated by saltmarsh vegetation. The higher elevations of the salt marsh and managed duck ponds are frequently known to contain salt pannes, which are areas of the salt marsh devoid of vegetation, probably as a result of their high surface soil salinities (160 ppt). In southern California marshes there are usually Cordylanthus plants in the islands of vegetation in the middle of these salt deserts as well as around the edges. Because this species is an annual plant it is evident only for short periods during the spring and summer. It is thought that this species can survive the warm dry summer without frequent tidal submergence because it is an obligate hemiparasitic plant. Its roots develop haustoria that penetrate a variety of other species, especially *Distichlis spicata* and *Monanthochloe littoralis* to gain water and nutrients. A little disturbance appears to open habitat for seedling establishment and the activities of mammals may be an important part of the plant's ecology. However, too much disturbance (e.g., repeated trampling, soil compaction) prevents survival. In addition, ground nesting bees (*Bombus spp.*) and tiger beetles are thought to be the known pollinators for this species. Therefore, management efforts should also focus on providing the necessary habitat for salt marsh bird's beak pollinators.
dune larkspur *Delphinium parryi ssp. blochmaniae*	Ecological studies of this species' habitat requirements are lacking; however, it is known to occur within rocky or sandy areas within coastal scrub or sand dunes. Documented species occurrences indicate that this species prefers stabilized dunes communities that are relatively dry and that do not become inundated by tides.
beach spectaclepod *Dithyrea maritima*	Beach spectaclepod is a low growing, whitish-flowered perennial herb often found in small transverse foredunes within approximately 50-300 meters from the surf. Beach spectaclepod is usually found in areas of these fragile dunes where the sand is relatively unstable.

spiny rush *Juncus acutus ssp. leopoldii*	This species may have formed a conspicuous band around the upper marsh of pre-1900 wetlands, but only remnant populations are now found in southern California. Its distribution may correspond with high groundwater levels but with lower soil salinities than adjoining halophytic plant community; however, ecological studies are lacking.
Coulter's goldfields *Lasthenia glabrata ssp. coulteri*	This species occurs in tidal and saline seasonal marsh areas near the coast at the extreme upper end of tidal inundation. It has also been noted on the periphery of vernal pools such as near Miramar Airfield. This species is also found in alkaline marshes in the inland valleys of western Riverside County; *Frankenia salina* may grow nearby. This species has been documented within the palustrine emergent-persistent (*Salicornia, Jaumea, Atriplex*) seasonally-flooded-mixohaline-mid-high-diked-estuarine salt marsh wetland habitat (Jones and Stokes Associates, Inc 1998; CDFG 2004).
estuary seablite *Suaeda esteroa*	Estuary seablite is often found at the periphery of coastal salt marshes, frequently growing with *Salicornia subterminalis*. Soils at such locales are usually mapped as tidal flats and can be high in clays, silts, or sands. Oftentimes, only a narrow band of terrain on the very periphery of the salt marsh is utilized by this species.
wooly seablite *Suadea taxifolia*	This herbaceous perennial is usually restricted to coastal salt marshes; it rarely grows in peripheral scrublands adjacent to salt marshes or as isolated plants along beaches. Woolly seablite grows directly on the coast in areas with high salt content in the soil, water and air. This species likes full sun, and seaside conditions. It can tolerate salt, no drainage, and seasonal flooding.
Mammals	
southern California saltmarsh shrew *Sorex ornatus salicornicus*	This species' habitat requirements are poorly understood. It likely requires dense salt marsh habitat with nesting sites above the mean high tide line and fairly moist surroundings. This species was observed in the Study Area in saltmarsh habitat east of the slag pile in 1991. It may occur in saltmarsh habitat areas throughout Study Area.
Birds	
California brown pelican *Pelecanus occidentalis californicus*	This species utilizes mainland beaches, estuaries and lagoons for post-breeding dispersal, roosting and foraging. It may forage in estuarine, marine subtidal and marine pelagic habitats. This species roosts on the beach adjacent to J-Street Lagoon and can be seen flying over the entire Study Area. Nearby Mugu Lagoon is an important estuarine roost site.

light-footed clapper rail *Rallus longirostris levipes*	This species is associated with dense stands of cordgrass and pickleweed in southern coastal salt marshes. It utilizes adjacent shallow waters and mudflats for foraging on benthic invertebrates and takes cover in higher vegetation during high tides. High marsh and upland areas are essential to the survival of this species because they provide cover during high tides and winter storms when their primary habitat is inundated. Clapper rail nest in tall cordgrass where it builds a floating nest covered by the canopy of the flowering stems. This species is known to inhabit marshes at Mugu Lagoon (Tetra Tech 2002). Suitable habitat is available in the Study Area in southern coastal saltmarsh and coastal freshwater/brackish marsh areas.
western snowy plover *Charadrius alexandrinus nivosus*	This species occupies barren to sparsely-vegetated beaches, dunes, and salt pond levees in close proximity to ocean shoreline, mudflats, salt pannes/salt ponds, and sand flats. At the Study Area, this species breeds in the spring and summer in the coastal foredune habitat and utilizes ocean shoreline, palustrine emergent-persistent (*Scirpus*, *Typha latifolia*, *Distichlis spicata*) semi-permanently-flooded lagoon shore wetland habitat, and adjacent open waters for foraging opportunities. Salinity range: not available. This species is present at the Study Area along Ormond Beach from the J-street drain lagoon south to the Naval property boundary at Arnold Drive.
California least tern *Sterna antillarum (=albifrons)browni*	This species is associated with shallow tidal areas as well as deeper estuarine habitats. It requires large tracts of open sand or fine gravel substrate with sparse vegetation for nesting including, beaches, dunes, and unvegetated islands. This species tolerates a range of salinity levels as long as adequate numbers of small fish prey such as northern anchovy and silversides are supported. Such fish are usually found at marine or estuarine salinity levels. This species nests and roosts in the coastal foredune habitat at Ormond Beach and forages in the J-Street lagoon, nearby drainage channels and the Pacific Ocean.
Belding's savannah sparrow *Passerculus sandwichensis beldingi*	This species occupies the mid- to upper littoral zone of coastal saltmarsh habitats. It prefers to nest in pickleweed vegetation in areas of infrequent tidal inundation, preferably above the highest spring tides. It is capable of drinking salt water and tolerates salinity ranges that maintain the saltmarsh vegetation and invertebrate prey it requires for cover and food. This species is present in the southern coastal salt marsh habitat within the Study Area.

Fishes	
tidewater goby *Eucyclogovius newberryi*	This species is a benthic species that occupies low-salinity waters in shallow lagoons and the lower reaches of coastal streams. It has been documented in water temperatures from 35 to 73 degrees Fahrenheit, depths of 5 to 7 feet, and salinities from zero to 10 parts per thousand. The tidewater goby spends all life stages in the brackish waters of coastal lagoons. This species has been observed in the Oxnard Drain (J-Street Canal) at the Study Area.