Appendix A
Historical Conditions

APPENDIX A
Historical Conditions

1. Introduction

Understanding historical landscape patterns, their physical and ecological characteristics, the dynamic processes that shape the landscape, and the effect of human alterations is an important step in determining appropriate goals and opportunities for restoration and conservation. Historical ecology focuses on the interactions between people and the environment over long periods of time. This report focuses on aspects of the historical ecology of the Ormond Beach area to inform the Ormond Beach Restoration and Public Access (OBRAP) planning process.

The San Francisco Estuary Institute (SFEI) presents an excellent and detailed analysis of the historical ecology of the Ventura coast using the earliest maps, photographs, and historical accounts (Beller et al. 2011). Their analysis focuses on what our coastal wetlands and associated habitats might have looked like in the mid to late 19th century and how they changed in to the early 20th century. These early sources are our best chance at understanding our natural landscapes as they existed before the wholesale changes that have occurred over the last 150 years.

However, humans (Native Americans and early European settlers) were already having dramatic impacts on California's landscapes prior to the earliest maps and photographs and modifications to natural features have continued until recent times. Just as importantly, California's coastal ecosystems are naturally dynamic and are constantly responding to, and recovering from, rare extreme natural events and, in more recent times, man-made alterations. This report augments the SFEI analysis with additional references and assesses changes that have occurred from the early 20th century up until recent times.

2. Natural Dynamics

Southern California's landscapes have never been fixed. They respond in dramatic ways to natural forces including droughts, floods, geologic shifts (uplift or subsidence), tsunamis, and large wave events. The coast between the Ventura River and Point Mugu is a vast delta formed by the Santa Clara River, and to a lesser extent the Ventura River and Calleguas Creek. These rivers, especially the Santa Clara, have shifted course over the last several hundred years in response to natural forces (Beller et al. 2011). Estuaries formed at these shifting river mouths, a process repeated over thousands of years. The result was a dynamic complex of coastal wetlands that were intermittently connected to rivers and the ocean. Based on maps made in the 1850s

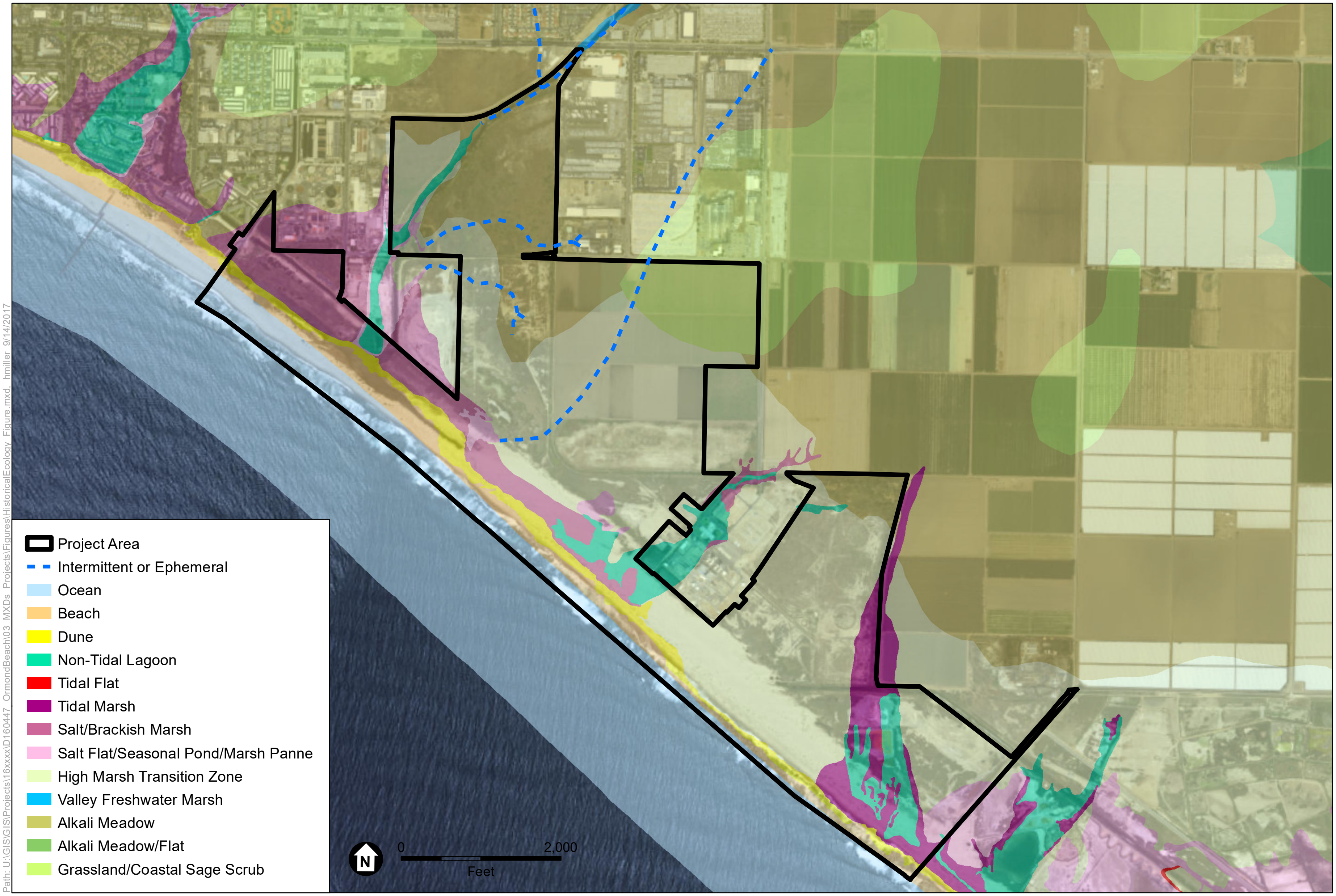
(**Figures A-1 and A-2**), Beller et al. (2011) estimated there were over 2,600 acres of open water, marsh, and transition habitats between (but not including) the current mouth of the Santa Clara River and Mugu Lagoon. These coastal wetlands functioned differently when they were connected to riverine inputs compared to periods when river mouths shifted elsewhere. Evidence suggests that the Santa Clara River may have moved to its current location as recently as 1812. Prior to this time the mouth was probably located near present day Port Hueneme with previous channels and estuaries more or less at the current location of the Ormond Lagoon (Beller et al. 2011).

Seven wetland areas with open water were mapped in the 1850s between Point Hueneme and Mugu Lagoon (Figure A-2). These probably represent historic mouths of the Santa Clara River. Early maps and other historical sources suggest that most of these wetlands were hydrologically connected to each other (at least in wet years), saline (brackish to hypersaline), and generally non-tidal (Beller et al. 2011). The source of salt was probably wave over-wash of the beach/dunes during winter storms. The wetlands in the vicinity of the Beach likely only connected to the tidal Mugu Lagoon in very wet years (presumably draining to the Mugu Lagoon). The lagoon just east of Hueneme (Figures A-1 and A-2) was noted in the late 1800s to have perennial fresh-to-brackish water and was fed by springs (Beller et al. 2011). Surface or sub-surface flows from the springs may have influenced the wetland areas further east as well. In general, though, these eastern wetland areas were probably intermittently flooded by rainfall or wave over-wash events as they tended to be referred to either as ponds or salt flats at various times.

3. Early Human Influences

Humans probably arrived in Southern California about 13,000 years ago (though recent evidence suggests the date may be closer to 130,000 years ago (Holen et al. 2017)) near the end of the Pleistocene Epoch. About 11,000 years ago, the diverse Pleistocene megafauna that had characterized much of California for over a million years was extinct. The loss of these huge grazers likely caused major shifts in plant communities. Over the next several millennia, early human societies manipulated landscapes with fire (intentionally or otherwise), moved species around (intentionally or otherwise), and employed various forms of agriculture.

By the time the first Europeans arrived in California in the early 16th century, the landscape looked very different. The Portola Expedition of 1769, one of the first overland explorations of Southern California, provided some accounts of what the landscapes looked like and how the Native Americans lived in relation to the land before European settlers arrived. The expedition passed through the Ventura area twice, but they reported little related to the natural landscapes. They found a large town of natives established near the mouth of the Ventura River. When they left Ventura heading north, Fray Juan Crespi wrote: "*At the start we crossed the river, which gave us some trouble on account of the stones and the large amount of water which ran above them*." (Bolton 1927). The observation of so much water is noteworthy since it was mid-August. Today, it would be rare for there to be significant natural flow in the Ventura River near the coast in August. The coastal wetlands of Ventura County probably experienced different hydrologic conditions before human modifications to streams, rivers, and shallow groundwater modifications began in the early 1800s.



Source: ESRI 7/19/2016, San Francisco Estuary Institute, Ventura County,

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Figure A-1
Project Area Historic Ecology
in the Early 1800s

ESA

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SOURCE: U.S. Coast Survey Maps of California

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Figure A-2
1855/57 Coast Survey T-Sheets

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4. The Spanish and Mexican Ranchos (1780s–1860s)

Spanish colonists soon followed the Portola Expedition, establishing a mission at Ventura in 1782. The missionaries brought an end to most of the traditional hunting, gathering, and agricultural practices of the Native American societies in the region. The natural landscapes of Southern California would undergo huge changes again. The Spanish introduced many plants (intentionally and unintentionally) and livestock to California. Agriculture expanded using Native American labor, and ranching became the backbone of the new economy.

The Mission San Buenaventura brought the first European-style agriculture to the area along with cattle and sheep. At its height, the mission's herd included 23,000 cattle and 12,000 sheep, which ranged throughout the Oxnard Plain and surrounding hills (San Buenaventura Research Associates 2014). All California missions were secularized in 1833, and their lands seized by the Mexican government and subsequently granted to Mexican citizens. The settlers primarily raised cattle, which grazed throughout the landscape and had devastating impacts on natural communities. During droughts, cattle and sheep would eat almost anything that was green, leaving vast tracts of land totally unvegetated. During this period plants introduced from Europe became invasive in their new setting. By the early 1800s invasive plants such as black mustard (*Brassica nigra*) dominated huge tracts of land throughout Southern California (Minnich 2008).

The profound impact of grazing on the habitats and natural processes was exacerbated during extreme natural events. In the winter of 1861-62 a storm battered California for several weeks straight, causing catastrophic flooding (Dettinger and Ingram 2013, Ingram 2013). The Ventura area reportedly received rain for 60 straight days (Mason 1883) during this atmospheric river event. Mason (1883) described conditions in Ventura thus: *"...so many land-slides happened that the face of the country was materially changed. In certain localities half of the land was moved a greater or less distance.*" This epic event delivered huge amounts of sediment into coastal wetlands and probably led to lasting changes to landforms and habitat distributions.

5. Farming, Hydrological Modifications, and Industrial Uses (1860s–Present)

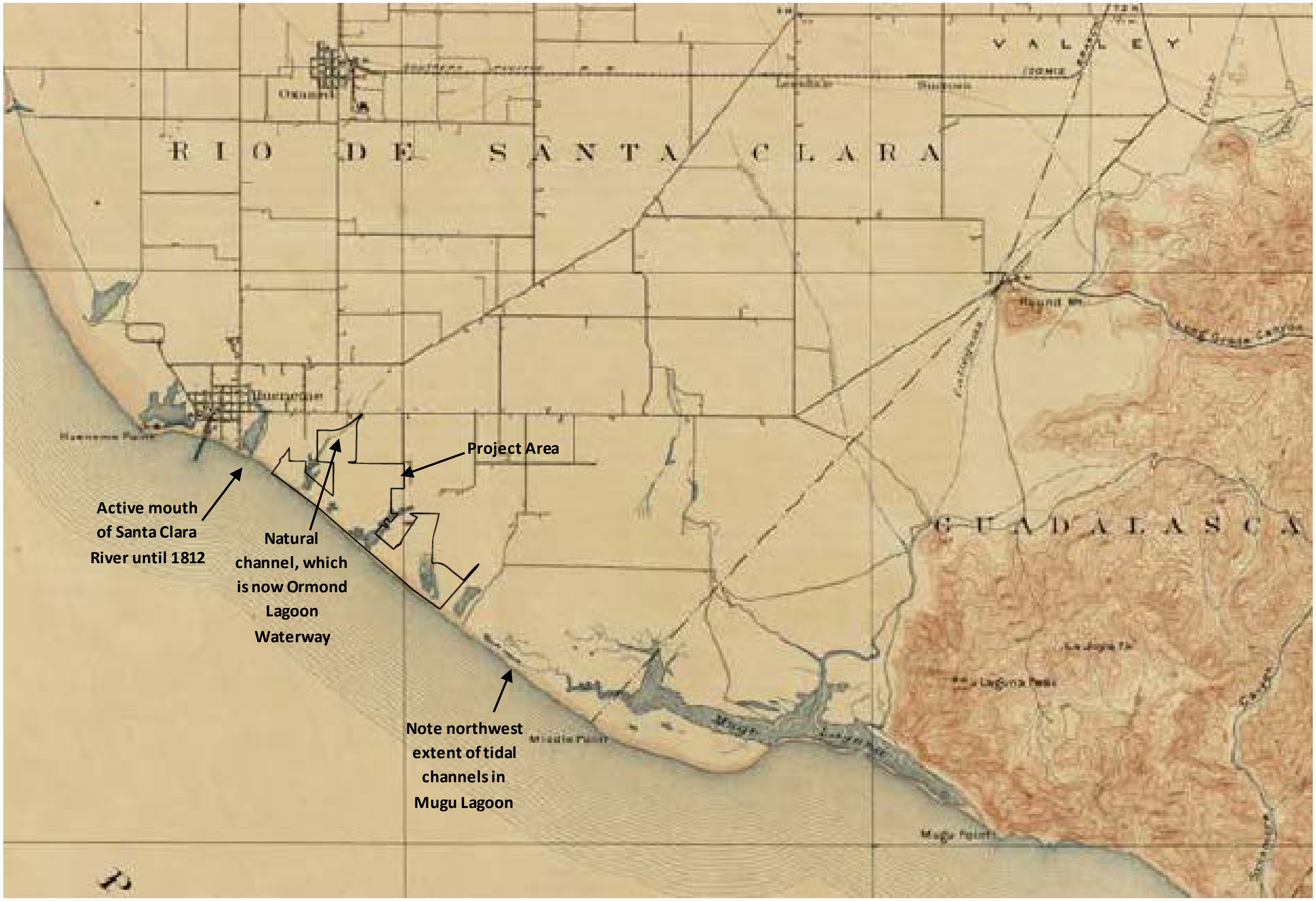
Following the devastating drought of 1863–64, in which the majority of cattle starved to death, the Southern California economy shifted from ranching towards farming (Troxell 1957), especially in areas with fertile soil and a water source for irrigation. Rapid conversion began on the Oxnard Plain in 1868, and by the early 1870s most of the plain was being farmed (Storke 1891).

The expansion of farming increased demand for more reliable sources of water, which led to hydromodification of the area. In 1871, the Santa Clara Irrigation Company was formed and dug a 12-mile-long canal (plus side branches) from the Santa Clara River to lands of an old rancho. This canal is not seen on early maps but followed what is, today, Rose Avenue from El Rio to Hueneme (San Buenaventura Research Associates 2014). As early as 1871, farmers on the Oxnard Plain started digging wells 125 to 150 feet deep that produced artesian flows. One well was said to be sufficient to irrigate 160 acres of grain (Storke 1891). A well dug by T.R. Bard in 1871 near Hueneme produced so much water that a ditch was dug to carry away the excess (Storke 1891). By the early 20th century, however, pumps were needed on most wells (San Buenaventura Research Associates 2014) as the aquifer was depleted.

The digging of ditches to control the movement of water continued as farming spread throughout the area. Tile drains were installed to drain salty marshland starting in 1901 (San Buenaventura Research Associates 2014) north of Hueneme (**Figure A-3**). South of Point Hueneme, agriculture had crept close to the coast by 1929, although the various lagoons in this area were still relatively intact (**Figure A-4**). The 1943 topographic map (**Figure A-5**) shows a ditch, referred to as Old Oxnard Drain or East Hueneme Drain, that leads from Bubbling Springs to Mugu Lagoon. This ditch can also be seen in an aerial oblique photo from 1942 (**Figure A-6**) and in the 1945 aerial (**Figure A-7**). The series of wetlands seen on earlier maps (Figure A-3) and aerial photos (Figure A-4) between Hueneme Point and Mugu Lagoon started to disappear and shrink during this time, drained by the ditch. The most dramatic conversion was to the permanently flooded lagoon south of Point Hueneme (Figure A-4), which is essentially gone by 1945 (Figure A-7). Remnants of the other wetlands can still be seen in 1945, although agriculture continued to take over more former wetlands (Figure A-7). While the central part of the East Hueneme Drain is gone today, the Ormond Beach Wetlands and the surrounding landscape are still bisected by numerous ditches, designed to deliver or remove water from various areas. Some of these ditches continue to affect the hydrology of the wetlands that remain.

Other significant hydromodifications in the area were done for the sake of duck hunting. The Ventura County Game Preserve Association was founded in 1908 and purchased between 1,200 and 2,500 acres of marshland near Mugu Lagoon and managed it for duck hunting (San Buenaventura Research Associates 2014). In 1929, the Point Mugu Game Preserve Association formed and developed 132 acres of ponds managed for duck hunting. The development of the duck ponds involved dividing up marshlands with berms, managing water levels with pumps and valves, and introducing species such as wild rice to attract different types of fowl. By 1945, a large area of duck ponds is evident north of Mugu Lagoon (Figure A-7). More duck ponds were established after 1945 northwest of Arnold Road **(Figure A-8**) on what is now California State Coastal Conservancy (SCC) property. It is not known how long these areas were managed for hunting, but many of the berms can still be seen today in the wetlands that remain.

Establishment of the Naval Air Station Point Mugu (now operated as the Naval Base Ventura County Point Mugu [NBVC]) also altered drainage and tidal exchange. Runway construction started in 1941. An agricultural drainage ditch (Oxnard Drainage Ditch #3) now drains east under Arnold Road, through the NBVC, and through a series of culverts under the NBVC runway and two roads, to Mugu Lagoon. This has impeded drainage to Mugu Lagoon and reduced and muted tidal exchange north of the runway.



SOURCE: United States Geological Survey (USGS)

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Figure A-3
1901 US Coast and Geodetic Survey Map,
Hueneme Quad

SOURCE: UCSB Maps and Imagery

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Figure A-4
1929 Aerial Photo

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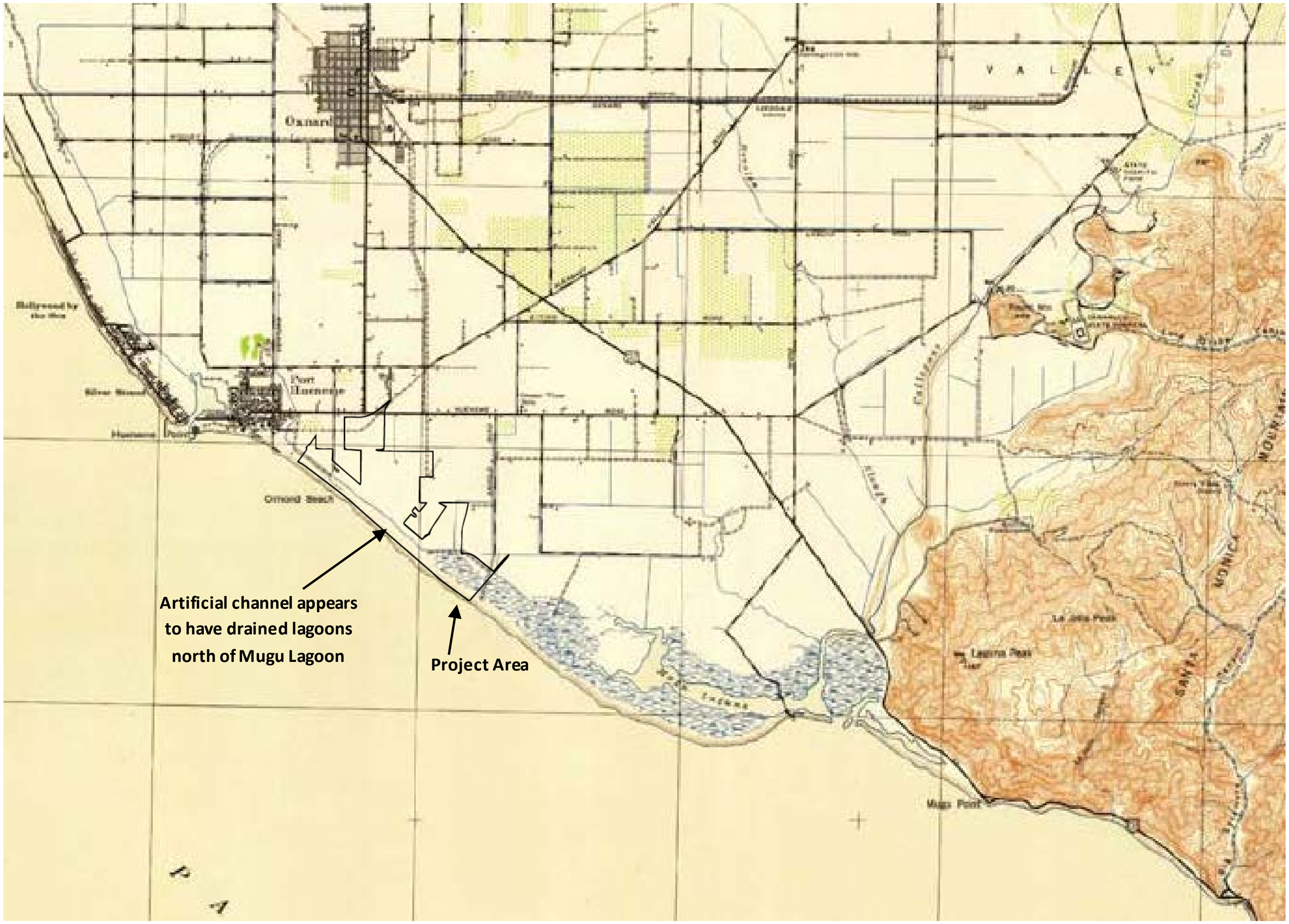

SOURCE: United States Geological Survey (USGS)

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Figure A-5
1943 USGS Topographic Map, Hueneme Quad

SOURCE: http://seabeemagazine.navylive.dodlive.mil/

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Figure A-6
1942 Aerial Oblique Photo

SOURCE: UCSB Maps and Imagery

Ormond Beach Wetlands Restoration

Figure A-7
1945 Aerial Photo

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SOURCE: UCSB Maps and Imagery

Ormond Beach Wetlands Restoration

Figure A-8
1964 Aerial Photo

ESA

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Another driver in the loss of wetlands in the project area was a rapid episode of coastal retreat that occurred after the Port of Hueneme was built in 1940. The jetties that protect the mouth of the port essentially stopped all down-shore transport of sand immediately following construction. Almost all of the sand moving down-coast to the project area from the northwest was trapped north of the new jetty, or diverted by the jetty to an offshore canyon, where it was lost to littoral processes (Herron and Harris 1966). While this made for a virtually maintenance-free harbor mouth, the effects down-coast were dramatic. By the mid-1960s the sand-starved beach and dune system in the project area retreated landward about 150 feet (**Figure A-9**). The beach and dune system did not get noticeably narrower between 1929 and 1964, it simply moved inland (Figure A-9). Over 100 acres of wetland were converted to dune and beach habitat during this time. In the mid-1960s, construction began on Channel Island Harbor just north of Port Hueneme. Sand supply to the project area changed in two important ways as a result. First, when Channel Island Harbor was dredged, much of the sand was discharged south of Port Hueneme, which delivered a one-time pulse of sand to the beach. Second, the harbor's northern jetty, which acts as a huge sand trap, is now regularly dredged and the sand is moved down-coast to Port Hueneme Beach, which is just south of the entrance to Port Hueneme (**Figure A-10**). The long-term result at Ormond Beach is a beach and dune system that has advanced seaward to its approximate pre-harbor condition. The back of the dunes has mostly stayed static, resulting in a beach and dune system that is approximately twice as wide as it was in 1929 and 1945 (Figure A-9).

The 1960s and 1970s also brought two major industrial developments that impacted what remained of Ormond Beach. The Halaco Engineering Company operated a metal smelter from 1965 to 2004 on an 11-acre parcel (**Figure A-11a**). The operation filled in much of the lagoon system with contaminated waste during its 40 years of operation. The facility directly discharged waste into the waterways from 1965 to 1970, and in 1970, Halaco began pumping waste to unlined settling ponds on an adjacent 26-acre parcel. Halaco ceased all operations in 2004, and the EPA estimates that more than 700,000 cubic yards of waste remain on site.

South of the Halaco Property, the Ormond Beach Generating Station (OBGS) was built on one of the remaining large wetlands, which was probably being managed for duck hunting at that time (**Figure A-11b**). The OBGS includes a once-through-cooling (OTC) power plant and adjacent tank farm. The tank farm was removed sometime in the late 1990s and this area is currently a mosaic of wetland and upland habitats with a mix of native and non-native plants. The OBGS bisected the shore-parallel backshore drainage channel, creating a drainage divide. As a result, water runoff northwest of the power plant flows northwest toward the Lagoon, while runoff southeast of the power plant flows southeast toward Mugu Lagoon. The OBGS is still operating in 2020, but is expected to be decommissioned within the next couple years and eventually dismantled.

The beach and dune habitats in the Beach area underwent severe degradation from vehicles during the last half of the 20th century. The beach was open to vehicles until sometime in the 1980s and was a popular spot for riding off highway vehicles. Vehicles destroyed almost all of the vegetation in some areas. As a result, dune-building processes were disrupted and the former dunes and hummocks turned into an essentially flat landscape (**Figure A-12a**). Arnold Road, at the southeastern end of the project area, was a primary vehicle access point. Early aerial photos showed well-developed dune vegetation in this area (Figures A-4 and A-7). By 1964 (Figure A-8), there seemed to be considerably less vegetation. The earliest available aerial oblique photo shows a few dunes in 1972, which were already destabilized by erosion moving down coast from Hueneme harbor due to the jetties, and active roads through the salt marsh areas (**Figure A-12**). By 2002, access to vehicles had been cut off and the dunes were beginning to recover. One of the major effects of the flattened dunes is also obvious in the 2002 photo, which shows evidence of a wave overwash event that would have delivered significant amounts of salt water to the wetlands.

The County of Ventura modified the local drainage for flood control purposes and to facilitate development in the area. tšumaš Creek, which was previously called the J-Street Drain, is a concrete-lined channel constructed in the 1950s-1960s, and recently widened and renovated. When constructed, the shore was farther landward than today (see above discussion on the effects of Hueneme Harbor), and the mouth of the lagoon was breached to allow drainage as needed (communication with the Ventura County Watershed Protection District [VCWPD], 2017). In 1992, the mechanical breaching was halted by environmental restrictions owing to concerns about impacts to fish and birds. Subsequently, the lagoon expanded and several flood events occurred. Following a large flood event in 2010, the County has been allowed to manage flood risk by a permitted “beach grooming” activity. Prior to large storm events (but no more frequently than three times per year) the berm separating the lagoon from the ocean is graded lower near the lagoon, so that as flood waters from the storm move downstream, the berm breaches naturally at a lower level and then drains, before waters can rise and flood the developed areas along Perkins Road.

The Project Partners began acquiring and protecting wetlands and uplands in the Ormond Beach area in 2002, with plans implement large-scale ecological restoration. Even though 630 acres of land is protected, hydromodification from past actions and ongoing management changes on adjacent properties are still driving changes in the ecological communities. The most dramatic change is occurring southeast of the Halaco Property, landward of the dunes, on the Nature Conservancy (TNC) property. In 2002, this area was dominated by salt marsh vegetation with areas of salt flats (**Figure A-13a**). This area was connected to the Lagoon by a small channel, which would have delivered salty water to this area, at least rarely. By 2006, the same channel was filled with cattail (*Typha* spp.) (**Figure A-13b**) and the saltmarsh/salt flat area was being invaded by brackish marsh species (probably alkali bulrush, *Bolboschoenus maritimus*), suggesting brackish lagoon water was no longer flowing through the channel or reaching the site. This may be due to the channel being filled with sediment (blowing sand) or by changing management of water levels in the Lagoon. By 2013, the isolated former saltmarsh/salt flat area was dominated by freshwater marsh species (tule, *Schoenoplectus californicus,* and cattails) (**Figure A-14**). This relatively rapid conversion of salt marsh habitat to fresh/brackish habitat is not uncommon in Southern California salt marshes that lose their connection to the ocean and/or receive increased freshwater runoff from human sources. By 2017, about 20 acres of fresh/brackish marsh were mapped where there was only salt marsh and salt flat just 15 years prior. The Lagoon hydrology and morphology will be evaluated further for the OBRAP process to further assess the drivers for the observed marsh conversion.

SOURCE: Google Earth 2017

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Figure A-9
Current and Historic Beach Limits

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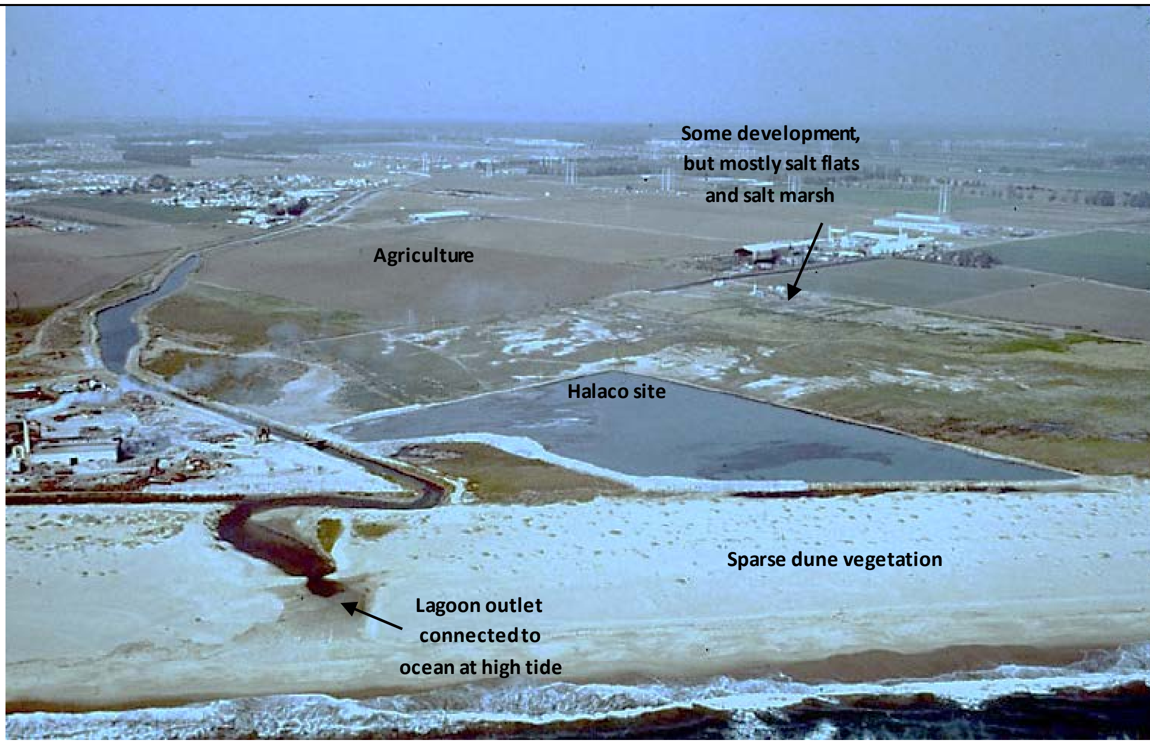
a

b

SOURCE: Google Earth 2017

Ormond Beach Wetlands Restoration

Figure A-10
2014 and 2015 Beach Widths



a

b

SOURCE: California Coastal Records Project

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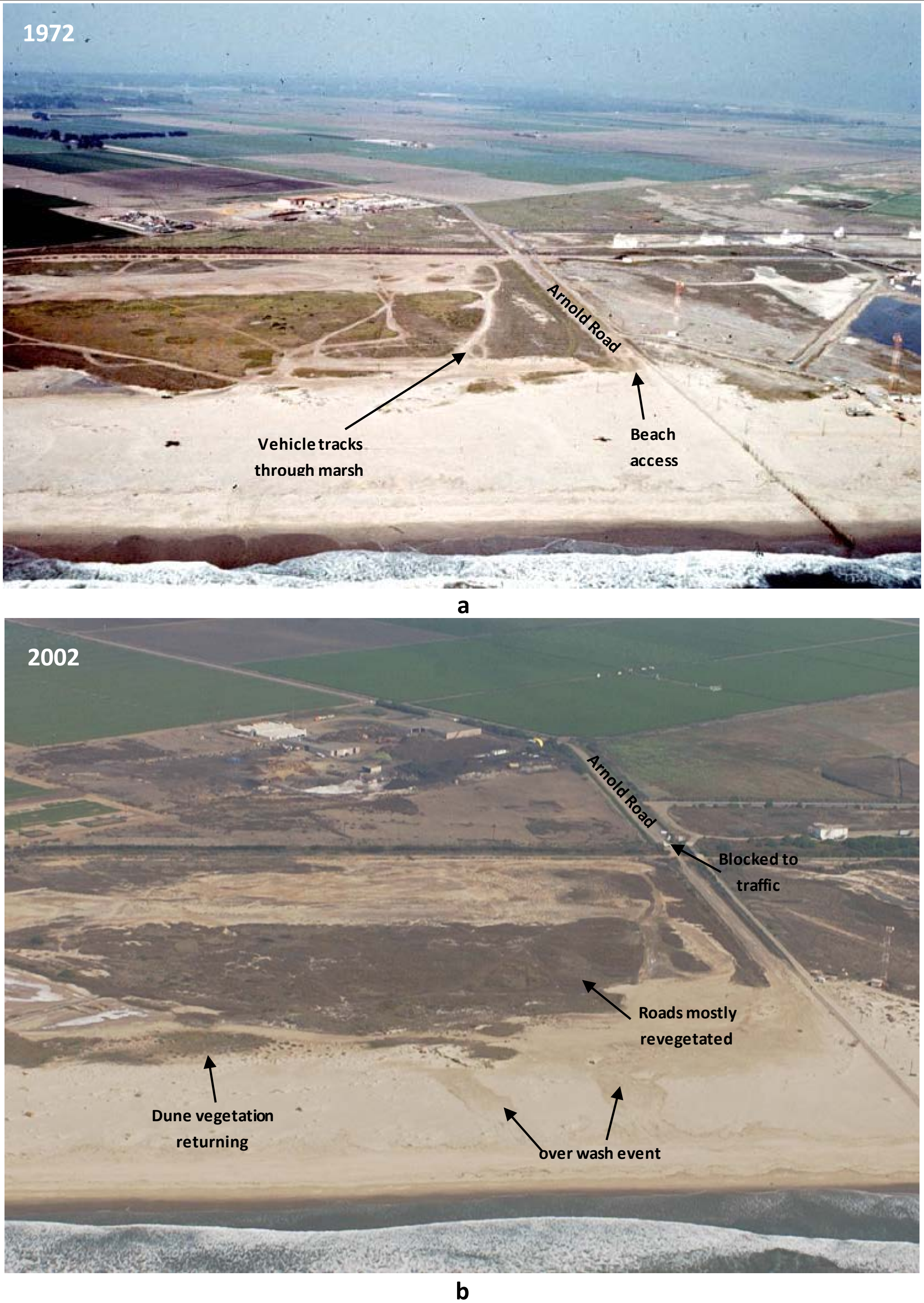
Figure A-11
1972 Aerial Oblique Photos

ESA Coastal Restoration Consultants



SOURCE: California Coastal Records Project

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Figure A-12
1972 and 2002 Aerial Oblique Photo Comparison

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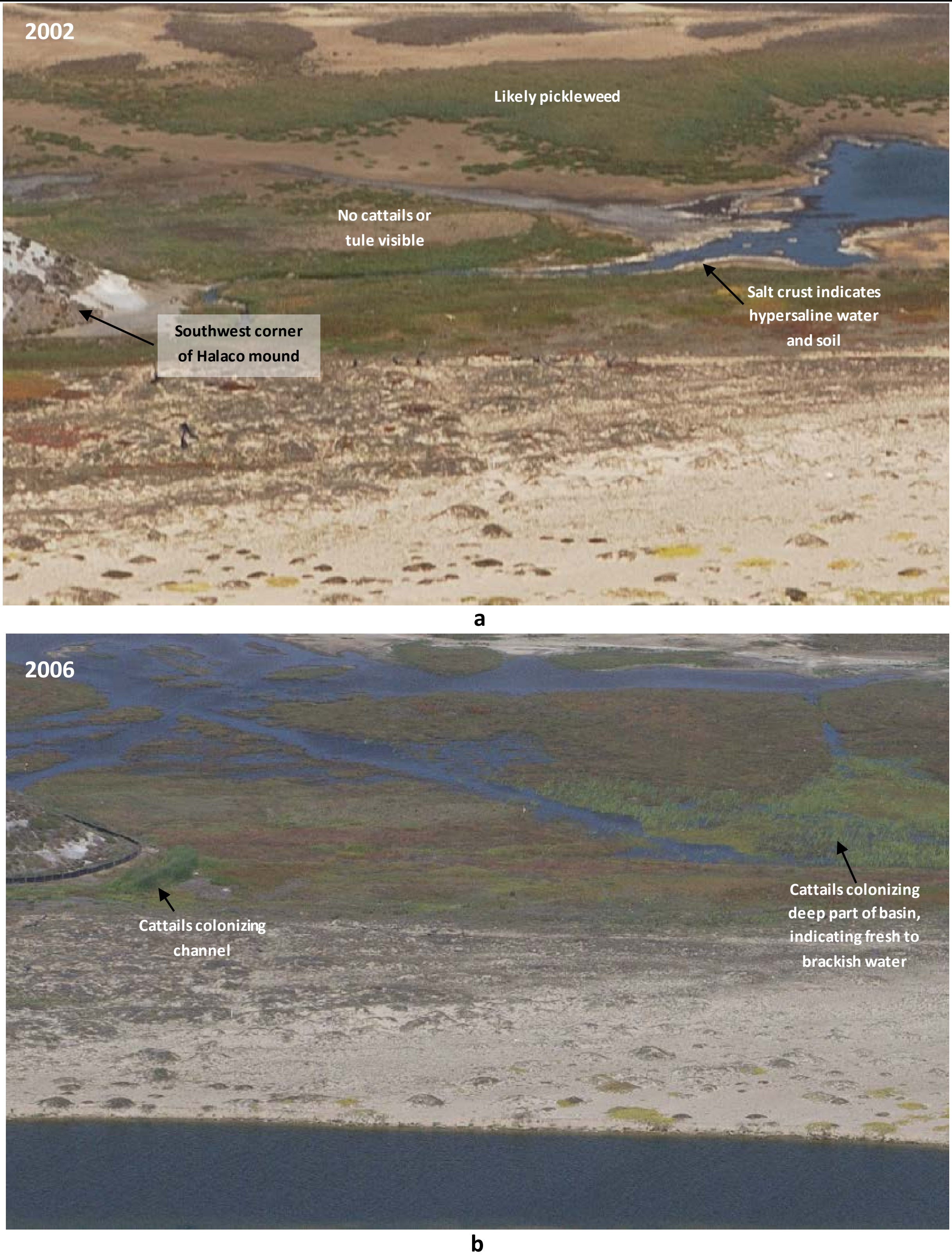

SOURCE: California Coastal Records Project

Ormond Beach Wetlands Restoration

Figure A-13
2002 and 2006 Aerial Oblique Photo Comparison,
Southern TNC Parcel

ESA Coastal Restoration Consultants

SOURCE: California Coastal Records Project

Ormond Beach Wetlands Restoration

Figure A-14
2013 Aerial Oblique Photo, Southern TNC Parcel

6. Implications for Restoration

The Ormond Beach area once supported a large complex of wetlands that were formed by the mouth of the Santa Clara River as it moved course over the Oxnard Plain over thousands of years. Historic river mouth locations supported lagoons, surrounded by other types of wetlands and transitional habitats. Where there were year-round freshwater inflows, lagoons were permanently flooded and naturally breached and therefore may have had intermittent tidal influence. Prior to the runway construction at the NBVC, wetlands closer to Mugu Lagoon probably had some tidal exchange in very wet years. Lagoons with only wet-season freshwater inputs were flooded after rains and then dried to salty flats. These seasonal lagoons were probably rarely inundated with salt water when storms or large wave events overwashed the dunes. Small remnants of permanently flooded lagoon, seasonal lagoon, and other wetlands persist within the project area but with significantly altered hydrology.

Some wetland-upland transition and upland habitats remain as well, but almost all are on landforms that have been altered over the years (e.g., berms, levees, abandoned crop land or development). Beach and dune habitats migrated landward in the middle of the 20th century, converting over 100 acres of wetlands to dunes. The current beach and dune system is nearly twice as wide as it was in the mid-1940s. In addition to physical alteration, invasive plant species have fundamentally altered the structure and composition of some habitats. In summary, the Ormond Beach site is still a beach-dune-wetland system, but greatly reduced, degraded, and modified. Yet despite the impacts over the last 250 years, important remnant habitats remain, along with opportunities for ecological restoration.

While historical ecology can inform the underlying processes that formed a landscape and its ecological conditions, restoration goals must also consider existing and anticipated future conditions. Restoring ecological functioning will require working within the constraints of the site. Habitat features will not necessarily be replaced in the exact location where they appear in historical maps or photos. Rather, the OBRAP project seeks to re-establish many of the physical and ecological processes that supported the diverse wetland and upland habitats once present at the site. This holds the most promise to restore self-sustaining ecological communities that are resilient to changing conditions and dynamic in space and time.

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Appendix B
Additional Information on Existing Conditions and Future No Project Conditions

APPENDIX B
Additional Existing Conditions and Future No Project Conditions

This appendix provides information from 2017 field surveys and other sources to describe existing conditions and to develop an understanding of the physical processes that shape the landscape, hydrology, soils, vegetation communities and species that inhabit the Ormond Beach area. This appendix also assesses future conditions without restoration (i.e., future without project conditions), based on available information.

2017 Field Surveys

ESA conducted field surveys at the Ormond Beach Restoration and Public Access Project Area (Project Area, **Figure B-1**) from May 30 through December 14, 2017. The surveys included water level gage installation, soil sampling, and topography and bathymetry surveys. ESA also surveyed vegetation elevations in coordination with CRC. Survey point locations are indicated in **Figure B-2**.

Topography and Bathymetry

ESA conducted a survey of the project area June 5 through 7, 2017 using Real Time Kinematic (RTK) GPS equipment. The survey was referenced to the NAVD88 vertical datum and California State Plane Zone 5, NAD83 horizontal datum and tied into the Leica SmartNet system. The purpose of the survey was to groundtruth the SCC CA California Coastal Light Detection and Ranging (LiDAR) dataset. Between 2009 and 2011, the SCC collected LiDAR elevation data along the entire California coast (**Figure B-3**).

The survey extent included the lagoon, beach, channels, marsh, and salt panne areas. Transects up to approximately 2,500 feet in distance were taken by the marsh and lagoon areas. Along-shore and cross-shore transects were taken along the beach. Excluding points surveyed on the beach, since LiDAR elevations collected for that area are seasonally variable, elevations from the LiDAR dataset are approximately 0.8 feet higher than those collected in the ESA survey, which is likely due to the LiDAR capturing the top of vegetation and/or the benchmarks used for each survey.

SOURCE: ESRI 7/19/2016, City of Oxnard, Ventura County

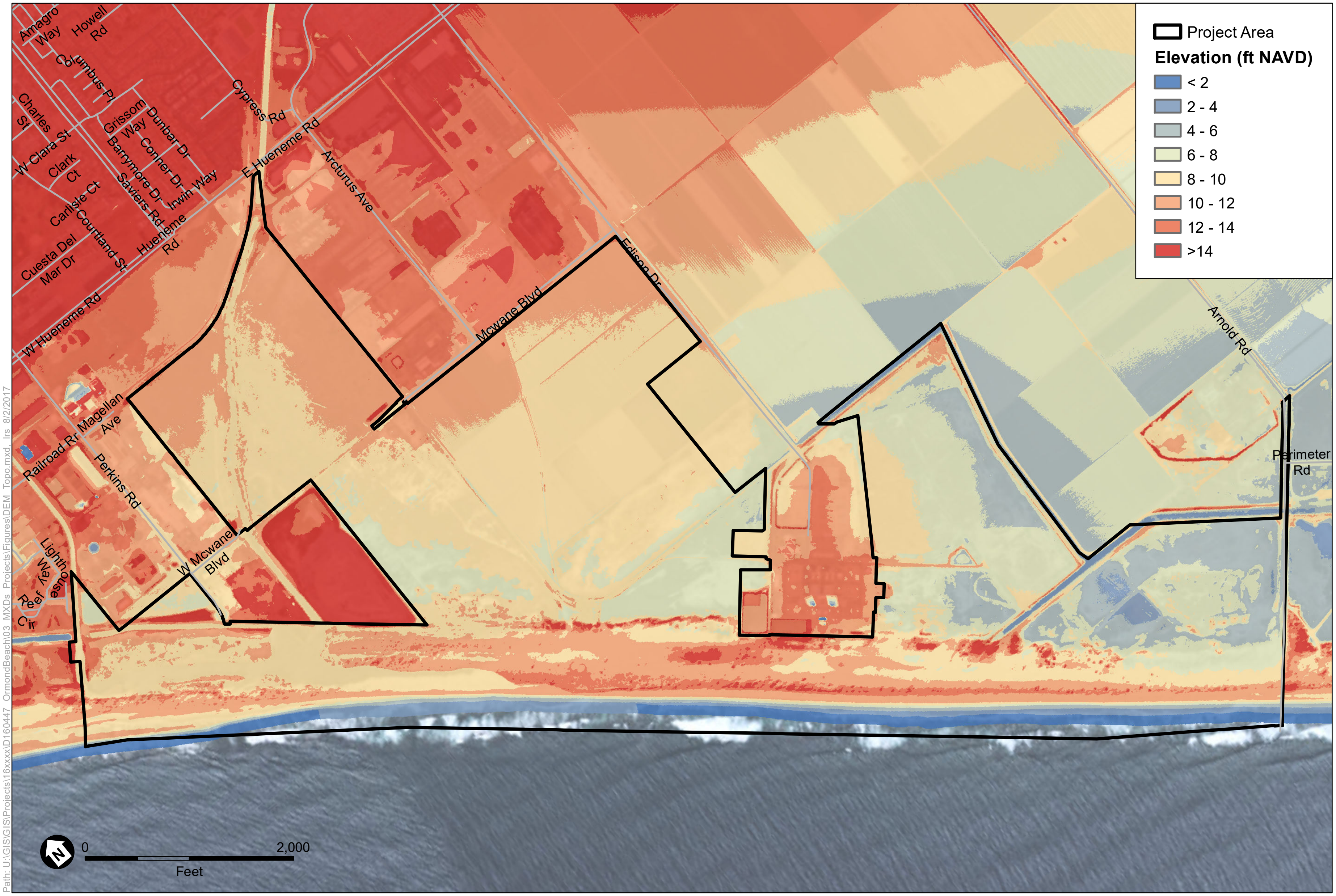
Ormond Beach Restoration and Public Access Plan

Figure B-1
Project Area and Site Areas

ESA

SOURCE: ESRI, City of Oxnard, Ventura County

Figure B-2
Water Level and Groundwater Guage Locations, and Survey Transects



SOURCE: ESRI, SCC 2011

Ormond Beach Wetlands Restoration

Figure B-3

Site Topography

ESA

Nine cross-shore transects on Ormond Beach were taken along the project site (**Figure B-4**). The beach transects measure between 200 feet and 400 feet in length and capture the foreshore and berm feature. The data show an increase in berm height from the north to the center of the lagoon, then a decrease in height near where the lagoon breaches to the south end of the lagoon (**Figure B-5**). Further south along the beach, the berm rises again. Across the project site, the berm crest ranges between 9.4 feet and 16.1 feet NAVD88. Marsh transects were also collected in the survey.

Water Levels

Pressure gages were installed to measure surface and groundwater elevations at six sites. Gages were installed on June 1, 2017 and monitored levels through December 14, 2017 at the sites shown in Figure B-2. **Figure B-6** shows water level time series from each of the gages. Due to the timing of the installation, these preliminary measurements are indicative of closed-mouth lagoon conditions and seasonally low water tables. Surface and groundwater sites near the Ormond Lagoon Waterway and the Ormond Lagoon have experienced a slow seasonal decline in water level through late July, punctuated by a high water level event in late June that may have been caused by wave overwash into the lagoon. At the salt panne near Arnold Rd (Area 6), surface water elevations in the Oxnard Drainage Ditch #3 have been stable, while groundwater levels appear to have fluctuated with the spring-neap tidal cycle.

Soil Sampling

Investigative soil test pits were dug in the Arnold Road salt pannes on June 1, 2017 for the purpose of investigating locations for shallow groundwater monitoring well installations. Pits were dug in two locations on opposite sides of the salt panne complex (**Figure B-7**). Site A was originally selected on the basis of proximity to existing plover nests (as far as possible), ease of access from the road, and representation of the surrounding area. At the time of digging, the area surrounding Site A was fully dried out, so an alternative test pit was deemed necessary near an area still ponded. Site B was selected near an area of ponded water and revealed a different set of soil types and stratification.

A thin surface layer of salty crust and lack of standing water were observed over the eastern salt panne area. For Site A, a layer of sandy clay was found two inches below the top salt layer and can be seen in (**Figure B-8**). The layer extended down 2.8 feet and was notably moist, although not entirely saturated. Drilling further, a very dense, moist clay lens of approximately 0.8 feet appeared at 1.1 feet NAVD. Immediately after punching through the clay lens, groundwater began to rise in the test pit due to the change in hydraulic head pressure as the clay was acting as a confining layer. Within 30 minutes of breaching the clay lens, the water level rose 2.3 feet, and within two hours, the water level had risen another foot. This potentially means that surface water at the site is forced to evaporate rather than infiltrate deeper into the profile, due to the clay layer.

SOURCE: ESA Survey (6/2017)

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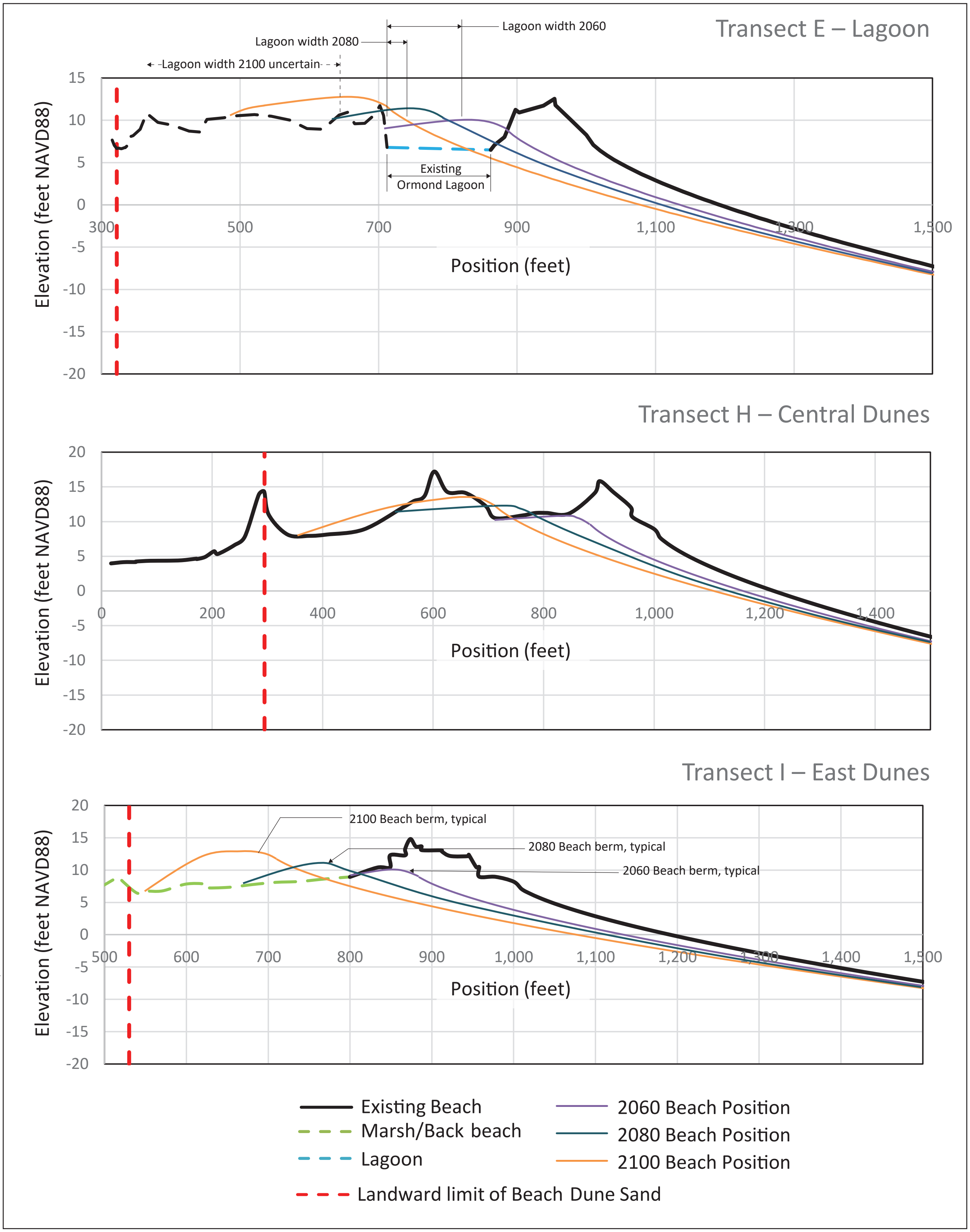
Figure B-4
Beach Transects Locations

ESA



SOURCE: ESA, 2017

NOTE: Transect E (top) is located at western beach strand Area 1 at Ormond Lagoon; Transect H is located at central beach strand 7 near backshore Area 3 and Transect I is located at eastern beach strand Area 9 near backshore Area 6.

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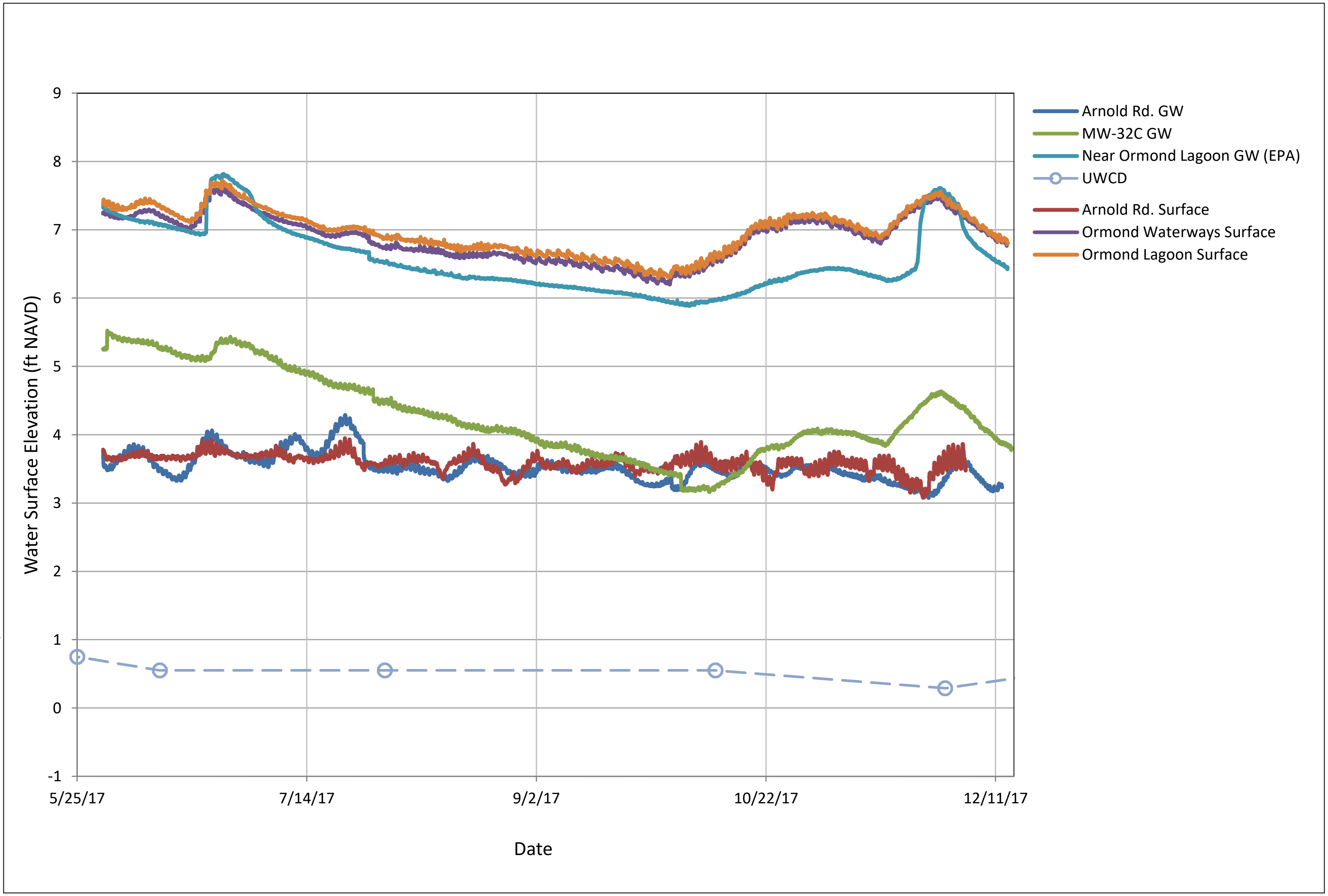
Figure B-5
Beach Transect Elevations

ESA



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SOURCE: ESA Water Level Gauges UWCD Groundwater Well

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Figure B-6
Water Levels

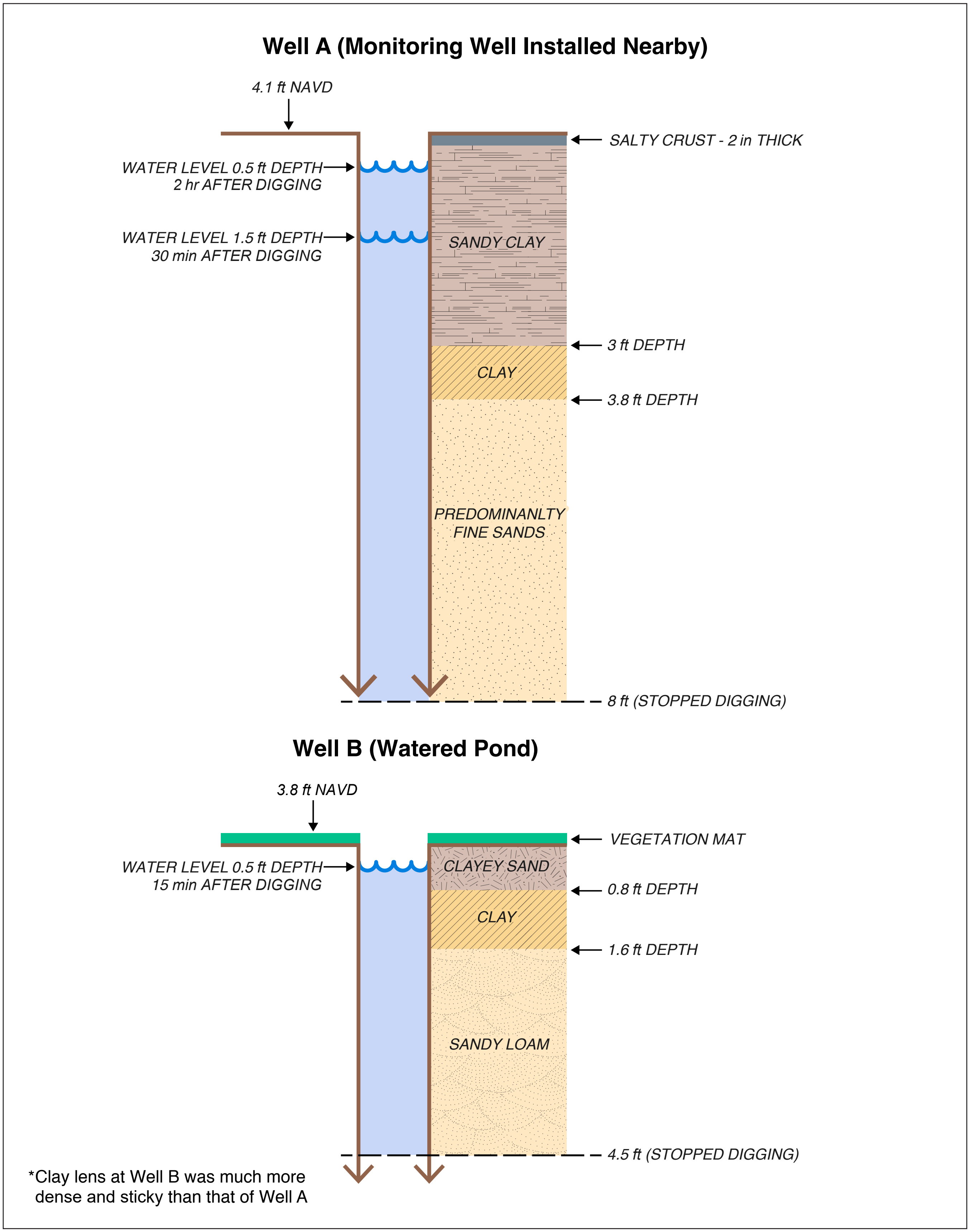
ESA

SOURCE: Google Earth Imagery

Ormond Beach Wetland Restoration

ESA

Figure B-7
Groundwater Monitoring Soil Test Locations



SOURCE: ESA, 2017

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Figure B-8

Groundwater Monitoring Well Soil Observations

ESA

The test pit for Site B was chosen near the edge of a large area of standing water in the northwestern area of the salt panne complex. Beneath a thin layer of matted vegetation, the top of the profile consisted of 0.8 feet of clayey sand that was moist, but not saturated (Figure B-8). Similar to Area A, a 0.8-foot-thick clay lens was discovered below this. The top of the lens, however, was found to be at an elevation of 3 feet NAVD, nearly 2 feet higher than the layer in Area A. After breaching the lens and arriving at the next layer of sandy loam, water immediately began to well up again. After 15 minutes, the water level had risen 1.1 feet, a similar rate to that of Site A. The higher elevation of the clay layer in Site B means less volume in the soil above the layer for water to pond. This may be why ponded water was visible near the test pit. Alternatively, there may be greater connectivity with the water table in the western area of the site or a breach in the clay layer may have led to the ponding.

Vegetation Elevations

ESA surveyed marsh plant elevations in coordination with CRC on June 7, 2017. Elevations of vegetation transitions, salt marsh bird's beak occurrences, and coulter's goldfield occurrences were collected. Figure B-2 shows the location of the surveyed data.

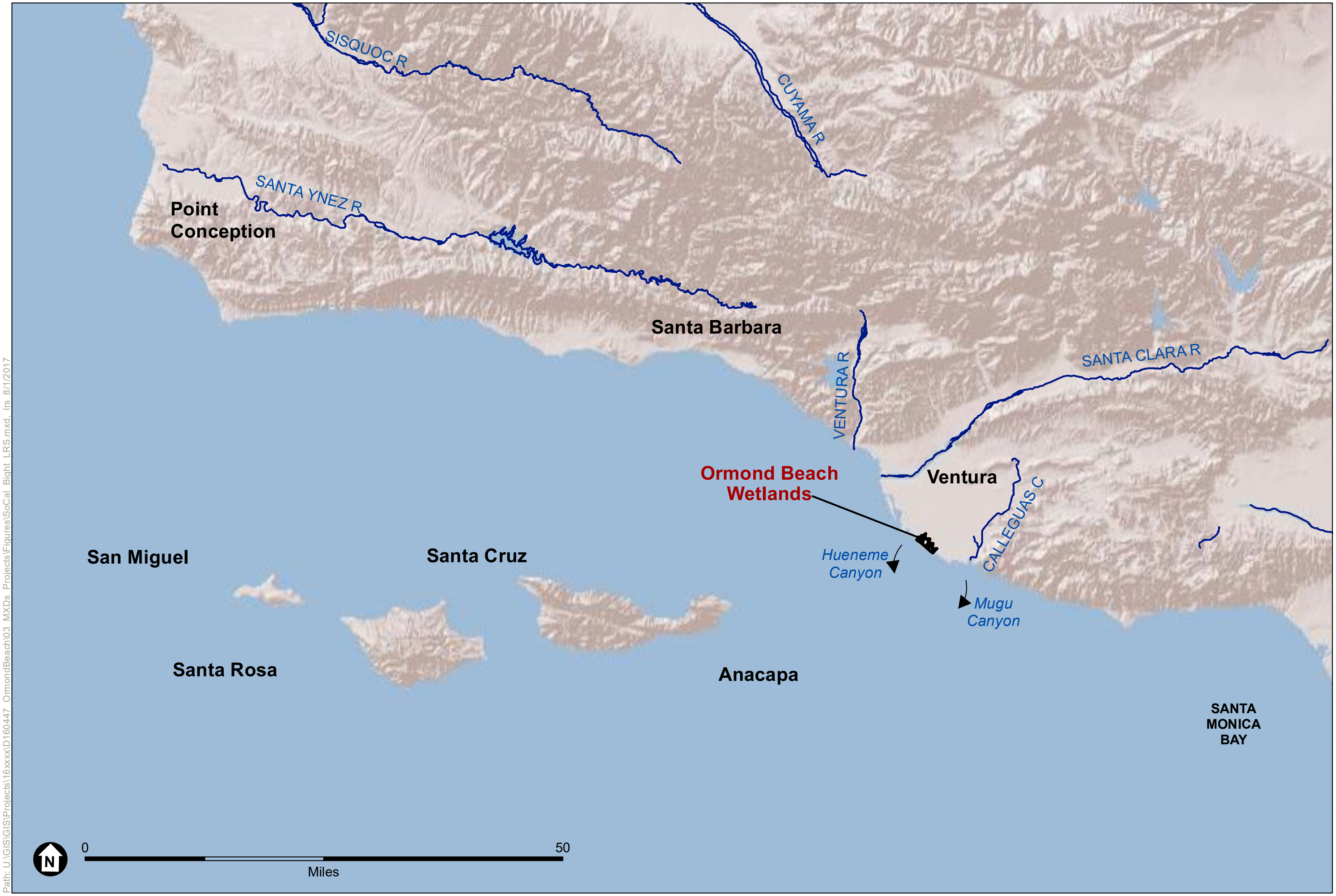
Table B-1 presents the elevation statistics for each plant species or habitat type by basin.

TABLE B-1
VEGETATION ELEVATIONS AT ORMOND BEACH

Vegetation Type	Location	Elevation Range (ft NAVD88)	Average Elevation (ft NAVD88)
Salt Marsh Bird's Beak	Area 6 - South SCC Salt Panne and Marsh	5.3 – 8.0	6.4
	Area 3b - Southeast TNC/SCC Marsh	5.7 – 7.1	6.4
	Area 3a - Southwest TNC Marsh	7.5	7.5
Coulter's Goldfields	Area 3a - Southwest TNC Marsh	8.1 – 9.6	8.9
Marsh to Upland Transition	Area 5 - South SCC Salt Panne and Marsh	4.5 – 6.4	5.3

Existing Conditions - Physical Processes

The Project Area is located on the oceanside of the Oxnard Plain, a large alluvial plain created by the deposition of sediment eroded from the surrounding mountains (**Figure B-9**). The major regional drainage channels are the Ventura and Santa Clara Rivers and Calleguas Creek. The extent of the sediment plain is limited and the shore orientation is controlled by the Hueneme and Mugu submarine canyons, which affect ocean waves and wave-driven sand transport (Herron and Harris 1966). The sandy shore is built by waves and winds, forming a ridge of sand dunes that inhibits drainage of rainfall to the ocean. **Figure B-10** shows the historical wetlands that existed behind this littoral (coastal) ridge of dunes, including lagoons and back-dune wetlands (Beller et al. 2016). Development has significantly modified the drainages to and from the site, and the extent of wetlands.



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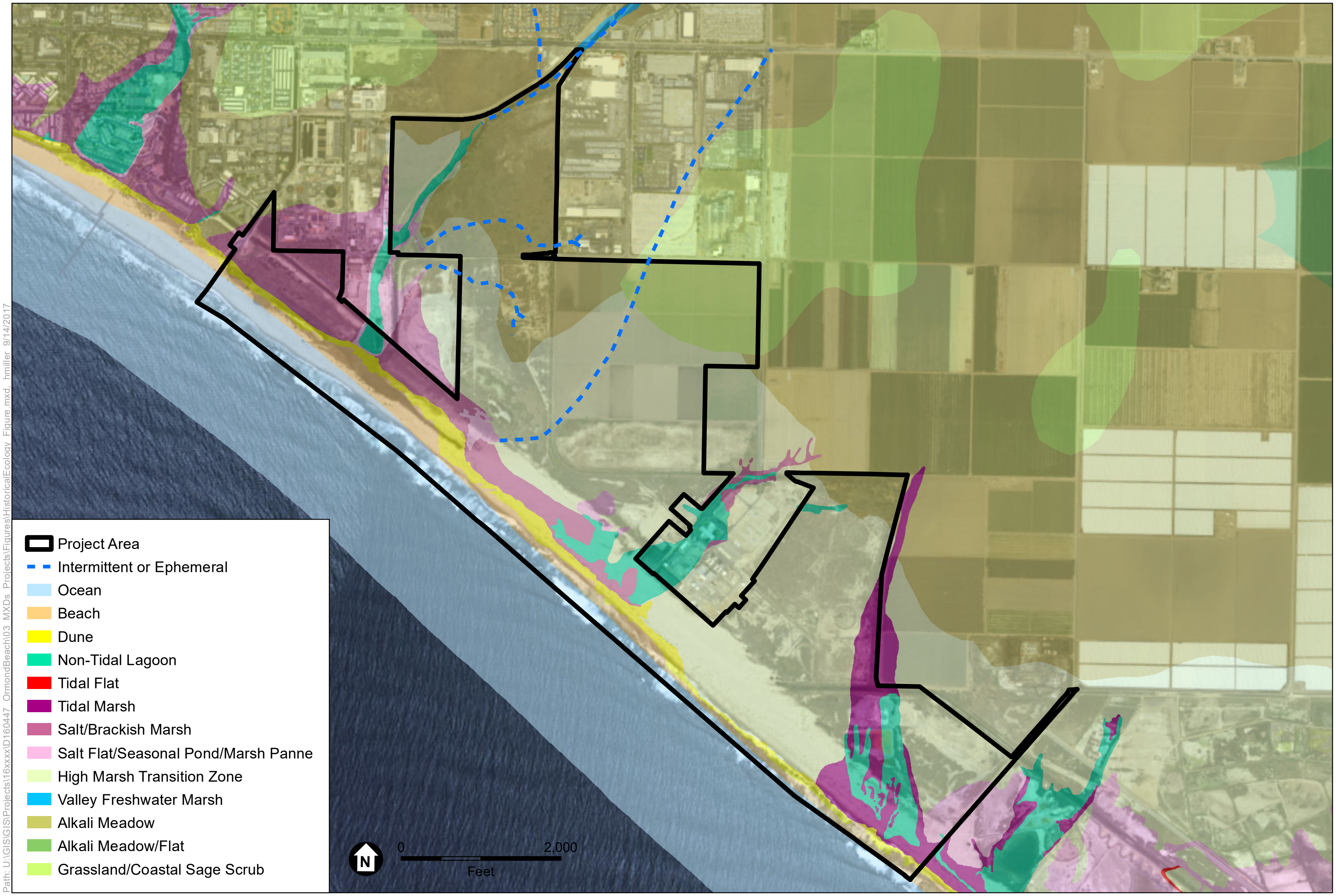
SOURCE: ESRI

Ormond Beach Wetlands Restoration

Figure B-9
Southern California Bight

ESA



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Source: ESRI 7/19/2016, San Francisco Estuary Institute, Ventura County,

Ormond Beach Restoration and Public Access Plan

Figure B-10
Project Area Historic Ecology in the Early 1800s

ESA

Watershed Processes

The Project Area is located in a Mediterranean climate zone and experiences mild, wet winters and warm, dry summers. The Project Area receives an average total annual precipitation of 17 inches, with the most rainfall occurring in January and February (Aspen 2009). Measurements from Oxnard Airport (WRCC 2017) and the offshore National Data Buoy Center buoy at Anacapa Passage show that winds predominantly arrive from the west year-round (HDR 2008a). Average maximum temperatures in the summer (Jun-Aug) reach 75.0° Fahrenheit while average minimum temperatures in the winter (Dec-Feb) are around 44.7° Fahrenheit (WRCC 2017). Evaporation exceeds seasonal precipitation at the site (Philip William and Associates [PWA] 2007).

Freshwater Flow

The Ormond Lagoon Waterway (OLW), tšumaš Creek, and the Hueneme Drain (via the Hueneme Pump Station), are the main sources of freshwater runoff to the Lagoon. Seasonally wetted areas in the TNC parcel (Area 3a) receive freshwater via overflow from the Lagoon, and wetted areas in the SCC parcel arrive from drainage ditches draining agricultural lands east of the OLW. In general, freshwater runoff reaches the Lagoon much more quickly than it would have under historical conditions due to channelization (URS 2005, HDR 2008a). Typical and event discharges along the three major drainages are summarized in **Table B-2**.

TABLE B-2
FLOWS IN THE ORMOND LAGOON WATERWAY, TŠUMAŠ CREEK, AND HUENEME DRAINS

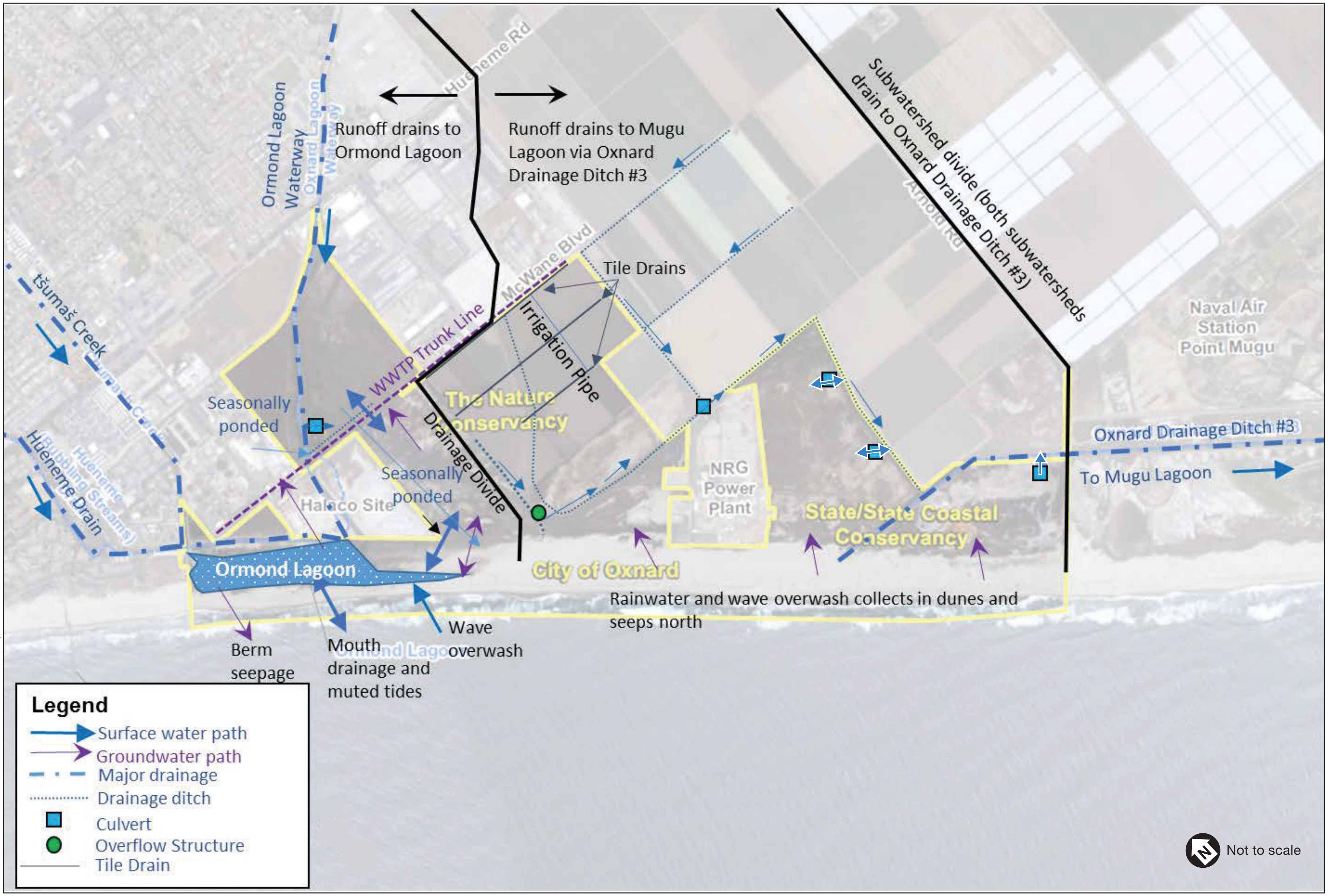
	Typical (CFS)	10-year (CFS)	50-year (CFS)
Ormond Lagoon Waterway	7-8	2,798	4,115
tšumaš Creek	1-2	1,049	1,542
Hueneme Drain	1-2	251	369

NOTE: CFS = Cubic feet per second

SOURCE: PWA 2007, based on information provided by Impact Sciences (1996) and Kennedy/Jenks Consultants (1999)

Hydrologic Connections Between Sub-Areas

Although most of the available freshwater runoff is routed to the Lagoon or to Oxnard Drainage Ditch #3 (ODD #3), ponding behind the beach berm prior to mouth breaching allows surface water to transfer to the TNC Area. This is illustrated schematically in **Figure B-11** and described in detail by CH2M Hill 2008. When the lagoon drains, water is trapped in the TNC Area 3a as seasonal ponds. After the rainfall event recedes, the mouth may remain open for several weeks, at which time muted tides may enter the lagoon from the ocean (CH2M Hill 2008). However, tide levels in the lagoon tend to be several feet lower than water levels during closed-mouth conditions, meaning that the TNC Area 3a, and parts of the tšumaš Creek and OLW, are hydrologically disconnected from the lagoon when the mouth is open. Farther east, the leaky flap gate connecting Mugu Lagoon to the ODD #3 communicates muted tides to the pickleweed marsh, open water, and salt panne areas east of the SCC parcel (PWA 2007).



SOURCE: ESRI 7/19/2016, PWA (2007), CH2M Hill (2008, 2012), HDR (2008a)

Figure B-11
Schematic of Surface and Groundwater Flow Paths through the Project Area

Fluvial Sediment Supply

Sediment delivery to the Project Area via the three primary drainages is thought 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. HDR (2008b) estimated the total combined delivery from tšumaš Creek, Hueneme Drain, and OLW at less than 400 cubic yards per year (59 percent sand, 26 percent silt, 15 percent clay). Among these three pathways, 95 percent of the sediment load comes from the OLW.

The much larger sediment sources to Coastal Ventura County, the Ventura and Santa Clara Rivers, both discharge sediment into the tidal waters farther north of the Beach. Calleguas Creek supplies a significant amount to nearby beaches, but the predominant eastward littoral drift prevents this from reaching the site (Herron and Harris 1966). Much of the delivery by these sources occurs during brief, episodic discharge events, with 50 percent of the suspended sediment discharge occurring during only 0.1 percent of the time (Warrick and Milliman 2003). Willis and Griggs (2002) have estimated that the Santa Clara River and Ventura River discharge approximately 1.63 and 0.215 million cubic yards of sand and gravel per year, respectively. 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 (PWA 2007).

Fluvial Flood Hydrology and Hazards

Most flooding at the site occurs as a result of water collecting in the Lagoon during rainfall events, prior to the mouth breaching and draining of water to the ocean. When the lagoon mouth is closed, ponded water backs up into the OLW and tšumaš Creek, and typically spills east and north into the TNC Area 3a (EPA 2008, CH2M Hill 2012). On January 18, 2010 large swell waves built a high beach berm and complicated these actions, causing trapped runoff to flood the WWTP, International Paper plant, and Hueneme Road, leading to a mouth breach under an emergency permit from the CCC (Ventura County Watershed Protection District [VCWPD] 2010). Following this event, the County has been allowed to manage flood risk by a permitted "beach grooming" activity. Prior to large storm events (but no more frequently than three times per year) the berm separating the lagoon from the ocean is graded lower near the lagoon, so that as flood waters from the storm move downstream, the berm breaches naturally at a lower level and then drains, before waters can rise and flood the developed areas along Perkins Road (VCWPD 2016, 2017).

Farther east, high rainfall on agricultural lands draining to the ODD #3 can at times overwhelm the series of drainage ditches in the area. In 2017, roughly 4.2 inches of rainfall were recorded between February 17^{th} and 18^{th}, causing the Arnold Road drainage ditch to fill beyond capacity and flood across Arnold Road at the turn in Arnold Road adjacent to the Agromin parcel (personal communication with K. Krause).

Fluvial flooding at the site has been modeled by Tetra Tech (2005), URS (2005), and HDR (2008a). The HDR effort took into account beach management and movable bed conditions while modeling the 2-, 10-, 50-, and 100-year recurrence interval floods.

Coastal Processes

The Project Area is located within the Southern California Bight, an area that includes several offshore islands, submarine canyons, and a narrow continental shelf (Figure B-9). The site is subject to multiple coastal processes, including tides, waves, and littoral drift. These processes are described in more detail below.

Ocean Tides

Continuous oceanic tide level measurements are available from NOAA north of the site at Santa Barbara and south of the site at Santa Monica. Tidal datums are similar at each site, suggesting that these are representative of tides adjacent to the Beach. The tidal datums for the 1983–2001 epoch and observed extreme water levels at both gages are summarized in **Table B-3**, and referenced to the North American Vertical Datum of 1988 (NAVD88).

TABLE B-3
OCEANIC TIDAL DATUMS AT SANTA MONICA AND SANTA BARBARA

Tidal Datum	Santa Monica, CA (NOAA #9410840[1]) ft. NAVD88	Santa Barbara (NOAA #9411340[2]) ft. NAVD88
Maximum Observed	8.31[1]	7.54[2]
Mean Higher High Water (MHHW)	5.24	5.31
Mean High Water (MHW)	4.50	4.55
Mean Tide Level (MTL)	2.62	2.72
Mean Sea Level (MSL)	2.59	2.70
Mean Low Water (MLW)	0.73	0.89
Mean Lower Low Water (MLLW)	-0.20	-0.09

NOTES:
1 Observed 11/30/1982 7:54
2 Observed 12/13/2012 16:36

Waves

In addition to oceanic tides, wave conditions have a major influence on the Project Area, both by shaping the Beach, which forms the barrier between the ocean and Project Area and by influencing nearshore water levels and directly contributing ocean water to the lagoon during wave overwash events. Wave conditions near the site are heavily influenced by the regional

1 NOAA website tides and currents, last visited August 19 2020 https://tidesandcurrents.noaa.gov/datums.html?id=9410840

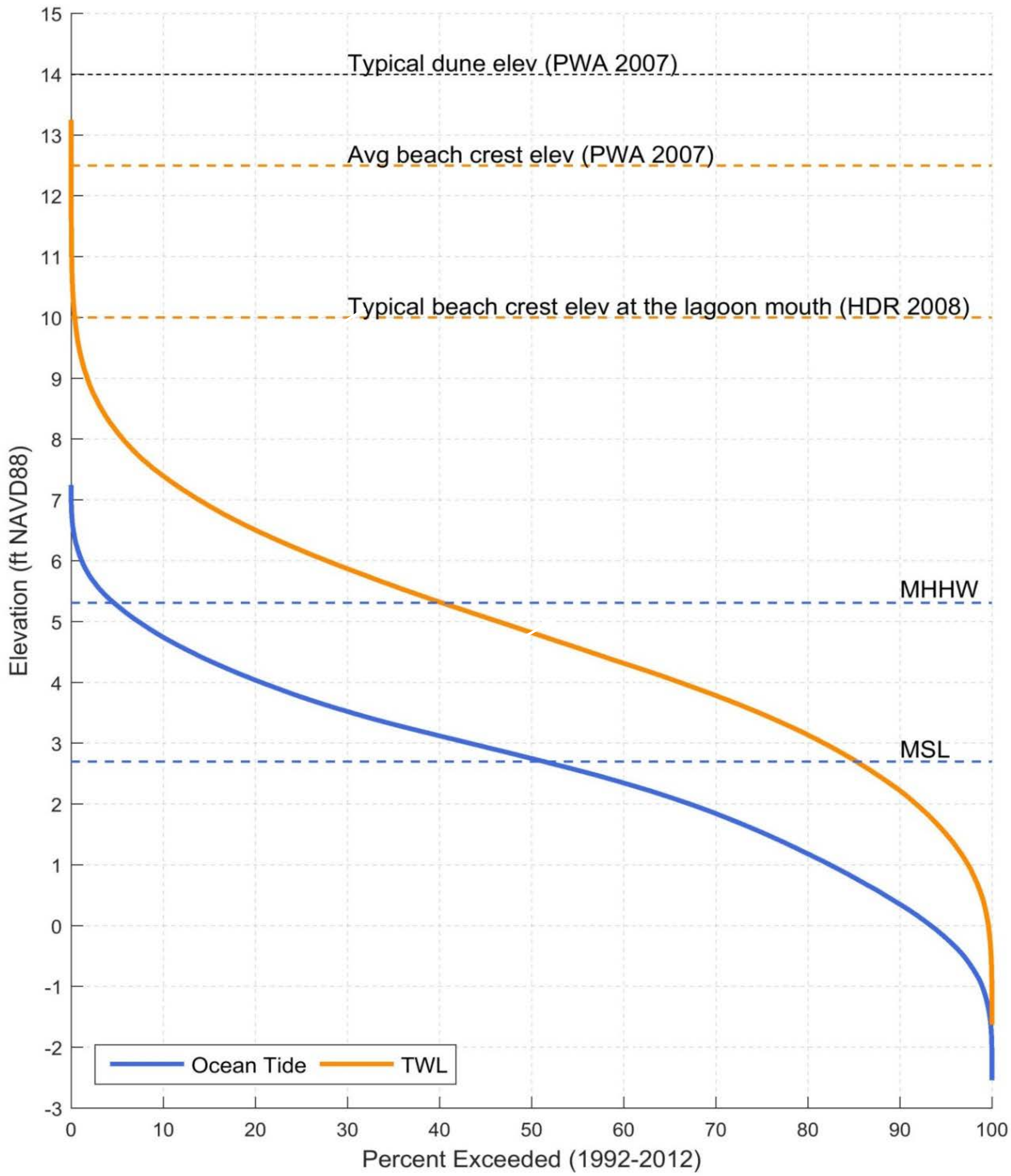
2 NOAA website tides and currents, last visited August 19 2020 https://tidesandcurrents.noaa.gov/datums.html?id=9411340

setting. 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 (Figure B-9). In general, this stretch of coastline is subject to energetic winter waves and more calm conditions during the summer months (Moffatt and Nichol 1986, PWA 2007). The area is also exposed to elevated breaking waves during swells from the southern hemisphere during spring, summer, and fall months, and occasionally from tropical storms off the Mexico coast in the fall. The bathymetry around Mugu Canyon amplifies these waves along the shore around Arnold Road and Mugu Lagoon.

Wave exposure at the 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 (Herron and Harris 1966; Moffatt and Nichol 1986). PWA (2007) and HDR (2008a) have characterized offshore wave conditions by assessing directional wave buoy data available from the Coastal Data Information Program (CDIP). In general, waves at the Anacapa Buoy (15 miles west of the Project Area) are nearly unidirectional and westerly due to sheltering by the northern chain of the Santa Barbara Channel Islands and Point Conception, whereas waves recorded at the decommissioned Point Dume buoy (16 miles southeast of the Project Area) are more broadly distributed and show exposure from the west to south, although the largest and most frequent waves arrived from due west. The largest waves are 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 (PWA 2007; HDR 2008a).

In 2012, ESA PWA (2013) developed nearshore wave predictions as part of TNC's Ventura Coastal Resilience project (TNC 2016). These were used in concert with beach topography information to develop time series of total water level (ocean tide + wave runup on the beach) from 1992 to 2012 at the site. Nearshore wave conditions are also available from CDIP at 10 meter depths along the Ventura coastline, from a series of monitoring and prediction points located at 100 meter intervals along the coast. These were developed using a similar methodology (see O'Reilly and Guza 1993).

Figure B-12 summarizes the TWL estimates developed by ESA PWA (2013), and shows how these compare against important tidal datums and observed beach and lagoon conditions. Typical beach crest elevations of 10–12.5 feet NAVD88 correspond to TWL levels that are exceeded for one percent of the time from 1992 to 2012. Beach crest elevations of 14 feet NAVD88 are higher than predicted TWL levels. This discrepancy may result from additional sand accumulation due to aeolian transport (PWA 2007, HDR 2008a). Also, the wave exposure and TWL elevations may increase with distance south from Hueneme to Mugu Lagoon, resulting in a higher beach berm elevation.



SOURCE: ESA PWA (2013) nearshore wave and TWL estimates, NOAA ocean tide data at Santa Barbara

Ormond Beach Wetlands Restoration

Figure B-12
Ocean Tide and Total Water Level

Littoral Drift

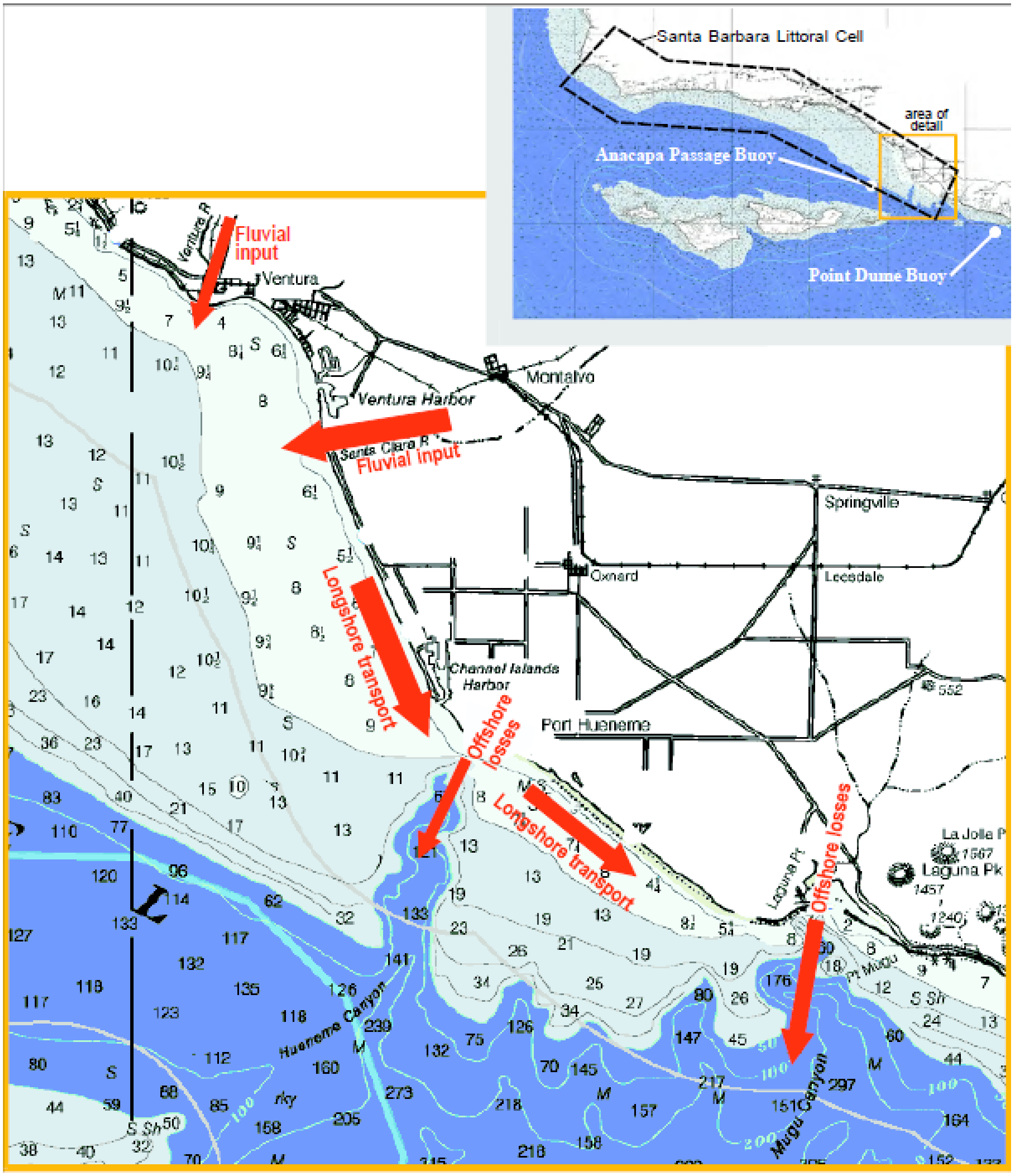
Following construction of the Hueneme and Channel Islands Harbors, sediment supplied by the Santa Clara and Ventura Rivers traversed a series of artificial sand bypasses before arriving at the site and maintaining the Beach (Herron and Harris 1966). Owing to the east-west shoreline orientation and the primarily westerly wave conditions, littoral sediment transport is almost exclusively eastward towards Point Mugu (**Figure B-13**). In the 10 years following construction of the Port Hueneme jetties in 1940, observations of 600 feet of shoreline accretion north of Hueneme suggest a net longshore transport of roughly 1.2 million cubic yards per year in the vicinity of the Project Area (Harris and Heron 1966, Moffatt and Nichol 1986). Most of this supply is thought to have naturally bypassed Point Hueneme historically, as observations of local shoreline changes between 1856 and 1940 suggest a stable shoreline between Point Hueneme and Point Mugu (Herron and Harris 1966).

While the site was historically within the Santa Barbara littoral cell, the jetties that maintain a permanent opening at the Port of Hueneme essentially create an artificial boundary to the littoral cell, and sand supplied to the Beach has become dependent on the biennial mechanical bypassing project managed by the USACE (Moffatt and Nichol 1986, PWA 2007). This project delivers sand dredged from Channel Islands and Port Hueneme harbors to the beach west of the Beach, immediately east of the eastern Port Hueneme jetty. Bypassing occurs approximately every 2 years depending on the severity of the shoaling in the sand trap and budgetary requirements (Moffatt and Nichol 1986; Brady et al., 2012). Dredged sand is bypassed with a hydraulic dredge and graded with heavy equipment, typically until the crest has an elevation of approximately 12 feet MLLW (~12 feet NAVD88), and a width of at least 300 feet (Moffatt and Nichol 1986; USACE 2012). The total amount of bypassed sediment varies, but has declined somewhat from the estimated historical rate of 1.2 million cubic yards per year, as summarized in **Table B-4**:

TABLE B-4
SEDIMENT BYPASSING HISTORY AT ORMOND BEACH

Year	Dredge Volume
1960 - 1987	1,200,000[1]
1984 - 1993	750,000[2]
1994 - 2002	850,000[3]
2001	1,235,950[4]
2003	2,062,695[4]
2005	2,168,115[4]
2007	1,171,035[4]
2009	2,884,040[4]
2011	968,530[4]

NOTES:
1 Wiegel 1994
2 Impact Sciences 1996
3 PWA 2007
4 USACE, LA District



SOURCE: PWA (2007)

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Figure B-13
Regional Littoral System

Coastal Flood Hydrology and Erosion Hazards

The Project Area is susceptible to flooding due to ocean conditions, primarily when high ocean levels and high wave runup coincide to result in overtopping of the beaches and dunes by wave uprush pulses (ESA PWA 2013). Beach and dune erosion can also occur during these elevated ocean conditions, resulting in temporarily narrow beaches and dune erosion. Projections of coastal hazards for existing and future conditions were developed to inform coastal planning and maps are publically available via the TNC Coastal Resilience website[3] and the USGS CoSMoS website[4]. Wave overwash also transports sand to backshore areas and is an important physical process that affects shore morphology. Additional information about coastal hazards is provided in Section 2.3.

Watershed-Coastal Interface

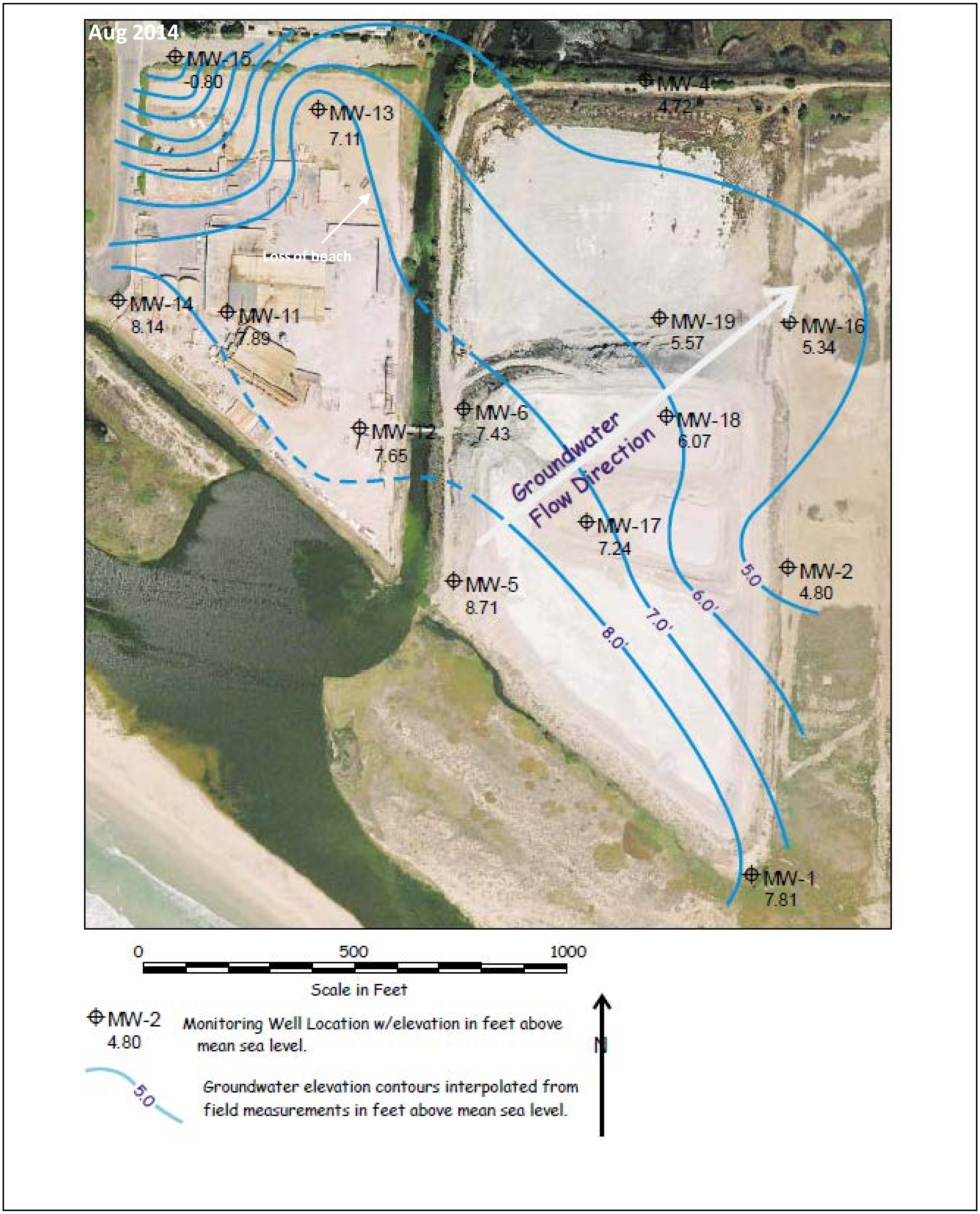
The Project Area is at the interface of watershed and coastal processes. In particular, the Lagoon is a dynamic system that fluctuates based on rainfall and runoff, waves, and sediment transport.

Natural Lagoon Dynamics

Water levels in the Lagoon respond to the balance of water inflows and outflows, which is dictated by the seasonal hydrology and by the condition of the lagoon mouth. When the mouth is open, it typically acts as a drainage outlet (Behrens et al. 2015), but tidal exchange through the mouth can lead to limited tidal fluctuations in the lagoon (CH2M Hill 2008). Waves deposit sediment in the mouth, which can either be removed by tidal and freshwater currents (effectively maintaining the opening), or can lead to blocking (closure) of the mouth, effectively separating the lagoon from the ocean (PWA 2007). When the mouth is closed, watershed runoff, groundwater flows, occasional wave overwash, and direct precipitation collect in the lagoon, causing water levels to rise. Since the lagoon is situated at a high elevation relative to ocean tides, this trapped water experiences a persistent head gradient between the lagoon and ocean, causing flows to seep through the beach toward the ocean (beach/berm seepage). As shown by CH2M Hill (2008, 2012), a persistent head gradient toward the WWTP trunk line to the north also causes upland-directed seepage from the lagoon (**Figures B-14**). Seepage and evapotranspiration allow water to leave the lagoon, and can be stronger than the combined inflows for extended periods of time (PWA 2007).

In a given year, winter flood events with more than 0.5 inches of rain are thought to be sufficient to raise water levels to the level of the beach crest, leading to scouring of beach sediments and opening of the mouth, allowing flood flows to drain to the ocean (Su 2007). The actual water level needed to breach the lagoon depends on how high waves have built the beach crest, which usually varies from 8–10 feet (PWA 2007; HDR 2008a). After the initial flood subsides, the mouth may remain open for some time, allowing lagoon water levels to fluctuate with the tides until waves eventually close the mouth again. Historically, the lagoon, which was located west of

3 http://maps.coastalresilience.org/california/ last visited, August, 2017
4 https://www.sciencebase.gov/catalog/item/57b125bbe4b0fc09fab0ce4b last visited August 2017



SOURCE: CH2M Hill (2008)

ESA

Figure B-14
Groundwater Elevation Contours in June 2006, During a Period of Lagoon Mouth Closure

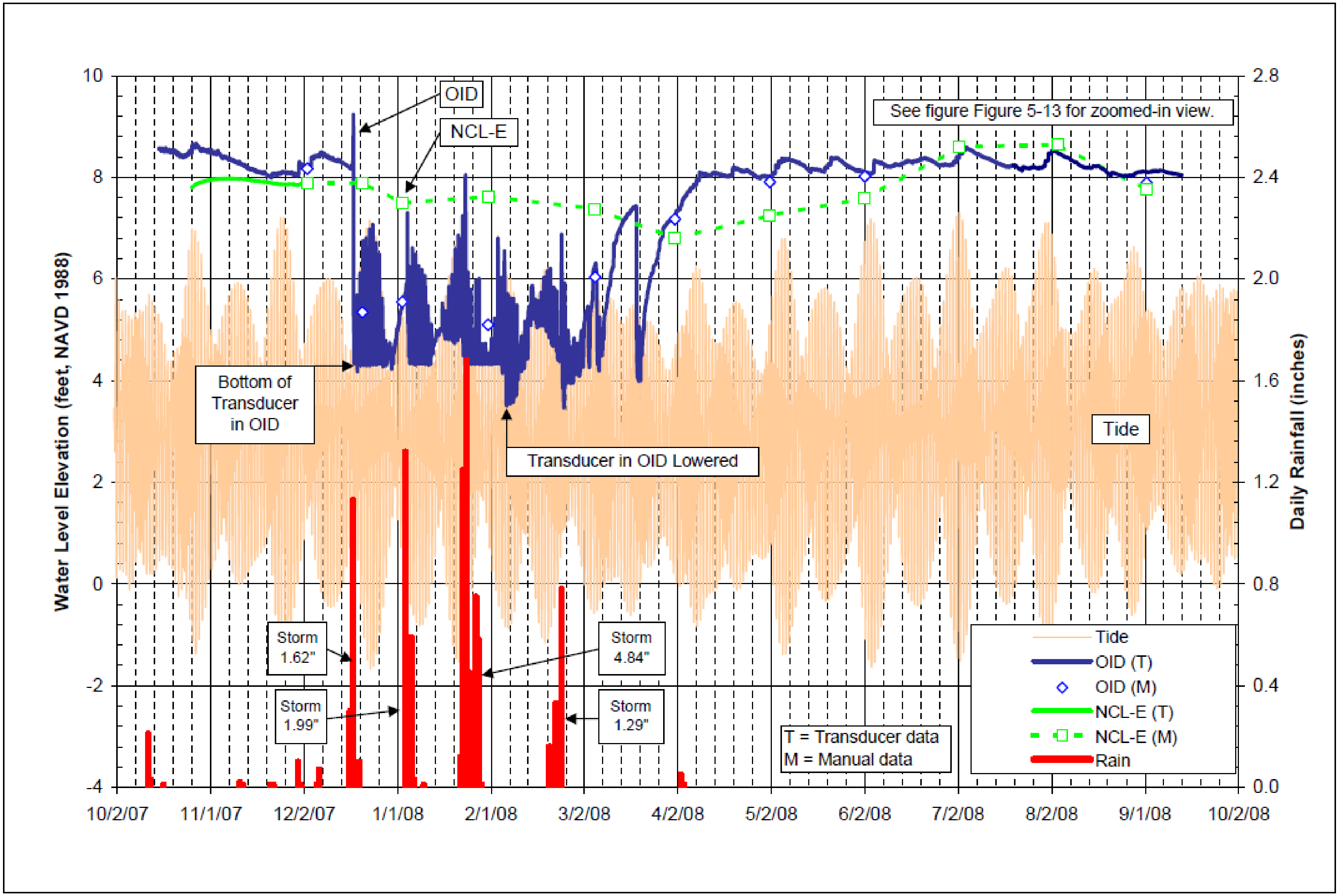
the existing location (see Section 2.1) may have had a tidal prism of 120 acre-feet, which may have allowed tidal currents large enough to keep the mouth open for extended periods of time regardless of watershed runoff conditions (PWA 2007). In its present state, the lagoon has less than 20 acre-feet of tidal prism, so mouth condition is largely dependent on watershed runoff events (HDR 2008a).

Compared to a typical oceanic tide range of 5–7 feet (see Table B-3), tidal water levels in the lagoon during open mouth conditions are on the order of 1–3 feet. This is typical for very small coastal lagoons, and these constrained flows through the mouth 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 (PWA 2007).

The lagoon varies in size throughout the year, which makes continuous water level measurement a challenge. However, surface water data collected as part of the Halaco Site remediation provide an illustration of the seasonal variability of the site. Water levels are also currently being measured in the lagoon as part of the present study. **Figure B-15** illustrates how water levels fluctuated in the Lagoon from October 2007 to September 2008, showing several important features:

- The mouth was closed until December 18, 2007, when approximately 1.6 inches of rainfall increased the lagoon water level from 8 to 9 feet NAVD88 over several hours.
- A series of rainstorms in January and February maintained an open mouth, as indicated by lagoon tides (measured in the OLW) fluctuating between 3.5 and 7 feet NAVD88.
- The lagoon underwent a series of short closure and breach events in early March, before experiencing seasonal closure on March 20th.
- The smooth rise of the water level through early April is an indication that net inflows were sufficient to fill the lagoon, but not to reach the beach berm crest and re-open the mouth.
- From mid-April through September, the mouth reached an equilibrium of 8-8.5 feet NAVD88.
- Punctuations in the water level coincide with high spring tide events throughout summer, which is an indication that wave overwash was likely entering the lagoon during extremely high tides and contributing saltwater to the lagoon (ESA PWA 2015).

The VCWPD also maintained a tide gage in the Ormond Lagoon Waterway (formerly called the Oxnard Industrial Drain and referred to as “OID” in the source document) from 2002 to 2005. This record shows a series of closure and breaching events (see HDR 2008a), but this was not referenced to a vertical datum. Water levels have also been collected manually since 2008 by referencing a tide staff at the site (CH2M Hill 2012). While these do not provide enough resolution to understand tidal fluctuations at the site, they generally show that water levels during periods of seasonal mouth closure range from 6.5 to 9.5 feet NAVD88.



SOURCE: CH2M Hill (2008)

NOTE:

OID = Oxnard Industrial Drain (now referred to as Ormond Lagoon Waterway)

NCL = The Nature Conservancy Land

Tide = Oceanic tide measured at Santa Monica

Ormond Beach Wetlands Restoration

Figure B-15

Surface Water Level Measurements in Ormond Lagoon and TNC Parcel from October 2007 to September 2008

Lagoon Mouth Management

From the early 1960s until 1992, the mouth of the Lagoon was breached periodically to drain the lagoon and prevent flooding of upland areas. This was performed by the VCWPD (formerly the Ventura County Flood Control District) with heavy equipment by digging a small pilot channel in the beach and allowing the lagoon to begin spilling toward the ocean. After the practice was discontinued in 1992, flooding has remained a concern, as rainfall events coinciding with closed-lagoon mouth conditions can cause high water levels to build in the hours before the mouth naturally breaches and drains the lagoon.

HDR (2008a, b) explored the impacts of emergency breaches and of lowering the beach berm elevation prior to the arrival of the rainfall event. They found that

- For typical beach conditions without beach management, peak water levels within the lagoon could reach 11.5 feet and 12.1 feet NAVD88 during the 2-year and 100-year recurrence fluvial flood events, respectively.
- Overtopping of the beach occurs prior to the peak of the hydrograph for a 100-year event.
- Lowering a 50 meter (~160 ft.) segment of the beach to 7 feet NAVD88 could lower peak flood levels at the lagoon for a 2-year event to 8.5 feet NAVD88.
- Creating an emergency breach at tšumaš Creek prior to the 2-year storm event could reduce the peak elevations at the lagoon during a 2-year event to 7.9 feet NAVD88.
- Creating an emergency breach at tšumaš Creek prior to the 100-year storm event could reduce the peak elevations at the lagoon during a 100-year event to 10.8 feet NAVD88.

The VCWPD mitigates flooding by lowering (grooming) the beach crest for a 100-foot-wide segment of the beach to a specified level allowed by the Beach Elevation Management Program (BEMP) established under the Coastal Development Permit 4-12-051 (6.5 feet NGVD29, or 8.9 feet NAVD88, CCC 2013) or 0.5 feet above lagoon water level whichever is higher), up to three times per year (HDR 2012) VCWPD actively monitors beach elevations and forecasts precipitation and stream levels to determine if beach grooming is required. Maintenance activities under the permit have been documented for fiscal years 2015–2017. Post-grooming reports highlight how rapidly beach elevations can increase after grooming when breaching does not occur immediately (VCWPD 2017). Forecasting includes the following considerations:

- Minor flooding around the Lagoon for stages of 9.4-10.9 ft. NAVD88
- Flooding begins to impact Oxnard WWTP and International Paper plant at stages of 10.9-11.4 ft. NAVD88
- Major impact to Oxnard WWTP, International Paper plant, and Hueneme Road for stages above 11.4 ft. NAVD88.

Existing Conditions - Biological Processes

This section summarizes the physical drivers that support and shape the distribution and abundance of biological resources at the site. This analysis builds an understanding of how the current habitats and populations are functioning and changing, and informs the development and assessment of restoration alternatives. The findings will also support future studies that will be needed as part of the permitting and CEQA process.

Habitat Types

The habitats that establish on site are largely driven by salinity levels (**Figure B-16**). High soil salinities or a regular influx of salt water will create salt marsh or salt panne habitats. Fresher soils and waters lead to freshwater marsh. Areas in between become brackish marsh. Changes in soil salinity, through leaching or increased tidal inputs, will change the types of habitat that establish on the site. Salinity monitoring conducted in the spring of 2017 is discussed below, followed by the current understanding of the biological processes that regulate salt marsh and saline seasonal wetlands. The trend of salt marsh conversion to brackish/freshwater marsh is discussed after.

Project Area Salinity

Shallow basins retain rainwater and can pond for several months in wet years. When ponded, these areas are used by waterfowl and shore birds. A wide range of salinities was documented in different basins in the spring of 2017 (**Figure B-17**). In general, ponds got saltier as water levels dropped (suggesting evaporation was an important driver in the dropping water level). There was also a trend of increasing salinity from west (TNC parcel), where salinities ranged from 6 ppt to 16 ppt between March and late May, to the east (SCC parcel), which ranged from 20 ppt to 81 ppt over the same timeframe. Areas near the power plant were sampled less frequently, but ranged from about 5 ppt in March to 37 ppt in early June.

These salinity patterns are consistent with the existing habitats. The TNC parcel has large areas of tule and cattail, neither of which tolerates high salinities. The lower parts of the SCC salt panne and marsh basin are unvegetated and there is a salt crust on the soil surface when dry. The areas near the power plant are mostly pickleweed, with small areas of salt marsh bulrush and tule starting to get established.

Salt Marsh

All of the salt marsh habitat on site is currently non-tidal. Only the SCC salt panne and marsh basin (Area 6) (Figure B-17) still receives direct seawater influence in the form of occasional wave overwash events. Salt marsh species persist in other areas presumably due to high-salinity soils that exclude other species. The high-salinity soils are an indicator of an historic connection to the ocean.

Brackish Marsh

Brackish marshes form where fresh surface water and salt water meet, or where groundwater reaches the surface and mixes with tidewater. Extraction of groundwater for agricultural and municipal uses, along with channelization of streams and rivers, has lowered the water table near the site. The lower groundwater will limit opportunities to restore brackish marsh in these areas.

Saline Seasonal Wetlands

Seasonal wetlands occur on the TNC parcel next to agricultural land in Area 4. These areas pond water for very short periods of time, maybe only in wet years. The Areas 3a and 4 (near the railroad) are hydrologically connected to the lagoon, but only during periods of high water, so when the lagoon drains, water is trapped in these areas as seasonal ponds. Some of these wetlands may also be supported by high groundwater. Wetlands that rely on rainfall for their hydrology, even if salty now, will eventually evolve into freshwater habitats as salts are either leached out of the soil or removed from the site in runoff. Maintaining and restoring saltwater-dominated habitats is desirable at the site in order to maintain and increase biodiversity of coastal wetland-dependent species.

It is not clear what the main hydrologic drivers of this habitat are across the project site. Soils are almost certainly saline and appear to be better drained than most of the salt marsh areas on site. During field surveys, there was no ponding in most of these areas. The water table may be very close to the surface (and perhaps brackish) in these areas. Further study is warranted to understand these hydrological patterns.

Seasonally wetted areas are created elsewhere in the site by muted tidal connection to Mugu Lagoon via the ODD #3 (Area 5 on SCC parcel), direct exposure to rainfall, interaction with the local groundwater table, or local wave overwash create seasonally wetted areas. As an example, the wetted salt pannes on the SCC parcel (Area 5), may be fed by a combination of groundwater interaction and wave overwash.

Uplands

Uplands and upland-wetland transition habitats exist in parts of the project site and are important components of the overall ecological potential. These include the agricultural lands on the TNC parcel (Area 4) and the former tank farm area on the SCC parcel (Area 5). This potential includes high-water refuge for wetlands species and space for wetland migration with sea-level rise.

Plants and Wildlife

Understanding the physical and biological processes of a system is key to understanding how plants and animals will establish and use a site. The plants and animals that live within Southern California’s estuaries have evolved over many thousands of years to tolerate, and even take advantage of, the highly dynamic nature of these systems. This section considers how plants and animals function within the habitats created by those processes.

SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

NOTE: Based on field mapping of site in Spring 2017. Minimum mapping unit was approximately one acre in most cases, so some small habitat features are not shown.

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Figure B-16
Existing Habitats

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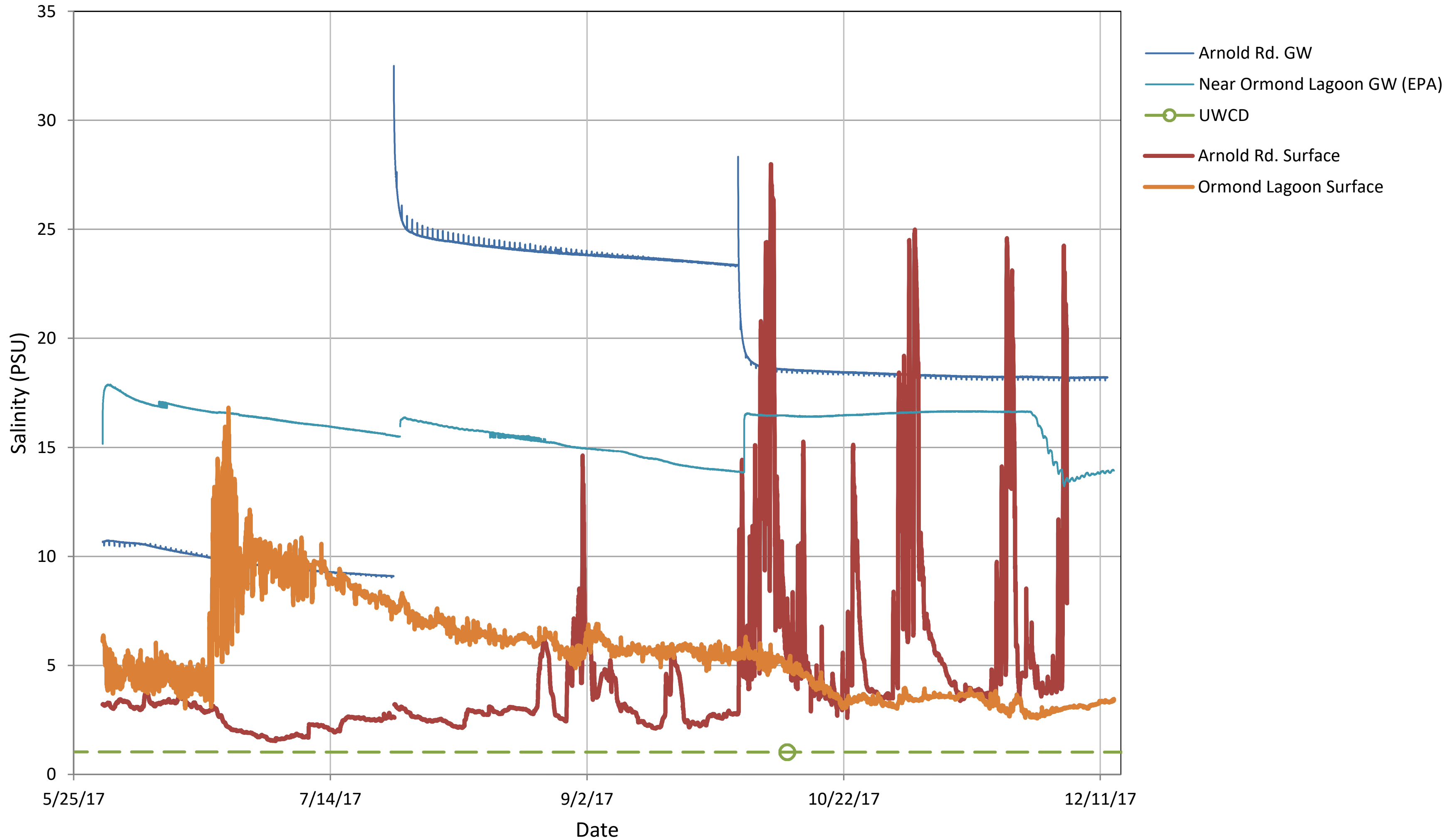


SOURCE: ESA Water Level Gauges UWCD Groundwater Well

Figure B-17
Salinity

Special Status Plant Species

Salt Marsh Bird's Beak

Salt marsh bird's beak tends to establish in areas of low salt marsh cover, often on the edges between bare ground and vegetation. Comparing mapping efforts at the site over time suggests this species has a high degree of small-scale site fidelity within the wetland complex (i.e., it tends to be found in the same location year after year). The species is threatened by the conversion of salt marsh to brackish marsh that is occurring at the site.

The mean elevations of salt marsh bird's beak vary by about a foot among the three wetland basins, based on surveys conducted in June 2017. The lowest distribution (mean 5.8 feet NAVD88, range 5.3 to 6.5 feet), for plants in the SCC salt panne and marsh basin, was nearly identical to the elevation distribution of salt marsh bird's beak in the muted tidal estuary at Carpinteria in 2017 (upper limit at Carpinteria 6.4 feet) (Page, Doheny, Hoesterey, Johnson, Hubbard, and Shroeter, *unpublished data*). The mean elevations for the other two basins surveyed at Ormond Beach were 6.4 feet NAVD88 (range 5.3 to 6.5 feet) and 6.8 feet NAVD88 (range 6.0 to 8.0 feet). These values are similar to the median reported by Zedler (2000) for fully tidal systems.

Coulter's Goldfields

Coulter's goldfields tends to establish on salty soils in areas where there is little or no plant cover. It is an annual plant that usually grows in wetlands (salt marsh, playas, vernal pools) but is occasionally found in non-wetlands. In salt marshes, Coulter's goldfields is found on the edges of salt pannes (unvegetated flats with salty soils) or in vernal basins (shallow pools that form in the cool season) (Zedler 2000). The population size of Coulter's goldfields varies strongly with soil moisture and salinity between years (Noe 1999). The population is large and presumed stable, however, the eventual leaching of salts out of soils will open up its current habitat to other species that might eventually out-compete it.

Coulter's goldfields occurred at elevations between 8.1 and 9.6 feet NAVD88, with an average elevation of 8.9 feet. This average distribution was more than 2 feet higher than in the fully tidal estuary at Carpinteria salt marsh in Santa Barbara County in 2017 (Page, Doheny, Hoesterey, Johnson, Hubbard, and Shroeter, *unpublished data*). The distribution is also 1.3 feet higher than the median elevation reported by Zedler (2000)

Elevated distributions are expected for coastal wetland plants in systems like Ormond Beach that do not get regular tidal exchange and that are not influenced by groundwater controlled by tidal processes. Since the system is perched above mean sea level, inundation, soil saturation, and high soil salinity limit plant distributions to elevations higher than those expected under fully tidal systems. These physical conditions will be important factors to consider in developing approaches to conserving these species under climate change scenarios and in restoration alternatives.

Sea Blite

Sea blite[5] is a succulent-leaved perennial shrub of the goosefoot family (Chenopodiaceae). Plants that appear to be *Suaeda taxifolia* occur at the site along the path in the southern portion of the SCC salt panne and marsh basin (Area 6), and in a large patch in the southwest TNC marsh parcel (Area 3a). Wooly sea blite grows in saline habitat at the margins of salt marshes and coastal dunes and bluffs (California Native Plant Society 2018).

Spiny Rush

Spiny rush (*Juncus acutus* ssp. *Leopoldii)* establishes on the edge of salt marshes, under moderately high salinities without inundation. This species was observed in 2017 scattered throughout the wetlands on SCC property (Areas 3b, 5, and 6). This survey indicates the species is expanding at the site since the Feasibility Study (Aspen 2009), which may be a result of the conversion of salt marsh to brackish marsh.

Red Sand Verbena

Red sand verbena establishes in dune habitat and fills an important role in dune building. This survey indicates the species is expanding at the site since the Feasibility Study (2009).

Birds

California Least Tern

The California Least Tern (*Sterna antillarium* ssp. *browni*) nests on the bare sand near the lagoon. The adults forage for fish in the lagoon and nearshore waters (Hartley 2017). This species was regularly observed flying over the site and diving for fish in open water habitats throughout the site during all of the field visits in 2017. As of late June 2017, there were more than two-dozen nests established on bare sand near the lagoon. VAS surveys (2003-2018) indicate a high concentration of nesting on the beach south of the lagoon on City property in Area 7 (Cynthia Hartley, VAS, personal communication to Kim True, August 29, 2018).

Western Snowy Plover

The Western Snowy Plover (*Charadrius alexandrius* spp. *nivosus*) inhabits the beach, dunes, and salt panne on the SCC parcel (Areas. In 2017, nests were dispersed over the entire 2-mile length of Ormond Beach (Hartley 2017). Chicks and fledglings were either at the salt panne to the south or near the lagoon (Hartley 2017). VAS surveys (2003-2018) in Area 7 indicate a high concentration of nesting on the beach south of the lagoon on City property, and extending south to SCC property in front of the OBGS (C. Hartley, VAS, personal communication to K. True, August 29, 2018).

5 Two special-status sea blites were previously documented on the site by others: woolly sea blite (*Suaeda taxifolia*) and California sea blite (*Suaeda californica*). However, *Suaeda taxifolia* is highly variable in appearance, and *Sueda californica* is now known to occur only north of Point Conception (USFWS 2010). Therefore, *Sueda californica* is not likely to be present on-site.

Belding's Savannah Sparrow

Belding's Savannah Sparrow (*Passerculus sandwichensis beldingi*) nests in pickleweed in coastal salt marshes. The conversion of salt marsh to brackish marsh is a threat to the species on site. Salt marsh areas that have converted to brackish marsh (cattail and tule) will generally not support nesting for this species.

Ridgway's Rail

Rallus longirostris levipes) nest in tidal salt marshes, preferring tall intertidal cordgrass (*Spartina foliosa*) where it builds a floating nest. Nesting in muted tidal or non-tidal areas of tidal marshes has been documented at Mugu Lagoon and Carpinteria Salt Marsh in spiny rush (*Juncus acutus*) and saltmarsh bulrush (*Bolboschoenus maritimus*). It is unlikely that the habitats in the Project Area can support breeding of the Ridgway's Rail due to the lack of important prey species (crabs and mollusks) that are found in tidal systems. Ridgway's rails are known to nest in non-tidal areas of tidal systems, but breeding in non-tidal systems is probably very rare (USFWS 2009).

Fish

The fish community of the Lagoon is shaped by the dynamics of mouth closure, salinity gradients, and physical habitat structure. Water levels in the Lagoon respond to the balance of water inflows and outflows, which is dictated by seasonal hydrology and by the condition of the lagoon mouth (Section 2.2.3). In general, when the mouth is open, marine fish species can enter to use the estuary for spawning or rearing habitat. Topsmelt and striped mullet have been documented in the Lagoon (Cardno 2017). However, access for marine fishes is likely limited since the Lagoon is perched at a higher elevation and has only minimal tidal connection.

Salinity gradients are strong drivers for estuarine fish assemblages (Allen et al. 2006). Estuarine fish species tolerate a wide range of salinity and temperature. When the mouth is closed but the lagoon is still receiving freshwater inflow, salinity will decrease. This can favor fish species adapted to lower salinities. Salinity measured in the Lagoon (mouth closed) was 1.7 ppt to 2.6 ppt (October 2015), 12.3 ppt to12.7 ppt (April 2016), and 6.9 ppt to 12.9 ppt (October 2016) (Cardno 2015b, 2016a, 2016b). Several non-native species in the Lagoon and tšumaš Creek are typical of brackish to freshwater conditions, including mosquitofish, sailfin molly, and Mississippi silverside. These species are competitors with the endangered tidewater goby. The long-jawed mudsucker , another native goby, preys on tidewater goby and can eliminate them in small closed lagoons (Brenton Spies, UCLA, *personal communication*).

Contaminants that impair water quality are a concern, as noted earlier in Section 2.2.1.2. Fish kills have occurred in the Project Area. On July 20, 2015, thousands of dead fish were observed in the tšumaš creek (formerly J Street Drain) following a large storm (CDFW 2015). Two live tidewater gobies were rescued, and no dead gobies were observed. Necropsy of dead fish revealed high levels of bifenthrin, a pyrethroid insecticide, present in gills and liver. The likely source was urban and agricultural runoff.

Tidewater Goby

The tidewater goby is uniquely adapted to low-salinity estuaries and lagoons, such as found at the Lagoon. The Project Area encompasses tidewater goby critical habitat unit *VEN-3 J Street Drain-Ormond Lagoon* (USFWS 2013). Attributes of critical habitat (USFWS 2013), include a seasonally closed lagoon, shallow low-salinity waters, still-to-slow-moving water, areas of sand and silt substrate for the construction of burrows for reproduction, and submerged and emergent aquatic vegetation, such as pondweed (*Ruppia maritima, Potamogeton pectinatus*), bulrush (*Scirpus* spp.), and cattail (*Typha latifolia*). Of particular importance is the presence of the sandbar(s) across the mouth of a lagoon or estuary during the late spring, summer, and fall that closes or partially closes the lagoon or estuary, thereby providing relatively stable water levels and salinity. In general, backwater areas or off-channel marsh habitat provide valuable low-flow refugia and foraging habitat (Swenson 1999).

The Lagoon provides many of these critical habitat elements, in particular a closed lagoon, low salinity waters, suitable substrate, and pondweed. However, the presence of non-native fishes is a concern. Increasing the frequency of tidal exchange, while still maintaining seasonal lagoon closure would increase salinity levels and fluctuations, which could reduce the freshwater species.

As discussed previously, VCWPD grooms the berm between the lagoon and the ocean to allow for natural breaching of the lagoon berm during storm events. The approach of tying berm grooming to storm events is designed to protect tidewater goby populations; in response to pre-storm environmental cues, the fish will move upstream and thereby minimize the likelihood of being washed out to sea when the berm breaches (C. Dellith, U.S. Fish and Wildlife Service, personal communication to L. Riege, TNC, October 5, 2017).

Future Conditions

This section provides an initial summary of available information and assessment of future conditions without restoration (i.e., future without project conditions). This assessment of future conditions will be refined as part of developing and evaluating restoration alternatives.

Future Physical Conditions

Future conditions at the Project Area have been considered in a number of studies led by the Pacific Institute and TNC. These have incorporated regional projections of sea level rise, future watershed conditions, regional shoreline geology, and built infrastructure constraints to consider future coastal and fluvial flooding conditions, and storm erosion. Related studies examined economic tradeoffs of future management actions at the site, as well as future marsh accretion in the nearby Mugu Lagoon.

In 2009, Philip William and Associates (PWA) was funded by the Ocean Protection Council (OPC) to provide a technical hazards analysis in support of the Pacific Institute report on the "Impacts of Sea Level Rise to the California Coast" (Pacific Institute 2009). PWA projected future coastal flooding hazards for the entire state based on a review of existing FEMA hazard maps. PWA also projected future coastal erosion hazard areas for the northern and central California coastline, but did not include Ventura County at that time. This study led to the development of a methodology for assessing coastal erosion (Revell et al. 2011), but was constrained by a lack of data in parts of the State, including the Ventura coast. The Pacific Institute (2009) used information from this study to evaluate potential socio-economic impacts of sea level rise.

The Coastal Resilience Ventura project led by TNC built on this prior work, improving and adding to the methods of the Pacific Institute (2009) study and applying them to the Ventura study area with higher resolution local data to analyze the coastal hazards associated with sea level rise (Section 4.1). This work led to projections of future coastal hazards that were suitable to supporting local planning processes, as well as a series of decision-support tools intended to aid conservation, planning, and policymaking. Hazard zones were developed at three planning horizons (2030, 2060, and 2100) based on guidance from the steering committee.

The sections below summarize some of the main findings from the Pacific Institute and TNC studies. For more information on the technical details, refer to PWA (2009), and ESA PWA (2013 and 2014).

Sea Level Rise

ESA PWA (2013) assessed future sea level rise based on guidance from the National Research Council (NRC 2012) and the U.S. Army Corps of Engineers (USACE 2011). These studies considered the outputs from global circulation models (GCMs), to produce local sea level rise estimates based on a range of future carbon emissions scenarios. The USACE medium curve was selected as the low curve by ESA PWA because it is the lowest of all the USACE and NRC projections that incorporates future increases in the rate of sea level rise. The high and medium curves were based on the high and middle range of models discussed in the NRC 2012 report. All curves include an adjustment for local vertical land motion using the Santa Monica tide station (NOAA #9410840). **Table B-5** summarizes the sea level rise rates.

TABLE B-5
SEA LEVEL RISE PROJECTIONS, RELATIVE TO 2010

Year	Low SLR	Medium SLR	High SLR
2030	6 cm (2.3 inches)	13 cm (5.2 inches)	20 cm (8.0 inches)
2060	19 cm (7.4 inches)	41 cm (16.1 inches)	64 cm (25.3 inches)
2100	44 cm (17.1 inches)	93 cm (36.5 inches)	148 cm (58.1 inches)

NOTE: SLR = sea level rise
SOURCE: ESA PWA 2013

Watershed Runoff Conditions

ESA PWA (2013) also assessed regional climate change impacts on watershed runoff, looking at potential changes to the 100-year recurrence interval flood on the Ventura and Santa Clara Rivers. The impact of rising coastal water levels from sea level rise was also considered. Although runoff to the Ormond Beach Project Area was not modeled, relative changes to the Ventura and Santa Clara Rivers is assumed to provide a useful proxy for regional change.

To model future runoff conditions, ESA PWA (2013) relied on prior work by Cayan et al. (2012), who regionalized broad scale GCM data and identified the models that most reliably capture the climate phenomena in California. Future hydrology projections for Ventura County were obtained from the Coupled Model Intercomparison Project database for daily runoff and baseflow, which are available to the public through an online database (http://gdodcp.ucllnl.org/downscaled_cmip3_projections/). ESA PWA (2013) performed a fluvial flood hazard analysis using a combination of these downscaled climate projections, hydraulic modeling, and floodplain inundation mapping to evaluate the impact of climate change on fluvial flooding. Results for the Santa Clara and are shown in Table 9 of ESA PWA 2013. Generally, for a medium-high emissions scenario these show an increase of 11-23 percent in the peak flows for the 100-year recurrence flood, versus a 4-14 percent decrease for a low emissions scenario. Although the watershed for the Project Area is largely urban, these results give a sense of the direction of change in peak runoff conditions for future climate scenarios.

Coastal Flooding

ESA PWA (2013) mapped coastal flooding under several future cases. These included:

- Rising tide inundation zones: considering only inundation from oceanic tides
- Coastal storm wave impact area: considering the zones where water could potentially rush inland due to waves breaking at the coast
- Coastal storm flood hazard zones: flooding caused by storm waves rushing inland and by ocean storm characteristics such as storm surge (a rise in the ocean water level caused by waves and pressure changes during a storm)
- Combined storm flood hazard zones: combining the above terms and fluvial storm flooding into a single comprehensive, combined storm flood hazard area.

Figure B-18 shows the predicted flooding extents under present day, 2030, 2060, and 2100 conditions under tidal conditions. **Figure B-19** shows future flooding under storm conditions These conditions show the expected extents of inundation if the existing infrastructure, drainage pathways, and topography remain the same in the future. These changes do not consider changes to position of the beach, dunes, or other habitat over time. A separate study by ESA PWA (2014) examines changes to wetland and adjacent ecotone habitat in and adjacent to Mugu Lagoon.

Coastal Erosion and Beach Adjustment

Under future sea level rise conditions, the Project Area will undergo a series of hydrologic changes as the beach responds geomorphically to the rising water levels. The Beach will likely respond to rising oceanic water levels by migrating inland (transgressing), and shifting upward. Depending on the rate of transgression, the existing dune system may be eroded, since higher oceanic water levels would mean that existing dunes would be exposed to waves on a more frequent basis. If the future lagoon and wetland system are allowed to migrate inland, the hydrology may remain similar in the future, although the groundwater table will likely shift upward along with the rising tides.

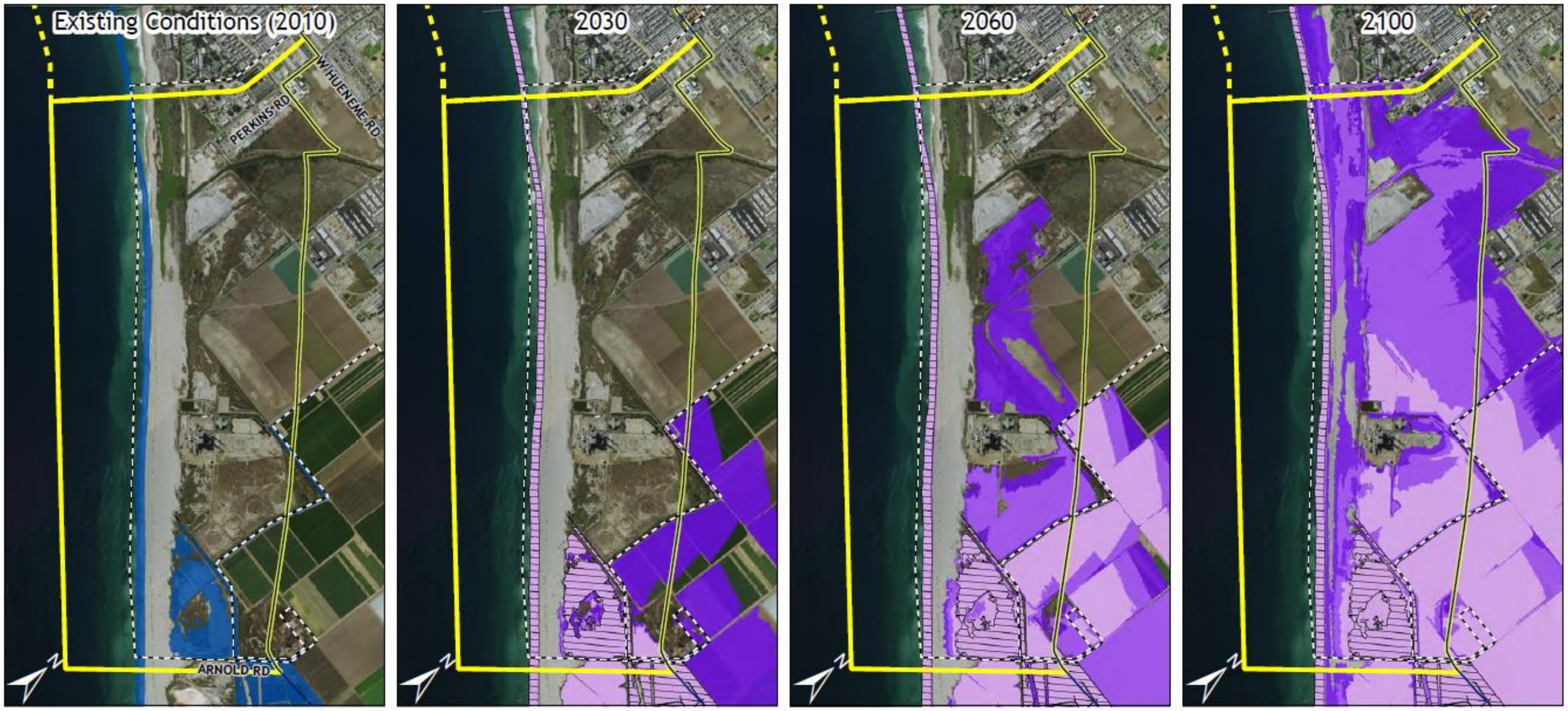
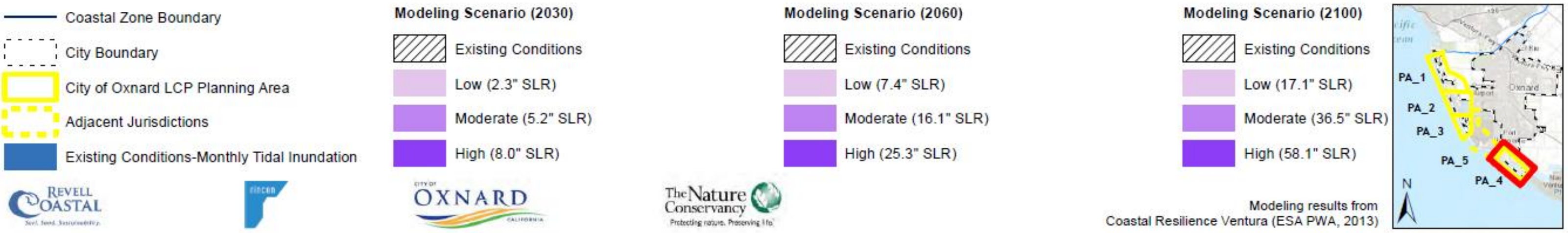


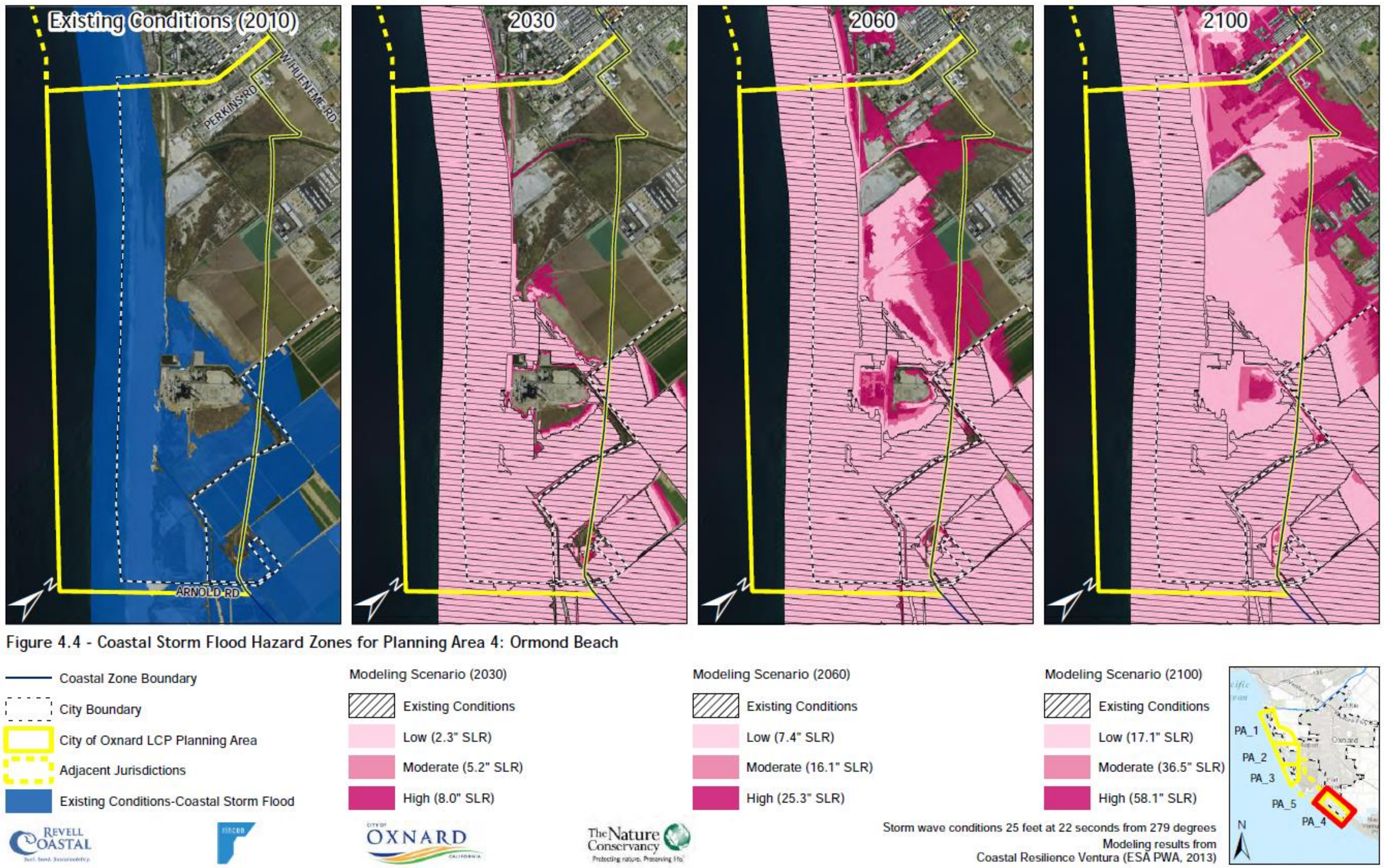
Figure 4.1 - Monthly Tidal Inundation Hazard Zones for Planning Area 4: Ormond Beach



SOURCE: ESA PWA 2013

Ormond Beach Wetlands Restoration

Figure B-18
Future Monthly Tidal Inundation Hazard Zones



SOURCE: ESA PWA 2013

Ormond Beach Wetlands Restoration

Figure B-19
Future Coastal Storm Flood Hazard Zones

If the lagoon remains in place due to existing property constraints, the beach will likely erode over time, potentially eliminating the lagoon and wetlands (HDR 2008, ESA PWA 2015). ESA PWA (2015) performed an analysis to examine how the beach width could adjust over time.

Lagoon Mouth Dynamics

The effects of sea level rise on intermittent lagoons, such as the Lagoon, depends on the future response of the beach, and on changes to runoff patterns and locations of infrastructure and roadways that constrain the back edge of the lagoon. If the beach transgresses inland and existing roadways and infrastructure remain in place, the lagoon could reduce in size over time, since it would have no room to move inland, which would reduce flows through the mouth over time. In general, the maximum height of the beach berm at the mouth will rise at a one-to-one ratio with sea level rise (assuming sufficient sand supply), meaning the maximum water level in the marsh will rise proportionately. Depending on the rate of future sedimentation (either from delivery of inorganic sediments to the lagoon or from decay of organic material), this rise in maximum water level could increase tidal prism in the lagoon (if sea level rise outpaces deposition) or remain comparable (if sea level rise is comparable to deposition rates). A larger tidal prism could lead to longer periods of open conditions (PWA 2007). Since the Project Area currently receives very little sediment each year, this future deposition rate will likely depend on organic deposition rates within areas of restored marsh. Modeling of these future mouth dynamics will be completed as part of the Ormond Beach Restoration and Public Access Plan.

Future Biological Conditions

Current Trends

The most obvious current trend at the site is conversion of salt marsh and salt flat habitat to brackish and freshwater marsh habitats. This is driven by decreased influence of sea water on the site over the last few decades as the dunes have grown wider and taller (limiting wave overwash). The growth of the Ormond Lagoon since the suppression of mechanical breaching (1992) has also likely increased the extent of fresh water effects, whereas the “beach grooming” (also known as breach priming) that has been practiced following a 2010 flood event (VCWPD 2010, 2016, 2017) seemingly is less impactful that the historic mechanical breaching. This has led to a situation where rainfall and runoff from the local watershed have become more important drivers of hydrology and salinity for the western portion of the site. Unless seawater influence on the site is increased, more and more of the current salt marsh habitats is expected to convert to tule and cattail marsh, which is not as high a regional wetlands priority as salt marsh (WRP 2018).

Much of the north TNC marsh (Area 2) and the north SCC marsh (Area 5) are in the process of recovery from severe disturbance. Both areas support wetland habitats and native salt marsh species to a limited extent. Neither area has salt water influence, though, and it is expected that if rainfall continues to be the primary hydrologic driver, these areas will become less saline and non-native invasive species will come to dominate. Without restorative actions, these areas are unlikely to recover to high functioning wetland habitat on their own.

The salt marsh and panne habitat are persisting in the southeastern area (Area 6), likely because of wave overwash, less rainfall runoff, and resulting salt concentrations. The wave overwash is attributed to the narrower and lower dune field geometry in this location. Historical maps show that the relatively narrower beach and dune field in this area is natural. However, it appears that the dunes were destabilized by erosion following the Hueneme Harbor construction, resulting in very low dunes which allow greater wave overtopping and foster higher salinity levels in the wetlands.

Long-Term Changes Due to Sea Level Rise

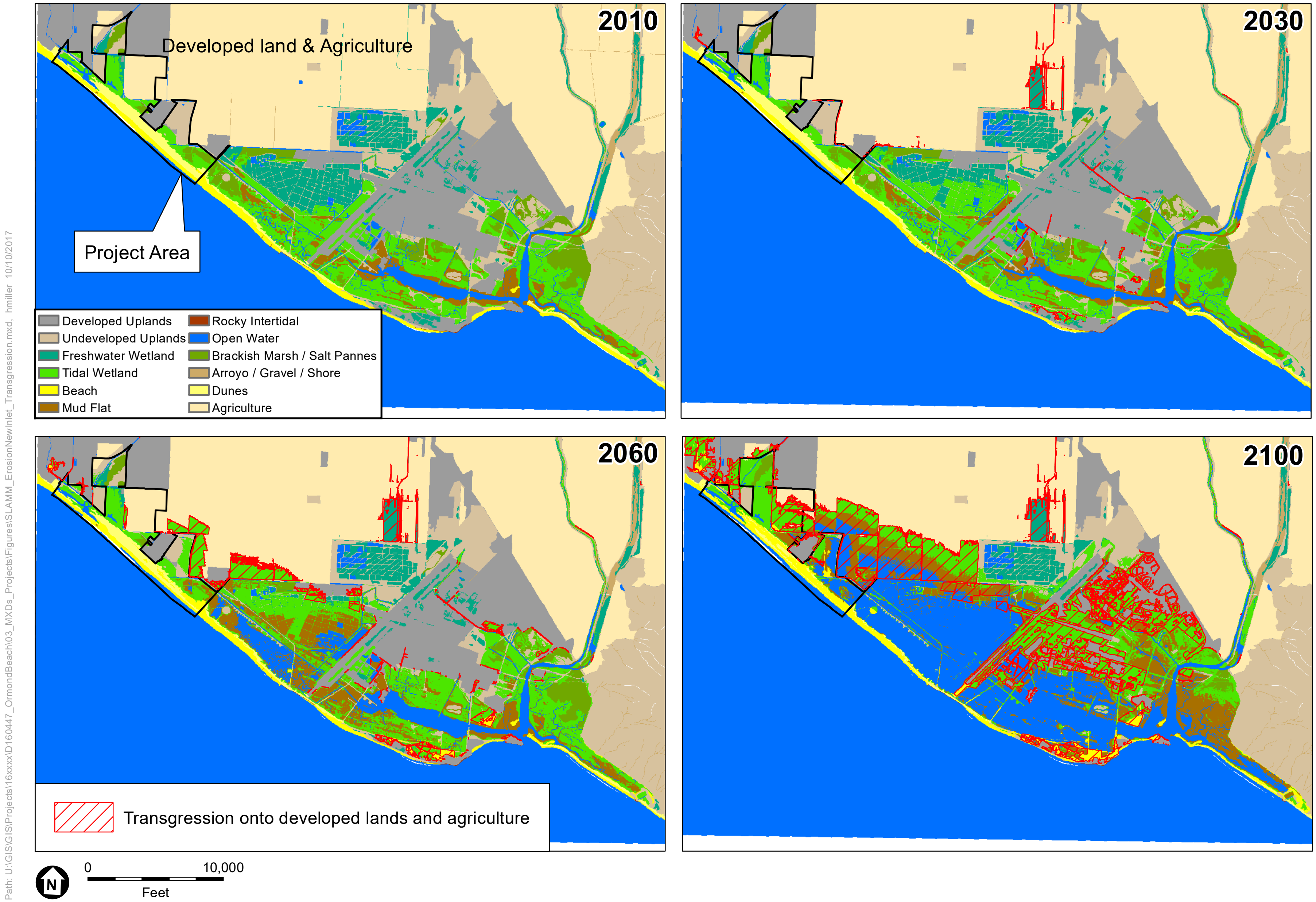
Sea level rise is expected to affect the beach and dunes, as well as groundwater levels, and in-turn affect the hydrology and salinity of the wetlands. Prior studies provide insight into the effects of sea-level rise on wetland hydrology and habitat changes. Much of the prior work was accomplished recently (2014) as part of the Coastal Resilience Ventura program lead by TNC and partners. This section outlines some of those projected changes to provide background. Site evolution is assessed in more detail as part of the OBRAP technical studies (Appendices C, D, E and F).

Prior SLAMM Projections

As part of TNC's Coastal Resilience Ventura project, ESA PWA (2014) modeled habitat evolution with sea level rise along the Ventura coastline for different management scenarios. ESA PWA used the EPA's Sea Level Affecting Marshes Model (SLAMM) to look at the effects of sea-level rise, accretion and erosion, and freshwater inflow on different coastal habitats. The Coastal Resilience online tool[6] shows future conditions for the Project Area with sea level rise. SLAMM, which is based on U.S. Atlantic Coast embayments, required modification to apply to Ventura coastlines. ESA PWA made modifications to improve the accuracy of projecting habitat change within the Mugu Lagoon. These modifications included using California wetland habitat types and accounting for tidal muting within Mugu Lagoon. At the time of the study, SLAMM could not accurately represent intermittently-open lagoon and backbarrier systems such as Ormond Lagoon and the backbarrier salt marsh and pannes at Ormond Beach. More recently, ESA has teamed with Warren Pinnacle Consulting (WPC) and TNC to improve SLAMM to better represent back-barrier wetlands with perched hydrology (water levels higher than ocean tides) (WPC 2016). This is an important improvement because backbarrier habitat in west coast systems is less dependent on tides than in east coast systems (WPC 2016). This ongoing work will allow refinement of future projections as part of the OBRAP process, but the results presented here are based on prior work that used the older version of SLAMM (ESA PWA 2014; Environs and ESA PWA, 2015).

Figures B-20 and B-21 show the existing (2010) habitat zones for the Project Area and projections for 2030, 2060, and 2100 based on a 'high' sea level rise case of 58.1 inches (4.8 ft.) by 2100 (NRC 2012). Both cases also consider a low sedimentation rate, and the potential for marsh to transgress upland into existing agricultural and developed areas (if marsh transgression/restoration is allowed). Figure B-20 shows projected conditions assuming a new tidal inlet erodes west of the base runway (which could be analogous to improving tidal connectivity between Ormond Beach and Mugu Lagoon), whereas projections in Figure B-21 assume no new inlet. The model showed progressive

6 http://maps.coastalresilience.org/california/#



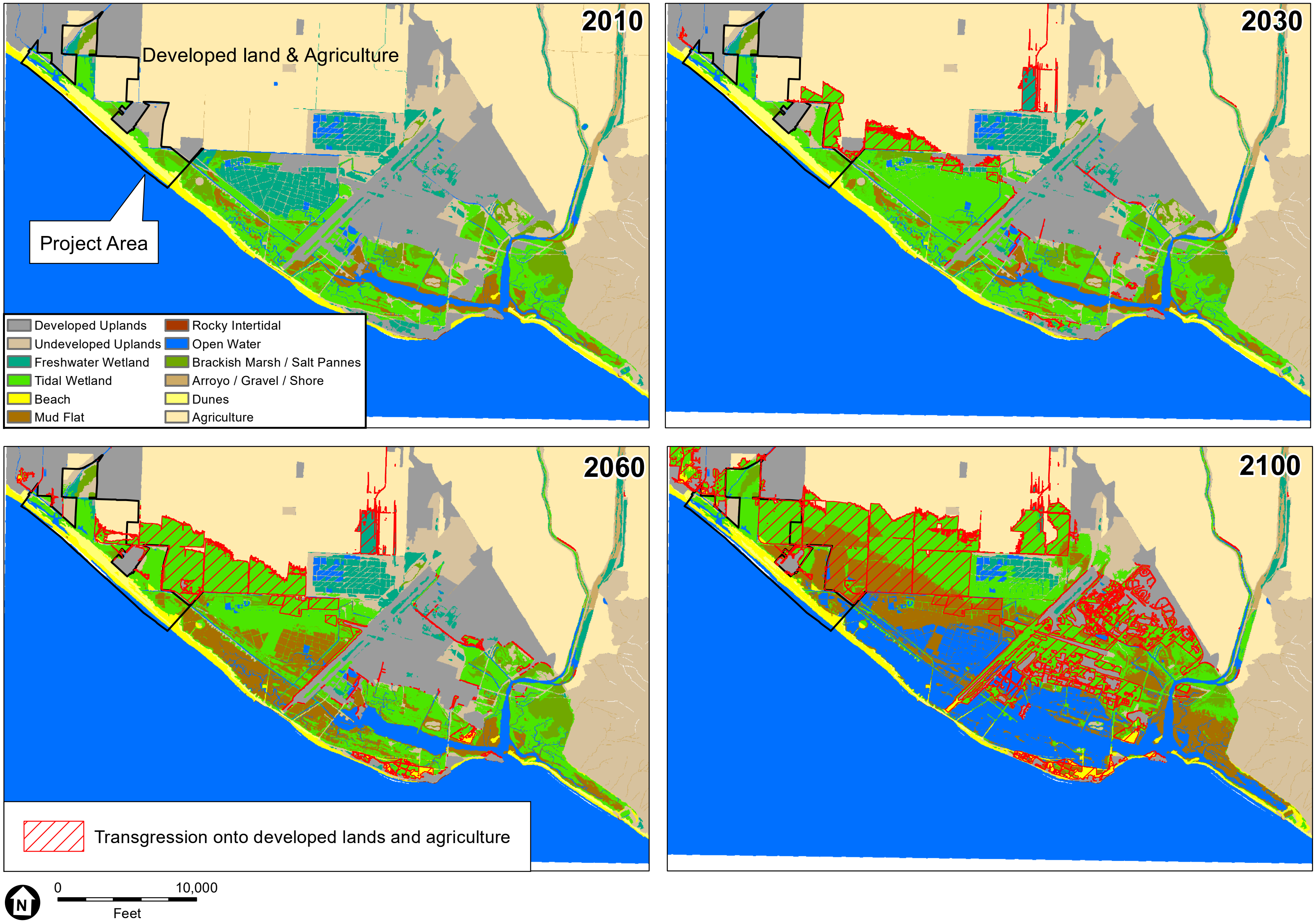
SOURCE:ESA PWA 2014

Ormond Beach Restoration and Public Access Plan

Figure B-20

SLAMM Results: High SLR, Low Accretion, Erosion of New Inlet, Allow Marshes to Transgress

ESA



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SOURCE:ESA PWA 2014

Ormond Beach Restoration and Public Access Plan

Figure B-21

SLAMM Results: High SLR, Low Accretion, No Erosion of New Inlet, Allow Marshes to Transgress

ESA

drowning, or conversion of existing salt marsh habitat to mudflat, and mudflat conversion to open water. This is more pronounced for the case without erosion of a new inlet west of the base runway. These results indicate that existing salt marsh habitat are vulnerable to sea-level rise. The existing salt marsh could be largely lost in the future without adaptation measures such as restoring marsh/allowing for marsh transgression onto existing agricultural and upland areas. These results and findings led to the investigation of adaptation scenarios described in the following section.

Several of the aspects of this previous modeling will be revised as part of the OBRAP process in order to assess habitat evolution and resiliency with sea-level rise specifically at Ormond Beach. In particular, the response of the Ormond Beach dune and beach system to sea level rise will be examined in more detail (see the additional discussion in the Shoreline Response and Salinity of Backbarrier Wetted Areas section below). It is also important to note that the persistence of marsh habitat in the Project Area will depend on whether marsh habitats can transgress inland. Lack of transgression space would constrain marsh, mudflat, and open water areas, including the Lagoon, as the beach moves inland, most notably in Area 1 and around the Halaco Superfund Site. Fortunately, there is room for marsh migration on the uplands at the TNC property on agricultural lands (Area 4) and the SCC property on former tank farm land (Area 5).

Economic Analysis of Nature-Based Adaptation to Climate Change for Ventura County

Beach and wetland changes were also analyzed as part of an analysis of the economics of sea level rise adaptation scenarios (Environs and ESA PWA 2015). Two responses (adaptation strategies) to sea level rise were modeled: One response favors engineered solutions, and is referred to as the Engineering Based Adaptation, or EBA, while the other is called the Nature Based Adaptation strategy, or NBA. The work builds on the prior forecasting and mapping of climate change-induced hazards along with projections of wetlands responses developed for TNC by ESA (ESA PWA 2013, 2014). Additional shore response analysis was employed to support the economics assessment, which included accounting for ecological value. Areas of different habitats were modeled over time, driven by sea-level rise and adaptation actions (e.g. allow erosion, or construct a wall or dune).

Beach modeling was conducted through a simple “two-line” shore model, which tracked the position of the high tide shore (roughly 5.5 feet NAVD) and the backshore line where the beach meets the dunes, development, or other “backshore” feature. The difference between these two locations is called the “dry sand beach width”. The scenario that allowed for dune erosion is most pertinent to the OBRAP, and the results are summarized here. For the Ormond Beach sub-area, the beach in front of the Ormond Beach Generating Station was selected for analysis. This location had a dry beach width of 590 feet based on topography measured with LiDAR in November 2009 (NOAA 2012). ESA PWA estimated the minimum natural beach width to be about 400 feet (120 meters). Conceptually, once the dry beach width narrows to the minimum natural beach width, waves reach the dunes, resulting in erosion. ESA PWA computed the shore erosion rate to change from 0.4 feet per year in 2010 to 4.5 feet per year by 2100, owing to accelerating sea-level rise. This resulted in the erosion of about 260 feet of dune (total dry width reduced from 1079 to 814 feet). The projected erosion does not penetrate through the dunes in this location.

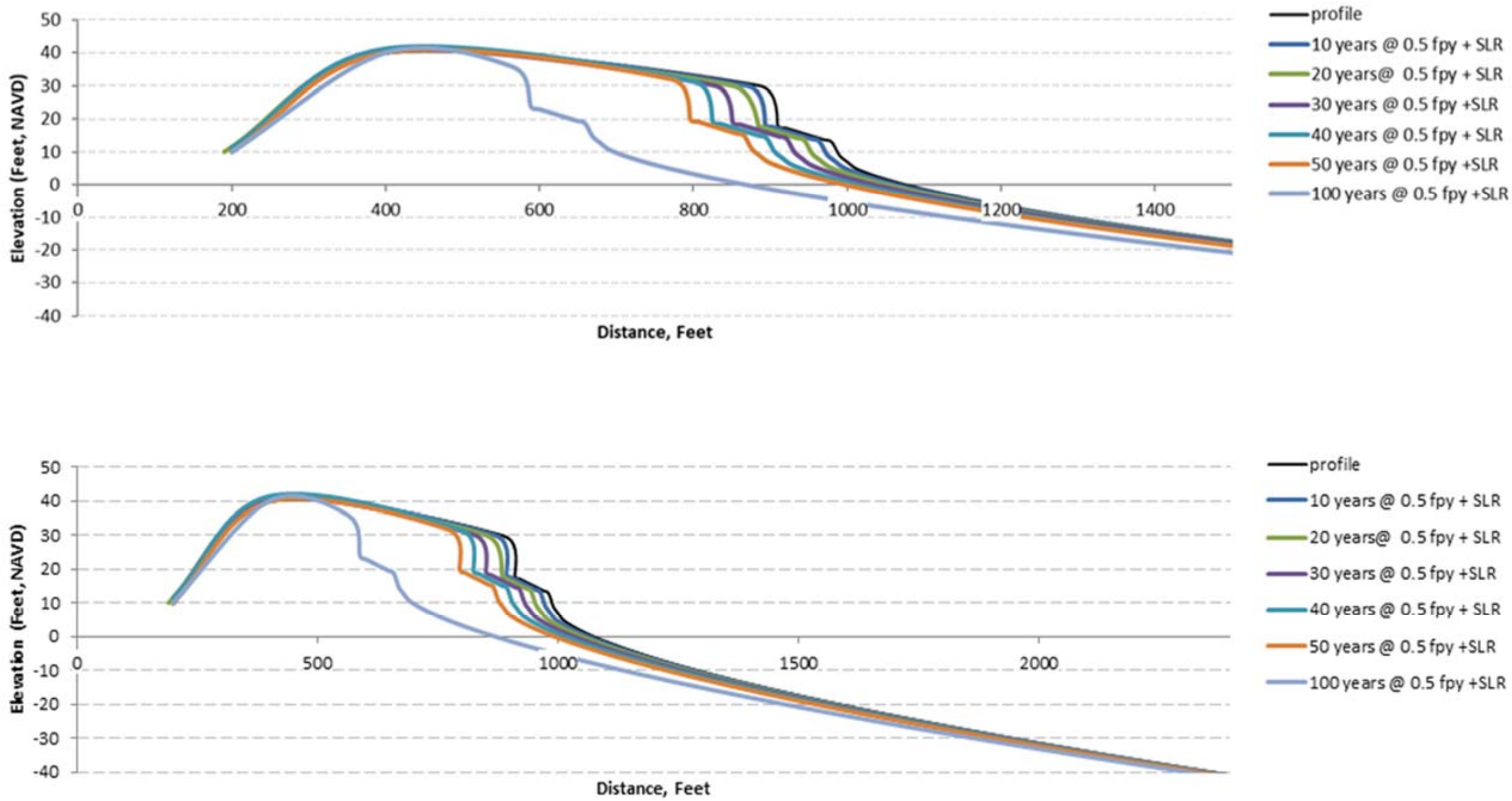
The Environs and ESA PWA study (2015) used similar analyses to estimate shore changes throughout Ventura County from 2010 to 2100 for three scenarios: Baseline (no action), NBA and EBA. The results indicated that the area of Ventura County's beaches will decrease from 800 acres to 530 acres by 2100, or to 270 acres, if coastal armoring is employed. Ormond Beach provides a large portion of the remaining beach area.

Shoreline Response and Salinity of Backbarrier Wetted Areas

Apart from changes in hydrology, salinity conditions at the site could change as a result of rising sea level. The Lagoon and the south SCC salt panne and marsh currently experience seawater influence, but water levels do not vary regularly with the tides as in a fully or intermittently tidal system. The existing dunes that back much of the Beach along the Project Area (see Figure B-20) influence the amount of salt entering ponded areas from wave overwash, so future salinity will depend on the persistence of coastal dunes. Other wetland areas may see increased saltwater influence (wave overwash or saline groundwater), which might help sustain salt marsh habitat that is otherwise converting to brackish or freshwater marsh. Hence, the future beach and dune geometry and associated future wave overwash may affect the wetlands.

Sea level rise will result in waves breaking at higher elevations, which will cause the sandy shore to change geometry. This "geomorphic response" can be approximated by presuming that the wave exposure and tidal conditions are the same except for a higher sea level. **Figure B-22** illustrates this concept of shore change driven by sea level for a sandy dune shore profile constructed to be representative of California conditions using geomorphic guidance such as an equilibrium beach profile (Dean, 1990). Figure B-22 shows the results using an ambient shore erosion rate (historic rate due to sediment supply issues) of 0.5 feet per year and a relatively high sea level rise scenario consistent with USACE guidance derived from the NRC 2012 report. The profile includes a beach between 15 and 18 feet NAVD, and a dune that rises to 40 feet NAVD.

The top panel of Figure B-22 focuses on the upper part of the profile while the lower panel includes the surf-zone out to about -40 feet NAVD. Note that the shore migrates landward and up, but is presumed to maintain its conceptual "equilibrium" shape. This shape is representative of a highly dynamic system, which can be thought of as an envelope of profiles around each "average" profile plotted in Figure B-22. The output predicts that about 400 feet of dune will be eroded by the shore recession. Therefore, it can be postulated that any dune field less than 400 feet in landward extent could be degraded over time by shore response to sea-level rise. Removal of dunes will allow greater wave overtopping, which will result in increased ocean water supply and salt supply to the wetlands. A review of dune field dimensions indicates that the eastern portion of the Project Area will likely have increased ocean effects (water and salt), whereas the central portion will be able to maintain dunes. This approximate analysis will be refined for the OBRAP process, but provides insight to future conditions.



Note: Shore profile response to sea-level rise is shown for a sandy beach and dune system that has an ambient erosion rate of 0.5 feet per year (fpy) and sea-level rise of 5.7 feet over 100 years. The colored lines are the shore profile in 10-year time steps for the first 50 years plus a shore at 100 years into the future. The upper plot is a "close up" of the upper elevations and the lower plot shows more of the offshore surf zone down to elevation -40' NAVD.

ESA

Figure B-22
Shore Profile Response to Sea Level Rise

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Appendix C
Sea-Level Rise

APPENDIX C
Sea Level Rise Policy and Guidance

This appendix summarizes existing federal and state policy and guidance related to sea-level rise planning and describe current sea-level rise projections relevant to Ventura County from various data sources.

Federal

FEMA provides Flood Insurance Rate Maps (FIRM) as part of the National Flood Insurance Program (NFIP), which show coastal and fluvial flood hazards. The maps do not consider future sea-level rise or erosion and only evaluate existing hazards. Additionally, FEMA maps do not present flooding information related to extreme events with a lower probability than the 1% chance of occurrence.

State

As per Executive Order S-13-08 issued by Governor Schwarzenegger, the California Ocean Protection Council (OPC) released a statewide guidance document in 2010 to assist state agencies with incorporating sea-level rise into planning decisions. The subsequent update (OPC 2013) was informed by *Sea Level Rise for the Coasts of California, Oregon, and Washington* by the National Research Council (NRC 2012), which provided new projections of future SLR. An update to the OPC guidance is expected in early 2018 and is outlined in Section 3.3.

The California Coastal Commission (CCC) issued SLR policy guidance in 2015 (CCC 2015). The document outlines a methodology for addressing SLR and adaptation planning in Local Coastal Programs (LCPs) and Coastal Development Permits (CDPs) using "best available science" and specifies climate change scenarios relevant to local risk and vulnerability assessments. The framework for addressing SLR in CDP applications is summarized as follows (CCC 2015, p. 20):

1. Establish the projected sea-level rise range for the proposed project's planning horizon using the best available science, which is currently the 2012 NRC report.
2. Determine how physical impacts from sea-level rise may constrain the project site, including erosion, structural and geologic stability, flooding, and inundation.

3. Determine how the project may impact coastal resources, considering the influence of future sea-level rise upon the landscape as well as potential impacts of sea-level rise adaptation strategies that may be used over the lifetime of the project
4. Identify alternatives to avoid resource impacts and minimize risks throughout the expected life of the development.
5. Finalize project design and submit CDP application.

Both OPC (2013) and CCC (2015) recommend considering a range of scenarios which represent low, medium and high rates of climate change (OPC 2013; CCC 2015), as caused by greenhouse gas emissions and estimates of future rates of ice sheet loss. Scenario-based analysis helps elucidate extent and severity of impacts caused by different amounts of climate change. Recent studies of current greenhouse gas emissions and projections of future loss of ice sheet indicate that the low scenario probably underrepresents future SLR (Rahmstorf et al. 2012; Horton et al. 2014). Also, note that even if SLR does not increase as fast as projected for the High scenario, SLR is projected to continue beyond 2100 under all scenarios. The assumptions that form the basis for the NRC (2012) scenarios are as follows:

Low Scenario – The low scenario assumes population growth that peaks mid-century, high economic growth, and assumes a global economic shift to less energy-intensive industries, significant reduction in fossil fuel use, and development of clean technologies.

Medium Scenario – The medium scenario assumes population growth that peaks mid-century, high economic growth, and development of more efficient technologies, but also assumes that energy would be derived from a balance of sources, thereby reducing greenhouse gas emissions.

High Scenario – The high scenario assumes population growth that peaks mid-century, high economic growth, and development of more efficient technologies. The associated energy demands would be met primarily with fossil-fuel intensive sources.

2018 SLR Guidance Update

The California Natural Resource Agency and Ocean Protection Council released a draft (OPC 2017) and final (OPC 2018) 2018 guidance update to the 2013 State of California guidance document (OPC 2013). The guidance update provides a synthesis of the best available science on SLR in CA, a step-by-step approach for state agencies and local governments to evaluate SLR projections, and preferred coastal adaptation strategies. The key scientific basis for this update was developed by the working group of the California Ocean Protection Council Science Advisory Team (OPC-SAT) titled *Rising Seas in California: An Update on Sea-Level Rise Science* (Griggs et al. 2017). SLR scenarios were selected for the OBRAP prior to the OPC 2018 and CCC 2018 updates were finalized. However, the OBRAP scenarios are generally consistent with the 2018 updates owing to use of the draft guidance update (OPC 2017) and consideration of the science update document (Griggs et. al. 2017). References to the earlier guidance documents (OPC 2017, CCC 2015, and OPC 2013) and science document (NRC 2012) are made for context.

The 2018 guidance update includes the following key changes and additions to the OPC 2013 guidance:

- **For years before 2050, SLR projections are provided only for the high emissions scenario (RCP 8.5).** The world is currently on the RCP 8.5 trajectory, and differences in SLR projections under different scenarios are minor before 2050.
- **Includes new "extreme" SLR projections associated with rapid melting of the West Antarctic ice sheet.**
- **Shifts from scenario-based (deterministic) projections to probabilistic projections of SLR.** The guidance update recommends a range of probabilistic projections for decision makers to select given their acceptable level of risk aversion for a given project.
- **Provides estimated probabilities of when a particular SLR amount will occur.** In addition to SLR projections that are tied to risk acceptability, updated guidance provides information on the likelihood that sea-level rise will meet or exceed a specific height (1 foot increments from 1 to 10 feet) over various timescales.

The guidance update includes significant advances in the scientific understanding of SLR. Compared to the ***scenario-based*** SLR projections in the 2013 version of state guidance, the updated guidance incorporates ***probabilistic*** sea-level rise projections, which associate a likelihood of occurrence (or probability) with various sea-level rise heights and rates into the future and are directly tied to a range of emissions scenarios (described below). Using probabilistic sea-level rise projections is currently the most appropriate scientific approach for policy setting in California, providing decision makers with increased understanding of potential sea-level rise impacts and consequences. The guidance update also includes an extreme SLR scenario that is based on rapid melting of the West Antarctic ice sheet.

The guidance update also provides a range of probabilistic projections of SLR that are based on two Intergovernmental Panel on Climate Change (IPCC) emissions scenarios called representative concentration pathways (RCPs[1]), as well as a non-probabilistic projection associated with rapid West Antarctic ice sheet mass loss. These three climate scenarios are explained below:

- **RCP 2.6 *Scenario* –** This scenario corresponds closely to the aspirational goals of the 2015 Paris Agreement, which calls for limiting mean global warming to 2 degrees Celsius and achieving net-zero greenhouse gas emissions in the second half of the century. This scenario is considered very challenging to achieve, and is analogous to the Low scenario in NRC (2012).
- **RCP 8.5 *Scenario* –** This scenario is consistent with a future where there are no significant global efforts to limit or reduce emissions. This emission scenario is consistent with that used to develop the High SLR scenario in NRC (2012) but the 50th percentile is closer to the Mid SLR rate and amount in NRC (2012).

1 Named for the associated radiative forcing (heat trapping capacity of the atmosphere) level in 2100 relative to pre-industrial levels.

- **H++ *Scenario*** – This extreme scenario was proposed by the Ocean Protection Council Science Advisory Team in response to recent scientific studies that have projected higher rates of SLR due to the possibility of more rapid melting of ice sheets.

Because differences in SLR projections under the various emissions scenarios are minor before 2050, the update only provides RCP 8.5 projections of SLR up to 2050. **State-recommended projections for use in low, medium-high and extreme risk aversion decisions are outlined by red boxes in Table C-1**.

TABLE C-1
PROJECTED SEA-LEVEL RISE IN FEET (OPC 2017; 2018)

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		Median *50% probability sea-level rise meets or exceeds…*	Likely range *67% probability sea-level rise is between…*		1-in-20 chance *5% probability sea-level rise meets or exceeds…*	1-in-200 chance *0.5% probability sea-level rise meets or exceeds…*	
				Low-risk Aversion		Medium - High risk Aversion	Extreme-risk Aversion
High emissions	2030	0.6	0.5 -	0.7	0.8	1	1.2
	2040	0.9	0.7 -	1.1	1.2	1.6	2.0
	2050	1.2	0.9 -	1.5	1.7	2.3	3.1
Low emissions	2060	1.3	1.0 -	1.7	2	2.8	
High emissions	2060	1.5	1.2 -	1.9	2.2	3.1	4.3
Low emissions	2070	1.6	1.2 -	2	2.4	3.5	
High emissions	2070	1.9	1.4 -	2.4	2.9	4	5.6
Low emissions	2080	1.8	1.4 -	2.4	2.9	4.4	
High emissions	2080	2.3	1.7 -	2.9	3.5	5.1	7.2
Low emissions	2090	2.1	1.5 -	2.7	3.4	5.3	
High emissions	2090	2.7	2.0 -	3.5	4.3	6.2	8.9
Low emissions	2100	2.3	1.7 -	3.1	3.9	6.3	
High emissions	2100	3.1	2.3 -	4.1	5.1	7.6	10.9
Low emissions	2110	2.5	1.9 -	3.3	4.2	7.1	
High emissions	2110	3.3	2.6 -	4.3	5.2	8	12.7
Low emissions	2120	2.7	2.0 -	3.7	4.8	8.2	
High emissions	2120	3.7	2.9 -	4.9	6.1	9.4	15.0
Low emissions	2130	3	2.1 -	4	5.3	9.4	
High emissions	2130	4.2	3.1 -	5.5	6.9	10.9	17.4
Low emissions	2140	3.2	2.3 -	4.4	5.9	10.7	
High emissions	2140	4.6	3.4 -	6.2	7.8	12.5	20.1
Low emissions	2150	3.4	2.3 -	4.8	6.6	12.1	
High emissions	2150	5	3.7 -	6.8	8.7	14.1	23.0

The State suggests using a risk-adverse approach for sea-level rise planning when evaluating projects with a long life span, limited adaptive capacity, and/or medium to high consequences of inundation. In these scenarios, the medium-high sea-level rise projections should be used across the range of emission scenarios. The State further recommends incorporating the H++ scenario in planning and adaptation strategies for projects that could result in threats to public health and safety, natural resources and critical infrastructure such as large power plants, wastewater treatment, and toxic storage sites.

The H++ projection is a single scenario and does not have an associated likelihood of occurrence as do the probabilistic projections. Probabilistic projections are with respect to a baseline of the year 2000, or more specifically the average relative sea level over 1991 - 2009.

SLR Projections for Ventura

The National Research Council (NRC) performed an analysis of SLR for the coasts of California, Oregon, and Washington (NRC 2012), which was used by the State of California including the CCC's SLR Policy Guidance (CCC 2015, updated 2018). The report evaluates each major contributing component to global sea-level rise and combines these contributions to provide values of sea-level rise at various planning horizons for the West Coast. The report also discusses regional and local contributions to sea-level rise. Four regional sea-level rise estimates are reported for the West Coast. The values for Los Angeles (the closest station to San Diego for which data are available) are reported in **Table C-2**. These values include an estimate for vertical land motion of -1.5 mm/year ± 1.3 mm/year, which NRC uses for all of California south of Cape Mendocino and refers to as the "San Andreas" region. Note that these sea-level rise projections do not account for any local effects of subsidence in the Ventura region; data or evidence of local subsidence is not available or known.

TABLE C-2
NRC 2012 SEA-LEVEL RISE PROJECTIONS[1]

Projection	2030	2050	2100
Low-range	2 in	5 in	17 in (1.4 ft)
Mid-range	6 in	11 in	37 in (3.1 ft)
High-Range	12 in	24 in	66 in (5.5 ft)

NOTE:
1 Inches and feet of sea-level rise since 2000

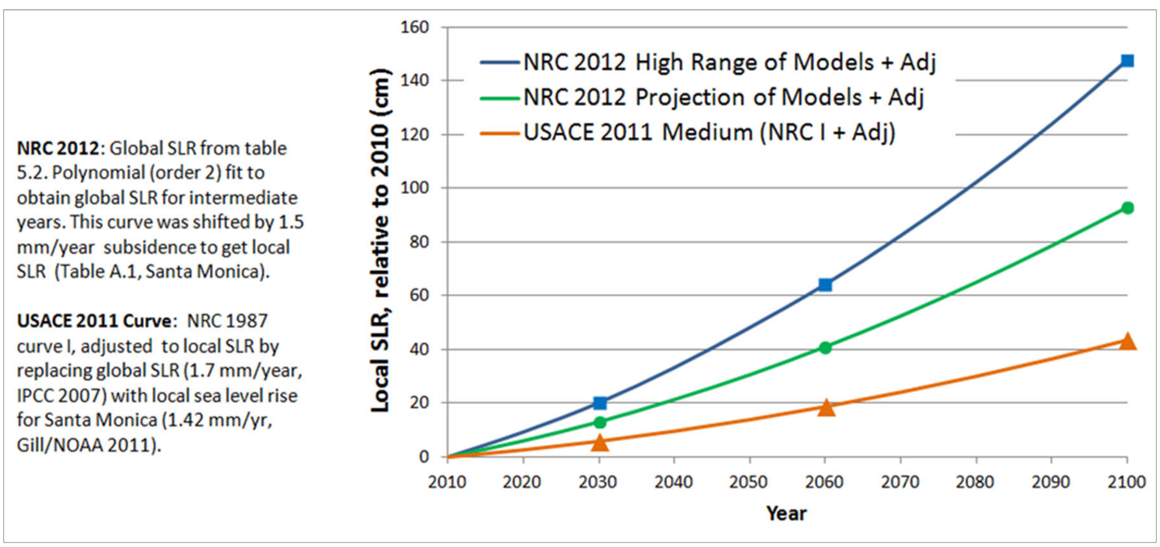
The 2100 estimates reflect the range in greenhouse gas emission scenarios, with low emissions resulting in 17 inches of sea-level rise and high emissions resulting in 66 inches. To date, emissions have been tracking on the high scenario (Flint and Flint 2012). Assuming continuation of the high emissions trajectory, the higher range of sea-level rise projections would apply.

The State of California and The Nature Conservancy funded an analysis of sea-level rise hazards for Ventura County as part of a program called Coastal Resilience Ventura (CRV). **Table C-3** provides the sea-level rise values used in that study, which were also derived from NRC 2012 and U.S. Army Corps of Engineers (USACE, 2011) guidance. The sea level rise scenarios used in this project are based on recent National Research Council (NRC, 2012). The State of California guidance on sea-level rise in effect at the time (OPC, 2010) prescribed the use of 55 inches of rise by 2100, the CRV study attempted to combine federal and scientific guidance in anticipation of revised guidance expected to be issued by the state shortly after the completion of this study (ESA PWA, 2013). Hence the CRV values are generally consistent with the existing guidance and are generally consistent with the subsequent OPC (2013) and CCC (2015, updated 2018), and tailored to Ventura County. The USACE medium curve was selected as the low curve because it is the lowest of all the USACE and NRC projections that incorporates future increases in the rate of sea-level rise. The high and medium curves are based on the high and middle range of models discussed in the NRC 2012 report. All curves include an adjustment for local vertical land motion using the Santa Monica tide station (NOAA #9410840). The sea-level rise at each planning horizon is shown in **Table C-3** and marked in **Figure C-1**.

TABLE C-3
CRV SEA-LEVEL RISE PROJECTIONS[1]

Projection	2030	2060	2100
Low-range	2.3 in	7.4 in	17.1 in (1.4 ft)
Mid-range	5.2 in	16.1 in	36.5 in (3.1 ft)
High-Range	8.0 in	25.3 in	58.1 in (4.8 ft)

NOTE:
1 Inches and feet of sea-level rise since 2000



Ormond Beach Restoration and Public Access Plan

Figure C-1
Sea Level Rise Scenarios (Local SLR, relative to 2010)

SLR Projections for OBRAP

The sea-level rise scenarios selected for the OBRAP are a subset of the Ventura County Coastal Resilience Ventura, specifically the mid-century (2060) and end-of-century (2100) Medium and High values (see Table C-3 and Figure C-1). Use of these values will be consistent with the coastal planning underway in Ventura County and the City of Oxnard, who are using the CRV program products.

A comparison of these values with draft updated California Guidance (OPC, 2017, finalized 2018) is provided in **Figures C-2 and C-3**. Figure C-2 shows that the selected values from CRV are similar to those low-risk aversion and medium-high risk aversion developed from the draft guidance update. The OPC (2017, finalized 2018) and CRV (2013) values are plotted in Figure C-3 for comparison.

Coastal Resilience Ventura (CRV) (as per Ormond Beach Existing Conditions 2017)

TABLE 2-13
SEA LEVEL RISE PROJECTIONS, RELATIVE TO 2010

Year	Low SLR	Medium SLR	High SLR
2030	6 cm (2.3 inches)	13 cm (5.2 inches)	20 cm (8.0 inches)
2060	19 cm (7.4 inches)	41 cm (16.1 inches)	64 cm (25.3 inches)
2100	44 cm (17.1 inches)	93 cm (36.5 inches)	148 cm (58.1 inches)

SOURCE: ESA PWA 2013
SLR = sea level rise

Discontinued

similar

0.5-~2 ft higher

Latest CA Guidance (OPC 2017; Griggs et al. 2017) Table 25: Projected SLR for Santa Monica

Year	Low risk (67% chance)	Med-High Risk (0.5 % chance)	Extreme Risk (~0.1% or less chance)
2050	1.1 ft	1.9 ft	2.6 ft
2100	2.3-3.3 ft	5.5-6.8 ft	10.0 ft*

*Exceeds capacity of models to project erosion and flooding

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Figure C-2
Comparison of CRV (2013) and OPC (2017) SLR Scenario Tables

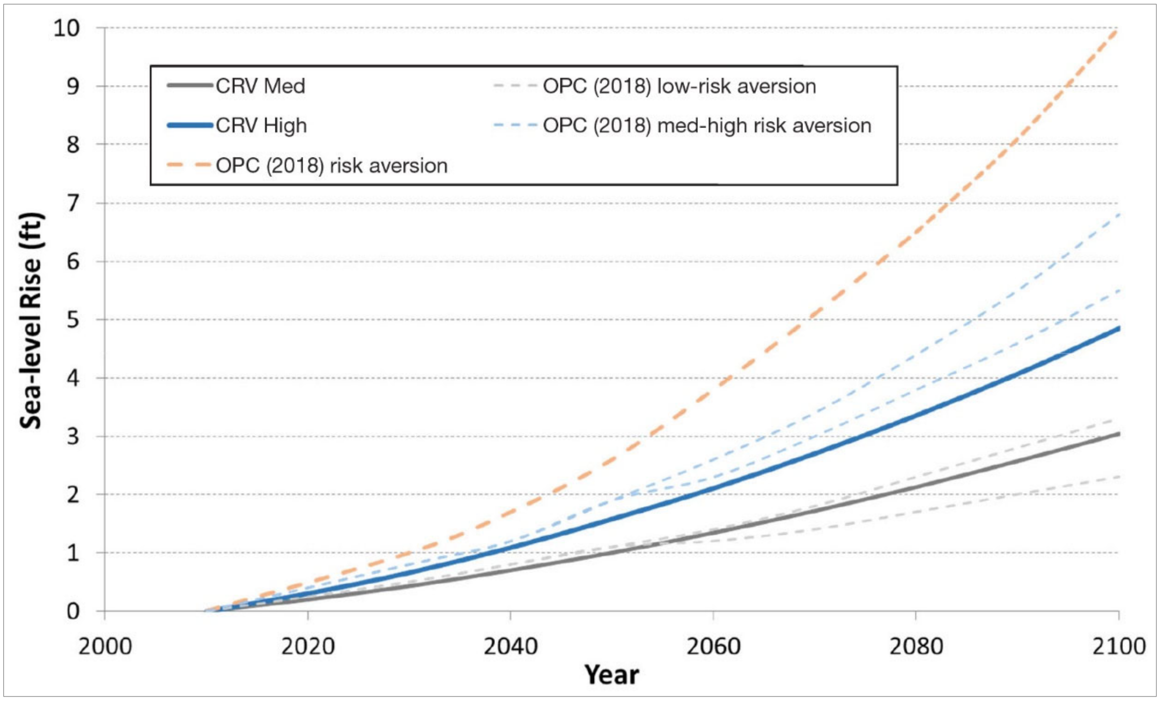

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Figure C-3
Comparison of CRV (2013) and OPC (2017) SLR Scenario Graphs

Appendix D

Shore Migration and Overtopping (Beach QCM)

APPENDIX D
Shore Migration and Wave Overtopping

Introduction

The Ormond Beach Restoration and Public Access Project (OBRAP) project area crosses several coastal habitats, from open beach, to dune, to various types of back-dune marsh and wetland. While habitat modeling examines the effect of changing water levels on the wetlands behind the beach and dunes, it generally overlooks the erosion and transgression of the beach. Ormond beach is expected to transgress inland with rising sea level, as waves propelled by higher water levels push the beach up and inland.

In addition, a critical feature of the wetlands behind the beach and dunes is their salinity, and this is driven by the balance of freshwater from the inland side and saltwater from the coast. Coastal saltwater tends to reach the inboard side of the dunes through groundwater seepage (saltwater intrusion) and by wave overtopping, the latter of which is expected to increase nonlinearly with sea level rise, as higher water levels bring larger waves farther inland during more of the year.

Methods

Shore Migration Methods

Long-term erosion is common on the California coast, and the rate varies along over 800 miles between the Mexican border and the Oregon border. The United States Geologic Survey (USGS) has recorded the location of the coast at irregular intervals for several decades, and this can be used to estimate the long-term erosion rate in different portions of the coast. According to these coastlines, the average trend at Ormond beach is actually one of accretion (beach building); however, this is a regional outlier, and there are local physical processes that are believed to have obscured the actual long-term trend at the beach. Ormond beach has a high annual longshore transport volume (on the order of 800,000 cubic yards of sand moving along the coast each year, Herron and Harris 1966), which travels from northwest to southeast. After the construction of Port Hueneme, much of that transport was disrupted or blocked, rapidly eroding the regional coastline around Ormond beach. Now, about every two years, sand is pumped past the port to offset this erosion. This means that the coast southeast of Port Hueneme (i.e. the Ormond project site) fluctuates a great deal between these sand deposition projects, and the infrequent USGS shoreline measurements are scattered and do not capture an actual annual trend in shore position. In light of this, the average accretion rate was eschewed and the regional erosion rate of 0.5 feet per year was used for the Ormond beach project site.

In addition to the long-term erosion already underway at the site, sea-level rise is expected to drive inland transgression of the beach. This is likely to happen more quickly than wind can rebuild the dunes, meaning that the beach will eat into the existing dunes until it cuts through to the wetlands behind them. Beach transgression with changing sea levels is a common process, and is often modeled using the Bruun method (USACE 2006), which estimates the movement of the beach and dune face up and inland as the sand is eroded from the existing beach face and deposited offshore. The Bruun method migrates an equilibrium beach profile inland based on a representative shore slope. Based on survey and bathymetric data, this slope was determined to be 1:55 in the Ormond beach region. According to the Bruun method, when sea level rises, the beach will rise vertically an equal amount, and it will move inland that distance multiplied by the slope. For example, for one foot of sea-level rise, the beach would move up one foot and inland 55 feet.

The Bruun method assumes that the beach has enough time to reach equilibrium as sea level rises, which is a reasonable assumption for the beach itself, but the dunes behind the beach berm tend to develop and adapt more slowly. As such, they were assumed stationary, as the transgressing beach steadily eroded its way into them. For each analyzed transect (E, H, and I in **Figure D-1**), the representative dune slope was measured from the survey transect, and that was used to connect the berm of the transgressing beach to the existing dune profile. Each time the beach transgressed inland, segments of the dune outboard of the beach berm were removed, and the berm was connected to the closest inland survey point with a line at the representative dune slope. This representative slope varies between transects, but is generally within the range of 10:1 to 20:1 (horizontal to vertical). As the berm erodes through the back side of the dunes, this method generated unrealistic profiles, so they were smoothed into a typical 100-foot back beach area, using a shape consistent with sand transport associated with wave overwash.

This level of beach analysis is not included in the habitat model used in this study (SLAMM), but it was considered important to account for erosion and transgression in analyzing the OBRAP alternatives. To do this, the beach berm positions from each transect were connected at three time horizons, and areas offshore of this line were assumed to be open water. Then, the 100-foot band inland of the beach berm line was assumed to convert to beach/coastal strand to account for the back-beach area. These two regions were overlain on the SLAMM results to represent the coastal processes not captured in the habitat model.

Wave Overtopping Methods

Significant overtopping generally occurs in stormy high-water events, leading to ponded saltwater trapped behind the dunes. These effects are expected to be negligible in the west portion of the site, where lagoon processes dominate, but in the central and east portion of the site (areas 3a, 3b, 5, and 6 in **Figure D-2**), ponding from overtopping events is considered a major source of salt. To assess changes in operational conditions, each of these areas were analyzed for ponded water resulting from overtopping during conditions expected at least once per year.

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Figure D-1
Beach transects E, H and I were used to represent beach strand areas 1, 7 and 9, respectively

SOURCE: ESA 2018, SCC 2011

Ormond Beach Restoration and Public Access Plan

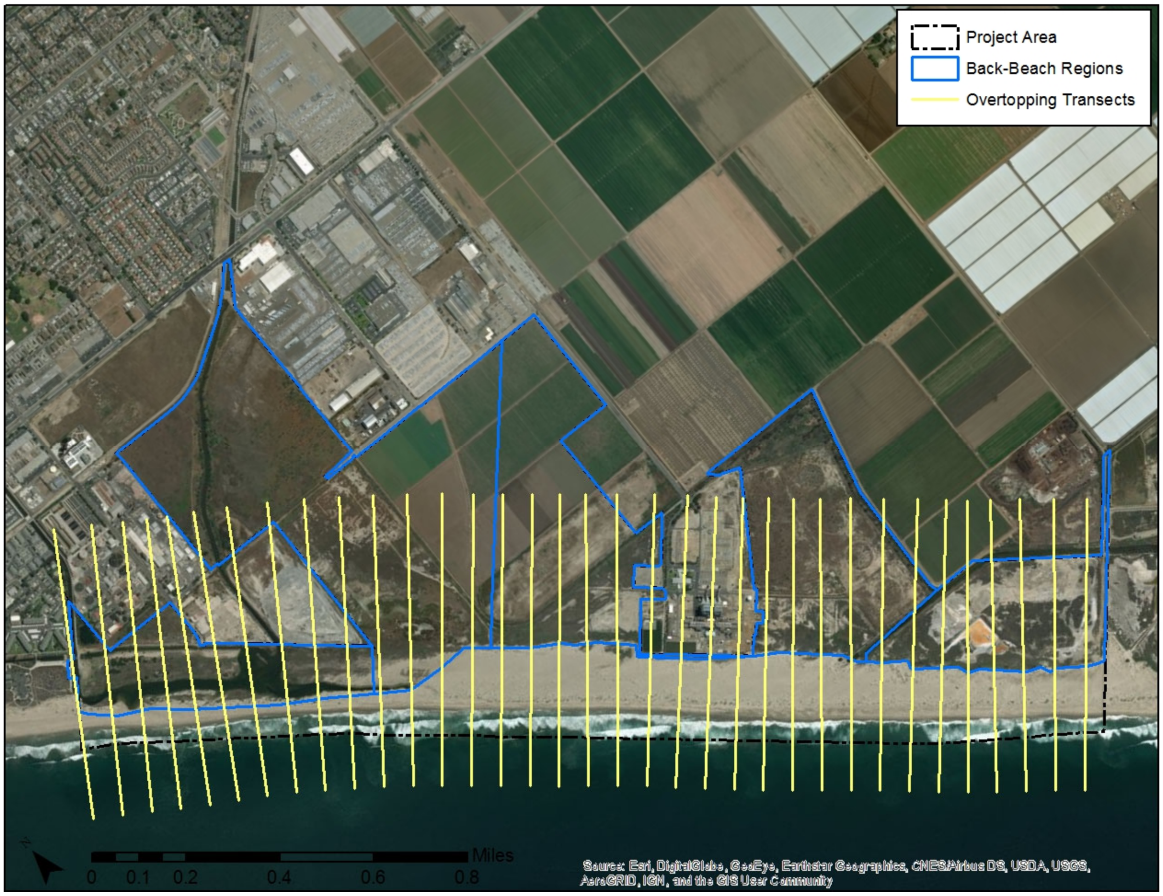
Figure D-2
Ormond Beach Overtopping and Ponding Regions of Interest

Overtopping volumes were calculated in the same manner as in the Coastal Resilience Ventura (CRV) study (ESA PWA 2013) for consistency. Water levels and wave conditions for a period of approximately 20 years were provided by NOAA, and these were used to generate a rough estimate of the 2% runup elevation using the Stockdon method for natural beaches. While this method is not entirely accurate for long-period waves arriving on beaches with steep backshore profiles (i.e. west-coast, dune-backed beaches), it is considered a reasonable approximation for this level of analysis. As in CRV, overtopping rates were calculated for each record in the 20-year time series based on the European overtopping manual (Pullen et al. 2007), which provides an estimate of overtopping rate (cubic meter per second per linear meter of coast) as a function of crest elevation, water level, runup elevation, and surf similarity parameter (the ratio of the beach slope to the wave slope). From these, annual maximum overtopping rates were identified, and the smallest of these – the maximum overtopping rate reached at least once during each year in the record – was selected to represent annual storm overtopping conditions. It was assumed that this event would last four hours, rising from no overtopping to peak overtopping in two hours, then declining back to zero; integrating over this period gave an overtopping volume per linear meter of beach.

The described analysis was performed on thirty-five cross-shore transects (**Figure D-3**) along the Ormond coastline. These were extracted from LiDAR (SCC 2010) at 120-meter intervals as part of CRV (ESA PWA 2013). The slopes and dune crests on each profile were identified and used in the analysis described above. Nearshore wave conditions at these transects were determined by transformation of waves recorded by NOAA[1] and CDIP[2] at their Santa Barbara offshore buoy. This analysis was performed for CRV, and details can be found in the report from that study. The overtopping analysis, applied to these inputs, resulted in a set of overtopping volumes per linear-meter along the Ormond coast, which was integrated by multiplying by the transect spacing (120 meters) to yield a total volume of water crossing each transect during a large storm event occurring at least once per year. Each transect was linked to a backshore area, resulting in an estimate of the total volume captured by each area. This volume of overtopped water was converted to ponding elevation based on the minimum elevation in the area and a hypsometric curve (elevation vs. volume) generated from the topography for each ponding region (Figure D-2).

Upon inspection of site topography, a few modifications were made to the raw overtopping volumes. First, the overtopping method estimates the volume crossing the first coastal barrier and does not account for additional rows of dunes or an extensive back beach. Since the project is primarily concerned with saltwater reaching and ponding in the wetland areas behind the back beach, a reduction factor of 0.1 was used to account for the backshore distance separating overtopping water from the wetlands of interest (on the order of 700-1000 feet under existing conditions). The beach transgression and dune erosion analysis performed as part of this study indicates that the beach is apt to recede on the order of 300 feet by the end of the century, greatly diminishing the backshore buffer between the ocean and the wetlands. To account for this, the reduction factor was weakened linearly to 0.5 by 2100.

1 National Oceanic and Atmospheric Administration, National Data Buoy Center, https://www.ndbc.noaa.gov/. Accessed March 2019.
2 Coastal Data Information Program, http://cdip.ucsd.edu/. Accessed March 2019.



SOURCE: ESA 2018

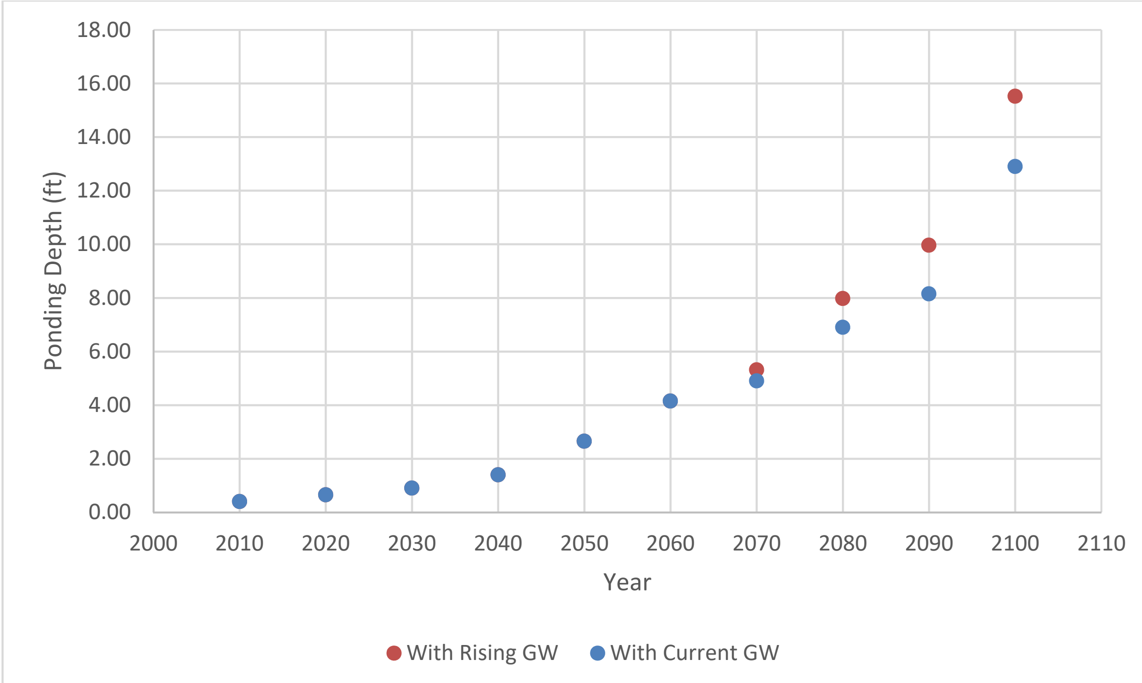
Ormond Beach Restoration and Public Access Plan

Figure D-3
Ormond Beach Overtopping Transects and Ponding Regions

Second, the central region of the project area – Area 5 – has a wider beach than the east and west ends of the project area. In this area, the beach is backed by two rows of dunes, separated by a shallow swale, before descending into wetlands. To account for this wide backshore, the reduction factors were intensified, beginning at 0.05 and weakening to 0.25 by 2100.

Third, there is a tall set of dunes at the inland edge of Ormond Beach in front of Area 3, but this dune ridge only covers half the coastline contributing overtopping water to Area 3. To account for this, the transects crossing the high dune ridge were not included when summing the overtopping volumes entering Area 3.

Finally, Area 6 is relatively low-lying with a high groundwater table. The area is expected to see an increase in ponded surface water as the groundwater table rises with sea level rise. To account for this, once sea level rises above the current groundwater depth (2 feet), the difference was added to the ponding elevation calculated in the overtopping analysis. The resulting difference can be seen in **Figure D-4**, though this effect only begins after mid-century, at which point high sea levels and beach transgression may have introduced new physical processes that dominate those analyzed in this study.



SOURCE: ESA 2018

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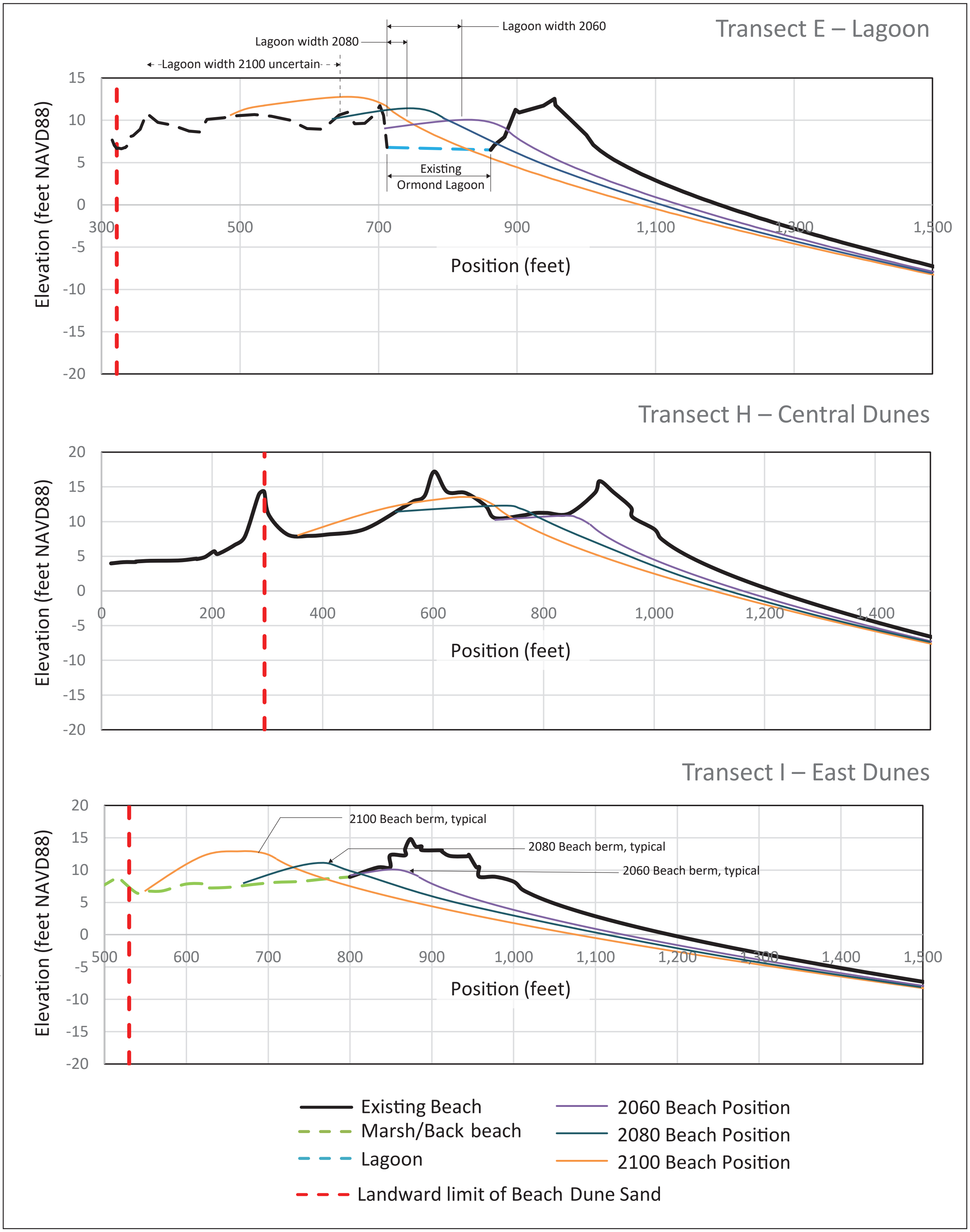
Figure D-4
Ponding Depth in Area 6,
With and Without Rising Groundwater

Results

Shore Migration Results

Cross sections for the shore migration transects from Figure D-1 are presented in **Figure D-5**. These three transects represent the dunes in front of Ormond Lagoon (Transect E), the dunes in the center of the beach (Transect H), and the dunes in the east of the beach (Transect I). Including both long-term erosion and beach transgression with sea-level rise, these transects are expected to move inland approximately 300 feet each, with different effects in different parts of the beach.

At each of these three locations, the shore geometry is shown in black in Figure D-5. For example, in the top schematic in Figure D-5, the black solid line is based on a survey of ground elevations (beach transect I), the black dashed line is derived from LiDAR, and the blue dashed line is the water surface of Ormond Lagoon at the time of the LiDAR data collection. The vertical red dashed line corresponds to the landward edge of the beach-dune strand and corresponds to the red line in Figure D-1. The horizontal position is a scale in feet with a "zero" location inland of the changes. The width of the existing lagoon is depicted by the blue dashed line. Note that the vertical scale is exaggerated to clarify the relief. Future shore geometries are shown in other colors, per the figure legend. As sea level rises, the wave-shaped seaward face of the profile responds rapidly by migration, while landward elevations are held steady.



SOURCE: ESA, 2017

NOTE: Transect E (top) is located at western beach strand Area 1 at Ormond Lagoon; Transect H is located at central beach strand 7 near backshore Area 3 and Transect I is located at eastern beach strand Area 9 near backshore Area 6.

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Figure D-5
Beach Transect Elevations

ESA

Note that at Transect E, the waves overtop the beach and reach the lagoon, and hence this "overwash" area also migrates with the seaward beach. At Transect E the existing Ormond Lagoon is impacted by shore migration. Note that the lagoon width decreases in 2030 and approaches zero in 2060. By 2100 the beach migrates inland of the existing dune and the extent of lagoon is difficult to predict. Transect E indicates that the lagoon (at least its east end) will be pinched by rising sea level by mid-century; without erosion, the east end will have closed by late-century; and by end-of-century, this half of the lagoon will have basically disappeared. This profile modeling neglects scouring of the backshore, which may happen during breaching events with rapid drainage and high OLW discharge. Therefore, the resulting lagoon footprint may be larger than implied by the beach migration modeling. Also, large expanses of low-elevation areas in Area 3b and 3a are likely to pond during high beach levels, indicating that the lagoon may "shift" location to the north and east.

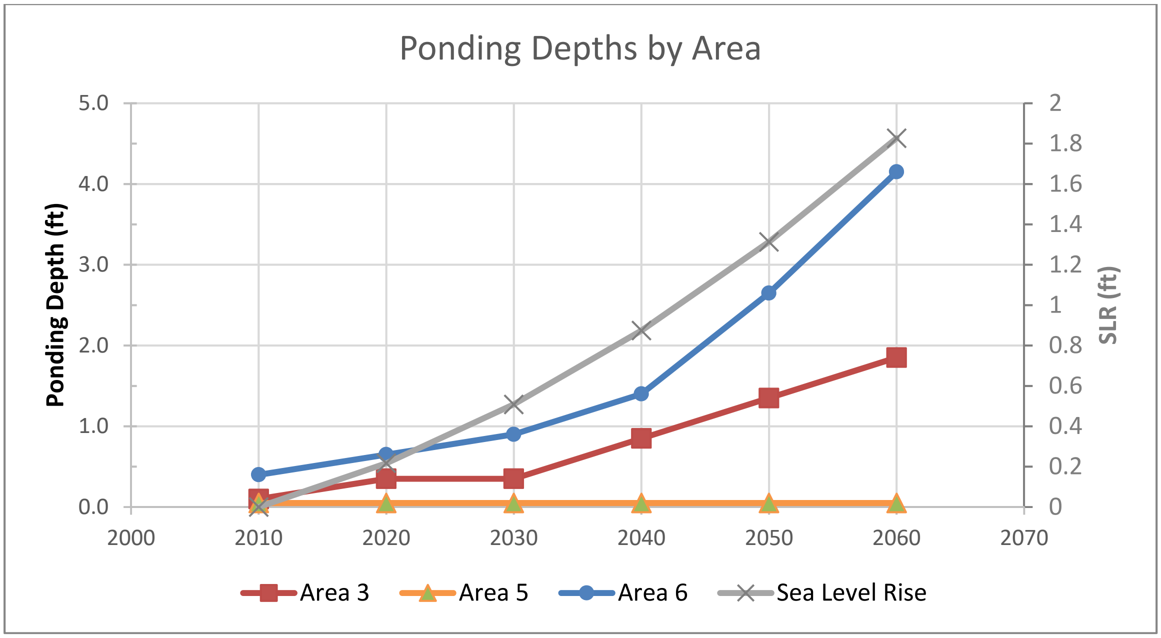
Transect H indicates that the first row of dunes will erode by mid-century, exposing flat plover habitat between the two dune rows; this area will be steadily eroded through late-century; and entirely gone by end-of century, leaving the second dune ridge exposed. At Transect H, waves are not predicted to overtop the dunes sufficiently to cause the sand deposition in the lee of the dunes, resulting in a reduction of the width of the dune field.

Transect I indicates that the east dunes will be eroded by mid-century, leaving a berm and back-beach transgressing into the salt panne currently behind the dunes; and this process will continue basically unimpeded through late-century and end-of-century.

Wave Overtopping Results

The wave overtopping analysis led to an estimate of ponding elevation for a relatively common storm ("operational conditions") in Areas 3, 5, and 6, as presented in **Figure D-6**. Area 3 shows a slow but steady increase into mid-century, thanks to the large wetland area that lies behind the gap in the high dune ridge there. Area 5 shows no increase through mid-century due to its second line of dunes, which block most of the overtopping volume until sea levels are even higher and the first row of dunes has eroded, later in the century. Area 6 shows an exponential increase in ponding depth, rising from approximately 0.5 feet to over 4.0 feet by mid-century, even before rising groundwater begins to raise the ponding elevation even more quickly.

In this analysis, the areas were assumed to be separate behind the dunes, which is not the case once water reaches higher elevations. This behavior could be harnessed in Areas 5 and 6, where one (Area 6) fills rapidly and the other (Area 5) is relatively resilient to increased overtopping from sea-level rise. The berm and ditch separating the two areas could be flattened to allow water to spread between the two more readily, reducing the nonlinear rise in ponding depth in Area 6 and making Area 5 wetter, promoting certain wetland habitats.



SOURCE: ESA 2018

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Figure D-6
Ponding Depth in Areas 3, 5, and 6
Compared with SLR (right axis)

References

ESA PWA. 2013. Coastal Resilience Ventura: Technical Report for Coastal Hazards Mapping. Prepared by ESA PWA, San Francisco, for The Nature Conservancy. July 2013.

Herron, W.J. and Harris, R.L., 1966. "Littoral Bypassing and Beach Restoration in the Vicinity of Port Hueneme, California" Coastal Engineering, Vol. 1, 1966.

Pullen, T., Allsop, N.W.H., Bruce, T., Kortenhaus, A., Schuttrumpf, H., van der Meer, J.W., 2007. EurOtop: Wave Overtopping of Sea Defenses and Related Structures: Assessment Manual. Available: www.overtopping-manual.com.

State Coastal Conservancy (SCC). 2011. California Coastal Conservancy Coastal Lidar Project. Available: https://coast.noaa.gov/dataviewer.

U.S. Army Corps of Engineers (USACE). 2006. Cross-shore sediment transport processes. Chapter 3 of Part III of the Coastal Engineering Manual, EM 1110-2-1100.

Appendix E

Ormond Lagoon Hydrology and Morphology (Lagoon QCM)

APPENDIX E
Lagoon Quantified Conceptual Model

This appendix summarizes modeling of Ormond Lagoon and surrounding areas using a quantified conceptual model (QCM) of Ormond Lagoon's water balance. As described in the main body of the report, the project involves developing restoration concepts to enhance critical habitats, sustainability, and public value of Ormond Lagoon and surrounding areas that are managed by the state Coastal Conservancy, the City of Oxnard, and The Nature Conservancy. Ormond Lagoon is a heavily modified back-barrier lagoon-wetland system at the mouth of an urbanized watershed. Much of the historic Ormond Lagoon and surrounding wetlands have been converted to other uses, while upstream urban and agricultural development has increased the intensity of storm flows (see ESA 2017). The QCM provides an understanding of how Ormond Lagoon's morphology and hydrology could evolve, under the influence of future climate change and the proposed conceptual restoration actions. Interpretation of Ormond Lagoon's evolution can then inform how restoration may affect focal species' future habitat.

Section 1 summarizes the conceptual model lagoon conditions that inform the QCM. Additional details about the site can be found in the Existing Conditions report by ESA (2017). Sections 2 and 3 describe the model approach and data sources, respectively. Section 4 describes the preliminary results, and Section 5 discusses some of the uncertainties resulting from data gaps and future evolution of the site.

1. Conceptual Model of Site Conditions

The Ormond Lagoon is a perched system (see classification of Jacobs et al. 2010) that collects water from the Ormond Lagoon Waterway (OLW), tšumaš Creek, and Bubbling Springs (also called Hueneme Drain). After pooling in Ormond Lagoon, this water drains to the Pacific Ocean over and through a heightened beach berm that typically prevents tides from having a strong influence in Ormond Lagoon. Although the mouth of Ormond Lagoon is groomed prior to significant storms to facilitate natural breaching to alleviate flooding, waves elevate the mouth near or above high tides by delivering more sand than can be removed by stream inputs. The coastal sediment supply and beach morphology is heavily influenced by U.S. Army Corps of Engineers (USACE) dredging and beach nourishment activities west of the site, which involve mechanically bypassing the Port of Hueneme and placing of this sand updrift of Ormond Lagoon approximately every two years (see ESA 2017).

Under present conditions, Ormond Lagoon spills water out to the ocean during the winter months, when runoff from local municipal and agricultural runoff is highest. Flows from the watershed are concentrated into a series of drainage channels, which cause flood flows to rapidly arrive at Ormond Lagoon during rainfall events, and to rapidly tail off after rainfall ceases. The OLW provides the majority of the runoff to Ormond Lagoon, with smaller amounts arriving from tšumaš Creek and Bubbling Springs. The local groundwater table is influenced by the accumulation of runoff in Ormond Lagoon and by the nearby trunk line for the Oxnard Wastewater Treatment Plant (OWWTP). Because Ormond Lagoon's water surface is perched, water seeps from Ormond Lagoon as groundwater toward the ocean through the sandy beach, northward toward the sewer trunk line and the seasonally ponded area located immediately east of the Halaco Site (ESA 2017).

Even when the mouth is open to the ocean, Ormond Lagoon receives relatively little tidal action, owing to its high elevation on the beach (beach elevations vary around +8 to +12 feet NAVD along Ormond Beach (ESA 2017)). When runoff declines in the spring, wave action closes the mouth seasonally, usually for periods of at least 4-6 months. During these closure periods, residual runoff ponds in the closed Ormond Lagoon, but balances with seepage and evaporative losses, giving relatively stable water levels of about 8-8.5 feet NAVD in the dry season. In drier years, such as 2017, evaporation and seepage may overmatch runoff, leading to a lowering of water levels throughout the dry season, to as low as 6.5 feet NAVD (ESA 2017). Flooding can result when high runoff is initially trapped behind the beach berm during a wet season rainfall event. This occurred on January 18th, 2010, leading to flooding of many of the local roadways and the OWWTP (VCWPD 2010). Following guidance from HDR (2011), the Ventura County Water Protection District (VCWPD) has managed the beach to prevent further flooding events by lowering a portion the beach crest to an elevation of 8.9 feet NAVD88 when a series of water level, beach, and predicted precipitation triggers are met. This allows the mouth to breach at a lower elevation before flooding occurs during the initial flood pulse.

The available brackish habitat in Ormond Lagoon and surrounding areas is mostly governed by the state of the mouth. When it is closed, trapped runoff provides highest water levels, greatest surface area, and greatest volume. When the mouth breaches, Ormond Lagoon drains and tends to have lower water levels and saltier conditions. The existing hydrology and habitat of the system are described in more detail by ESA (2007; 2017).

2. Lagoon Modeling Approach

To provide an understanding of how the Ormond Lagoon would respond to future changes, ESA developed a quantified conceptual model (QCM) for the site, which predicts lagoon mouth morphology and the resulting water levels of the lagoon. The current QCM approach is an adapted and refined version of earlier approaches for tidal conditions from Crissy Field Lagoon (Battalio et al. 2006) and for fluvial conditions for the Carmel River (Rich and Keller 2013), and builds on lessons learned from both approaches. In recent years, ESA has further developed the QCM as a more complete tool to assess systems with both tidal and fluvial characteristics

(Behrens et al. 2015). It has been used most recently by ESA at Pescadero Creek (ESA 2017) in northern California, and at Los Peñasquitos Lagoon (ESA 2016) and Devereux Slough (ESA 2015), in southern California.

The QCM approach is centered on a water budget for the lagoon, which is coupled with a sediment budget for the lagoon mouth. The model is based on two core concepts:

- All water flows entering and leaving the lagoon should balance.
- The net erosion/sedimentation of the inlet channel results from a balance of erosive (fluvial and tidal) and constructive/deconstructive (wave) processes.

The model uses time series of nearshore waves and tides, watershed runoff, and evapotranspiration data as boundary conditions. Using these as forcing conditions with the lagoon's topography, the model dynamically simulates time series of lagoon water levels, along with inlet, beach, and lagoon state. With each time step, the net inflows or outflows to the system are estimated, along with the net sedimentation or erosion in the mouth. The flow terms vary depending on whether the mouth of the lagoon is open or closed. During closed conditions, inflows are based on watershed runoff, wave overwash into the lagoon, and while outflows are based from beach berm seepage and evapotranspiration. For more information on how the model resolves different processes, refer to Behrens et al. (2015).

As the model steps forward in time, it continuously transitions the mouth through tidal, perched, and closed conditions. When deposition in the inlet bed exceeds erosion, the bed rises vertically, eventually perching above most tidal elevations and closing. Mouth closure occurs in the model when sediment fills the bed higher than lagoon water levels. Breaching occurs in the model when the lagoon fills from accumulation of either watershed runoff or wave overwash, and water levels overtop the beach berm crest, eroding a new lagoon mouth.

Model accuracy is tested by comparing modeled lagoon water level time series against observed water levels, and by comparing the timing and length of inlet closure events to those of historical records. Closure time series and lagoon water level time series usually provide a good indication of which processes are dominating the system at a given time, such as runoff during floods, or powerful waves prior to closure. Thus, reproducing these time series is taken to mean that the dominant processes are meaningfully represented.

3. Data Sources

Input data for the QCM were obtained from a variety of publically available sources and field data collected by ESA and others. **Table E-1** summarizes the data sources for the model.

TABLE E-1
SOURCES OF HYDROLOGY, CLIMATE, AND TOPOGRAPHIC DATA AT THE PROJECT SITE

Parameter	Source/Location	Availability
Coastal Hydrology		
Offshore Waves	CDIP Harvest Buoy (#071)	1995-present
Nearshore Wave Estimates	ESA (2012)	1992-2012
	CDIP MOP	2000-present
Tide Stage	NOAA Santa Monica Gage (#9413450)	1985-present
Watershed Runoff, Local Climate, and Lagoon Hydrology		
Runoff	VCWPD gage 790	Peak flows 2002-2015, peak daily flows 2002-2005
	USGS Calleguas Creek Gauge (#11106550)	1996-2016
Evapotranspiration	CIMIS #156 (Oxnard)	2001-present
Rainfall	VCWPD gage 17C - Oxnard Sewer Plan	2004-present
	CIMIS #156 (Oxnard)	2001-present
Lagoon Stage	VCWPD (unreferenced OID gage)	2002-2005
	CH2M Hill (2011)	2007-2009
	VCWPD (OID staff gage referenced to NAVD)	2008-2013
	ESA (2018)	June 2017 – December 2017
Groundwater	CH2M Hill (2008)	2006-2012
Morphology		
Beach Topography	Coastal Frontiers: RTK GPS	March 2008
	State Coastal Conservancy LiDAR DEM	2011
	ESA: RTK GPS	2017
Lagoon Topography	HDR: RTK GPS	March 2008

3.1 Coastal Conditions

Hourly wave height, period, and direction near the Ormond Lagoon mouth were obtained from nearshore transformed wave data provided by the Coastal Data Information Program (CDIP) California Coastal Wave Monitoring and Prediction System (O'Reilly et al. 2016) at the CDIP model output point number VE254. VE254 is located approximately 2,000 feet offshore of Ormond Lagoon in approximately 33 ft of water. Model data were downloaded from January 2000 to November 2017. The wave data are a driver of beach elevation, which contributes to establishing the water levels in Ormond Lagoon, and influences the state of Ormond Lagoon (i.e., open, closed, perched overflow, etc.).

These nearshore wave predictions were compared against predictions from ESA PWA (2012), generated as part of the Coastal Resilience Ventura (CRV) project, and were generally found to correlate well. These prior predictions were based on a similar modeling approach that provided wave information from 1992-2012 at the site.

Hourly ocean water level data were obtained from NOAA's Santa Monica Tide Gage Station (NOAA #9413450) from 2005 to 2017. The Santa Monica Station is located approximately 35 miles from the Ormond Lagoon mouth. All data was downloaded in the North American Vertical Datum of 1988.

3.2 Lagoon Hydrology

The hydrology of Ormond Lagoon is summarized in detail by ESA (2017). This includes a description of the watershed conditions, and flows from the three main tributaries to the site.

Only limited observations of inflows to Ormond Lagoon are available. The VCWPD has maintained a gauge approximately 2 miles upstream of Ormond Lagoon that records high flow events. This gauge only captures flows above 50 cubic feet per second (cfs), and was in place from 2002 to 2015. As described in ESA (2017) and HDR (2008), several groups have scaled watershed inflows for the purpose of modeling flood conditions, but these do not provide a complete picture of the seasonal hydrograph or summer/fall base flows, which is critical information for understanding lagoon conditions when the mouth is closed during the dry season. A nearby gauge on Calleguas Creek upstream of Mugu Lagoon (see Table 1) was operated until 2016, and likely provides representative agricultural and municipal runoff conditions.

Runoff to Ormond Lagoon was scaled using information from the VCWPD gauge, the nearby Calleguas Creek gauge (USGS #11106550), and information from prior reports (PWA 2007). Calleguas Creek flows were scaled to the site using a ratio of drainage areas. Flood flows measured on the VCWPD gauge upstream of the site were also scaled to Ormond Lagoon by accounting for the ratio of drainage areas above the gauge and Ormond Lagoon, respectively. The scaled flood flows from both gauges were then compared, and the scaled Calleguas flows were adjusted to fit the scaled VCWPD flood peaks. Lastly, base flows were augmented by adding approximately 2 cubic feet per second to account for consistent urban runoff. Neither of the gauges used to develop this synthetic record had measurements in 2017.

Evaporation and precipitation data were obtained from Oxnard and Camarillo California Irrigation Management Information System (CIMIS) stations (Station #156 and #152, respectively). These stations were assumed to be representative of the rainfall and evaporation in the drainages upstream from Ormond Lagoon. Data were downloaded from the Oxnard Station from January 2002 to May 2016. After May 2016, data from the nearby Camarillo CIMIS Station #152 was appended to the Oxnard record.

Ormond Lagoon water levels collected from 2007 to 2017 were used to calibrate the model and test its accuracy. From October 2007 to September 2009, water level data were collected continuously with a logger by CH2M Hill as part of an EPA study of the Halaco Site (CH2M Hill 2011). Although continuous measurements ended in 2009, spot measurements were taken every two weeks from 2009 to 2011 using a staff gauge at the site referenced to the NAVD88 datum (CH2M Hill 2012). ESA deployed several continuous water level loggers in June through December 2017.

3.3 Beach and Lagoon Morphology

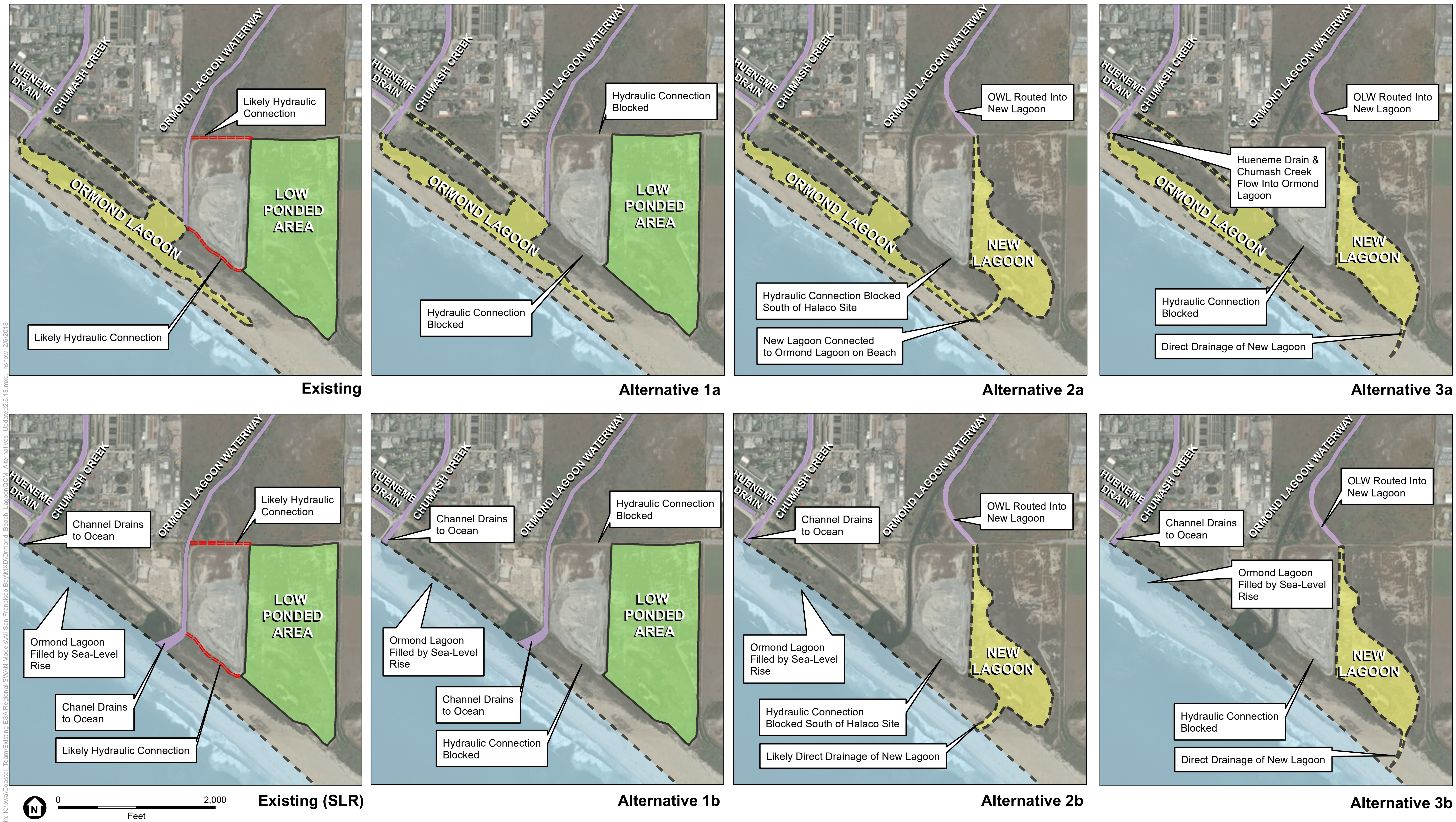
ESA compiled topographic data sources at Ormond Lagoon to create a ground surface elevation basemap. The basemap was used to build a stage-storage curve for Ormond Lagoon. A survey by Coastal Frontiers in 2008 provided elevations on the beach and in Ormond Lagoon. This field data was supplemented with 2009-2011 California Coastal Conservancy LiDAR in upland areas. Elevations within channels draining to Ormond Lagoon were approximated based on the Coastal Frontiers data. Note that the OLW was dredged after the 2008 Coastal Frontiers survey and the increased depth is not represented in the basemap. Additionally, Ormond Lagoon has likely accumulated sand over the past several years of extended drought in California, and thus, volumes in the stage-storage curve may overestimate present Ormond Lagoon storage. ESA also collected several transects of Ormond Lagoon and beach in the summer of 2017, and these were used to check for any changes in lagoon bed elevation between 2008 and 2017. A comparison of the transects showed that the southern arm of Ormond Lagoon which was not fronted by vegetation had partially filled-in with up to approximately 4 feet of sand between 2008 and 2017. This sand was likely deposited by wave overwash and had not scoured out during the low-flow drought years. Survey data from 2017 in other parts of Ormond Lagoon is too limited to make a comparison with the 2008 data.

4. Model Results

ESA ran the QCM from October, 2007 to October, 2017, a period that includes a range of wet and dry years, and a high overlap of available data sets for testing the model. Although the wave and tide data extend back further, the measured water levels are restricted to more recent years. To explore how future changes could influence the behavior of Ormond Lagoon, we ran the same 2007-2017 time series with 3 feet of SLR and with several restoration and management options. These initial restoration/management options are intended to inform the assessment of the restoration alternatives.

The modeled alternatives are summarized in **Table E-2** and shown graphically in **Figure E-1**. Alternatives 0 (existing conditions) through 3 were modeled with and without SLR. The Alternatives were given the suffix label “a” when sea-level rise (SLR) was not added, and the label “b” when 3 feet of SLR was included. The calibration run did not include SLR.

The conceptual restoration alternatives are introduced here for context, but are described in more detail in the main body of the report. Alternative 1 involved isolating the existing brackish habitat immediately east of the Halaco properties. Alternatives 2 and 3 include the creation of a new water system (called “New Lagoon” as it is modeled as a separate body in this lagoon model) in this area (see conceptual depiction in Figures 1). For this analysis, the New Lagoon was considered to be roughly the same volume as the portion of the existing Ormond Lagoon in front of the dune line. For Alternative 2, the New Lagoon (the re-routed OLW and surrounding floodplain) is assumed to be connected hydraulically to the OLW and to the existing Ormond Lagoon. Conversely, the New Lagoon and Ormond Lagoon are disconnected under Alternative 3



SOURCE:

Ormond Beach Restoration and Public Access Project

Figure E-1
Lagoon QCM Alternatives
Alternatives 1 through 3

ESA

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TABLE E-2
ORMOND LAGOON QCM SCENARIOS

Alternatives	Alt. Description	SLR	Hydrology	Beach Management
Calibration	Existing conditions without beach grooming	0'	Existing conditions	No beach grooming
0a	Existing conditions (do nothing)	0'	Existing conditions	Beach grooming to 8.9'
0b	Existing conditions (do nothing), include SLR	3'	Existing conditions	Partial loss of Ormond Lagoon due to SLR, no beach grooming
1a	Block hydraulic connection between Ormond Lagoon and ponded area east of Halaco slag pile	0'	OWL is disconnected from ponded area, Ormond Lagoon is disconnected from ponded area	Beach grooming to 8.9'
1b	Block hydraulic connection between Ormond Lagoon and ponded area east of slag pile, include SLR	3'	OWL is disconnected from ponded area (Area 3a), Ormond Lagoon is disconnected from ponded area	Partial loss of Ormond Lagoon due to SLR, no beach grooming
2a	Relocate OLW to area east of slag pile, connect to Ormond Lagoon	0'	Ormond Lagoon is hydraulically connected to OLW floodplain	Beach grooming to 8.9'
2b	Relocate OLW to ponded area east of slag pile, connect to Ormond Lagoon, include SLR	3'	Ormond Lagoon is hydraulically connected to OLW floodplain	Partial loss of Ormond Lagoon due to SLR, no beach grooming
3a	Create New Lagoon in ponded area east of slag pile, separate from Ormond Lagoon	0'	OWL is rerouted into New Lagoon. New Lagoon and OWL are blocked from Ormond Lagoon. New Lagoon discharges to ocean southeast of slag pile.	No beach grooming in front of New Lagoon. Beach grooming to 8.9' in front of Ormond Lagoon.
3b	Create New Lagoon in ponded area east of slag pile, separate from Ormond Lagoon, include SLR	3'	OWL is rerouted into New Lagoon. New Lagoon and OWL are blocked from Ormond Lagoon. New Lagoon discharges to ocean southeast of slag pile.	Partial loss of Ormond Lagoon due to SLR, no beach grooming

and were modeled separately with the New Lagoon receiving 80% of the original streamflow and the old Ormond Lagoon receiving the remaining 20% of the flow, to account for diversion of the OLW. Under Alternative 3, we assumed that the New Lagoon will drain directly to the ocean via a new unmanaged ephemeral lagoon outlet (mouth) and will not pond onto the beach between the beach berm and the dune line. The implications of this assumption are discussed later in Section 5.

For the sea level rise "b" cases, we assumed that part of the existing Ormond Lagoon will be filled in by sand as the beach transgresses landward, as described in the main report. For Ormond Lagoon, we predict that the majority of Ormond Lagoon in front of the dune line would be lost under 3 feet of sea level rise, representing a loss of 20-40% of the overall lagoon system storage.

To represent the influence of the current beach grooming practice, we applied a cap of 8.9 feet NAVD for beach berm growth for the "a" Alternatives, effectively assuming that VCWPD would breach the mouth if water levels ever reached this elevation. This means that if Ormond Lagoon water levels fill to 8.9 feet NAVD during a closure event, the model assumes the beach crest is instantaneously excavated to 8.9 feet, allowing Ormond Lagoon waters to spill over the beach and erode a new mouth. We assumed that the current beach grooming policy would no longer be relevant under 3 feet of sea level rise, and thus, the “b” cases did not include a beach height cap. The 3a alternative also does not include grooming in front of the New Lagoon.

4.1 Existing Conditions – Model Calibration

To train the model, we tested (1) predictions of water levels in the lagoon and (2) predictions of mouth closure and breach timing. We use the period from October 2007 to October 2011 to match water levels in the lagoon, and the mouth closure record interpreted from water level time series.

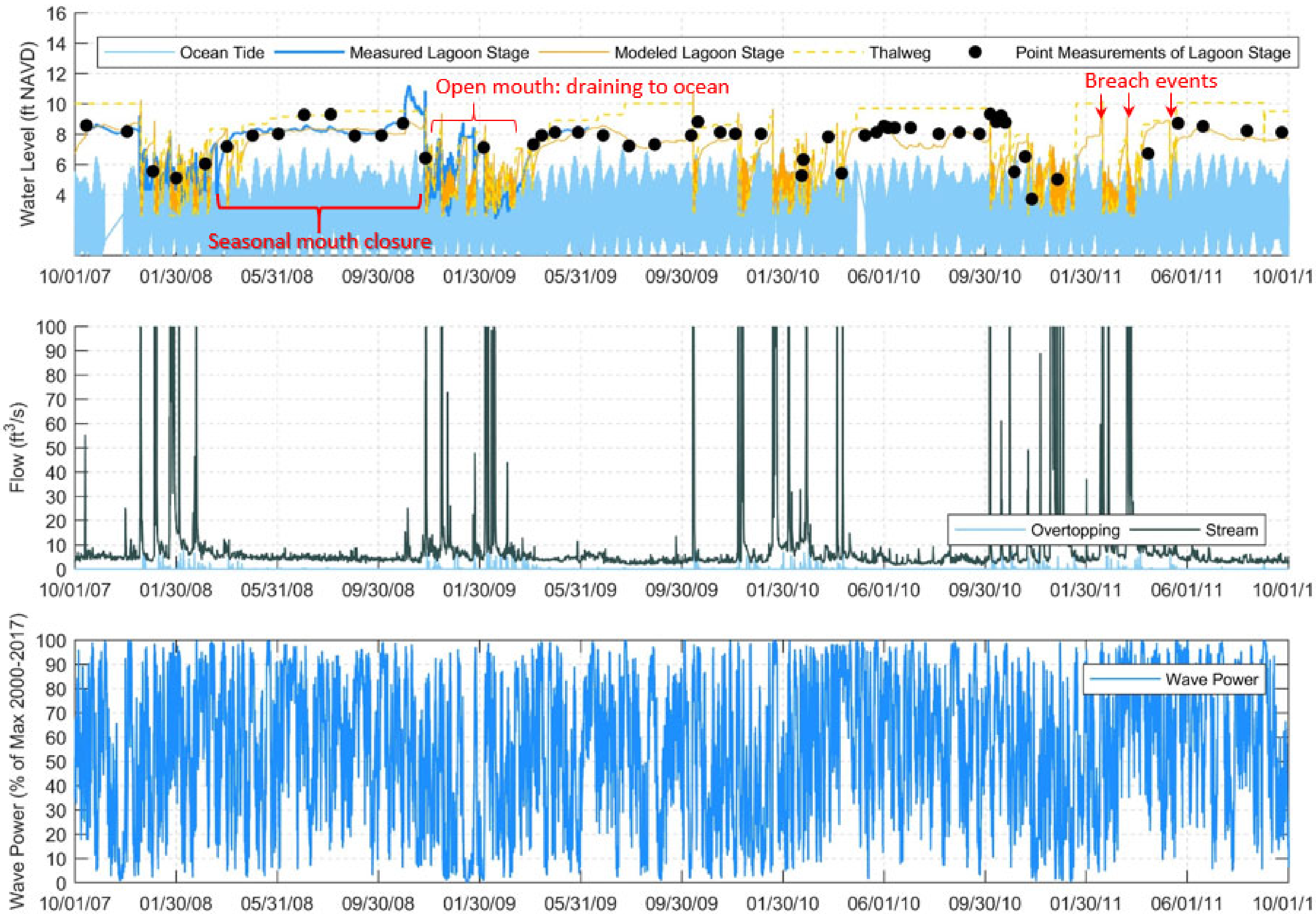
Figures E-2 and E-3 show how the model calibration run compares against the lagoon water level data from October 2007 to October 2011. Although the exact timing of the closure and breaching events are not always captured, the model reproduces a number of important aspects, such as (1) periods of mouth scour during high watershed runoff, (2) mouth closure during high wave events, (3) stabilization of the water level at 8-9 ft NAVD during seasonal closure events, and (4) natural mouth breaching during floods.

Given the complexity of Ormond Lagoon and other similar estuaries, the QCM is best used to reproduce the seasonality of the closures and the expected distribution of water levels in the lagoon, and not the exact timing of closure or breach events. Overall, the model performs well in reproducing the water level exceedance (Figure E-3) in the lagoon and the percentage of days closed (**Figure E-4**). The model correctly predicts the seasonality of closure, although it tended to overpredict mouth closure in late winter and fall. Since the model was driven by a synthetic inflow time series, and water level observations were limited, it is likely that it could be improved significantly as more data are collected.

4.2 Impact of Restoration Alternatives

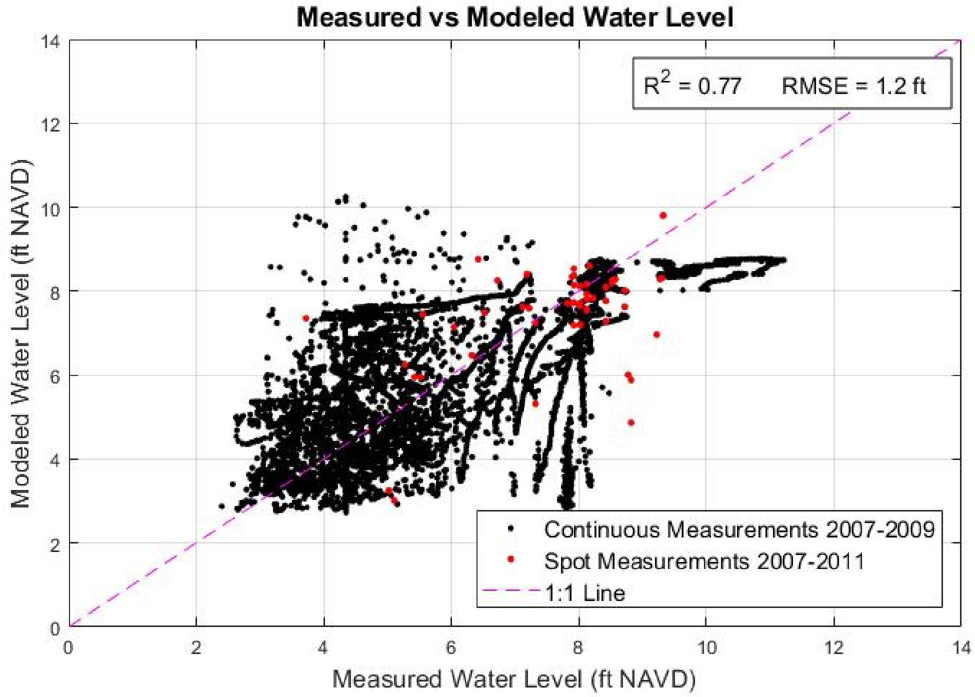
Table E-2 outlines the conceptual alternatives, and lists the ways that they were represented in the model. The restoration alternative “a” cases are representative of existing sea level, while the “b” cases represent future sea levels, and an absence of mouth management. **Figures E-5 through E-8** provide a summary of model results that highlight the predicted water levels in the lagoon, the changes in the seasonal mouth closure pattern, and the expected changes in the wetted area and volume. These characterize the hydrology of the system, while the SLAMM model described in the main body of the report addresses specific habitat responses.

Figure E-5 shows a time series of modeled water level in the lagoon for each of the alternatives, without SLR (upper panel) and with 3’ of SLR (lower panel). For the third alternative, water levels are indicated both for the Ormond Lagoon area, fed by tšumaš Creek and Bubbling Springs, and for the New Lagoon area fed by a redirected OLW. Figure E-6 illustrates the seasonal closure pattern for each of the alternatives, in terms of number of days of mouth closure



SOURCE: ESA

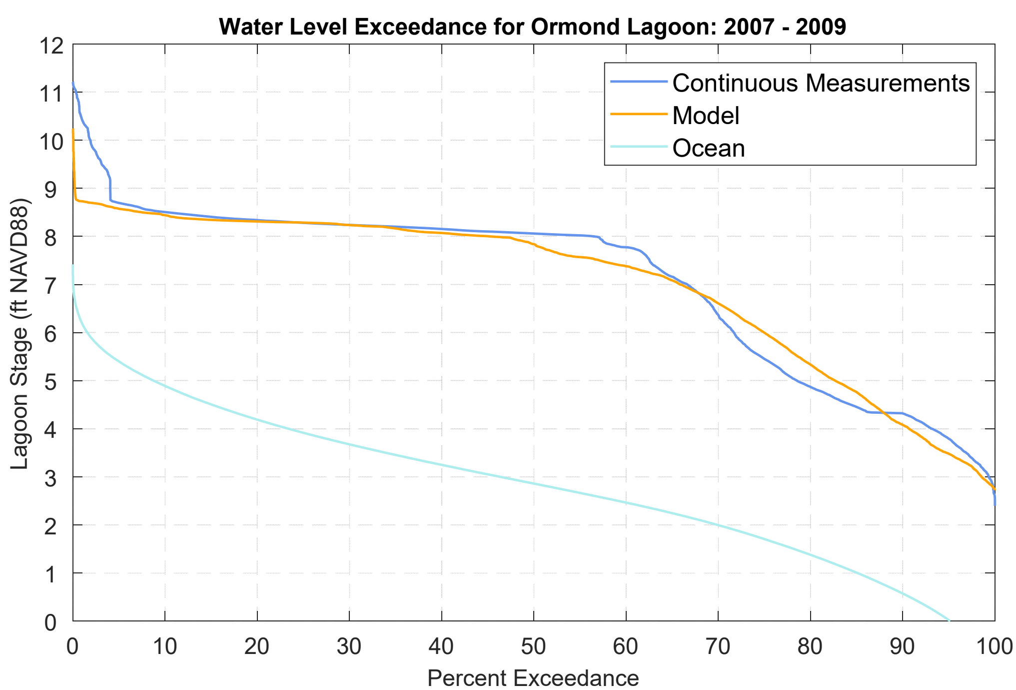
Figure E-2
Comparison of **(top)** modeled and observed water levels in Ormond Lagoon, **(middle)** synthetic time series of runoff and predicted wave overwash, and **(bottom)** nearshore wave power.



Ormond Beach Wetlands Restoration / D160447.00

SOURCE: ESA

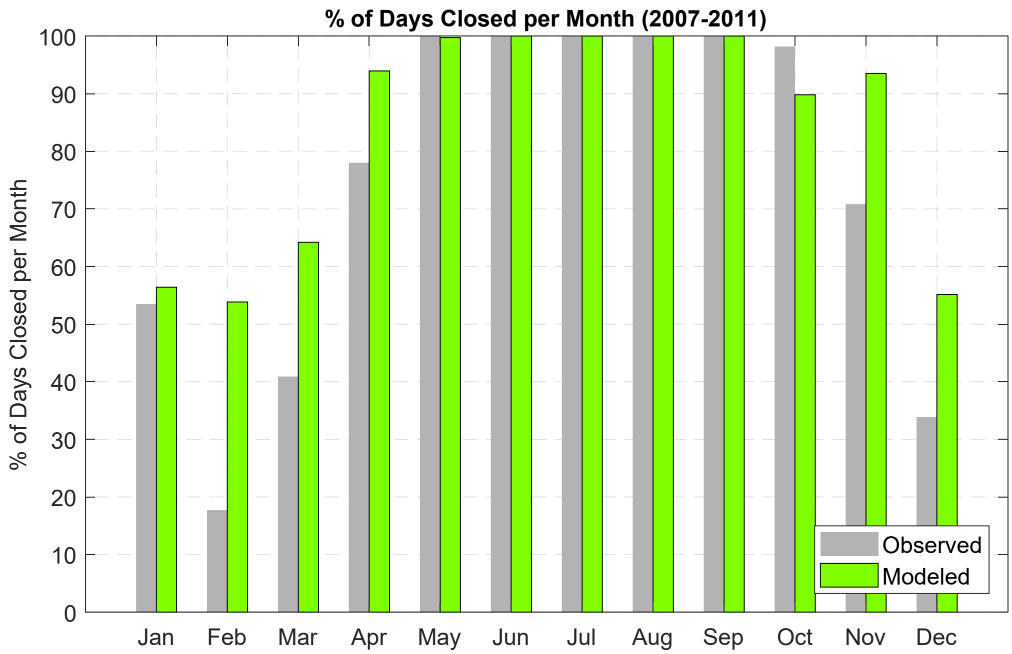
Figure E-3
Comparison of modeled and observed water levels in Ormond Lagoon from 2007 to 2009.



Ormond Beach Wetlands Restoration / D160447.00

SOURCE: ESA QCM model. Water level observations provided by CH2M Hill (2012)

Figure E-4
Comparison of modeled and observed water level exceedance in Ormond Lagoon from 2007 to 2009.



Ormond Beach Wetlands Restoration / D160447.00

SOURCE: ESA

Figure E-5
Comparison of modeled vs observed percentage of days closed per month

for each month of the year over the period from 2007 to 2017. The seasonal closure pattern is apparent in each of the curves from the dip in the number of closure days in winter months (during higher flow conditions) and higher number of closure days in the drier months (when runoff is low and the mouth is more likely to be blocked by sand from wave action).

Figure E-8 condenses the water level time series from Figure E-6 into probability density function (pdf) curves. These curves represent the relative number of times that lagoon water levels were predicted within certain bands of elevation. As an example, a pdf curve of oceanic tides would show high density of occurrences between mean lower low water (MLLW) and mean higher high water (MHHW). For Ormond Lagoon, water levels are typically much higher, so the pdf curves show a higher density above MHHW. The goal of this plot is to show subtle changes in water level between the alternatives more clearly than a time series alone could reveal. Figure E-8 also shows pdf curves for wetted area and lagoon volume, which were calculated from the water levels by relating them to the hypsometry (volume vs elevation) relationships for each case. Figure E-9 is similar to Figure E-8 but illustrates the SLR scenarios.

Alternative 1a was the only alternative to reduce the volume of Ormond Lagoon, since it isolated the ponded area east of the Halaco site. Compared to existing conditions, this alternative resulted in slightly higher water levels during seasonal closure (Figure E-6), but this caused Ormond Lagoon to breach earlier relative to existing conditions (Figure E-7). This meant that Ormond Lagoon drained earlier and more frequently than the other alternatives. Overall, the effects on water levels were small, although the isolation of part of Ormond Lagoon meant that wetted area and water volume were reduced (Figure E-8).

Alternative 2a resulted in slightly lower water levels than for existing conditions, but the added lagoon volume east of the Halaco site added a significant amount of wetted area and volume (Figures E-6 and E-8). Since oceanic tides have a small presence under existing conditions, the added volume had only a small impact on maintaining a longer opening, and relatively larger impact on impounding more water behind the beach during seasonal closure events. In systems that are much lower in elevation, adding volume within the tidal range can increase tidal currents in the mouth and make it harder for waves to deposit sediment and close the mouth (e.g. Behrens et al. 2015). In this case, the impact of the grading was predicted to have a relatively small impact on mouth conditions (Figure E-7).

Alternative 3a had the most marked impact on lagoon water levels and mouth closure, and had a similar effect as Alternative 2a with respect to increasing wetted area and volume. The New Lagoon under Alternative 3a was predicted to experience higher water levels than for Ormond Lagoon under existing conditions. This is a result of:

- Smaller storage capacity of inflows when compare to the capacity of the entire existing system,
- Reduced seepage toward the ocean given that the New Lagoon would mostly be situated behind the dune line, rather than on the beach, and
- Lack of beach management, allowing the beach crest to reach equilibrium levels of 9-11 feet NAVD during seasonal closures. This would allow the New Lagoon to hold more water behind the beach berm.

These changes contributed to significant gains in water volume east of the Halaco site, despite the fact that a portion of the inflows (Chumash Creek and Bubbling Springs) were directed to Ormond Lagoon. In contrast, the Ormond Lagoon experienced a reduction of 1-2 feet in water levels, since its storage capacity remained the same and the OLW would be diverted to the New Lagoon. This is anticipated to have a net benefit on flood management, as it delayed ponding during floods and reduced the number of times that peak water levels reached the grooming elevation of 8.9 ft NAVD (Figure E-6).

Despite the separation of inflows, when combined, the New Lagoon and Ormond Lagoon segments are predicted to provide a net increase in overall brackish habitat in the system as indicated by the curves for wetted area and volume in Figure E-8. The increase is similar in magnitude to Alternative 2a. The model also predicted significant changes in mouth closure duration. Despite the assumed continuation of beach grooming by VCWPD in front of Ormond Lagoon in the future, the reduced inflow to Ormond Lagoon meant that closure events lasted significantly longer on average (Figure E-7).

Figure E-6
Alternatives Timeseries

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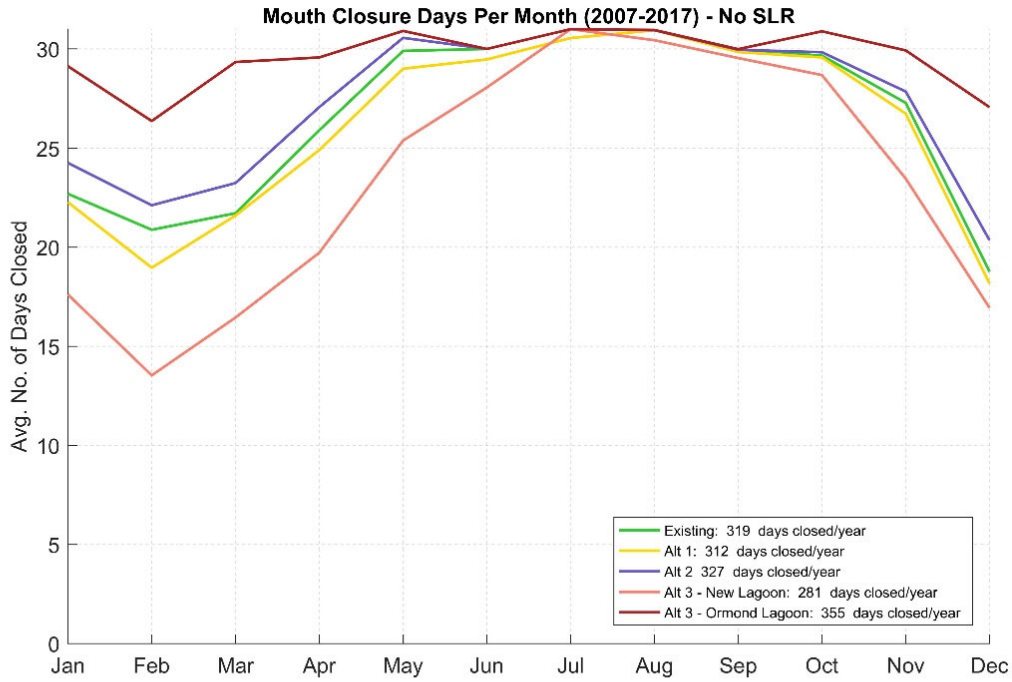

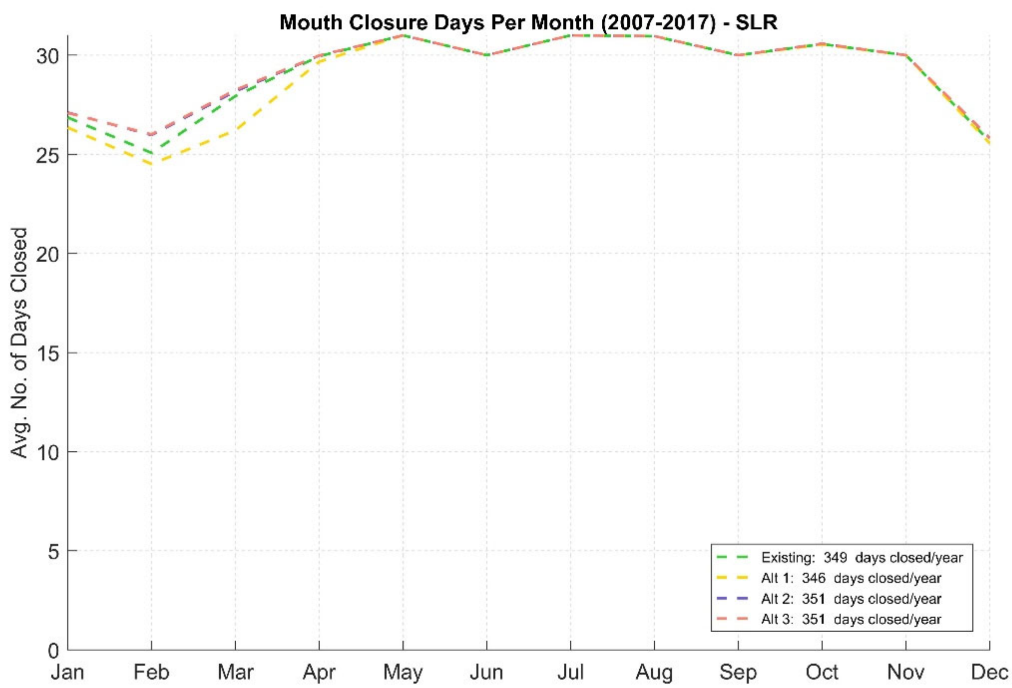

SOURCE: ESA QCM Model

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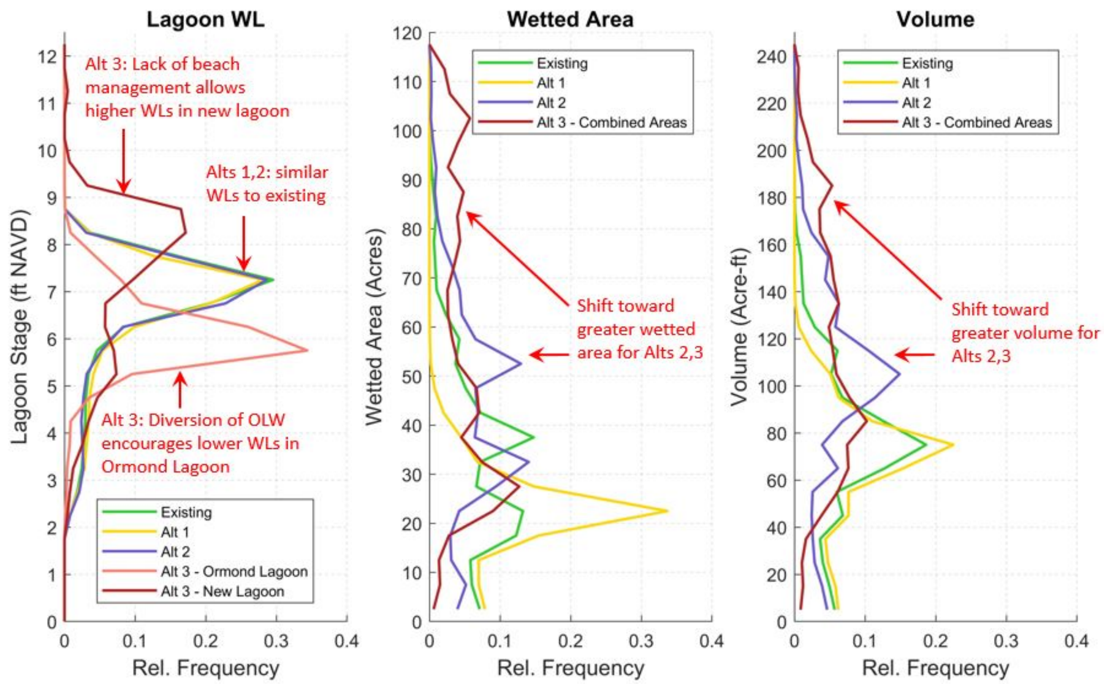
Figure E-7
Lagoon Mouth Closures in Days per Month
No Sea-Level Rise (top) and 3' of Sea-Level Rise (bottom)



SOURCE: ESA QCM model

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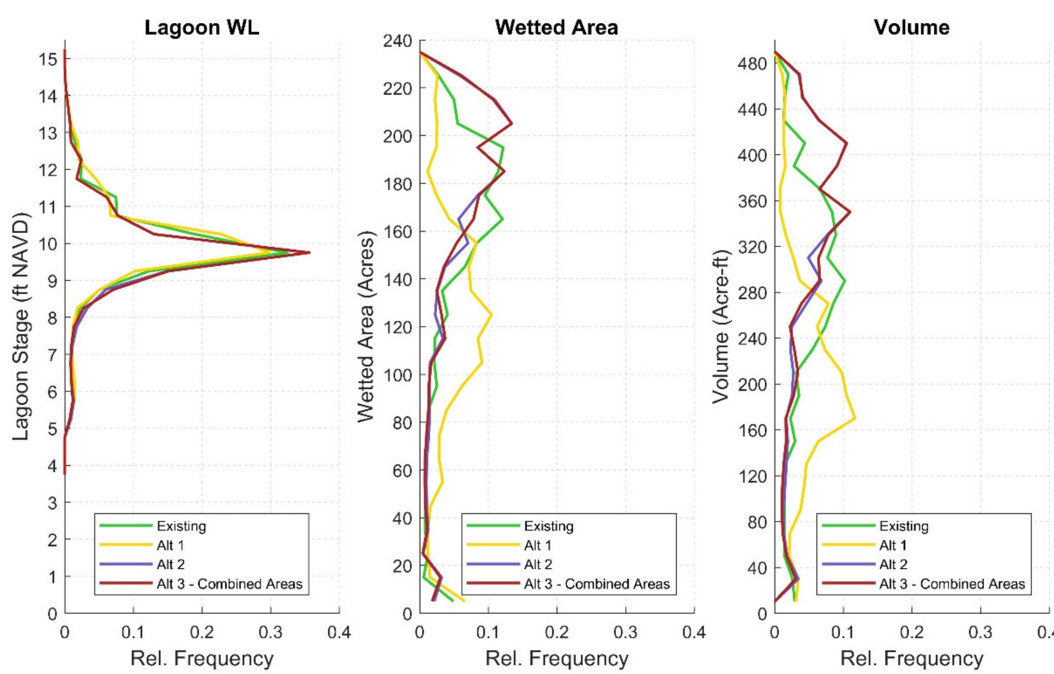
Figure E-8
Modeled Lagoon Stage (Water Level) (left), Area (middle), & Volume (right) Probability Distributions for 2007-2017.



SOURCE: ESA QCM model

Ormond Beach Restoration and Public Access Plan

Figure E-9
Modeled Lagoon Stage (Water Level) (left), Area (middle), & Volume (right) Probability Distributions for 2007-2017. With 3 feet of Sea level Rise

4.3 Impact of Sea Level Rise

Under the sea level rise scenarios ("b" alternatives), water levels are very similar across the alternatives. This is likely because the elevated water levels will fill low areas behind the dune line. The capacity of these areas to store water is higher than the relatively small area of the Ormond Lagoon that would be lost to beach transgression inland. Therefore, the differences in storage capacity between the cases are small relative to the total storage capacity. Figure 7 (bottom) shows that for the SLR cases, the mouth is closed on the majority of the days each month. A similar seasonal pattern with winter and spring breaches is still observed with sea level rise, although the pattern is less pronounced. These results imply that the increase in the extent of inundated areas behind the dune line would contribute more to impoundment of water than to maintaining an open mouth. As SLR increases water levels above 3', more frequent open-mouth conditions may result: This response was predicted for Devereux Slough in Santa Barbara County, for high levels of SLR (ESA 2016). For Ormond Beach area, the very low topography would not constrain the water surface at these higher sea-levels, and a more detailed analysis of the basin hydrology is required to provide meaningful projections.

4.4 Conclusions

In the short- to mid-term time horizon, Alternative 3 provides the greatest wetted area and volume for tidewater goby habitat. Although Alternative 3 can cause elevated water levels in the New Lagoon (which potentially poses a flooding risk), the fraction of time in which water levels are above 10 feet NAVD is small. If Alternative 3 were to be pursued, flooding risks to nearby areas should be assessed. Also note that Alternative 3 is sensitive to input assumptions and thus the results for Alternative 3 include more uncertainty than the other Alternatives. Alternative 2 was found to have a comparable increase in water volume, although water levels were constrained by continued beach management, limiting the allowable gain of lagoon habitat. Alternative 1, provided the least lagoon elevation and area (habitat), but would likely be simpler to implement and would preserve more brackish/saline habitats than the other alternatives.

As sea level rises, the differences between the Alternatives becomes less significant. With 3 feet of sea level rise, Alternative 3 has a smaller advantage over existing conditions in the amount of wetted area and volume provided. However, it is assumed that construction of this alternative would allow formation of critical backbarrier lagoon habitat, that could then transition and adjust inland with SLR, rather than being squeezed and constrained against infrastructure behind the beach. Also, Alternative 3 is more consistent with future conditions with higher sea levels for all of the Alternatives because the proposed New Lagoon location is where a lagoon is predicted to form at higher sea level.

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5. Uncertainties and Restoration Implications

5.1 Data Gaps and model uncertainty

While the model was able to reproduce seasonal mouth closure conditions and water levels, the short span and limited geographic scope of some of the available data contributed to some of its uncertainty. Model calibration relied heavily on data collected from 2007 to 2011 since this period had the greatest overlap of different data sets required for testing the model. Although this period of time included relatively dry and wet years, year-to-year variability in the California climate is often very high, and 4-5 years of data cannot describe the full breadth of hydrologic conditions that might be expected in the future, with or without restoration.

While data collection by the EPA, CH2M Hill, and others was intensive, and has done much to illustrate the function of the system, there are several data gaps that impacted this modeling study:

- Runoff data into Ormond Lagoon were unavailable. A synthetic record was developed from nearby gauges to attempt to approximate the seasonality if runoff (described in Section 3), but the uncertainty of this synthetic time series is unknown without data to compare against. No runoff data were available from either of these nearby gauges for 2017.

- No water level records were taken in Ormond Lagoon from 2012 to 2016.

- Records of mouth closure periods have not been kept, except for the dates of beach management actions. Timing of mouth closure events was interpreted from water level time series.

- The impact of biennial beach nourishment activities from the USACE, is thought to impact beach growth at the site, but seasonal and inter-annual measurements of the beach crest are not available.

- Groundwater interactions between area 3a and areas to the east are uncertain, which implications all alternatives. Area 3a is thought to have a groundwater connection to OLW and Ormond Lagoon (CH2M Hill 2012), but its connectivity to areas immediately to the east, including the ODD#3 is less certain. Ground water is affected by the existing waste water system, which is connected to the groundwater via pipeline leaks (CH2M Hill, 2012), but the existing and future implications to groundwater are not adequately understood.

Future refinement efforts of the restoration design would benefit greatly from additional data collection that would address these gaps. The goal of this data collection would be to gather information in a wider range of hydrologic conditions than were observed from 2007 to 2011. In particular, water level data collected in Ormond Lagoon and in area 3a would be relatively cost-effective and provide a much broader understanding of how Ormond Lagoon and outlying ponded areas respond to the driest and wettest of years. Runoff measurement near Ormond Lagoon would also provide a large benefit to the restoration design. Since the existing Ormond Lagoon rarely experiences ocean tides, we found that the seasonal runoff pattern has relatively high importance in governing the morphology of Ormond Lagoon mouth and the resulting water levels. This is consistent with other lagoons that whose topography lies mostly above the tide range, including Scott Creek in central California (ESA 2016) and at Aliso Creek, north of San Diego (ESA year).

5.2 Uncertainties in Site Evolution

For all alternatives, we assumed that beach transgression with sea level rise will impact the available volume on the beach, as the beach begins to squeeze Ormond Lagoon against the hard line of infrastructure immediately landward. Unlike the beach crest fronting Ormond Lagoon, we have assumed that the dune line would be more resilient and would front the Lagoon constructed in area 3a as part of Alternatives 2 and 3.

We have assumed that the New Lagoon created under Alternative 3 would mostly be comprised of the ponded areas behind the dune line, and would have an ephemeral connection to the ocean via a New Lagoon mouth channel on the beach. For simplicity, we assumed that the channel connecting the New Lagoon to the ocean on the beach would not expand to form a seasonally ponded area of its own on the beach (similar to the ponded area that makes up the existing Ormond Lagoon). At several other sites in California, this condition is true, but it requires that vegetation or other environmental constraints prevent the channel from migrating along the beach. The proposed grading for Alterative 3 includes dune creation to inhibit connection to the existing Ormond Lagoon, but pooling along the beach to the east is possible and even likely, and should be considered in reviewing alternatives effects and effectiveness.

While we did not explicitly model this case, the expected result of this lagoon formation on the beach would be:

- A gradual increase in wetted area and volume available (beyond those already predicted for Alternative 3), and
- An increase in seepage losses from the New Lagoon, potentially resulting in lower water levels

6. List of Preparers

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Appendix F

Wetlands Habitat Evolution Modeling (SLAMM)

APPENDIX F
Wetlands Habitat Evolution Modeling

Introduction

As sea level rises, the beach and wetland habitats at Ormond beach are expected to change due to increasing inundation and geomorphic migration inland. To project habitat changes at the site due to sea-level rise, this study employed the Sea Level Affecting Marshes Model (SLAMM). SLAMM, written and maintained by Warren Pinnacle Consulting, Inc., is a program that simulates wetland conversion and shoreline change due to sea-level rise (WPC 2016). It was developed in the 1980s and has been adapted and updated since, leading to the most recent version 6.7, which includes updates specific to California estuaries and lagoons. In general, SLAMM uses ground elevation and slope, along with an initial habitat map and a sea-level rise curve, to estimate the conversion and migration of habitat areas over large time steps (on the order of years to decades).

For this study, habitat changes under future conditions through 2100 were modeled for the No-Project case and for each of the three alternatives.

Methods

This study was performed with SLAMM version 6.7 because it is the latest iteration of the software and includes some features developed for California estuaries and perched lagoon systems (WPC 2016). Earlier versions of SLAMM were developed for sites and ecosystems on the east coast of the United States, and as such they did not capture the suite of California estuarine habitats and their relationship to perched lagoon hydrology. The latest version includes a separate set of habitat classifications and conversion functions tailored to California. SLAMM v6.7 also introduces a perched lagoon model, which allows estuarine water levels behind a coastal barrier beach to be perched above the ocean water level and to experience a muted tidal range. Lagoon perching is represented by a parameter, beta, and two physical benchmarks, mean tide level and the barrier beach crest elevation. Beta is multiplied by the difference between the barrier beach crest elevation and the mean tide level to represent the perched water level (WPC 2016).

The Coastal Resilience Ventura (CRV) project applied SLAMM v6.2 beta to the stretch of shoreline including both Ormond Beach and Mugu Lagoon to the southeast (ESA PWA 2014). The CRV project was intended as a regional-scale assessment of coastal wetland habitat vulnerability to sea-level rise, whereas the current study is intended as guidance for designing the Ormond Beach restoration. As such, the inputs to these two versions of SLAMM are similar, but not identical. Overall, the findings from the two studies are similar, particularly in that Ormond Beach will begin to experience significant increase in inundation after two feet of sea-level rise that escalates to affect nearly all the Project Area as sea-level rise approaches five feet.

The key inputs for ground elevations, habitat extents, and sea-level rise for this study's SLAMM model are as follows:

- **Ground elevation** - Over the OBRAP project site, a digital elevation model (DEM) at 1-meter resolution was taken from the SCC California Coastal LiDAR dataset (SCC 2011). Portions of this DEM were updated based on surveying and site observations to correct for LiDAR bias in densely vegetated areas. Outside the project area, the topography from CRV was deemed sufficient, and the two datasets were spliced together to provide a single DEM covering the model domain. The elevation bands can be seen in **Figure F-1**, with the two data source regions outlined. This merged DEM was sampled at 5-meter resolution to serve as input to SLAMM.

- **Existing habitats map** - As part of the OBRAP existing conditions report, habitat surveys were performed at the site, identifying different types of beach, wetland, and upland habitats in the area based on salinity, elevation, existing plant and animal communities, and access to water (ESA 2017, Figure 2-28). The SLAMM California habitat categories for each of these regions were identified to create the SLAMM existing habitats input file. For parts of the model domain outside the surveyed project area, the habitat map from CRV was converted to California categories as indicated by the cross-walk in **Table F-1**. This merged existing habitats map is presented in **Figure F-2**.

- **Sea-level rise** - For this study, the CRV 'High SLR' sea-level rise curve was used. This curve is based on guidance from the National Research Council (NRC 2012) and the US Army Corps of Engineers (USACE 2011) and projects sea-level rise of 4.8 feet at 2100. This elevation was selected based on reviews of prior work and consideration of California guidance and Ventura County planning, as described in more detail in Appendix A.

SLAMM allows the user to define subareas with different hydrologic parameters, and two of these were defined for this model: the Ormond Lagoon Subarea and the Arnold Road Subarea (as outlined in Figure F-2). The Ormond Lagoon Subarea was defined to capture the effects of perched Ormond Lagoon water levels on habitat conversion in the west, and the Arnold Road Subarea was defied to capture the effects of rising groundwater levels on habitat conversion in the east. The rest of the domain includes developed areas, which are assumed to have unchanged land use from their current development, and the exposed beach and dune areas, which directly experience the open ocean tides and waves. The hydrology of each subarea was characterized with a local definition of mean tide level, tide range, and berm crest and beta-parameter. These parameters are summarized in **Table F-2** and described in the following paragraphs.

The part of the domain not contained in either subarea is exposed to the open ocean, so it experiences the full oceanic tidal range (5.4 ft). The mean tide level applied to the model from the open ocean was based on published tidal datums at the NOAA's Santa Barbara gage #9411340. This area has a small perching factor applied via the lagoon module to account for groundwater higher than sea level, which is described in more detail in the description of Arnold Road Subarea below.

TABLE F-1
SLAMM TRADITIONAL TO CALIFORNIA HABITAT CATEGORY CROSS-WALK

Traditional Name	Trad. Code	CA Name	CA Code
Developed Dry Land	1	Developed Dry Land	101
Undeveloped Dry Land	2	Undeveloped Dry Land	102
Swamp *	3		
Cypress Swamp *	4		
Inland-Fresh Marsh	5	Freshwater Marsh	108
Tidal-Fresh Marsh	6	Tidal Fresh Marsh	114
Trans. Salt Marsh	7	Irreg.-Flooded Marsh	115
Regularly-Flooded Marsh	8	Regularly-flooded Marsh	120
Mangrove *	9		
Estuarine Beach	10	Ocean Beach	119
Tidal Flat	11	Tidal Flat and Salt Panne	122
Ocean Beach	12	Ocean Beach	119
Ocean Flat	13	Tidal Flat and Salt Panne	122
Rocky Intertidal	14	Rocky Intertidal	121
Inland Open Water	15	Inland Open Water	106
Riverine Tidal	16	Riverine Tidal	124
Estuarine Open Water	17	Estuarine Open Water	126
Tidal Creek	18	Tidal Channel	125
Open Ocean	19	Open Ocean	127
Irreg.-Flooded Marsh	20	Irreg.-Flooded Marsh	115
Inland Shore	22	Inland Shore	107
Tidal Swamp	23	Tidal Fresh Marsh	114
Flooded Developed Dry Land	25	Flooded Developed	128
		Dunes **	111

NOTES:
* These Traditional Categories to not apply to the California Coast, so they were not mapped.
** There was not a direct cognate in the Traditional Categories. CRV used “Flooded Forest” for this category, but the two are not consistently comparable.

TABLE F-2
DOMAIN HYDRAULIC PARAMETERS

	Model Domain Outside of Subareas	Ormond Lagoon Subarea	Arnold Road Subarea
Mean Tide Level (ft NAVD88)	2.6	2.6	2.6
GT Great Diurnal Tide Range (ft)	5.4	0.3	0.3
Lagoon Beach Crest Elev. (ft, NAVD88)	9.6	9.6	9.6
Lagoon Beta Parameter (-)	0.082	0.5	0.082

The Ormond Lagoon Subarea includes parts of Area 1, the existing lagoon and surrounding beach and marsh areas; Area 2, upstream on the Ormond Lagoon Waterway; and Area 3a, the wetland area potentially connecting the two; and Area 4, the land inland of the existing railroad embankment. These are hydraulically connected via by Ormond Lagoon Waterway, the channel along the south edge of the Halaco site, and the similar ground surface elevations. Tides in the lagoon are damped, and the representative tide range of 0.3 ft was selected based on results from water level observations and the lagoon QCM (Appendix C. Based on water level gauges deployed from June-December 2017 as part of the OBRAP field work, the minimum dry season water level in Ormond Lagoon is expected to be 6.5 feet NAVD. This is about 3.5 feet higher than oceanic mean tide level, so the beach crest elevation and lagoon beta parameter were set to representative values that result in this 6.5-foot NAVD perched elevation.

The Arnold Road Subarea includes the western portion of the OBRAP project area, comprising Area 3b, between the railroad embankment and the beach; Area 5, east of the power plant; and Area 6, the salt panne area at the end of Arnold Road that is between Oxnard Drainage Ditch #3 and the dunes. These areas are lower-lying and exposed to a shallow groundwater table, as indicated by water level gauges deployed from June-December 2017. These observations indicated that the groundwater in this area varied from 3.2 to 4.3 ft NAVD, and had a representative value of 3.7 ft NAVD, slightly higher than oceanic mean tide level. This slight elevation above oceanic mean tide was likely due to the regional groundwater gradient sloping down to the ocean. The groundwater observations exhibit muted fluctuations at periods corresponding to the daily and spring-neap tidal cycle, confirming the groundwater's connectivity to the ocean. To represent this ocean-connected groundwater, the Arnold Road sub area was modeled as a lagoon with a very small beta parameter. A beta parameter of 0.082 raises the water levels by about 0.7 feet under current conditions, aligning with field observations, such as the surface water in ODD #3. For current conditions, this water level is below the surface in most of the subarea, but with sea-level rise, it will rise above the ground surface and become a groundwater-sourced lagoon. The SLAMM tide range parameter was set to be consistent with the tidal fluctuations observed in the groundwater, 0.3 ft.

Using the hydraulic conditions in each subarea, SLAMM begins with the initial-conditions habitats (input) and steps forward in time by raising sea level and calculating changes to the topography – both horizontal recession by erosion, and vertical growth by accretion. Based on the elevation and slope of each cell, SLAMM calculates the new inundation frequency for that cell. SLAMM includes a set of conversion pathways – for example, leading from Irregularly-Flooded Marsh to Regularly-Flooded Marsh, to Tidal Flat/Salt Panne, to Estuarine Open Water – and as the inundation frequency of each cell changes, it shifts toward wetter or drier habitat categories (though wetter is far more frequent as sea level rises). For cells not directly connected to the ocean, SLAMM also considers saturation, assuming groundwater rises with sea level, allowing fresher wetlands to move into upland areas, even if they are not directly inundated.

SLAMM was developed to primarily to examine the effect of changing water levels in estuarine wetlands, and as such, it does not consider coastal processes affecting the beach and dunes themselves. Sea-level rise will cause landward transgression of water levels and waves, which, in turn, will cause erosion and shift the shoreline itself further inland. These processes were addressed outside SLAMM, and then applied to the SLAMM results. It was assumed that the beach could freely transgress inland and upwards according to the Brunn rule, while the dunes would erode permanently as sea-level rise outpaces aeolian dune formation. This methodology is described in more detail in Appendix B. The result was a new beach berm location, representing the inland extent of SLAMM's open ocean habitat category at each time horizon, and a new back beach extending 100 feet behind that line. These two habitat areas were overlain on the SLAMM habitat results, representing the inland transgression of the beach overtaking other potential habitats with rising sea level.

Results

1.1 No-Project

The SLAMM results for the No-Project case are presented in **Figure F-3**, **Figure F-4**, and **Figure F-5** at three future time horizons.

At 2060 (Figure F-3), projected sea-level rise is about two feet (2.1 ft). In the western side of the project area, water is still generally confined to existing waterways, and the beach is beginning to pinch off the east end of the lagoon, but Ormond Lagoon is generally still intact. In Area 6, on the east end of the project area, much of the salt panne at the end of Arnold Road has converted to open water, with the higher area around that converting from marsh to salt panne and the existing marsh shrinking slightly. Across the site, more saline and wetter influence is projected to move upslope, potentially shifting nearly all the uplands towards brackish wetlands. This is consistent with the project area's existing vegetation distribution (ESA 2017, Figure 2-28), which includes saline wetlands at elevations up to about 10 ft NAVD. With two feet of sea-level rise, the band of potential saline influence is likely to also shift upwards by two feet, to 12 ft NAVD. Nearly all the project area's ground surface falls below 12 ft NAVD (Figure F-1).

At 2080 (Figure F-4), projected sea-level rise is about three feet (3.4 ft). In the west, the marsh in Area 3a has mostly converted to open water, and is anticipated to have perched water levels that function similar to and somewhat connected to Ormond Lagoon. The surrounding areas have converted to a single class containing both unvegetated salt panne and tidal flat. These habitats are primarily differentiated by evaporation and hydraulic connectivity, process for which SLAMM does not account. Since SLAMM habitats are based on only elevation and tidal range, the model does not differentiate between tidal flat and salt panne and instead groups them together into a single category. While the figures in this appendix use more habitat distinctions and refer to those areas as "salt panne," they are generalized as "unvegetated flats" when the habitat areas are summarized into fewer categories for the main report. The beach has transgressed far enough inland to overrun the east side of the lagoon. The low-lying portions Area 2 near Ormond Lagoon Waterway have also converted to salt marsh and begun to show patches of permanent open water. Open water, salt panne, and salt marsh have begun to migrate into Area 4 from the west, and the lower area closer to the ocean is permanently ponded. The eastward extent of this open water, which is attributed to perched lagoon conditions, may be limited by the available freshwater volume and not spread out quite as far as shown, except during wet season runoff evens. In the east, the existing salt panne in Area 6 has been squeezed to the margins of a growing pool of open-water there, which likely acts as a lagoon supplied by a combination of groundwater, channels from Mugu Lagoon, and increasingly frequent wave overwash.

At 2100 (Figure F-5), projected sea-level rise is nearly 5 feet (4.8 ft). By this time, most of the project area is permanently inundated by open water. Groundwater's connectivity to the ocean provides an effectively unlimited water supply to support groundwater inundating the project area in the lower areas, including Areas 5 and 6, and progressing as far west as Area 3b. However, in the western portion of the project area, while the site is expected to be very wet by end-of-century, this figure may overstate the actual inundation. SLAMM does not account for limited water supply, whereas in reality as the western area inundates from Ormond Lagoon and its waterways, more volume would be required to raise the water surface as the water spreads over a wide area. SLAMM assumes that there is enough water to fill any potential space below the inundating water level, thereby likely overestimating inundation in Areas 2, 3a, and 4. Although the western inundation is likely overestimated for 4.8 ft of sea-level rise, higher amounts of sea-level rise, which are projected as possibilities for the end of the 21st century or into the 22nd century, would eventually result in conditions similar to inundation extent in Figure F-5 as the continued increase in groundwater augments the inundation from the watershed and lagoon perching.

1.2 Proposed Restoration Alternatives

SLAMM was also used to evaluate the habitat evolution of the proposed restoration alternatives. For each alternative, described in Section 6 of the preliminary restoration plan, the ground elevations in the DEM were modified to represent the proposed grading and the initial habitat map was revised to reflect the target habitats. Then SLAMM was run for each alternative using all the same configuration as for the No Project scenario, except for the altered DEMs and habitat maps. Unless otherwise stated, the alternatives' habitat evolution in Areas 6-9 are roughly similar to the No Project scenario. Differences from the No Project scenario and between the alternatives are summarized in the sections below.

The alternatives propose a range of management for the dunes, such as vegetation management, grading swales, and dune building. These types of management are not resolved by the approach for coastal erosion (Appendix B) that was applied to the SLAMM results, so projections for beach and dune erosion are mapped the same in all alternatives as for the No-Project scenario.

1.2.1 Alternative 1

Since Alternative 1 proposes mostly enhancements to existing habitats and relatively mild grading, its initial conditions (**Figure F-6**) are very similar to existing conditions in the No Project scenario. Because of the similarity to No Project's initial conditions, the resulting habitat evolution is also similar to the No Project scenario.

At 2060 (**Figure F-7**), with two feet of sea-level rise, the most prominent change is open water in Area 6.

At 2080 (**Figure F-8**), with three feet of sea-level rise, inundation spreads to a substantial fraction of the project area, and the reduced connectivity to ODD #3 results in larger open water and unvegetated in the western portion of Area 5.

At 2100 (**Figure F-9**), the majority of the site is inundated.

1.2.2 Alternative 2

The proposed grading in Alternative 2, notably the re-alignment of Ormond Lagoon Waterway in Areas 2 and 3a, and the wetland swales in Area 4, modify this alternative's the initial habitat conditions (**Figure F-10**).

At 2060 (**Figure F-11**), with two feet of sea-level rise, the southern-most wetland swale in Area 4 become permanently inundated. Because of the better connectivity via the Waterway's re-alignment, Area 3a has more vegetated wetlands rather than the unvegetated flats predicted for this area for No Project and Alternative 1. The lower portion of the re-aligned channel also provides connectivity between the Waterway and the Lagoon across a wider swath of Area 1.

At 2080 (**Figure F-12**), with three feet of sea-level rise, inundation from the Ormond Lagoon Waterway spills out across Area 3a, re-creating lagoonal conditions which would be displaced at the original Ormond Lagoon by beach transgression. In Area 4, the landward transgression of inundation progresses, deepening the water in the southern swale and activating the next swale north with permanent inundation. In Area 5, the proposed embankment will slow the encroachment of inundation in the northeast part of the site as compared to the No Project scenario.

At 2100 (**Figure F-13**), with almost five feet of sea-level rise, the majority of the site is inundated, with slight variation in the inundation's distribution due to this alternative's proposed grading.

1.2.3 Alternative 3

Alternative 3 proposes more extensive grading to re-align the Ormond Lagoon Waterway, excavate a lagoon at its downstream end, and create wetland depressions in Area 4 and Area 5. These proposed actions result in the initial habitat conditions shown in **Figure F-14**.

At 2060 (**Figure F-15**), with two feet of sea-level rise, all of major grading areas become inundated. Conditions are similar to Alternative 2, except the more extensive excavation increases the inundated extents.

At 2080 (**Figure F-16**), with three feet of sea-level rise, the rising inundation spills out from the excavated areas onto adjacent properties. The combination of the grading and increased connectivity yields more contiguous wetlands across Area 3a and Area 4. Inundation in Area 5 is largest for this alternative.

At 2100 (**Figure F-17**), with almost five feet of sea-level rise, the majority of the site is inundated, with slight variation in the inundation's distribution due to this alternative's proposed grading.

Discussion

SLAMM's predictions of habitat evolution are based on simplifying assumptions and only consider ground surface elevations, sea-level rise, representative water levels, and proximity to preceding habitats. Habitat evolution depends on a broader range of physical processes, including watershed hydrology, evapotranspiration, ground surface slope, groundwater, soils, and salinity. There is not enough available data to fully characterize the project area and watershed conditions that determine these processes. Even if sufficient existing data were available, full deterministic modeling of the processes over nearly a century is not feasible. In spite of these limitations, SLAMM's general trends in projected habitat evolution provide an indication of future site condition for the designated sea-level rise thresholds, even if the thresholds do not arrive exactly at the assumed decade.

Ground survey transects suggest LiDAR elevations may be high by a half a foot to a foot (e.g., southern part of Area 3a, central portion of Area 6) due to the LiDAR observing the vegetation canopy rather than the ground surface. In these areas, inundation would occur sooner than predicted by SLAMM.

The mapped open water areas are based on minimum observed elevations within the project site in 2017. During extended droughts, evaporation and limited watershed could lower these water levels. However, with anticipated wet season precipitation, inflow from the watershed, increased groundwater, and wave overwash, higher water levels and greater extent of inundated area are likely for portions of non-drought years.

Since the focus of this study is restoration, SLAMM was configured so as to not map inundation in the developed areas west and north of Areas 1, 2, 3a, and 4, as well as the power plant. These developed areas are vulnerable to coastal flood and erosion hazards, as evaluated in ESA PWA (2013) and in the County's hazard assessment. As sea-level rise exceeds about two feet, coastal flooding hazard begins to impinge upon developed areas at the southern end of Perkins Road. With five feet of sea-level rise, coastal flood risk extends further northward, extending across McWane Boulevard. As flood management planning for these areas progresses, it can be coordinated with the restoration project.

As the site, its environs, and climate evolve, adaptive management should be supplemented with hydrologic, hydraulic, and geomorphic modeling informed with additional data.

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Warren Pinnacle Consulting, Inc. (WPC). 2016. SLAMM 6.7 Technical Documentation Sea Level Affecting Marshes Model, Version 6.7 beta.

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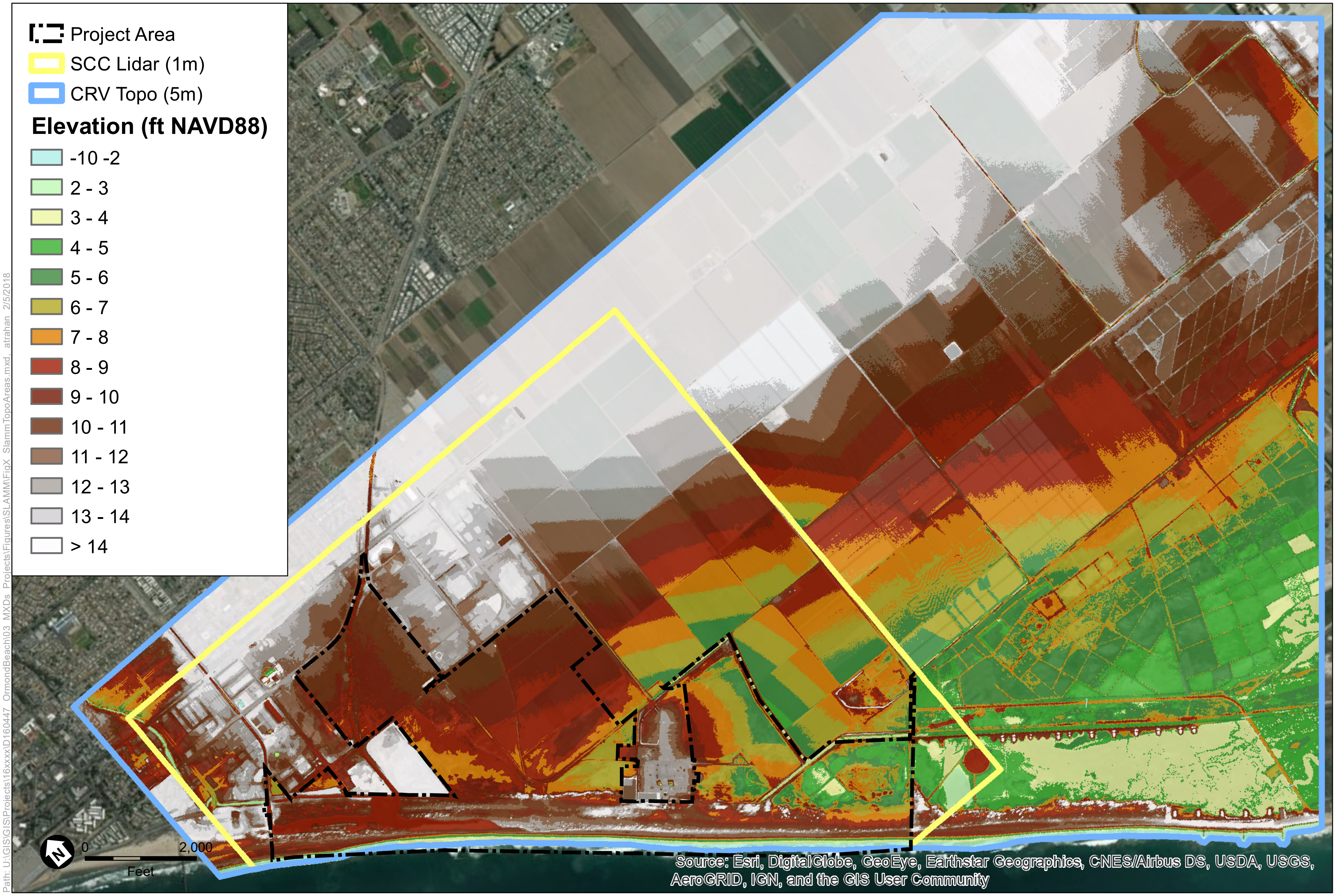
Figure F-16. Alternative 3, 2080, +3.4 ft SLR
Figure F-17. Alternative 3, 2100, +4.8 ft SLR



SOURCE: SCC 2011, ESA PWA 2014, ESA 2017

Ormond Beach Restoration and Public Access Plan

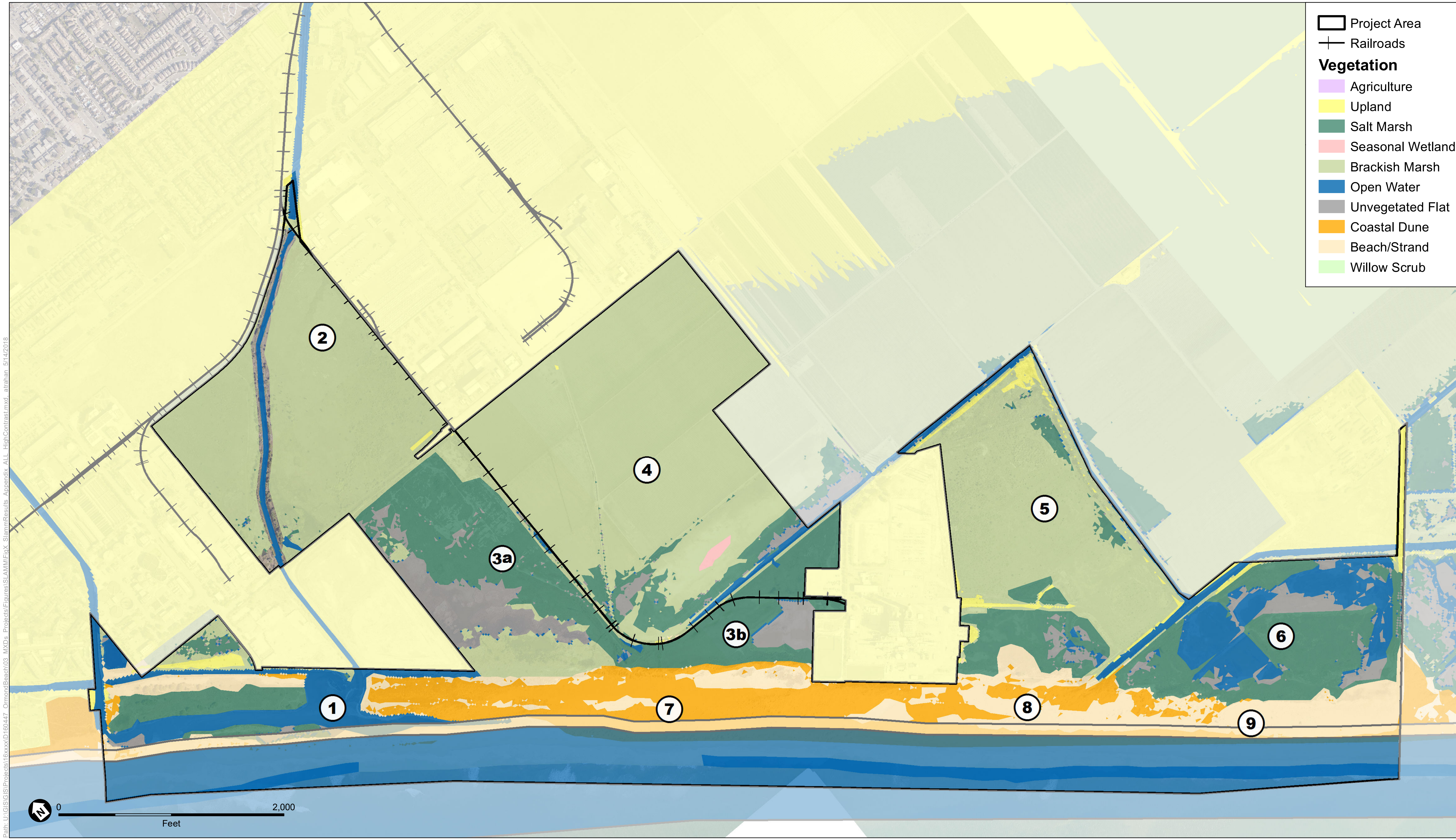
Figure F-1
Site Topography and Data Sources

ESA

SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-2
SLAMM Results wtih Beach Transgression
Existing Conditions, Current-Day



SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-3
SLAMM Results wtih Beach Transgression
Existing Conditions, 2060 +2.1 ft SLR

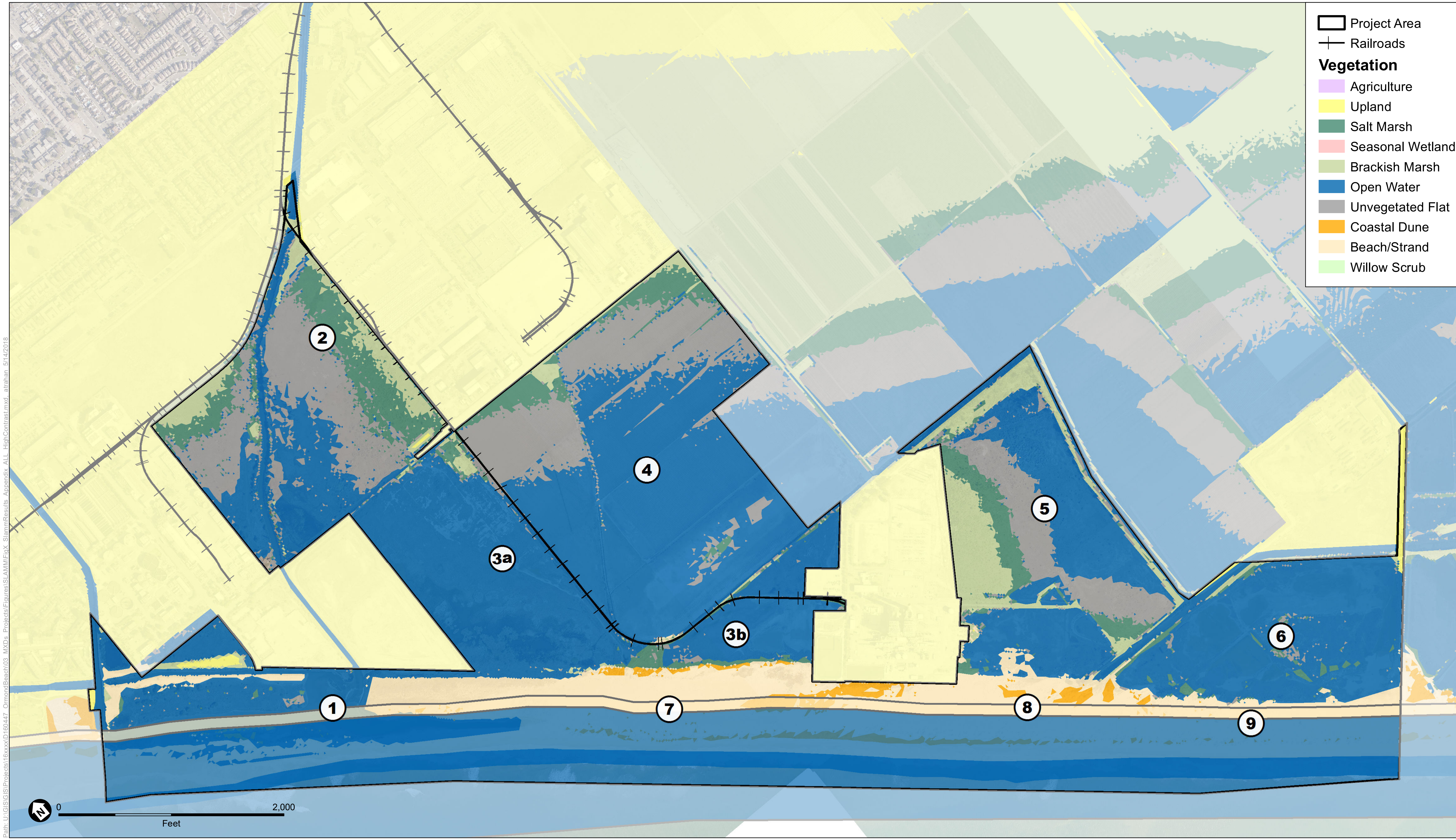
ESA

SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-4
SLAMM Results wtih Beach Transgression
Existing Conditions, 2080 +3.4 ft SLR

ESA

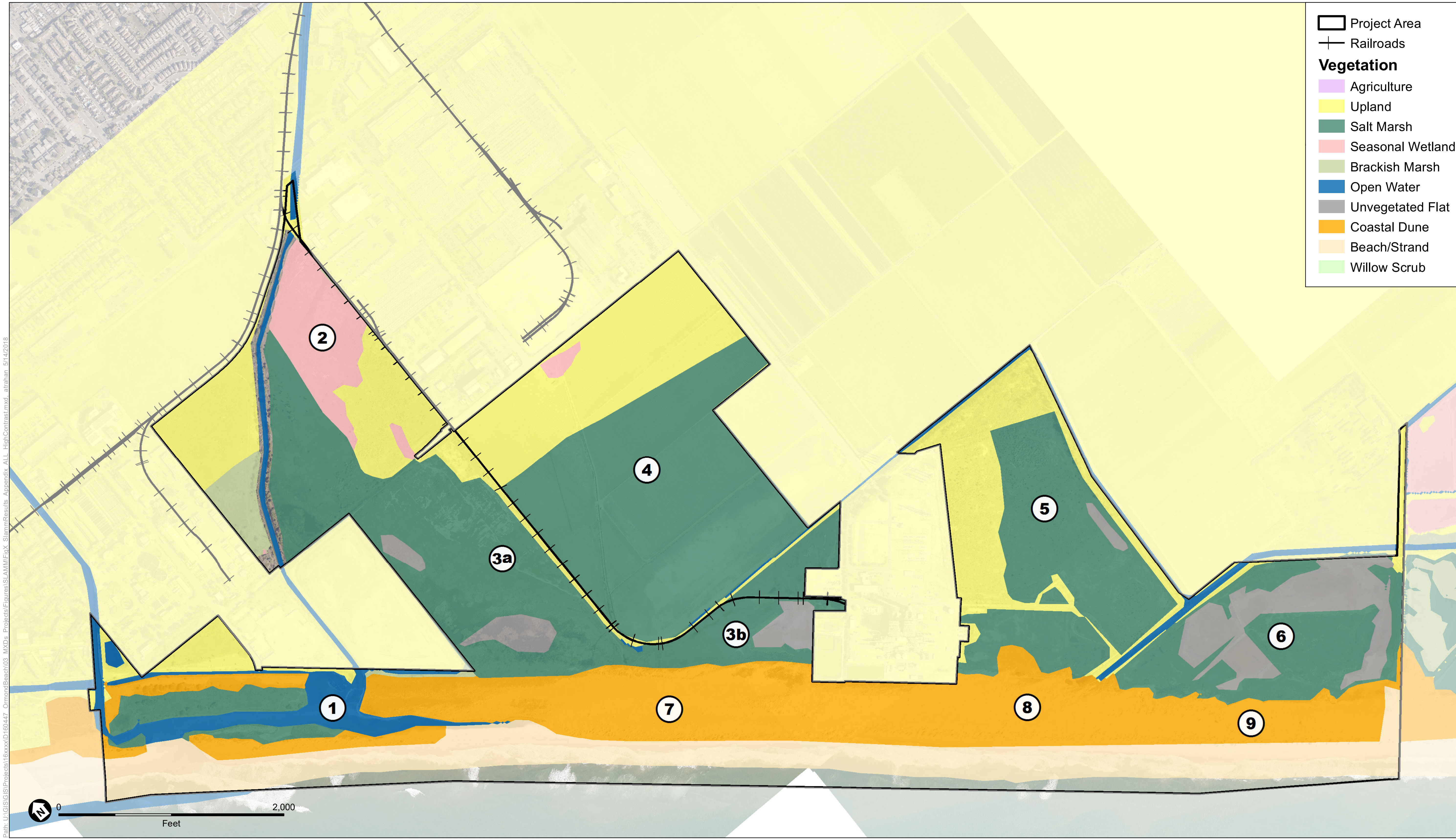


SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-5
SLAMM Results wtih Beach Transgression
Existing Conditions, 2100 +4.8 ft SLR

ESA

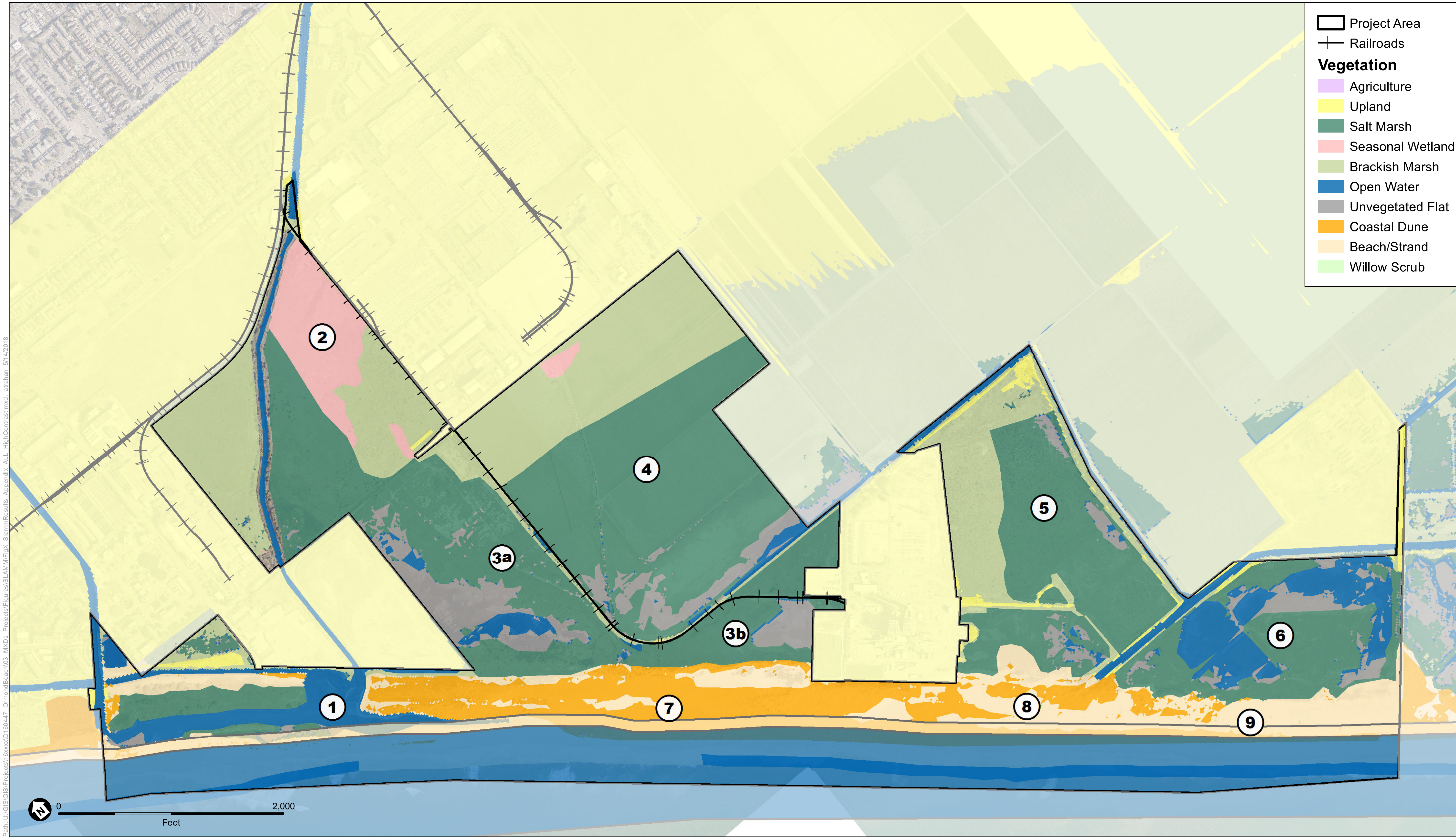


SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-6
SLAMM Results wtih Beach Transgression
Alternative 1, Current-Day

ESA



SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

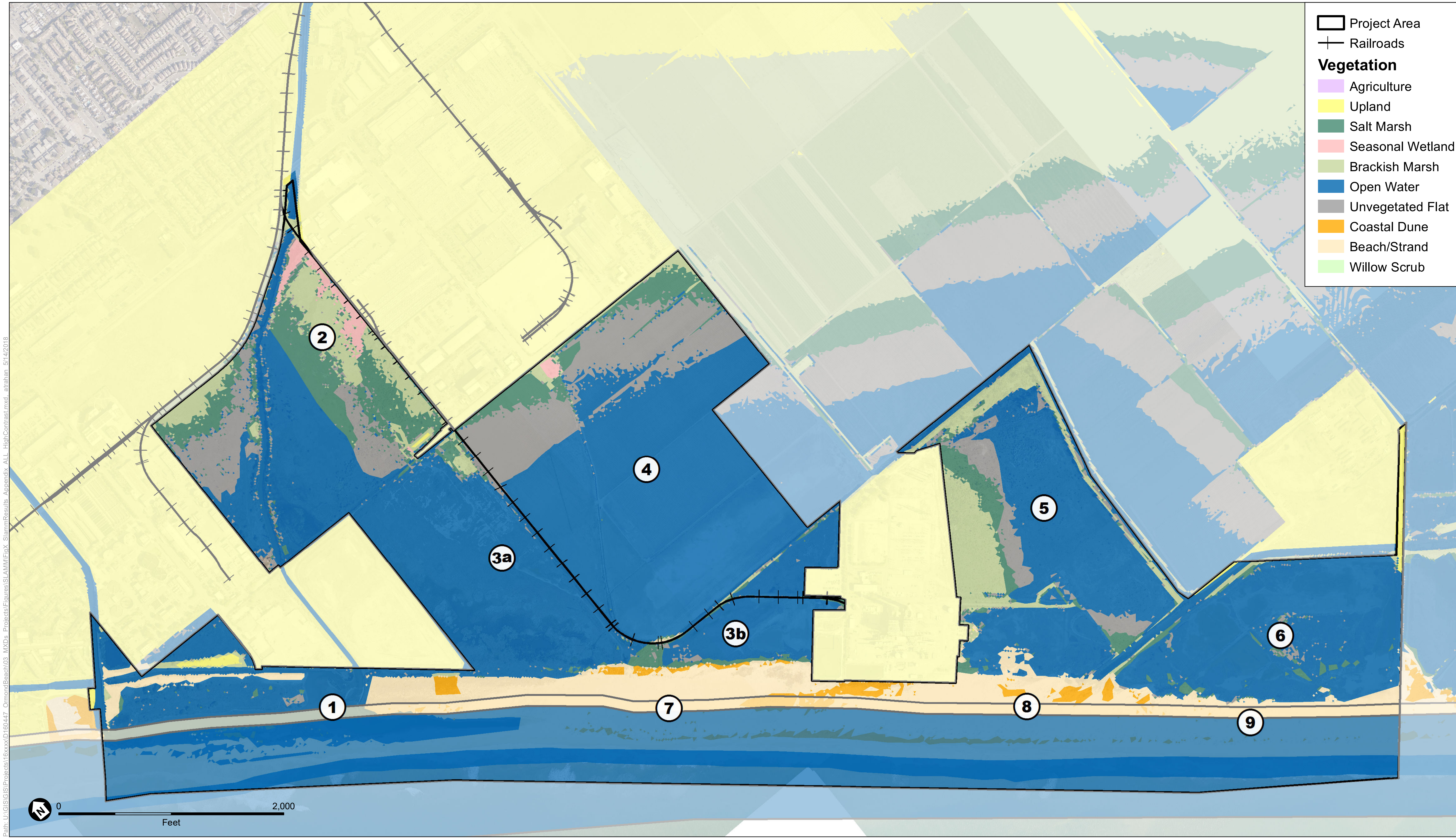
Figure F-7
SLAMM Results wtih Beach Transgression
Alternative 1, 2060 +2.1 ft SLR

ESA

SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-8
SLAMM Results wtih Beach Transgression
Alternative 1, 2080 +3.4 ft SLR

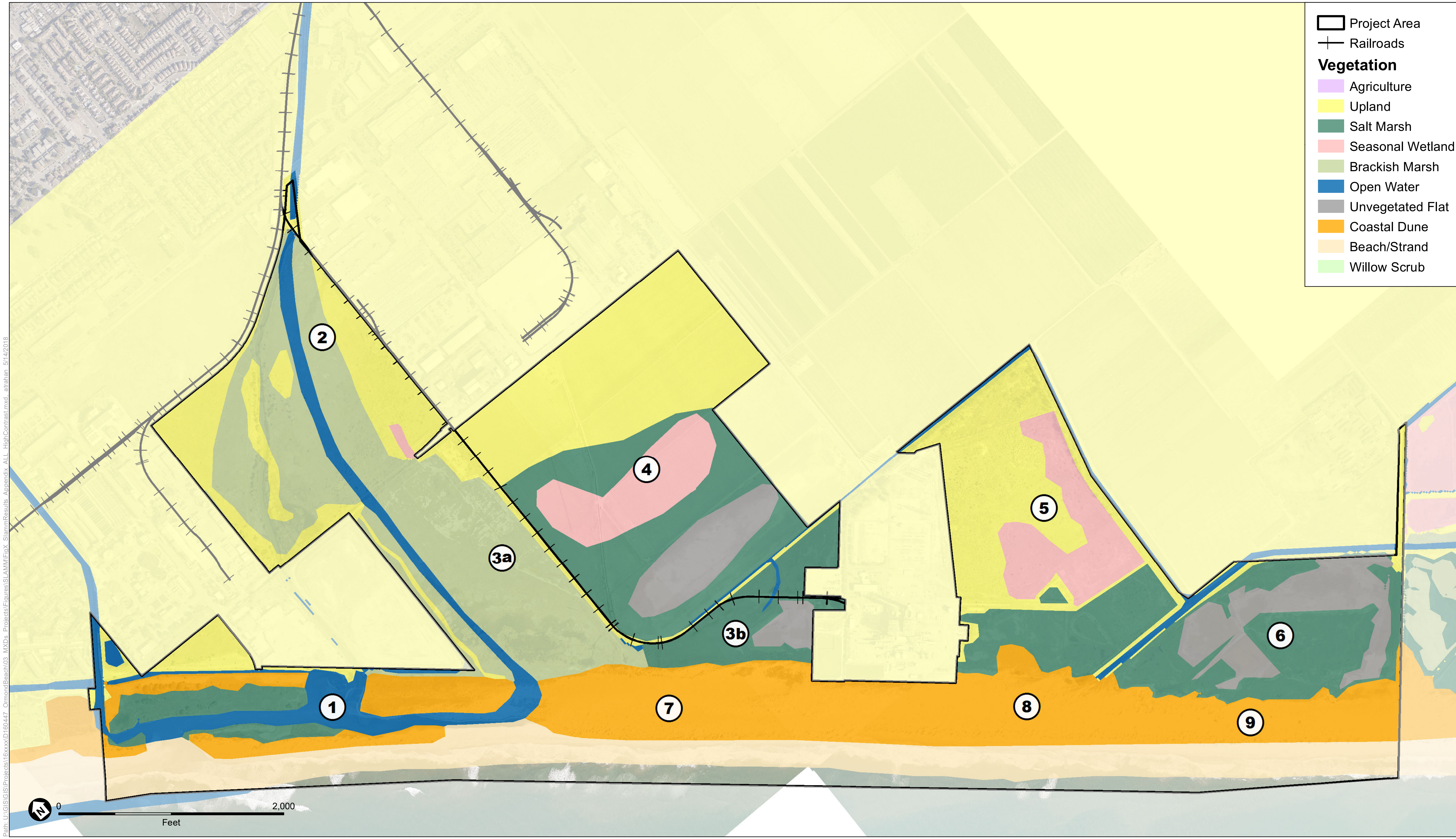


SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-9
SLAMM Results wtih Beach Transgression
Alternative 1, 2100 +4.8 ft SLR

ESA



SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-10
SLAMM Results wtih Beach Transgression
Alternative 2, Current-Day

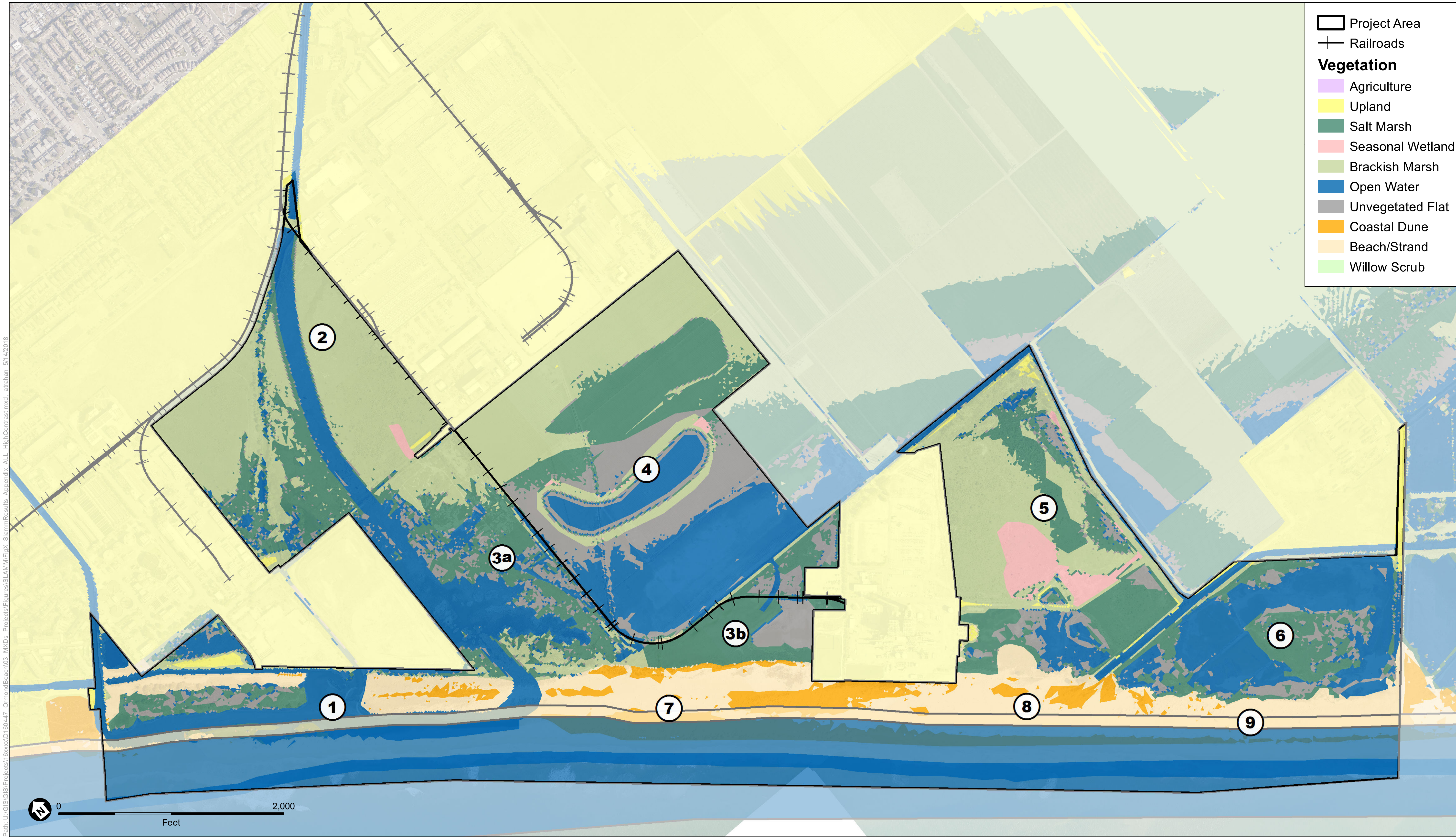
ESA

SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-11
SLAMM Results wtih Beach Transgression
Alternative 2, 2060 +2.1 ft SLR

ESA

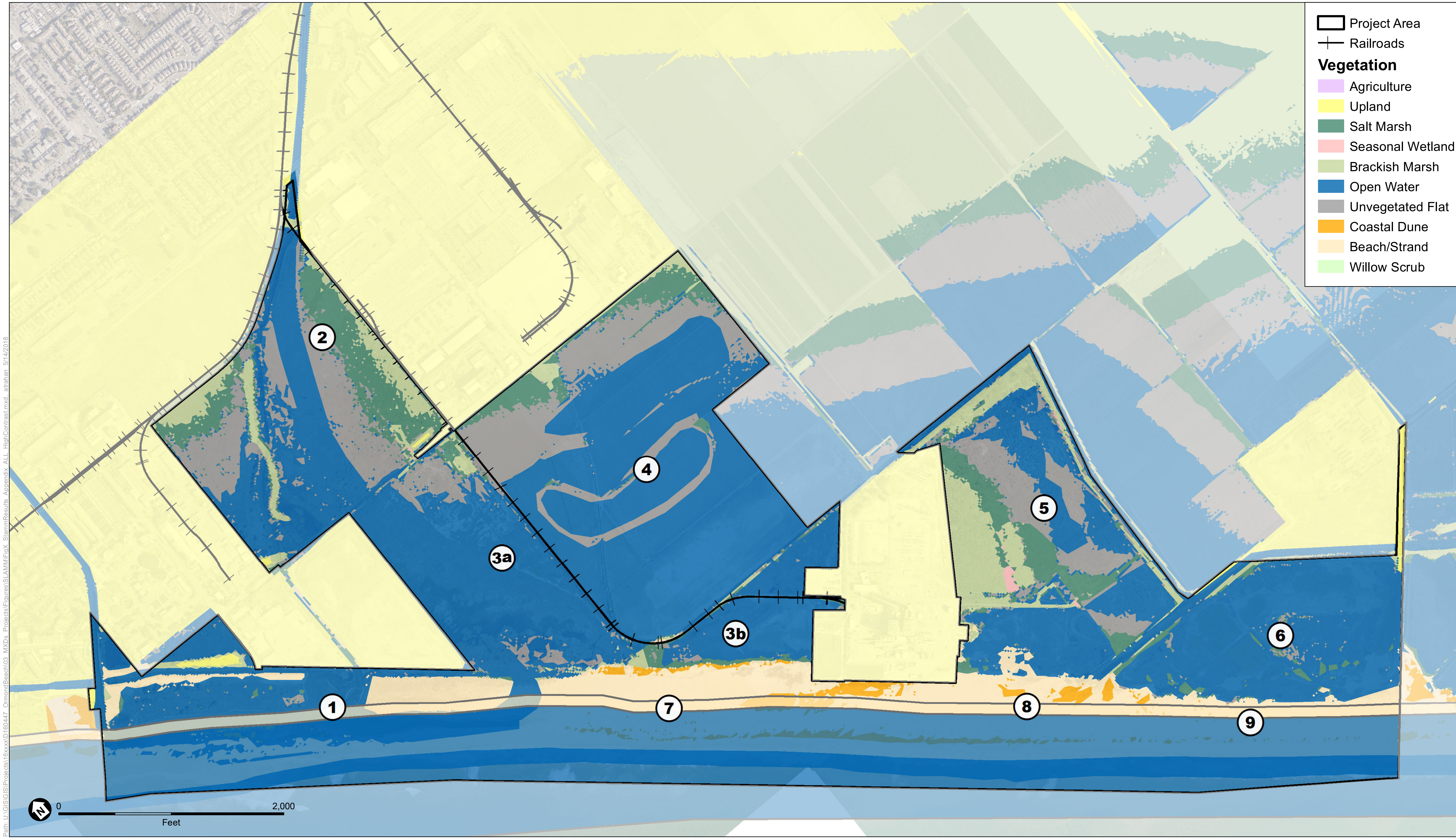


SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-12
SLAMM Results wtih Beach Transgression
Alternative 2, 2080 +3.4 ft SLR

ESA



SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-13
SLAMM Results wtih Beach Transgression
Alternative 2, 2100 +4.8 ft SLR

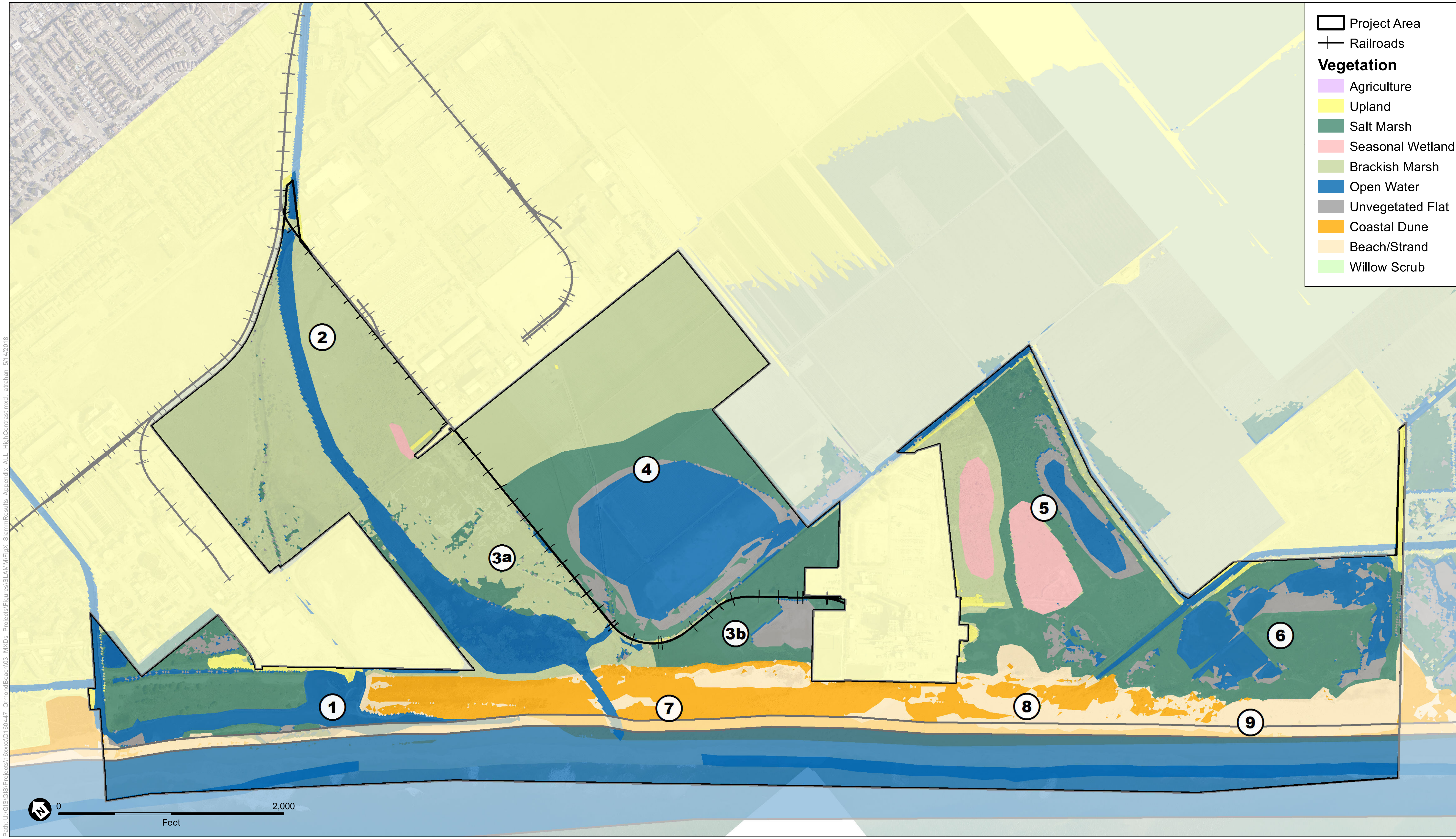
ESA

SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-14
SLAMM Results wtih Beach Transgression
Alternative 3, Current-Day

ESA



SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-15
SLAMM Results wtih Beach Transgression
Alternative 3, 2060 +2.1 ft SLR

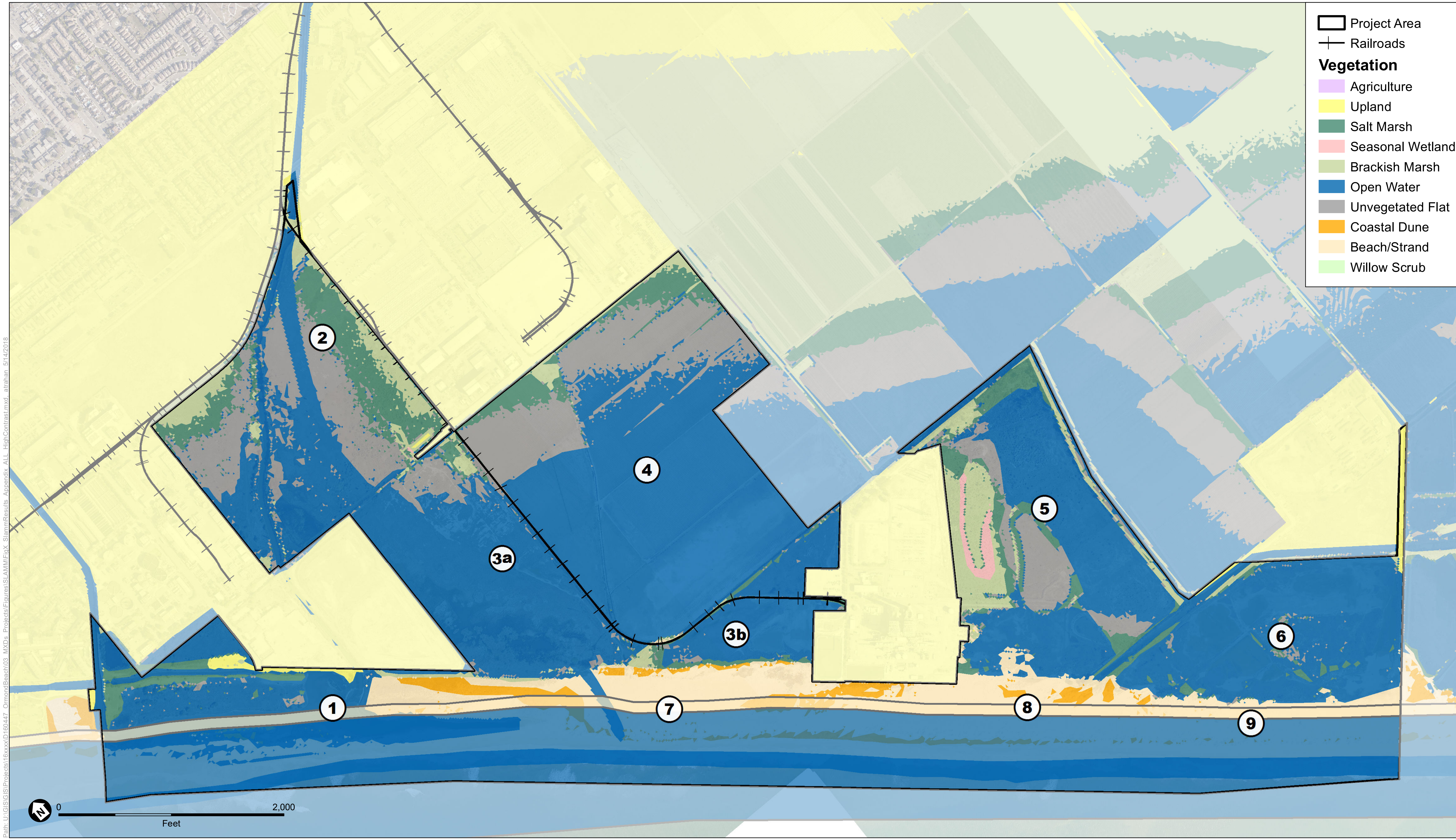
ESA

SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-16
SLAMM Results wtih Beach Transgression
Alternative 3, 2080 +3.4 ft SLR

ESA



SOURCE: ESA (2017), CA Coastal Conservancy LiDAR (2011)

Ormond Beach Restoration and Public Access Project

Figure F-17
SLAMM Results wtih Beach Transgression
Alternative 3, 2100 +4.8 ft SLR

ESA

Appendix G
Preliminary Design Drawings

PRELIMINARY SUBMITTAL
NOT FOR CONSTRUCTION

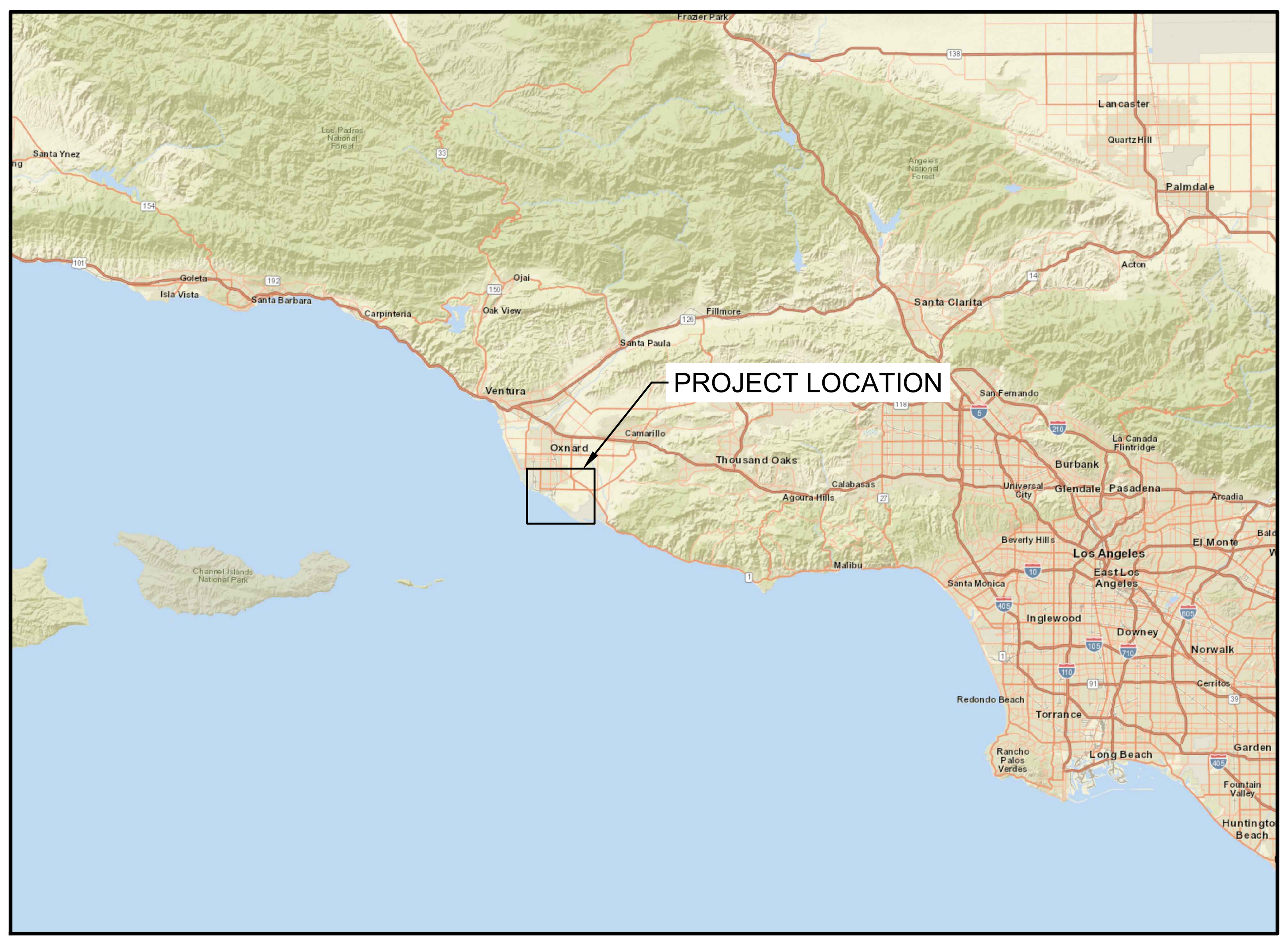
ORMOND BEACH RESTORATION AND PUBLIC ACCESS PROJECT

CALIFORNIA STATE COASTAL CONSERVANCY, THE NATURE CONSERVANCY AND CITY OF OXNARD

Coastal Conservancy

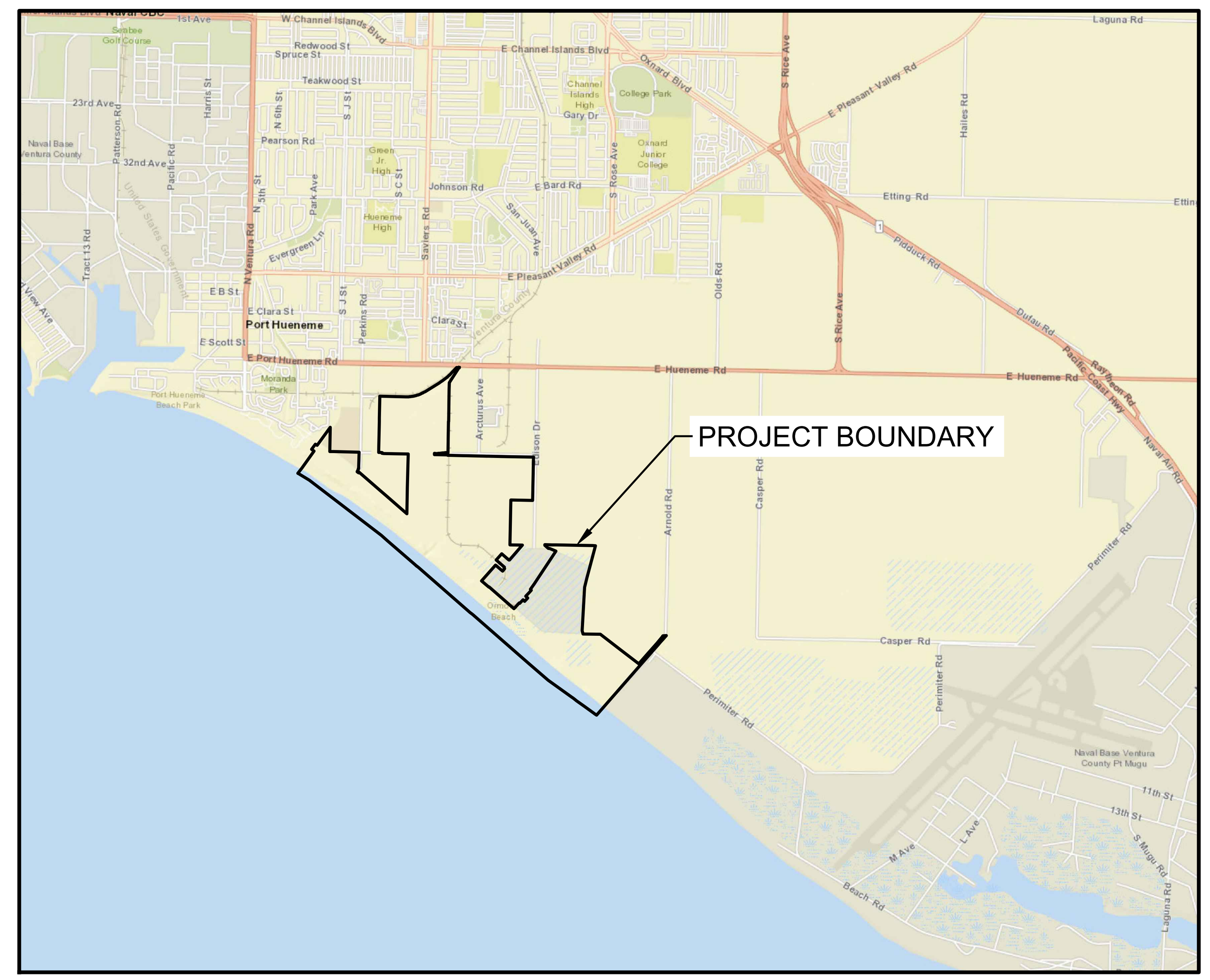
The Nature Conservancy
Protecting nature. Preserving life.

CITY OF OXNARD CALIFORNIA



VICINITY MAP

NOT TO SCALE



LOCATION MAP

NOT TO SCALE

SHEET LIST TABLE

Sheet Number	Sheet ID	Sheet Title
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2	G-2	NOTES, ABBREVIATIONS & LEGEND
3	G-3	EXISTING CONDITIONS
4	C-1	PROJECT OVERVIEW
5	C-2	GRADING PLAN - WESTERN
6	C-3	GRADING PLAN - CENTRAL
7	C-4	GRADING PLAN - EASTERN
8	C-5	GRADING SECTIONS
9	L-1	PLANTING & ACCESS PLAN - WESTERN
10	L-2	PLANTING & ACCESS PLAN - CENTRAL
11	L-3	PLANTING & ACCESS PLAN - EASTERN
12	L-4	PLANTING LISTS
13	L-5	TRAILS DETAILS

DATUMS

VERTICAL: NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88)
UNITS: FEET

HORIZONTAL: NORTH AMERICAN DATUM OF 1983
PROJECTION: CALIFORNIA STATE PLANE ZONE 5 FEET

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TRUE NATURE
Coastal Restoration Consultants

PROJECT NAME: ORMOND BEACH RESTORATION AND PUBLIC ACCESS PROJECT
OXNARD, CA

REVISIONS

#	DATE	DESCRIPTION

DESIGNED	RB, KT, EPK
DRAWN	JJ, AI, IS
CHECKED	AB, RB, EPK
IN CHARGE	ROBERT T. BATTALIO PE C41765
PROJECT NUMBER	D160447.00
ISSUE DATE	MM/DD/YY

SCALE IS AS SHOWN WHEN PLOTTED TO FULL SIZE (22"x34")

PHASE
PRELIM CONSTRUCTION DOCUMENTATION

SHEET TITLE
TITLE SHEET

SHEET NUMBER
G-1

SHEET 1 OF 13

FILE: K:\projects_2016\D160447.00 - Ormond Beach Wetlands Restoration\10 CAD\Dwgs\TITLE_NOTE-ABRV-LGND.dwg PLOT DATE: 8/17/2020 1:42:28 PM PLOTTED BY: AMBER INGGS

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ABBREVIATIONS

APPROX	APPROXIMATE
B	BEACH/STRAND
BM	BRACKISH MARSH
BI	BIOSWALE
D	COASTAL DUNES
DSW	DUNE SWALE WETLAND
EL	ELEVATION
EX	EXISTING
EG	EXISTING GRADE
FG	FINISHED GRADE
MHHW	MEAN HIGHER HIGH WATER
MLLW	MEAN LOWER LOW WATER
N	NEW
NAD83	NORTH AMERICAN DATUM OF 1983
NAVD88	NORTH AMERICAN VERTICAL DATUM OF 1988
NBVC	NAVAL BASE VENTURA COUNTY
OBRAP	ORMOND BEACH RESTORATION AND PUBLIC ACCESS PROJECT
ODD	OXNARD DRAINAGE DITCH
OLW	ORMOND LAGOON WATERWAY
PIP	PROTECT IN PLACE
SM	SALT MARSH
SP	SALT PANNE
SW	SEASONAL WETLAND
TYP	TYPICAL
U	UPLANDS
WSE	WATER SURFACE ELEVATION
WT	WETLAND-UPLAND TRANSITION

LEGEND

	EXISTING	PROPOSED
WORK LIMIT	N/A	
PROPERTY LIMIT		N/A
FENCE	X	X
RAILROAD TRACKS		N/A
MATCH LINE	N/A	
GRADE BREAK	N/A	
MAJOR CONTOUR	5	5
MINOR CONTOUR	4	4
TOP OF BANK	N/A	
TOE OF BANK	N/A	
FLOWLINE		
GROUND (SECTION/PROFILE)		
OVERHEAD POWER LINE	OH	N/A
POTABLE WATER LINE	W	N/A
SANITARY SEWER LINE	SS	N/A
UNDERGROUND OIL LINE	U	N/A
EXCAVATION (SECTION/PROFILE)	N/A	
FILL (SECTION/PROFILE)	N/A	
BRACKISH MARSH REVEGETATION	N/A	
BRACKISH MARSH ENHANCEMENT	N/A	
SALT MARSH REVEGETATION	N/A	
SALT MARSH ENHANCEMENT	N/A	
COASTAL SAGE SCRUB REVEGETATION	N/A	
COASTAL SAGE SCRUB ENHANCEMENT	N/A	
COASTAL DUNE ENHANCEMENT	N/A	
SEASONAL WETLAND REVEGETATION	N/A	
WETLAND-UPLAND TRANSITION REVEGETATION	N/A	
WETLAND-UPLAND TRANSITION ENHANCEMENT	N/A	
BIOSWALE	N/A	
OPEN WATER	N/A	
NEW SALT PANNE	N/A	
EXISTING SALT PANNE	N/A	
NATIVE ORNAMENTAL	N/A	
BEACH/STRAND	N/A	
PRIMARY TRAIL	N/A	
SECONDARY TRAIL	N/A	
TERTIARY TRAIL	N/A	
BEACH TRAIL	N/A	
BOARDWALK	N/A	
BRIDGE	N/A	
BIRD FENCE - EXISTING	N/A	
BIRD FENCE - PROPOSED	N/A	
ACCESS NODE	N/A	A
OVERLOOK PLATFORM	N/A	
CONSTRUCTION FENCE	N/A	
STAGING AREA	N/A	

LEGEND (CONT.)

A / C-X:
- INDICATES SECTION NUMBER
- VIEW DIRECTION
- SHEET NUMBER ON WHICH SECTION APPEARS

1 / C-X:
- INDICATES DETAIL NUMBER
- SHEET NUMBER ON WHICH DETAIL APPEARS

TITLE DATUM

OCEANIC TIDAL DATUMS AT SANTA MONICA AND SANTA BARBARA

TIDAL DATUM	SANTA MONICA, CA (NOAA #9410840) FT NAVD88	SANTA BARBARA (NOAA #9411340) FT NAVD88
MAXIMUM OBSERVED	8.31[1]	7.54[2]
MEAN HIGHER HIGH WATER (MHHW)	5.24	5.31
MEAN HIGH WATER (MHW)	4.50	4.55
MEAN TIDE LEVEL (MTL)	2.62	2.72
MEAN SEA LEVEL (MSL)	2.59	2.70
MEAN LOW WATER (MLW)	0.73	0.89
MEAN LOWER LOW WATER (MLLW)	-0.20	-0.09

1. OBSERVED 11/30/1982 7:54
2. OBSERVED 12/13/2012 16:36

GENERAL NOTES

1. TOPOGRAPHIC CONTOURS BASED ON CA COASTAL CONSERVANCY LIDAR (2011) AUGMENTED BY LAND SURVEY BY ESA (2017).
2. PROPERTY LINE LOCATIONS ARE APPROXIMATE, EASEMENTS NOT SHOWN.
3. UTILITY LOCATIONS ARE APPROXIMATE AND ALL UTILITIES ARE NOT SHOWN.
4. TIDAL DATUMS FOR NOAA 1983–2001 EPOCH

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OXNARD, CA

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PHASE
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SHEET TITLE
NOTES, ABBREVIATIONS & LEGEND

SHEET NUMBER
G-2

FILE: K:\projects_2016\D160447.00 - Ormond Beach Wetlands Restoration\10 CAD\Dwgs\TITLE_NOTE-ABRV-LGND.dwg PLOT DATE: 3/23/2021 2:31:38 PM PLOTTED BY: AMBER INGGS

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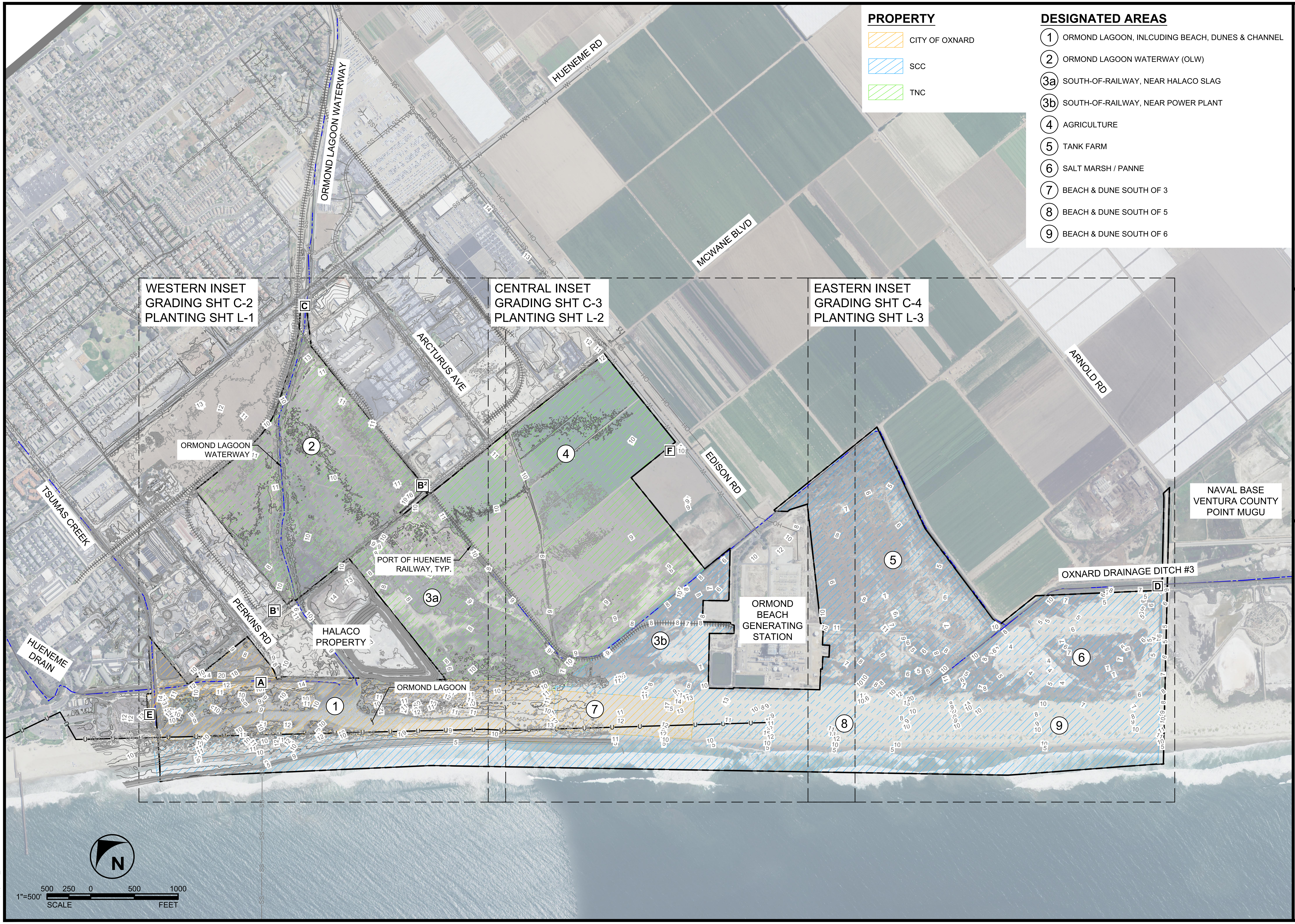

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PHASE
PRELIM CONSTRUCTION DOCUMENTATION

SHEET TITLE

EXISTING CONDITIONS

SHEET NUMBER

G-3

SHEET 3 OF 13

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FILE: \\sfo-file01\esapwa\Data\projects_2016\D160447.00 - Ormond Beach Wetlands Restoration\10 CAD\Dwgs\OVERVIEW.dwg PLOT DATE: 5/21/2021 2:52:02 PM PLOTTED BY: AMBER INGGS

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PHASE
PRELIM CONSTRUCTION DOCUMENTATION

SHEET TITLE

PROJECT OVERVIEW

SHEET NUMBER
C-1

SHEET 4 OF 13

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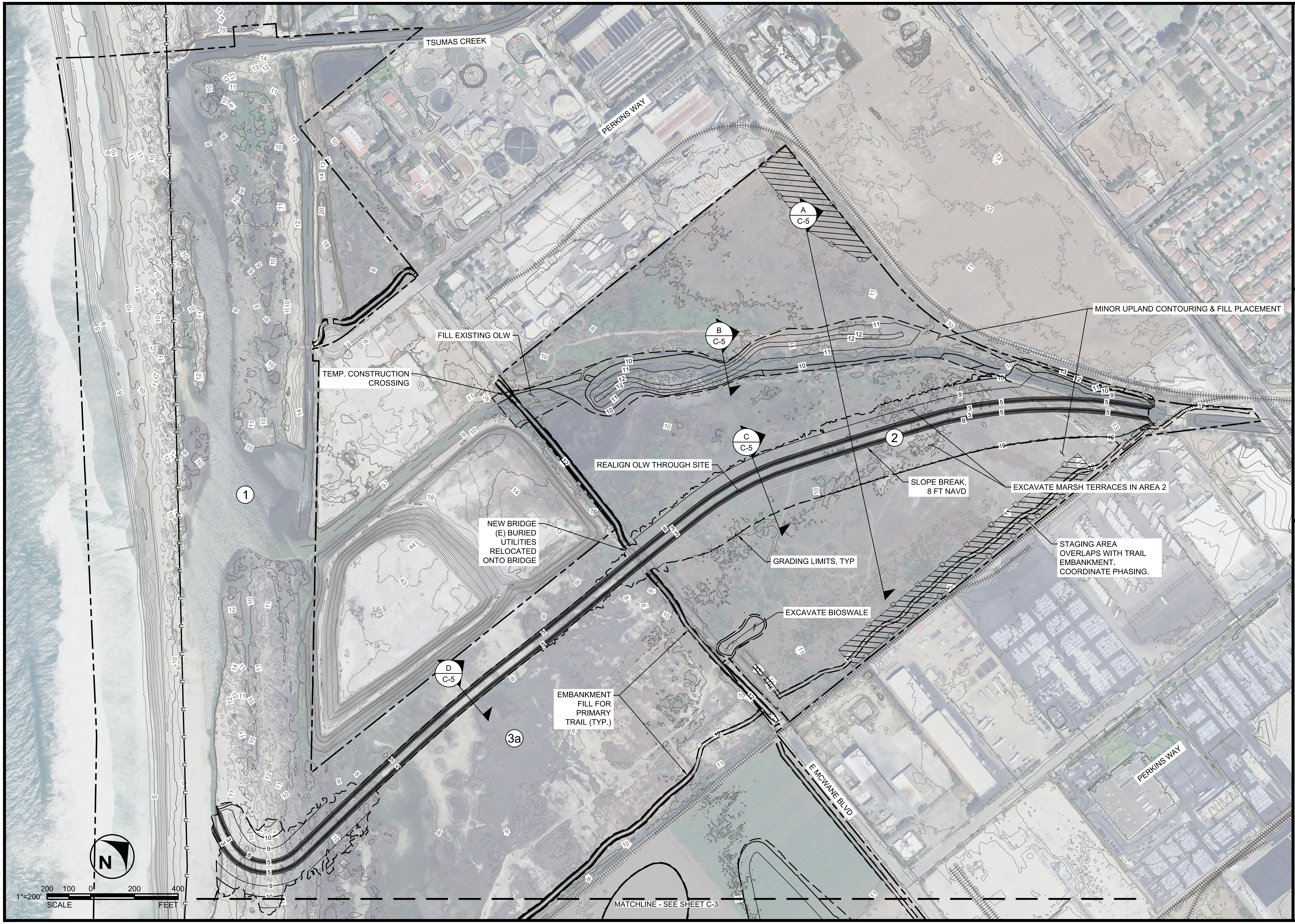

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PHASE
PRELIM CONSTRUCTION DOCUMENTATION

SHEET TITLE
GRADING PLAN - WESTERN

SHEET NUMBER
C-2

SHEET 5 OF 13

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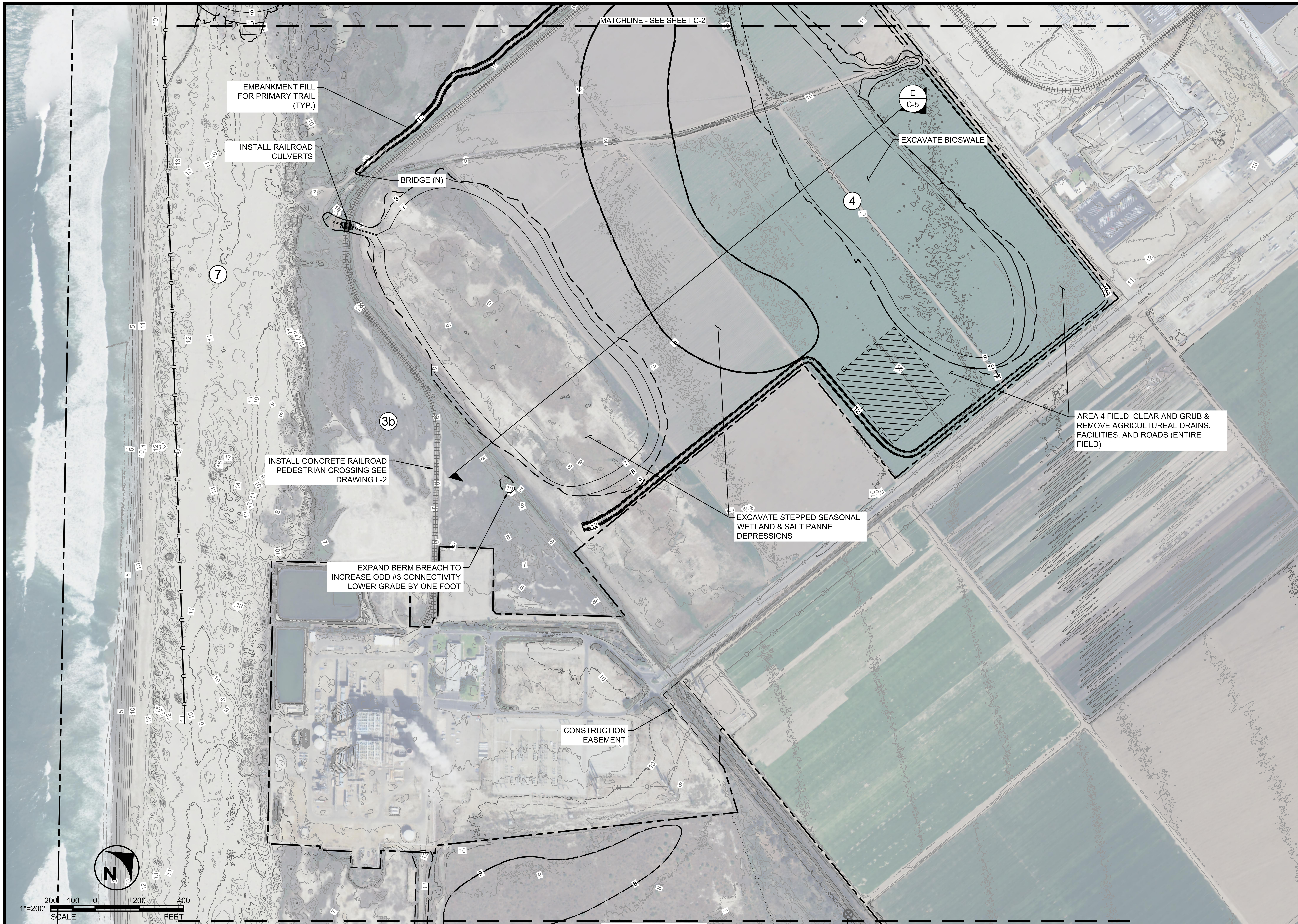

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PHASE

PRELIM CONSTRUCTION DOCUMENTATION

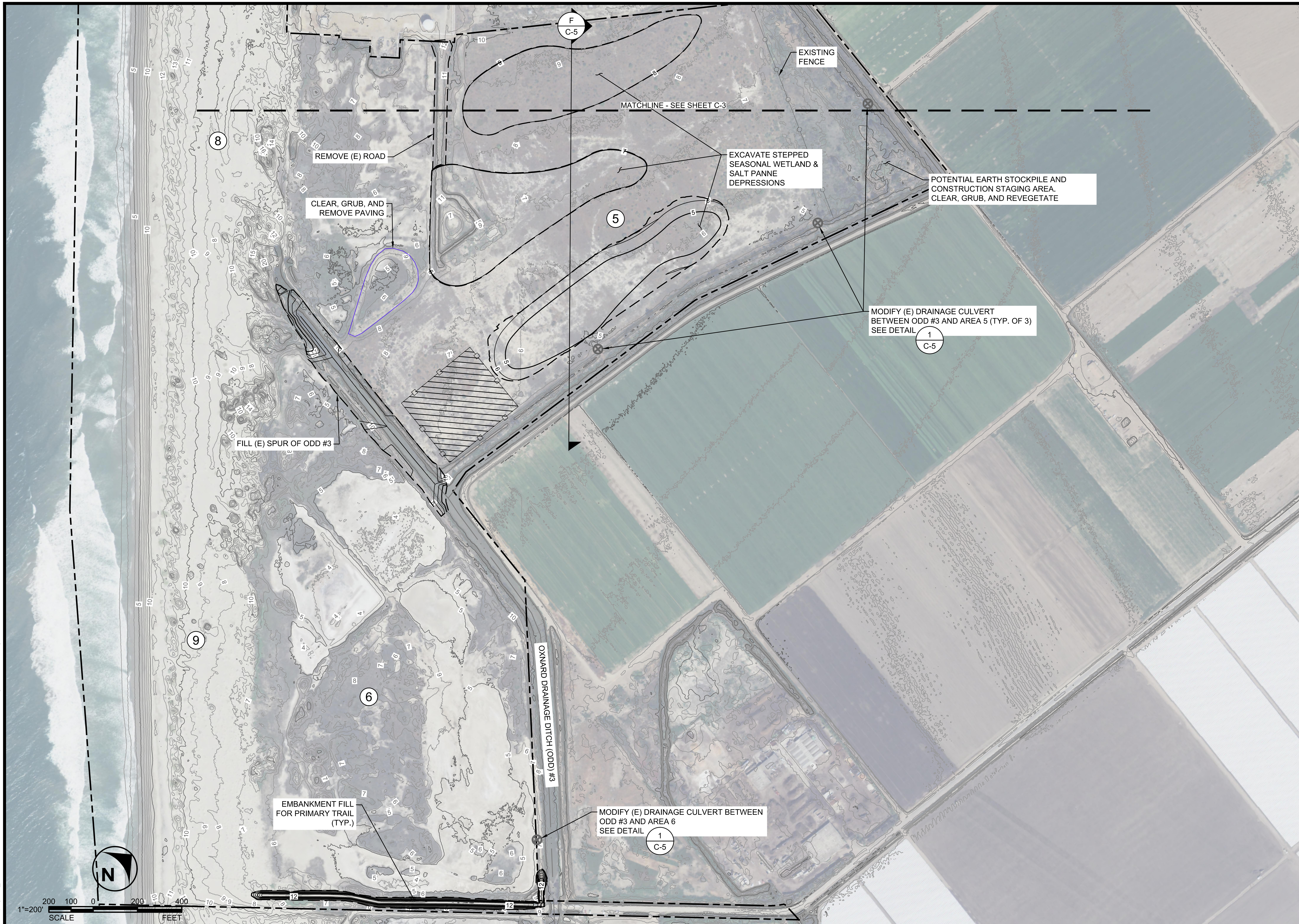
SHEET TITLE

GRADING PLAN - CENTRAL

SHEET NUMBER

C-3

SHEET 6 OF 13



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PHASE
PRELIM CONSTRUCTION DOCUMENTATION

SHEET TITLE
GRADING PLAN - EASTERN

SHEET NUMBER
C-4

FILE: K:\projects_2016\D160447.00 - Ormond Beach Wetlands Restoration\10 CAD\Dwgs\GRADING.dwg PLOT DATE: 3/23/2021 2:12:45 PM PLOTTED BY: AMBER INGGS

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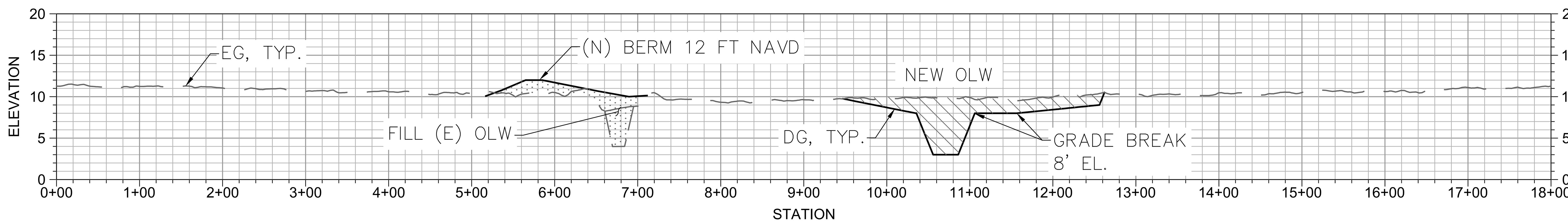
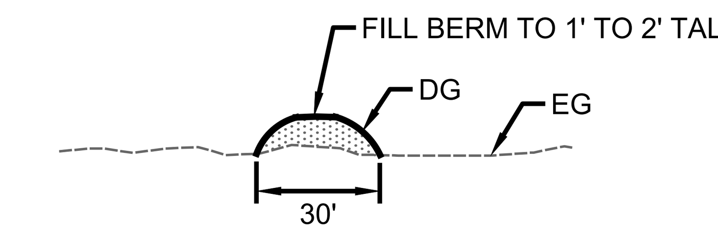
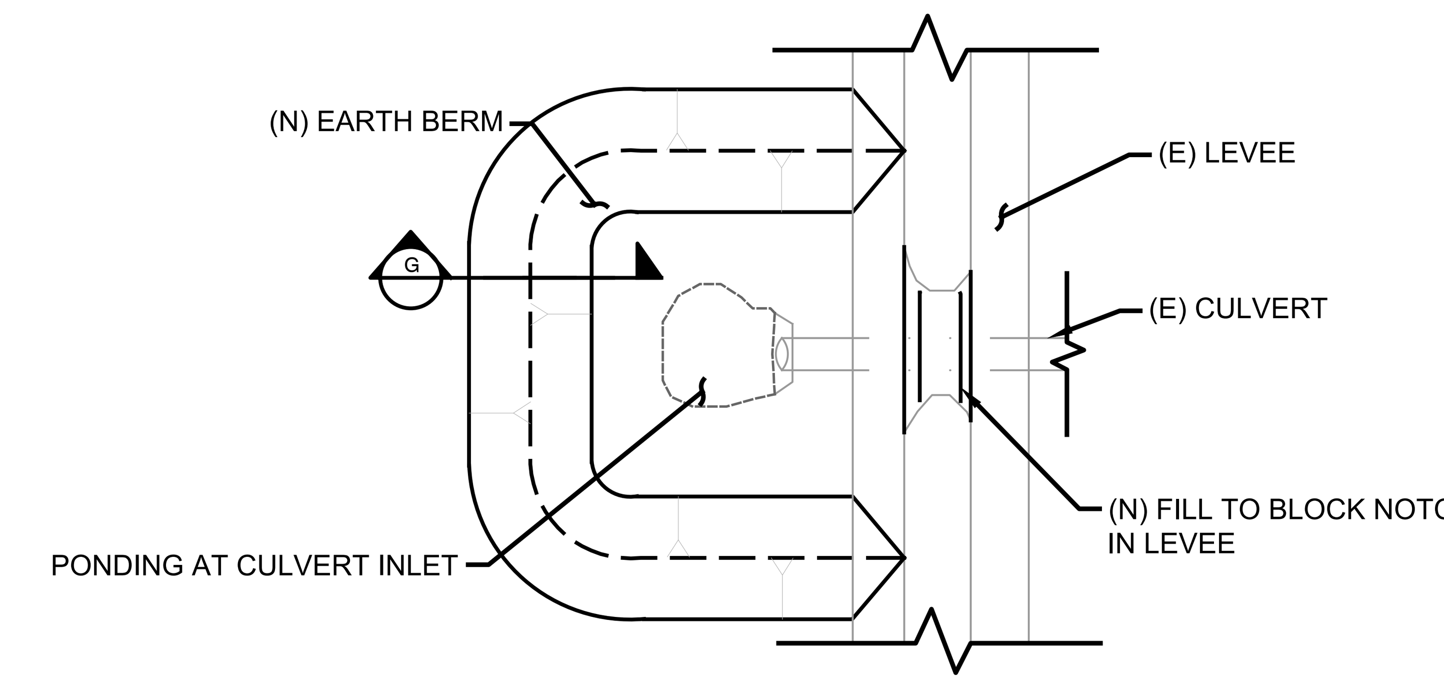


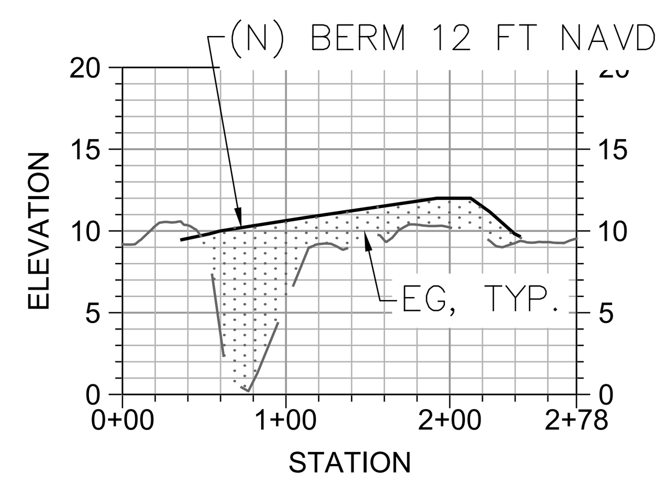
A C-2 AREA 2 - OLW REALIGNMENT
SECTION
SCALE:
H: 1" = 100'
V: 1" = 10'



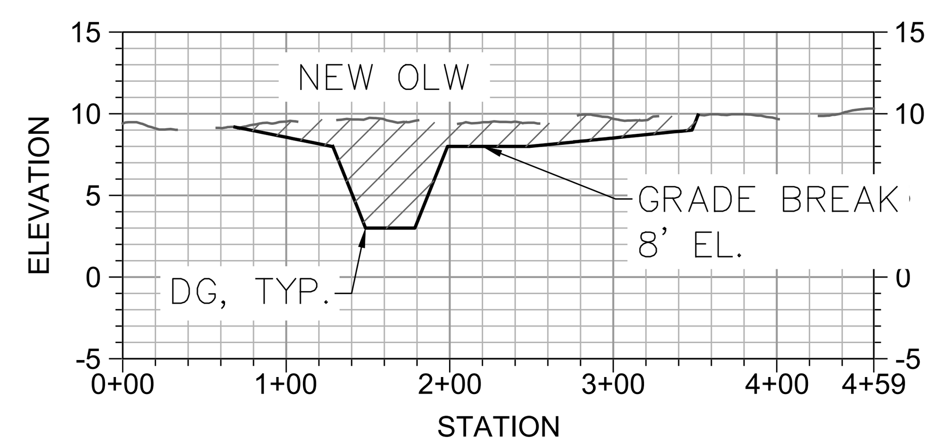
G - DRAINAGE CONTROL BERM
TYPICAL SECTION
SCALE:
H: 1" = 40'
V: 1" = 8'



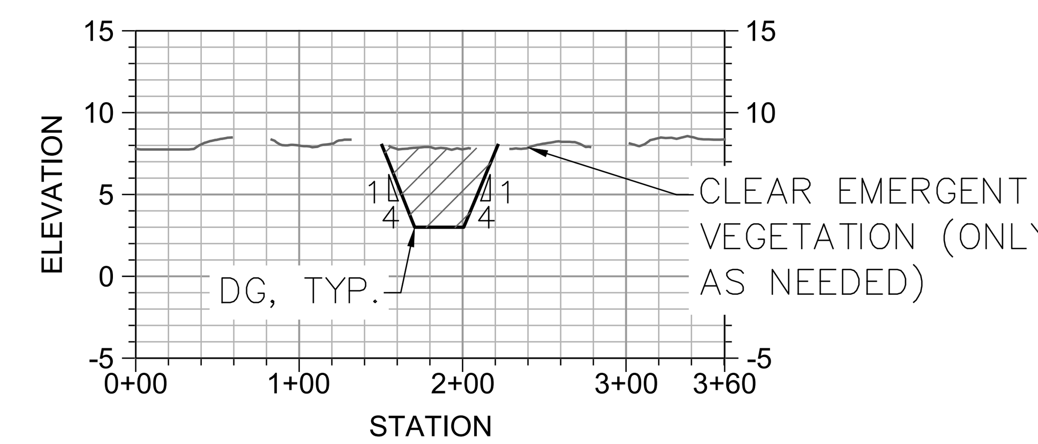
1 C-4 MODIFICATIONS AT ODD #3
PLAN
SCALE: 1" = 40'



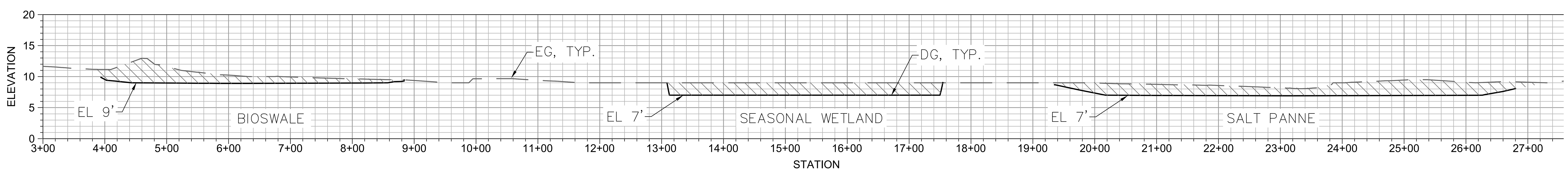
B C-2 AREA 2 - OLW WATERWAY FILL
SECTION
SCALE:
H: 1" = 100'
v: 1" = 10'



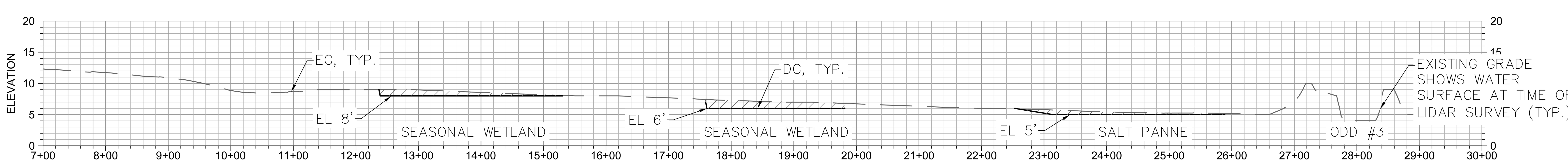
C C-2 AREA 2 - NEW OLW
SECTION
SCALE:
H: 1" = 100'
v: 1" = 10'



D C-2 AREA 3A - (N) OLW CHANNEL
TYPICAL SECTION
SCALE:
H: 1" = 100'
V: 1" = 10'



E C-3 AREA 4 - DEPRESSIONS
SECTION
SCALE:
H: 1" = 100'
V: 1" = 10'



F C-4 AREA 5 - DEPRESSIONS
SECTION
SCALE:
H: 1" = 100'
v: 1" = 10'

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CONSULTANT

PROJECT NAME:
ORMOND BEACH
RESTORATION
AND PUBLIC ACCESS
PROJECT
OXNARD, CA

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IN CHARGE	RS

PROJECT NUMBER D160447.00

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PHASE
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SHEET TITLE
GRADING SECTIONS

SHEET NUMBER
C-5

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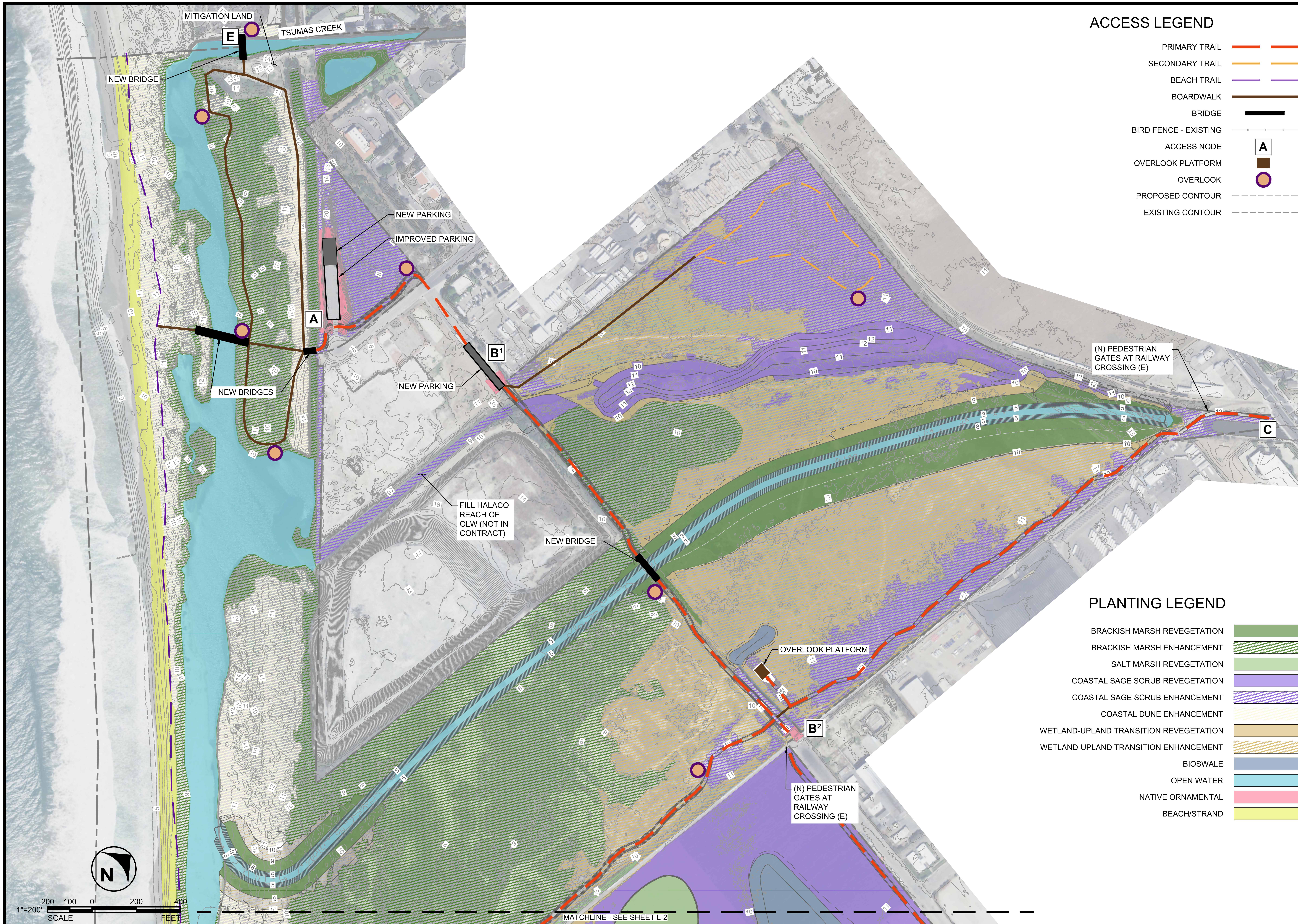

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SHEET TITLE
PLANTING & ACCESS PLAN - WESTERN

SHEET NUMBER
L-1

SHEET 9 OF 13

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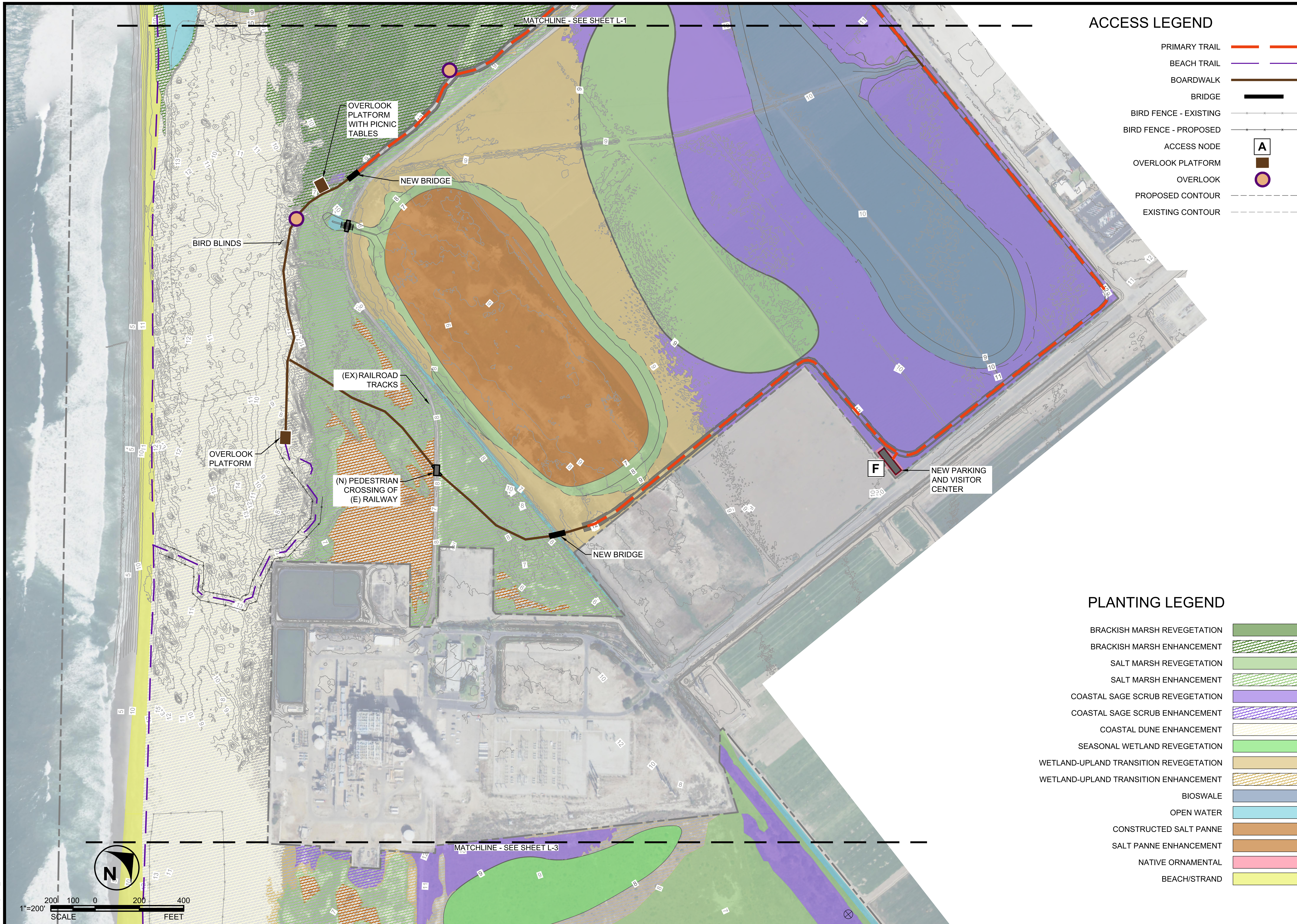

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|← 1" →|

PHASE
PRELIM CONSTRUCTION DOCUMENTATION

SHEET TITLE
PLANTING & ACCESS PLAN - CENTRAL

SHEET NUMBER
L-2

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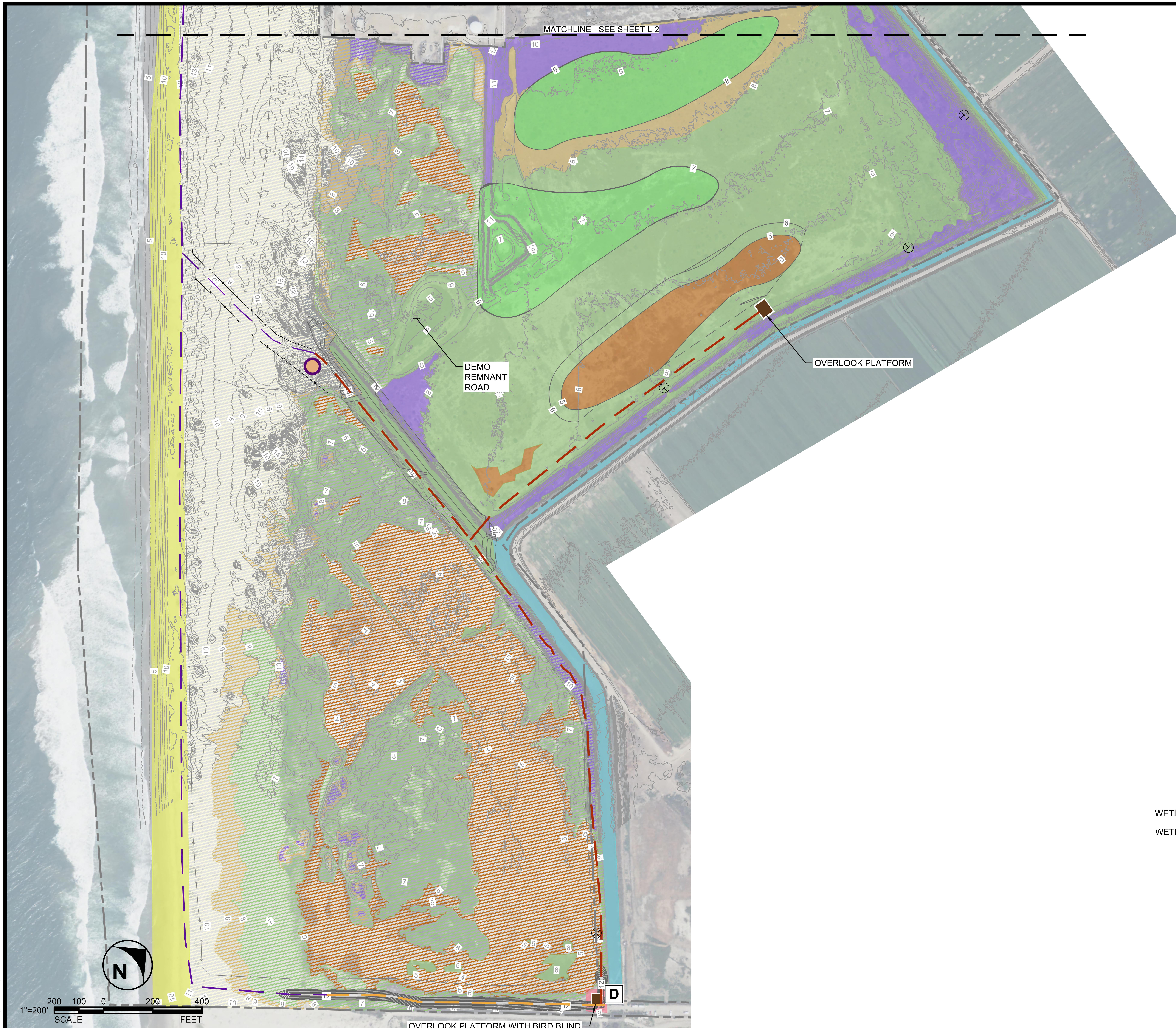

ACCESS LEGEND

- SECONDARY TRAIL
- TERTIARY TRAIL
- BEACH TRAIL
- BIRD FENCE - EXISTING
- BIRD FENCE - PROPOSED
- ACCESS NODE (A)
- OVERLOOK PLATFORM
- OVERLOOK
- PROPOSED CONTOUR
- EXISTING CONTOUR

PLANTING LEGEND

- SALT MARSH REVEGETATION
- SALT MARSH ENHANCEMENT
- COASTAL SAGE SCRUB REVEGETATION
- COASTAL SAGE SCRUB ENHANCEMENT
- COASTAL DUNE ENHANCEMENT
- SEASONAL WETLAND REVEGETATION
- WETLAND-UPLAND TRANSITION REVEGETATION
- WETLAND-UPLAND TRANSITION ENHANCEMENT
- OPEN WATER
- CONSTRUCTED SALT PANNE
- SALT PANNE ENHANCEMENT
- NATIVE ORNAMENTAL
- BEACH/STRAND

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SHEET TITLE
PLANTING & ACCESS PLAN - EASTERN

SHEET NUMBER
L-3

SHEET 11 OF 13

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Salt Marsh

Species	Common Name
Arthrocnemum subterminale	Parish's glasswort
Cressa truxillensis	Alkali weed
Distichlis spicata	Salt grass
Extriplex californica	California saltbush
Frankenia salina	Alkali heath
Jaumea carnosa	Fleshy jaumea
Juncus acutus	Spiny rush
Lasthenia glabrata ssp. coulteri	Salt marsh goldfields
Limonium californicum	Sea lavender
Malvella leprosa	Alkali mallow
Distichlis littoralis	Shore grass
Salicornia pacifica	Pickleweed
Suaeda taxifolia	Wooly seablite
Triglochin concinna	Arrow weed

Brackish Marsh

Species	Common Name
Fresh/Brackish Marsh	
Anemopsis californicus	Yerba mansa
Bolboschoenus robustus	Robust bulrush
Elymus triticoides	Alkali rye grass
Equisetum hymale	Scouring rush
Euthamia occidentalis	Western goldenrod
Juncus balticus	Baltic rush
Juncus textilis	Basket rush
Schoenoplectus californicus	Tule
Typha domingensis	Southern cattail
Typha latifolia	Broadleaf cattail
Brackish/Salt Marsh	
Baccharis glutinosa	Salt marsh baccharis
Bolboschoenus maritimus	Saltmarsh bulrush
Distichlis spicata	Salt grass
Frankenia salina	Alkali heath
Jaumea carnosa	Fleshy jaumea
Juncus acutus	Spiny rush
Salicornia pacifica	Pickleweed
Schoenoplectus californicus	Tule

Coastal Dune

Species	Common Name
Foredunes	
Abronia maritima	Red sand verbena
Ambrosia chamissonis	Beach bur
Atriplex leucophylla	Beach saltbush
Back dunes	
Abronia maritima	Red sand verbena
Abronia umbellata	Pink sand verbena
Acmispon glaber	Deerweed
Ambrosia chamissonis	Beach bur
Calystegia soldanella	Beach morning glory
Camissoniopsis cheiranthifolia	Beach evening primrose
Ericameria ericoides	Mock heather
Lupinus arboreus	Bush lupine

Wetland - Upland Transition

Species	Common Name
Arthrocnemum subterminale	Parish's glasswort
Atriplex lentiformis	quail bush
Cressa truxillensis	alkali weed
Distichlis litoralis	shoregrasas
Distichlis spicata	salt grass
Isocoma menziesii	Coast goldenbush

Seasonal Wetland

Species	Common Name
Arthrocnemum subterminale	Parish's Glasswort
Cressa truxillensis	Alkali weed
Distichlis spicata	Salt grass
Frankenia salina	Alkali heath
Lasthenia glabrata ssp. coulteri	Salt marsh goldfields
Malvella leprosa	Alkali mallow
Salicornia pacifica	Pickleweed
Suaeda taxifolia	Wooly seablite

Bioswale

Species	Common Name
Anemopsis californicus	Yerba mansa
Carex praegracilis	field sedgeedge
Distichlis spicata	Salt grass
Elymus triticoides	creeping wild rye
Hordeum brachyantherum ssp. brachyantherum	California barley
Schoenoplectus californicus	Tule
Typha domingensis	Southern cattail
Typha latifolia	Broadleaf cattail

Coastal Sage Scrub

Species	Common Name
Artemisia californica	California sagebrush
Atriplex lentiformis	Big saltbush
Baccharis pilularis	Coyote brush
Encelia californica	California encelia
Eriogonum fasciculatum	California buckwheat
Eschscholzia californica	California poppy
Isocoma menziesii	Coast goldenbush
Lupinus succulentus	Arroyo lupine
Mimulus aurantiacus	Sticky monkey flower
Salvia leucophylla	Purple sage
Salvia mellifera	Black sage
Suaeda taxifolia	Woolly seablite

Native Ornamental

Species	Common Name
Artemisia californica	California sagebrush
Baccharis pilularis	Coyote brush
Dudleya caespitosa	Coast dudleya
Dudleya lanceolata	Southern California dudleya
Dudleya pulverulenta	Chalk dudleya
Encelia californica	California encelia
Eriogonum fasciculatum	California buckwheat
Eriogonum cinereum	Asheyleaf buckwheat
Eschscholzia californica	California poppy
Isocoma menziesii	Coast goldenbush
Lupinus succulentus	Arroyo lupine
Mimulus aurantiacus	Sticky monkey flower
Salvia apiana	White sage
Salvia leucophylla	Purple sage
Salvia mellifera	Black sage

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CONSULTANT

PROJECT NAME:
ORMOND BEACH RESTORATION AND PUBLIC ACCESS PROJECT
OXNARD, CA

REVISIONS

#	DATE	DESCRIPTION

DESIGNED BB, KT, EPK
DRAWN JJ, AI, IS
CHECKED AB, BB, EPK
IN CHARGE RS

PROJECT NUMBER D160447.00
ISSUE DATE MM/DD/YY
SCALE IS AS SHOWN WHEN PLOTTED TO FULL SIZE (22"x34")
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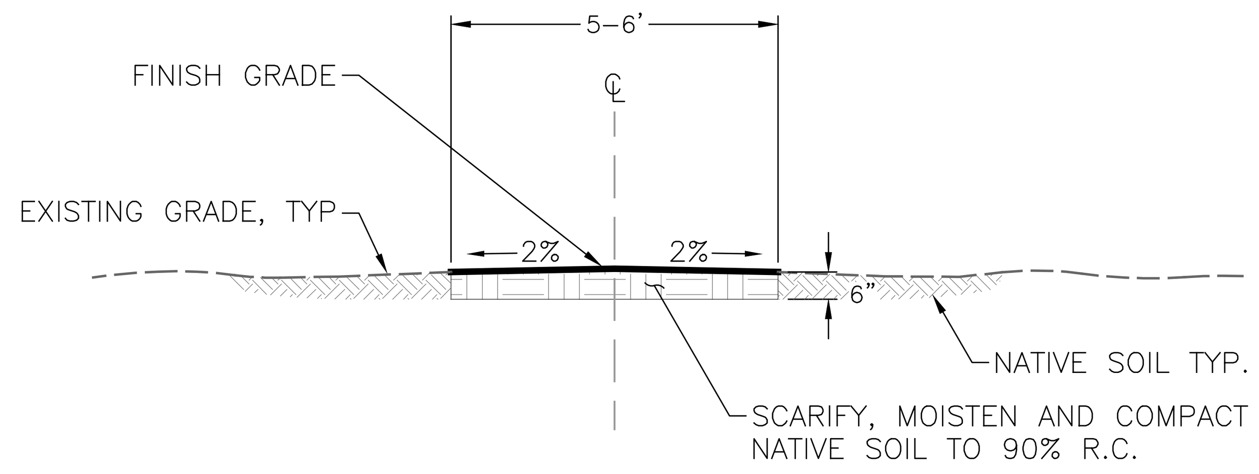
PHASE
PRELIM CONSTRUCTION DOCUMENTATION

SHEET SCALE: NOT TO SCALE

PLANTING LISTS

SHEET NUMBER
L-4



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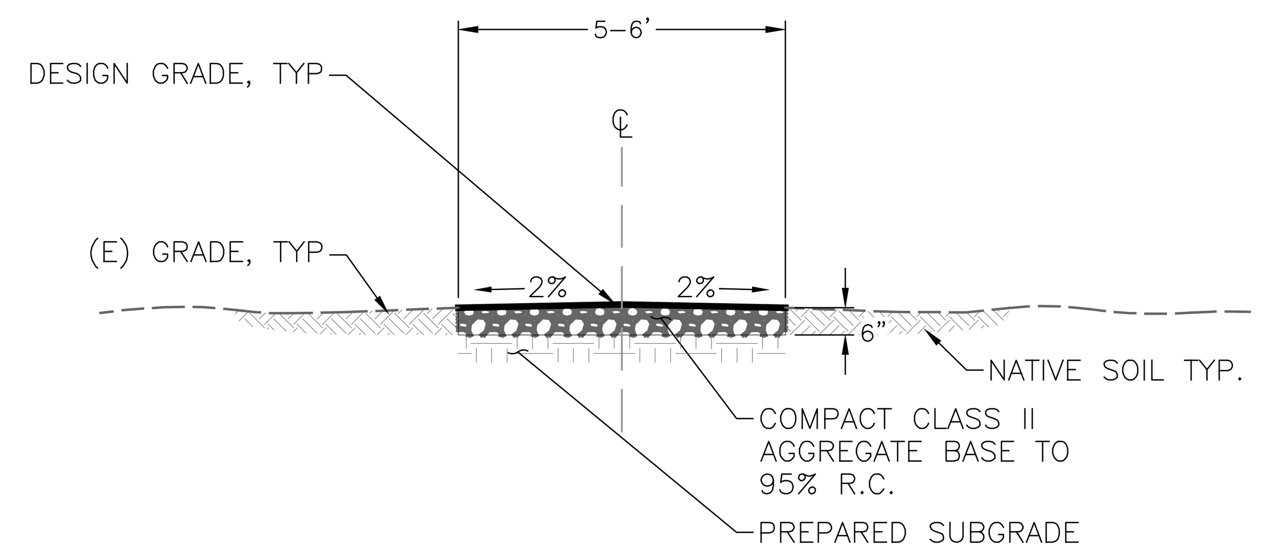

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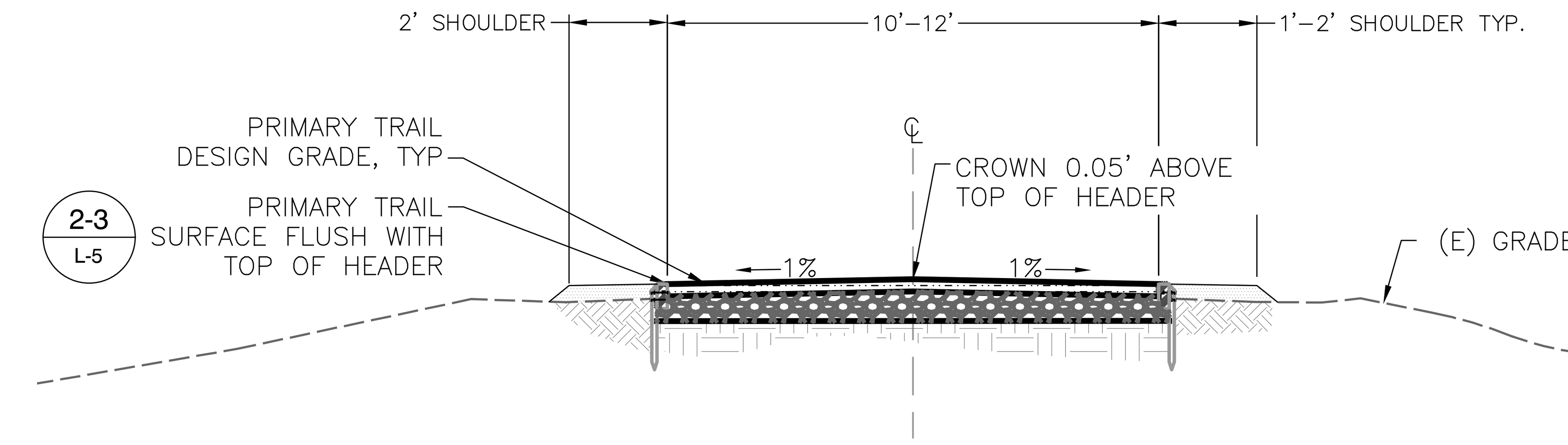

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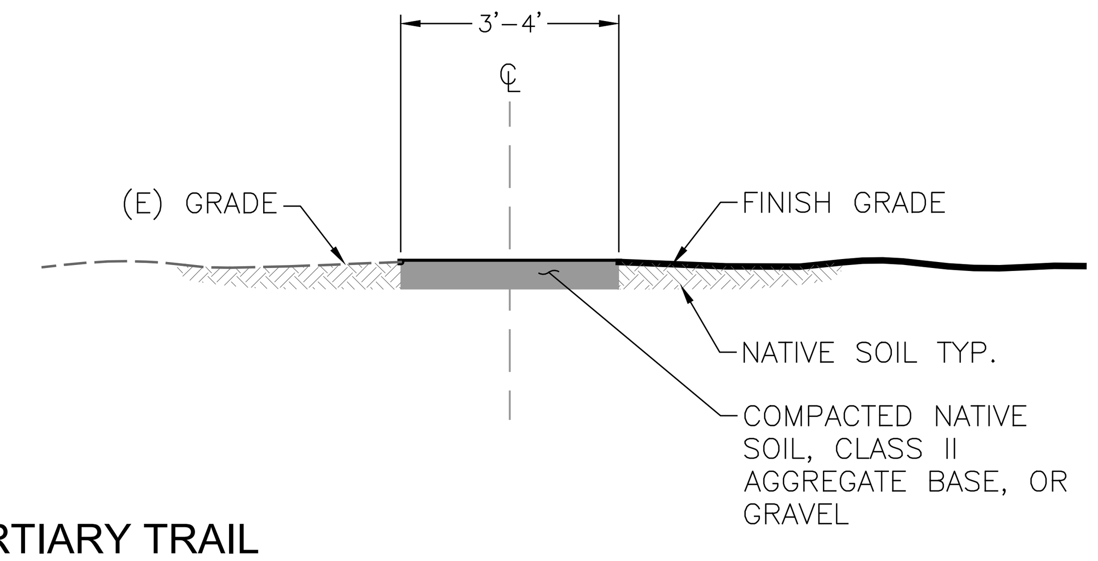

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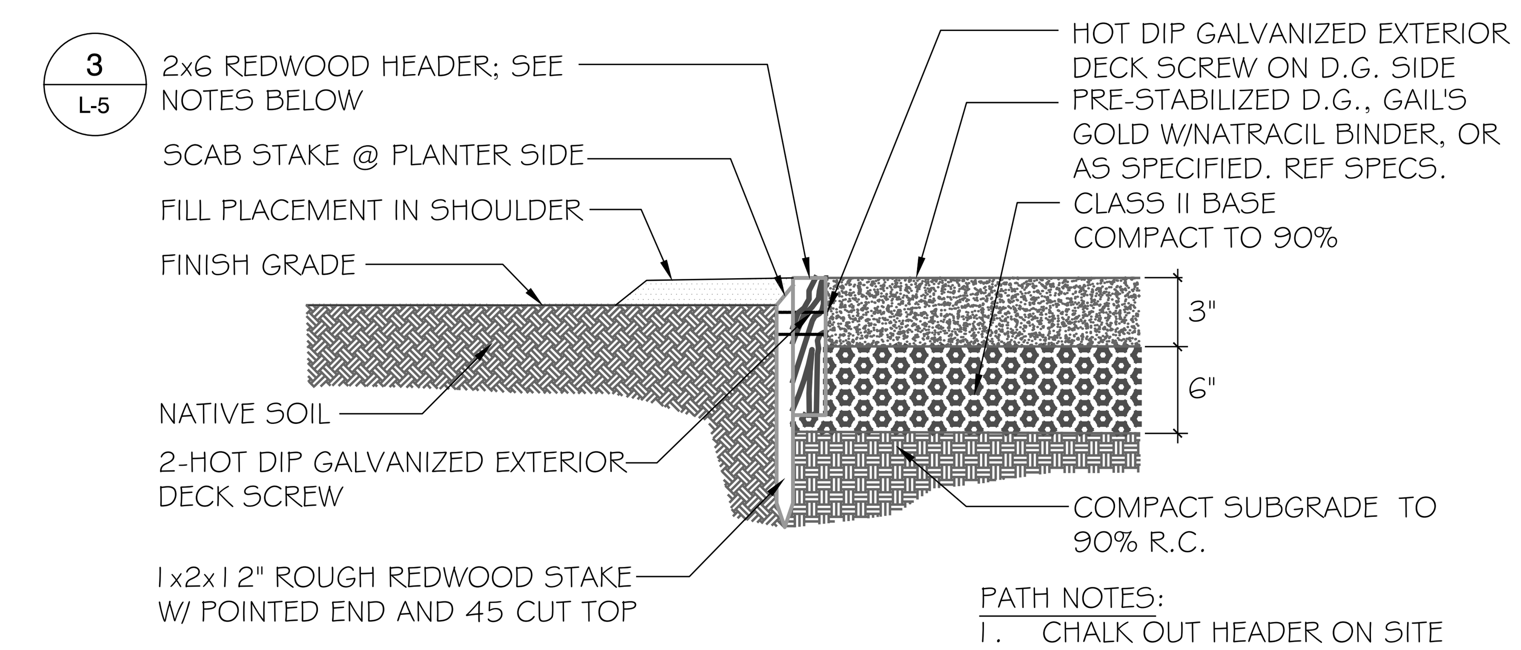
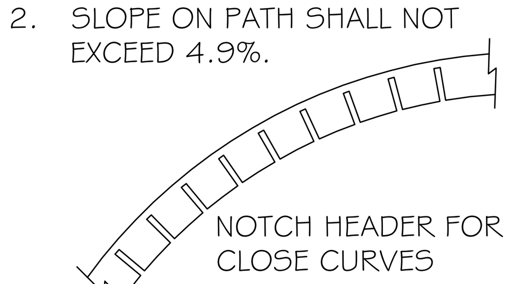
SECTION SCALE: N.T.S.



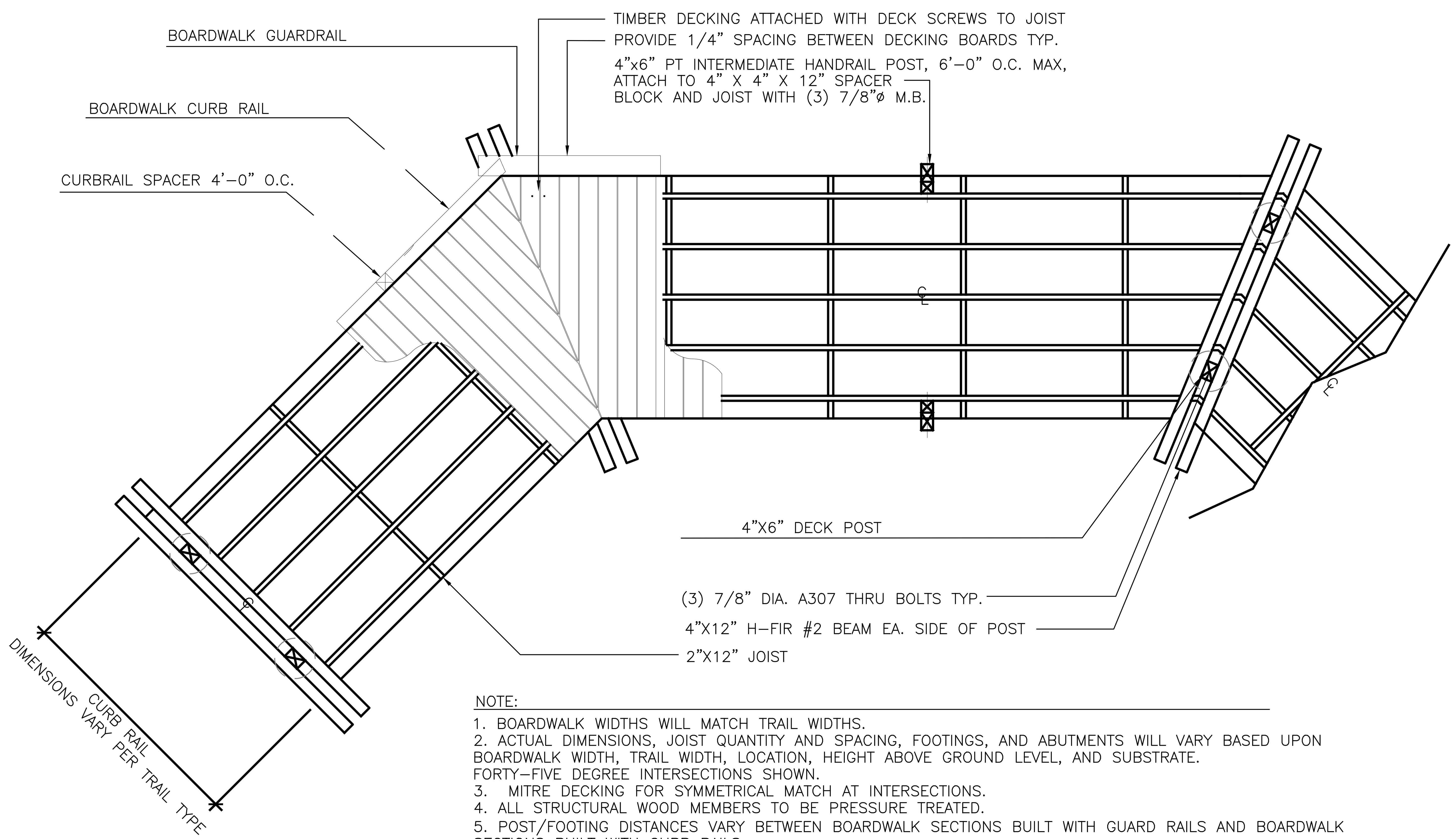
HEADER NOTES:
1. STRAIGHT LINES=2x6 HEADER WITH 3/8"x4x24" REDWOOD; SCAB EACH SPLICE. STAKES AT 6' MAX SPACING
2. GRADUAL CURVES=2-1x6's WITH 4' MIN OVERLAP. GALV. DECKING SCREWS AT 2' ON CENTER. STAKES AT 5' MAX SPACING, OR SAW CUT 2x4.
3. CLOSE CURVES=SAW-CUT NOTCHES ON INSIDE EDGE OF 2x6 HEADERS AS INDICATED ABOVE. STAKES AT 4' MAX SPACING.
4. CONTRACTOR SHALL LAYOUT HEADER BOARDS W/GYPSUM AND CALL LANDSCAPE ARCHITECT FOR REVIEW.

PATH NOTES:
1. CHALK OUT HEADER ON SITE PRIOR TO INSTALLATION. UTILIZE HAND TOOLS TO GRADE PATH.
2. SLOPE ON PATH SHALL NOT EXCEED 4.9%.



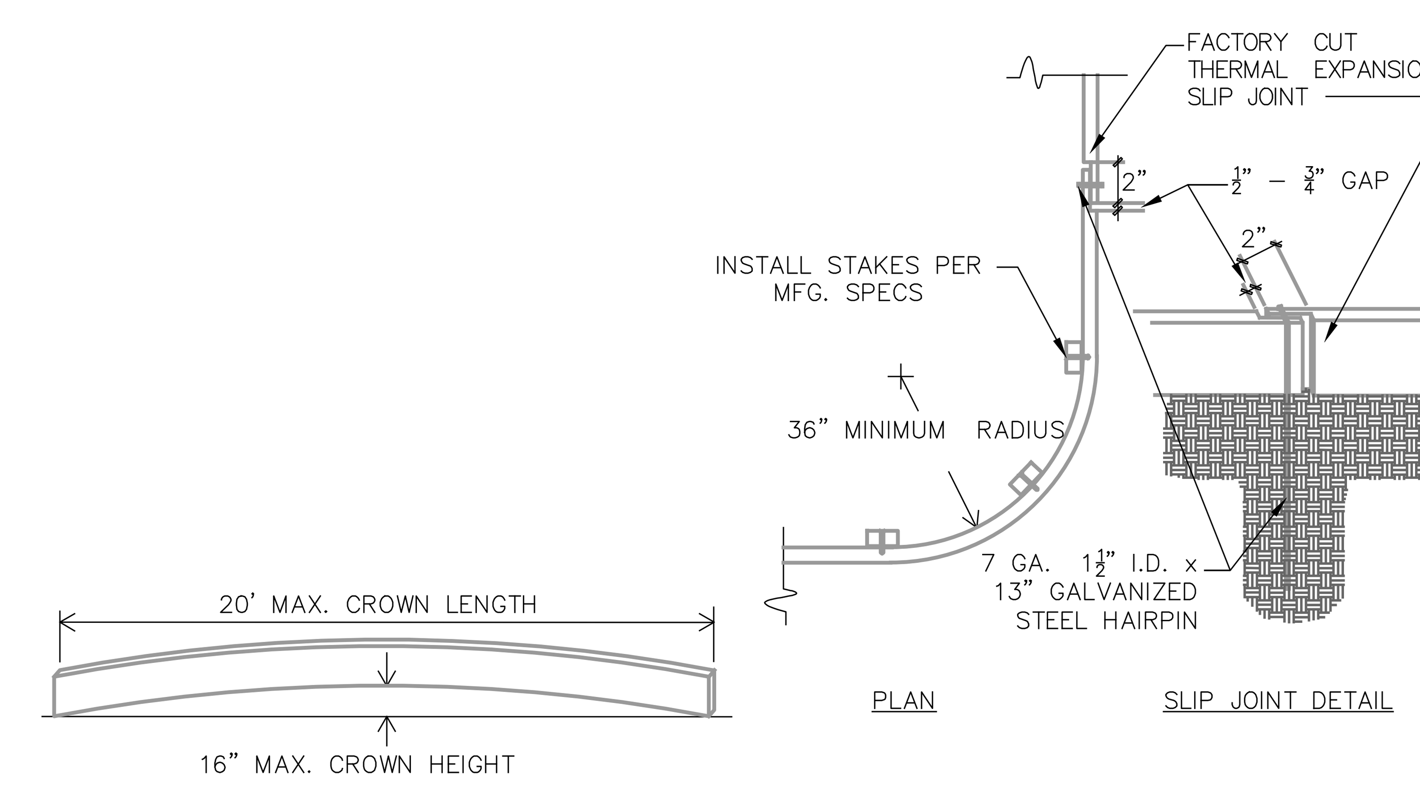
PLAN VIEW - N.T.S

2 PRIMARY TRAIL SURFACING
SECTION SCALE: N.T.S.



NOTE:
1. BOARDWALK WIDTHS WILL MATCH TRAIL WIDTHS.
2. ACTUAL DIMENSIONS, JOIST QUANTITY AND SPACING, FOOTINGS, AND ABUTMENTS WILL VARY BASED UPON BOARDWALK WIDTH, TRAIL WIDTH, LOCATION, HEIGHT ABOVE GROUND LEVEL, AND SUBSTRATE. FORTY-FIVE DEGREE INTERSECTIONS SHOWN.
3. MITRE DECKING FOR SYMMETRICAL MATCH AT INTERSECTIONS.
4. ALL STRUCTURAL WOOD MEMBERS TO BE PRESSURE TREATED.
5. POST/FOOTING DISTANCES VARY BETWEEN BOARDWALK SECTIONS BUILT WITH GUARD RAILS AND BOARDWALK SECTIONS BUILT WITH CURB RAILS.
6. CURB RAIL FOOTINGS AND GUARD RAIL FOOTINGS TO BE LOCATED BY CENTERING THEIR SEPARATION OVER THE CENTERLINE OF THE BOARDWALK.
7. CHAMFER CORNERS AT TERMINATION OF HANDRAIL.
8. IN LOCATIONS WHERE POST/FOOTING SPACING IS LESS THAN 12' O.C., CONTRACTOR TO DIVIDE SPACE EQUALLY WITH INTERMEDIATE HANDRAIL POST.
9. ALL FASTENERS SHALL BE 100% STAINLESS STEEL.

7 BOARDWALK - CONCEPTUAL LAYOUT
PLAN VIEW SCALE: N.T.S.



HEADER PLAN VIEW DETAIL NOTES:
1. CONTRACTOR SHALL USE 2X6 REDWOOD BOARD. INSTALL ACCORDING TO MANUFACTURER'S INSTRUCTIONS.
2. CONTRACTOR SHALL LAYOUT EDGE BOARDS WITH GYPSUM (CHALK) AND CALL OWNER'S REPRESENTATIVE FOR REVIEW PRIOR TO INSTALLATION.
3. CONTRACTOR SHALL ALLOW FOR THERMAL EXPANSION WHEN INSTALLING EDGE BOARDS; DO NOT SCREW THROUGH SLIP JOINT.
4. CONTRACTOR SHALL USE WOODWORKING TOOLS FOR CUTTING AND DRILLING EDGE BOARDS.

3 PRIMARY TRAIL HEADER W/ STAKE
SECTION SCALE: N.T.S.

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SHEET TITLE
TRAILS DETAILS

SHEET NUMBER
L-5

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Appendix H
Conceptual Revegetation Plan

Ormond Beach Wetlands Conceptual Revegetation Plan

July 8, 2020

Prepared by:
Coastal Restoration Consultants

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Ventura, CA 93003
Contact: Matt James
matt@crcsb.com

Prepared for:
ESA
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San Francisco, CA 94108

1. INTRODUCTION

Re-establishment of native vegetation communities is a crucial aspect of implementing ecological restoration projects. Native plants provide many important ecosystem services, including:

- Stabilization of soils and erosion control,
- The basis for the food web and nutrient cycling,
- Physical structure that supports wildlife,
- Increasing resistance to invasion by non-native plants, and
- Improving water quality.

Despite the obvious importance of revegetation, in practice, many restoration projects struggle with achieving desired outcomes related to establishing target plant communities and reaching goals for metrics such as native plant cover and diversity. This can happen for many reasons, but a common problem is failure to match appropriate species to their appropriate physical growing conditions. Important physical factors vary widely by habitat, but some important processes that effect patterns in southern California's coastal wetlands include soil moisture dynamics, hydrology, scour and sedimentation, soil salinity, soil texture, slope steepness and aspect, and climate. In order for revegetation to be successful at a restoration site, these physical growing conditions must be understood across different areas of the site. This allows us to match appropriate native plant communities and species to the appropriate areas. Or, conversely, to design a restoration project to support target habitats.

In southern California's coastal wetlands, relatively small differences in elevation can lead to very different vegetation communities. This is due to the fact that important physical stressors on plants (*e.g.*, flooding duration and depth, soil salinity, etc.) can vary strongly with elevation. Our tidal estuaries have highly variable but fairly predictable water levels and salinities, therefore the elevation ranges for typical plant communities are fairly well understood in these systems. In contrast, the intermittently tidal and non-tidal wetlands at Ormond Beach will have water levels and salinities that vary considerably both within and between years in ways that will be difficult to predict. Restoring these natural dynamics is an important aspect of the overall restoration effort for this site. Establishing self-sustaining native plant communities in such dynamic conditions will be challenging and will require experimental and adaptive approaches.

1.1 Purpose of This Plan

The Ormond Beach Restoration and Public Access Plan includes a conceptual plan for the site that identifies target habitats expected after alterations to existing hydrology and topography. The proposed grading plan was developed to optimize the project's attainment of its goals and objectives, including those related to target plant communities. While these plans are based on the best available information for the site, important data gaps remain (*see* OBRAP Restoration Plan Section 8). Until some of the most important data gaps are filled, developing a detailed revegetation plan for the site will not be feasible. Proposed future planning work, especially the development of a conceptual model linking existing hydrology and vegetation patterns to expected post-restoration hydrology and vegetation patterns, will be crucial in fine-tuning where different plant species will be expected to occur on site. This conceptual model will allow for much more detailed planning and cost estimations for the revegetation effort.

The purpose of this chapter is to provide more detailed definitions of the different plant communities targeted for restoration and to lay out a plausible path towards establishing those communities. Restoring target plant communities within different parts of the Ormond Beach Wetlands complex will be complicated given myriad differences in surface and groundwater hydrology, soil texture and salinity, and ground surface elevations throughout the site. Given this above-average uncertainty, it will be important to develop and employ an adaptive management framework to guide the revegetation efforts to assure that appropriate strategies are being used to accomplish project goals. This conceptual revegetation plan is meant to provide guidance for future rounds of planning and support the environmental review process.

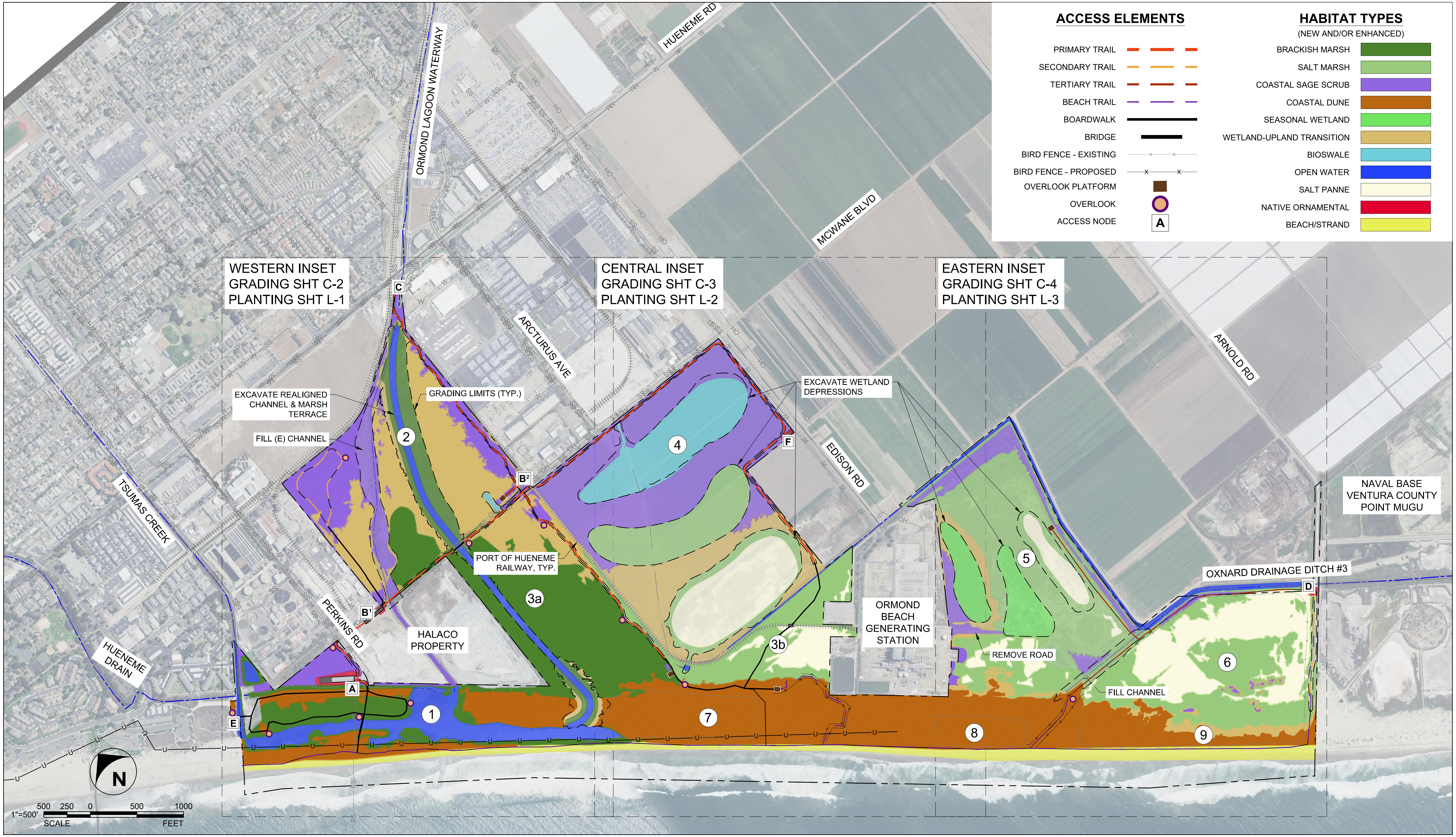
2. NATIVE PLANT COMMUNITIES

The proposed project will expand wetland habitats at the site and restore existing degraded wetland, transition, and upland habitats. The primary restoration actions include re-routing of the Oxnard Lagoon Waterway (OLW), earthmoving to lower ground surface elevations and create ponding features, improving hydrologic connectivity within the site, and converting agricultural land to native habitats. Post-restoration, the site could support brackish marsh, salt marsh, open water, foredune and dune scrub, dune swale wetlands, saline-affected seasonal wetlands, coastal sage scrub, and a range of transitional habitats (**Figure 1**). The exact distribution of these habitats will depend strongly on the post-restoration hydrology, especially as it relates to water levels (or depths) and salinity. At this stage of restoration planning, many of these details are not known. The goal of this conceptual revegetation plan is to lay out general approaches for successfully establishing native plant communities and controlling invasive non-natives on the restored site.

2.1 Fresh/Brackish and Brackish/Salt Marsh

Brackish marsh is a general term used to describe the types of wetlands that occur where typical water salinities are between 0.5 parts per thousand (ppt) and 30 ppt. Brackish conditions are also referred to as mixohaline by Cowardin et al. (1979), and distinct from limnetic (<0.5 ppt), euhaline (30-40 ppt) and hyperhaline (>40 ppt). Cowardin et al. (1979) distinguish three types of wetlands within mixohaline class, oligohaline (0.5-5 ppt), mesohaline (5-18 ppt) and polyhaline (18-30 ppt). In southern California, brackish marshes within these three subclasses generally have different vegetation associations. These habitats are expected to occur in Areas 1, 2, and 3a. Generally, oligohaline (referred to in this plan as fresh/brackish marsh) would be expected in Area 2 and northern parts of 3a and mesohaline (referred to as brackish/salt marsh) would be expected in Areas 1 and southern parts of 3a where there is more influence from the ocean.

Different brackish marsh species occur at different elevations within a given marsh. The stratification of vegetation is due to differing stress tolerances of different species and interspecific competition. In oligohaline systems, vascular vegetation can grow in areas that are flooded more or less year-round to about three feet in depth; elevations below this will be open water or may support algae and/or aquatic vegetation.



SOURCE: ESRI 7/19/2016, City of Oxnard, Ventura County

Figure 1 Project Overview

ESA

In mesohaline systems, vascular vegetation is expected to grow in areas flooded more or less year-round to a foot or two of depth and perhaps somewhat deeper in the non-growing season (winter). Seasonal salinity dynamics will play a role in the lower distributional limit of vascular plants in both systems.

Deeper areas in oligohaline marshes will support monotypic stands of cattail (*Typha* spp.), which might be co-dominant with tule (*Schoenoplectus californicus*) in areas with shallower flooding. Tule will likely dominate seasonally flooded areas though other fresh/brackish species (Table 1) may co-occur or even dominate under certain hydrology/salinity regimes. Areas one to two feet above elevations that flood at least seasonally and don't go hypersaline, are expected to support other native wetland species (Table 1) due to saturated soils (from capillary action in the soil or shallow water table).

Mesohaline or brackish/salt marsh habitats are expected where there is more influence from the ocean (due to wave overwash or shallow saline ground water). This habitat will intergrade with oligohaline marsh and share many of the same plant species but will also support species such as pickleweed (*Salicornia pacifica*) and fleshy jaumea (*Jaumea carnosa*) where soil or surface water salinities are highest. Several other perennial halophytes are expected to grow in these areas at different flooding depths (Table 2).

Table 1. Typical species of an oligohaline fresh/brackish marsh in coastal southern California. These would be typical species around and within the new OLW in Area 2.

Species	Common Name	Preferred Conditions
Anemopsis californicus	Yerba mansa	Saturated soil
Bolboschoenus robustus	Robust bulrush	Seasonally flooded
Elymus triticoides	Alkali rye grass	Seasonally saturated soil
Equisetum hymale	Scouring rush	Saturated soil
Euthamia occidentalis	Western goldenrod	Seasonally saturated soil
Juncus balticus	Baltic rush	Saturated soil
Juncus textilis	Basket rush	Saturated soil
Schoenoplectus californicus	Tule	Seasonally flooded
Typha domingensis	Southern cattail	Permanently flooded
Typha latifolia	Broadleaf cattail	Permanently flooded

Table 2. Typical species of a mesohaline brackish/salt marsh in southern California. These would be typical species along OLW in Area 3a and around Ormond Lagoon in Area 1.

Species	Common Name	Preferred Conditions
Baccharis glutinosa	Salt marsh baccharis	Seasonally saturated soil
Bolboschoenus maritimus	Saltmarsh bulrush	Seasonally flooded
Distichlis spicata	Salt grass	Seasonally saturated soil
Frankenia salina	Alkali heath	Seasonally saturated soil
Jaumea carnosa	Fleshy jaumea	Seasonally flooded
Juncus acutus	Spiny rush	Saturated soil
Salicornia pacifica	Pickleweed	Seasonally flooded
Schoenoplectus californicus	Tule	Seasonally-permanently flooded

2.2 Salt Marsh

Salt marsh habitats occur in southern California in tidal and non-tidal euhaline and hyperhaline wetlands. These habitats are dominated by perennial halophytes such as pickleweed, fleshy jaumea, salt grass (*Distichlis spicata*), and alkali heath (*Frankenia salina*). Salt marsh currently occurs in Areas 3b, 5, and 6. At least two salt marsh species that are typically only found in tidal systems in southern California are known to occur at the site, including salt marsh bird's beak (*Cordylanthus maritimus* ssp. *maritimus*) and arrow grass (*Triglochin concinna*). Both occur in euhaline habitats that are rarely flooded. Existing salt marsh areas could be enhanced to increase floral diversity. New salt marsh habitats may be restored and/or created in Areas 1, 3a, and 5.

Unvegetated hyperhaline salt flats are also an important component of the salt marsh habitats at the site, though they do not support vascular plants. They currently occur in Areas 3b, 5 and 6. Additional salt flats may be restored and/or created in Areas 4 and 5.

Table 3. Typical species of salt marsh habitats in non-tidal coastal wetlands in southern California.

Species	Common Name	Preferred Conditions
Arthrocnemum subterminale	Parish's Glasswort	Seasonally saturated soil
Cressa truxillensis	Alkali weed	Seasonally saturated soil
Distichlis spicata	Salt grass	Seasonally saturated soil
Extriplex californica	California saltbush	Saline soil
Frankenia salina	Alkali heath	Seasonally saturated soil
Jaumea carnosa	Fleshy jaumea	Saturated soil
Juncus acutus	Spiny rush	Saturated soil
Lasthenia glabrata ssp. coulteri	Salt marsh goldfields	Seasonally hypersaline soil
Limonium californicum	Sea lavender	Seasonally saturated soil
Malvella leprosa	Alkali mallow	Saline soil
Monanthochloe littoralis	Shore grass	Seasonally saturated soil
Salicornia pacifica	Pickleweed	Saturated soil
Suaeda taxifolia	Wooly seablite	Saline soil
Triglochin concinna	Arrow weed	Saturated soil

2.3 Coastal Sage Scrub

The upland areas of the site are expected to support coastal sage scrub habitat. Coastal sage scrub (sometimes called soft chaparral) is a highly diverse community dominated by drought-tolerant shrubs and sub-shrubs. Coastal sage scrub occurs on a range of different slope aspects and soil types, which, along with distance from the coast, determine what species are dominant at a given location. Some species such as coast goldenbush (*Isocoma menziesii*), woolly seablite (*Suaeda taxifolia*) and saltbush (*Atriplex lentiformis*) are tolerant of seasonally saline soils and very rare flooding. Most species (Table 4), while tolerant of salty sea spray, do not tolerate these stressors. Coastal sage scrub habitats are found in parts of Area 1, 2, 3a, 5, and 6, though overall diversity tends to be very low. These areas could be enhanced and additional coastal sage scrub may be created and/or restored in all these areas as well as parts of Area 4.

Table 4. Typical species found in coastal sage scrub habitat in southern California.

Species	Common Name	Habit
Artemisia californica	California sagebrush	Shrub
Atriplex lentiformis	Big saltbush	Shrub
Baccharis pilularis	Coyote brush	Shrub
Encelia californica	California encelia	Shrub
Eriogonum fasciculatum	California buckwheat	Sub-shrub
Eschscholzia californica	California poppy	Annual/short-lived perennial
Isocoma menziesii	Coast goldenbush	Sub-shrub
Lupinus succulentus	Arroyo lupine	Annual
Mimulus aurantiacus	Sticky monkey flower	Sub-shrub
Salvia leucophylla	Purple sage	Shrub
Salvia mellifera	Black sage	Shrub
Suaeda taxifolia	Woolly seablite	Shrub

2.4 Coastal Dune Scrub

Coastal sand dune systems in southern California support a range of different annual and perennial plant species that are specifically adapted to burial by blowing sand, well-drained and low-nutrient soils, and seasonal drought. In general, growing conditions are most stressful closer to the ocean, where winter waves can overrun plants and erode sand. This zone, generally referred to as foredune scrub, includes plants that tolerate burial by blowing sand and overwash by ocean waves (Table 5). More landward areas, called backdunes, are not subject to direct impacts from waves and support a different suite of species (Table 6). Both of these habitats are found extensively in Areas 1, 7, 8 and 9. Revegetation efforts in these areas should focus on increasing floral diversity, especially in the back dunes.

Table 5. Typical species found in foredune scrub habitat in southern California.

Species	Common Name	Habit
Abronia maritima	Red sand verbena	Sub-shrub
Ambrosia chamissonis	Beach bur	Sub-shrub
Atriplex leucophylla	Beach saltbush	Sub-shrub

Table 6. Typical species found in backdune scrub habitat in southern California.

Species	Common Name	Habit
Abronia maritima	Red sand verbena	Sub-shrub
Abronia umbellata	Pink sand verbena	Sub-shrub
Acmispon glaber	Deerweed	Sub-shrub
Ambrosia chamissonis	Beach bur	Sub-shrub
Calystegia soldanella	Beach morning glory	Sub-shrub
Camissoniopsis cheiranthifolia	Beach evening primrose	Sub-shrub
Ericameria ericoides	Mock heather	Shrub
Lupinus arboreus	Bush lupine	Sub-shrub

2.5 Dune Swale Wetlands

Dune swale wetlands occur in depressions in dune systems where the water table is at or very near the soil surface. The shallow water table in large dune systems like the one at Ormond Beach is typically fresh and floating on top of salty ground water. The elevation of the salty groundwater controlled primarily by the ocean. The plants found in dune swale wetlands are mostly hydrophytes (Table 7) and may or may not have tolerance to salty soil. Dune swale wetlands could be created in Areas 7, 8 and 9 but current plans do not include this habitat type.

Table 7. Typical species found in dune swale wetland habitat in southern California.

Species	Common Name	Habit
Carex praegracilis	Sedge	Herbaceous perennial
Distichlis spicata	Salt grass	Rhizomatous grass
Heliotropium curassavicum	Seaside heliotrope	Herbaceous perennial
Juncus acutus	Spiny rush	Perennial rush
Juncus balticus	Wire rush	Rhizomatous rush
Juncus textilis	Basket rush	Rhizomatous rush

2.6 Saline-affected Seasonal Wetlands

Saline-affected seasonal wetlands occur where rainfall or seasonal fluctuations in surface or groundwater levels lead to seasonal ponding or seasonally saturated soils in the rooting zone. This habitat is currently found in Areas 2, 4, and 5, and totals 78.8 acres (12 percent of the Project Area). Seasonal wetlands might occur in depressions that pond water or on flats with clay soils that retain moisture and salt after rainfall. Seasonal wetlands near the coast that are influenced by salt are uncommon today in southern California but can support a wide range of regionally and globally rare plant species, including Virginia pickleweed (*Salicornia depressa*), Coulter's saltbush (*Atriplex coulteri*), Pacific saltbush (*A. pacifica*), Davidson's saltbush (*A. serenana* var. *davidsonii*), horned sea blite (*Suaeda calceoliformis*), and Ventura marsh milk vetch (Astragalus pycnostachyus var. lanosissimus). Some other common species expected in these habitats are listed in Table 8. All the different species will have somewhat different tolerances to different levels of salinity, depths and durations of inundation, and dry-season drought stress.

Table 8. Typical species of saline-affected seasonal wetland habitats in coastal southern California.

Species	Common Name	Preferred Conditions
Arthrocnemum subterminale	Parish's Glasswort	Seasonally saturated soil
Cressa truxillensis	Alkali weed	Seasonally saturated soil
Distichlis spicata	Salt grass	Seasonally saturated soil
Frankenia salina	Alkali heath	Seasonally saturated soil
Lasthenia glabrata ssp. coulteri	Salt marsh goldfields	Seasonally hypersaline soil
Malvella leprosa	Alkali mallow	Saline soil
Salicornia pacifica	Pickleweed	Saturated soil
Suaeda taxifolia	Wooly seablite	Saline soil

2.7 Open Water and Salt Flats

The lowest areas of the project, primarily in Areas 1, 2, and 3a, will be too deep for cattail and will be flooded almost all the time. The open brackish water could support algae and aquatic plants (Table 9). If there are high levels of nutrients (phosphorus and nitrogen) in the water, algae blooms may become a nuisance. When algae becomes abundant and then dies, the microorganisms that consume the dead algae can severely deplete the available oxygen in the water column, leading to die offs of fish and other aquatic species.

Salt flats occur in shallow depressions with very poorly drained soil that trap rainwater and/or wave overwash. As the water evaporates, salts are left behind and soils become too salty for vascular vegetation. These habitats exist currently on site in Areas 5 and 6 and are expected to be created in Areas 4 and 5. These areas may support algae such as sea lettuce (*Ulva* spp.) when flooded.

Table 9. Typical aquatic species found in brackish sub-tidal habitats in southern California.

Species	**Common Name**	**Habit**
Ruppia cirrhosa	Spiral ditch grass	Floating vascular plant
Ruppia maritima	Ditch grass	Floating vascular plant
Ulva intestinalis	Sea lettuce	Floating algae
Ulva lactuca	Sea lettuce	Floating algae

3. REVEGETATION STRATEGIES

We developed a set of general strategies (below) for planting and weeding the site in order to provide a very rough cost estimate for revegetation efforts. A refined revegetation plan and then a detailed implementation plan will need to be developed for the project that will refine these strategies. Those plans will need to be developed concurrently with the final grading plan and include any special conditions set forth in project permits issued by the regulatory agencies. A restoration ecologist familiar with implementing restoration and/or mitigation projects in coastal southern California should prepare the plan.

3.1 Rare and Extirpated Species

The Ormond Beach Wetlands are known to support several rare plant species. These include salt marsh bird's beak (*Chloropyron maritimum* ssp. *maritimum*), red sand verbena (*Abronia maritima*), Coulter's goldfields (*Lasthenia glabrata* ssp. *coulteri*), spiny rush (*Juncus acutus* ssp. *leopoldii*), and woolly seablite (*Suaeda taxifolia*), all of which were observed by CRC during fieldwork for this project and have been found in previous studies. Other rare species have been documented at the site[1] including California seablite (*Suaeda californica*) and island mallow (*Lavatera assurgentiflora* ssp. *assurgentiflora*), though their current status at the site is not clear. Special care should be taken to preserve all existing populations of these species. Ideally, restoration actions should lead to the expansion of those populations.

[1] www.calflora.org

Additionally, there are several regionally or globally rare species that occurred within the region that the site could support, including Coulter's saltbush (*Atriplex coulteri*), south coast saltscale (*Atriplex pacifica*), Davidson's saltscale (*Atriplex serenana* var. *davidsonii*), Lewis' evening primrose (*Camissoniopsis lewisii*), Ventura marsh milk vetch (*Astragalus pycnostachyus* var. *lanosissimus*), beach spectaclepod (*Dithyrea maritima*), curly-leaved monardella (*Monardella undulata*), and California spineflower (*Mucronea californica*). Establishing new populations of such species at Ormond Beach could help with their recovery and conservation. Special permissions from regulatory agencies would be needed to introduce some of these species.

3.2 Planting and Seeding

Planting palettes for the different habitats should be based on Tables 1-7 (we do not recommend "planting" aquatic species in the open water or salt flat areas). These lists will likely need to be adjusted and/or expanded as project planning proceeds through the next stages. Only species native to coastal southern California should be used. Horticultural cultivars of native species should never be used. Plant material (seed and nursery stock) should only be sourced from firms who are able to document the geographic area where propagules were collected for each species. This will help assure appropriate genotypes are introduced. For most of the common species, propagules should be sourced from natural stands (not restoration/mitigation sites) along the coast between Los Angeles and southern Santa Barbara Counties.

Wetland and upland areas should be planted with nursery stock or seeded. Small nursery containers (*e.g.*, 2-inch pots or plugs) are preferred for most species. Large wetland plants such as tule and cattail should be planted from standard 1-gallon nursery stock. Planting in these areas should take place in spring so new plantings can experience a full growing season (spring and summer) and establish extensive root systems capable of stabilizing soil and mechanically anchoring the plants during winter flooding. Planting densities will vary by species. Some wetland species such as pickleweed establish easily on restoration sites from seed. Direct seeding of such species will save substantial money.

Foredune, backdune, and coastal sage scrub areas should be re-vegetated with a combination of small nursery stock and seed. Planting and seeding in these areas should occur in early winter to take advantage of natural rain. Temporary irrigation could be installed in these areas and used only to the extent necessary. Over-irrigation may lead to plants growing less extensive root systems than those required to survive once irrigation has ceased. There should be a plan and funding in place to remove the irrigation after plants are established (1-3 years).

3.3 Weeding

Weeds are not expected to be a major problem in flooded wetland areas. However, elsewhere on site invasive annual species will be a problem. If not controlled, they can out-compete natives and cause the revegetation effort to fail. If possible, we recommend at least one grow-kill cycle before planting in the coastal sage scrub areas. This is typically done by irrigating the site briefly to sprout weeds from seed and then killing seedlings using an aquatic-approved herbicide, hand weeding, solarization, or similar method. Weeding is much more efficient before native plants are installed or native seed is spread. Weeding non-native annuals will need to continue after planting (spot herbicide or hand removal). Minimizing irrigation will generally favor natives and discourage annual non-native plants. As native shrubs and trees grow larger, they will shade the ground and discourage many of the most problematic annual weeds from germinating.

Non-native perennial plant species are often a long-term maintenance issue at restoration sites. Detecting and removing these species (*e.g., Arundo donax, Cynodon dactylon, Pennisetum clandestinum, Nicotiana glauca, Cortedaria selloana,* and *Tamarix ramosissima*) should be a priority during the installation phase (the first three to five years) and beyond. These species typically require treatment with herbicide or mechanical removal. Early detection, when plants are still small, makes control efforts much easier. A detailed weeding strategy for annual and perennial non-natives should be part of the final implementation plan and should be tailored to achieve goals for non-native cover laid out in regulatory permits.

3.4 Site Preparation and Short-term Maintenance

Future studies and permit conditions will dictate specific measures that need to be undertaken to assure the revegetation effort is successful. These will include at least, an erosion control plan, soil texture and salinity analyses to assess the possible need for soil amendments, short-term fencing to protect new plantings from trampling and, signage to inform the public about the sensitivity of the restoration site to trampling and other disturbance. Plantings should also be monitored for herbivory by gophers, rabbits, squirrels, birds, etc. If plants are being killed or damaged, herbivore protection will need to be installed. This would likely only be a problem in the coastal sage scrub and backdune areas. These issues should all be addressed in the implementation plan, which will be prepared in conjunction with final project design and permitting phases.

4. ECOSYSTEM MONITORING

A detailed monitoring plan will need to be developed for the project as plans are finalized and permits are issued. Most restoration project measure a few fairly simple vegetation metrics (*e.g.,* percent cover of natives and non-natives, diversity, stature, etc.). While these usually are valuable metrics for assessing a project, other biological factors like general wildlife usage (*e.g*., bird surveys) or efforts directed at target species (e.g., tide water goby) are often more effective at demonstrating project benefits and impacts. Collection of data on physical metrics is equally important. Surface water measurements of things like salinity, depth, dissolved oxygen levels, nutrient levels and temperature are relatively easy to collect and are underlying factors that can explain things like wildlife usage and plant zonation. Other physical factors such as erosion and sedimentation dynamics, mouth dynamics and soil salinity are also useful in explaining biological patterns.

A comprehensive ecosystem monitoring program like this serves three primary purposes. First, monitoring is used to assess progress towards project goals and performance criteria. This might include specific requirements that come with funding sources for the actual implementation of the project. For instance, an in-lieu fee mitigation or other off-site mitigation funding source might come with much more complex performance criteria requirements than typical grant funding sources would. Second, monitoring should be used to support decision-making in the adaptive management program (see details below). Third, monitoring reports should contribute knowledge to the greater restoration community on the efficacy of the techniques and approaches used to implement the restoration project (*i.e*., the reports should be publicly available).

5. ADAPTIVE MANAGEMENT

Adaptive management is a tool for achieving success where there is considerable uncertainty as to what actions will be needed to accomplish specific goals. Ecological restoration is inherently filled with uncertainty. There are simply too many variables to control, especially in systems like the Ormond Beach Wetlands with its complex hydrology. Designing and implementing this project using an adaptive management approach will lead to better outcomes and help assure the project meets its goals.

The importance of using an adaptive management approach in ecological restoration has long been recognized, but in practice, it is seldom applied. In many cases, this is due to the fact that most biologists and engineers are reluctant to admit they are uncertain of how a project will proceed. In this conceptual plan, we have emphasized the need to restore ecosystem processes and let naturally functioning habitats develop over time. We only have our educated best guesses as to exactly how these processes will develop and evolve once earthmoving and hydro-modifications are complete. Careful analysis of as-built conditions and continuous hydrologic and salinity monitoring will provide guidance on early revegetation efforts in the wetlands. Elevation ranges may need to be adjusted for different species and communities. Pilot planting efforts (*e.g.,* using a limited number of plants to assess survival at different elevations) can help fine tune planting strategies before large numbers of plants are installed.

We have provided a plausible path towards developing more naturally functioning habitats at the site. We are confident that the site will support these habitats though the exact locations and proportions of given habitats are uncertain. Careful monitoring and experimental approaches should be used to help understand how the site is evolving and predict future conditions. Data should be used to inform changes to initial implementation strategies for all aspects of the restoration implementation, including erosion control, planting and weeding.

6. COST ESTIMATES

It is premature to estimate costs for revegetation of the site. The more detailed revegetation plan that will be developed based on the conceptual model (*see* Section 1.1 of this plan) will allow for more realistic budgeting. Ultimately, costs will depend on the strategies chosen (*e.g.,* seeding vs. planting, herbicide vs. no herbicide, etc.), yet to be determined details for the planting areas (*e.g*., need for soil amendments, availability of irrigation water, etc.), and phasing. As budgets for the revegetation effort are developed, it will be important to also include funds for longer term maintenance (at least five years) and ecosystem monitoring and reporting (at least annually for five years).

7. REFERENCES

Cowardin L., Carter V., Golet F., Laroe E. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Serv. Office of Biological Services. FWS/OBS-79/31. 103.