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Aramburu Island Shoreline Protection and Ecological Enhancement Project
Draft Enhancement Plan

April 19, 2010

Prepared for:
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Audubon CALIFORNIA

In Partnership with:
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MARIN COUNTY
OPEN SPACE DISTRICT
DEPARTMENT OF PARKS AND OPEN SPACE

Project No. 1145

Prepared in Collaboration with:
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1 Introduction

The Aramburu Island Ecological Enhancement Project (Project) is located on and adjacent to Aramburu Island in Richardson Bay, Marin County, California (**Figure 1**). The 17-acre island was originally part of Strawberry Spit, which was constructed in the late 1950s and early 1960s by the deposition of navigational dredging spoils and upland fill in the open waters of Richardson Bay. The island became a popular haul out site for harbor seals (*Phoca vitulina*) during the 1960s and 1970s. The northern portion of Strawberry Spit was made into Aramburu Island in 1987 by excavating a navigation channel in the middle of the Spit. The San Francisco Bay Conservation and Development Commission (BCDC) required creation of this shorebird and harbor seal refuge island as a permit condition for housing development on the spit. Following island creation, the developer deeded the island and its surrounding waters (a parcel 35.81 acres in total) to the Marin County Department of Parks and Open Space.

The Project purposes are to (1) increase the stability of the eroding eastern shoreline, (2) enhance and create aquatic, wetland and terrestrial habitats to support a range of target species and natural communities, and (3) provide a platform for ecosystem adaptation to sea level rise, allowing for gradual dynamic transitions. In addition, the Project seeks to meet the adjacent residents' goals of (1) not enhancing or creating habitats that would attract the state and federally listed endangered California Clapper Rail (*Rallus longirostris obsoletus*) that could interfere with their maintenance dredging permits, (2) not affecting sediment dynamics in the navigation channels that would affect maintenance dredging, (3) preserving existing view sheds, and (4) not encouraging increased public access to the island.

The renovated landscape of Aramburu Island would achieve a suite of new habitats emulating historic ecosystem structure in Richardson Bay, including sand and gravel beaches, high tidal marsh gradients, native seasonal wetlands , and lowland grasslands. The Project proposes to address erosion along the island's eastern shoreline with "soft"

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engineering conducive to shorebird and harbor seal use, instead of traditional rock rip-rap shoreline armoring that lacks ecological benefits. Three different natural shoreline design approaches will be applied to address the gradient of wave energy environments of the eastern shoreline. These soft shoreline engineering treatments will also serve as a demonstration project for the effectiveness of natural beach construction as an alternative to more traditional hardened engineering approaches to shoreline protection.

The Project design aims to facilitate gradual transition of estuarine and terrestrial habitats during the next many decades of forecasted accelerated sea-level rise. Slopes, sediments, vegetation, and shoreline structure will be modified to allow gradual beach retreat and transition from lowland grassland and seasonal wetlands to high tidal marsh during estuarine transgression (submergence due to sea-level rise).

The Project will contribute to the regional restoration effort presented in the Baylands Ecosystem Habitat Goals Report, which specifically identified the following recommended restoration and management actions for "Strawberry Spit" (of which Aramburu Island was formerly a part) and Richardson Bay (Goals Project 1999, p. 117 and Appendix D) that are incorporated into the conceptual design:

- Protect and enhance harbor seal haul-out sites at Strawberry Spit
- In Richardson Bay, restore and enhance fringing marsh along northwest edge for Point Reyes bird's-beak (*Chloropyron maritimum*)
- Restore and enhance tidal marsh
- Restore high marsh near populations of rare and uncommon salt marsh plants to enable their expansion

Wetlands and Water Resources, Inc. (WWR), in cooperation with Roger Leventhal, P.E. of FarWest Restoration Engineering and Peter Baye, Ph.D. coastal ecologist, have prepared this Draft Enhancement Plan for the Richardson Bay Audubon Sanctuary (the Sanctuary) and Marin County Department of Parks and Open Space (the County). This plan includes the following elements:

- Site Description (Section 2)
- Project Goals and Design Objectives (Section 3)
- Enhancement Design (Section 4)

2 Site Description

This section describes historic and current conditions on the project site and in the immediate vicinity that are pertinent to developing the restoration design.

2.1 History of Richardson Bay

The project site is located within Richardson Bay, a small, shallow, ecologically rich arm of San Francisco Bay that is surrounded roughly by the cities of Sausalito, Mill Valley, Belvedere, and Tiburon in Marin County, California (**Figure 1**). Historic U.S. Coast Survey maps of Richardson Bay prepared in the 1850s represented fringing salt marshes, small pockets of bay-head salt marsh and tidal creek systems, wide tidal flats, and barrier beaches (**Figure 2).** During the late 19th and early 20th centuries, many of the fringing marshlands and other shoreline habitats were filled, drained, or otherwise modified for residential and commercial development. These developments led to a decline in populations of native fish, waterfowl, shorebirds, and plants. In 1960, the National Audubon Society acquired the rights and responsibilities to manage 911 acres of baylands and adjacent uplands in Richardson Bay, thus creating the Richardson Bay Audubon Sanctuary (Griffin 1998). The Sanctuary is responsible for preserving, enhancing, and restoring the habitats of Richardson Bay for the benefit of birds, fish and other wildlife as well as native plants.

2.2 History of Aramburu Island and Harbor Seal Haul-Out

Aramburu Island is located in the northwest region of Richardson Bay on the east side of Strawberry Point. **Figure 3** displays a sequence of aerial photographs from throughout the island's history. The island was originally part of Strawberry Spit, an artificial peninsula off the mainland which was constructed in the late 1950s and early 1960s by the deposition of fill in the open waters of Richardson Bay. The fill originated from dredge spoils from local navigational channel maintenance, which were later capped with hillslope material excavated during the development of adjacent Strawberry Point. Fill deposition had ceased by 1964 and the spit slowly became colonized by vegetation, dominated by non-native species.

By the late 1960s, Strawberry Spit had become a popular haul-out area for harbor seals. A partially completed navigational channel through the northern part of the spit, which subsequently became a sheltered cove, was the primary haul-out site. During the winter of 1975 -1976 it was estimated that approximately one third of the total population of harbor seals in San Francisco Bay was using the spit as a haul-out site (Risenbrough et al. 1979). The seals hauled out at the spit primarily at night, likely due to human disturbances during the day (Paulbitski 1975). From the late 1970s to the early 1980s seal use at the spit declined dramatically. Seals were last observed hauling out on the spit in 1985 (Allen 1991) and have not been observed hauling out since. In 1976 the Marine Mammal Commission undertook a study of the population biology of harbor seals in San Francisco Bay. The report found that human disturbance was having a negative impact on seals hauling out at the spit and recommended reducing these impacts by turning the northern end of the spit into an island and redirecting boat traffic away from the primary haul-out site (Risenbrough et al. 1979).

In 1983, the development of 62 single-family homes on the southern half of Strawberry Spit was approved by Marin County and BCDC. As part of the BCDC permit conditions for this development, the following measures were required to mitigate for impacts to wildlife on the spit:

1. Dredge a 165 ft-wide channel through the spit, thus making the northern end into an island
2. Excavate a new seal haul-out cove 1,000 ft north of the original cove
3. Construct an earthen berm, fence, and landscaping at the south end of the island to serve as a visual buffer and post signs on the north end of the residential development identifying the island as sensitive wildlife habitat

These measures were implemented in 1987. The island is currently owned by Marin County and managed by the Marin County Department of Parks and Open Space. The Marin County Board of Supervisors dedicated the island as an open space and wildlife preserve in 1997. The last significant management action on the island itself, which occurred in 2006, was a major cleanup effort funded by both Marin County and the neighboring community to remove trash and other marine debris that had washed up on the island over the years.

In addition to the above listed mitigation measures, the maintenance dredging of the navigation channel changed in conjunction with island creation. Prior to island creation, the navigation channel traversed the east side of the spit (known as the "Salt Works Canal"). This navigation channel provided a deep-water channel along the eastern shoreline of the spit. Following island creation, the navigation channel was relocated to utilize the new cut through Strawberry Spit, thus abandoning the route along the east side of what became Aramburu Island. The abandoned navigation channel then filled in with sediment over time, eliminating the deep water channel along the east side of the Island. Harbor seal biologist Sarah Allen has hypothesized that this loss of deep water access to the former haul-out areas on the east side of Aramburu Island precludes their reoccupation and use by harbor seals (S. Allen, pers. comm.).

2.3 Surrounding Land Uses and Habitats

The Richardson Bay shoreline in the vicinity of the island is dominated by suburban development with some limited areas of open space. The island is bordered to the east by the 911-acre Richardson Bay Audubon Sanctuary, which contains several important aquatic resources including eelgrass beds, native oyster beds, and shorebird foraging and roosting areas (**Figure 4**). To the north of the island are two smaller islands of tidal marsh that were constructed of the same dredge material that built the foundation of Aramburu Island. These small islands, however, were not capped with upland fill material and thus have a much lower topographic profile than that of Aramburu. The mudflats adjacent to these islands are popular foraging grounds for shorebirds in Richardson Bay. The island is bordered to the south and west by a deep-water navigational channel that serves the local boating community. Several of the homes along Strawberry Spit and Strawberry Point have private docks and the Harbor Cove apartment complex to the northeast of the project site has a marina which also utilizes the navigational channel. Harbor seals, pelicans, egrets, grebes, cormorants, and other wildlife are commonly present in this dredged channel. These species are also common in the Richardson Bay Audubon Sanctuary waters, and in Richardson Bay outside of the Sanctuary.

2.4 Current Project Site Conditions

The 35.81-acre Project site consists of the island terrace (17.06 ac) and surrounding intertidal and subtidal "bay" habitats (18.75 ac). Within these two components of the Project site are nine "landscape units". **Figure 5** presents their location and **Table 1** provides the acreage of each unit. Representative site photographs of these features can be found in **Appendix A**. This Enhancement Plan will refer to each of these landscape units. These units are:

1) Island terrace unit
    - Uplands throughout the terrace (Photo 1)
    - Mid and high tidal marsh around the terrace margins (Photo 2)

- Non-tidal seasonal wetlands on the terrace interior (Photo 3)
- Gravel spits at the southeast corner of each of the two eastern coves (Photo 4)
- Rock rip-rap revetment at the south end (Photo 5)

2) Bay unit
   - Intertidal coves: two shallow excavated embayments on the east side and one on the west side, containing high mudflat and salt marsh (Photo 6)
   - Intertidal boulder lag field on the east side, originating from upland fill soils used to construct the island and exposed by erosion of finer grain material (Photo 7)
   - Intertidal mudflats of variable widths around the island (Photo 9)
   - Subtidal waterways bayward of the intertidal areas

Table 1. Landscape Unit Acreages, Existing Conditions

	Acreage	
Landscape Unit	**Subunit**	**Unit**
1) Island Terrace Unit (shoreline upward)		17.06
1.1 Tidal marsh	6.11	
1.2 Seasonal wetland	2.37	
1.3 Gravel spits	0.12	
1.4 Rock rip-rap revetment	0.19	
1.5 Upland	8.27	
2) Bay Unit (shoreline bayward)		18.75
2.1 Coves	1.98	
2.2 Boulder lag fields	10.28	
2.3 Intertidal mudflat	2.57	
2.4 Subtidal	3.92	
Total		35.81

The following sections describe the current site conditions in terms of topography and bathymetry, soils, hydrology, erosion and sediment transport, biological resources, jurisdictional areas, and cultural resources/infrastructure. The descriptions refer to these landscape units throughout.

2.4.1 Topography and Bathymetry

WWR collected topographic data on the island and bathymetric data in surrounding intertidal and subtidal areas in January 2009. **Figure 6** presents the digital elevation model (DEM) of the island and adjacent off-shore areas. All elevation data are referenced to the North American Vertical Datum of 1988 (NAVD88).

Island Terrace. The island terrace is relatively flat, with most of its elevations ranging between 6 and 10 ft. About 35% of the island terrace is tidal marsh at elevations ranging about MHHW (5.9 ft) ±~1 ft, with the marsh below MHHW commonly referred to as "mid marsh" and that above MHHW as "high marsh". The seasonal wetlands and uplands occupy elevations above the highest tides up to maximum island elevations of 10ft, which cover the remaining 65% of the terrace. The seasonal wetlands occupy depressions on the terrace interior. There is a long, elevated ridge along the center "spine" of the island and a small hill along the western shoreline. At the southeast corner of each of the two eastern abandoned harbor seal haul-out coves are gravel spits; their elevations range from about MHHW up to 8 ft. The southern terrace contains a rock rip-rap revetment along the constructed navigation channel with the rip-rap extending from about 10ft elevation down to the subtidal zone. The eastern side of the island terrace is characterized by a steep erosional scarp down to the intertidal boulder lag field; the scarp ranges in height from about 1 to 3 ft. The western and northern shorelines generally exhibit a more gradual transition to mudflats and, on the west, to the dredged navigation channel. These shorelines do exhibit some steep edges also.

Bay. The eastern shoreline consists of three segments of boulder lag fields, large rocks from the original upland-derived fill soils left behind from scour of finer fill soils. These lag fields range in elevation from about mean tide level (MTL) up to mean high water (MHW). East of the boulder lag fields are low-elevation intertidal mudflats grading gently down into the subtidal environs of Richardson Bay. Also on the eastern shore are two intertidal mudflat coves ranging around MTL ±1-1.5 ft, with gravel spits bonding the southeast corner of the coves and fringing tidal marshes at the terrace margins. Intertidal mudflats also fringe the island terrace on the west and north including occupying the third cove in the northwest corner of the site. The western shoreline continues to grade down from the mudflats into the dredged navigation channel.

2.4.2 Geology and Soils

Island Terrace

As described earlier, the island was constructed from navigational dredging spoils overlaid by hillslope fill material derived from the adjacent Strawberry peninsula. The USDA soil survey of Marin County indicates that the soils of Aramburu Island and Strawberry Spit are upland fill material (**Figure 7**). The soils of Strawberry peninsula, where this fill material originated, are Los Osos-Urban Land-Bonny Doon complex. These are well drained soils derived from weathered sandstone and shale and typically have a 10-40 inch profile of gravelly loam and clay overlying parent bedrock.

WWR and Audubon performed an investigation of sub-surface soil properties on Aramburu Island in September 2009. In this investigation we dug four deep trenches along the north-south axis of the island (**Figure 8**) using a small excavator and characterized the soil profile. The results of this investigation are presented in **Appendix B**. In general, the soils are characterized by a layer of rocky, upland fill material from three to seven feet thick overlaying navigational dredge spoils and native Bay mud (**Figure 9**). The thickness of this fill layer increases from south to north. Approximately 25-50% of the fill layer is composed of rock material. The division between the upland and marine material layer occurs between 5.5 and 1.5 ft NAVD88. We observed groundwater saturation at 2.6 ft NAVD88 in Pit 2, 0.1 ft NAVD88 in Pit 3, and 4.1 ft NAVD88 in Pit 4. The groundwater salinity was around 20 ppt, indicating that the Bay was the primary water source at the time of the investigation.

Bay

On the eastern side of the island and within the footprint of the originally-constructed northern tip of Strawberry Spit that is now Aramburu Island are three segments of boulder lag fields (**Figure 5**). This boulder lag consists of a variety of angular rock sizes from about 4 to 15 cm. This rock fill originally came from the adjacent hill slopes and has been eroded from the island terrace over time (see Section 2.4.4 below). Interspersed amongst these rocks are interstitial fine sediments, mainly sands, silts and clays. Beyond these boulder lag fields are typical intertidal and subtidal silt-clay mudflats of Richardson Bay. North of the island terrace is further silt-clay intertidal and subtidal mudflats. West of the island is a modest band of silt-clay intertidal mudflat that slopes down into the dredged navigation channel.

2.4.3 Hydrology

Table 2 presents the tidal datums at Sausalito. Most of the island terrace, with the exception of a few fringing tidal wetlands, is above the normal range of the tides. However, the presence of wrack lines and salt tolerant vegetation indicate that certain areas are occasionally subject to storm overwash. There are a few small groves of oak trees on the island, indicating that a perched, fresh groundwater table exists in certain areas of the island. There are also several seasonal wetlands found throughout the island which are fed by rainwater and, in some locations, overwash during storm events. As described above in Section 2.4.2, we found saline groundwater saturation at various depths below ground surface, indicating that the Bay was the primary groundwater source at the time of sampling. Salinity levels in Richardson Bay normally range from 24 to 33 parts per thousand (ppt), depending on the time of year (Audubon Center, unpub. data). Though our field investigation took place in September, near the end of the dry season, we would expect that direct rainfall would contribute to shallow groundwater during wet times of the year. The subsurface lithology and presence of oaks (low salinity tolerance) on the island also suggest that perched, freshwater lenses may occur in some areas.

Table 2. Tidal Datums, Sausalito

Tidal Datum for NOS 941-4806 [1]		Elevation (ft NAVD88)
Highest Observed Water Level [2]	(HOWL)	8.48
Mean Higher High Water	(MHHW)	5.86
Mean High Water	(MHW)	5.26
Mean Tide Level	(MTL)	3.29
Mean Low Water	(MLW)	1.31
Mean Lower Low Water	(MLLW)	0.17
Lowest Observed Water Level [3]	(LOWL)	-2.54

[1] National Ocean Service. 2004. Tidal Benchmark, Sausalito, CA. Feb 5. Period of record 11/77 - 10/79
[2] HOWL observed 1/9/78
[3] LOWL observed 5/5/77

2.4.4 Erosion and Sediment Transport

The eastern island shoreline faces the open fetch of Richardson Bay at an oblique angle and is therefore exposed to high wind-wave energies generated from southeasterly storms. This exposure to wind-wave action has caused a significant amount of erosion and longshore drift along the eastern island shoreline. Shoreline erosion cuts a low cliff or scarp (vertical face) in the island fill, and leaves behind a deposit of cobble and boulder lag material in the footprint of the original island fill. This lag deposit armors bay mud, making the intertidal zone unsuitable for many soft-sediment invertebrate infauna and shorebird foraging. The width of the lag footprint gives an indication of the amount of erosion that has occurred since the island's creation; although the width of the footprint varies across the length of the shoreline, it is on average around 75 ft. Assuming fill deposition ceased in 1964, the eastern shoreline has experienced an average erosion rate of 1.6 ft/year. However, much of the erosion likely occurred in the first few years prior to vegetation establishment. Historical aerial photograph analysis of shoreline erosion beginning in 1970 (when vegetation was well established on the island) indicates that between 15 and 36 ft (depending on location) of erosion has occurred since that time (**Figure 10**), leaving a considerably large amount of erosion to have occurred between 1964 and 1970.

The island fill material contains insufficient sand and gravel sediments to form substantial bay beaches in response to waves. Limited gravel supply does form small gravel beaches at the toe of the eroded scarp. Storms easily transport and rework the gravels that makes up these deposits and beach forms are constantly changing in response to the local wind-wave climate. The dominant direction of material transport (longshore drift) along the shoreline is to the northwest. As such, gravel beach deposits tend to accumulate along the southern face of small shoreline promontories and other obstructions. Northward transported gravel also accumulates along the shoreline gravel spits across the excavated coves in the east-facing shoreline. A study of grain size distributions in various eastern shoreline features is presented in **Appendix C**, while a study of shoreline material transport in response to a large storm event in October 2009 is presented in **Appendix D**.

2.4.5 Biological Resources

WWR and Audubon Center staff evaluated the project site biological conditions and performed a full floristic inventory in the spring of 2009 and an informal oyster survey in the fall of 2009. These surveys provided input to enhancement opportunities and also to determining the potential for special status species that, if present, would have to be addressed during regulatory compliance. The results of these biological surveys are described in detail in the project Biological Assessment document (Audubon and WWR 2010) and summarized below.

Plant Communities

Aramburu Island is dominated by patchy, heterogeneous non-native terrestrial vegetation that has colonized the artificial fill substrate. The weedy plants of the Aramburu uplands reflect the prevalent weeds of the adjacent Tiburon and Strawberry residential landscapes and semi-wild vegetation of small, undeveloped patches within it; other native terrestrial vegetation has established within the matrix of non-native weeds. Some native plant populations appear to be remnants of past artificial plantings, including the small stand of coast live oak at the north end of the island. The tidal wetlands along the edges of the island have developed partly on artificial fill substrate, and partly on naturally deposited bay mud (estuarine silt and clay). These tidal wetlands, in contrast with uplands of the island, support mostly native salt marsh vegetation. Non-tidal seasonal wetland flats and depressions within the terrestrial vegetation support mostly non-native vegetation. The plant communities in each of these habitats are described below. The 2009 vegetation map of the island is presented in **Appendix E** along with the complete floristic inventory, while **Figure 11** displays the distribution of native vs. non-native dominated vegetation stands.

Terrestrial (Upland) Areas. The island's terrestrial (upland) vegetation stands include the following local dominant non-native (and mostly invasive) species: Harding grass (*Phalaris aquatica*), iceplant (*Carpobrotus edulis* x *chilensis*), French broom (*Genista monspessulana*), Italian thistle (*Carduus pycnocephala*), vetches (*Vicia* spp.), bromes (*Bromus diandrus*), fennel (*Foeniculum vulgare*), wild oat (*Avena fatua*), and acacia (*Acacia decurrens).* These are all common weeds on the adjacent mainland. The vegetation of the island's uplands is unstable: French broom appears to be expanding rapidly into grass-dominated stands, based on the distribution of seedlings and juvenile plants. Iceplant also appears to be expanding into low-growing forb and grass stands. Acacia saplings are encroaching low vegetation surrounding seed-bearing mature trees.

The upland vegetation of the island does contain some native plant species that are locally common in a few areas, which are likely the remnants of past plantings. Most native woody species occur at low density, and exhibit either low vigor or significant dieback. None appear to be spreading. Native coyote-brush (*Baccharis pilularis*) is a subdominant shrub among Harding grass and vetch stands at the south end of the island. Small stands of native purple needlegrass (*Nassella pulchra*) are co-dominated by weeds such as bird's-foot trefoil (*Lotus corniculatus*) and vetch at the north end of the island, along with small patches of sky lupine (*Lupinus nanus*) limited to areas where taller non-native grasses and weeds such as Harding grass and Italian thistle are absent. The most important native vegetation are plantings of coast live oak (*Quercus agrifolia*) which form a grove at the edge of the northern salt marsh cove. The understory of the oaks is composed mostly of non-native grasses and French broom.

Seasonal Wetlands. Seasonally wet flats within the uplands (seasonal wetlands above tidal influence) are also dominated by heterogeneous non-native vegetation stands, most of which have been grazed to a low turf by Canada geese. These wetlands grade into non-wetland vegetation along drainage gradients within flats and depressions. Dominant non-native species of the seasonal wetlands include widespread weeds such as bird's-foot trefoil, hyssop-leaf loosestrife (*Lythrum hyssopifolium*), brass-buttons (*Cotula coronopifolia*), and wild barley (*Hordeum murinum* ssp. *gussoneanum*). These include patches of common native species such as coast tarweed, *Madia gracilis or M. sativa*.

Tidal Marsh. The tidal marsh vegetation is composed of patchy mixed stands dominated by pickleweed *(Sarcocornia pacifica*), alkali-heath (*Frankenia salina*), and California sea-lavender (*Limonium californicum*). Non-native vegetation within tidal marshes fringing the island includes iceplant extending down from uplands, and large patches of a European spurrey species, *Spergularia media*, a regionally uncommon salt marsh weed that is locally abundant in Richardson Bay. Tidal marsh edges are dominated by iceplant and non-native grasses in most parts of the island, but three patches of a regionally uncommon native sedge, *Carex praegracilis*, form the upland transition zone locally. Native saltgrass *(Distichlis spicata*), usually mixed with iceplant, also forms transition zone patches.

Sensitive Plant Communities

Only the narrow fringe of tidal marsh vegetation on the island can be classified meaningfully within standard California vegetation classification systems such as the Manual of California Vegetation (Sawyer *et al*. 2009) or the California Department of Fish and Game (CDFG) CNDDB Vegetation Classification and Mapping Program (CDFG 2003). The fine-scale, patchy heterogeneous non-native vegetation of the island's uplands contains only minor inclusions of native species, and comprises irregular combinations of dominant species. These are treated as "semi-natural stands", following Sawyer *et al.* (2009), and have been mapped as local stands based on local dominants and subdominant weed species. The small areas with significant native plant cover are remnants of artificial plantings, and of these, only coast live oaks dominate any vegetation layer.

Special Status Plant Species

No sensitive, rare, threatened or endangered plant species have been observed on Aramburu Island during multiple winter, spring, summer, and fall vegetation surveys and wetland delineations. Aramburu Island's recent creation (four decades ago) out of artificial fill soils and its current weed-dominated condition do not provide suitable habitat for any special-status terrestrial plants species. No special-status plant species are known from neighboring mainland native vegetation remnants, such as the Richardson Bay Audubon Sanctuary. Tidal salt marshes in southern Richardson Bay and Corte Madera do support significant large populations of one special-status plant, northern salt marsh bird's-beak (*Chloropyron maritimus* ssp. *palustre*; syn. *Cordylanthus maritimus* ssp. *palustris*). None were found on Aramburu Island and neighboring Strawberry School tidal marsh during the early summer/late spring peak flowering period, when they were conspicuous and abundant in southern Richardson Bay. No bird's-beak populations have been observed in northern Richardson Bay (P. Baye, pers. obs. 1991-present). The only other (nominally) sensitive species known to occur in the Richardson Bay-Corte Madera shoreline area is "Marin knotweed", *Polygonum marinense*. This species has spread rapidly through the Bay in recent decades like an invasive species, which it may be: taxonomic doubts suggest that it may be a misidentified non-native species of *Polygonum* (Flora of North America 2009; Hickman *et al.* 1993). None has been found on shorelines or seasonal wetlands of Aramburu Island. No other sensitive plant species are known to occur or expected at the site or hillslopes and filled lands in surrounding residential areas.

Special Status Wildlife Species

Review of the California Natural Diversity Database (CNDDB) and knowledge of the project region identified six special-status bird species that could potentially occur on the project site. Three of the species have a low likelihood of occurrence due to the presence of marginal or poor habitat conditions: **California clapper rail** (*Rallus longirostris*), **California least tern** (*Sternula antillarum browni*), and **Northern harrier** (*Circus cyaneus*). The species with the greatest likelihood of occurring on site include: **Double-crested cormorant** (observed at the site) (*Phalacrocorax auritus)*, **White-tailed kite** (occasionally observed foraging in Richardson Bay) (*Elanus leucurus)*, and **San Pablo song sparrow** (*Melospiza melodia samuelis*). Harbor seals protected under the

Marine Mammals Act occur seasonally in the adjacent navigation channel, but have not hauled out on the island since the 1980s (Allen 1991).

Native Oysters

The Audubon Sanctuary conducted a cursory survey for native Olympia oysters (*Ostrea lurida*) along the Aramburu Island shoreline in January of 2010 (**Appendix F**). They found a large number of oysters, ranging in size from 0.5 to 4.5cm, on the underside of rocks that were at least 6" in diameter. The most heavily colonized rocks had up to 15 oysters on them, which is the highest concentration of native oysters observed to date within the Sanctuary (**Figure 4)**. Most of the oysters occurred between approximately 1 and 2ft MLLW (1.2ft - 2.7 ft NAVD88). The oysters were most heavily concentrated in the southern half of the island shoreline where rock sizes are the largest.

2.4.6 Jurisdictional Wetlands, Tidelands, and Shorelines

WWR developed jurisdictional determinations for the federal Clean Water Act (CWA) and Rivers and Harbors Act (RHA) (Corps) and for the state McAteer-Petris Act (BCDC).

U.S. Army Corps of Engineers

WWR conducted a jurisdictional delineation in late April/early May, 2009 to identify areas subject to the jurisdiction of the U.S. Army Corps of Engineers (Corps) under Section 404 of the CWA and Section 10 of the RHA. In this effort, we delineated all areas falling within the parcel boundary of the island (including the island terrace and surrounding open water areas). The delineation was verified by the Corps in October 2009. The results are presented in the official project wetland delineation report (WWR 2010B) and are summarized below. The locations of all jurisdictional Waters of the U.S. are displayed in **Figure 12**.

The tidal water areas surrounding the island, up to the elevation of MHW (5.3ft NAVD88), are subject to Corps jurisdiction under RHA Section 10 as navigable waters (18.539 ac). These areas, and additional tidal water areas between MHW and the elevation of the local high tide line (HTL) (0.390 ac), are also subject to Corps jurisdiction under CWA Section 404 as "other waters". There are a total of 8.476 ac of wetlands on the project site that fall under Section 404 jurisdiction. Of these, 1.121 ac are below MHW and are thus subject to Section 10 jurisdiction as well, with the remaining 7.355 acres subject to Section 404 jurisdiction only. The wetlands on the site fall into two general categories: tidal marsh (6.109 ac) and non-tidal seasonal wetlands (2.367 ac), the location of which are shown in **Figure 13**.

Bay Conservation and Development Commission

Almost the entire extent of the project site is within BCDC jurisdiction (35.228 ac of 35.805 ac total) (**Figure 14)**. There are 24.648 ac that fall under BCDC Bay jurisdiction: open waters of the Bay (18.359 ac), tidal marshes on the island terrace (6.109 ac), while 10.580 ac on the island terrace fall under Shoreline Band jurisdiction, which extends 100 ft inland from the landward limit of Bay jurisdictional areas.

2.4.7 Cultural Resources and Infrastructure

As the island was constructed from imported fill material in the late 1950's and early 1960's and never developed, we assume there are no significant cultural resources present on the site; however, a full archeological investigation has not been performed. There are several small, manmade structures present on the site including defunct groundwater monitoring wells, wooden signs, navigational pilings, and a chain-link fence. There are no utility lines (PG&E, water, cable, etc.) on the property.

2.5 Opportunities and Constraints

The purpose of this section is to describe how the current conditions on and surrounding the project site provide both opportunities and constraints for shoreline protection and ecological enhancement and creation. These opportunities and constraints guided the development of the enhancement design described in Section 4. We have identified the following opportunities and constraints, which are described in detail below:

1. Ecological resources
2. Topography and hydrology
3. Soils
4. Invasive plants
5. Adjacent land uses

2.5.1 Ecological Resources

The project site and regional setting provide a unique opportunity to enhance and create a variety of habitats that can benefit many native species. The fact that the site is an undeveloped island, already designated as a wildlife preserve, makes it a highly desirable target for habitat enhancements in the urbanized Richardson Bay region as it is relatively isolated from human disturbance and terrestrial predators. The island is also adjacent to the 911-acre Richardson Bay Audubon Sanctuary, which provides and protects many important habitat resources for native species. In its current configuration the Project site supports several different habitat types including intertidal shoreline, tidal marsh, seasonal wetlands, non-native grasslands and scrub, and a short linear planting of coast live oaks, many of which are in a degraded state (tidal marsh being the exception). The limited functions of existing habitats provide an opportunity to improve ecological conditions that would provide benefits to the following native plants and wildlife:

- **Harbor seals** may benefit from expanded and new bay beach habitat that provides potential haul-out habitat.
- **Shorebirds** may benefit from expanded and new bay beach and seasonal wetland habitats that provides additional foraging and high-tide roost habitat.
- **Waterfowl (dabbling ducks) and wading birds (herons and egrets)** may benefit from seasonal wetland enhancements that provide foraging and roosting habitats.
- **Rare salt marsh plants** may benefit from establishment of gentle shoreline slopes providing suitable upper intertidal transition zones for reintroducing populations of some rare tidal marsh edge and subsaline vernal pool plant species.

2.5.2 Topography and Hydrology

Elevations on the artificial island range from subtidal (<0 ft NAVD88) at the property margins, to 4 ft above the range of the tides (>10 ft NAVD88) in the island interior. There is no natural topography on the island to preserve or protect, allowing for recontouring the island terrace and shoreline. Establishing a new estuarine beach profile and a new, gentler backshore profile will allow gradual beach retreat and tidal marsh submergence and transition from lowland grasslands and seasonal wetlands to new tidal marsh. This gradual transition would replace the existing unstable vertical erosional scarp of the eastern shore, which provides no transition – just an abrupt collapse of uplands and erosion to the intertidal boulder lag field shoreline. The gentler shoreline topographic gradient, combined with the dynamics of an expanded estuarine beach, should enable the shoreline to self-adjust and adapt to forecasted accelerated sea level rise and extreme storm events. The undeveloped, detached island shoreline provides an excellent opportunity to build, test, and monitor a “soft” shoreline protection system consisting of gravel/sand beach habitats as opposed to conventional rock rip-rap armoring.

2.5.3 Soils

The surface soils on the uplands are well-drained, coarse rocky hillslope fill material with inclusions of drained, dredged bay mud with irregular artificial topography. As such, these soils are poor foundations for the types of seasonal wetlands and native lowland transitional grasslands that depend on deep clay loam soils that restrict infiltration of rainwater, provide substrate for roots and rhizomes of creeping plants, and hold soil moisture in spring and summer. Seasonal wetland areas would benefit from compaction of underlying soils to increase water retention. Addition of clayey soils to provide a thin cap over stony fill would, in some seasonal wetlands, increase habitat diversity by supporting the development of creeping perennial spikerushes and sedge turf. Lowland grassland areas, providing transitions from tidal marsh edges to terrestrial lowlands of the island, would also benefit from addition of clayey soils to support dense growth of creeping native grasses, sedges, and forbs.

2.5.4 Invasive Plants

The island is dominated by weedy, non-native vegetation, which has resulted in the accumulation of a large weed seed bank. Many of the invasive species on the project site, such as French broom and acacia, produce highly persistent seeds that can remain viable in the soil for many years (in the case of French broom, it can be in excess of 25 years). Any native plant revegetation effort on the project site that occupies the existing surface soil profile with its legacy of weed seed banks would be subject to overwhelming dominance of accumulated weed seeds. Since we assume the use of pre-emergent herbicides is precluded in the sensitive estuarine and Sanctuary setting, managing successful revegetation will require either (1) removal (excavation) of the existing weed seed banks, (2) deep burial of the existing weed seed banks, or (3) establishment of new soil conditions (such as high salinity) that would severely inhibit or kill emerging weed seedlings, while promoting native revegetation.

The adjacent residential landscape also provides a chronic rain of weed seeds to the island, dispersed by wind and birds. This constraint of the landscape matrix on the island habitat affects goals to minimize active maintenance and wildlife disturbance. It sets up a need to design habitats that tend to exclude weed dominance by either vegetation structure (competitive exclusion) or physical environmental stresses.

2.5.5 Considerations for Adjacent Land Uses

The island is adjacent to Strawberry Point and Strawberry Spit, which have residential housing developments. It is the intention of the Richardson Bay Audubon Sanctuary and Marin County that shoreline protection and habitat enhancement activities do not cause a nuisance to the residents of these areas. In particular, this Plan avoids the following nuisances:

- Increasing the production of mosquitoes in seasonal wetlands over current levels
- Obstructing the viewshed of neighbors by dramatically increasing the elevation profile of the island or planting large trees
- Restricting the ability of boaters and adjacent property owners to use or maintain the deep-water navigational channel adjacent to the island
- Ongoing routine use of noise-generating motorized equipment for vegetation maintenance
- Significant increases of human intrusion on the sanctuary for maintenance or monitoring

3 Project Goals and Design Objectives

This section describes the overarching goals of the project and the specific design objectives that will allow us to meet these goals.

3.1 Project Goals

The Aramburu Island Enhancement Project has six primary goals:

1. **Reduce erosion along the eastern shoreline**
2. **Enhance island resilience to sea-level rise**
3. **Enhance habitats for shorebirds, waterfowl, and wading birds**
4. **Enhance suitability of haul-out habitats for harbor seals**
5. **Enhance habitats for rare salt marsh plants**
6. **Establish native vegetation on the island terrace**

These goals, described in further detail below, were developed in close collaboration with Audubon, Marin County, and meetings with local community members, based on the opportunities and constraints identified above in Section 2.5. Project goals were informed by the Baylands Ecosystem Habitat Goals Report, which specifically identifies the following recommended restoration and management actions for "Strawberry Spit" (of which Aramburu Island was formerly a part) and Richardson Bay (Goals Project 1999, p. 117 and Appendix D):

- Protect and enhance harbor seal haul-out sites at Strawberry Spit
- In Richardson Bay, restore and enhance fringing marsh along northwest edge for Point Reyes bird's-beak (*Chloropyron maritimus* ssp. *palustre*, syn. *Cordylanthus maritimus* ssp. *palustris*)
- Restore and enhance tidal marsh
- Restore high marsh near populations of rare and uncommon salt marsh plants to enable their expansion

3.1.1 Reduce Erosion along the Eastern Shoreline

The eastern island shoreline faces the open fetch of Richardson Bay at an oblique angle and is therefore exposed to high wind-wave energy generated from south-approaching storms. The artificially steep erosional scarp of the eastern shoreline of Aramburu Island contains fine sediment and provides waves a chronic source of additional fine sediment in response to steep, high wind-waves at high tide. This source of fine sediment, combined with natural erosional events (southerly storms coinciding with spring tides) lead to pulses of suspended sediment in the water column that may be detrimental to adjacent eelgrass beds and aquatic biota.

The unstable and steep erosional scarp is progressively retreating, and is not reaching a gently sloping, equilibrium profile. Unlike the dredge material islands to the north of Aramburu Island, which are made of dredge material only, the residual substrate resulting from erosion of the scarp is a lag "pavement" of intertidal boulders and cobbles that inhibits natural salt marsh formation or formation of valuable soft-bottom intertidal mudflat. It also perpetuates a steep cliff shore profile that acts as a barrier to use by seals as haul-outs (ramp-like access between uplands and deepwater escape habitat), as they did in the early stages of the island's history. The island fill contains insufficient sand and pebble content to generate beach-size sediments to establish gentle shoreline slopes that buffer shoreline erosion and provide shorebird high tide roost habitats and potential suitable seal haul-out habitats as it retreats. Thus, the island is likely to collapse as it erodes with rising sea level, rather than make a transition to more valuable and resilient habitat types. Loss of the island would also leave the adjacent

Strawberry shoreline without the protective buffer against wind-wave erosion that the island currently provides. Our rehabilitation design utilizes "soft" shoreline stabilization techniques in the form of beach nourishment to reduce erosion rates while at the same time providing functional transitional habitats (beach and sheltered backshore grassland, salt marsh) to benefit native wildlife and plants.

3.1.2 Enhance Island Resilience to Sea-Level Rise

In its current condition the project site has an abrupt, unstable divide between uplands and intertidal habitats, marked by the unstable, steep, retreating erosional scarp. This unstable shore profile has no significant resilience to storm wave impacts and sea level rise. The proposed design creates a gentle ramp-like backshore profile and provides coarse beach sediment (gravel, shell, and sand) and low groin-like features to maximize potential buffering of wave erosion by beaches and increase residence time of beach materials. The beach and low-angle shore profile would transform the island from wave-reflecting to wave-dissipating profile, and change shoreline dynamics from progressive scarp erosion to gradual beach transgression (landward migration with rising sea level). This approach would provide the geomorphic foundation for gradual transgression and ecological transition of native vegetation and habitats associated with the renovated shoreline. These modifications are expected to allow the island habitats to adapt to forecasted sea level rise for the coming decades with a succession of valuable transitional intermediate habitats, instead of resulting in the progressive erosion of the island and formation of a boulder lag pavement with limited habitat value to priority wildlife species.

3.1.3 Enhance Habitats for Shorebirds, Waterbirds, and Wading Birds

The current state of the eastern shoreline of Aramburu Island (steep erosional scarp and boulder-armored substrate) does not provide adequate foraging or high-tide roosting habitats for shorebirds. Enhancing the shoreline through beach nourishment and stabilization will improve foraging and roosting habitat functions for these species. Also, enhancing habitats on the island terrace such as seasonal wetlands, pans, and transitional grassland areas will provide additional foraging, roosting, and nesting habitats for shorebirds, as well as waterbirds and wading birds.

3.1.4 Enhance Suitability of Haul-Out Habitats for Harbor Seals

The part of Strawberry Spit that is now Aramburu Island was once a popular haul-out site for harbor seals in San Francisco Bay. The island itself was created to provide a refuge for these seals after the southern half of the spit was developed. However, a number of factors including human disturbance levels, erosional steepening of the shoreline profile, and loss of deep-water areas adjacent to suitable haul-out sites, were associated with the seals abandoning the island. By improving haul-out site conditions through beach nourishment and re-establishing a connection to deep-water escape areas, the site may become attractive for seal use again.

3.1.5 Enhance Habitats for Rare Salt Marsh Plants

The soils of Aramburu Island provide an uncommon opportunity to enhance and create new high tidal marsh habitats for certain rare salt marsh plants found elsewhere in Richardson Bay. Gentle slopes on natural terrestrial soils at the high tide line have been replaced by levees throughout most of the San Francisco Estuary. Stony terrestrial soils at the high tide line inhibit growth of dominant native salt marsh plants such as pickleweed and saltgrass, and provide vegetation gaps and sparse, turf-like vegetation favorable for rare native annual forbs (broadleaf flowering plants) and other native perennial salt marsh forbs that are naturally fugitives from competition with dense pickleweed. The project design includes this now scarce terrestrial soil-based high salt marsh transition zone. Three annual native salt marsh plants, salt marsh bird's-beak (*Chloropyron maritimus* ssp. *palustre*), salt marsh owl's-clover (*Castilleja ambigua*), and smooth goldfields (*Lasthenia glabrata* ssp. *glabrata*) are proposed for reintroduction in this enhanced habitat. The latter two species also occur in alkaline or saline vernal pools.

3.1.6 Establish Native Vegetation on the Island Terrace

In its current condition, the habitats on the island terrace are dominated by non-native, weedy vegetation. Re-conditioning the substrate on the island to favor native plants, combined with intensive planting and seeding with native species, is expected to result in approximate replication of native shoreline vegetation types that have become scarce in Marin baylands, but are expected to be well-adapted to the modified island and transition to other vegetation types as sea level rise. These include lowland grassland and sedge meadows (saltgrass, creeping wildrye, field sedge, basket sedge, alkali-heath) and seasonal wetlands (spikerush, field sedge, vernal pool wildflowers). The resulting renovated and transitional native vegetation stands are expected to benefit native wildlife species.

3.2 Design Objectives

To achieve the above-stated project goals, the enhancement design for Aramburu Island has the following objectives:

1. **Enhance shoreline beach habitats** to provide habitats for shorebirds and harbor seals, and to buffer the shoreline against erosion;
2. **Provide deep-water seal access on the eastern shoreline** to encourage use of enhanced beach habitats;
3. **Enhance and create high tidal marsh** to provide habitats for rare salt marsh plants;
4. **Enhance and create seasonal wetlands** to provide habitats for migratory shorebirds, wading birds, and waterbirds;
5. **Enhance terrestrial grassland areas** to provide habitats for native vegetation;

4 Shoreline Protection and Ecological Enhancement Designs

The Aramburu Island shoreline protection and ecological enhancement designs include several innovative ways to achieve the Project goals and objectives and therefore has the opportunity to serve as a valuable demonstration of these approaches for San Francisco Bay. The Project designs can be divided into two broad components, which may or may not be implemented concurrently:

1) **Shoreline** protection and enhancement on the island east side (Objectives 1 and 2)
2) **Island terrace** enhancements (Objectives 3-5)

This Enhancement Plan presents approaches for the two landscape units: shoreline and island terrace. For the **shoreline** (Section 4.1), we present one enhancement alternative that combines several different design elements. Originally, we had considered multiple design alternatives but after examining their ecological outcomes, shoreline protection benefits, and construction costs, we determined that the alternative presented here is the most effective approach. For the **island terrace** (Section 4.2), we have identified several enhancement elements that can be combined in various ways to result in multiple enhancement alternatives. All alternatives achieve the Project goals and objectives though with variations in the details of their ecological outcomes; the description for each alternative describes these details. The selected island terrace enhancement alternative will be based on consideration of the ecological outcomes, results of environmental review, construction costs, and available construction funds.

4.1 Shoreline Protection and Ecological Enhancement

The shoreline protection and ecological enhancement design represents one of the innovative aspects of the Aramburu project. We propose to combat shoreline erosion and rebuild the shoreline while providing important habitats for birds and seals using a "design from nature" based approach to the shoreline design. Aramburu Island offers this relatively rare opportunity because we have the flexibility to recontour the uplands (to shift shoreline landward) rather than the traditional case where the uplands must be retained thereby forcing all work to be bayward of the shoreline. The design involves rebuilding a natural gravel/sand/shell beach system using three different approaches aligned with the local wave energy gradient of the Aramburu eastern shoreline and the available room to lay back the beach slopes into the island terrace. This section summarizes the key elements of the proposed shoreline design and **Appendix G** contains a memorandum presenting the more detailed engineering design basis and calculations for the shoreline design.

The aim of the shoreline demonstration aspect of the project is to show that there are habitat-compatible alternatives to traditional coastal engineering approaches for addressing shoreline erosion, especially in the relatively low wave energy environment of San Francisco Bay (where significant waver heights rarely exceed 3 to 4 feet). Given the undeveloped character of the site and the historic former gravel spit in the project vicinity, we recommended that a demonstration project to construct a natural dynamic shoreline consisting of three different shoreline design approaches was the most appropriate erosion control design approach for this location. These approaches include (1) augmenting an existing gravel spit with oyster shell, (2) flattening the backshore profile to allow for placement of a sand/gravel mix, (3) constructing a gravel storm berm and foreshore in the higher wave energy part of the shoreline. The range of design approaches will allow for an evaluation of the effectiveness of different approaches depending on the wave climate and the amount of space available to lay back the beach slope.

4.1.1 Design Rationale

The shoreline protection and enhancement features described herein were designed based on conditions observed at beach systems around San Francisco Bay with variable exposure to wave energy, equal or greater than wave exposure at Aramburu Island. We investigated beach slopes and beach material grain size at five reference sites that represent a range of wave energy exposures and substrate types (**Figure 15**). The data report from this study is presented in **Appendix H**. In addition, we investigated topography (**Figure 6**), material grain size distribution (**Appendix C**), and particle transport (**Appendix D**) along the eastern shoreline of Aramburu Island, which informed us of which shoreline protection and enhancement elements would be most stable at the Project site. **Appendix G** describes in detail how all these data were analyzed and applied to the design of the Aramburu Island shoreline enhancement. Representative photographs of reference sites for the various shoreline enhancement elements can be found in **Appendix A**.

4.1.2 Design Elements

For design purposes, the eastern shoreline of Aramburu Island was divided into three shoreline segments or cells based on consistency of geomorphic features and apparent incident wave energy (**Figure 16**). The cells are marked by discontinuities to longshore sediment transport, caused by the artificially excavated coves of the eastern island shoreline.

The northern cell extends from the north-east corner of the island down to the first cove, a distance of approximately 475 linear ft. The northern cell has the gentlest, dissipative shore profile, protected by wide mudflats in all directions. It exhibits the lowest wave energy impacts (very low scarp, confined to the south "headland" end of the cell) and contains a long, narrow gravel beach with very limited sediment supply. The central cell is the largest segment of the shoreline. It extends between the two coves for a length of approximately 1,000 linear ft. This cell shows more evidence of wave-cut scarp erosion (up to approximately 2.5 ft high) than the northern zone. The southern cell extends approximately 375 ft from the southern cove south to the end of the island. This southern cell experiences the highest wave energy due to the deeper water and steep shoreline profile at the mouth of the dredged navigation channel, allowing direct attack from wind-waves propagating across the long southerly fetch to the Golden Gate. The angle of wave attack from southerly wind-waves is oblique to the shoreline, resulting in northward longshore transport of coarse sediment at the shoreline.

The proposed dynamic shoreline protection and beach design proposed for Aramburu consists of different shoreline treatments for each cell. Since the goal is a demonstration project with variable locally adapted shoreline treatments, the apparent alongshore wave energy and erosion gradient along the eastern shore of Aramburu Island facilitates the implementation of different shoreline design alternatives adapted to different local wave energy microclimates. Subsequent monitoring will assess the effectiveness of these different shoreline treatments along the shoreline erosion/wave energy gradient. A plan view of the shoreline enhancement features is presented in **Figure 16. Table 3** provides a matrix of the suite of design elements and how they are applied to each of the shoreline cells.

Table 3. Shoreline Protection and Enhancement Construction Elements

Shoreline Protection and Enhancement Elements	Shoreline Cells		
	North Cell	**Central Cell**	**South Cell**
1) Beach Habitats			
Oyster Shell Beach	X		
Sand/Gravel Beach		X	
Gravel Beach Berm			X
Sand Foreshore	X	X	
2) Beach Retention Features			
Beach Retention Micro-Groin	X	X	X
Sand Foreshore Retention Micro-Groin	X	X	
3) Seal Access Channel			X
4) Large Woody Debris	X	X	X
5) Grade Gentle Profile into Island Terrace		X	

North Cell

The northern cell experiences the lowest wind-wave energy environment across the site; it is located farthest from wind-waves approaching from the maximum fetch to the south, and is most protected by wave energy dissipation of mudflats. Rather than regrade and import sand/gravel to rebuild a beach profile, we propose to supplement the existing gravel/shell berms with San Francisco Bay dredged native oyster shell "hash" (a mixture of shell fragments of variable sizes and shapes) to provide a wider, higher beach profile, with more consolidated habitat area that is more visible and attractive to shorebirds. The supplemented beach will also increase erosion-buffering functions of the shoreline profile. This design approach will demonstrate the effectiveness of augmenting areas of existing beach berms with additional material to resist wave erosion.

The northern cell includes the following design elements:

- **Oyster Shell.** Add approximately 600 cubic yards of imported native oyster shell (small Olympia oyster shell and fragments; "shell hash") and place onto the existing gravel beach and spit, allowing winter (southerly) storm waves to rework the added material.

- **Sand Foreshore.** Place enough sand on the foreshore (low tide terrace) to be reworked by waves into a 3- to 6-inch layer on the surface. We expect sand on the lower foreshore to become mixed with bay mud during low wave energy periods, increasing cohesion of the sand-mud mixture with very low capacity for longshore transport. This lower foreshore mixed sand-mud sediment is typical of the bay's beaches.
- **Beach Retention Micro-Groins.** Construct two or three shore-perpendicular barriers to act as groins that restrict longshore transport of sand and gravel in the backshore and upper foreshore zones of the beach. These "micro-groins" will be constructed of either imported rock from local Bay Area quarries, eucalyptus wood fences, or logs embedded in underlying bay mud. If the minimum amount of sand is used for the foreshore (3" – 6"), the sand will likely mix relatively quickly with mud and become cohesive prior to the onset of heavy winter storms. If the final design includes more foreshore sand (greater than 6" thickness), then the northernmost of these groins may be extended further out into the intertidal zone (as shown in Figure 16) to prevent foreshore sand from being transported around the northern tip of the island and depositing in the navigational channel.
- **Sand Flat Retention Micro-Groins.** Low, cobble/boulder extensions of the beach retention micro-groins may be constructed from the on-site lag material for the purpose of restricting longshore transport of sand placed on the foreshore. These un-engineered features may be subject to some movement during large storm events. As with the terminal groin described above, these features are not essential design components due to the small amount of sand we anticipate placing on the foreshore. If the design is modified to include more foreshore sand (greater than 6" thickness), then these groins will be included in the final project design.

Figure 17 shows a typical cross-section of the proposed restored beach profile in the northern cell. A typical cross section of the beach micro-groin is displayed in **Figure 18**.

Central Cell

The central cell has experienced significant wind-wave erosion due to the higher elevation of fill at the shoreline, resulting in a steeper, more reflective shoreline profile. The central cell is relatively less protected by southerly wind-wave energy dissipation across mudflats, compared with the north cell. Given that there is sufficient room on the island to lay back and flatten the existing scarp profile beach slope, the design approach in this zone is to grade back the beach slope into the island terrace to a more stable, dissipative 15:1 horizontal:vertical (h:v) slope flattened backshore profile (ramp-like shelf or foundation for the beach), and place a mixture of sand and gravel to be reworked by winter waves during high spring tide series into natural beach profiles over the new gently sloped shelf. The relatively flattened backshore slope will allow the beach profile to migrate continuously and gradually landward as sea level rises. This design approach will demonstrate the effectiveness of sand/gravel beach construction in locations where engineered set-back of the shoreline position is not constrained by developed residential and commercial property values.

The primary design elements of the central cell are as follows:

- **Island Terrace Grading.** Grading back of the existing shoreline vertical erosion scarp to a flattened 12 to 15:1 (h:v) slope to allow for placement of a sand/gravel mix.
- **Sand/Gravel Beach.** Placement and rough grading of a sand/gravel mix to be sorted and reworked along-shore and cross-shore by wave action, thus producing a short-term equilibrium beach slope profile that moves the available gravels towards the upper end of the swash range and sorts sands to the lower beach face and foreshore.
- **Sand Foreshore.** Placing enough sand on the foreshore terrace to be reworked by waves into a 3- to 6-inch layer on the surface. We expect sand on the lower foreshore to become mixed with bay mud during low wave energy periods, increasing cohesion of the sand-mud mixture with very low capacity for longshore transport. This lower foreshore mixed sand-mud sediment is typical of the bay’s beaches.
- **Beach Retention Micro-Groins.** Construct up to five low shore-perpendicular barriers to act as groins that restrict longshore transport of sand and gravel in the backshore and upper foreshore zones of the beach. These “micro-groins” will be constructed of either imported rock from local Bay Area quarries, eucalyptus wood fences, or logs embedded in underlying bay mud.
- **Sand Flat Retention Micro-Groins.** Low, cobble/boulder extensions of the beach retention micro-groins may be constructed from the on-site lag material for the purpose of restricting longshore transport of sand placed on the foreshore. These un-engineered features may be subject to some movement during large storm events. These features are not essential design components

due to the small amount of sand we anticipate placing on the foreshore. If the design is modified to include more foreshore sand (greater than 6″ thickness), then these groins will be included in the final project design.

Figure 19 shows a typical cross-section of the proposed restored beach profile in the central cell. A typical cross section of the beach micro-groin is displayed in **Figure 18**.

South Cell

The southern cell is exposed to the highest wind-wave energy from the long wind fetch associated with the higher energy winter storms from the south. Various factors likely contribute to the relatively greater erosion in this cell: the south facing exposure to the erosive, storm-generated wind waves, a gradual deepening of Richardson Bay to the south that results in slightly less sediment shoaling to dissipate wave energy, and the dredged navigation channel along the east side of present-day Strawberry Spit that provides a path for higher wave energy. In this location, we propose to place a mix of coarser gravels in the 50-60 mm size (2-3 inches) to build a pure gravel beach armoring the existing shoreline scarp. We may increase this rock size during final design if further analysis reveals the need for larger shoreline material in this cell. This zone is also targeted to provide a haul-out location for harbor seals; therefore, a more rounded gravel mix will be imported to create a smooth beach face that will be stable in the higher wave energy shoreline. The shoreline enhancements in this cell will provide an important demonstration of the ability of gravel beaches to buffer shoreline erosion in higher wind-wave energy environments.

The primary design elements of the Southern cell approach are as follows:

- **Gravel Beach Berm.** Gravel beach berm constructed of 50-60 mm rounded river rock mixed with smaller gravel screenings or native oyster shell imported to the Site and placed along the shoreline to be worked into place by tidal action.
- **Toe Rock (optional).** A layer of imported ¼ ton toe rock from local Bay Area Quarries (artificial cobble-boulder berm) may be placed at the bottom of the scarp to inhibit wave erosion should the gravel berm prove ineffective in resisting movement by winter storm waves. This item may be eliminated due to budget constraints.

- **Beach Retention Micro-Groins.** One to two micro-groins to contain the placed sediments constructed with imported 1/4 ton rock from local Bay Area quarries and on-site lag deposits.

Figure 20 shows a typical cross-section of the proposed restored beach profile in the southern cell. A typical cross section of the beach micro-groin is displayed in **Figure 18**.

Large Woody Debris

Large woody debris (decaying, persistent logs and limbs) (LWD) may be placed in various locations along the shoreline to provide shoreline complexity and enhance habitats for a variety of organisms. The number and location/configuration of these features will be determined during final design.

Seal Access Channel

The shoreline enhancement design incorporates elements for maximizing attractiveness of the shoreline for renewed seal haul-outs. The criteria were recommended by Dr. Sarah Allen, a marine mammal expert with the National Park Service, Point Reyes National Seashore, who has observed the seals in Richardson Bay (including Strawberry Spit/Aramburu Island) since the 1980s (Allen 1991). The habitat criteria for seal haul outs are:

1) Proximity to deep water access
2) Wide view to see approaching predators
3) Nearby food source
4) Island or peninsula where terrestrial predators cannot access

The island and surrounding areas already provide for criteria 2 to 4 and the shoreline design has many aspects that make it suitable for seal haul out habitat:

- Rounded gravel beach berm and backshore flats are located at the shoreline adjacent to the excavated deepwater access channel
- Extensive, continuous smooth beach profiles with low vegetation on the beach and adjacent island terrace provide wide views

- Extensive, continuous beach profiles are consolidated on the eastern shoreline, farthest from recreational boating and potential human disturbance in the navigational channel, maximizing isolation of hauled-out seals

To enhance seal access to deep-water escape areas, we will excavate a small, subtidal channel immediately offshore from the southern shoreline cell. The channel will be approximately 10ft wide by 4ft deep and 300ft long and will connect to the existing navigational channel running along the southern end of the island. Excavated materials will be used on the island terrace for its enhancement needs. It is believed that the loss of deep-water access along the eastern island shoreline, following the silting in of the original navigational channel (Old Saltworks Canal), was a factor contributing to the abandonment of the island as a seal haul-out site (Sarah Allen, pers. comm.).

4.1.3 Habitat Benefits

We anticipate significant habitat benefits to shorebirds from replacement of the relatively low prey-productivity lag field with a more productive sand-mud foreshore. Unvegetated (wave-disturbed) linear substrate at and above the stillwater high tide line (wave uprush elevation of the beach crest) is expected to provide attractive high tide roost habitat for shorebirds flooded off of mudflats at high tide. The consolidated, extensive, continuous beach shoreline (some of which would be closely adjacent to subtidal and intertidal escape routes for seals) is expected to increase suitability of the shoreline habitat for seal haul-outs. The south cell is proposed for construction with a larger, rounded gravel compatible with local higher wave energy, and new excavated seal haul-out channel that will provide suitable habitat to support reoccupation of the site by harbor seals. The beach is also likely to support native beach and foredune plants that are uncommon in San Francisco Bay.

LWD placed along the shoreline may provide perching/roosting habitat for herons and egrets. Those LWD features placed in the intertidal zone will also provide habitat structure for aquatic plants, invertebrates, and fish when submerged. Rock micro-groins will provide hard substrate that may be beneficial habitat for sessile marine invertebrates such as native oysters and mussels.

4.1.4 Construction Methods

The shoreline enhancement elements will be constructed from a combination of on-site and imported materials obtained from local sources around the San Francisco Bay Area. Construction will involve (1) equipment mobilization, (2) localized grading/excavation, and (3) material import and placement. The construction of the beach features and microgroins are described below.

Equipment Mobilization

The heavy equipment required to construct the shoreline enhancement features is expected to consist of:

- one low ground pressure (LGP) bulldozer,
- one 50,000-lb excavator,
- one LGP or amphibious excavator,
- one wheel loader,
- two LGP track dump trucks,
- one tracked skid steer

This equipment will be brought to the island via barge, which will pull up to the island along the southeastern shoreline where the water is deepest and the shoreline scarp is lowest. The County and Audubon have successfully brought vehicles and heavy equipment to the island before using this method with no impact to sensitive wetland or mudflat habitat, or nuisance to the neighboring community. We anticipate one barge trip per piece of equipment for a total of six trips to mobilize equipment. The equipment will be loaded in Sausalito (approximately 2 mi from the project site). When not in use, equipment will be staged in upland areas of the island (outside of wetland areas).

Localized Grading/Excavation

Micro-groins will be constructed of a combination of import and on-site rocks (approximately 200 lb to ¼ ton size) and/or eucalyptus logs brought to the site by barge. Groin construction will require shallow excavation (6”-12”) along their alignments to “key” them in and provide more stability. LWD placed on the intertidal foreshore may also require keying in if these features are to remain fixed in place over time. The excavation will be performed from the island terrace where possible, or from the lag field at low tides (when there is no water present). The material extracted from these cuts can be handled in several ways. It may be spread on the adjacent lag field, or stockpiled temporarily on the island terrace (in upland areas) and later placed as capping material over the top of the groins (if built from rock) once they are completed (to serve as rooting substrate for marsh vegetation), or used as capping material for seasonal wetland enhancement areas on the island terrace (see Section 4.2.2 below).

Construction of the central shoreline cell will require grading of the shoreline to remove the vertical shoreline scarp and provide a gentle ~15:1 profile for beach formation. This grading will be performed using the LGP bulldozer. The dozer will work from the adjacent lag field at low tides (when no water is present) and will push the scarp material back onto the island terrace where it will be stockpiled in upland areas until it will be re-spread across the island terrace during that enhancement phase (see Section 4.2.2, below).

The seal access channel will be constructed using either an LGP or amphibious excavator. The channel will be excavated at low tide, when no water is present on the mudflats. The material will be transported by track dump truck to the adjacent island terrace where it will be stockpiled in upland areas and used as capping material for grassland enhancement activities (see Section 4.2.2, below).

Material Import and Placement

The shoreline features (beaches, micro-groins, LWD) will be constructed primarily from imported materials obtained from a variety of sources throughout the San Francisco Bay Area. The material quantities for the various shoreline enhancement features are presented in **Table 4**. Since the project area is an island, materials will be brought in by barge. The material transport will likely utilize two barges – a larger "transport" barge bringing the material near the island and a smaller "ferry" barge to bring it through the shallow water to the island. The larger barge (2,000 – 5,000 cy capacity) containing the shoreline materials will be anchored in the deepwater area of Richardson Bay. Material will be transferred from this barge onto the smaller barge, which will then ferry the material to the island where it will be offloaded by wheel loader. The smaller ferry barges will pull up to the southeast corner of the island, which is adjacent to the deep-water navigation channel. The shoreline in this area is armored by rock rip-rap material, which will be temporarily removed during the material import period so that barges can pull up to the island without being damaged. A barge will be parked at the island for approximately 30 – 90 minutes during each trip while it is unloaded. Due to the shallow mudflat habitat adjacent to the island, the ferry barges will not be able to operate at low tides. Alternately, depending on the results of future feasibility studies, it may be possible to bring the larger barge directly to the island at high tides and offload the material using a barge crane. This alternative, while being less expensive and more efficient, would likely cause greater disruption to use of the navigational channel than the ferry barge system.

Table 4. Shoreline Enhancement Imported Material Quantities and Sources

Shoreline Materials Enhancement Elements	Units[1]	Quantities[2] North Cell	Central Cell	South Cell	Total	Anticipated Material Source[3]
1) Beach Habitats						
Oyster Shell Hash	cy	750			750	Jerico, in-Bay dredging
Pea gravel (waste screenings)	cy			405	405	Hanson Aggregates, in-Bay dredging
50-60 mm rounded gravel	cy			405	405	Syar Quarry, Napa
Sand/gravel mixture	cy		2375		2375	Hanson Aggregates, in-Bay dredging
Sand	cy	230	750		980	Jerico, in-Bay dredging
2) Beach Retention Features						
200lb or 1/4 ton rock (Opt 1)	cy	225	260	235	720	Syar Quarry, Napa
Geogrid fabric (Opt 1)	sf	2490	2905	2625	8020	Standard contractor supply store
30' eucalyptus trunks (Opt 2)	#	5	10		15	Local tree removal
3) Large Woody Debris						
Tree trunks/logs	#	5	5	5	15	Local tree removal

[1]cy = cubic yard, sf = square foot
[2]all quantities increased by 25% over current estimates to allow for potential changes during final design
[3]different material sources may be used depending on availablitly and pricing at time of construction

Once the material is offloaded from the small ferry barge, it will be temporarily stockpiled on the island terrace in upland areas. The material will then be loaded into track dump trucks which will transport it to the appropriate location along the shoreline for placement.

Micro Groins. The micro-groins will be the first shoreline features constructed. For groins constructed of rock, once shallow excavation along the alignment has been completed, a geo-textile fabric will be placed within the excavated cut to provide more stability to the structure and prevent the groins from sinking into the substrate. The groins will then be built from the rock material by excavator. Eucalyptus groins will be constructed by positioning the trunks within the excavated cut and then anchoring them in place with log cross braces driven into the substrate. An alternate eucalyptus groin configuration involves creating a “fence” from logs driven vertically into the substrate.

Beaches. The beach materials will be placed in piles along the appropriate shoreline cell and roughly graded by bulldozer. We will rely upon natural wave action and storm events to work the material into the beach forms.

Large Woody Debris. LWD may be placed in various locations along the shoreline. Some larger pieces, if placed on the intertidal foreshore, may require keying into the substrate or anchoring with cross braces to remain fixed in place over time.

Material Stockpiling

All material that is imported or existing material that is excavated will be stockpiled temporarily in upland areas. Suitable stockpile areas will be identified in advance of construction implementation, demarcated in the field with appropriate materials, and, if necessary, surrounded by silt fencing or other sediment retention materials if there are any possibilities of material mobilization.

4.2 Island Terrace Enhancements

The island terrace currently supports fringing high and mid elevation tidal marsh, seasonal wetlands, non-native grasslands, and oak groves. The island terrace component of the Project involves enhancements to these areas aimed at creating a mosaic of terrestrial, wetland, transitional, and beach habitat types that collectively address the project design objectives. We selected a range of natural vegetation types that occur as ecotones (transition zones) at the edges of Central Bay and North Bay tidal habitats as models to emulate in our designs for the rehabilitated landscape of Aramburu Island. Section 4.2.1 describes the suite of target habitat types. Section 4.2.2 then describes enhancement elements (including some options) necessary to construct each habitat type. The proposed island terrace enhancement alternatives (Section 4.3) then combine varying quantities and locations of the different habitat types described in Section 4.2.1.

4.2.1 Palette of Enhanced Habitat Types

The various habitats targeted for enhancement on the island terrace are described individually below. Representative photographs of the proposed habitats can be found in **Appendix A**.

High Tidal Marsh

Southern Richardson Bay supports some of the largest remaining populations of the northern subspecies of salt marsh bird's-beak (Point Reyes bird's-beak). This species has found refuge in sparse, short cover of pickleweed and sea-lavender growing on eroded artificial terrestrial sediments in the high tide lines of Manzanita and Almonte districts in Mill Valley. Very similar soil and vegetation conditions exist at Aramburu Island. Enhancements to existing high tidal marsh areas and expansion of these areas will provide suitable habitat for salt marsh bird's-beak and associated regionally rare salt marsh annuals such as salt marsh owl's-clover and smooth goldfields.

It is important to note that this short, turfy high tidal marsh habitat is not designed for the benefit of, nor is it suitable for, California clapper rail or black rail. These rail species require thick, dense, tall vegetation in the high marsh zone (tall pickleweed and gumplant), extensive tidal channels, and nest and forage tidal marshes with well developed channel networks. The target vegetation structure for rare salt marsh plants (sparse, open, low stature) is the reverse of that needed for high quality rail habitat.

Seasonal Wetlands

The existing seasonal wetlands on the island terrace will be enhanced, and in some cases expanded, to produce three different types of seasonal wetlands. All of these seasonal wetland types will provide roosting and foraging habitats for shorebirds and waterbirds to varying degrees.

Vernal Pool. Vernal pools, in the context of this project, are shallow vegetated or partly vegetated depressions that pool with rainwater in the winter and early spring. Vernal pools bordering the San Francisco Estuary may be freshwater, alkaline, or slightly saline, depending on parent soils and influence of extreme high tides. The soils in these areas are compacted hardpan stony soils with highly restricted rooting depth zones, resulting in short, sparse, vernal pool vegetation. In modern and historic vernal pools bordering Marin baylands, this vegetation included water-starwort (*Callitriche* spp.), annual toad rush (*Juncus bufonius*), flowering-quillwort (*Lilaea scilloides*), goldfields (*Lasthenia* spp.), popcorn-flower (*Plagiobothrys* spp.), and owl's-clover (*Castilleja ambigua*) as well as bractless hedgehyssop (*Gratiola ebracteata)* and tiny mousetail (*Myosurus minimus)*. These areas provide foraging habitats for waterbirds such as dabbling ducks and may potentially support amphibious invertebrate communities and tree frogs that form a prey base for egrets and herons (note: tree frogs cannot naturally disperse to Aramburu Island across tidal water, and would need to be introduced).

Vernal Marsh (seasonal rush/sedge marsh). Rush/sedge marshes are essentially lowland wet meadow seasonal wetlands formed on silty-clay soils that are flooded in winter and dry in summer. These areas are dominated by dense stands of creeping grass-like plants related to sedges (common spikerush, *Eleocharis macrostachya*; field sedge, *Carex praegracilis* [native to the island]; saltgrass; dwarf spikerush, *Eleocharis* *parvula*). Vernal marsh requires deeper water to provide an open water surface above the height of the matted, saturated leaf litter in winter, compared with prostrate or low forbs typical of vernal pools.

Saline Flats and Pans. Saline flats and pans are common backshore seasonal wetlands characterized more by high springtime soil salinities and prolonged saturation, with little or very shallow standing water during the rainfall season. These habitats are normally sparsely vegetated and thus contain large areas of saturated soil or very shallow open water (depending on drainage and topography) following rain events, similar to the vernal pool habitats described above. Pans are undrained flats or depressions that evaporate and concentrate saline water, resulting in mostly barren, unvegetated hypersaline surface soils or muds in the dry season. Salt flats are somewhat drained or poorly drained, also subject to restrictively high soil salinities that exclude all but relatively salt tolerant vegetation such as saltgrass, alkali-heath, pickleweed, salt heliotrope *(Heliotropium curassavicum*), western ambrosia (*Ambrosia psilostachya*), and smooth goldfields. The benefits of these habitats to shorebirds and waterfowl would be similar to those of the vernal pool habitats.

<u>Terrestrial Grasslands</u>
The bulk of the island terrace is covered in non-native grasslands. These existing areas will be enhanced and converted to two different types of grassland habitats.

Perennial Lowland Grassland and Sedge Meadow. Grass-sedge meadows are native to some transitional floodplain and lowlands habitats with clay-silt loam soils bordering to tidal marshes around San Francisco Bay, particularly near active alluvial fans. These meadows are suitable for establishment on thick clay-loam soil profiles with relatively low salinity. They are dominated by perennial creeping native grasses and grass-like plant species such as creeping wildrye (*Leymus triticoides*), basket sedge (*Carex barbarae*), and field sedge, Baltic rush (*Juncus arcticus* ssp. *balticus*), meadow barley (*Hordeum brachyantherum*) grading into saltgrass, western ragweed (*Ambrosia psilostachya*) and alkali-heath where soil salt content increases. These grasses, grass-like plants, and creeping forbs have moderate tolerance to soil salinity, and their rhizome connections enable them to tolerate locally extreme salinity at the edge of tidal influence. The sods formed by these creeping species are highly erosion-resistant compared with soils formed by other vegetation types. The combination of high erosion resistance and salt tolerance of this vegetation type facilitates ecological resilience during sea level rise. The dense cover of creeping perennial grassland and sedge meadows supports abundant small mammals (especially California voles), prey species of herons and raptors.

Saltgrass Meadow. Saltgrass meadows intergrade with lowland perennial grasslands and salt flats and pans, or may occur as extensive communities. They occur on high salinity soils that favor species such as saltgrass, field sedge, alkali-heath, salt heliotrope, and western ambrosia. Saltgrass turf and sods provide relatively high erosion resistance compared with pickleweed marsh. This grassland vegetation requires soil salinities that would exclude nearly all of the invasive non-native weeds on Aramburu Island, particularly the most persistent weed seeds.

Backshore Sand Flat

The backshore sand flat is a sand/shell beach terrace, above the reach of normal tides, behind the gravel beach along the eastern shoreline. This habitat is meant to be attractive to harbor seals for use as haul-out habitat. It will provide them with a soft-substrate, sparsely vegetated platform within easy reach of deep-water escape areas.

Oak Grove

The existing strip of coast live oaks and scattered individual oaks on the island will be preserved until rising sea levels inevitably kill them. The understory vegetation around may be managed to eliminate non-native species and foster the development of a more native ecosystem. Under some design alternatives, excavated soils may be placed in berms around these features to protect them from saline irrigation water (described in Section 4.2.2 below).

4.2.2 Habitat Enhancement Construction Elements

The habitats described above in Section 4.2.1 will require a variety of different construction approaches for enhancement as displayed in **Table 5**. These enhancement elements are described in detail below. Construction volumes for island terrace enhancement elements can be found in Section 4.3, Enhancement Alternatives.

Table 5. Island Terrace Enhancement Construction Elements

Habitat Type	Enhancement Elements [1]							
	Grading	Compaction	Soil Profile Inversion	Dredge Material Cap	Sand/ Oyster Shell Cap	Saline Irrigation	Revegetation	Manual Weeding
High Tidal Marsh	X						X	
Seasonal Wetlands [2]								
Rush/Sedge Marsh	X	X	Opt1	Opt2			X	
Vernal Pool	X	X					X	
Saline Flats and Pans	X	X			X	X	X	
Terrestrial Grasslands [2]								
Grass-Sedge Meadow	Opt2		Opt1	Opt2				
Saltgrass Meadow	X					X	X	
Backshore Sand Flat	X				X			
Oak Grove Berms	X						X	X

[1] This table identifies the suite of enhancement element needed to construct each habitat type.

[2] Though enhancing or creating all the seasonal wetland and terrestrial grassland habitat types would yield the greatest habitat diversity and thus consequent ecological benefits, funds might not be available to construct them all. Selection of seasonal wetland and grassland types and their respective extents will be determined during final design as costs and construction funds are finalized.

Equipment Mobilization

The heavy equipment required to construct the shoreline enhancement features will depend upon the design alternative selected. The complete list of equipment that could be needed is similar to that for the shoreline enhancements:

- one low ground pressure (LGP) bulldozer,
- one 50,000-lb excavator,
- one wheel loader,
- two LGP track dump trucks,
- one tracked skid steer.
- one compactor

The equipment will be mobilized to the island in the same method as for the shoreline enhancements (see Section 4.1.4, above). If the island terrace enhancements are constructed in a subsequent construction season from the shoreline enhancements (which is likely), this equipment will need to be remobilized.

Material Stockpiling

All material that is imported or existing material that is excavated will be stockpiled temporarily in upland areas. Suitable stockpile areas will be identified in advance of construction implementation, demarcated in the field with appropriate materials, and, if necessary, surrounded by silt fencing or other sediment retention materials if there are any possibilities of material mobilization.

Grading

Most of the habitat enhancement areas will need a minimal amount of grading either for the purpose of deepening and enlarging existing seasonal wetland areas to enhance ponding/reduce drainage or for bulk vegetation and seed bank removal (i.e., clearing and grubbing). The grading will be accomplished by bulldozer.

High Tidal Marsh. High tidal marsh enhancement and expansion areas will be graded slightly (0.5 ft to 1 ft below current grade) to bring elevations down to the approximate elevation of the high tide line (6.5ft to 7ft NAVD88) to expose these areas to occasional inundation during extreme high tides and storm overwash events. This grading and exposure to moderate wave energy should improve habitat suitability for targeted rare tidal marsh plants and allow their establishment at Aramburu Island.

Seasonal Wetlands. All enhanced seasonal wetlands will require moderate grading to deepen them by approximately 0.5-1 ft to increase ponding depths. Some upland areas of the island terrace will also be graded to expand the footprint of existing seasonal wetland areas.

Grass-Sedge Meadows. Option 2, dredge material cap, for soil reconditioning in the grass-sedge meadow areas may require grading to remove invasive vegetation prior to soil placement.

Saltgrass Meadows. Saltgrass meadow enhancement areas will be graded to remove invasive vegetation and provide appropriate drainage.

Backshore Sand Flat. This area will be graded approximately 1ft below present grade to form a terrace basin immediately behind the enhanced gravel beach, which will later be filled with a sand/shell mixture.

Compaction

All enhanced seasonal wetlands will require compaction to decrease soil permeability and drainage. Compaction will be accomplished using either the tracked bulldozer (for minimal compaction) or a specialized compactor (for heavy compaction).

Soil Profile Inversion (Grass-sedge meadow and rush-sedge marsh)

The surface soils on Aramburu Island are unsuitable for rush/sedge marsh and grass-sedge meadow habitats due to their physical properties (sediment texture: stony, deficient in clay) and extensive weed seed banks. The vegetation will therefore require a re-conditioning of the substrate. The first option for providing suitable soils for these habitats involves inverting the existing soil profile of the island. Clean, silty-clay Bay mud, suitable substrate for the targeted habitat types, exists beneath the surface soils of the island. This Bay mud layer begins between 3 and 6 ft below the island surface. Obtaining this material for use as substrate would involve the following procedure:

1) Scraping the top 0.5 to 1 ft of soil from the targeted enhancement areas and stockpiling it on site
2) Digging long, linear trenches along the north-south axis of the island and quarrying the native Bay mud and deposited dredge material that lies under the hillslope fill
3) Backfilling the trenches with the scraped weed seed-filled hillslope material
4) Spreading the quarried estuarine (bay mud) sediments across the enhancement areas to appropriate thickness

This method, while preferred due to it not requiring the import of any additional material, is quite expensive due to the amount of material handling (excavation, stockpiling, replacement and relocation) involved. If project funds are insufficient to allow treatment of all proposed areas with this method, it may be possible to treat remaining areas with spoils obtained from local navigational and berth dredging.

Dredge Material Cap (Grass-sedge meadow and rush-sedge marsh)

The second option for re-conditioning the soils at Aramburu Island for enhancement of rush/sedge marsh and grass-sedge meadow habitats involves burying the existing soils under a layer of imported Bay mud obtained from dredging operations. The most likely source of this material would be from the adjacent navigational channel and berths, which are dredged on a regular cycle by the local Strawberry Recreation District. If this material is dredged using an appropriate method (clamshell, not hydraulic) and meets beneficial reuse screening criteria, it could be used for substrate reconditioning at Aramburu Island. The method for using dredge material as a substrate cap would involve the following procedure:

1) The barge carrying the dredged material will pull up to the island at the southeast corner (the offloading point for the shoreline enhancement materials) where it will be offloaded by wheel loader. The material will be stockpiled on site in upland areas.
2) Track dump truck will transport this material from the stockpile to locations where it is needed for enhancement elements.
3) The material will be graded to appropriate thickness over the existing ground surface.

This alternative is less expensive than quarrying material on-site because the only cost would be to offload and distribute the material. The local community is interested in this option because it provides them with a free, local disposal alternative for their dredge material. Dredged material would be compatible with salt flat habitats (saltgrass meadows and salt pans/saline seasonal wetlands). After salt leaching, it would also be compatible with lowland grassland vegetation planting in succession following initial saltgrass. Saline dredged material must be excluded from direct placement around any oaks that are to be conserved.

Sand/Oyster Shell Cap (saline flats and pans, backshore sand flat)

Approximately 50% of the surface area of the saline flats will be capped with a thin (2”) layer of oyster shell hash to maintain sparsely vegetated pan habitats. The backshore sand flat will be capped with a thicker (0.5ft to 1ft) layer of sand and potentially oyster shell hash which will form a suitable terrace for harbor seals to utilize as haul out habitat. This material will be brought to the island by barge in the same manner as the shoreline enhancement materials (see Section 4.1.4, above), where it will be offloaded by wheel loader and stockpiled on site in upland areas. Track dump trucks will then distribute this material to the enhancement locations where it will be spread to the appropriate thickness over the designated area.

Saline Irrigation (saltgrass meadow and saline flats and pans)

In the saltgrass meadow and saline flats and pans, remediation of the persistent weed seed bank will be accomplished by saline irrigation. Saline irrigation is a cost-effective soil conditioning method of weed management suitable for saline to brackish lowland habitats bordering the bay, first tested in the San Francisco Bay National Wildlife Refuge in 2006 (Baye 2008). The goal of saline irrigation is to increase soil salinities to a level that kills off intolerant, nuisance vegetation. Germination of salt-intolerant weed seed banks is encouraged during winter and early spring, following soil grading disturbance during fall construction. Soils are salinized by gradual, slow irrigation at the end of the rainfall season (Feb-Mar) when terrestrial plant seedlings are vulnerable to exposure to lethal salinity levels. Soils must be infiltrated by saline irrigation to depths sufficient to contact the majority of the seedling root zone (including tap roots), using repeat irrigations (total approximately 5-6"). High residual soil salinity prevents germination of dormant seeds. The resulting salinized soils will be suitable for seeding and planting with native salt-tolerant native vegetation. Soil salinities in soils with drainage gradually decline with leaching due to winter rainfall, unless saline irrigation is repeated. Gradual decline in salinity allows for transition to less salt-tolerant vegetation over time, if desired. This process has proven to be highly effective for managing terrestrial weed vegetation on levees and flats in transitional ecotone habitats adjacent to salt marshes in San Francisco Bay (San Francisco Bay National Wildlife Refuge, Alviso Environmental Education Center; Baye 2006, 2008; Genie Moore, USFWS, pers. comm.).

The following is a generalized preliminary account of saline irrigation methods applicable to Aramburu vegetation management, to be refined for final design with vegetation management specifications. Saline irrigation will be accomplished by installing temporary irrigation line and an array of sprinklers across the treatment area. The irrigation system will be fed saline Bay water from a pump installed in the navigational channel along the west side of the island. The pump may be either a self-contained floating pump, or an electric submersible pump that is powered by a sheltered, enclosed noise-damping generator on the island. The submersible pump would have the lowest noise impacts to adjacent neighbors. The pump will be located along the channel margins and operated during high tides to avoid interference with boat traffic and will be clearly marked to make it visible to boaters.

Following grading, and immediately after the first flush of weed seed germination triggered by fall rains, the targeted enhancement areas will be irrigated for approximately **two days** to kill off any emergent weeds and prevent their further germination. The following spring, following winter germination of salt-intolerant vegetation, the enhancement areas will be irrigated again in intensive pulses of approximately 5”- 6”. This salinization will likely be accomplished in **three, two-day irrigation cycles**. Depending on rainfall patterns in spring, repeat applications may be needed. This spring irrigation cycle may be repeated the following year as well. In addition, prior to initial site grading it may be preferable to salinize the existing habitats in early winter (around peak seedling emergence) to reduce pre-grading weed seed loads and reduce germination potential following construction. This salinization could be accomplished in **two, two-day irrigation cycles**. All irrigation durations and amounts given are approximate and will vary based on conditions at the time of implementation (precipitation, Bay salinity, soil condition, etc.).

Revegetation

Following initial grading of habitat enhancement areas and substrate reconditioning to eliminate/neutralize weedy seed banks found in the soils, all areas, with the exception of high tidal marsh, will be revegetated. The individual revegetation strategies for the different habitats will be as follows.

Rush-Sedge Marsh. Rush-Sedge marshes will be built upon a Bay mud cap over depressions enclosed by low-relief berms. Native Bay mud will initially have elevated salinities that will be too high for some target plant species. It will take approximately two to three years of rainfall leaching and temporary artificial drainage (depending on rainfall amounts) to reduce soil salinities to a level appropriate for revegetation with all target species. During the desalinization period, these areas will be dominated by naturally salt-tolerant target vegetation including saltgrass, field sedge, alkali-heath, western ragweed, goldfields, spurrey, and pickleweed. Once appropriate soil salinities have been reached, the habitats will be planted with relatively salt-intolerant target species, including native common spikerush.

Vernal Pool. Once scraped and compacted, vernal pool areas will be heavily seeded with native vernal pool annuals with strong colonizing ability including popcornflower, goldfields, toad rush, flowering quillwort.

Saline Flats and Pans. The depressional saline flats will be planted with saltgrass and alkali heath in winter, prior to the first irrigation cycle. A mix of creeping perennials including pickleweed, salt heliotrope, and western ambrosia will be planted in the following fall. Annual salt-tolerant forbs such as goldfields will be seeded directly as soon as salinities are suitable. As described earlier, sparse vegetation cover in pans to facilitate high tide shorebird roost habitat functions will be maintained by placing a thin layer of oyster shell hash over approximately 50% of the flats.

Grass-Sedge Meadow. As with the rush-sedge marshes, the grass-sedge meadows will be built upon a Bay mud cap which will have initial soil salinity in excess of what target vegetation for this habitat type can tolerate. A "cover crop" of saltgrass will be used to stabilize the initial bay mud cap. The salinity of these soils will be lowered to acceptable levels by rainfall leaching and drainage (runoff over convex topography), which is anticipated to take approximately two years because of higher efficiency of salt leaching in soils with positive drainage. Once acceptable salinity levels have been reached, these areas will be planted with clonal divisions of creeping wildrye, basket sedge, and meadow sedge. Closed vegetation of creeping grasses and sedges is expected to replace saltgrass in approximately five years after transplanting.

Saltgrass Meadow. The first spring after salinization, saltgrass meadow areas will be planted with a mix of saltgrass and alkali heath which will form dense creeping stands of vegetation.

Oak Groves. Terrestrial grassland bordering the oak grove may be constructed on either of two types of fill substrate: (a) clay-silt loam derived from low-salinity/desalinized bay mud, or (b) stony gravelly loam hillslope soils. Dredged materials or other high salinity soils may not be placed directly over the root zones of existing oaks because they contain excessive amounts of salt that would harm oaks during salt leaching. The two soil types, stony gravelly loam and clay-silt loam, would support different terrestrial grassland types. The stony gravel loam, which would likely contain abundant weed seeds, would support native bunchgrasses (blue wildrye, *Elymus glaucus*; purple needlegrass), bulbs (blue-dicks, *Dichelostemma capitata*, and soapplant, *Chlorogalum pomeridianum*), and forbs (sky lupine, *Lupinus nanus*; tarweed, *Hemizonia congesta*). In contrast, the clay-silt loam would be dominated by creeping, sod-forming perennial native grasses, creeping wildrye, field sedge, and basket sedge, mixed with at least some initial cover of saltgrass. The sod-forming perennial grassland would establish closed cover (live leaf canopy), dense leaf litter mats, and dense root/rhizome sods that would be likely to minimize long-term weed competition.

Manual Weeding

Upland areas around the oak groves, which are not either capped with Bay mud or saline irrigated may require manual weeding to remove invasive plants. It is anticipated that this manual vegetation management may be needed for a period of up to five years due to the large weedy seed bank found within the existing island soils.

4.3 Enhancement Alternatives

We have identified three different enhancement alternatives for Aramburu Island. All three alternatives have the same shoreline enhancement design (see Section 4.1), but differ in the treatments for the island terrace (see Section 4.2). Specifically, the different island terrace enhancement alternatives combine the habitat types (Section 4.2.1) and enhancement approaches (Section 4.2.2) into three combinations to reflect distinct enhancement strategies. **Table 6** displays the quantities of the various habitat types contained in each alternative.

Table 6. Island Terrace Habitat Types in Enhancement Alternatives

	Enhancement Alternatives		
	Alt 1	Alt 2	Alt 3
Habitat Type	Lowland Wetland-Grassland Matrix (ac)	Saline Backshore (ac)	Hybrid Design (ac)
1) Retain Existing Conditions			
Fringing Tidal Marsh	6.11	6.11	6.11
Oak Groves	0.57	0.57	0.57
2) Enhancement and Creation			
High Tidal Marsh	1.70	0.53	1.64
Seasonal Wetlands			
Rush/Sedge Marsh and Vernal Pools	2.75	0.00	0.75
Saline Flats and Pans	0.00	6.34	4.40
Terrestrial Grasslands			
Grass-Sedge Meadow	4.74	0.35	1.07
Saltgrass Meadow	0.00	2.08	1.44
Backshore Sand Flat	0.11	0.00	0.00
Oak Grove Berms	0.16	0.16	0.16
Total Acreage	16.14	16.14	16.14

4.3.1 Alternative 1: Lowland Wetland-Grassland Matrix

Under this alternative, the island terrace will emulate a lowland alluvial grassland and sedge meadow ecotone (**Figure 21)**. The terrace will be dominated by a matrix of grass-sedge meadows with interspersed rush/sedge marshes and vernal pools. High tidal marsh enhancement and expansion will also take place and a backshore sand flat will be constructed behind the gravel beach berm along the southeastern island shoreline. A typical cross section view of the island terrace under this alternative is shown in **Figure 22.**

This alternative employs the soil replacement methodology (soil profile inversion or dredge material capping) across most of the island terrace to address the weed seed banks. There is no saline irrigation involved in this alternative. This alternative is the most expensive to implement.

4.3.2 Alternative 2: Saline Backshore

Under this alternative the island terrace will emulate a saline backshore system dominated by a matrix of saltgrass meadows and saline flats/pans (**Figure 23**). This alternative also includes high tidal marsh enhancement and expansion. A small area of grass-sedge meadow will be constructed at the south end of the island on Bay mud substrate obtained from excavating the adjacent seal access channel. A typical cross section view of the island terrace under this alternative is shown in **Figure 24.**

This alternative employs re-grading along with soil salinization across most of the island terrace to address the weed seed banks. Only a small area at the southern end of the island will be treated by soil replacement using excavated Bay mud. This alternative is the least expensive.

4.3.3 Alternative 3: Mixed Design

This alternative incorporates elements of Alternatives 1 and 2 to provide a suite of all potential habitat types (**Figure 25)**. Under this alternative, the northern island terrace (north of the northern cove) will be the same as under Alternative 1, a matrix of grass-sedge meadows interspersed with rush/sedge marshes and vernal pools built on a Bay mud substrate cap. Some high tidal marsh areas will be enhanced as well. The central portion of the island terrace (between the two coves) will be the same as in Alternative 2, a matrix of saltgrass meadows and saline flats/pans on salinized soils (**Figure 24**). The southern island terrace (south of the southern cove) will be the same as in alternative 2, which includes grass-sedge meadows and saline flats/pans along with enhanced high tidal marsh.

This alternative represents the most complete use of the various habitat types available for enhancement and presents a unique opportunity to monitor the success of different habitat enhancement approaches on a relatively small site. The mixed design presented here is only one potential combination of the various habitat types. It is possible to vary the quantities of the different habitats to achieve a desirable matrix that meets restoration goals while staying within the allotted project budget. The cost of this alternative will depend upon the ratio of the different habitat types in the final design and would be intermediate to Alternatives 1 and 2.

4.3.4 Enhancement Alternative Construction

The three island enhancement alternatives will involve varying degrees of earthwork and material import/placement. This information, along with anticipated construction duration is presented in **Table 7**, below.

Table 7. Construction Quantities and Estimated Durations

Description	Units[1]	Shoreline	Terrace			
			Alt 1, Option 1[2]	Alt 1, Option 2[2]	Alt 2	Alt 3
1) Earthwork Volume[3]						
Excavation/grading of onsite materials	cy	3,000	58,060	11,855	5,700	7,495
2) Imported Materials[3]						
Oyster Shell Hash	cy	750			1,025	790
Pea gravel (waste screenings)	cy	405				
50-60 mm rounded gravel	cy	405				
Sand/gravel mixture	cy	2,375				
Sand	cy	980	470	470		
Dredged silty clay	cy			11,375		2,020
200lb or 1/4 ton rock (Opt 1)	cy	720				
Geogrid fabric (Opt 1)	sf	8,020				
30' eucalyptus trunks (Opt 2)	#	15				
Misc. tree trunks/limbs (LWD)	#	15				
3) Construction Duration[4, 5]	days	40	60	40	40	40

[1]cy = cubic yard, sf = square foot

[2]Option 1: quarry silty clay cap material on-site; Option 2: import silty clay cap material

[3]All earthwork and material quantities are increased 25% from current estimates to allow potential changes during final design

[4]Construction duration only. Does not account for salinization or revegetation duration

[5]Construction durations listed assume that shoreline and terrance enhancements are done separately. If both units are constructed at the same time, the total duration will be reduced by approximately 1/3.

4.3.5 Alternative Comparison

Implementation of the different enhancement alternatives will alter the configuration and relative amounts of habitats within the project boundary from current conditions. The changes in habitat configuration for both the bay and shoreline units of the project site are described in **Table 8**, below.

Table 8. Change in Project Site Habitat Configuration

Habitat	Existing Conditions	Alternative 1	Alternative 2	Alternative 3
1) Island Terrace Unit (shoreline upward)				
Tidal marsh	6.11	7.81	6.64	7.75
Seasonal wetland	2.37	2.75	6.34	5.15
Oak Groves/berms	0.57	0.73	0.73	0.73
Gravel spit [1]	0.12	-	-	-
Terrestrial grasslands	7.70	4.74	2.43	2.51
Backshore sand flat	0.00	0.11	0.00	0.00
Rock rip-rap revetment	0.19	0.19	0.19	0.19
Subtotal, Island Terrace	17.06	16.33	16.33	16.33
2) Bay Unit (shoreline bayward)				
Coves [2]	1.98	1.98	1.98	1.98
Gravel/sand/shell beaches and spits [1,2]	0.00	1.62	1.62	1.62
Sand foreshore [2]	0.00	1.22	1.22	1.22
Beach retention groins	0.00	0.31	0.31	0.31
Boulder lag fields [2]	10.28	7.86	7.86	7.86
Intertidal mudflat	2.57	2.47	2.47	2.47
Subtidal	3.92	4.02	4.02	4.02
Subtotal, Bay Unit	18.75	19.48	19.48	19.48
Total	35.81	35.81	35.81	35.81

[1] Existing gravel spits after enhancement are counted as Bay Unit habitat types.

[2] Acreage based on assumed beach configuration after natural material distribution. Final configuration will vary temporally based on wave conditions.

Although there are differences in the amounts and types of habitats created, the three enhancement alternatives all achieve the project goals and design objectives stated in Sections 3.1 and 3.2. **Table 9**, below, describes how each alternative performs with regard to these criteria.

Table 9. Alternative Comparison Matrix

Project Goals and Design Objectives	Alternatives			
	1 - Lowland Wetland-Grassland Matrix	2 - Saline Backshore	3 - Mixed Design	No Action
PROJECT GOALS				
1) Reduce erosion along the eastern shoreline	The beach elements of the shoreline enhancements will buffer wave energies and reduce erosion	Same as Alternative 1	Same as Alternative 1	Shoreline erosion continues at existing rates; could lead to significant island loss and storm wave exposure to properties on navigation channel
2) Enhance island resilience to sea level rise	The beach and low-angle shore profile would transform the island from wave-reflecting to wave-dissipating profile, and change shoreline dynamics from progressive scarp erosion to gradual beach transgression	Same as Alternative 1	Same as Alternative 1	Progressive scarp erosion continues
3) Enhance habitats for shorebirds, waterfowl, and wading birds	The shoreline enhancement will improve foraging and roosting habitat functions for these species. Vernal pool and sedge-rush marsh habitats (2.75 ac) will provide foraging habitats for waterbirds such as dabbling ducks and may potentially support amphibious invertebrate communities and tree frogs that form a prey base for egrets and herons	The shoreline enhancements are the same as Alternative 1. Saline flats and pans (6.34 ac) in this alternative will provide similar habitat as vernal pools for waterbirds and waterfowl. Saline flats and pans, however, will not support amphibian populations	This alternative will provide vernal pool/sedge rush marsh (0.75 ac) and saline flats and pans (4.40 ac)	No habitat enhancement for these species
4) Enhance suitability of haul out habitats for harbor seals	By improving haul-out site conditions through beach nourishment and re-establishing a connection to deep-water escape areas, the site may become attractive for seal use again	Same as Alternative 1	Same as Alternative 1	Lack of haul out continues
5) Enhance habitats for rare salt marsh plants	Enhancement to high tidal marsh areas (1.70 ac) will provide habitats for rare salt marsh plants	Similar to Alternative 1, but only 0.53 ac will be restored	Similar to Alternative 1, but only 1.64 ac will be restored	No enhancement or restoration of habitats for rare salt marsh plants
6) Establish native vegetation on the island terrace	Enhancements to all areas of the island terrace will establish native vegetation	Same as Alternative 1	Same as Alternative 1	Island terrace remains dominated by non-native vegetation

Table continued on next page

Table 9: Continued

Project Goals and Design Objectives	Alternatives			
	1 - Lowland Wetland-Grassland Matrix	2 - Saline Backshore	3 - Mixed Design	No Action
DESIGN OBJECTIVES				
1) Enhance shoreline beach habitats	Will restore 3.15 ac of shoreline habitats	Same as Alternatve 1	Same as Alternative 1	No change from current conditions
2) Provide deepwater access alog the eastern shoreline	The shoreline enhancement includes excavating a channel along the southern shoreline cell to provide deepwater access to seals	Same as Alternative 1	Same as Alternative 1	No change from current conditions
3) Enhance and create high tidal marsh	1.7 ac of high tidal marsh will be enhanced/created	0.53 ac of high tidal marsh will be enhanced/created	1.64 ac of high tidal marsh wll be enhanced/created	No change from current conditions
4) Enhance and create seasonal wetlands	2.75 ac of sedge-rush marsh and vernal pool habitats will be created	6.34 ac of saline flat and pan habitat will be created	0.75 ac of sedge-rush marsh and 4.40 ac of saline flat and pan habitat will be created	No change from current conditions
5) Enhance Terrestrial grassland areas	4.74 ac of grass-sedge meadow will be created	0.35 ac of grass-sedge meadow and 2.08 ac of saltgrass meadow will be created	1.07 ac of grass-sedge meadow and 1.44 ac of saltgrass meadow will be created	No change from current conditions

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Figures

1:30,000 (1" = 2,500' at letter size)

0 2,500 5,000 ft

0 700 1,400 m

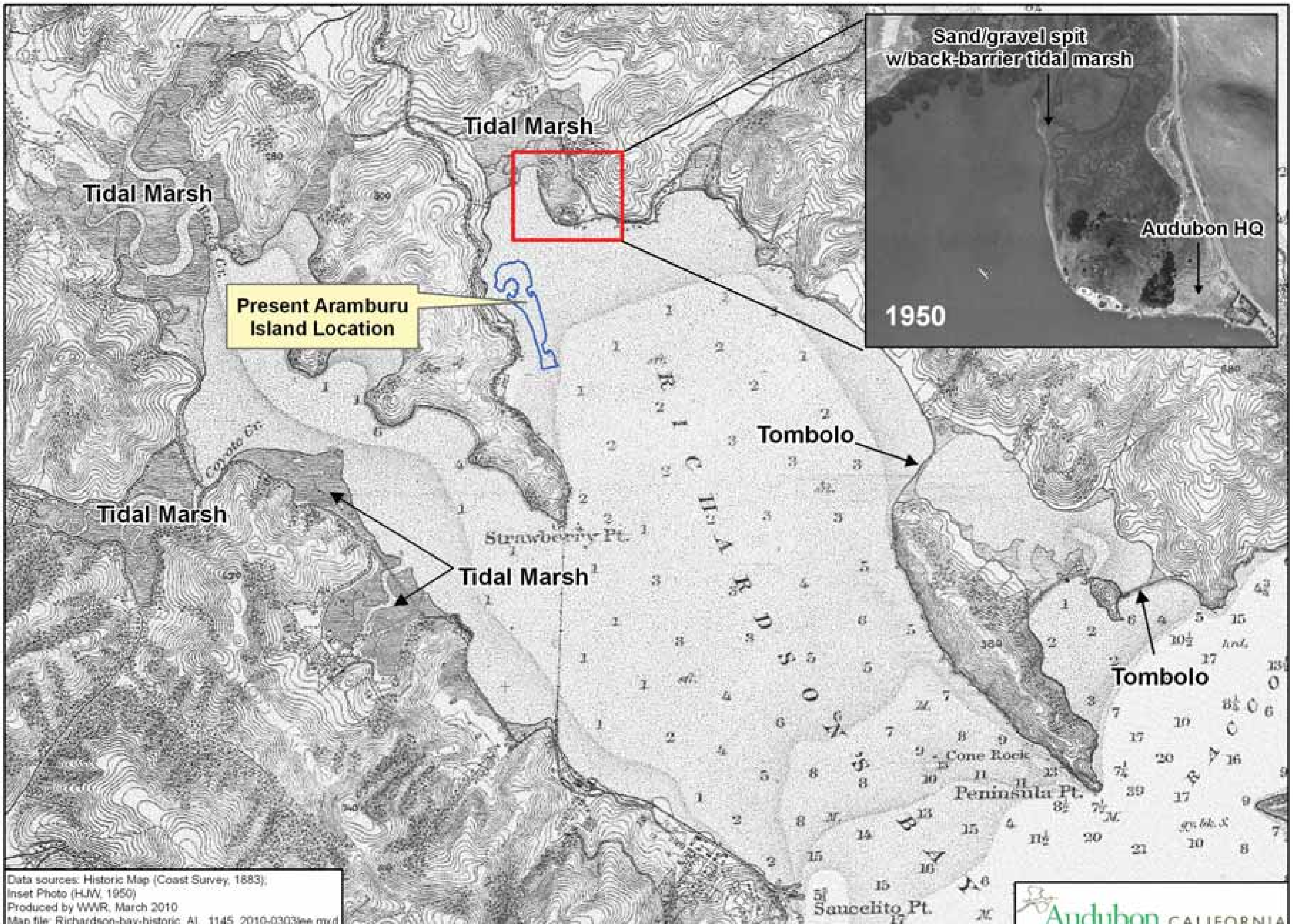
N W E S

WETLANDS AND WATER RESOURCES

VICINITY MAP

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project 1145	Figure 1



1:33,000 (1"=2750' at letter layout)

0 0.5 1 mi

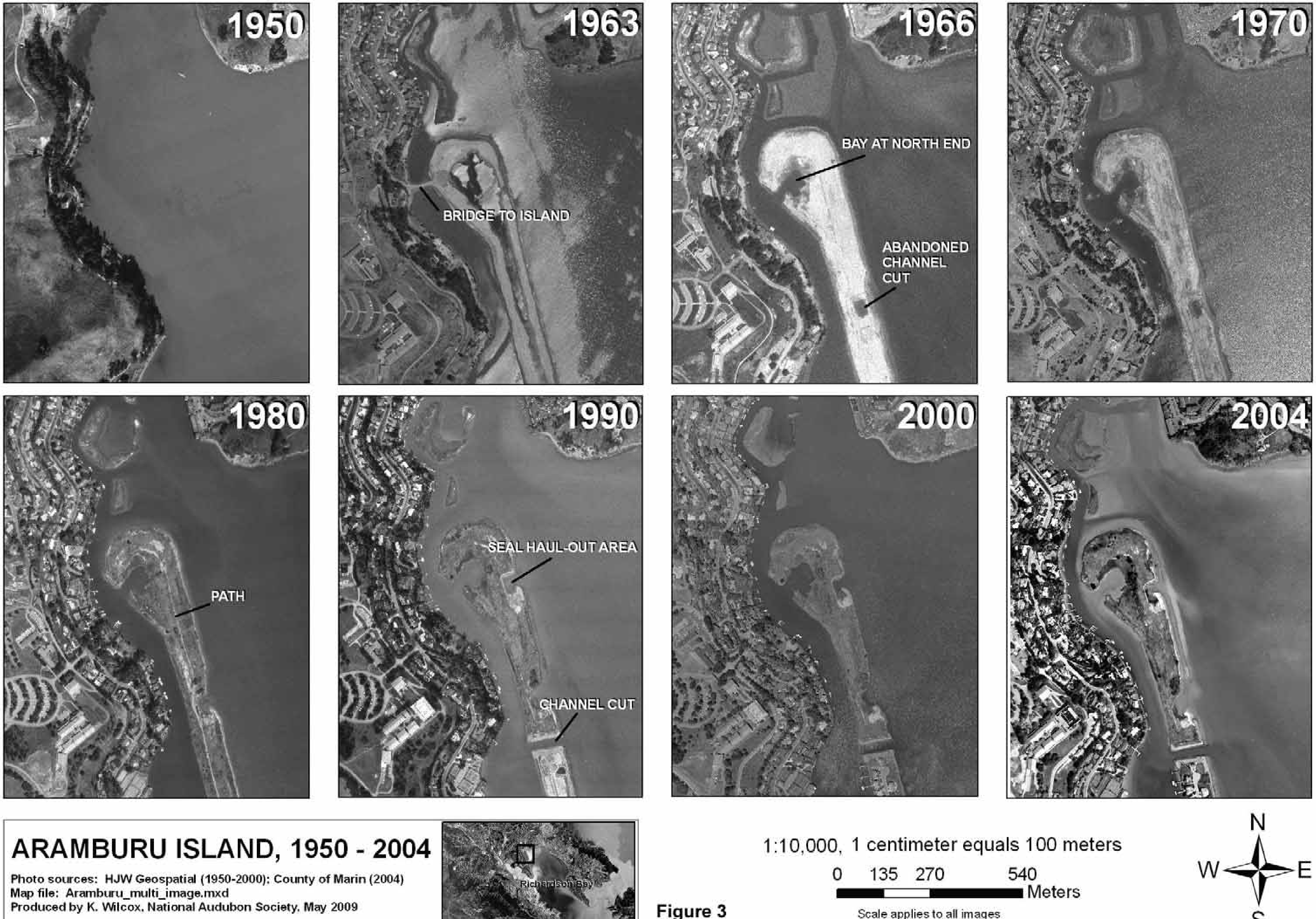
0 0.75 1.5 km

WETLANDS AND WATER RESOURCES

HISTORICAL RICHARDSON BAY: 1883 COAST SURVEY

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

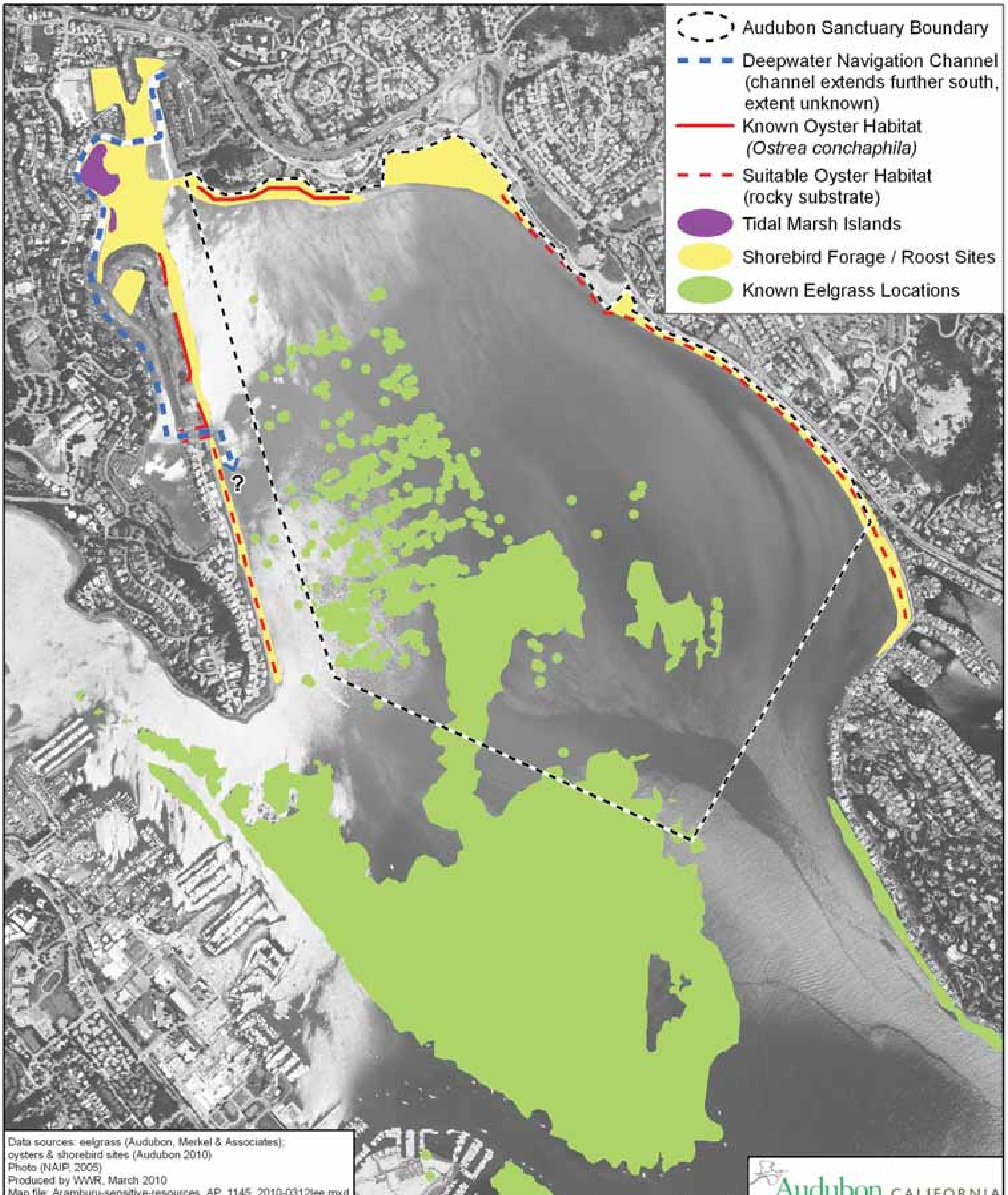
March 2010	Project No. 1145	Figure 2



ARAMBURU ISLAND, 1950 - 2004

Photo sources: HJW Geospatial (1950-2000); County of Marin (2004)
Map file: Aramburu_multi_image.mxd
Produced by K. Wilcox, National Audubon Society, May 2009

Figure 3



1:18,000 (1" = 1,500' at letter size)

0 0.25 0.5 mi

0 0.5 1 km

N W E S

WETLANDS AND WATER RESOURCES

SURROUNDING HABITATS AND SENSITIVE RESOURCES

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project 1145	**Figure 4**

1:3,600 (1" = 300' at letter size)

0 150 300 600 ft

0 50 100 200 m

Air photo source: Marin County (2004)
Map file: landscape-units_AP_1145_2010-0304lee.mxd

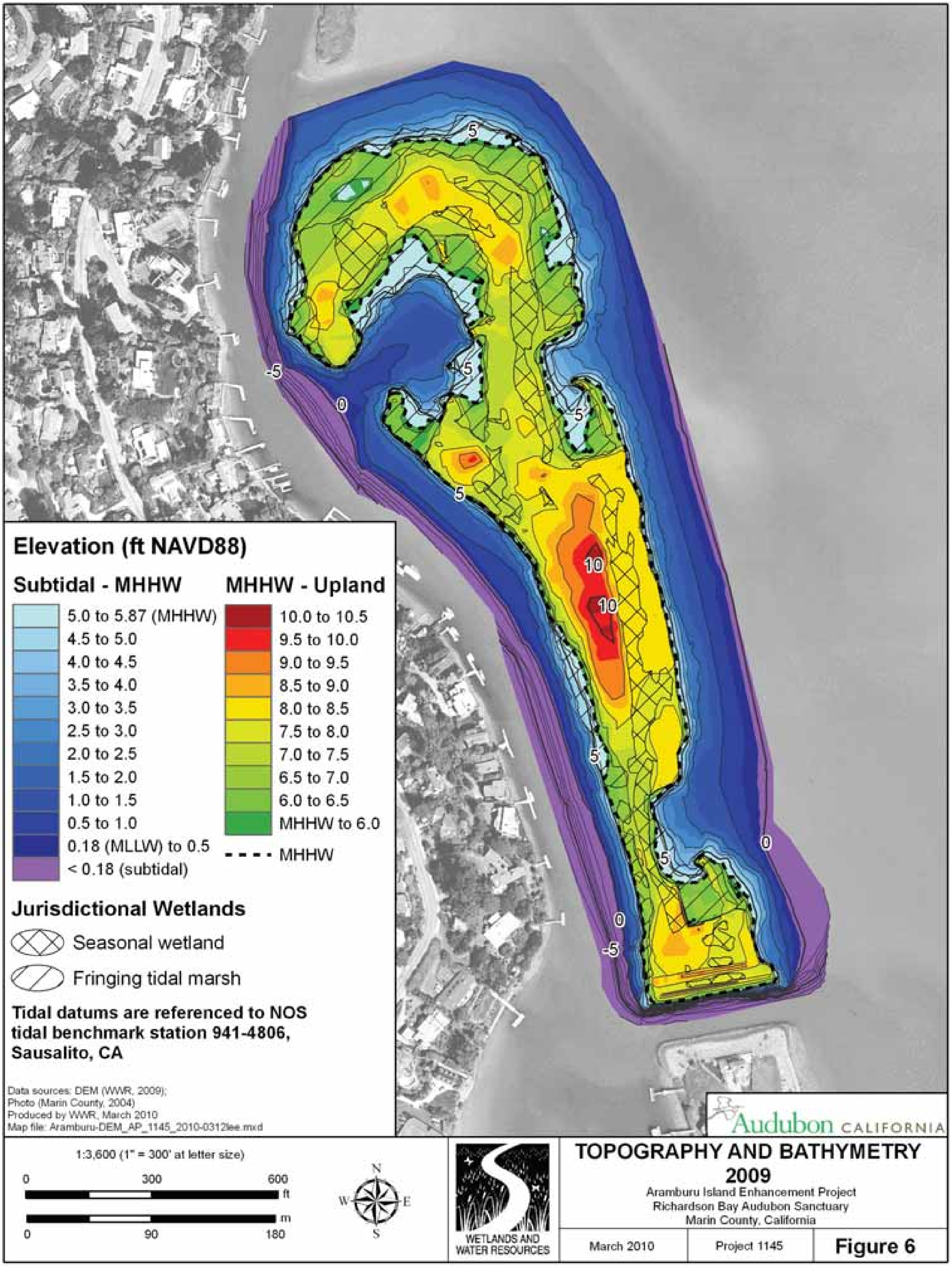
N W E S

WETLANDS AND WATER RESOURCES

LANDSCAPE UNITS

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project No. 1145	**Figure 5**



Elevation (ft NAVD88)
Subtidal - MHHW
5.0 to 5.87 (MHHW)
4.5 to 5.0
4.0 to 4.5
3.5 to 4.0
3.0 to 3.5
2.5 to 3.0
2.0 to 2.5
1.5 to 2.0
1.0 to 1.5
0.5 to 1.0
0.18 (MLLW) to 0.5
< 0.18 (subtidal)
MHHW - Upland
10.0 to 10.5
9.5 to 10.0
9.0 to 9.5
8.5 to 9.0
8.0 to 8.5
7.5 to 8.0
7.0 to 7.5
6.5 to 7.0
6.0 to 6.5
MHHW to 6.0
MHHW
Jurisdictional Wetlands
Seasonal wetland
Fringing tidal marsh
Tidal datums are referenced to NOS tidal benchmark station 941-4806, Sausalito, CA
Data sources: DEM (WWR, 2009);
Photo (Marin County, 2004)
Produced by WWR, March 2010
Map file: Aramburu-DEM_AP_1145_2010-0312lee.mxd
5
-5
0
10
10
Audubon CALIFORNIA
1:3,600 (1" = 300' at letter size)
0 300 600 ft
0 90 180 m
N
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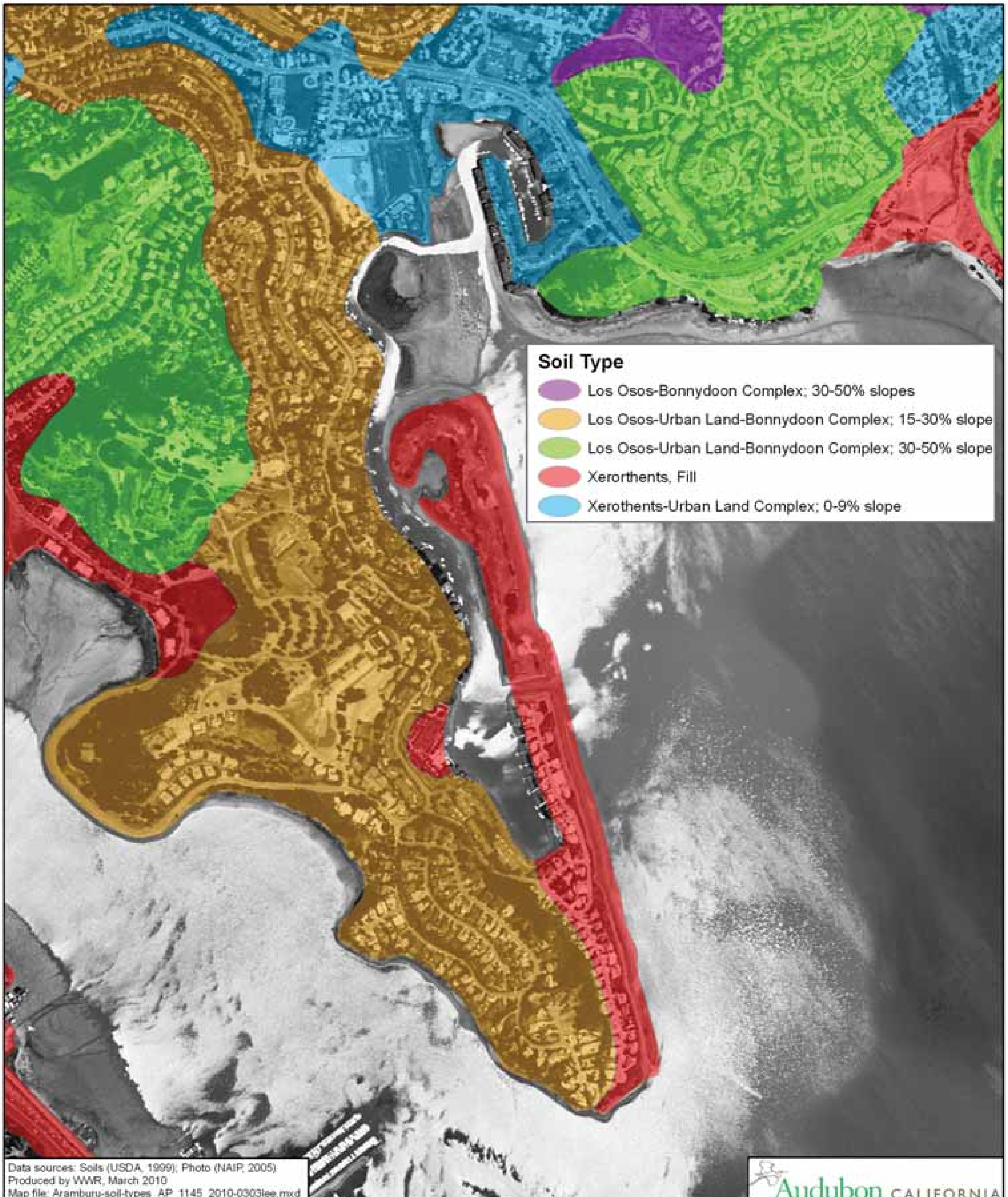
E
S
WETLANDS AND WATER RESOURCES
TOPOGRAPHY AND BATHYMETRY 2009
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California
March 2010
Project 1145
Figure 6



1:12,000 (1" = 1000' at letter size)

0 1,000 2,000 ft

0 300 600 m

N W E S

WETLANDS AND WATER RESOURCES

SOIL TYPES

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project 1145	**Figure 7**

Soil Pit Locations

Data sources: Soil pit locations (WWR, Audubon, 2009);
Photo (NAIP, 2005)
Produced by WWR, March 2010
Map file: Aramburu-soil-pit-locations_AP_1145_2010-0303lee.mxd

Audubon CALIFORNIA

1:3,600 (1" = 300' at letter size)

0 300 600 ft

0 100 200 m

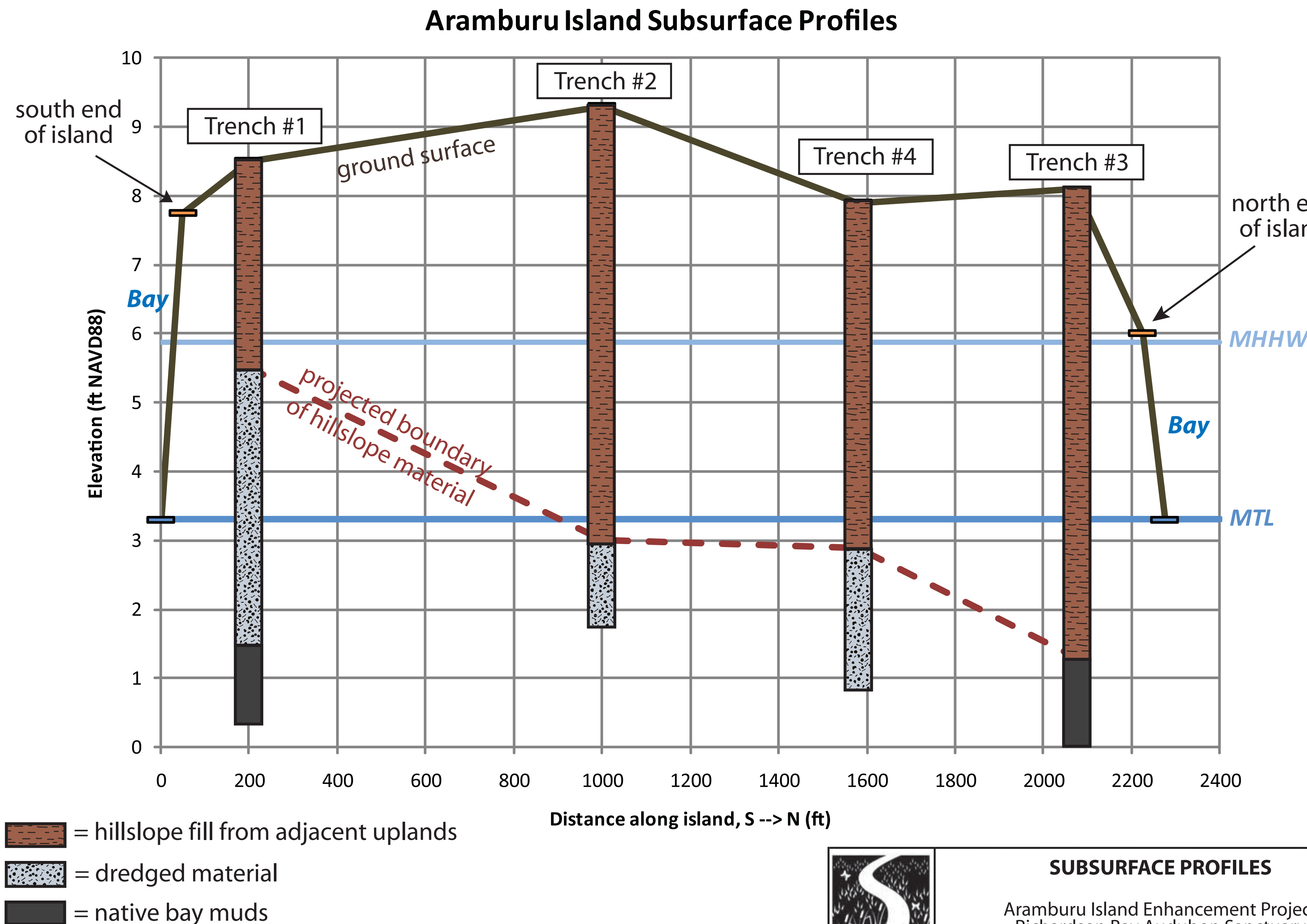
N S E W

WETLANDS AND WATER RESOURCES

SOIL PIT LOCATIONS

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project 1145	Figure 8



Note: see trench locations on Figure 8

Audubon CALIFORNIA

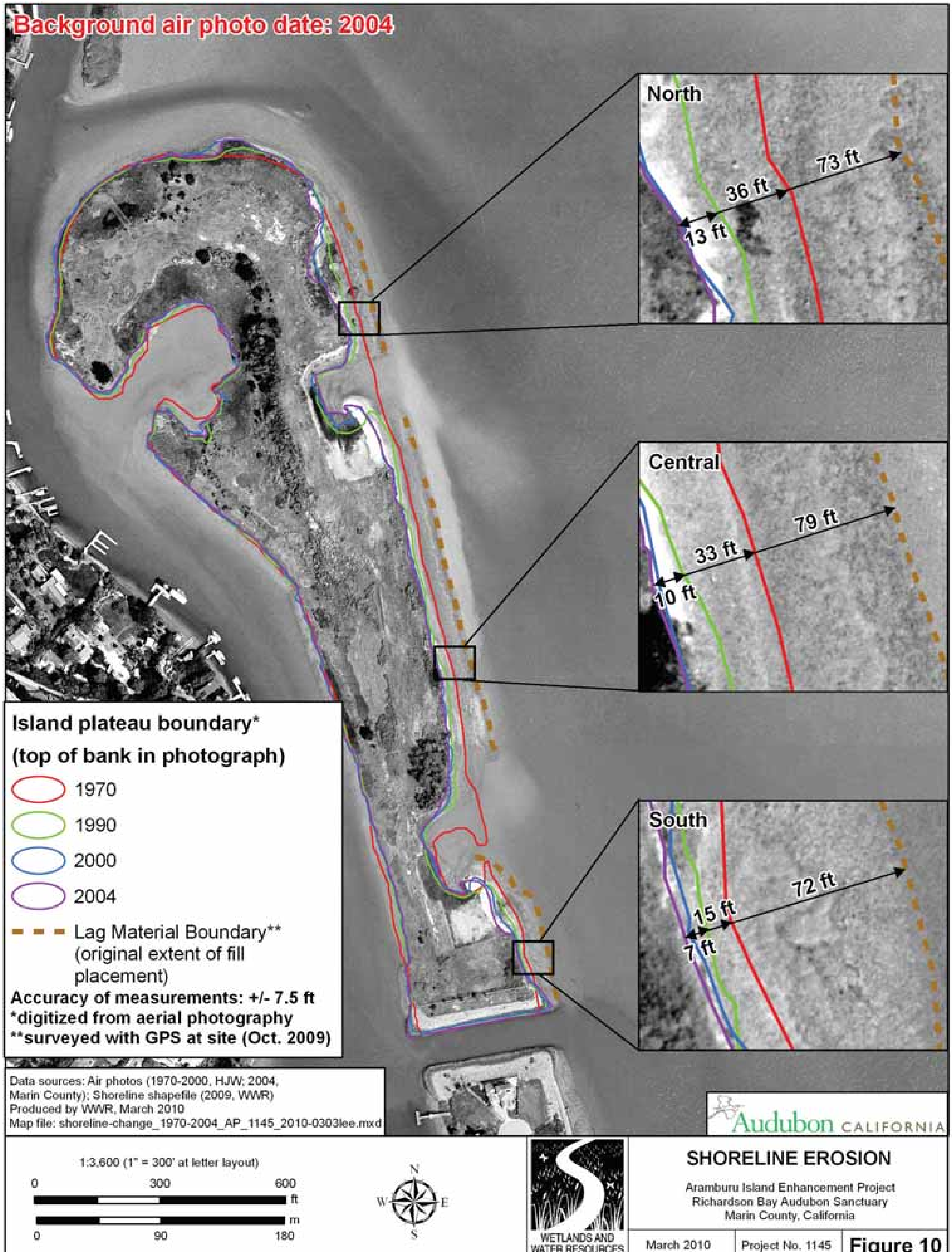
WETLANDS AND WATER RESOURCES

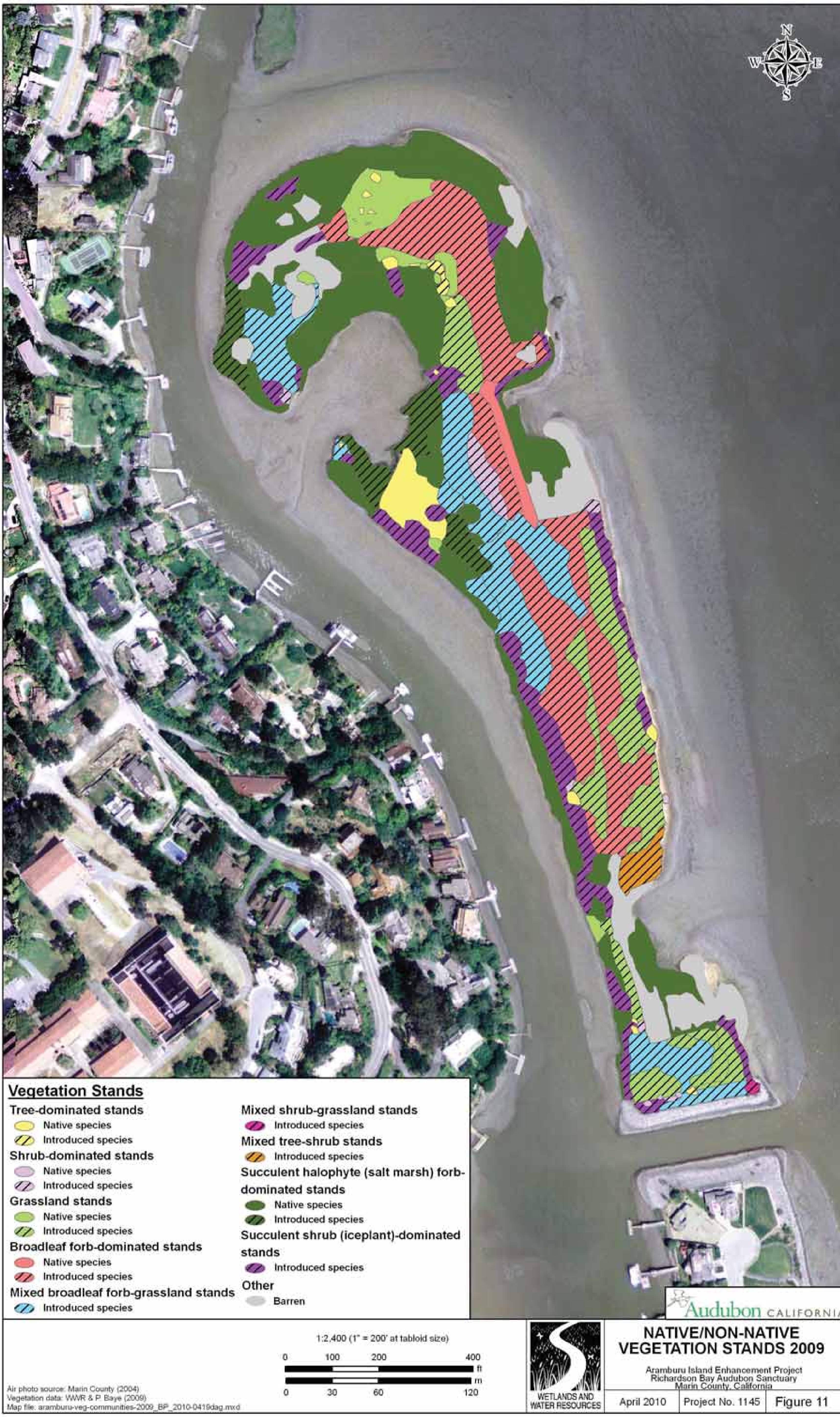
SUBSURFACE PROFILES

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project No. 1145	Figure **9**

Data source: data for AI graphic_2009-1012ct.xls
Graphic file: Fig-09_subsurface profiles_AL_2010-0303ct.ai


Background air photo date: 2004
North
13 ft
36 ft
73 ft
Central
10 ft
33 ft
79 ft
South
7 ft
15 ft
72 ft
Island plateau boundary*
(top of bank in photograph)
1970
1990
2000
2004
Lag Material Boundary**
(original extent of fill placement)
Accuracy of measurements: +/- 7.5 ft
*digitized from aerial photography
**surveyed with GPS at site (Oct. 2009)
Data sources: Air photos (1970-2000, HJW; 2004, Marin County); Shoreline shapefile (2009, WWR)
Produced by WWR, March 2010
Map file: shoreline-change_1970-2004_AP_1145_2010-0303lee.mxd
Audubon CALIFORNIA
1:3,600 (1" = 300' at letter layout)
0
300
600
ft
m
0
90
180
N
W
E
S
WETLANDS AND WATER RESOURCES
SHORELINE EROSION
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California
March 2010
Project No. 1145
Figure 10


N
W
E
S
Vegetation Stands
Tree-dominated stands
Native species
Introduced species
Shrub-dominated stands
Native species
Introduced species
Grassland stands
Native species
Introduced species
Broadleaf forb-dominated stands
Native species
Introduced species
Mixed broadleaf forb-grassland stands
Introduced species
Mixed shrub-grassland stands
Introduced species
Mixed tree-shrub stands
Introduced species
Succulent halophyte (salt marsh) forb-dominated stands
Native species
Introduced species
Succulent shrub (iceplant)-dominated stands
Introduced species
Other
Barren
Audubon CALIFORNIA
Air photo source: Marin County (2004)
Vegetation data: WWR & P. Baye (2009)
Map file: aramburu-veg-communities-2009_BP_2010-0419dag.mxd
1:2,400 (1" = 200' at tabloid size)
0 100 200 400 ft
0 30 60 120 m
WETLANDS AND WATER RESOURCES
NATIVE/NON-NATIVE VEGETATION STANDS 2009
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California
April 2010
Project No. 1145
Figure 11


Jurisdictional Waters of the U.S.
A) Navigable Waters
Acres
Section 10 and Section 404 18.539
B) Wetlands
Section 10 and Section 404 (< MHW) 1.121
Section 404 (> MHW) 7.355
Total Wetlands 8.476
C) Other Waters
Section 404 0.390
Total Jurisdictional Waters 27.405
Notes:
"Section 10" = Section 10, Rivers and Harbors Act
"Section 404" = Section 404, Clean Water Act
All open water areas outside the parcel boundary, below MHW, are Navigable Waters
Field verification date: October 20, 2009
wetland 22
wetland 23
wetland 7
pt14
pt13
wetland 20
wetland 21
pt15
wetland 24
pt12
wetland 6
pt11
pt10
wetland 17
pt16
pt17
pt20
pt18
pt9
pt19
wetland 5
pt7
pt21
pt8
wetland 8
wetland 19
pt6
pt5
pt22
wetland 16
wetland 18
pt29
wetland 26
wetland 25
pt23
pt24
wetland 15
pt4
wetland 4
pt25
pt3
wetland 14
wetland 3
pt26
wetland 2
wetland 9
pt2
wetland 13
wetland 1
pt28
pt27
pt1
wetland 11
wetland 10
wetland 12
Sample points
Mean high water (5.3 ft NAVD88)
Mean higher high water (5.9 ft NAVD88)
Property boundary
Data sources: delineation data (WWR, 2009);
Air photo (Marin County, 2004);
Parcel boundary (Marin County, 2009)
Map file: jurisdictional-waters-FINAL_BP_1145_2010-0303lee.mxd
1:2,400 (1" = 200' at tabloid size)
0 100 200 400 ft
0 30 60 120 m
N
W E
S
Audubon CALIFORNIA
WETLANDS AND WATER RESOURCES
JURISDICTIONAL WATERS OF THE U.S.
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California
October 2009
Project No. 1145
Figure 12


Mean high water line (5.3 ft NAVD88)
Wetland Habitats on Site
Acres
Seasonal wetland 2.367
Fringing tidal marsh 6.109
8.476
Data sources: delineation data (WWR, 2009);
Air photo (Marin County, 2006)
Map file: wetlands-only_AP_1145_2010-0303lee.mxd
Audubon CALIFORNIA
1:3,600 (1" = 300' at letter size)
0 150 300 600 ft
0 45 90 180 m
N
W
E
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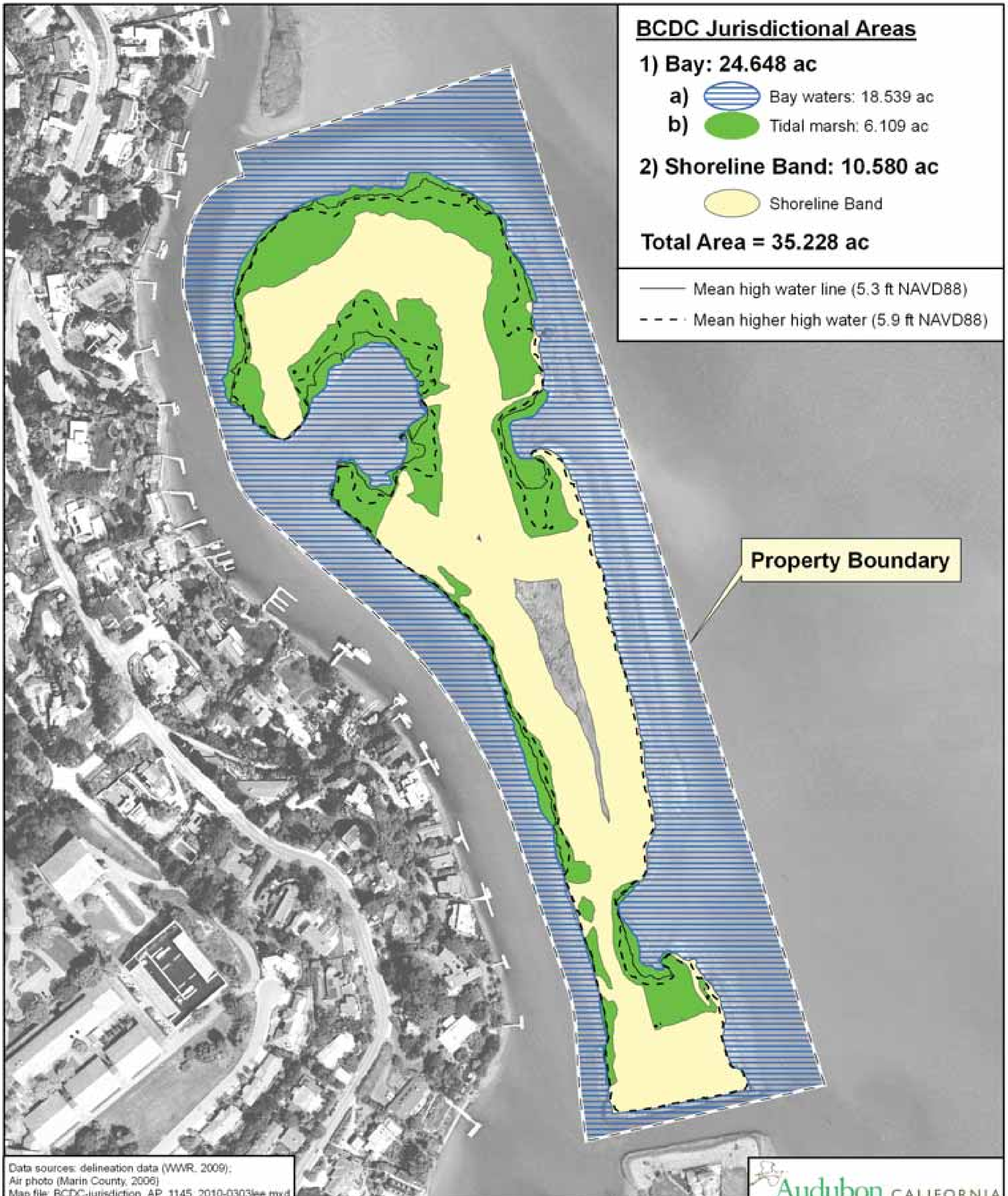
WETLANDS AND WATER RESOURCES
WETLAND HABITATS DELINEATED ON SITE
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California
March 2010
Project No. 1145
Figure 13



BCDC JURISDICTIONAL AREAS

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010 | Project No. 1145 | **Figure 14**

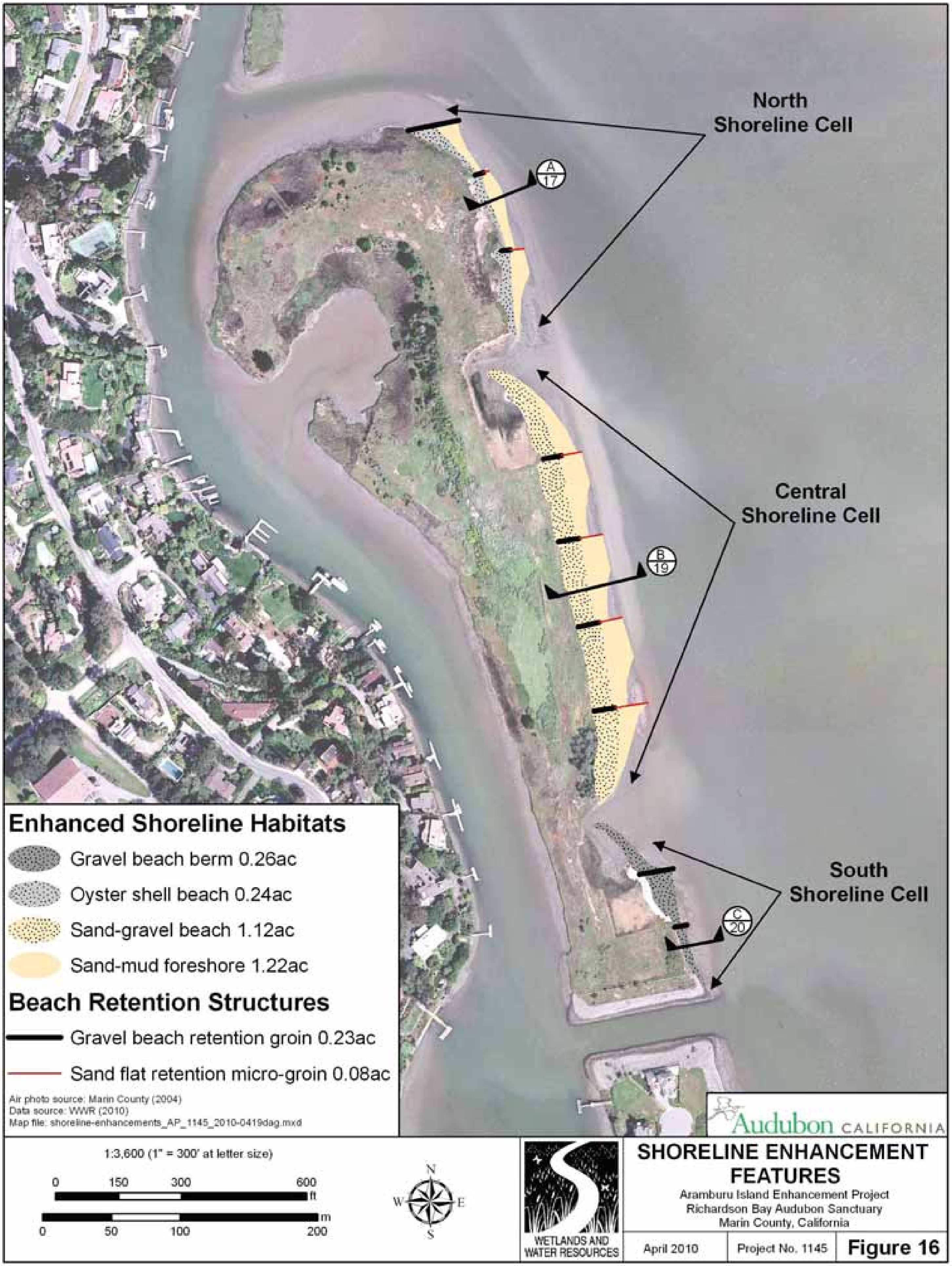
Audubon CALIFORNIA

WETLANDS AND WATER RESOURCES

STUDY BEACHES

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

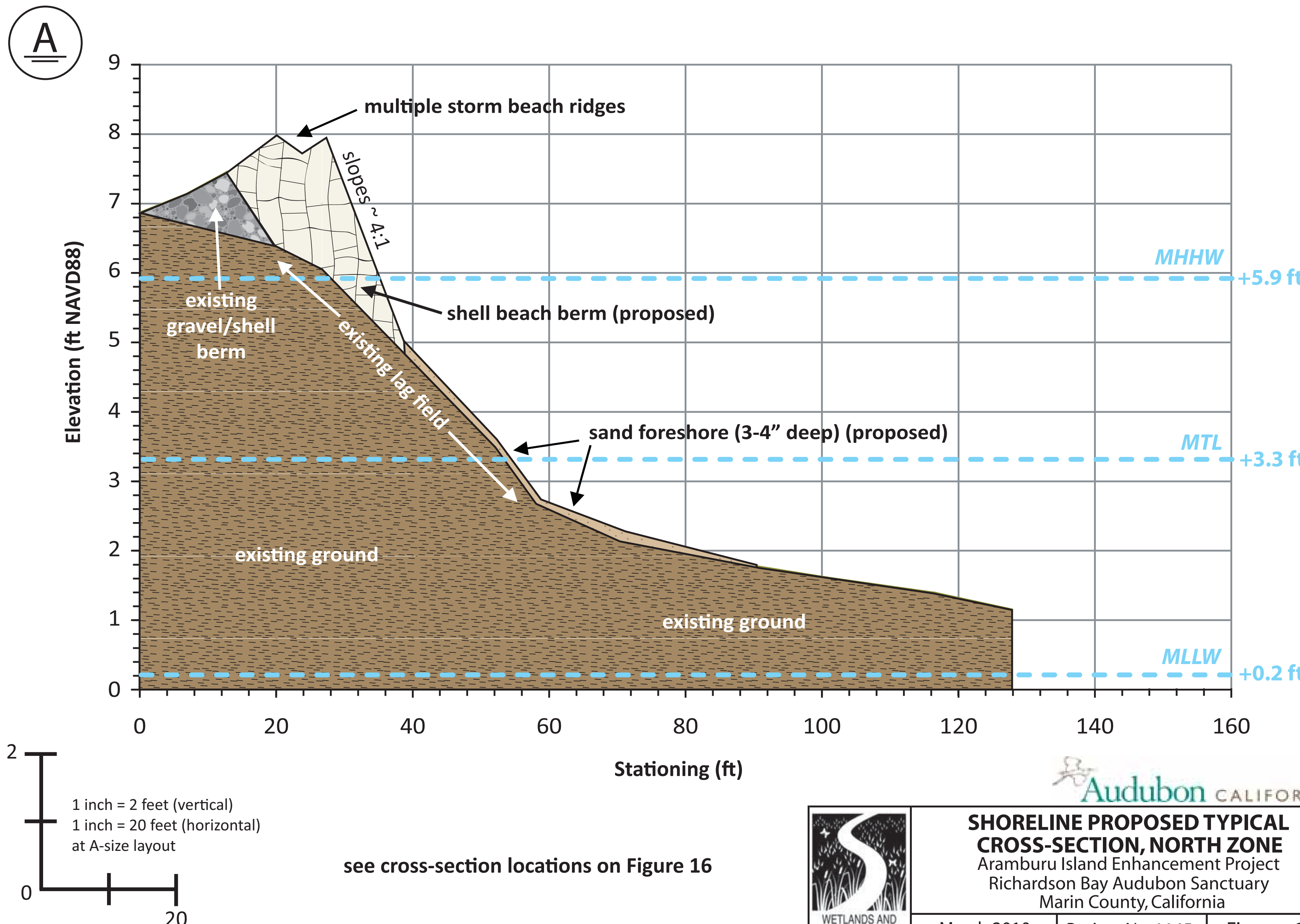
March 2010 | Project No. 1145 | **Figure 15**



SHORELINE ENHANCEMENT FEATURES

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

April 2010 | Project No. 1145 | **Figure 16**



see cross-section locations on Figure 16

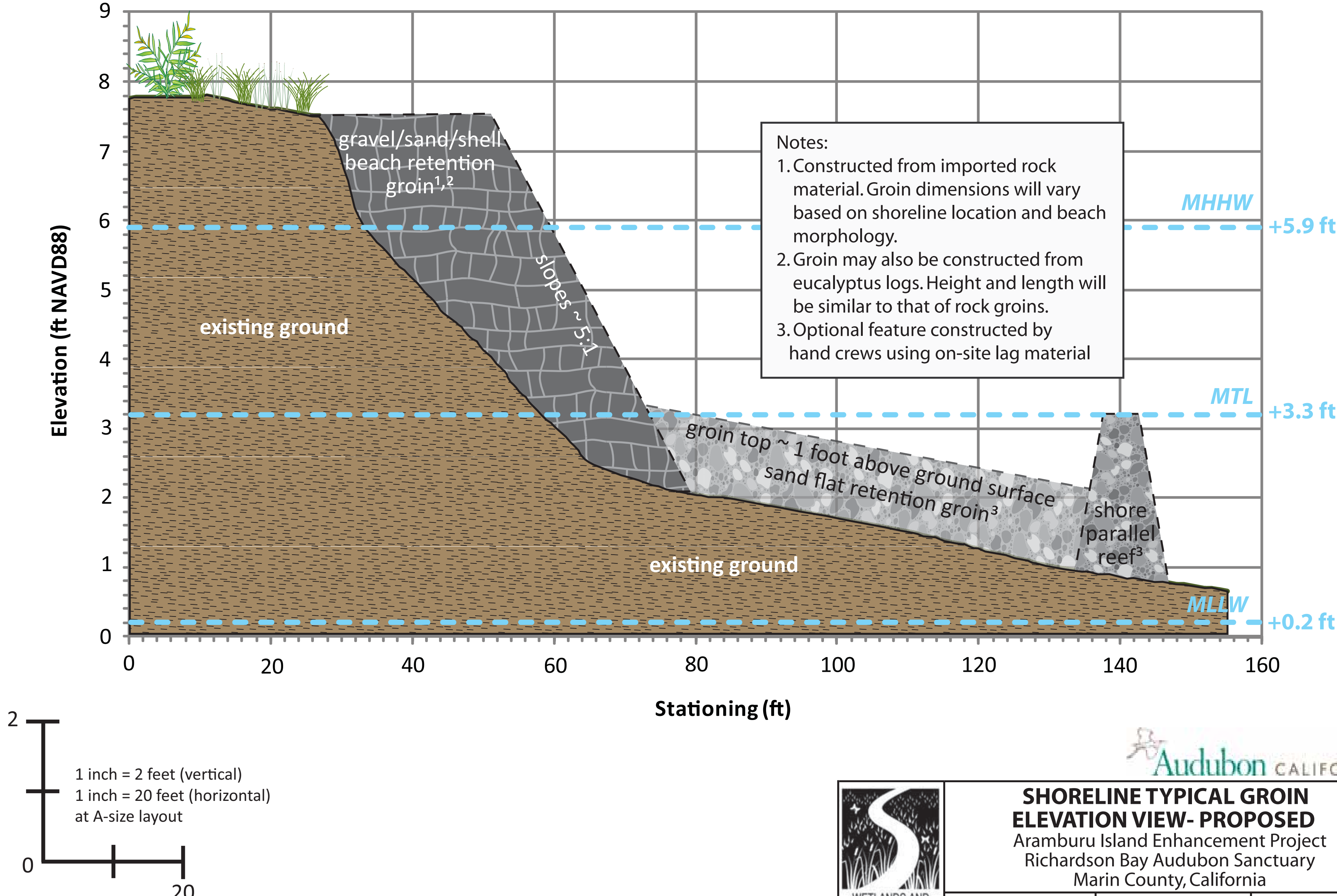
Audubon CALIFORNIA

WETLANDS AND WATER RESOURCES

SHORELINE PROPOSED TYPICAL CROSS-SECTION, NORTH ZONE
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project No. 1145	Figure **17**

Graphic file: Fig-17_beach XS north zone_2010-0304ct.ai



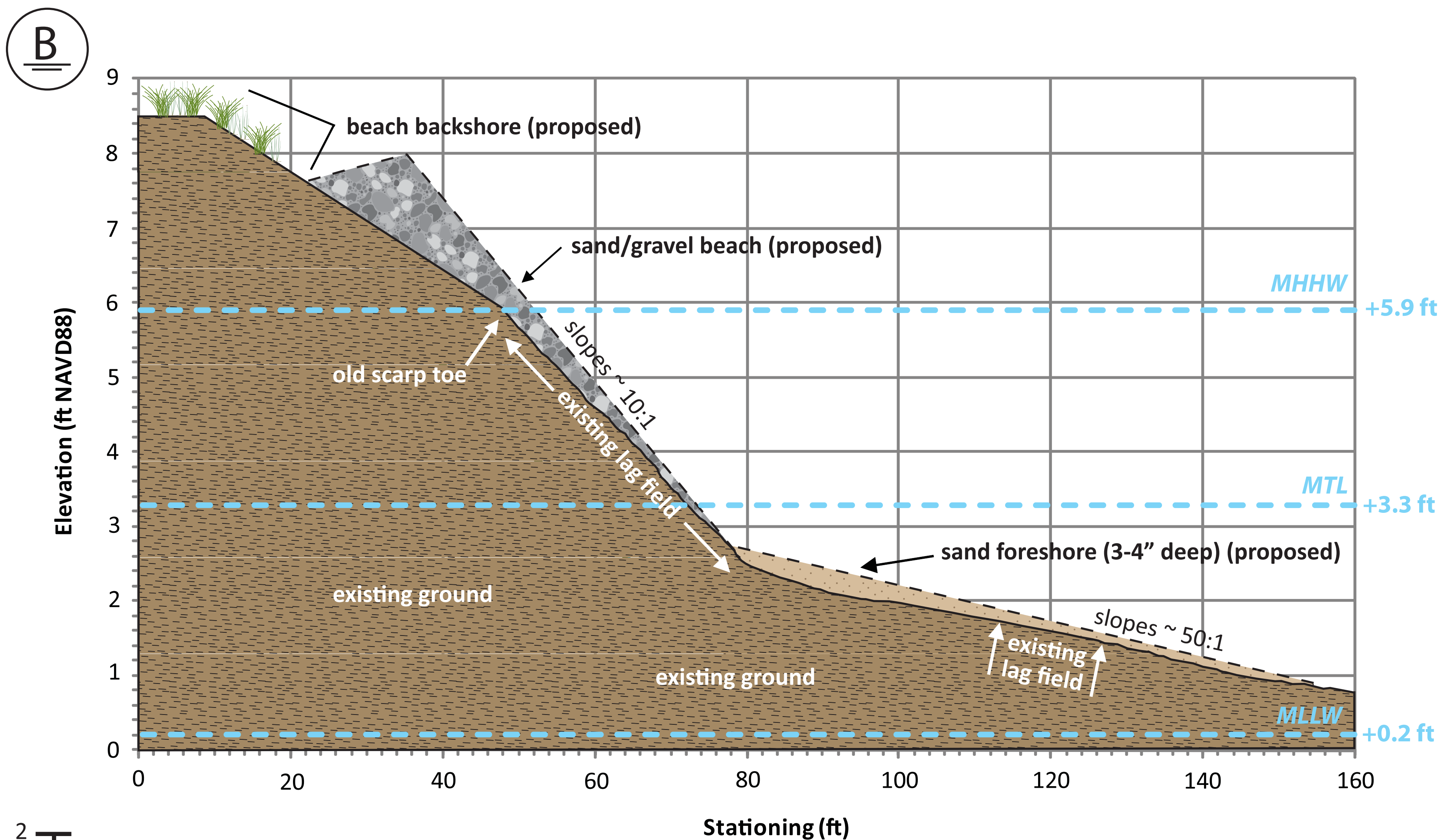
Audubon CALIFORNIA

WETLANDS AND WATER RESOURCES

SHORELINE TYPICAL GROIN
ELEVATION VIEW- PROPOSED
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project No. 1145	Figure **18**

Data source: aramburu_XS_sec_typ_RDL.xls
Graphic file: Fig-18_beach groin_2010-0304ct.ai



2

0 20

1 inch = 2 feet (vertical)
1 inch = 20 feet (horizontal)
at A-size layout

see cross-section locations on Figure 16

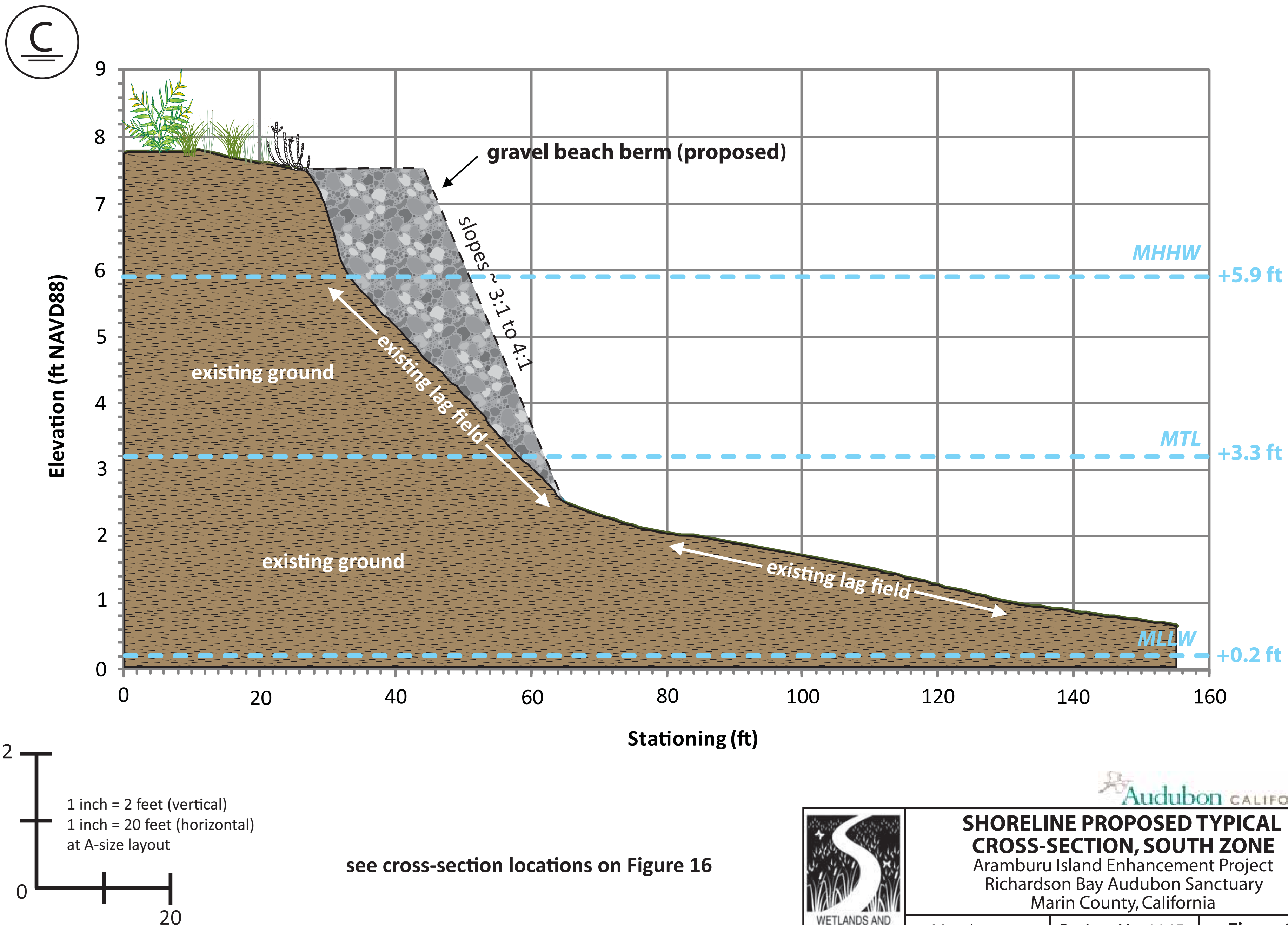
Audubon CALIFORNIA

WETLANDS AND WATER RESOURCES

SHORELINE PROPOSED TYPICAL CROSS-SECTION, CENTRAL ZONE
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project No. 1145	Figure **19**

Graphic file: Fig-19_beach XS central zone_2010-0304ct.ai



see cross-section locations on Figure 16

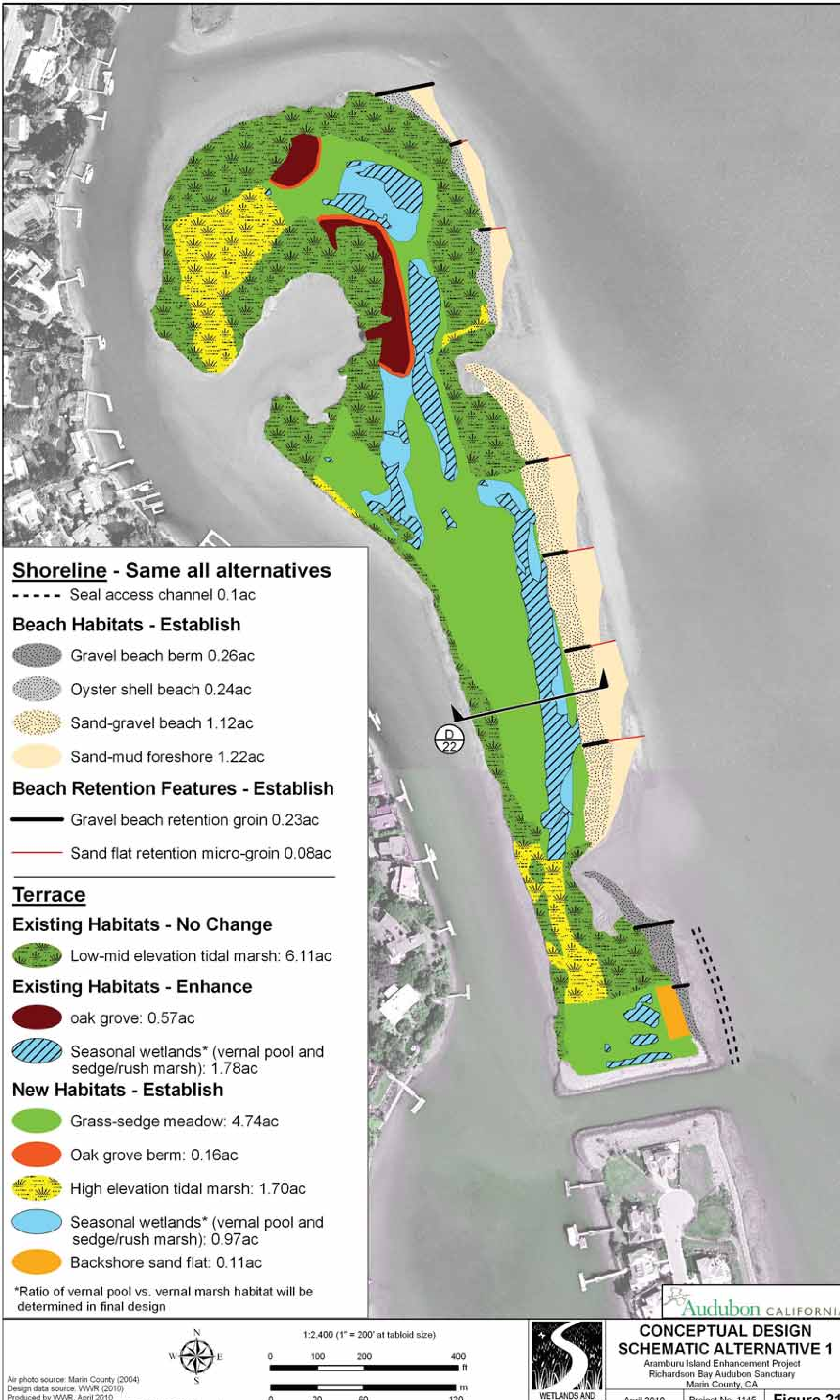
Audubon CALIFORNIA

WETLANDS AND WATER RESOURCES

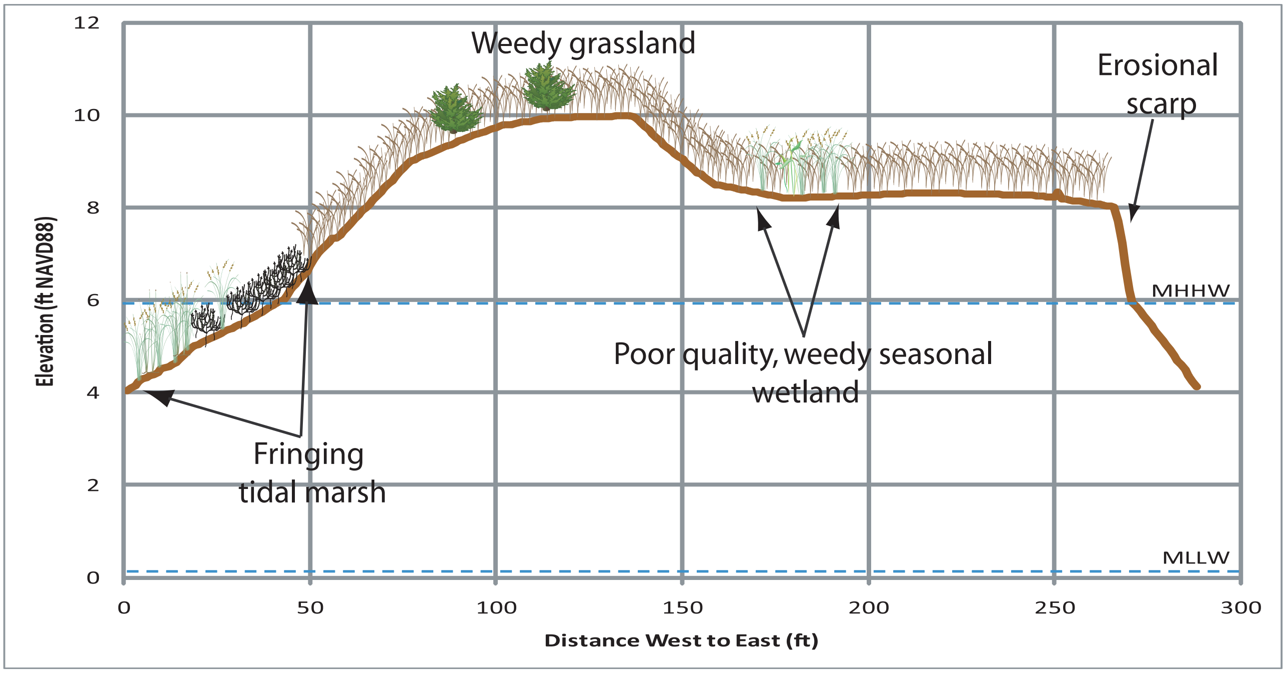
SHORELINE PROPOSED TYPICAL CROSS-SECTION, SOUTH ZONE
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project No. 1145	**Figure 20**

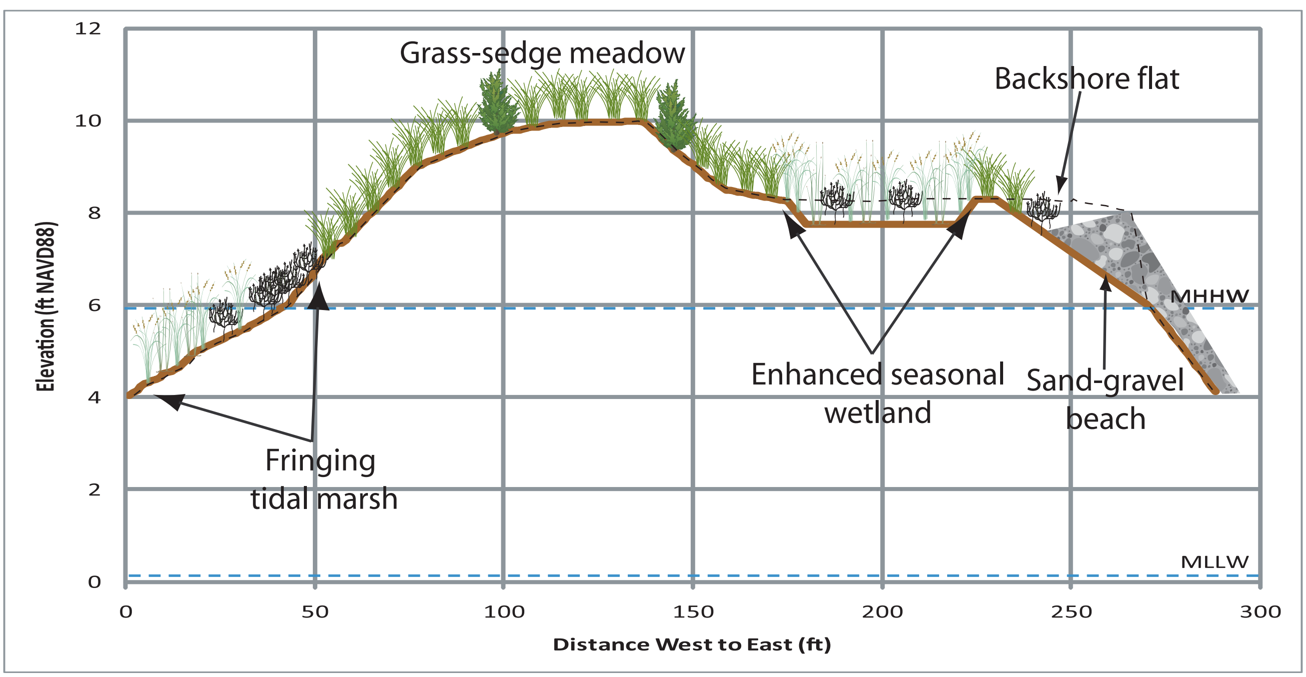
Graphic file: Fig-20_beach XS south zone_2010-0409lee.ai


Shoreline - Same all alternatives
Seal access channel 0.1ac
Beach Habitats - Establish
Gravel beach berm 0.26ac
Oyster shell beach 0.24ac
Sand-gravel beach 1.12ac
Sand-mud foreshore 1.22ac
Beach Retention Features - Establish
Gravel beach retention groin 0.23ac
Sand flat retention micro-groin 0.08ac
Terrace
Existing Habitats - No Change
Low-mid elevation tidal marsh: 6.11ac
Existing Habitats - Enhance
oak grove: 0.57ac
Seasonal wetlands* (vernal pool and sedge/rush marsh): 1.78ac
New Habitats - Establish
Grass-sedge meadow: 4.74ac
Oak grove berm: 0.16ac
High elevation tidal marsh: 1.70ac
Seasonal wetlands* (vernal pool and sedge/rush marsh): 0.97ac
Backshore sand flat: 0.11ac
*Ratio of vernal pool vs. vernal marsh habitat will be determined in final design
D
22
Audubon CALIFORNIA
N
W
E
S
Air photo source: Marin County (2004)
Design data source: WWR (2010)
Produced by WWR, April 2010
Map file: aramburu-design-Alt1_1145_BP_2010-0402dag.mxd
1:2,400 (1" = 200' at tabloid size)
0 100 200 400 ft
0 30 60 120 m
WETLANDS AND WATER RESOURCES
CONCEPTUAL DESIGN
SCHEMATIC ALTERNATIVE 1
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA
April 2010
Project No. 1145
Figure 21

1. Existing Conditions



2. Proposed Conditions



- - - - - Existing ground surface

Audubon CALIFORNIA

WETLANDS AND WATER RESOURCES, INC.

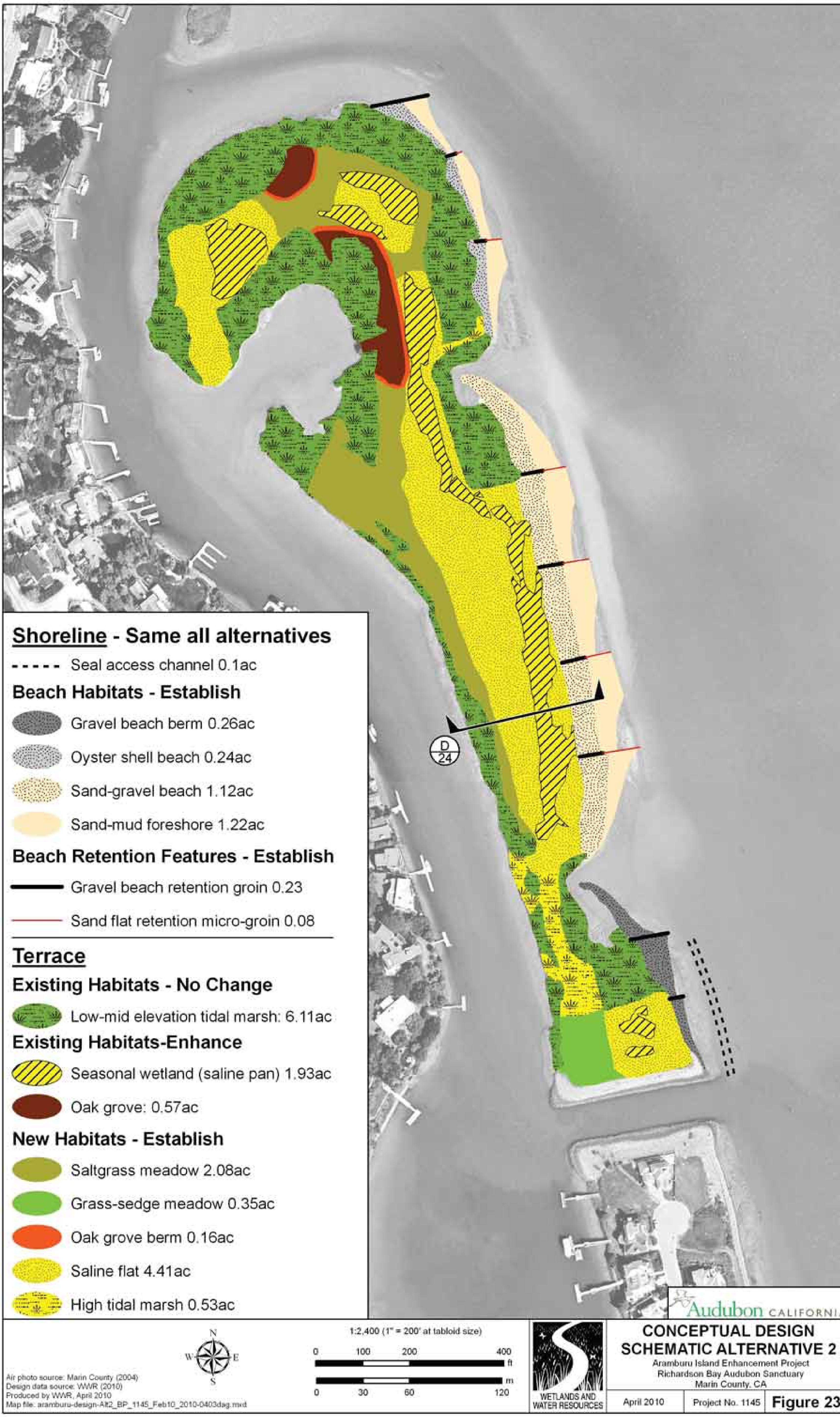
ISLAND TERRACE CURRENT AND PROPOSED CROSS SECTIONS, ALTERNATIVE 1

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

April 2010	Project No. 1145	**Figure 22**

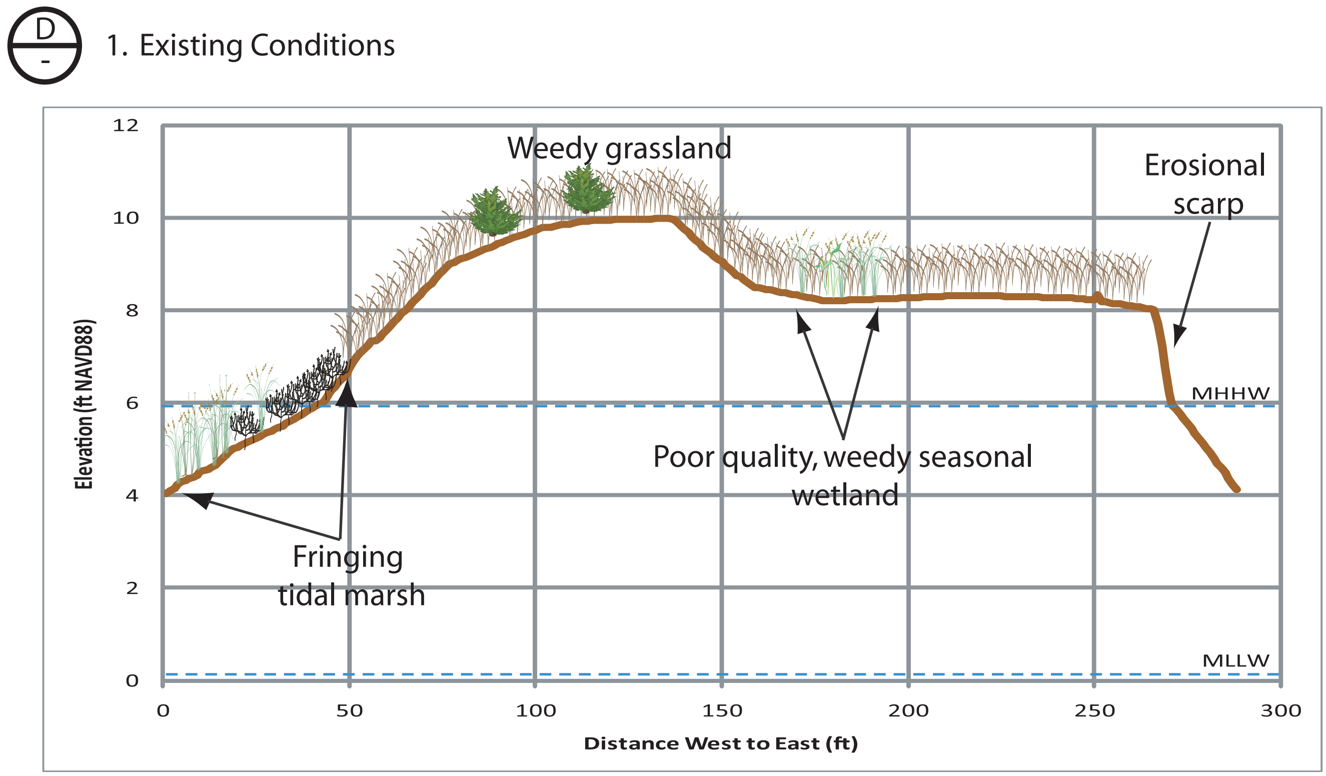
See cross-section location in Figure 21

Fig-22_Island-terrace-XS-Alt1_1145_2010-0409dag.ai

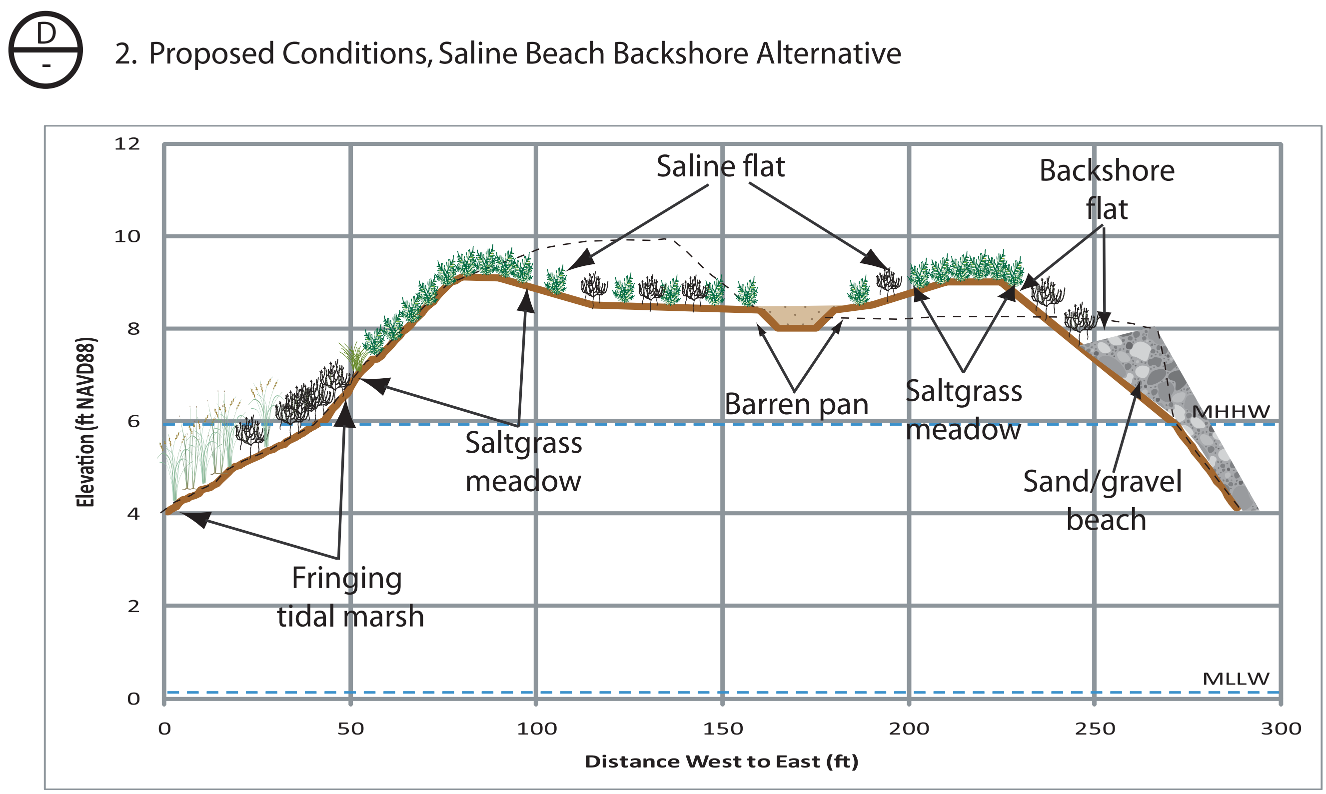


D
24
Shoreline - Same all alternatives
Seal access channel 0.1ac
Beach Habitats - Establish
Gravel beach berm 0.26ac
Oyster shell beach 0.24ac
Sand-gravel beach 1.12ac
Sand-mud foreshore 1.22ac
Beach Retention Features - Establish
Gravel beach retention groin 0.23
Sand flat retention micro-groin 0.08
Terrace
Existing Habitats - No Change
Low-mid elevation tidal marsh: 6.11ac
Existing Habitats-Enhance
Seasonal wetland (saline pan) 1.93ac
Oak grove: 0.57ac
New Habitats - Establish
Saltgrass meadow 2.08ac
Grass-sedge meadow 0.35ac
Oak grove berm 0.16ac
Saline flat 4.41ac
High tidal marsh 0.53ac
Audubon CALIFORNIA
N
W
E
S
Air photo source: Marin County (2004)
Design data source: WWR (2010)
Produced by WWR, April 2010
Map file: aramburu-design-Alt2_BP_1145_Feb10_2010-0403dag.mxd
1:2,400 (1" = 200' at tabloid size)
0
100
200
400
ft
m
0
30
60
120
WETLANDS AND WATER RESOURCES
CONCEPTUAL DESIGN
SCHEMATIC ALTERNATIVE 2
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA
April 2010
Project No. 1145
Figure 23

1. Existing Conditions



2. Proposed Conditions, Saline Beach Backshore Alternative



- - - - - Existing ground surface

See cross-section locations in Figures 23 and 25

Audubon CALIFORNIA

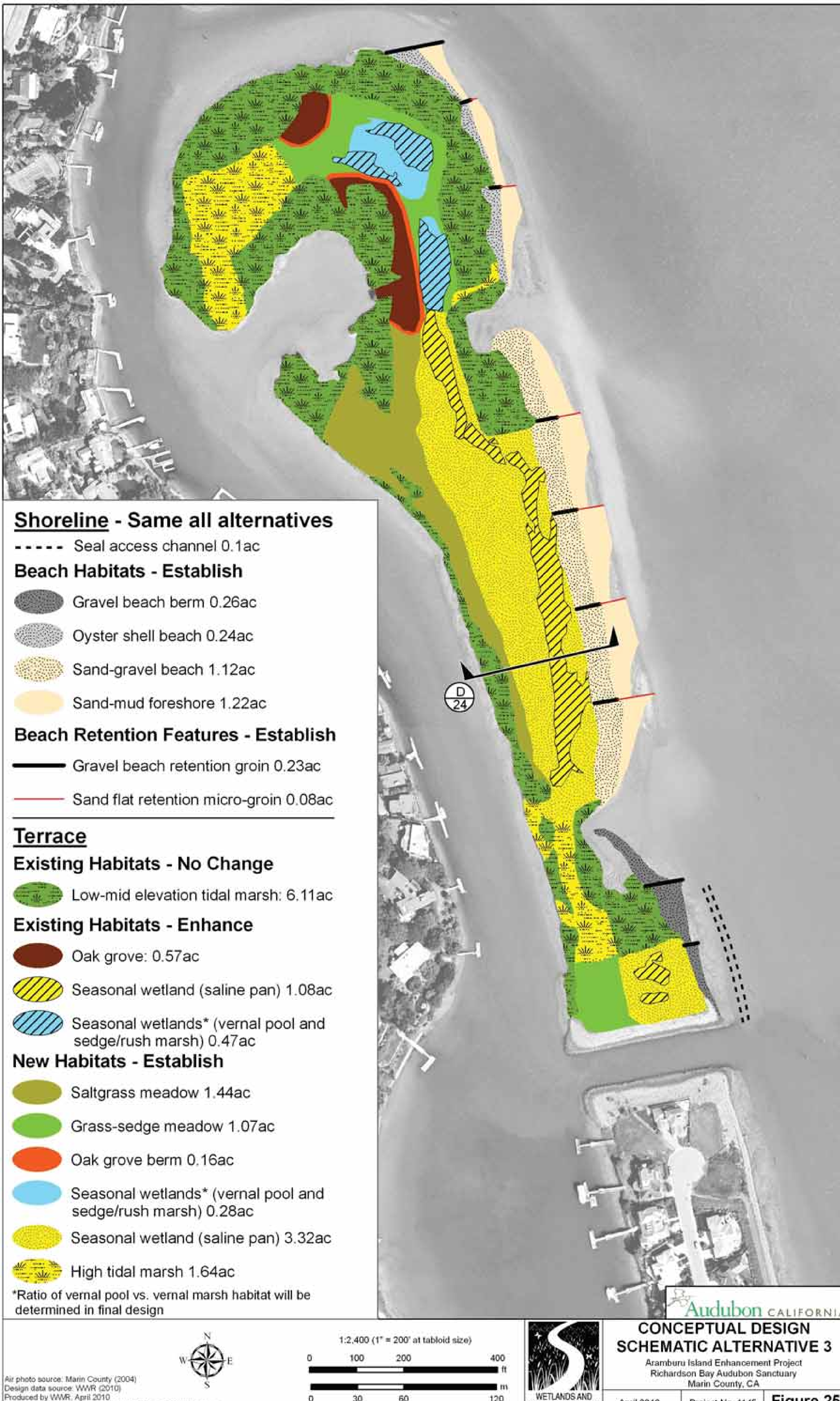
WETLANDS AND WATER RESOURCES, INC.

ISLAND TERRACE CURRENT AND PROPOSED CROSS-SECTIONS, ALTERNATIVES 2 AND 3

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California

March 2010	Project No. 1145	**Figure 24**

Graphic file: Fig-23_Island-terrace-XS-Alt2_1145_2010-0304ct.ai



Shoreline - Same all alternatives
Seal access channel 0.1ac
Beach Habitats - Establish
Gravel beach berm 0.26ac
Oyster shell beach 0.24ac
Sand-gravel beach 1.12ac
Sand-mud foreshore 1.22ac
Beach Retention Features - Establish
Gravel beach retention groin 0.23ac
Sand flat retention micro-groin 0.08ac
Terrace
Existing Habitats - No Change
Low-mid elevation tidal marsh: 6.11ac
Existing Habitats - Enhance
Oak grove: 0.57ac
Seasonal wetland (saline pan) 1.08ac
Seasonal wetlands* (vernal pool and sedge/rush marsh) 0.47ac
New Habitats - Establish
Saltgrass meadow 1.44ac
Grass-sedge meadow 1.07ac
Oak grove berm 0.16ac
Seasonal wetlands* (vernal pool and sedge/rush marsh) 0.28ac
Seasonal wetland (saline pan) 3.32ac
High tidal marsh 1.64ac
*Ratio of vernal pool vs. vernal marsh habitat will be determined in final design
D
24
Audubon CALIFORNIA
N
W
E
S
1:2,400 (1" = 200' at tabloid size)
0 100 200 400 ft
0 30 60 120 m
Air photo source: Marin County (2004)
Design data source: WWR (2010)
Produced by WWR, April 2010
Map file: aramburu-design-Alt3_1145_BP_2010-0403dag.mxd
WETLANDS AND WATER RESOURCES
CONCEPTUAL DESIGN
SCHEMATIC ALTERNATIVE 3
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA
April 2010
Project No. 1145
Figure 25

Appendices

Appendix A:
Representative Site Photographs

1. Existing Site Conditions

1.1 *Island Terrace Unit*

Photo 1. Upland, non-native grasslands (photo by Christina Toms, 1/29/2009)

Photo 2. Mid-elevation tidal marsh along western shoreline (photo by Dan Gillenwater, 5/7/2009)

Photo 3: Non-tidal, seasonal wetland (photo by Dan Gillenwater, 10/15/2009)

Photo 4. Southern gravel spit and adjacent cove on eastern shoreline (photo by Dan Gillenwater, 1/12/2009)

Photo 5. Rip-rap revetment along southern island shore (photo by Stuart Siegel, 9/12/2008)

1.2 *Bay Unit*

Photo 6: Southern cove and back-barrier tidal marsh behind gravel spit (photo by Dan Gillenwater, 9/15/2009)

Photo 7: Cobble and boulder lag field along eastern shoreline (photo by Dan Gillenwater, 10/15/2009)

Photo 8: Wave-cut, erosional eastern shoreline (photo by Peter Baye, 1/12/2009)


Photo 9: Offshore mudflats at north end of island (photo by Dan Gillenwater, 12/9/2009)

2. Proposed Conditions

2.1 *Shoreline*


Photo 10: Shell beach bordering intertidal sand/mudflat. Location: Foster City, San Mateo County. Reference site for Aramburu Island northern shoreline cell (photo by Dan Gillenwater)

Photo 11: Mixed sand/gravel beach. Location: Brisbane, San Mateo County. Reference site for Aramburu Island central shoreline cell (photo by Dan Gillenwater)

Photo 12: Gravel beach berm. Location: Pier 94, San Francisco. Reference site for Aramburu Island southern shoreline cell (photo by Dan Gillenwater)

2.2 *Island Terrace*

Photo 13: High tidal marsh. Eroded, compacted, wave-scoured upland fill in the high tide line, exposing rubble and gravel embedded in heavy sandy clay, supports sparse pickleweed and abundant salt marsh bird's-beak. Location: Pohono St. Marsh, North Sausalito. (photo by Peter Baye)

Photo 14: Seasonal vernal pool wetlands formed in depressions in consolidated, desalinized Bay Mud. Location: Bahia wetlands, Novato. (photo by Peter Baye)

Photo 15: Vernal spikerush marsh. <u>Location:</u> Diked baylands, Atherton Ave. at School St., Marin County, CA (Photo by Peter Baye)

Photo 16: Saline flat/pan complex. <u>Location:</u> Petaluma Marsh, Sonoma County (Photo by Peter Baye)

Photo 17: Perennial lowland grassland dominated by creeping wildrye (Leymus triticoides and L. x multiflorus) bordering tidal salt marsh. <u>Location:</u> Point Pinole, Contra Costa County (Photo by Peter Baye)

Photo 18: Saltgrass meadow (western ragweed/saltgrass co-dominants). <u>Location:</u> Rush Ranch, Solano County (Photo by Peter Baye)

Appendix B
Aramburu Island Soil Profile Analysis

Project No. 1145

Technical Memorandum

Aramburu Island Soil Profile Analysis

To: Project Design Team
From: Dan Gillenwater
Date: October 12, 2009

1. Introduction

On September 19, 2009, Dan Gillenwater of Wetlands and Water Resources, Inc. (WWR) and Suzanne Olyarnik of the Richardson Bay Audubon Sanctuary conducted an analysis of the soil profile on Aramburu Island. The purpose of this investigation was to determine the composition of the island foundation and if the subsurface material is suitable, and of sufficient quantity, to serve as capping material for seasonal wetland and transitional grassland habitat to be constructed as part of the island enhancement.

The island was constructed during the 1960s initially from dredge spoils from adjacent navigational channel maintenance and then capped with hillslope material excavated during the development of Strawberry Point. The soil of Strawberry Point is primarily Los Osos-urban land-Bonnydune complex (Figure 1), which is a well-drained upland, hillslope soil derived from weathered sandstone and shale. The typical profile of these soils is generally up to 18 inches of loam underlain by up to 18 inches of clay over bedrock.

2. Methods

The investigation was performed by digging four trenches positioned along the north-south axis of the island (Figure 2) with a small excavator, operated by staff from the North Bay Conservation Corps. The trenches were generally 4ft by 8ft and to a depth of 7-8ft below ground surface (BGS). At each trench, we collected the following data:

- Description of each distinct layer along the soil profile including material composition, color, and moisture.
- Soil samples from each distinct layer along the soil profile.
- Measurements of the dimensions of representative boulders excavated from the trenches.

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- Measurements of depth to saturation and depth to groundwater (if present) and measurements of groundwater salinity.
- Topographic surveys of the elevations of important features (top of trench, top of clay layers, groundwater seeps, standing groundwater, etc.)
- Photographs of the soil profile.

After the analyses were performed, the trenches were backfilled and graded to their approximate original condition.

3. Results

The results of the investigation of each soil trench are described individually below. The profile/boring log data for each trench are presented in Table 1 and measurements of representative boulders from the hillslope fill layers are presented in Table 2. Photographs of the trenches can be found in Appendix A. Individual samples of each soil layer in each trench are available at the WWR office for inspection or further laboratory testing.

Trench No. 1

Trench No. 1 is located at the south end of the island in a stand dominated by Harding grass. The total trench depth was 8′. The first 3′ of the soil profile consists of dry, rocky, silty clay, which becomes more compacted with depth. The rocks in this soil layer are predominantly sandstone of a wide size range (<1″ – 6″). From 3′-7′ is a layer of dark, slightly moist clay. This clay, likely dredged marine material, is very malleable, but breaks/fragments easily due to the lack of moisture. Below 7′ is the underlying, dark bay mud clay. This clay is very moist, soft, and malleable and had to be pried out of the excavator bucket. We observed no ground water at this location (even after 4 hours, there was no groundwater percolation into the pit).

Trench No. 2

Trench No. 2 is located along the central "spine" of the island, in a Harding grass stand on the edge of a large seasonal wetland. The total trench depth was 7.5′. The first 3′ of the soil profile consists of dry, rocky, silty clay similar to that found at Trench No. 1. From 3′-6.25′ is a layer similar to the first 3′, but more compact with higher clay content and redder in color than the overlying layer. Below 6.25′ the soil is dark, sandy/silty clay with a lot of plant fragments. This layer is likely dredged marine sediments. We could not dig beyond 7.5′ due to the presence of a large boulder at the bottom of the pit, and therefore never reached the solid, Bay clay layer that we found in Trench 1. Groundwater was present at 6.6′ (salinity~20ppt).

Trench No. 3

Trench No. 3 is located at the north end of the island in a mixed vegetation stand dominated by purple needlegrass on the edge of some seasonal wetlands. The total trench depth was 8′. The first 2′ of the soil profile consists of dry, rocky, silty clay similar to that found at Trenches 1 and 2, however this layer also contains a large amount of shale/siltstone fragments not noticed at the previous 2 locations. Immediately below this top layer is an 8″ (from 2′-2.6′) thick layer of very stiff, hillslope clay containing very few rocks. This shallow clay layer may account for the large number of seasonal wetland pockets found at the north end of the island. Below this layer, from 2.5′-6.8′, is a very heterogeneous mixture of sandy/silty hillslope clay and darker (likely Bay derived) silty clay deposits. There are still a lot of rocks in this layer, though not as large as those found in the surface layer. Below 6.8′ is the native, moist, malleable bay mud, identical to that found in Trench 1. This clay layer also contains many shell fragments. Saturation was noted at the bottom of the pit (8′), however we could not collect enough of a sample to determine the salinity.

Trench No. 4

Trench 4 is located between Trench 2 and 3, in a mixed stand of Italian thistle and French broom, between two seasonal wetlands. The total pit depth was 7′. The first 1.5′ of the soil profile is similar to the top layers in Trenches 1 and 2. Below this layer is an 18″ (from 1.5′-2.2′) layer of silty, hillslope clay, similar to layer 1, but redder in color. From 2.2′ to 5′ is a heterogeneous layer dominated by the silty, hillslope clay with pockets of darker, silty clay deposits. There were still a large number of rocks in this layer. Below 5′ the soil became more consistent dark, silty clay containing a lot of small diameter rocks. This layer is likely dredged marine sediments. A groundwater seep was noted at 3.8′ and ponded groundwater occurred at 7.4′ (salinity ~20ppt). The walls of this trench were not as sturdy as those of the other trenches, likely due to the high water table. Material was continually sloughing off the walls while the trench was open.

4. Summary

Based on the results of our investigation, we can make some generalizations about the subsurface composition of the island. A visual representation of the soil profile across the island is presented in Figure 3. A layer of hillslope fill of varying thickness, depending on location, exists immediately below the surface. This layer is thinnest (3′)

at the south end of the island (Trench 1), and thickest (6.8′) at the north end of the island (Trench 3). Beneath this hillslope layer at Trenches 1, 2, and 4 there is a layer of darker, clay material, likely representing deposits of dredged marine sediments. The texture, consistency, and rock/plant material content of this soil is variable at each location, indicating different sources. This type of soil was absent from the profile at Trench 3. At the south and north ends of the island (Trenches 1 and 3) the native, underlying bay clay layer was encountered at approximately 7′ BGS (1.5 ft NAVD). This clay layer was not reached at Trenches 2 and 4. We did not find groundwater at the north or south ends of the island, although saturation was noticed at the very bottom of Trench 3. We found standing groundwater in Trenches 2 and 4. The salinity of the groundwater in both trenches was ~20 ppt.

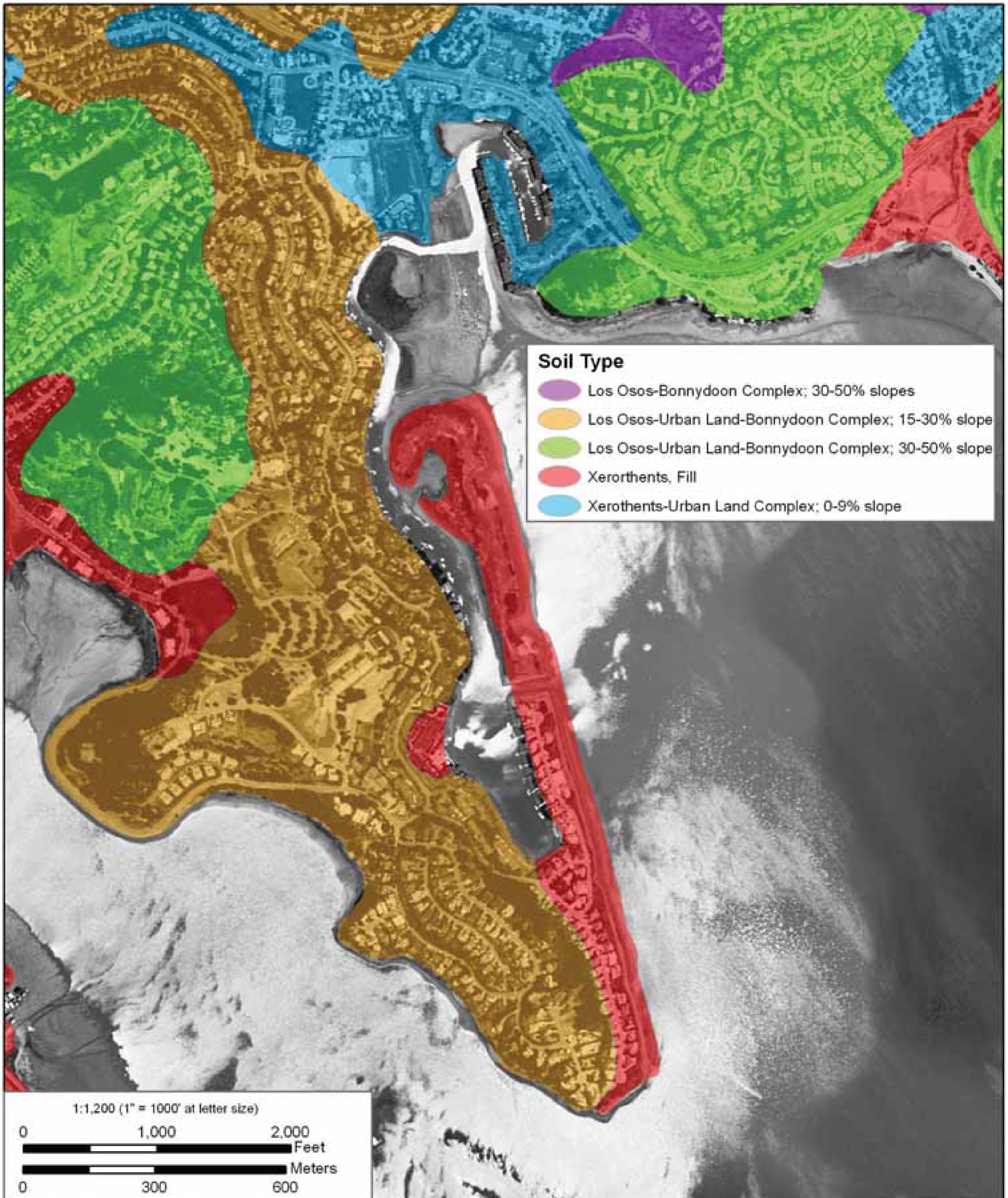
Tables and Figures

Table 1: Soil Trench Characteristics

Trench No.	Depth (in)	Elevation (ft NAVD88)	Moisture (Dry, Moist, Wet)	Munsell Color Matrix	Munsell Color Mottle	Layer Comments	Pit Comments	Depth to Water (in)	WSE (ft NAVD88)
1	0-16	8.5 - 7.2	Dry	10YR 4/2	NA	Silty hillslope clay, very rocky (rocks and boulders are 25-50% of matrix), primarily sandstone, some iron concentrations apparent in soil	Soild wall stability. Total pit depth 8 ft. No groundwater percolation even after 4 hours.	NA	NA
	16-36	7.2 - 5.5	Dry	5YR 4/1	NA	Similar to layer 1, but more compact, less loose material			
	36-84	5.5 - 1.5	Slightly moist	Gley 4/N	NA	Very pliable, dark clay, still somewhat dry and blocky in composition, no rocks			
	> 84	1.5 - 0.5	Moist	Gley 3/10Y	NA	Solid, underlying native bay clay, very sticky, had to pry out of bucket			
2	0-24	9.3 - 7.3	Dry	10YR 4/1	NA	Silty hillslope clay, very rocky (rocks and boulders are 25-50% of matrix), primarily sandstone, some iron concentrations apparent in soil	Soild wall stability. Total pit depth 7.5 ft. Groundwater present (salinity ~20ppt). Large boulder at 7.5 ft prevented further digging	80	2.6
	24-75	7.3 - 3.0	Dry	7.5YR 5/6	NA	Similar to layer 1, but with slightly more clay and more compact. Soil is more red in color due to presence of fine red sand			
	> 75	3.0 - 1.8	Moist to Saturated	2.5Y 3/0	NA	Very malleable clay w/some plant fragments, very few rocks			
3	0-24	8.1 - 6.1	Dry	10YR 4/4	NA	Silty hillslope clay, finer than in trenches 1 and 2. Very rocky (25-50% of soil matrix). Lots of shale/mudstone fragments along with the common sandstone	Soild wall stability. Total pit depth 8 ft. Groundwater saturation at bottom of pit	Saturation at 96	0.1
	24-32	6.1 - 5.4	Slightly moist	10YR 7/6	NA	Stiff hillslope clay. Very few rocks. This is an 8" layer of clay between the adjoining soil layers			
	32-82	5.4 - 1.3	Slightly moist	Variable	variable	Very heterogeneous mix of soil types, but predominantly hillslope clay with small pockets of dark, marine clay deposits. Still large number of rocks present, but of smaller size than soil layer 1			
	> 82	1.3 - 0.1	Moist	Gley N4	NA	Solid, underlying native bay clay, some shell fragments, very sticky. Had to pry out of bucket			
4	0-18	7.9 - 6.4	Dry	7.5YR	NA	Silty hillslope clay. Similar to layer 1 in trench 3, but less presence of shale/siltstone. Still lots of sandstone boulders (25-50% of soil matrix)	Wall not as stable, saturated hillslope material sloughing into pit. Total pit depth 7ft. Much higher water table than other trenches. Salinity ~20ppt	Saturation at 46. Ponding at 74	Saturation at 4.1. Ponding at 1.7
	18-26	6.4 - 5.7	Dry	10YR4/4	NA	Silty clay, similar in texture to layer 1, but more red in color.			
	26-60	5.7 - 2.9	Moist-saturated	Variable	variable	Primarily silty, hillslope clay with scattered pockeks of darker (bay) clay. Large number of small-diameter rocks present (10-20% of soil matrix)			
	>60	2.9 - 0.9	Saturated	Gley N4	NA	Darker, more consistent clay layer. Still a lot of small angular (< 1") rocks present (10-20% of matrix by volume).			

Table 2: Boulder Measurements

	Boulder (b axis) Measurements (in)			
	Trench 1	Trench 2	Trench 3	Trench 4
	3	5.2	3.8	4.7
	3.5	2.5	2.8	4.7
	3	3.2	3.7	6
	3	4.1	4.1	4
	4.5	2.9	4.6	5.5
	5.8	2.7	3.1	5.1
	4.4	2.7	5.2	3.5
	3.8	3	2.9	6.2
	3.8	3.5	3.2	6
	1.9	2.5	2.5	6.2
Mean	3.67	3.23	3.59	5.19
Median	3.65	2.95	3.45	5.3
Max	5.8	5.2	5.2	6.2



Data sources: Soils (USDA, 1999);
Photo (NAIP, 2005)
Produced by WWR, October 2009
Map file: Aramburu-soil-types_2009-1008dag.mxd

SOIL TYPES
ARAMBURU ISLAND

Richardson Bay Audubon Sanctuary

October 2009	Project 1145	Figure 1

Soil Pit Locations

Data sources: Soil pit locations (WWR, Audubon, 2009); Photo (NAIP, 2005)
Produced by WWR, October 2009
Map file: Aramburu-soil-pit-locations_2009-1008dag.mxd

N W E S

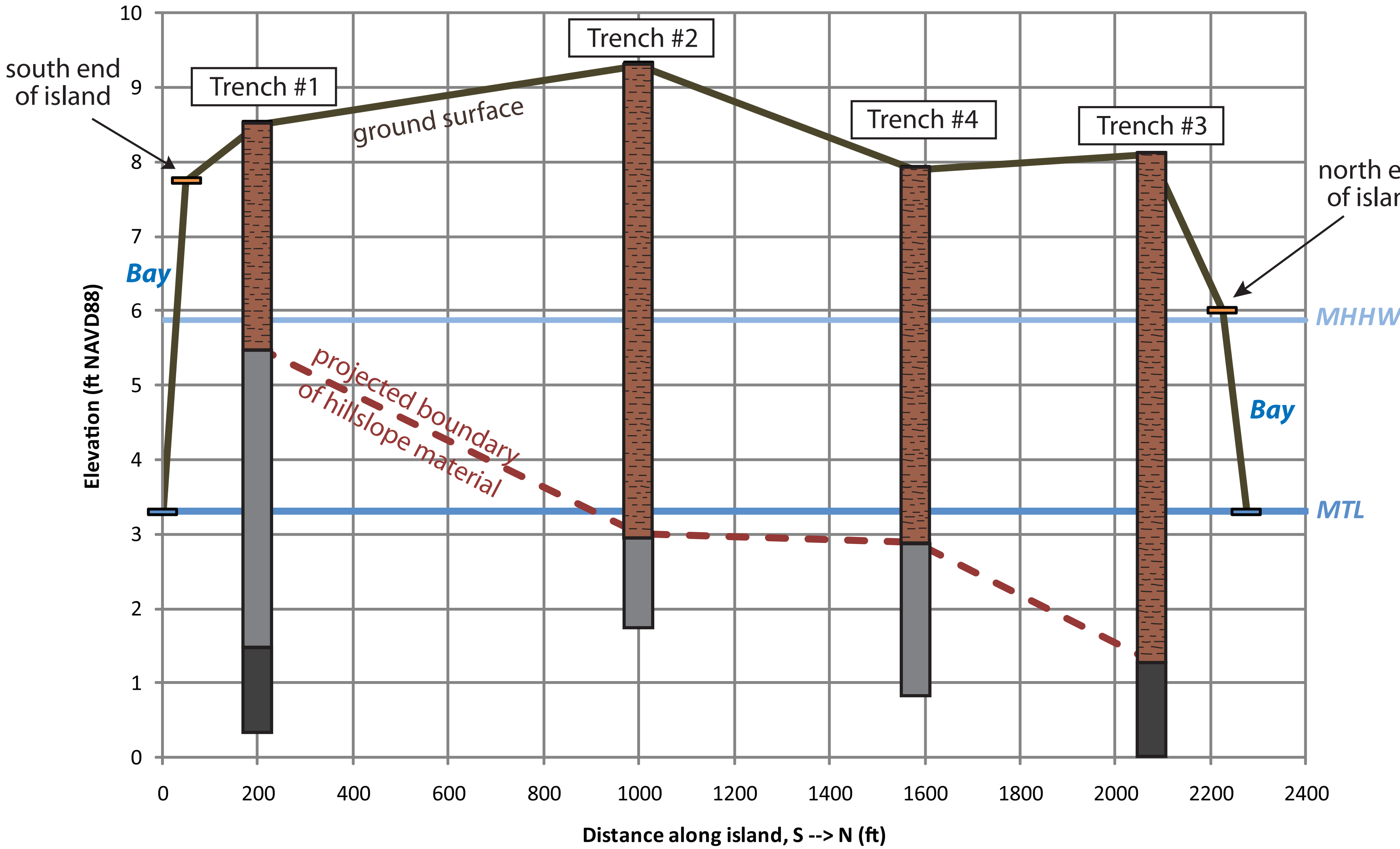
WETLANDS AND WATER RESOURCES

SOIL PIT LOCATIONS
ARAMBURU ISLAND

Richardson Bay Audubon Sanctuary

October 2009 | Project 1145 | Figure 2

Aramburu Island Subsurface Profiles



= hillslope fill from adjacent uplands

= dredged material

= native bay muds

SUBSURFACE PROFILES

Aramburu Island Enhancement Project
Marin County, California
Richardson Bay Audubon Sanctuary, California

WETLANDS AND WATER RESOURCES

October 2009	Project No. 1145	Figure 3

Data source: data for AI graphic_2009-1012ct.xls
Graphic file: Fig-03_subsurface profiles_2009-1012ct.ai

Appendix A:
Representative Photographs


Photo 1. Trench 1, soil profile


Photo 2. Trench 1, soil layers 1 and 2 (hillslope material)


Photo 3. Trench 1, boundary between soil layers 2 (hillslope) and 3 (underlying clay)

Photo 4. Deep, bay clay extracted from Trench 1. Note retention of bucket shape

Photo 5. Trench 2, soil layers 1 and 2

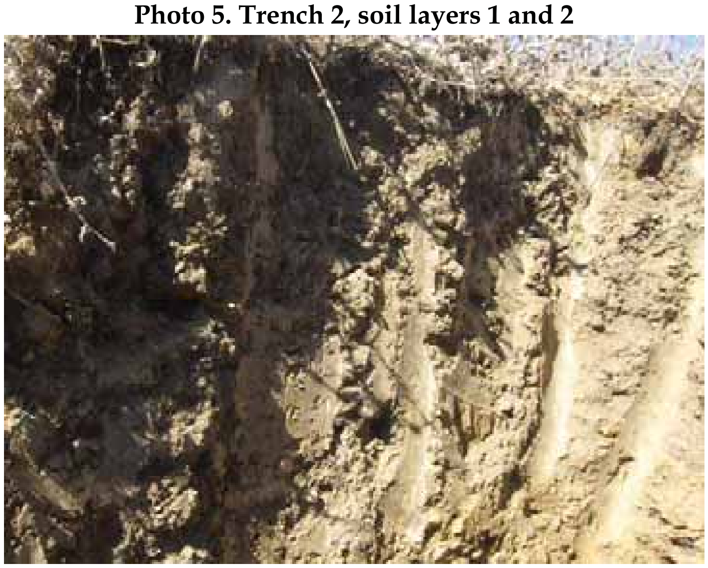


Photo 6. Trench 2, soil layer 1

Photo 7. Trench 2, soil layer 2

Photo 8. Trench 2, ground water. Note dark clay-dominated layer starting ~6" above water line

Photo 9. Trench 3, soil layer 1


Photo 10. Trench 3, soil layer 2 (stiff clay) between layers 1 and 3


Photo 11. Trench 3, soil layer 3


Photo 12. Trench 3, deep, bay clay extracted from bottom of pit

Photo 13. Trench 4, soil profile

Photo 14. Trench 4, border between soil layer 3 (hillslope) and 4 (dark, silty clay)

Appendix C
Aramburu Island Shoreline Material Grain Size Analysis

Project No. 1145

Technical Memorandum

Aramburu Island Shoreline Material Grain Size Analysis

To: Project Design Team
From: Dan Gillenwater
Date: February 26, 2010

On October 14 and 15, 2009, Dan Gillenwater of WWR performed an analysis of the particle size distribution of various depostional shoreline features along the eastern shore of Aramburu Island. The purpose of this exercise was not to characterize the complete shoreline profile of the island, but to study discrete features that were of particular interest to the design team. A total of seven shoreline features were investigated in this effort (Figure 1). This memorandum describes the methods of this investigation and the features that were studied. The grain size distribution histograms and grain size curves for each of the features can be found at the end of this document. Additional analyses on the data presented herein can be performed at the request of the project team.

Study Methods

At each study location we first determined the boundary of the feature of interest and, if necessary, divided the feature into distinct zones based on homogeneity of particle size distribution. The particle size distribution was sampled separately in each of these zones. To perform the sampling, we utilized a transect-intercept sampling method in which we laid a transect tape along a representative section of each zone and sampled the particles lying at set intervals along the line. The sampling interval was set so that 100 samples were collected along each transect. For example, for a 10m transect, we would sample particles every 10cm to achieve the 100 samples necessary for the zone. The diameter of each sampled particle was measured using a gravelometer and logged in the appropriate size class on field datasheets. We measured the diameter of the largest particle found within the zone (D_{max}) and measured the thickness of the shoreline deposit (i.e. depth to underlying substrate) wherever possible. We also took photographs of each zone and logged the position using a Trimble GeoXT handheld GPS.

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Shoreline Features

This section describes the seven shoreline features that were investigated in this study.

Feature 1: Northern Gravel Bar

This feature is a wide gravel bar at the northern tip of the island. The bar is colonized by vegetation at the crest, and terminates into the adjacent mudflats at the bottom of the slope (Photo 1). This berm wraps around the north end and terminates in a small spit. The deposit thickness in this area is generally between 1 and 3".

Photo 1. Feature 1, northern gravel berm

Feature 2: Northern Gravel Spit

This feature is a gravel spit that was originally constructed from imported rock material to mimic the appearance of the southern gravel spit that had served as a popular seal haul out site. The northern gravel spit is divided into three separate zones as described below.

Zone 1: Hillslope Material Beach Ridge

Along the southern end of the spit, a small deposit of medium to fine gravel eroded from the island hillslope fill material has accumulated on top of the imported rock material comprising the "backbone" of the spit (Photo 2). This material is transported north along the island shore and deposits on the spit. Zone 1 is the crest of this hillslope material deposit (Photo 3). The beach ridge is 3.5” at its thickest.

Photo 2. Feature 2, Zone 1: Crest of hillslope deposit

Zone 2: Swash Slope of Hillslope Deposit

This zone is the swash slope along the hillslope deposit. The particles in this area are slightly larger, and more heterogeneously distributed than those in Zone 1 (Photo 3). The maximum thickness of this deposit is 1.5”.

Photo 3. Feature 1, Zone 2: Swash slope of hillslope deposit

Zone 3: Imported Spit Material

The northern spit was originally constructed from imported, quarried rock. This imported rock has mixed with rock material eroded from the island fill and this combination is fairly homogeneously distributed across the entire spit, outside the area of the hillslope material deposit, from the spit crest down to the lag field (Photo 4).

Photo 4. Feature 2, Zone 3: imported spit material

Feature 3: Gravel Toe Berm along Central Island Shore

This feature is a narrow deposit of medium to fine gravel at the base of the wave eroded scarp on the eastern shore of the island (photo 5). This material appears to be very mobile and the berm width, height, and thickness vary along the length of the shoreline. The material piles up along the southern side of fill promontories, root wads, or any other feature that provides a backstop to the northward transport of material. At the time of sampling, the particle size distribution was far more heterogeneous than noted during previous site visits due to the actions of the October 13 storm event. The average thickness of the deposit is 2" – 3".

Photo 5. Feature 3, gravel toe berm

Feature 4: Southern Gravel Spit

The southern gravel spit was formed from hillslope material eroded from the island and deposited along the mouth of the southern embayment. There is also a large amount of shell material in this feature, more than in other features on the island. This spit was divided into four zones for sampling.

Zone 1: Spit Crest

This is the crest of the gravel spit (Photo 6).

Photo 6. Feature 4, Zone 1: southern gravel spit crest

Zone 2: Beach Ridge Deposit

This feature is a small beach "ridge" of medium to fine gravel and shell material that had recently formed, likely as a result of the storm event of the previous day (Photo 7).

Photo 7. Feature 4, Zone 2: beach ridge

Zone 3: Upper Swash Slope

This area is the area just below the beach ridge deposit. The material size distribution in this area is more heterogeneous than in the beach ridge deposit (Photo 8).

Photo 8. Feature 4, Zone 3: upper swash slope

<u>Zone 4: Lower Swash Slope</u>

This area is situated between the upper swash slope and the lower lag field. The particle size distribution is more heterogeneous than in the upper swash slope (Photo 9).

Photo 9. Feature 4, Zone 4: lower swash slope

Feature 5: Lag Field

This area is the large cobble and boulder field off the eastern shore of the island that is composed of material eroded from the island terrace (photo 10). This material is not easily transported by normal wave and current energy, although significant movement of these particles was noted following the October 13 storm. The particle size distribution of the lag material is fairly homogenous across most of the island shoreline, although boulders (diameter > 6″) become more common at the south end of the island (Photo 11). We only sampled the lag material at one location along the central island shoreline.

Photo 10. Lag field along the central island shoreline

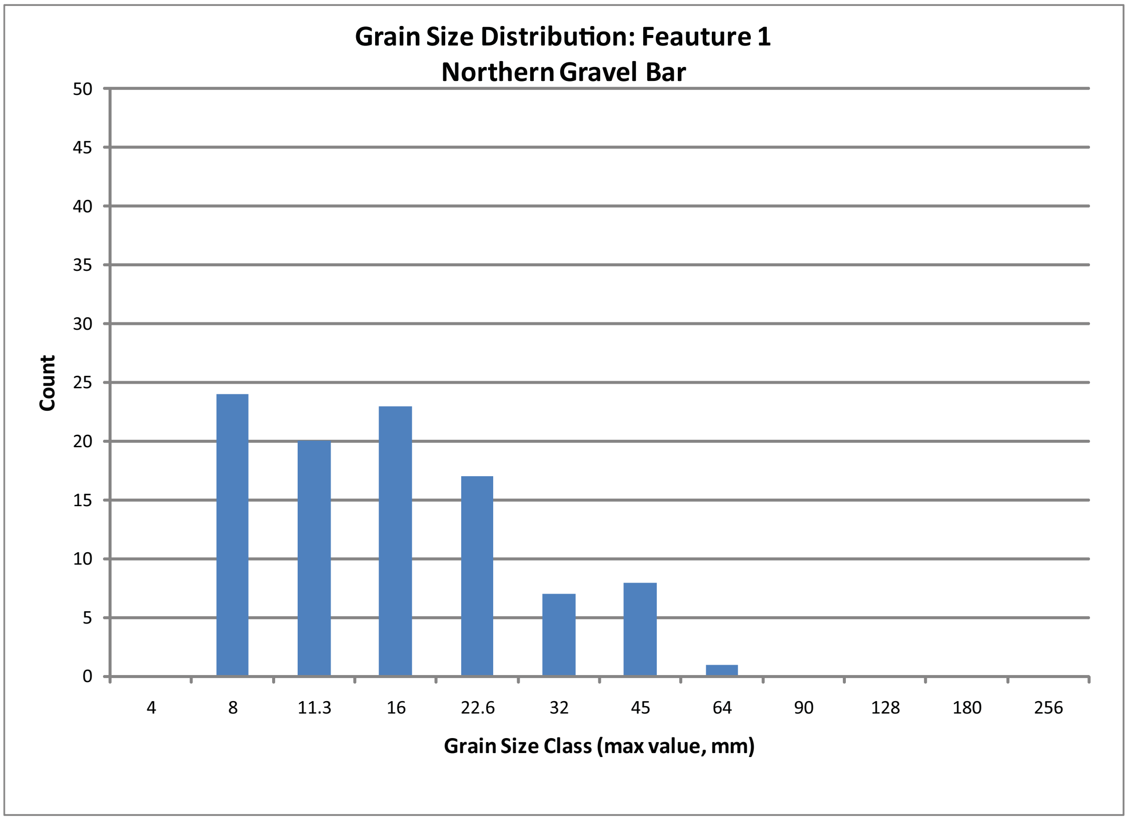
Photo 11. Lag field along southern island shoreline

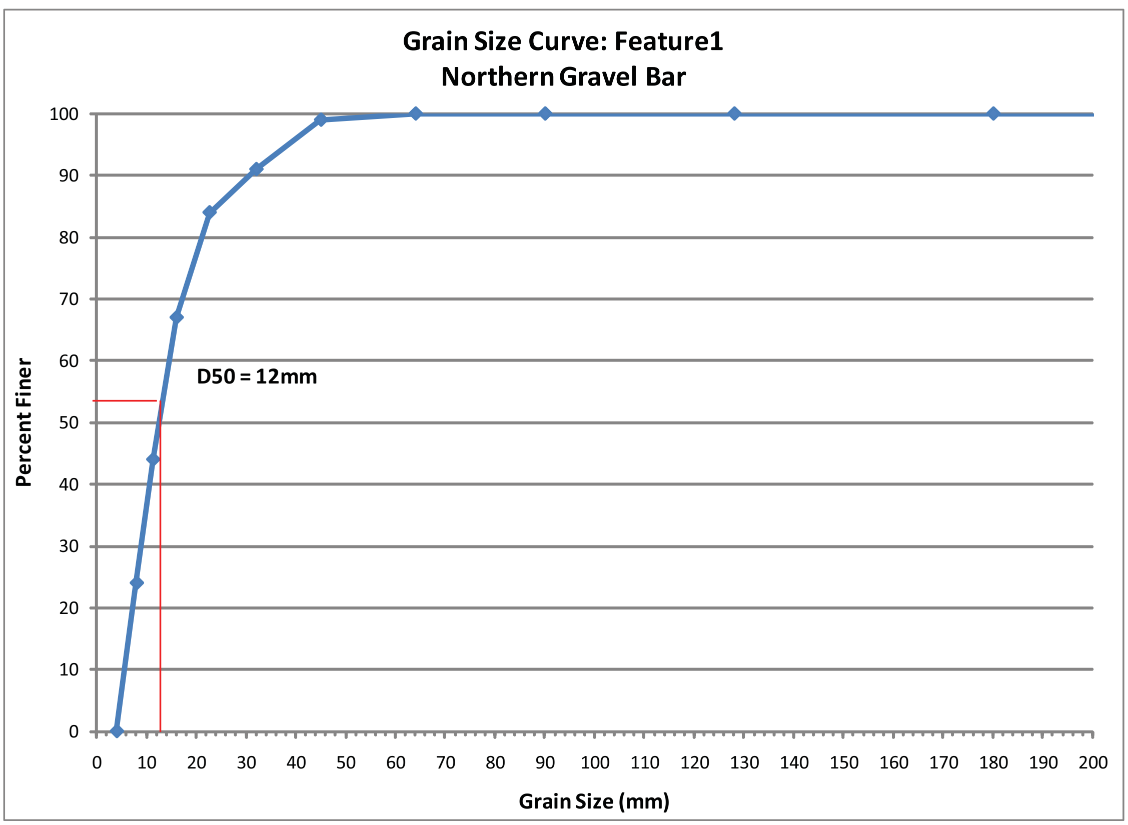
Features 6 and 7: Sand Beaches

Sand beaches exist inside each of the two harbor seal haulout cuts (Photo 12). At these locations we collected grab samples to be sieved for grain size analysis as opposed to performing the usual transect based survey.

Photo 12. Sand beach at south end of island

Grain Size Distribution Histograms and Grain Size Curves



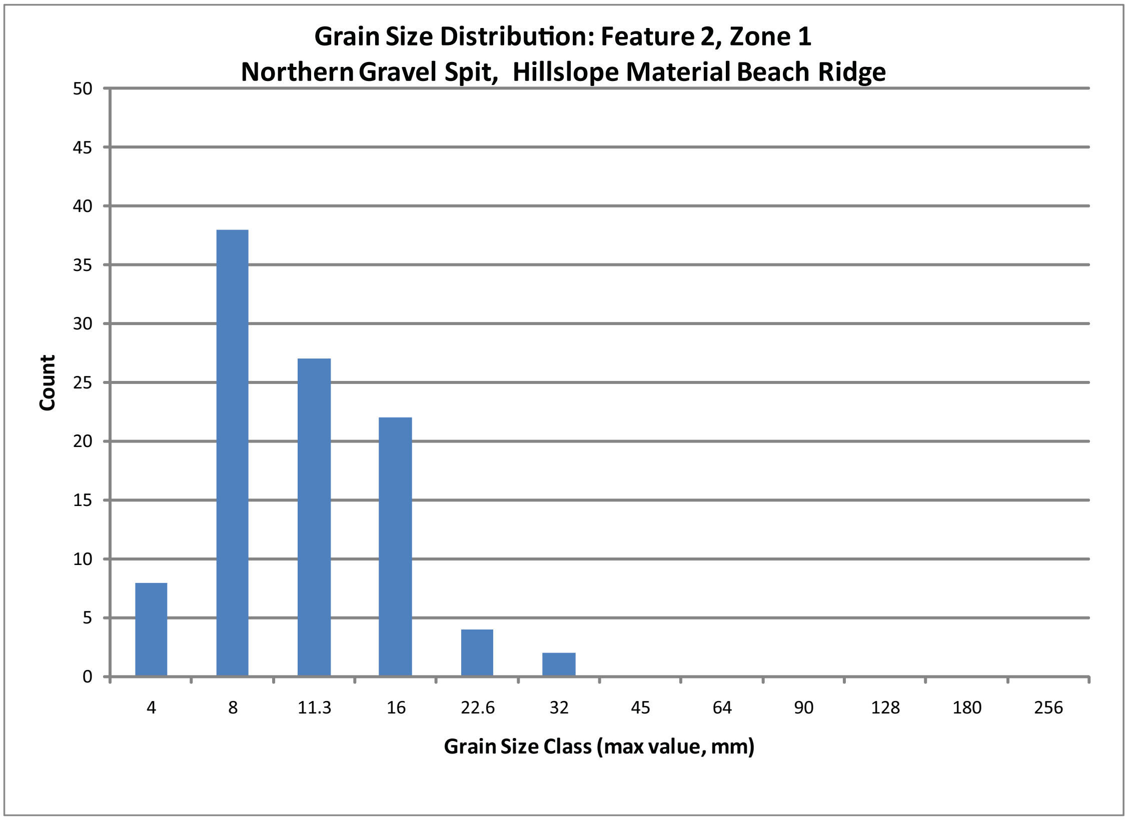


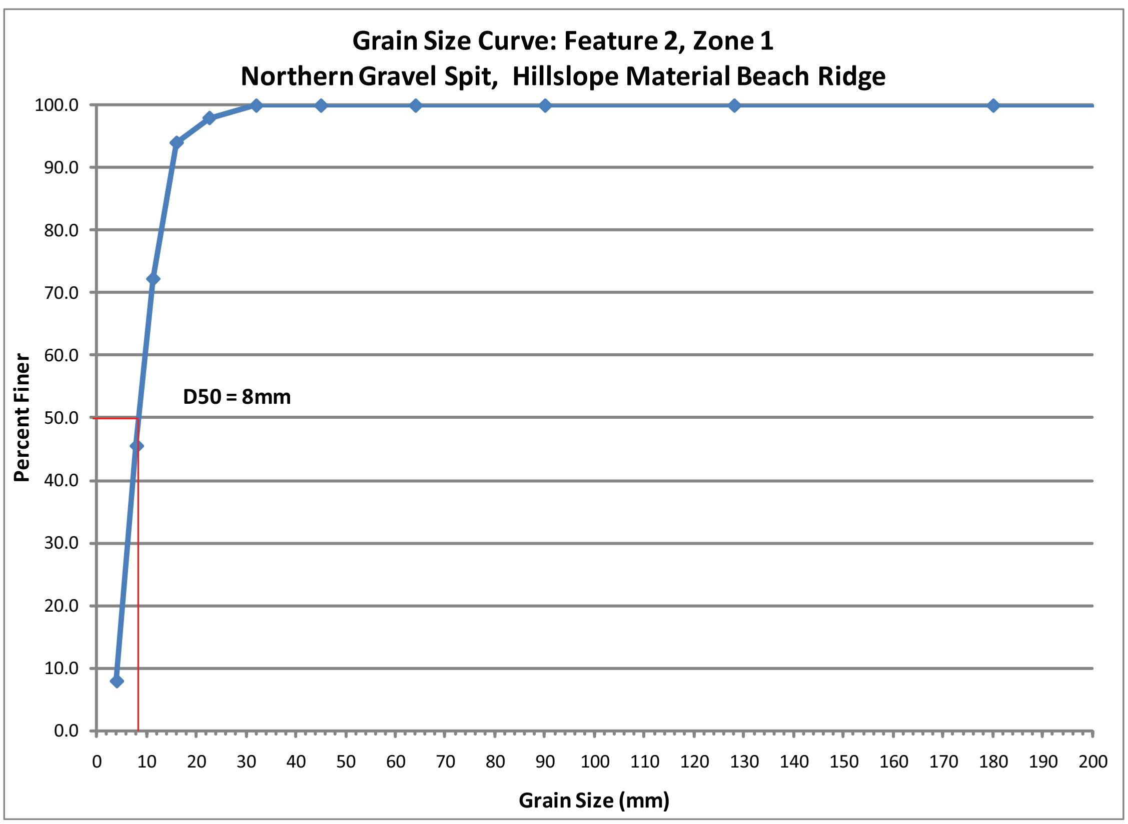
WETLANDS AND WATER RESOURCES

GRAIN SIZE DISTRIBUTION: FEATURE 1
NORTHERN GRAVEL BAR
Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010	Project No. 1145

Graphic file: grain-size-feature1_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls



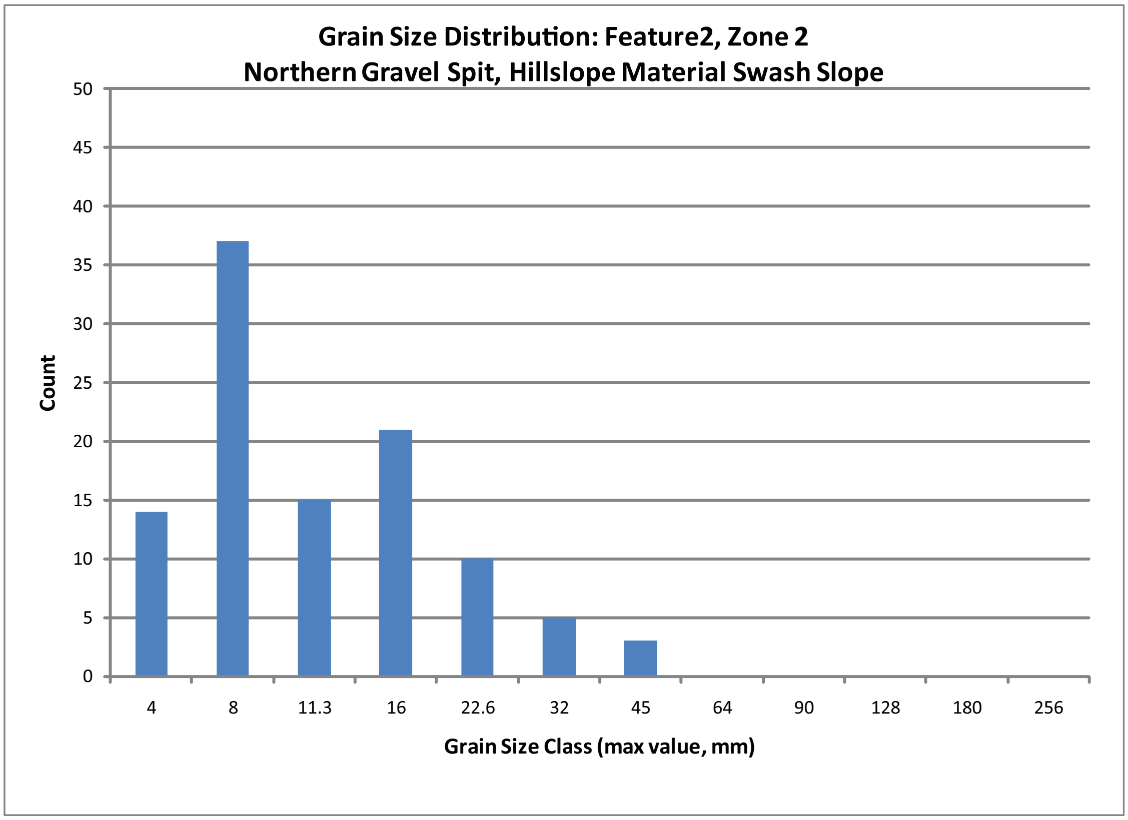


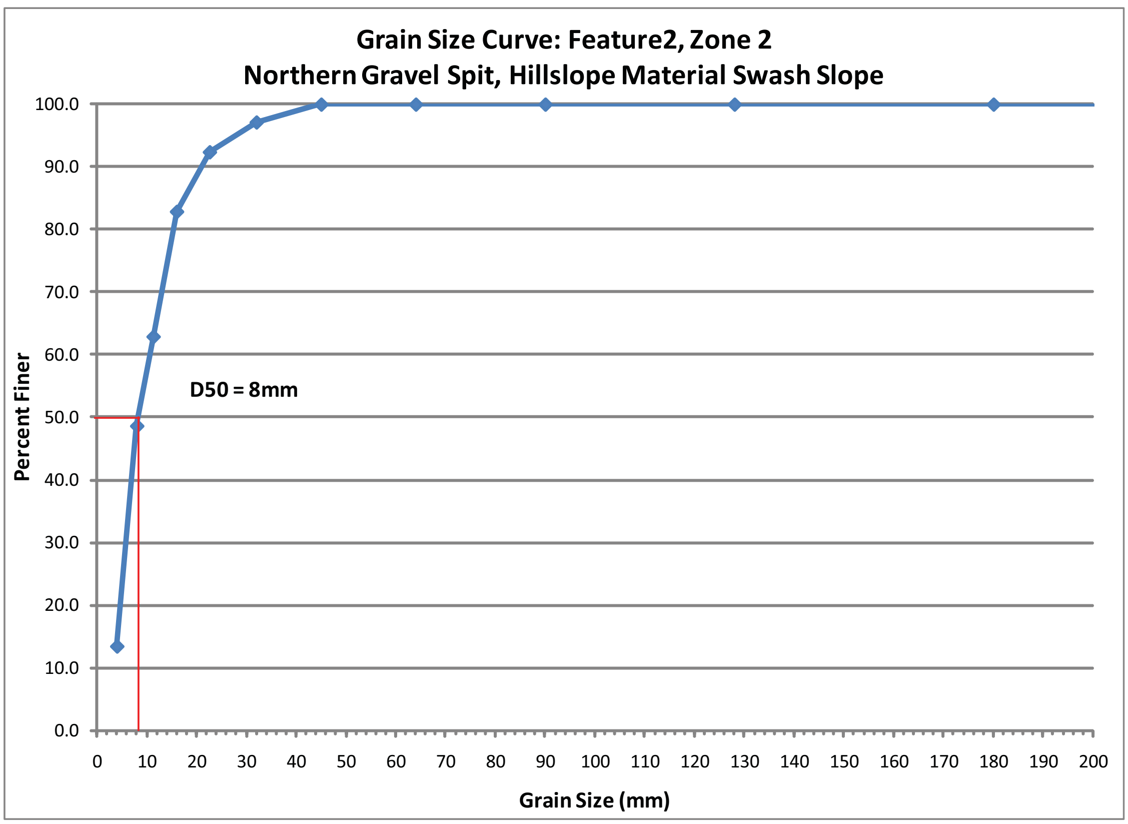
WETLANDS AND WATER RESOURCES

GRAIN SIZE DISTRIBUTION: FEATURE 2, ZONE 1
NORTHERN GRAVEL SPIT
Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010	Project No. 1145	

Graphic file: grain-size-feature2-zone1_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls





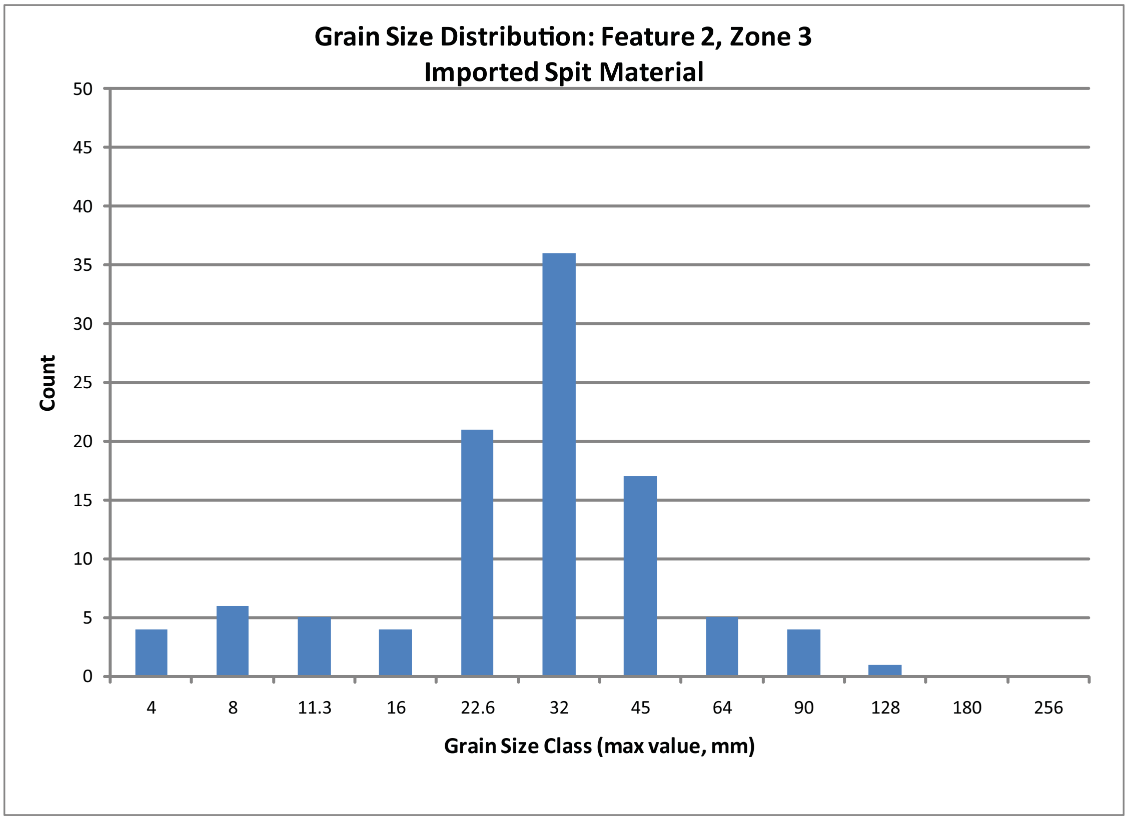
WETLANDS AND WATER RESOURCES

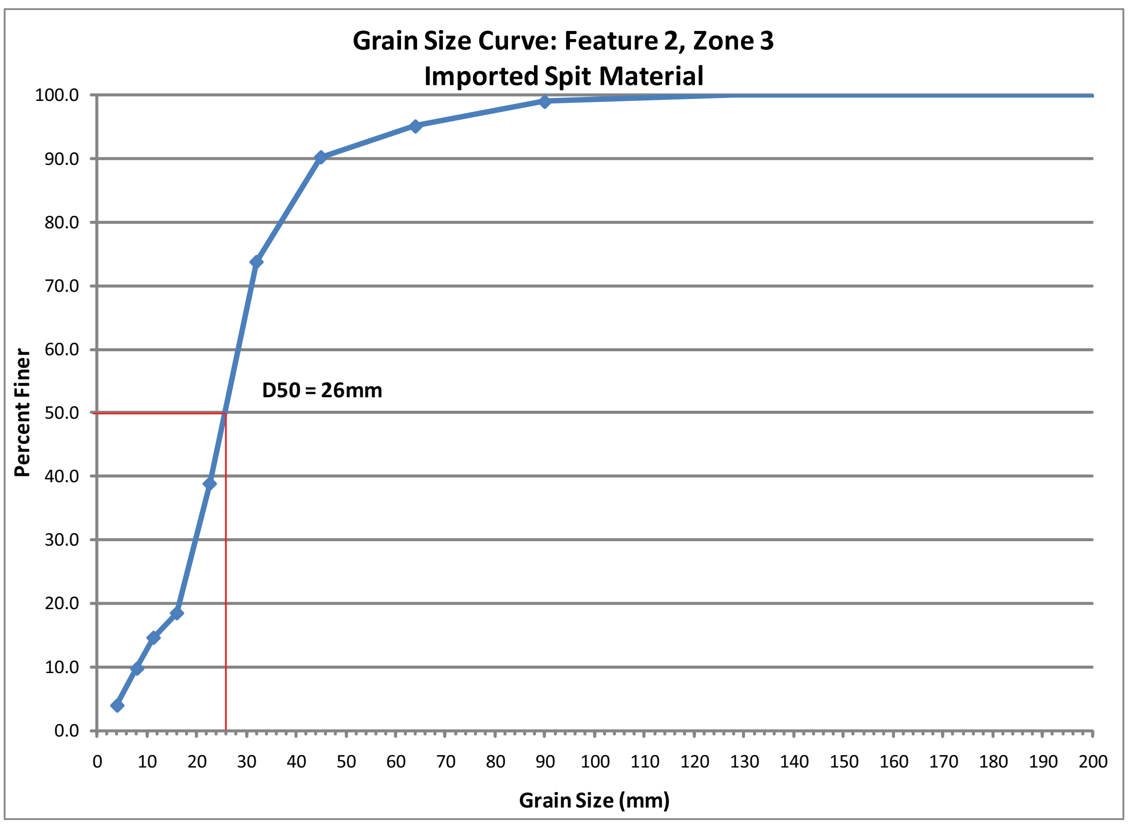
GRAIN SIZE DISTRIBUTION: FEATURE 2, ZONE 2
NORTHERN GRAVEL SPIT

Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010 | Project No. 1145

Graphic file: grain-size-feature2-zone2_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls





WETLANDS AND WATER RESOURCES

GRAIN SIZE DISTRIBUTION: FEATURE 2, ZONE 3
IMORTED SPIT MATERIAL

Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010 | Project No. 1145

Graphic file: grain-size-feature2-zone3_2010-0226lee.ai
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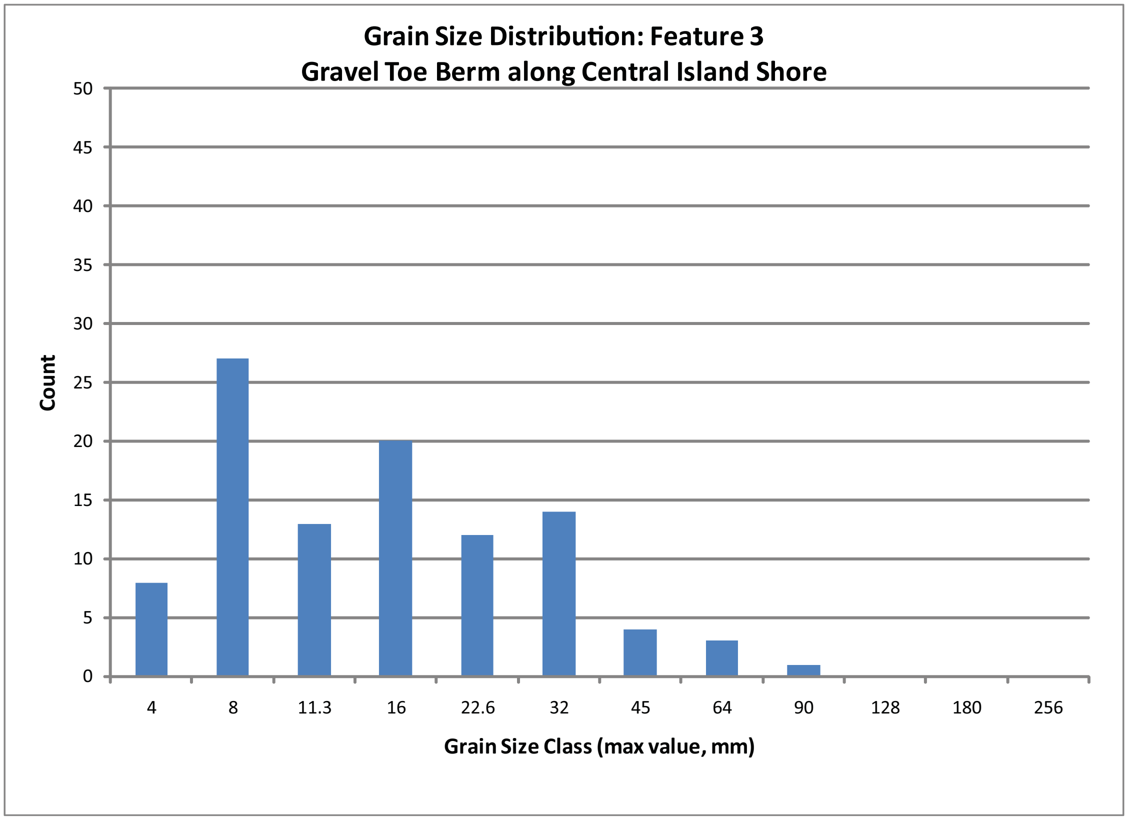
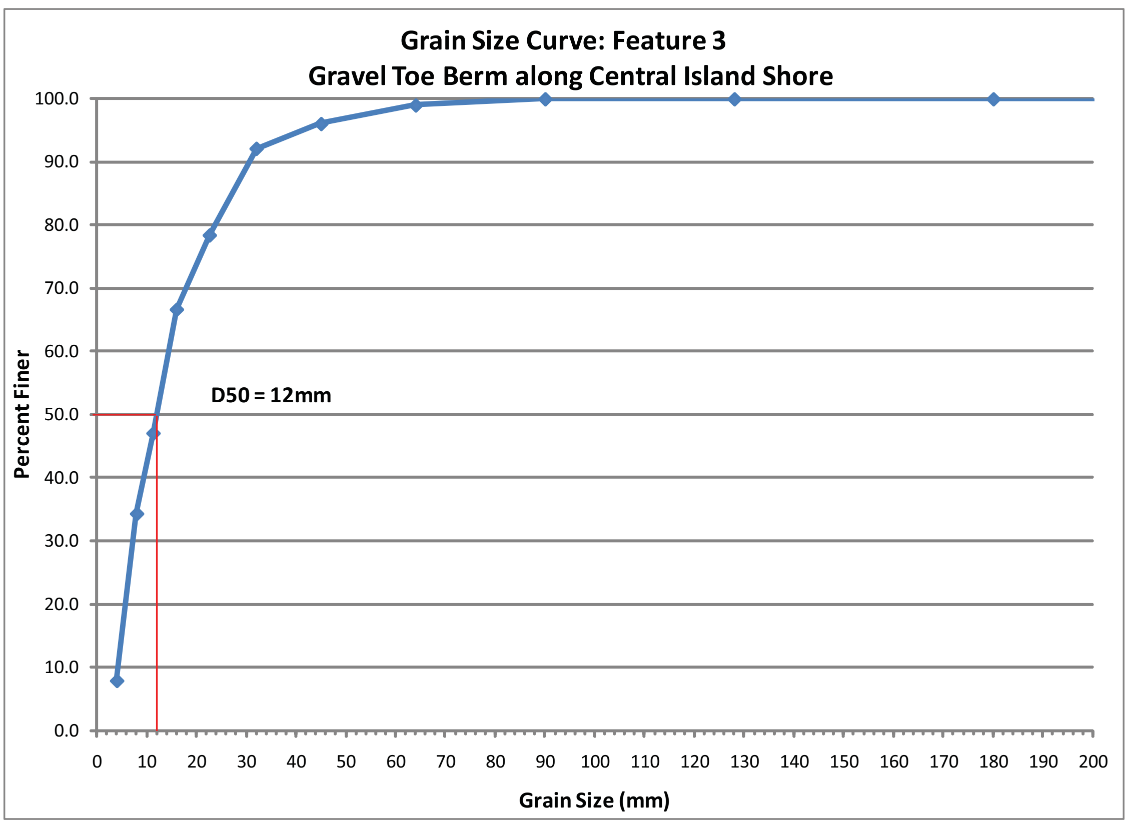




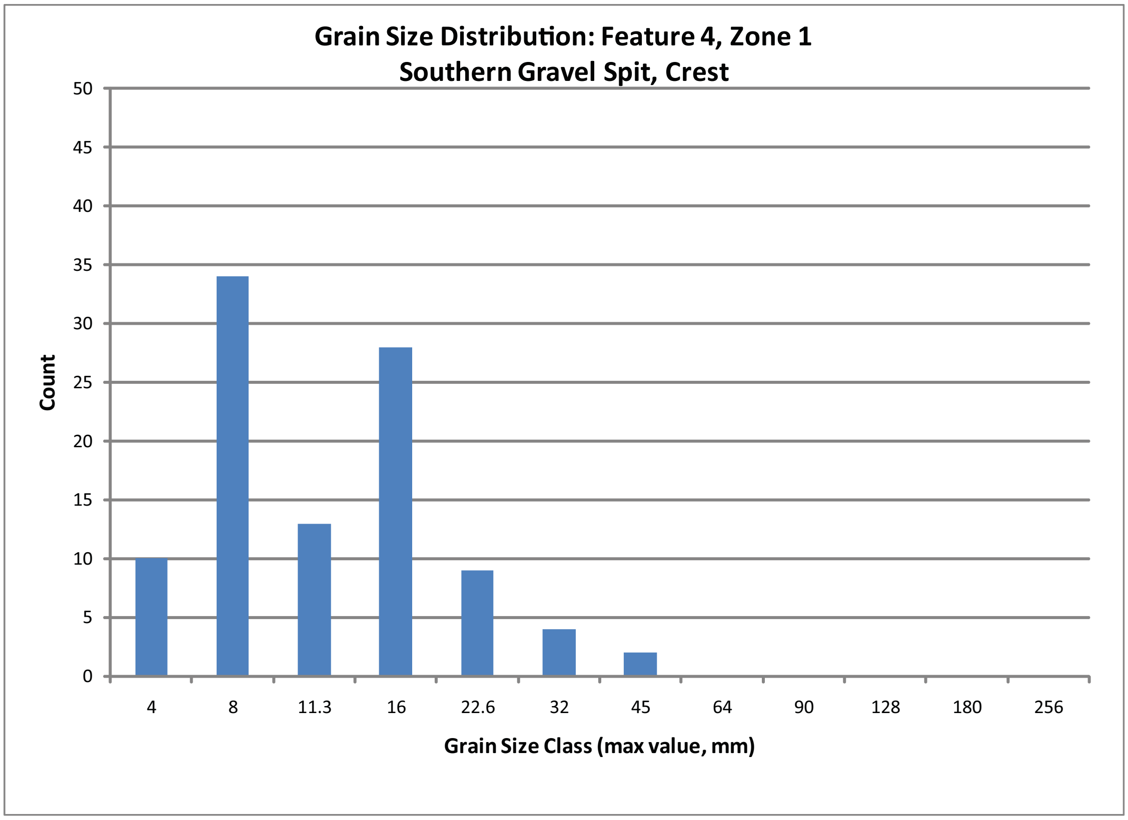
WETLANDS AND WATER RESOURCES

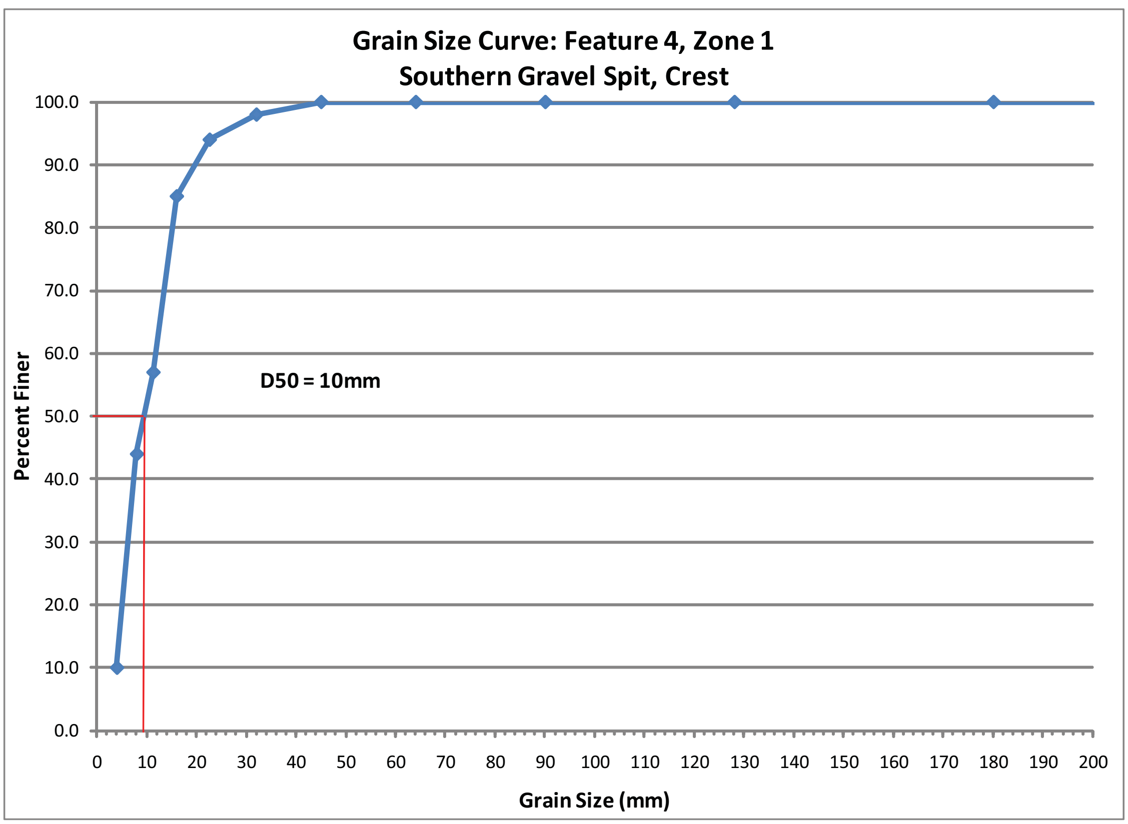
GRAIN SIZE DISTRIBUTION: FEATURE 3
GRAVEL TOE BERM

Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010 | Project No. 1145

Graphic file: grain-size-feature3_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls





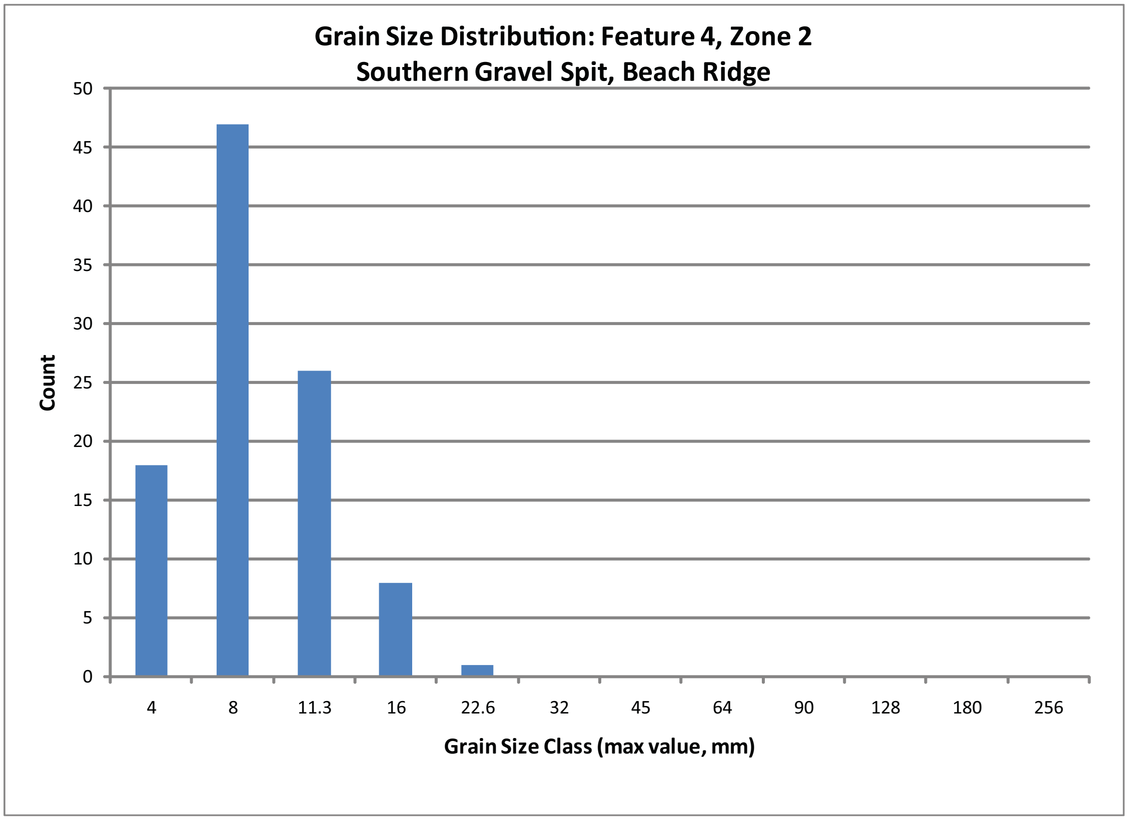
WETLANDS AND WATER RESOURCES

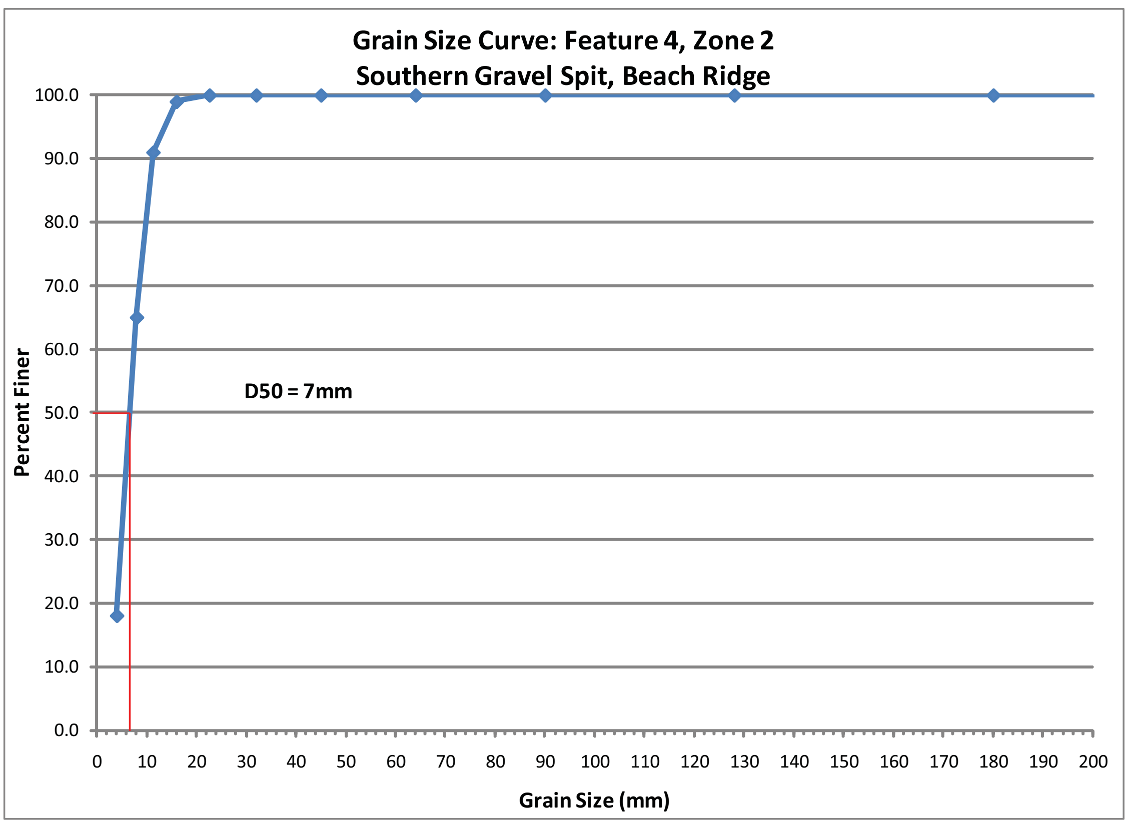
GRAIN SIZE DISTRIBUTION: FEATURE 4, ZONE 1
SOUTHERN GRAVEL SPIT

Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010 | Project No. 1145

Graphic file: grain-size-feature4-zone1_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls





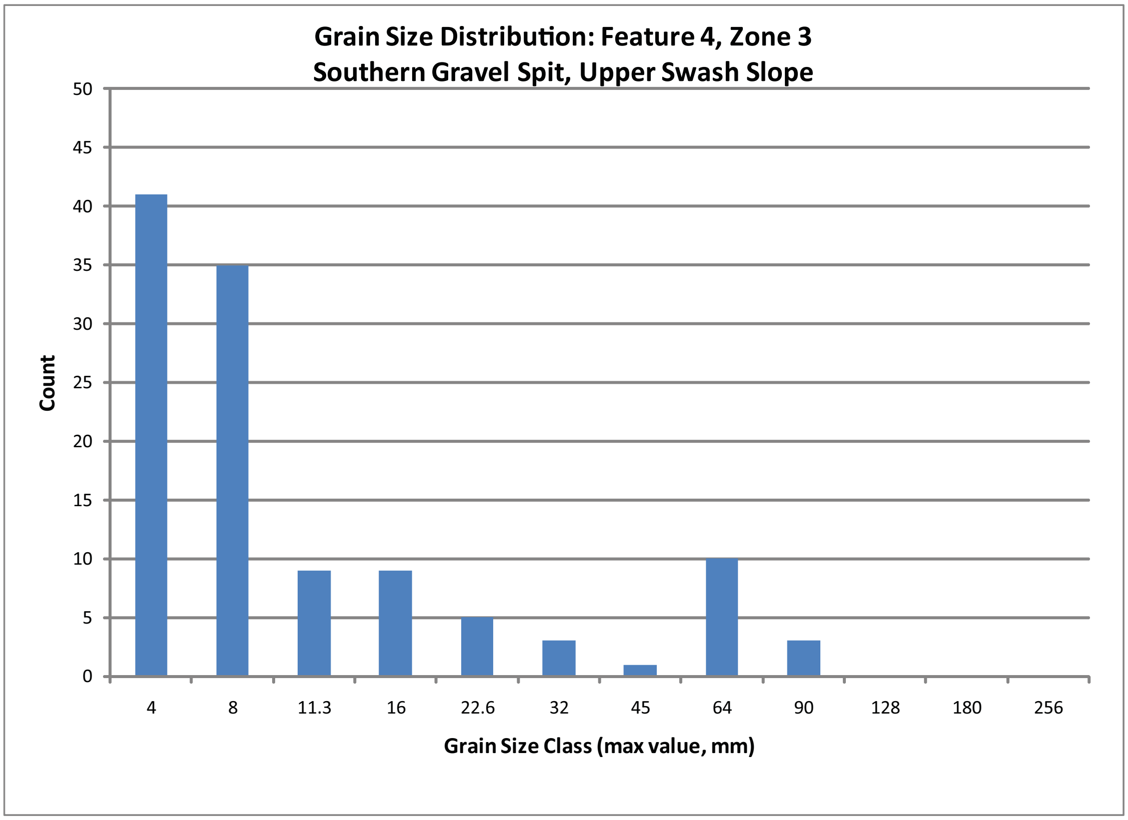
WETLANDS AND WATER RESOURCES

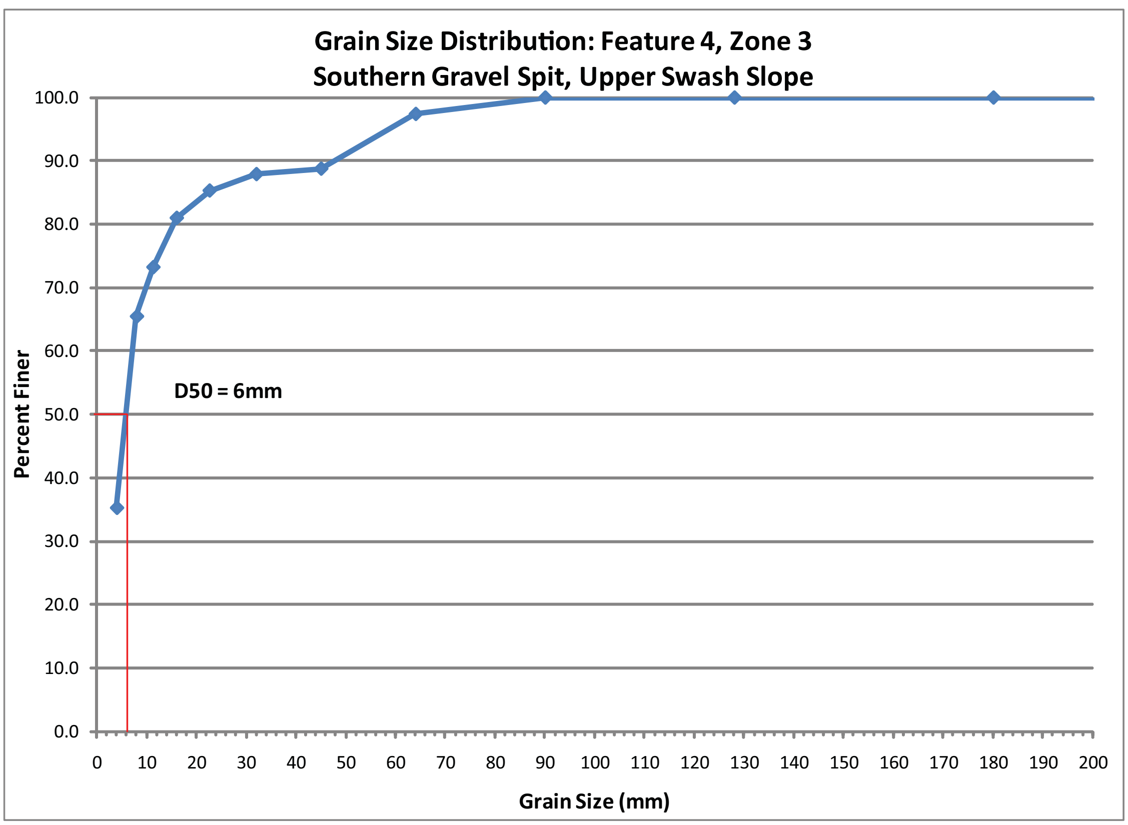
GRAIN SIZE DISTRIBUTION: FEATURE 4, ZONE 2
SOUTHERN GRAVEL SPIT

Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010 | Project No. 1145

Graphic file: grain-size-feature4-zone2_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls





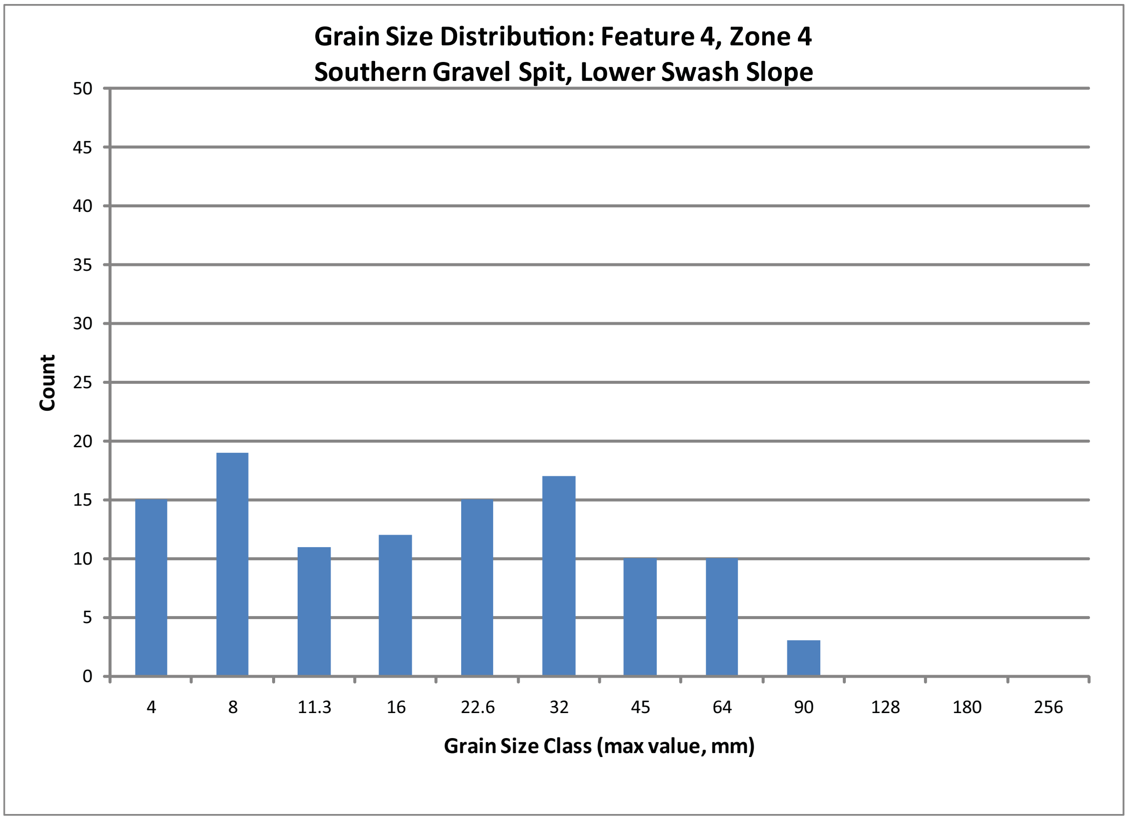
WETLANDS AND WATER RESOURCES

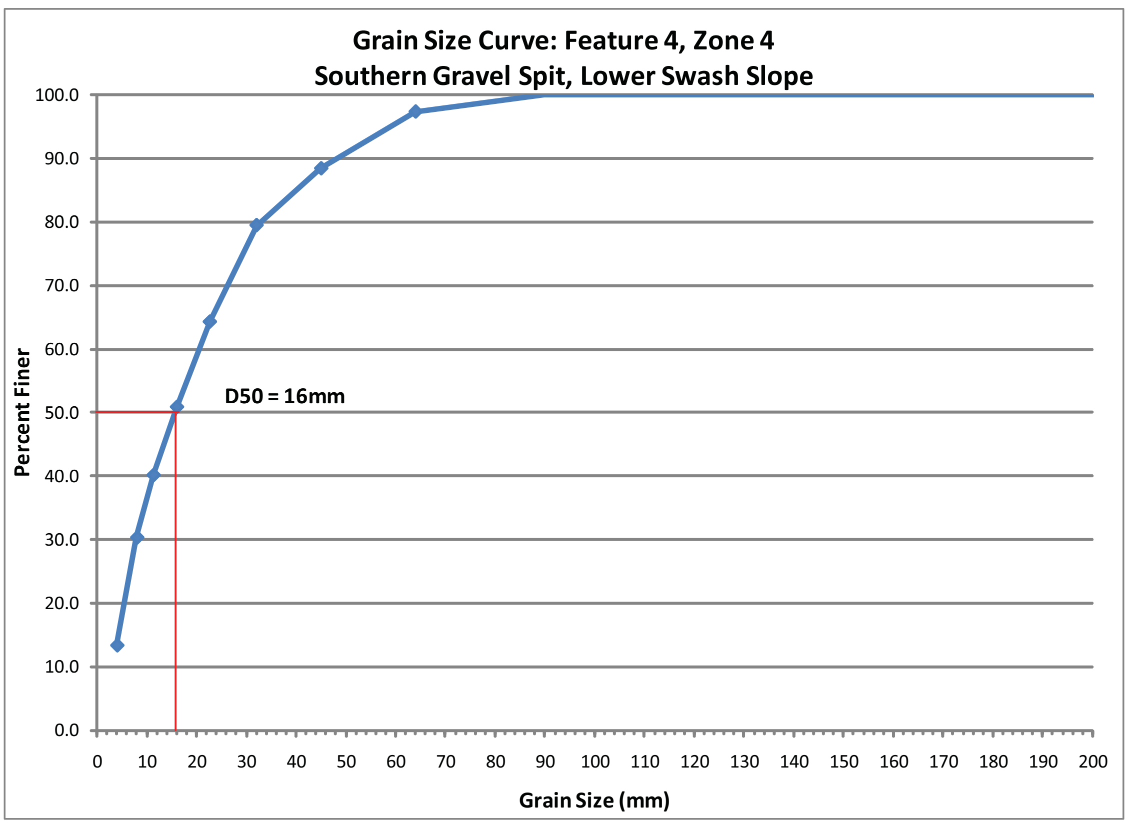
GRAIN SIZE DISTRIBUTION: FEATURE 4, ZONE 3
SOUTHERN GRAVEL SPIT

Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010	Project No. 1145

Graphic file: grain-size-feature4-zone3_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls





WETLANDS AND WATER RESOURCES

GRAIN SIZE DISTRIBUTION: FEATURE 4, ZONE 4
SOUTHERN GRAVEL SPIT
Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010 | Project No. 1145

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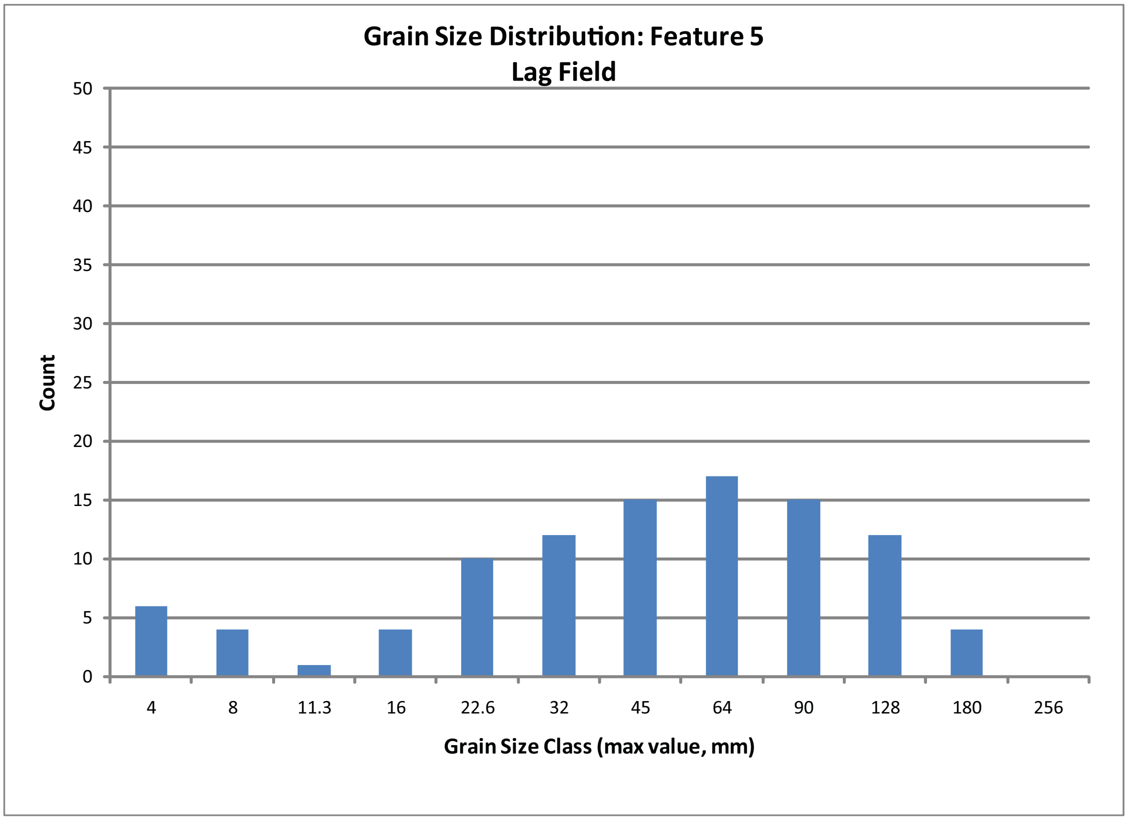
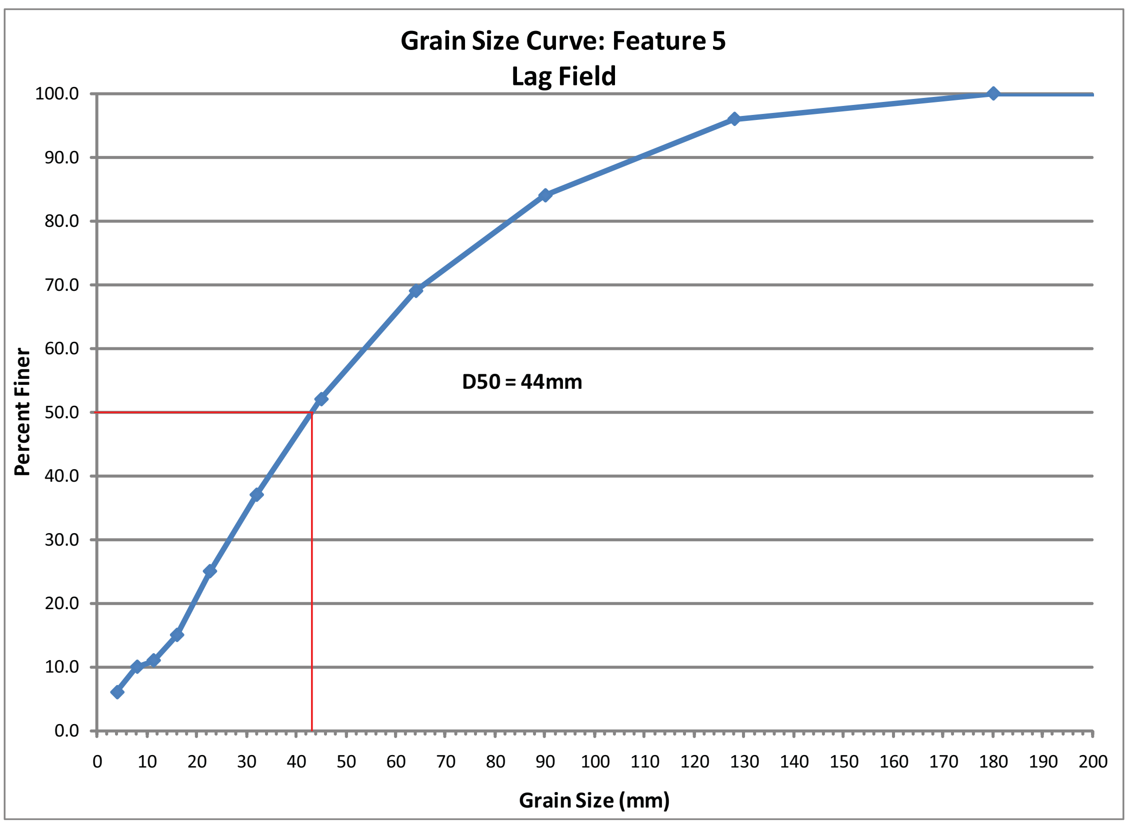




WETLANDS AND WATER RESOURCES

GRAIN SIZE DISTRIBUTION: FEATURE 5
LAG FIELD

Aramburu Island
Marin County, California
Richardson Bay Audubon, Marin County, California

February 2010 | Project No. 1145

Graphic file: grain-size-feature5_2010-0226lee.ai
Data file: Aramburu-beach-particle-data_1145_2009-1020dag.xls

Appendix D
Aramburu Island Beach Material Transport Analysis

Project No. 1145

Technical Memorandum

Aramburu Island Beach Material Transport Analysis

To: Project Design Team
From: Dan Gillenwater
Date: October 20, 2009

On October 12, 2009, Dan Gillenwater of WWR marked beach particles in several locations along the eastern shoreline of Aramburu Island prior to the October 13 storm event. The markings consisted of a 4" wide stripe of orange spraypaint applied along a shore-normal transect from beach crest to the lag field, or to the point where the beach material was saturated with water. A total of five paint stripes were applied along the island shoreline (Figure 1). Stripes were applied on the north and south gravel spits and at three locations along the central island shoreline. On October 14, 2009, we revisited the island to examine the paint stripes to determine what size range of particles were moved by wave action during the storm and what the movement patterns were. The results of this study are presented below.

Stripe 1: Northern Gravel Spit

The northern gravel bar is composed primarily of imported rock with a D_{50} of 26mm. The particle size distribution is rather homogenous across the entire spit from crest down to the adjacent lag field (Photo 1). The storm was capable of moving the entire range of particles sizes that were painted at this location. All particle movement was toward the north. The largest particle moved during the storm had a diameter of 57mm (2.5") and was transported 8m. The maximum particle displacement observed was 20m, to the terminus of the spit. No particles were transported across the mouth of the northern embayment.

818 Fifth Avenue, Suite 208, San Rafael, CA 94901
tel 415.457.0250 • fax 415.457.0260 • www.swampthing.org

Photo 1. Stripe 1 before the storm

Photo 2. Stripe 1 after the storm

Stripes 2 and 3: Central Island Shoreline

Stripes 2 and 3 were painted along the central island shoreline from the gravel berm along the base of the wave-eroded scarp, down to the lag field. These two locations were adjacent to small promontories (headlands) upon which the gravel berm was piled. Prior to the storm, the berm was composed primarily of fine to medium gravel (4 – 16mm) at the base of the scarp, becoming coarser toward the adjacent lag field (Photo 3). The storm completely reworked the material in this area (Photo 4). There was almost no sign of the paint stripes where they were originally marked. Fine gravel material was transported as far north as the northern gravel spit (~75m). Several rocks between 23 and 32mm in diameter were transported up to 50m north and a single rock 108mm (4.25”) in diameter was displaced 0.5m north. The material in the vicinity of stripes 2 and 3 was far more heterogeneous in nature following the storm. The promontories along the shoreline helped to hold the gravel toe berm in place as areas with northeast facing shorelines were almost completely wiped clean of gravel material.

Photo 3. Stripe (foreground) and 2 (background) before the storm

Photo 4. Location of stripe 3 following the storm

Stripe 4: Gravel Berm, Central Island Shoreline

Stripe 4 was positioned on a wide, gravel berm along the eastern shoreline. The particle size distribution in this location was similar to that of stripes 2 and 3, but this location lacked a northern promontory (Photo 5). Following the storm, the gravel deposit was almost completely washed away and the remaining pariticles were far more heterogeneous in size (Photo 6). Fine gravel (4 – 8mm) was transported up to 25m north while a single rock 89mm (3.5”) in diameter was moved 1m north.

Photo 5. Stripe 4 location before the storm

Photo 6. Stripe 4 location, following the storm

Stripe 5: Southern Gravel Spit

The southern gravel spit is composed primarily of fine gravel particles (D_{50} = 6-10mm) that appear to be primarily eroded from the hillslope fill material. There are also a large amount of shell fragments in this area (Photo 7). The paint stripe at this location only covered fine gravel material. No "lag" sized particles were marked. All marked material at this location was completely removed by the storm and transported north along the spit. A single shell particle was found to the south of the original stripe location. Following the storm, the particle size distribution along the stripe location was similar to that prior to the storm (Photo 8).

Photo 7. Strpie 5 before the storm

Photo 8. Stripe 5 after the storm

Rock Micro-Groin

During the September 15 design team site visit, we constructed a small groin from cobbles and boulders along the shoreline, which remained unmoved by wave action up until the date of the pain marking exercise on October 12 (Photo 9). The storm damaged this structure greatly and dispersed several of the large boulders (6″ – 9″ in diameter) within a meter of their original placement (Photo 10).

Photo 9. Rock micro-groin, as constructed on 9/15/2009

Photo 10. Rock micro-groin after the storm

BEACH MATERIAL MARKING LOCATIONS

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary

Figure 1

Appendix E
Aramburu Island Floristic Inventory

Aramburu Island
Vascular Plant Species 2009

Nomenclature and taxonomy follow Flora of North America (http://www.efloras.org/flora_page.aspx?flora_id=1) for taxa covered as of June 2009; other taxa not covered in FNP follow Jepson Manual revisions published in the Jepson Interchange (http://ucjeps.berkeley.edu/interchange.html), or the USDA Plants Database (http://plants.usda.gov/).

Data source: field surveys January, April, June 2009 performed by Peter Baye; additional plant identifications contributed from wetland delineation plant data collected by Diana Benner (The Watershed Nursery).

† Dagger denotes introduced species, not native to Marin County or San Francisco Bay area

CUPRESSACEAE	**Cypress Family**
†*Cupressus macrocarpa*	Monterey cypress
PINACEAE	**Pine family**
†*Pinus radiata*	Monterey pine
AMARYLLIDACEAE	**Amaryllis family**
†*Amaryllis belladonna*	Naked ladies
CYPERACEAE	**Sedge Family**
Carex praegracilis	field sedge, clustered field sedge
IRIDACEAE	**Iris family**
†*Crocosmia crocosmiiflora*	Crocosmia
JUNCACEAE	**Rush Family**
Juncus bufonius	Toad rush
LILIACEAE *(traditional)*	**Lily family**
Chlorogalum pomeridianum	Soap plant
POACEAE	**Grass Family**
†*Avena sativa*	Wild oat

(*A. fatua*, a related wild oat that is somewhat less common in Marin County, may co-occur with this species, but was not distinguished in field surveys).

†*Briza major*	Rattlesnake grass
†*Bromus diandrus*	Ripgut brome
†*Cortaderia jubata*	Jubata grass, Pampas grass
Distichlis spicata	Saltgrass
†*Hordeum marinum*	wild barley
Nassella pulchra	Purple needlegrass
†*Phalaris aquatica*	Harding grass
†*Polypogon monspeliensis*	Rabbit's-foot grass

†*Spartina densiflora****	Chilean cordgrass
Spartina foliosa	Pacific or California cordgrass
†*Spartina foliosa* X *alterniflora*	Hybrid smooth cordgrass
†*Vulpia myuros*	Annual fescue
†*Parapholis incurva*	sicklegrass
†*Vulpia bromoides*	brome fescue
AIZOACEAE	**Carpetweed Family**
†*Carpobrotus edulis* x *chilensis*	Iceplant
ANACARDACEAE	**Sumac Family**
Toxicondendron diversilobum	Poison-oak
APIACEAE	**Carrot Family**
†*Foeniculum vulgare*	Fennel
ASTERACEAE	**Aster Family**
Ambrosia chamissonis	Beach-bur
Artemisia douglasiana	Mugwort
*Artemisia californica***	California sagebrush
Baccharis pilularis	Coyote-brush
†*Carduus pycnocephala*	Italian thistle
†*Cirsium vulgare*	Bull thistle
†*Cotula coronopifolia*	Brass-buttons
†*Logfia gallica*	Slender-leaf filago
Gnaphalium stramineum	Cudweed
†*Gnaphalium luteoalbum*	Cudweed
Grindelia stricta var. *angustifolia**	San Francisco Bay gumplant
†*Hypochaeris radicata*	Cat's-ear
Microseris sp.	Microseris
Jaumea carnosa	Jaumea
Madia gracilis	Slender tarweed
Madia sativa	Coast tarweed
†*Picris echioides*	Bristly ox-tongue
†*Senecio vulgaris*	Common ragwort
†*Sonchus oleraceus*	Sow-thistle
†*Sonchus asper*	Bristly sow-thistle
BRASSICACEAE	**Mustard family**
†*Lepidium latifolium*	Perennial or broadleaf pepperweed
†*Raphanus sativus*	Wild radish
CARYOPHYLLACEAE	**Pink or Carnation family**
†*Spergularia bocconi*	Boccone's sand-spurrey
†*Stellaria media*	Chickweed
†*Spergularia media*	Sand-spurrey

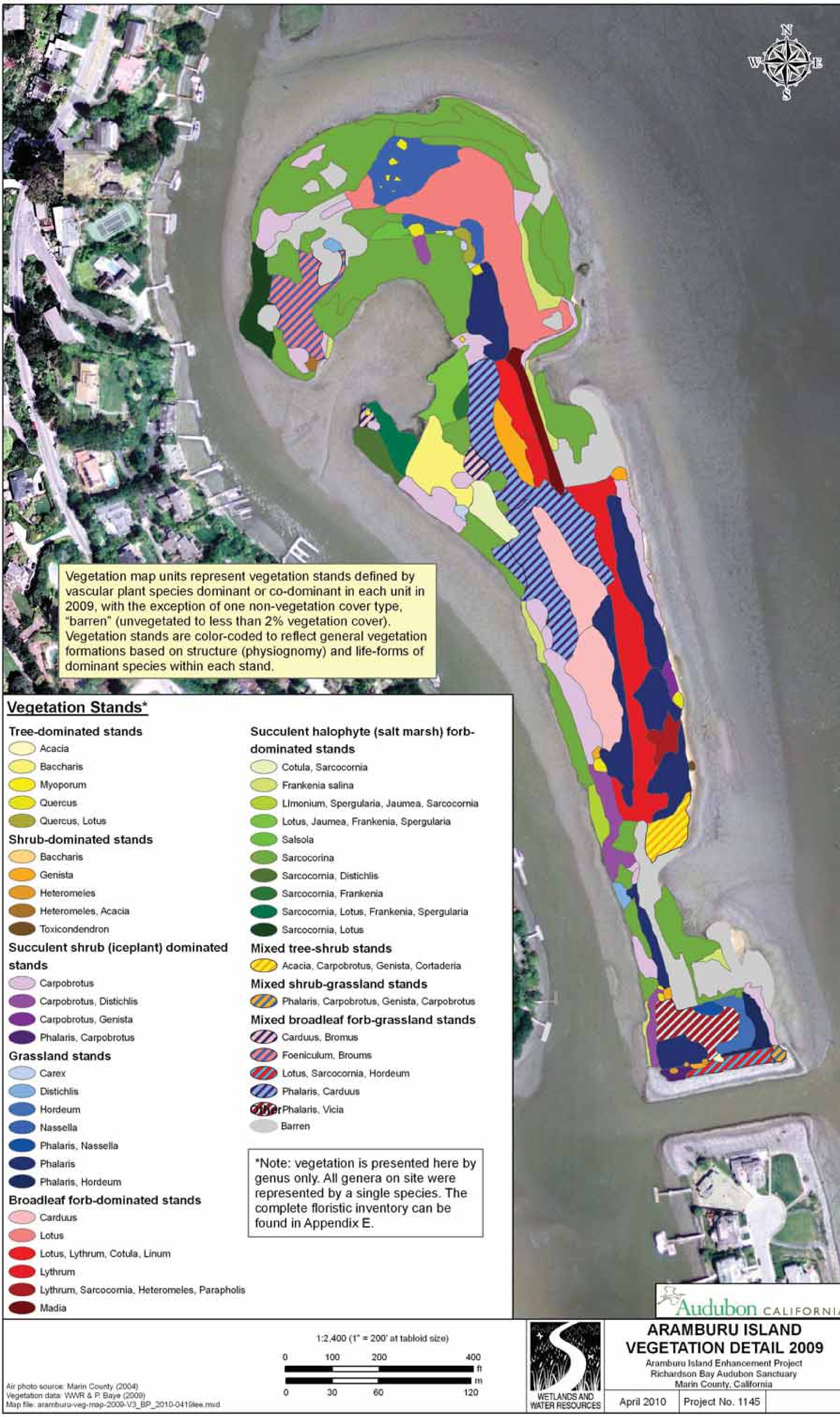
†*Spergularia rubra*	Sand-spurrey
†*Spergularia villosa*	Villous sand-spurrey
CHENOPODIACEAE	**Goosefoot family**
†*Atriplex prostrata*	Spearscale; fat-hen
†*Atriplex semibaccata*	Australian saltbush
†*Salsola soda*	Mediterranean saltwort
Sarcocornia pacifica	Pickleweed
CONVOLVULACEAE	**Morning-glory family**
Dichondra donelliana	Dichondra
DIPSACACEAE	**Teasel Family**
†*Dipsacus sativus*	Teasel
FABACEAE	**Pea or legume family**
†*Acacia decurrens*	Green wattle, acacia
†*Acacia melanoxylon*	Black acacia
†*Cytisus scoparius*	Scotch broom
†*Genista monspessulana*	French broom
†*Lotus corniculatus*	Bird's-foot trefoil
Lotus purshianus	Spanish clover
*Lupinus nanus***	Sky lupine
*Lupinus succulentus***	Arroyo lupine
†*Medicago polymorpha*	bur-clover
†*Melilotus indicus*	yellow sweet-clover
Trifolium sp.	[undetermined species found in vegetative state]
†*Vicia villosa* ssp. *varia*	Woolly vetch
†*Vicia benghalensis*	Mediterranean vetch
FAGACEAE	**Beach family**
*Quercus agrifolia***	Coast live oak
FRANKENIACEAE	**Alkali-heath family**
Frankenia salina	Alkali-heath
GENTIANACEAE	**Gentian family**
†*Centaurium floribundum*	Centaury
GERANIACEAE	**Geranium family**
†*Erodium cicutarium*	Filaree
†*Geranium molle*	Dove's-foot geranium
LYTHRACEAE	**Loosestrife Family**
†*Lythrum hyssopifolium*	hyssop-leaf loosestrife

LINACEAE	**Flax family**
†*Linum bienne*	Flax
MYOPORACEAE	**Myoporum family**
†*Myoporum laetum*	Myoporum
PLANTAGINACEAE	**Plantain Family**
†*Plantago major*	Common plaintain
†*Plantago coronopus*	Rattail plantain
†*Plantago lanceolata*	English plantain
PLUMBAGINACEAE	**Leadwort family**
Limonium californicum	California sea-lavender
POLYGONACEAE	**Buckwheat Family**
†*Polygonum aviculare*	Knotweed
PRIMULACEAE	**Primrose family**
†*Anagallis arvensis*	Scarlet pimpernel
ROSACEAE	**Rose Family**
Heteromeles arbutifolia	Toyon
†*Prunus cerasifera*	Cherry plum
SCROPHULARIACEAE *(traditional)*	**Snapdragon Family**
†*Bellardia trixago*	Mediterranean lineseed
†*Parentucellia viscosa*	Yellow glandweed
*Mimulus aurantiacus***	Sticky monkeyflower

* (placed in synonymy with *G. hirsutula*)
** (Likely introduced to the island by past artificial plantings)
*** (Likely extirpated by end of 2009 due to herbicide treatment)

<u>Floristic analysis</u>

- minimum 85 species
- % non-native species 73% (62/85)
- % native species 27% (23/85)
- % of native species likely introduced artificially: 17%
- Uncommon or noteworthy species in subregion: *Carex praegracilis*
- Non-detection of sensitive species searched: *Chloropyron maritimum* ssp. *palustre*


N
W
E
S
Vegetation map units represent vegetation stands defined by vascular plant species dominant or co-dominant in each unit in 2009, with the exception of one non-vegetation cover type, "barren" (unvegetated to less than 2% vegetation cover). Vegetation stands are color-coded to reflect general vegetation formations based on structure (physiognomy) and life-forms of dominant species within each stand.
Vegetation Stands*
Tree-dominated stands
Acacia
Baccharis
Myoporum
Quercus
Quercus, Lotus
Shrub-dominated stands
Baccharis
Genista
Heteromeles
Heteromeles, Acacia
Toxicondendron
Succulent shrub (iceplant) dominated stands
Carpobrotus
Carpobrotus, Distichlis
Carpobrotus, Genista
Phalaris, Carpobrotus
Grassland stands
Carex
Distichlis
Hordeum
Nassella
Phalaris, Nassella
Phalaris
Phalaris, Hordeum
Broadleaf forb-dominated stands
Carduus
Lotus
Lotus, Lythrum, Cotula, Linum
Lythrum
Lythrum, Sarcocornia, Heteromeles, Parapholis
Madia
Succulent halophyte (salt marsh) forb-dominated stands
Cotula, Sarcocornia
Frankenia salina
Limonium, Spergularia, Jaumea, Sarcocornia
Lotus, Jaumea, Frankenia, Spergularia
Salsola
Sarcocorina
Sarcocornia, Distichlis
Sarcocornia, Frankenia
Sarcocornia, Lotus, Frankenia, Spergularia
Sarcocornia, Lotus
Mixed tree-shrub stands
Acacia, Carpobrotus, Genista, Cortaderia
Mixed shrub-grassland stands
Phalaris, Carpobrotus, Genista, Carpobrotus
Mixed broadleaf forb-grassland stands
Carduus, Bromus
Foeniculum, Broums
Lotus, Sarcocornia, Hordeum
Phalaris, Carduus
Other Phalaris, Vicia
Barren
*Note: vegetation is presented here by genus only. All genera on site were represented by a single species. The complete floristic inventory can be found in Appendix E.
Audubon CALIFORNIA
Air photo source: Marin County (2004)
Vegetation data: WWR & P. Baye (2009)
Map file: aramburu-veg-map-2009-V3_BP_2010-0419lee.mxd
1:2,400 (1" = 200' at tabloid size)
0 100 200 400 ft
0 30 60 120 m
WETLANDS AND WATER RESOURCES
ARAMBURU ISLAND
VEGETATION DETAIL 2009
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, California
April 2010
Project No. 1145

Appendix F
Oysters on Aramburu Island

Memorandum

Oysters on Aramburu Island

Author: Suzanne Olyarnik

Date: January 26, 2010

During a cursory survey of Aramburu Island Jan 15, 2010, we found the presence of native oysters, *Ostrea conchaphila*. The survey was carried out between a +1.3 and 0 tidal height and focused on the eastern and southern shorelines.

On the southeastern shore, the boulder lag extends bayward to about a +1 foot tidal height, then it changes to mudflat (Fig. 1). Between approximately +2.5 and +1 tide height, there were many oysters found on the undersides of rocks which were at least 6 inches in diameter. There was a variety of class sizes with oysters ranging from 0.5-4.5cm. Some of the rocks had 10-15 oysters on them, which is significantly more than we've seen anywhere in the Audubon Sanctuary. This trend continued north beyond the first cove. As we approached the northern cove, there seemed to be fewer oysters and none were uncovered shoreward of the boulder lag.

We also inspected the riprap along the channel on the southern part of the island, but it did not reveal many oysters, at least from a kayak. We did see a couple of oysters despite the fact that most of the rocks were covered with mud. It was not possible to turn rocks over to check the underside and interstices, so it is possible they are present there. We did see many *Mytilus* mussels and barnacles also.

Figure 1. View of Aramburu Island eastern shoreline looking north. Tide height is approximately 1.0 feet. Many of the rocks here had native oysters on the underside.

Figure 2. Native oyster on the underside of a rock along the eastern shoreline of Aramburu. In addition to the oyster being pointed out, there are several others to the left and right.

Figure 3. The underside of another rock on the eastern shoreline of Aramburu. There are at least 14 native oysters shown, along with barnacles and scars from previous oysters.

Appendix G
Engineering Design Basis for Aramburu Island Gravel/Shell and Sand Beach Shoreline Demonstration Project, Marin County, California

FarWest
RESTORATION
ENGINEERING

Technical Memo

To: Dan Gillenwater/Stuart Siegel, WWR

From: Roger Leventhal, P.E.

Date: March 1, 2010

Subject: Engineering Design Basis for Aramburu Island Gravel/Shell and Sand Beach Shoreline Demonstration Project, Marin County, California

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Introduction

Aramburu Island is a 17 acre man-made island that was constructed by placement of both hillslope and dredge fill sediments on top of Bay sediments during development of nearby housing in Richardson Bay (Figure 1 Main Report). Aramburu Island is currently operated by the Audubon Society as a wildlife sanctuary and has undergone degradation in habitat values. The current condition of the Island is geomorphically unstable with extensive upland weed colonization and extensive wave-cut shoreline erosion along the eastern side of the Island resulting in a biologically unproductive upper intertidal lag pavement of cobbles. The goal of the overall conceptual enhancement design is to restore the island to create a smoother transition to a series of more valuable habitats as sea level rises and the shoreline retreats with more stable slopes and sediment sizes for shorebirds and harbor seals.

As a subcontractor to Wetlands and Water Resources (WWR), FarWest Restoration Engineering (FRE) has been asked to develop a preliminary engineering design for a dynamic mixed sediment gravel/shell storm berm and sandy foreshore beach system with the following primary engineering and habitat goals:

- Buffer wave erosion and slow shoreline retreat by decreasing slope and/or providing coarser grained sediments to increase energy dissipation of storm-generated waves striking the island at high tide and slow shoreline retreat along the eastern side of the island
- Provide gravel/shell beach high tide roost habitat for shorebirds
- Provide sand/mud low tide terrace to replace artificial cobble (lag armor) substrate, enhancing invertebrate productivity and shorebird foraging

- Provide suitable ramp-like shoreline profiles and grain size and shape suitable for use as seal haul-outs;
- Confine longshore transport of constructed sandy low tide terrace, prevent drift of beach sediment north (downdrift) into dredged areas.
- Implement a demonstration project to show that natural dynamic gravel beaches can be successfully implemented in San Francisco Bay as an alternative to hardened rip-rap levees and resiliency to sea-level rise.

Typical coastal engineering design alternatives for an eroding urban shoreline range from rip-rapped levees to concrete seawalls. Given the undeveloped character of the site and the historic former gravel spit in the project vicinity, Richardson Bay Audubon Sanctuary decided that a demonstration project to construct a natural dynamic shoreline consisting of three different shoreline design approaches was the most appropriate erosion control design approach for this location. These approaches including augmenting an existing gravel spit with oyster shell, flattening the beach slope to allow for placement of a sand/gravel mix and finally constructing a gravel storm berm and foreshore in the higher wave energy part of the shoreline. The range of design approaches will allow for an evaluation of the effectiveness of different approaches depending on the wave climate and the amount of space available to lay back the beach slope.

If successful, the dynamic shoreline design approach should allow for protection of the shoreline at much less cost then a typical engineered revetment such as rip-rap or seawall and form a natural system that will adjust itself to the wave conditions at the project site while providing habitat values. Constructing dynamic gravel-beach shorelines as a natural defense against wind-wave erosion and sea level rise is a relatively new approach to shoreline protection that has not been widely built or monitored (Komar 2009) so this project would be a demonstration project of this approach within SF Bay.

Note that this memorandum is limited to the shoreline restoration work. There is another important part of the Aramburu project involved with habitat restoration and weed control in the uplands areas of the Island. Depending on available budgets and the timing of the uplands part of the project, these two projects may happen during different times. The cost estimates have been prepared assuming that the shoreline project proceeds in conjunction with the uplands work. There may be construction cost increases if the two phases of the project happen at different times.

Limitations and Acknowledgements

This preliminary design memo based upon empirical observations, discussions with scientists and coastal geomorphologists who have built these systems, analytical calculations and professional engineering judgment. This work was developed in collaboration with Peter Baye of the design team, a local coastal ecologist, who has studied estuarine beach systems in San Francisco Bay. Much of the design work contained within is a direct result of his ideas and it is hoped that this report represents a more natural and cost-effective approach to shoreline protection with San Francisco Bay as an alternative to engineered and armored shoreline revetments. I also wish to thank Jonathon Allan, Oregon state coastal geomorphologist for his helpful input and design suggestions and Mark Lorang, Professor at the University of Montana for his review of calculations that use his technical papers and his design suggestions. As with any new and evolving design approach, there are associated uncertainties in how this design will perform over time. During the final design phase of the project, we recommend that additional engineering analysis and modeling should be performed to further refine the design for these structures. Finally, we recommend detailed monitoring of the performance of the system over several seasons and adaptive management to address performance issues and to inform future design efforts.

This technical memorandum of engineering design considerations is intended to be included as an appendix to the overall main conceptual design report being prepared by WWR, FRE and Peter Baye (”The Main Report”). Some of the figures referenced within this memo will refer to figures within the main report to avoid duplication and are identified as such when referenced.

Existing Shoreline Conditions

A full assessment of site conditions and history will be prepared by WWR within the Main Report to this memorandum. As shown on Figure 10 of the Main Report, the eastern shoreline of the island has eroded approximately 15 feet in the southern part of the island ranging to approximately 36 feet to the north based on a review of historic photos (1970 to 2004). The unstable steep erosional scarp is progressively retreating, and is not reaching a gently sloping equilibrium profile. As the island has eroded, the east-facing shoreline has developed a mobile gravel berm at the toe of the scarp. The development of the gravel berm appears to be limited by sediment supply from local fill erosion (sorting and transport of gravel and cobbles comprising a low percentage of fill volume). The berm is limited to a low swash slope rather than a full berm profile along many segments of the scarp. Towards the bay, cobble and boulder lag deposits from erosion of the island fill have developed, forming an artificial armored surface distinct from adjacent intertidal mudflats. Cobble/boulder lag deposits mantle bay mud below. Consolidated older bay mud (likely derived from former dredge spoil associated with past canal dredging) outcrops locally in the upper foreshore. . At the edge of the lag deposits, the island connects to a shallow, subtidal mud flat that deepens as it approaches the main part of SF Bay. Eleven shoreline transect surveys of the existing shoreline were conducted on December 9, 2009 (see main report). At the Southern end of the Island, there is a dredge cut channel and the island slopes in this area have been rip-rapped due to wave erosion.

The island fill contains insufficient sand and pebble content to generate beach-size sediments to establish gentle shoreline slopes that buffer shoreline erosion and provide shorebird high tide roost habitats and potential suitable seal haulouts habitats as it retreats. Thus, the island is likely to collapse as it erodes with rising sea level, rather than make a transition to a gentler slope and resilient habitat types.

Processes Driving Erosion at Aramburu Island

The primary process driving erosion of the Aramburu Island shoreline is wind-wave erosion, primarily occurring during infrequent storms in fall or winter with high southerly wind velocities coinciding with very high tides. The intensity of wave erosion, indicated by relative scarp height and horizontal retreat, is greatest at the south end of the island, decreasing northward. It is unclear to the extent that other processes (such as boat wakes) may contribute to shoreline erosion. Most boat wakes are generated in the navigable dredged channel on the landward side of the island; shallow intertidal flats restrict large craft on the bayward, east-facing side of the island.

Another important factor in the shoreline erosion rates of the Island is the erodibility of the island fill deposits. As mentioned, the shoreline erosion measured from historic aerial photographs are actually larger at the north end (approximately 33 feet) of the island and not the south end of the island (measured at 15 feet) where the wave energies are expected to be higher due to the longer southern fetch. This result is somewhat unexpected and likely due to the lower height of fill at the north end of the island, which results in a higher retreat rate per unit wave energy. Also, there appears to be fewer larger boulders in the hillslope fill to the north end of the island placed to create the island, and therefore, less lag armoring of the shoreline leading to increased erosion at lower wave energy.

Wind-Wave Climate of Richardson Bay

The wave climate of San Francisco Bay can be very complex and the incident wave energy striking the island depends on a variety of factors including wind fetch, water depth, and angle of wave hitting the shoreline. Under typical storm conditions, the expected breaking wave height along Central San Francisco Bay shorelines would be on the order of 1 – 2 ft. This range is significantly below typical ocean swell wave heights of the adjacent Marin coast. However, while the heights of the local wind-waves are not large, these waves are typically high frequency (wave periods on the order of 1 – 3 seconds) and are therefore steep (i.e. the ratio of wave height to wave length). These types of steep wind-waves can be very erosive at a shoreline (Allan and Kirk 2000) even though their wave height is not great. The rise and fall of tides is another factor contributing to the erosion of the shore, since the elevation of the tide determines where the waves are able to reach on the beach profile. As described below, higher wave heights on the order of 3 to 4 plus feet may be possible during extreme winter storms from the south (fetch up to 8 miles). These values are calculated using the significant wave height estimation methods contained in the USACE Coastal Engineering Manuals (USACE CEM 2004 and USACE SPN 1984) and described in more detail below, but this significant wave height is likely limited to extreme storm events.

Richardson Bay is a shallow semi-enclosed bay within greater San Francisco Bay off-shore of Marin County (main report). Richardson Bay is generally shallow with an average bottom elevation of approximately -3 ft MLLW. The waves within Richardson Bay are primarily wind driven with the primary wind direction from the west with a maximum wind fetch of approximately 1-2 miles in the east-west direction. The less frequent but stronger winds are from the south during winter storms and over a longer fetch distance and therefore produce higher wave heights which likely cause much of the island erosion. The maximum wind fetch along the southern approach could be up to approximately 7-8 miles from the Bay Bridge. Appendix G of the Main Report contains wind roses for various reference sites.

Tides

The Sausalito Station tide gauge (# 9414806) is the NOAA tide station closest to the site. This tide station is located at the entrance to Richardson Bay within a mile of Aramburu Island

Table 1: Tidal Statistics Near Project Site

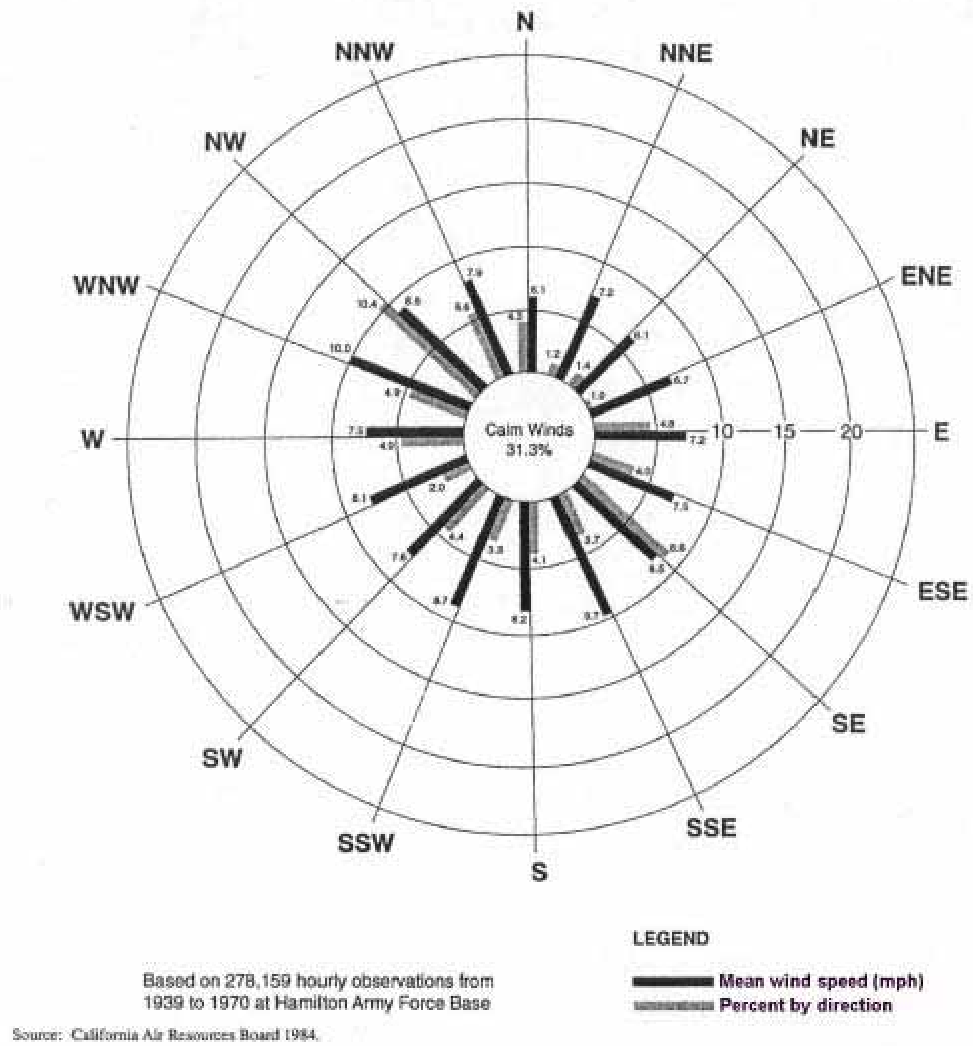
Tidal Datum	*Elevation (ft MLLW) tidal epoch 1983-2001*
Highest observed (1/9/78)	8.29
Highest observed at San Rafael shoreline reported at >100-year event – Noble Report (12/3/83)	9.3
MHHW	5.69
MHW	5.09
MTL	3.12
MLW	1.14
MLLW	0.0

Much of the highest wave energy and associated erosion occurs during winter storm periods corresponding to high tides (i.e. spring tides) when the waves are able to break at the shoreline and directly erode the Island shore. It is believed that significant erosion may take place during these storm and tide conditions.

Wind Conditions

The closest National Climate Data Center (NCDC) station with wind speed measurements is from the Alameda Naval Air Station (NAS ID# 23239) which has a 24-year record of continuous wind speed measurements from 1973 to 1996. The Hamilton Air Force Base (HAF) had an approximate period of record of over 30 years of wind data. The 50-year return period wind speeds (1-minute averaged) from the HAF dataset is approximately 74 miles per hour (mph).

The wind rose from Hamilton AFB is shown below:



Determination of Significant Wave Height

The significant wave height is the wave height of interest for any design study. Technically, it is the statistical term related to the average of the one-third highest wave of a given wave group, and therefore requires measured wave statistics to exactly quantify. The Shore Protection Manual (USACE 1984) and updated Coastal Engineering Manual (USACE 2004) contain simplified analytical methods to estimate the significant wave height (Hs) in the absence of measured wave data. A full hindcasting study which determines wind-wave heights for all compass directions was beyond the scope of this concept design study.

For this Concept Plan, we have estimated significant wave heights by two methods; 1) a review of a wave-hindcast studies for other nearby sites, and 2) by calculating significant wave heights using simplified analytical methods described in the USACE Shore Protection Manual (SPM 1984) that estimate wave height based on water depth, wind speed and the maximum fetch length. Note that there is uncertainty in the equations used in the SPM and ultimately, a wave study or more complicated 2-d wave model would be required to more accurately determine the significant wave height and is beyond the scope of this concept design memorandum.

Note that the design wave height to use in a natural beach design has not been fully determined in general. Most researchers note that the crest of the beach elevation is formed by the maximum wave height that reaches the beach. Since the goal of this analysis is to size the various rock sizes for the concept design, we have developed preliminary estimates of significant wave heights per the SPM and CEM and a more detailed analysis is not required at this phase of the design. We will use these values to develop the required rock sizes as described in detail under the proposed design section below.

Wind-Wave Studies in the Project Site Vicinity

Previous wind-wave hindcast studies were performed for the San Rafael Avenue Seawall Design Study (Noble 2007) along the eastern side of Richardson Bay. The maximum wind fetch for this site was less then 2 miles, significantly less then the maximum fetch length for Aramburu Island, but comparable for the typical fetch distance for the Island for all other directions then the South. Noble Consultants evaluated wind direction based on the Alameda wind gauge and determined that the significant wave height for their design storm (100 year return period) was 2.4 feet with a wave period of 2.5 seconds. In a separate study, Moffatt-Nichol Engineers evaluated wave conditions at Cullinan Ranch at the North end of San Pablo Bay using a 50-year return period for a wind fetch of approximately 3 miles and they calculated a significant wave height of 2.4 feet with a period of 2.3 seconds, comparable to the results for the San Rafael Seawall study although for a more frequent storm event.

Estimated Using USACE Shore Protection Manual

The maximum wind fetch distance for Aramburu Island from the south was estimated at 7 – 8 miles. To estimate the significant wave height, we calculated Hs using both deep water (fetch limited) and shallow water wave equations from the USACE Shore Protection Manual (1984). We did not modify for narrow fetches although that might be justified since we were attempting to develop the range of significant wave heights. The input parameters were adjusted wind speed, wind duration, fetch length (defined as the length of the water body, aligned parallel to wind direction, over which wind generates waves) and water depth. Depths from MLLW will range from 8.4 feet MLLW for a 10-year water level return period up to 12 feet MLLW for a 100-year water level in the main part of Richardson Bay, reducing to approximately 10 feet as the depths reduce towards the Island.

We have used the most conservative values for fetch and depth in order to provide a more conservative value for the rock sizes.

Table 2: Results of Simplified Calculation of Significant Wave Height using SPM and CEM for an 8 mile and a 3 mile fetch (South Cell and North/Central Cells respectively)

Analysis method	*Adjusted wind speed (mph)*	*Fetch (miles)*	*100 yr Water Depth (ft)*		*Calculated Significant Wave Height (ft)*	*Calculated Wave Period (sec)*
Deep water (fetch limited)	50 mph	8 miles (south Cell)	n/a		4.25 ft	4 s
Shallow water	50 mph	8 miles (south Cell)	10 feet		2.7 ft	3.3 s
Deep water (fetch limited)	50 mph	2 miles (north and central Cells)	n/a		2.1 ft	2.5 s
Shallow water	50 mph	2 miles (N/C Cells)	10 feet		1.8 ft	2.3 s

These values for wind speed and depth represent fairly extreme water conditions. The true values likely lie between these two ranges and it is unlikely that a 4.25 ft wave would strike the island very often under current conditions. The location of woody debris drift lines that have accumulated on the island over decades can provide an indication of elevated wave heights. Visual observations indicate little to no driftwood occurs above the scarp; it occurs mostly on the low parts of the island at the S and N, and mostly along the landward (wave-free) shore.

The ranges of calculated wave heights and periods will be used to evaluate rock sizes for the gravel berm and micro-groins as described in the proposed design section below. However, as sea level rises (current projections forecast up to 52 inches of rise by 2100), these currently more extreme wave conditions are likely to become more common.

Background on Natural and Constructed Gravel (or Cobble) Beaches as Shoreline Revetments

Coastal researchers have long recognized that gravel beaches are a natural and very effective form of shoreline protection, adjusting to the local wind-wave conditions even under conditions of extreme wave events. The strength of these types of dynamic systems is their adjustability to wave conditions. Unlike typical engineered revetment systems such as rip-rapped levees, movement of rocks and stone (i.e. adjustments in beach morphology) are an inherent strength of the gravel beach system and not an indication of failure. Analysis by Allan et. al (2004) showed that dunes fronted by composite gravel beaches experienced erosion rates that were typically 20% - 40% of pure sand beaches, highlighting the level of protection offered by a gravel beach as compared with a pure sand beach. In Southern California, researchers have noted that gravel beaches tend to gain material and increase their crest elevations during severe storms, while neighboring sand beaches eroded significantly so that the sand berms present on those beaches disappeared (Lorang *et al.* 1999, Everts *et al.* 2002).

As an engineered design approach to combating shoreline erosion, the construction of dynamic gravel beaches is relatively new and has not been widely implemented or studied. As part of this memo preparation, a focused literature review was conducted to determine where this approach has been applied as an engineered system. The best example found appears to be the Cape Lookout gravel beach project constructed in 1999 by the Oregon Parks and Recreation Department following three decades of coastal erosion at this site on the Oregon Coast. This project consisted of construction of a gravel/cobble berm with a sandy foreshore and an artificial dune complex backshore. Subsequent monitoring conducted by the Oregon Department of Geology in association with Prof, Paul Komar of Oregon State, has shown that this site has sustained minimal damage since construction despite undergoing several major storms with significant wave heights of several meters that have resulted in overtopping of the berm and artificial dune structure. Mr. Allan has also been involved in the design and monitoring of a gravel bridge construction project at the Hatfield Marine Center in central Oregon that has similar wave characteristics to the Aramburu site. To-date, the constructed gravel beach at this project has performed successfully since 2007 to inhibit wind-wave erosion (J. Allan, personal communication). Note that Prof. Komar (a noted coastal engineering professor emeritus at Oregon State) has been documenting the advantages of dynamic gravel beach systems and featured this system at a recent invitation only USGS sponsored workshop on shoreline armoring in May 2009.

Other project site where this approach has been implemented include a perched gravel beach constructed by Lorang in Flathead Lake, Montana (Lorang 1991) which has reportedly reduced erosion of the adjacent backshore. However, the site did experience some loss of gravels due to the oblique wave approach the caused northward sediment transport (M. Lorang, personal communication). Other reported project include several sites in the Great Lakes of North America where dynamic revetments proved to be cost-effective solutions for shoreline protection and a modified gravel beach design at the Port of Timaru on the east coast of the South Island of New Zealand (Kirk 1992). The accumulated gravel beach had reportedly been very successful in dissipating wave energy.

Note that as described in more detail below, the Aramburu project site may not have all the characteristics of a typical gravel/sand mixed beach, notably a permeable gravel bench below the supratidal berm.. It is not clear how these differences will impact the performance of the proposed design.

Analysis of Reference Site Data

Reference site studies were conducted at five reference sties within San Francisco Bay to inform the shoreline design work. The reference sites are used to represent the natural range of wave energy exposure and substrate types that may be suitable at Aramburu Island, including one local reference site (natural gravel beaches at Richardson Bay Audubon Sanctuary). Reference sites are used for both design and forecasting potential habitat uses of constructed beaches. The four sites were Radio Beach in xxx, Pier 94 in San Francisco, Foster City Beach, Sanctuary Beach in Richardson Bay (opposite Aramburu Island) and Brisbane Beach. At each site a cross-section survey was performed and discrete sediment grain samples collected for sieve analysis. Note that the sieving work was conducted with sieve sizes that were too widely spread apart and therefore, the computed D50 values are approximate. The Main Report and Appendix G contains details on the reference site work including the location maps, topographic survey and sediment size data by site. FRE conducted an analysis of the reference site data.

Attachment 1 to this memo contains a summary table compiled by FRE of the reference site data.

The results of the reference site analysis work indicate the following:

- Typical sand lower foreshore slopes at Radio Beach range from 2 to 4 percent
- The sandy lower foreshore (nearly flat low tide terrace below the beachface or swash slope of the upper intertidal profile) at the reference sites is often a relatively thin layer and sand mixed with mud that increases sand cohesion and reduces longshore movement;
- Gravel berm slopes range from 9 to 18 percent in line with surveyed Aramburu site slopes
- The reference site that is most applicable to the sand foreshore slope occurs at Radio Beach with a sand slope of 2 to 4 percent.

Analysis of On-Site Survey and Sediment Data

The site was surveyed by WWR on December 9, 2009 and the results presented in a series of cross-sections across all Cells of the eastern shoreline (Main Report).

Sediment Sizes

Several site features were sampled and their location is shown in Appendix G and the results summarized below:

location	*d50 (mm)*	*comments*
Area 1: Northern Gravel Bar	12 mm	proposed northern most gravel bar
Feature 2: Northern Gravel Spit	8 mm	Hillslope beach ridge crest
Feature 2: Northern Gravel Spit,	8 mm	Hillslope material swash-slope
Area 5: Northern Gravel Spit	26 mm	Imported spit material
Area 6: Gravel toe berm	12 mm	Central island shore
Area 9: Southern gravel spit	10 mm	Split crest
Area 9: Southern gravel spit	7 mm	Beach ridge
Feature 4: Southern gravel spit	6 mm	Upper swash-slope
Feature 4: Southern gravel spit	16 mm	Lower swash-slope
Feature 5: Lag Field	44 mm	Lag field deposits

The results of on-site surveys indicate the following:

- Gravel sediment sizes ranges from 6 to 25 mm
- Gravel slopes range from 11 to 20 percent
- The sediment sizes in the gravel bars appear to reflect the sizes of sediment eroded from the site fill deposits and do not appear to reflect wave sorting
- Visual observations show an increase in size for the lag field deposits from coarser in the south becoming finer to the northern end of the site

Proposed Aramburu Island Dynamic Shoreline Revetment Concept Design

For design purposes, the eastern shoreline of Aramburu Island was divided into three shoreline segments or cells based on field observations and surveys of the eastern edge of Aramburu Island (Figure 16 Main Report). The cells are marked by discontinuities to longshore sediment transport, caused by the artificially excavated coves (small embayments with pocket salt marshes) of the eastern island shoreline.

The northern cell extends from the north-east corner of the island down too the first cove, a distance of approximately xx feet. The northern cell has the gentlest, dissipative shore profile, protected by wide mudflats in all directions. It exhibits the lowest wave energy impacts (very low scarp, confined to the south “headland” end of the cell) and contains a long, narrow gravel beach with very limited sediment supply.

The central cell is the largest segment of the shoreline. It extends between two coves for a length of approximately xx linear feet. This cell shows more evidence of wave-cut scarp erosion (up to approximately 0.8 m high) than the northern cell. The southern cell extends from the south end of the Island to the tip of the gravel spit in the the southernmost cove/pocket salt marsh. This southern cell experiences the highest wave energy due to the deeper water and steep shoreline profile at the mouth of the dredged navigation channel, allowing direct attack from wind-waves propagating across the long southerly fetch to the Golden Gate . . Th angle of wave attack from southerly wind-waves is oblique to the shoreline resulting in northward longshore transport of coarse sediment at the shoreline.

The proposed dynamic beach design proposed for Aramburu consists of different shoreline treatments for each cell. Since the goal is a demonstration project of different natural shoreline treatments, the varying wave energy conditions along the eastern edge of Aramburu Island allow for design of different shoreline alternatives and subsequent monitoring to assess the effectiveness of these different shoreline treatments in the same location. Note that the original engineering plan was to rebuild a mixed sand/gravel/shell beach across the entire eastern shoreline, however, construction costs for this single approach were too expensive and exceeded the available project budget. Therefore, the preliminary design was modified to present a design approach in the Central Cell that increased the role of wave energy dissipation across a gentler backshore profile (replacing the unstable steep artificial scarp with a lower gradient slope). This modified design is more compatible with the objective of long-term beach transgression and increased reliance on wave energy dissipation rather than defending an artificially steepened shoreline profile of an undeveloped shore. The revised design better accommodates the natural wave energy gradient along the eastern shoreline. This modified approach allows us to compare the cost-effectiveness of different approaches to the different cells of the island.

Northern Cell

The northern cell experiences the lowest wind-wave energy environment across the site. it is located farthest from wind-waves approaching from the maximum fetch to the south, and is most protected by wave energy dissipation of mudflats. Rather then regrade and import sand/gravel to rebuild a beach profile, we propose to supplement the existing gravel berms with oyster shell (native oyster shell fragments, approximately 1/2 inch top 3/8 inch in size) to provide a wider, higher beach profile, with more consolidated habitat area that is more visible and attractive to shorebirds. It will also increase erosion-buffering functions of the shoreline profile. This design approach will evaluate demonstrate the effectiveness of augmenting areas of existing sand/gravel deposits with additional material to resist wave erosion.

The primary design element is the following:

- Add approximately 600 cubic yards of imported oyster shell and place onto the existing gravel beach and spit.
- Construct one to two micro-groin(s) to retain the placed shell and gravel mix

Figure17 shows a cross-section of the proposed restored beach profile and Figure 18 shows a cross-section through the proposed micro-groin.

Central Cell

The central cell has experienced significant wind-wave erosion due to the higher elevation of fill at the shoreline, resulting in a steeper, more reflective shoreline profile. The central cell is relatively less protected by southerly wind- wave energy dissipation across mudflats, compared with the north cell. Given that there is sufficient room on the island to lay back and flatten the almost vertical existing scarp profile beach slope, the design approach in this Cell is grade back the beach slope to a more stable and wave energy dissipative 15:1 (h:v) flattened slope and place a combination of waste gravel from in-bay sand mining operations at Pier 94 and/or mixed sand/gravel from the aquatic Hanson in-bay dredge site. We anticipate that winter waves during high spring tide series would rapidly rework the sand and gravel into natural beach profiles over the new gently sloped shelf. As discussed in Appendix A, waste gravels and this bay sand/gravel mix is the most cost-effective source of import sand and gravel sediments. The relatively flattened backshore slope will allow the beach profile to migrate continuously and gradually landward as sea level rises... This design approach will demonstrate the effectiveness of sand/gravel beach construction in locations in locations where engineered set-back of the shoreline position is not constrained by critical structures to protect.

The primary design elements of this Cell are as follows:

- Grading back of the existing shoreline vertical erosion scarp to a flattened 12 to 15:1 (h:v) slope to allow for placement of a sand/gravel mix from Hanson in-bay dredging operations.
- Placement and rough grading of a sand/gravel mix to be sorted and reworked along shore and cross-shore by wave action to build a short-term equilibrium beach slope profile that moves the available gravels towards the upper end of the swash range, and sorts sands to the lower beachface and foreshore;
- The sand placed on the lower foreshore (low tide terrace, cobble-boulder lag pavement) will be kept at a fairly minimum thickness of 3 to 6 inches. We

expect sand on the lower foreshore to mix with bay mud during low wave energy periods, increasing cohesion and reducing longshore transport of the sand-mud mixture. This lower foreshore mixed sand-mud sediment is typical of the bay's beaches.

- Construct up to five low shore-perpendicular barriers to act as groins that restrict longshore transport of sand, shell, and gravel in the backshore and upper foreshore Cells of the beach. These "micro-groins" will be constructed of either important rock, eucalyptus wood fences or logs embedded in underlying bay mud.

Figure 19 shows a cross-section of the proposed restored beach profile and Figure 18 shows a cross-section through the proposed micro-groin

South Cell

The southern Cell is exposed to the highest wind-wave energy from the long wind fetch associated with the higher energy winter storms from the South and is least buffered by mudflats because it is adjacent to a deepwater dredged channel that focuses wave energy at the southeast corner of the island. This cell has experienced significant wind-wave erosion and the southern end of the island has been protected with rock rip-rap to inhibit local shoreline erosion. In this location, we propose to place coarser gravels in the 50-60 mm size (2-3 inches) to build a pure gravel beach. This Cell is also required to provide a haul-out location for harbor seals, therefore, a more river rounded gravel mix will be imported to the site. The higher wind-wave energy in this Cell will provide an important demonstration of the effectiveness of gravel beaches in resisting higher wind-wave energy environments.

The primary design elements of the South Cell are as follows:

- Gravel back berm constructed of 50-60 mm rounded river rock imported to the Site and graded into place
- A layer of boulder toe rock (artificial cobble-boulder berm) may be placed at the bottom of the scarp to inhibit wave erosion should the gravel berm prove ineffective in resisting movement by winter storm waves. This item may be eliminated due to budget constraints.
- One to two micro-groins to contain the placed sediments constructed with imported 1/4 ton rock and on-site lag deposits.
- Excavation of a seal haul-out channel immediately off-shore of the slope

Figure 20 shows a cross-section of the proposed restored beach profile in the South Cell and Figure 18 shows a cross-section through the proposed micro-groin.

Differences between Typical Natural Gravel/Cobble Beach Systems and the Aramburu Site

Although we believe that Aramburu Island is an appropriate site for the dynamic gravel beach approach, there are some important differences between most natural gravel/cobble beach sites and the Aramburu site that may impact project performance. The following lists some of the differences that may impact performance and will be important to monitor as the site evolves.

Lack of Permeable Substrate at Aramburu Island – In many natural gravel beach systems, the substrate is permeable and this works to reduce the backwash velocity from wave attack. This process has been identified by some researchers as highly important because it's the reduced outwash velocity that allows the gravel/cobble to be moved upslope by large waves but then remain in place to dissipate wave energy because the outwash velocity has been lowered (Belen de San Ramon Blanco 2003). We are aware of no studies that have quantified the importance of this process for gravel beaches and therefore, the impacts from having an impermeable substrate (in this case bay mud) on project performance are currently unknown. Note that there are natural gravel beaches within SF Bay that do occur on wave cut bedrock benches that lack this permeable substrate, but the importance of a permeable substrate in wave energy reduction is unquantified.

Lack of Natural Sand/Gravel Source - Most natural gravel beach systems have a sediment source from local eroding headlands. At Aramburu, since this was an artificial, man-made island, there is no local source of sand or gravel to replenish the beach. There does not appear to be any significant longshore sediment transport off-shore of the island based on site field observations that show no gravel in the near shore. Therefore, we anticipate that all gravel and sand will have to be imported and placed on the island. The gravel sediments will be held in-place by construction of a series of small, low profile micro-groins. Periodic replenishment of the sand and gravel will likely be required. The frequency of replenishment will be determined by on-site monitoring of the beach.

Thinner Sand Thickness in Foreshore – The sand thickness at most of the studies have been at mixed gravel/sand beaches with a source of sand and therefore a larger sand foreshore thickness. The San Francisco bay beaches used as reference sites often contained a thinner sand thickness and the sand was often mixed with bay muds to produce a more cohesive sand/mud mixture that should be more resistant to longshore transport. The importance of sand thickness in dissipating wave energy is currently unquantified and therefore, will be a subject of the proposed beach monitoring program.

Higher Oblique Angle of Wave Attack – If winter storms from the South are responsible for much of the Island erosion, these storms will hit the shoreline at a very oblique angle of attack, likely higher then for most natural systems. The groins will likely absorb a lot of wave energy and there will be a strong northward transport force that will need to be resisted by the groins. Note that site field observations show a reduction in berm height and size northward indicating a reduction in both wave height and energy to the north and thus less longshore transport towards the north end of the island. Mr. Mark Lorang, who is an expert in these types of constructed beach systems, has identified wave approach as a critical component in beach design. His approach has been to use cobbles to induce wave breaking in a plunge zone and placing gravels on top of that, a sort of perched beach approach.

Height of Gravel Berm – In most natural gravel beach systems that are in equilibrium, the height of the gravel berm is approximately equal to the maximum wave swash (runup) height. Given that the top of the proposed berm and island scarp may be below or above this elevation, it is possible that the gravel berm will be overtopped during significant storm events.
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Design Basis of Project Shoreline Cell Design Elements

This section provides the design basis for the various constructed elements of the project. In some cases, the design basis is limited to professional judgment, which is always subject to unknowns and will have to be confirmed through monitoring of the project. Note that the discussion on sediment sources is somewhat general in this section and will be discussed in more detail under construction methods below because the selected source will depend on cost factors that may depend on the project bid quantities. The design parameters below represent design goals, however, project funding limitation may result in designs that do not meet these goals in all respects.

Northern Cell

In the northern cell, the major design parameters are the oyster shell to gravel mixture and the construction of two micro-groins. The design basis of each is discussed below:

Oyster Shell Placement Mixture: The design goal for the north cell is the placement of dredged oyster shell brought to the site and placed and mixed with the existing gravel deposits at the bottom of the wave cut scarp and onto the existing gravel spit at the northern end of the cell. Our design goal is a 50:50% mix of oyster shell to existing gravel on the beach and spit. This ratio may be modified depending on the final site construction budget. There is no design basis for this desired mixture but visual observations at the reference sites indicates that a 25 to 50% mix of oyster to gravel was commonly observed.

Micro-Groins- "Micro-groins" are designed as low, structures constructed of rock or eucalyptus logs scaled down to match low wave heights in the sheltered bay environment. The layout of the micro-groins in the North Cell is intended to contain as much of the placed shell and gravel mixture as possible within the Cell. Since the wave energy is lowest in this Cell, we anticipate constructing a short, approximately 20 to 30 foot long micro-groin perpendicular to the shoreline (Figure X). The northern most groin may be constructed slightly longer to provide a terminal groin to further inhibit longshore transport of any placed sediments into any navigational dredged channels.

The rock groin alternative assumed a 2-4 foot wide rock groin with 2:1 to 3:1 side slopes. Alternatively, the groins may be constructed out of eucalyptus logs placed perpendicular to the shoreline.

Central Cell

The design approach for the central cell is to grade back the existing shoreline to achieve a 15:1 beach slope. We will then import and place a sand/gravel dredge sediment mix onto this slope and allow the tides to create a mixed sand/gravel beach within this cell. In the central cell of the site, the major design parameters are the graded beach slope of the proposed mixed sand/gravel beach, sand thickness and the construction of up to five micro-groins. The design basis of each is discussed below:

Graded Beach Slope and Sediment Placement- Sand foreshore slope data from the Radio Beach reference site as well as on-site data shows slopes in the range of 1.5 to 4 percent.. Our design calls for regarding of the eroded cliff scarp and existing beach at a 15:1 (h:v) slope or approximately 7 percent. This slope is mildly steeper then the low terrace sand foreshore slopes but much less then the measured and observed gravel berm slope profiles that typically grade up to 25 percent. We believe that in this slope range the proposed sand/gravel mixture from the Hanson in-bay dredge site should be relatively stable over a range of sediment sizes. Note that the Hanson mixture may vary greatly in practice depending on local conditions at the dredge site so we wanted a slope that can handle a range of material sizes. Since a portion of this material is being transferred aquatically, there is no ability to screen the material to change the material ratio, therefore, we have opted to grade back the slope at a uniform equilibrium slope to allow for a range of sand/gravel ratios. The biggest design concern would be a much lower gravel/sand ratio from the dredge site resulting in a pure sand beach. Our goal is a gravel/sand mixture with the highest ratio of gravels possible to allow for natural construction of a mixed gravel/sand beach in this cell. As discussed in more detail under the constructability section below, FRE conducted a test of the possible gravel/sand ratio with Hanson at the dredge site. Sands placed for the beach nourishment will be from material barges off-loaded at the southern end of the site and positioned by land in several large piles at each of the required locations. The sand will not be manually graded into place but will be allowed to form a natural equilibrium by movement of the tides

Import Sand Thickness – To reduce the possibility of longshore drift of placed sands (and to save construction funds), we have proposed to reduce the thickness of import sands to a 3 to 6 inch lift in the lower foreshore cell. The goal is to replicate a condition found at the Bay Beach reference sites (especially Radio Beach) where the foreshore contained a sand/mud mix that increased the sand cohesion and made it less likely to transport. This thinner sand foreshore will not require an extended micro-groin to constrain longshore transport, therefore, the length of the micro-groins will be approximately 30 feet from the upboard edge of the beach to contain the swash gravels. This cell of the constructed beach will be monitored to assess any movement of import sands and the dissipation of wave energy from the constructed foreshore.

Sediment Sources – As described under constructability and material sources below, we anticipate using a sand/gravel mixture form the Hanson dredge site either directly from in-bay dredging and aquatic transfer or by barging in the gravel waste product form Pier 94 in San Francisco. We plan to use available higher energy naturally deposited marine sand and avoid the finer Aeolian sands such as the Marritt Sands from the Port of Oakland.

Micro-Groins- Up to five micro-groins will be constructed out of imported rocks and large on-site lag rock and/or imported large eucalyptus logs either laid parallel to the beach slope or installed as vertical “fence” posts into the beach. The layout of the micro-groins in the North Cell is intended to contain as much of the placed gravel/sand mixture in the upper part of the constructed beach. We anticipate constructing a series of relatively short groins, approximately 25 to 30 feet long, at a spacing of approximately 200 to 300 feet apart.

Southern Cell

The south cell represents the highest wave energy environment at the site. The design approach here is to import a larger rounded gravel size, approximately 50-60 mm (2 to 3 inches) to build a pure gravel beach.

The design basis of each is discussed below:

Gravel Berm and Beach Design – The gravel berm will consist of both imported and reused lag deposit gravels placed and graded along the shoreline as shown on Figure 16. The gravel berm design consists of several design elements including slope, berm height and width, layout, size and source of the gravel sediments. The gravel berm represents one of the most important design elements for the project. Each of the design parameters is discussed separately below.

Gravel Size **-** There is no established analytical equations for sizing gravel to resist wave energy during storm events. Much of the work by the USACE and traditional engineering documents is for rock riprap on slopes and is not directly applicable for the dynamic beach design approach. Based on a limited review of the literature, the work of Mark Lorang, , currently an Assistant Professor at the University of Montana, who produced a series of papers in this topic while working at Oregon State and continuing to-date, appears to be the most relevant. These papers have been referenced by several other recent journal articles and appear to be the best source of analytical equations for rock sizes in natural beach systems. However, these calculations are only a guide and were derived from boulder beaches and not for a gravel beach, therefore, the results below are approximate and presented as a guide to mobile and immobile rock sizes.

Lorang (2001) presents equations for both the rock mass that is moved by the wave energy and is not moved by wave energy. In this paper, Mr. Lorang developed a simplified calculation methodology for sizing the required rock mass (which I later converted to a rock size by assuming a spherical rock which is an approximation) to resist the various wave energy forces found at the site. Attachment 1 to this memo contains a MathCad worksheet that presents the results of this analysis for two project wave heights. For the gravel sizing in this section, we show the results for the equations that are just moved by wave energy since the goal of the gravel is to move in response to wave energy but not to wash out of the system. The rock groins will be sized using the other forms of his equations that calculate the rock size required to resist movement. These calculations are not definitive but used as a guide and a check on the reference site work done at other sites.

The results of this analysis based on the limiting assumptions from the Lorang equations for a variety of calculated wave conditions for the mobile gravel rock size are shown in the table below. The ranges in each significant wave height row are due to different values for one of the empirical coefficients, Kr, a non-dimensional coefficient of the geometric relationships between the boulders.

Significant Wave Height(ft)	*Estimated Fetch Length (miles)*	*Wave Period (sec)*	*Calculated Mobile Rock Mass (kg)*	*Calculated Mobile Rock Size (assuming a spherical rock)*
4.25 feet (South Cell) – deep water fetch limited	8 miles	4	9 – 30 kg	14 to 21 cm
2.70 feet (South Cell) – deep water fetch limited	8 miles	3.3	3.4 – 12 kg	10 to 16 cm
2.1 feet (North/Central Cells)	2 miles	2.5	1.5-5.5 kg	8 – 12 cm
1.8 feet (North/Central Cells)	2 miles	2.3	1.1 – 4 kg	7-11 cm

Note that due to budget constraints, we plan to use a 50%:50% mixture of larger imported river rock and smaller gravels in the South Cell from the on-site lag deposits or the Hanson aquatic dredge site gravels. The effectiveness of this gravel size mixture will be evaluated during the project monitoring phase.

<u>Gravel Slope, Height and Width</u> – The gravel slope was determined by comparing the slope from elevation 3 ft NAVD which corresponds to mean tide line which is the typically measured elevation where the gravel berm begins in the reference site surveys. The calculated slope from this elevation to the top of the berm scarp works out to approximately 20 to 25 percent within the range of measured values from the reference site

work. The width of the berm ranges from 15 to 25 feet to allow for some structural resistance to wave attack and to rebuild the island. The slope and length of the berm is designed so that the gravel berm extends to intersect with the sandy foreshore. The extent of the sandy foreshore is just to the outer edge of the foreshore lag deposits, which demarcates the extent of the original island. In other words, the project is not indenting to fill beyond the extent of the original island.

Source of Gravel Sediments – The larger rounded river gravel (50-60 mm) can be obtained from Syar Quarry in the North Bay. Note that the gravel used in the seal haul-out area of Cell 3 is best to be as rounded as practical and not as angular to allow for use by the seals. As discussed below, there are practical logistical issues associated with using the waste gravels from Pier 94 and workarounds that use the same in-Bay gravel source are discussed.

Toe Rock – A single layer of toe rock may be placed at the toe of the scarp and consists of a single design parameters; size and specifications of the rock. We anticipate using 200 lb to 1/4 ton rock (whatever is used for the micro-groins) and/or any large rocks that can be salvaged from the lag deposits. The toe rock will be piled one to two rocks high and placed at a slope of 2:1 at the foot of the active scarp. This rock is placed to provide for some erosion protection in the event that the gravel berm is transported away during significant storm events. We will likely use whatever rock is being used for the micro-groins but depending on cost, we may opt to use locally mined rock from the Dutra quarry. Note that this item will likely be eliminated due to project budget constraints.

Micro-Groin Design- The South Cell will contain a single micro-groins designed as low rock groin structures scaled to retain to the extent possible the placed gravel sediments in the wave environment. Micro-groins have the following design parameters; rock size, height, width and geotechnical considerations. Note that depending on project budget, one or more of the micro-groins may be constructed from eucalyptus logs or the equivalent. This may significantly reduce construction costs and if successful, provide another approach to stabilizing the sand foreshore.

Rock Size – As previously described, Lorang (2001) proposed equations for the required rock mass (kg) to resist movement by waves subject tot all the previously discussed limitations. These equations appear to be an improvement to the Hudson equations typically used by the USACE and others to size rock rip-rap. By assuming a spherical rock for sizing purposes, we calculated the required rock size. This estimate was used to size the rocks for the micro-groins. For the rock size, we have used the higher wave energies associated with the deep water conditions. The ranges in each significant wave height row are due to different values for one of the empirical coefficients, Kr, a non-dimensional coefficient of the geometric relationships between the boulders.

Significant Wave Height(ft)	*Estimated Fetch Length (miles)*	*Wave Period (sec)*	*Calculated Rock Mass to Avoid Movement (kg)*	*Calculated Rock Size To Avoid Movement (assuming a spherical rock)*	*Specified Commercially Available Rock Size (lbs)*
4.25 feet (South Cell) – deep water fetch limited	8 miles	4	22-78 kg	18-29 cm	1 /4 ton rock
2.70 feet (South Cell) – deep water fetch limited	8 miles	3.3	22-76 kg	18-28 cm	1/4 ton rock
2.1 feet (North/Central Cells)	2 miles	2.5	24 -83 kg	19 -30 cm	1 /4 ton rock
1.8 feet (North/Central Cells)	2 miles	2.3	24-84 kg	19-30 cm	1 /4 ton rock

We anticipate importing the 1 /4 ton rick to the site. We will also utilize the larger rock sizes down to the 200 lb size (approx 8 to 10 inches) form the available on-site hillslope deposits that comprise much of the island fill for construction of the micro-groins.

Layout and Construction of Groins – The top elevation of the micro-groins will equal the top of the island scarp or at a minimum exceed MHHW plus one foot. The top elevation will lower to MHW as the groin extends outward from the island. The groins will slope down at approximately 5:1 (h:v) to elevation approximately 3 ft NAVD (or mean tide elevation) where it meets the sandy foreshore and slopes out matching the existing ground slope. Micro-groins will be constructed using 2 to 3:1 side slopes with a top width of 2-3 feet. Figure 18 shows a cross-section through a typical micro-groin.

The southern most groin may be constructed as a T-groins to help contain placed gravels against the higher wave energies expected in the southern part of the site.

Geotechnical Considerations – It is unclear if construction of micro-groins will be geotechnically stable directly on top of the underlying Bay Muds that comprise the bottom part of the island and the native Richardson Bay substrate. Analysis of geotechnical stability is beyond the scope of this concept design report. For cost-estimating purposes, a geogrid (Tensar) has been assumed to be placed directly underneath of the bottom layer of rock to provide for some additional strength and stability for the micro-groin. The effectiveness of this geogrid or other measures to provide for micro-groin stability is important to evaluate during final design.

<u>Construction Methods and Costs</u>

This section presents a first cut estimation of construction methods and costs for the project. These costs and methods are preliminary and subject to change during final design.

A summary of work restrictions are as follows:

- No work before 6 am and after 8 pm
- No blocking of the adjacent home owner dredged channel along the western and southern edge of the island
- Noise decibel levels in compliance with Marin County Standards.

Material Source, Constructability and Construction Cost Issues

This section coves the likely sources and placement methods for the sand, gravel, rock and other materials (i.e. oyster shells) required for construction of the dynamic shoreline revetment work. It is anticipated that all materials will be brought to the site by materials handling barges and off-loaded using land based equipment. Final costs will depend on the source location for rock, sand and other materials sources brought to the island for construction. To avoid impacts to the neighboring property owners along the west side of the island, all material off-loading will occur at the south-eastern end of the island (shown on Figure 16). Given the shallow depths within Richardson Bay, materials will have to be brought to the site by staging the material transport barges in the deeper parts of Richardson Bay and transferring materials via smaller barges to the south-east corner of the site for off-loading by land based equipment.

The actual contractor construction bids received from the competitive bidding process are always an unknown and depend on many factors outside of the project, such as competitive pressures, fuel and labor costs. Given the economic conditions, we are currently in a relatively favorable bidding climate for construction costs. We anticipate setting up a project bid that contains bid alternatives that can be added or removed from the contractor bid to meet the available project budget. Therefore, we present the discussion of material sources and methods below in the context of several material and placement alternatives. The final selection of alternative may depend on receipt of contractor bids for the project work.

<u>*Gravel/Sand Sources and Placement*</u>- We currently anticipate using the available waste gravel fraction from Hanson site operations at Pier 94 in San Francisco supplemented with a direct dredged sand/gravel mix from the Hanson permitted aquatic dredge site in the Bay as the primary source of sand and gravel for the beach construction. We anticipate

requiring approximately 2,200 to 2,500 cubic yards of sand/gravel mix that will be placed in piles within the Central Cell and allowed to grade naturally by tidal action.

Hanson Products is only economically interested in the sand fraction of the dredge sediment mixture and screens out the gravel portion as a waste material in their gravel operations at Pier 94 in San Francisco. In a typical year, the waste gravel percentages from Pier 94 operations may be enough to satisfy much of the project needs. However, during this current economic downturn, Hanson has sharply reduced their material handling volumes at Pier 94, therefore, only a fraction of waste gravels of previous years are available for the project in 2010 and likely 2011. Therefore, our plan calls for supplementing the available Pier 94 waste gravel stream with the in-bay sand/gravel sediment dredged without the dredge screens to remove gravels and loaded aquatically by Hanson from their in-bay dredging operations. The Hanson waste gravel at Pier 94 in San Francisco has a d50 of approximately 6 to 14 mm. This gravel was used by Baye and Leventhal for the Pier 94 project to enhance habitat for the endangered shoreline plant, California sea-blite (*Suaeda californica*) and this size range should work within the re-graded Central Cell. Jerico Prodcusts has a Suisun Bay dredge site location that also produces a sand/gravel mix and this source may be used depending on costs.

For the Southern Cell, we propose to use a larger gravel size on the order of 50 – 60 mm (approximately 2 to 3 inches) to construct the gravel berms and gravel foreshore (there is no sandy foreshore in the South Cell). This gravel will have to be rounded because this area is also intended to be used as a seal haul-out site. Since this rock is not available within SF Bay, we plan to import this rock from the Syar Quarry in Napa County. Due to project budget constraints, the South Cell gravel mixture will be approximately 50% 3-inch rounded Syar rock mixed with the gravel fraction of the Hanson sediments.

We will also evaluate the cost-effectiveness of excavating and sieving the on-site soils for gravel and rock. Depending on the timing of the uplands restoration work, this source of excavated on-site soils may not be available. We anticipate requiring approximately 325 cubic yards of the 50-60 mm rounded gravel mixed with approximately 325 cubic yards of sand/gravel mix (targeting as much gravels as possible).

Rock Sources and Placement – One alternative for the micro-groins is to construct them out of rock. It may be possible to use some of the larger rocks excavated and segregated from existing on-site hillslope deposits, however, the timing and cost-effectiveness of reusing rock from on-site soils is unknown. Therefore, we have prepared cost-estimates assuming that rock for micro-groins have to be imported.

Audubon has expressed a preference to not use the bluish rock from the nearby Dutra quarry that is typically used for shoreline rip-rap, so we have also developed costs for importing rock from the Syar quarry in Napa as an alternative to the Dutra quarry rock. The Syar rock is more natural looking in color and somewhat lighter in weight because it is of extrusive volcanic origin. We have assumed import of 1/4 ton (or some smaller 200 lb rock) rock which is roughly the same cost to bring to the site and place. To provide against excessive settlement of rock into the underlying, soft bay mud substrate, we have included a cost for installing a geogrid under the bottom layer of rock. The need and design of this approach should be evaluated during final design by a geotechnical engineer.

Note that large eucalyptus tree trunks may be used in place of some of the rock micro-groins to save construction budget. We anticipate replacing one or more of the north end micro-groins with large logs depending on project bids.

Oyster Shells – The northern most terminal groin will have a quantity of oyster shells mixed in with the gravel berm to provide shorebird habitat. The ideal mix would be approximately 75% oyster shell to 25% gravel, however, the cost for oyster shell is expensive and the project budget may not allow for purchase of the shell material. The oyster shells source is commercial dredging of bay oyster shell "hash" deposits (a mixture of shell fragments ground-up shell the size of a coarse grained gravel) offshore from Foster City by Jerico Products.

Preliminary Cost Estimate

FRE has worked with WWR to prepare a construction cost estimate in coordination with Hanford-Arc contractor. This estimate is included within the cost section of the Main Report.

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Appendix H
Aramburu Island Reference Beach Study

1145

Technical Memorandum

Aramburu Island Reference Beach Study

To: Project Design Team
From: Dan Gillenwater
Date: March 10, 2010

On July 22 and 23, 2009 Wetlands and Water Resources, Inc. (WWR) collected data on beach slope and beach material grain sizes at five beaches around San Francisco Bay. The selected sites represent a variety of beach types that are subject to different wave and current regimes, thus representing a broad spectrum of beach conditions around the Bay. This information will be used for determining (1) the range of grain sizes needed for the beach nourishment activities at Aramburu Island, (2) the potential beach slope that could develop at the island, and hence (3) the quantities of material that would be required to construct a beach of a given slope and grain size. This memorandum describes the data collection methods and presents the data. The grain size distribution histograms and representative beach cross sections can be found at the end of this document. Analyses of these data for the purpose of supporting project engineering design will be completed at a later date and summarized in future documents.

Study Beaches

The locations of the five reference beaches are displayed in Figure 1. They are as follows:

818 Fifth Avenue, Suite 208, San Rafael, CA 94901
tel 415.457.0250 • fax 415.457.0260 • www.swampthing.org

1. **Radio Beach, North shore of Bay Bridge–** Naturally formed sand beach w/sandy foreshore

Photo 1. Radio Beach

2. **Audubon Sanctuary–** (1) Sand/gravel beach w/sandy foreshore and (2) gravel berm w/ sandy foreshore

Photo 2. Sanctuary beach (1)

Photo 3. Sanctuary beach (2)

3. **Pier 94, Hunters Point** – gravel berm constructed from Hanson Waste Screenings, no low-tide terrace

Photo 4. Pier 94 beach berm

4. **Brisbane/Candlestick spit** – Gravel/shell beach, mud/rubble low-tide terrace

Photo 5. Brisbane beach

5. **Foster City, Southeast shore** – Shell beach bordered by shallow mud flats

Photo 6. Foster City beach

Methods

At each study beach we surveyed three shore-normal topographic transects extending from the beach-backshore down to the low-tide terrace. We collected the topographic survey data using a *Leica 1200 Smart Rover* differential GPS system. The survey data were tied into various NGS benchmarks depending on beach location (Figure 1). The benchmark datasheets are can be found in the appendix to this document. Along each transect we collected beach material samples at discrete breaks in material composition, normally resulting in 3-5 samples per transect. These samples were later sieved into various material size classes using standardized methods from the American Society for Testing and Materials (ASTM 1985). In addition, we also constructed wind-roses for all beaches, except for the Sanctuary Beach, from local weather station data (Figure 1). The Sanctuary Beach was omitted because there was no acceptable weather station in the vicinity from which an accurate wind-rose could be constructed. The topographic transect and beach material sample locations for each beach, along with the local wind-rose, are displayed in Figures 2-6.

Results

Representative topographic cross sections and grain size distribution histograms for each of the study beaches can be found in the "Topography and Grain Size Data" section at the end of this document. Additional analyses on these data for engineering design purposes will be performed by the project team in later stages of the project.

Figures

Study Beaches

Benchmarks

Weather Stations

1:216,000 (1" = 18,000')

0 2 4 Mi

0 3 6 Km

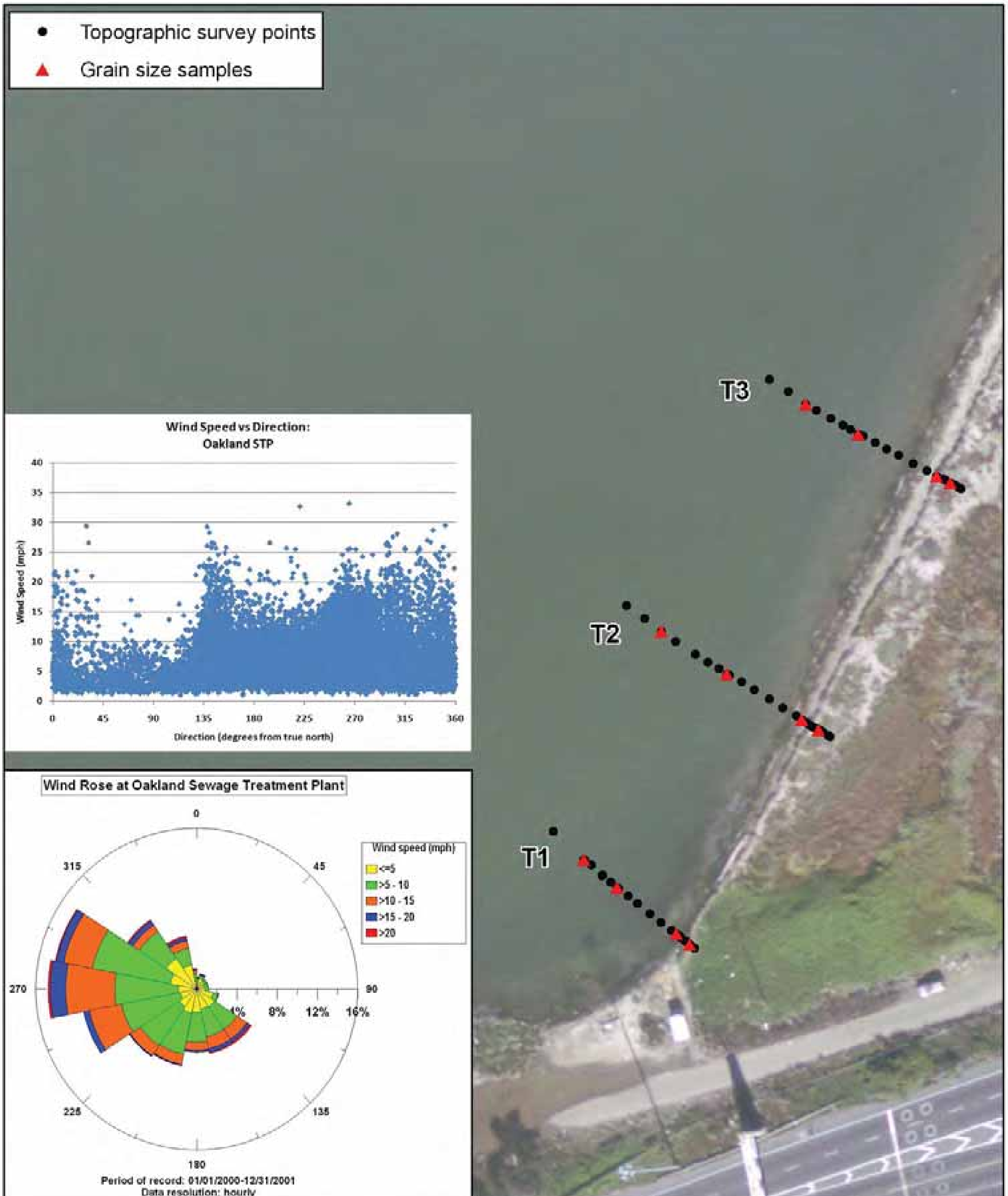
N W E S

WETLANDS AND WATER RESOURCES

STUDY BEACHES, BENCHMARKS, AND WEATHER STATIONS

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

March 2010	Project No. 1145	Figure 1



1:900 (1" = 75')

0 75 150 Feet

0 25 50 Meters

N W E S

WETLANDS AND WATER RESOURCES

RADIO BEACH TRANSECTS AND WIND DATA

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

September 2009	Project No. 1145	Figure 2

Image source: NAIP, 2005
Map file: Radio-beach-survey_2009-0914dag.mxd

1:1440(1" = 120')

0 120 240 Feet

0 40 80 Meters

N W E S

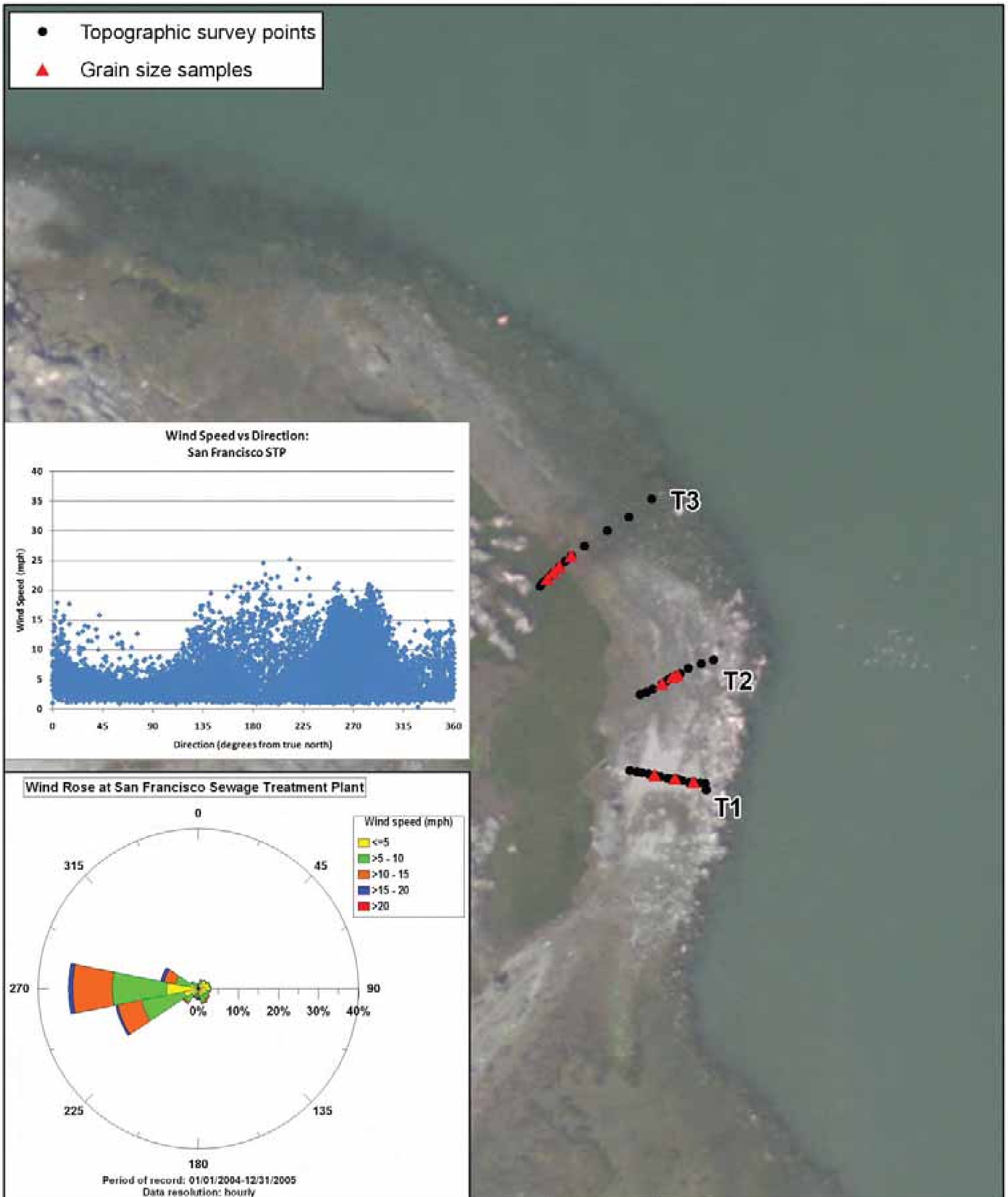
Image source: NAIP, 2005
Map file: sanctuary-beach-survey_2009-0902dag.mxd

WETLANDS AND WATER RESOURCES

SANCTUARY BEACH TRANSECTS

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

September 2009	Project No. 1145	Figure 3



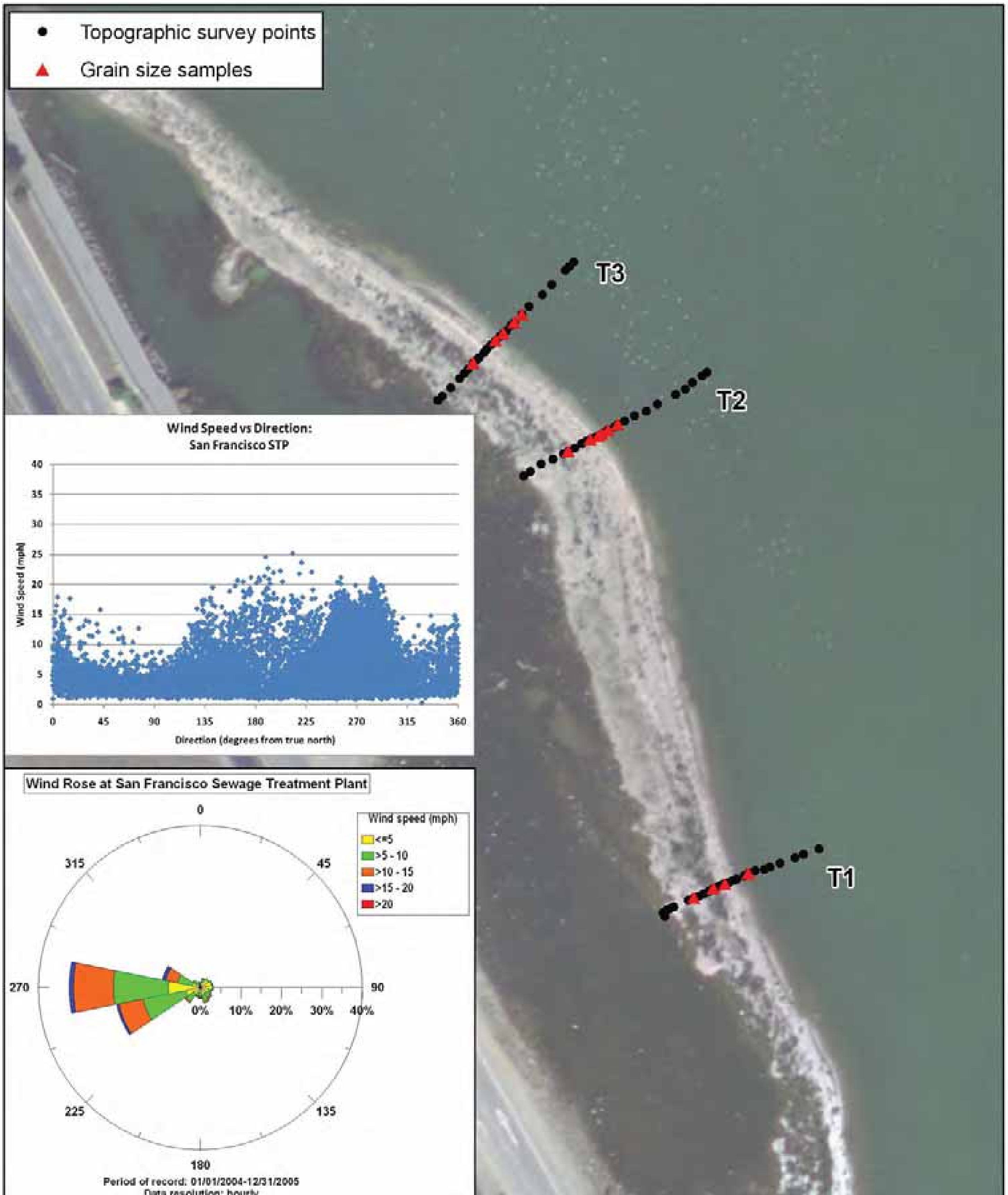
PIER94 BEACH TRANSECTS AND WIND DATA

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

WETLANDS AND WATER RESOURCES

September 2009 | Project No. 1145 | Figure 4

Image source: NAIP, 2005
Map file: Pier94-beach-survey_2009-0914dag.mxd



1:900 (1" = 75')

0 75 150 Feet

0 25 50 Meters

Image source: NAIP, 2005
Map file: brisbane-beach-survey_2009-0914dag.mxd

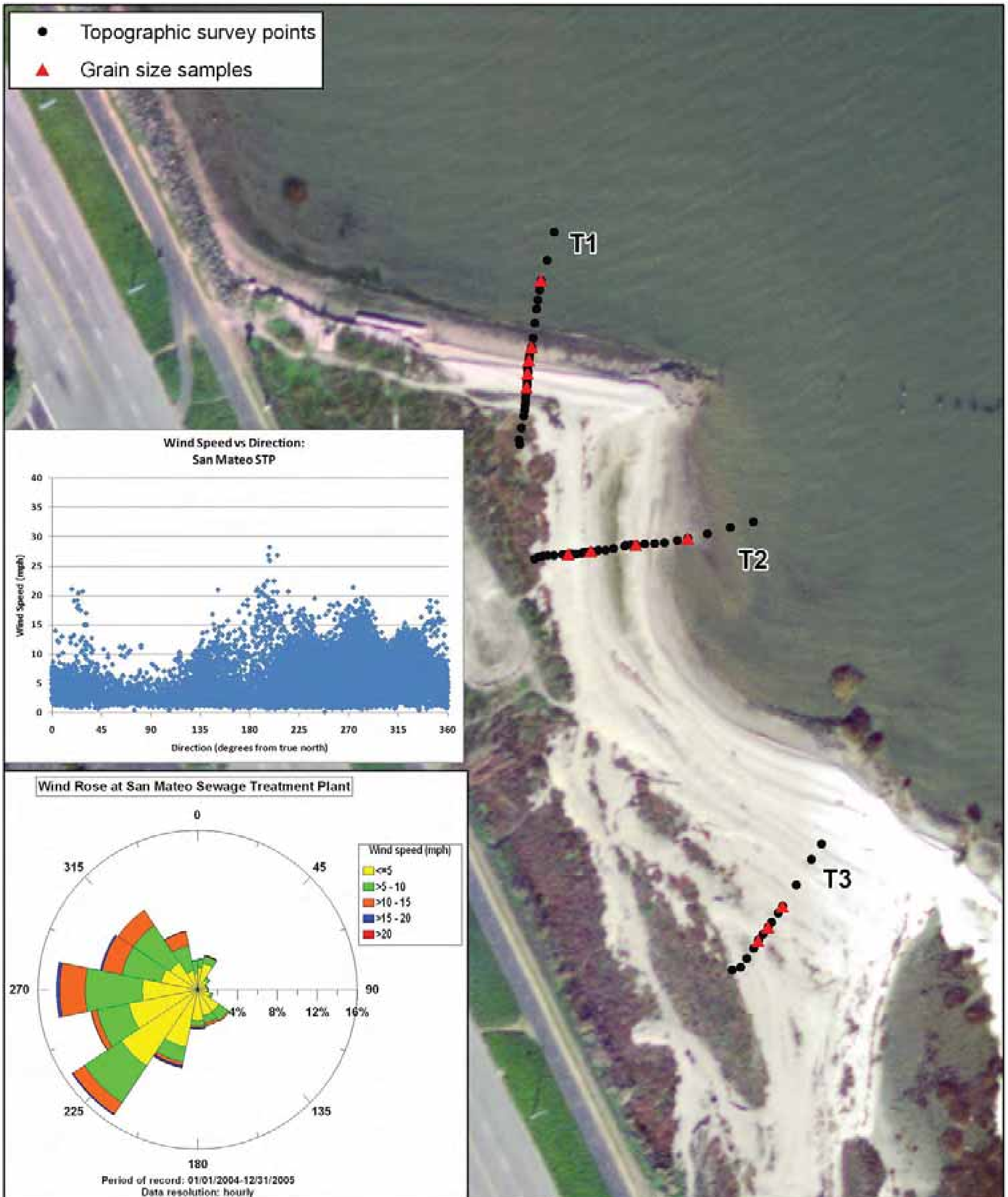
N W E S

WETLANDS AND WATER RESOURCES

BRISBANE BEACH TRANSECTS AND WIND DATA

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

September 2009 | Project No. 1145 | Figure 5



1:900 (1" = 75')

0 75 150 Feet

0 25 50 Meters

Image source: NAIP, 2005
Map file: Foster-beach-survey_2009-0914dag.mxd

N W E S

WETLANDS AND WATER RESOURCES

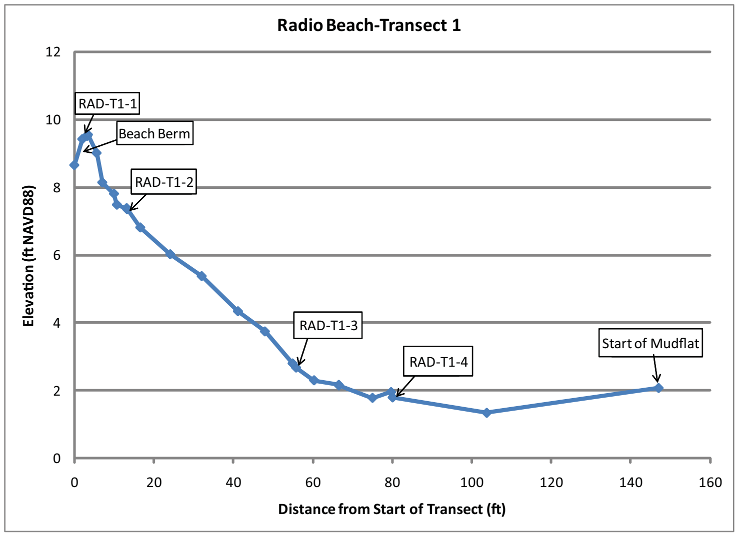
FOSTER CITY BEACH TRANSECTS AND WIND DATA

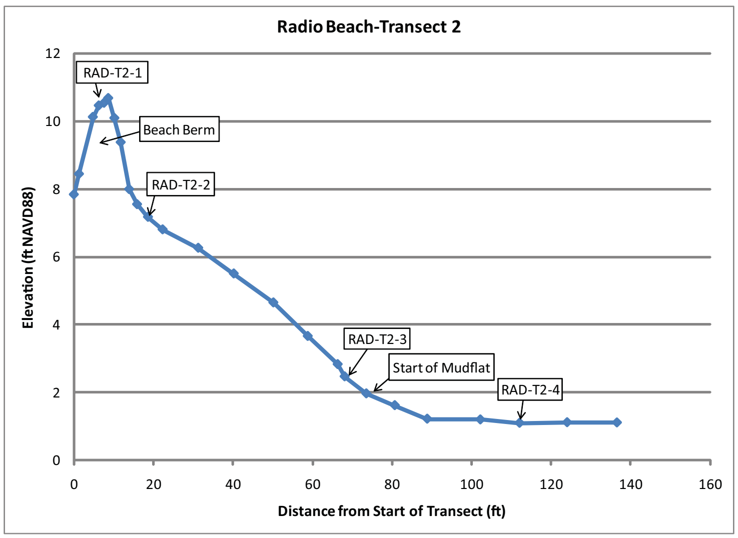
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

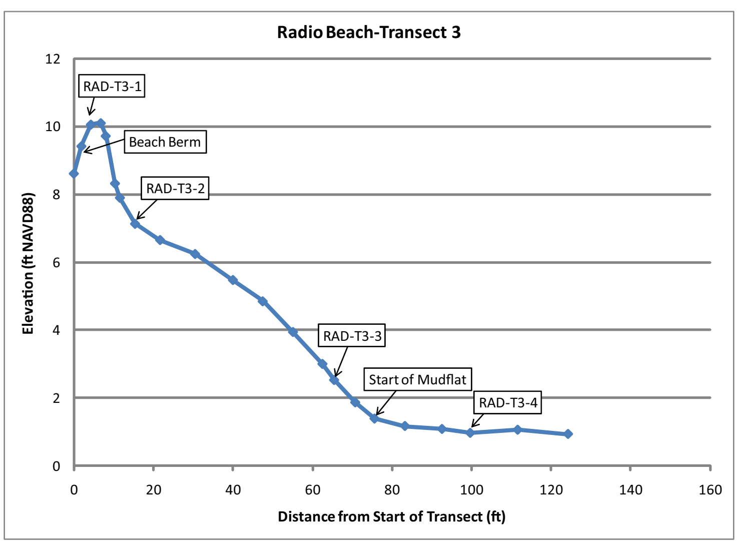
September 2009	Project No. 1145	Figure 6

Topography and Grain Size Data

Radio Beach





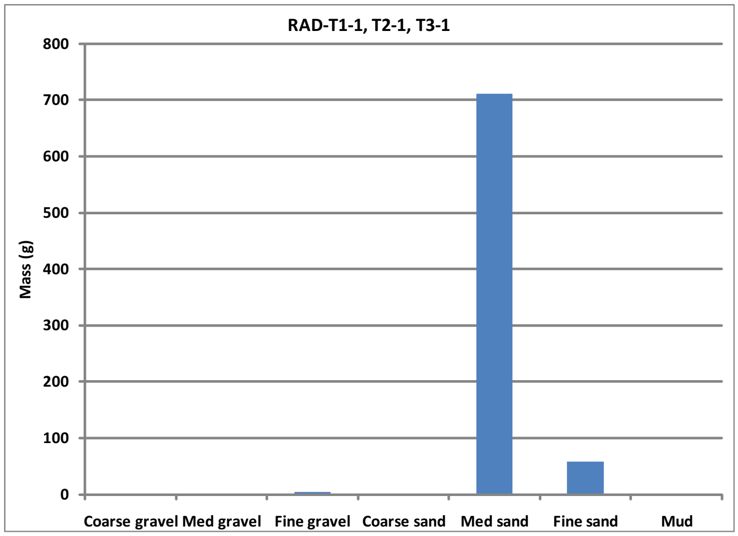


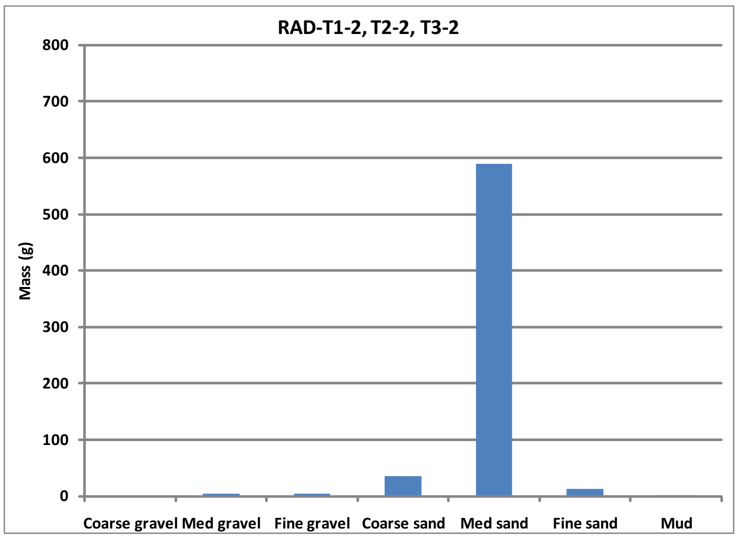
WETLANDS AND WATER RESOURCES

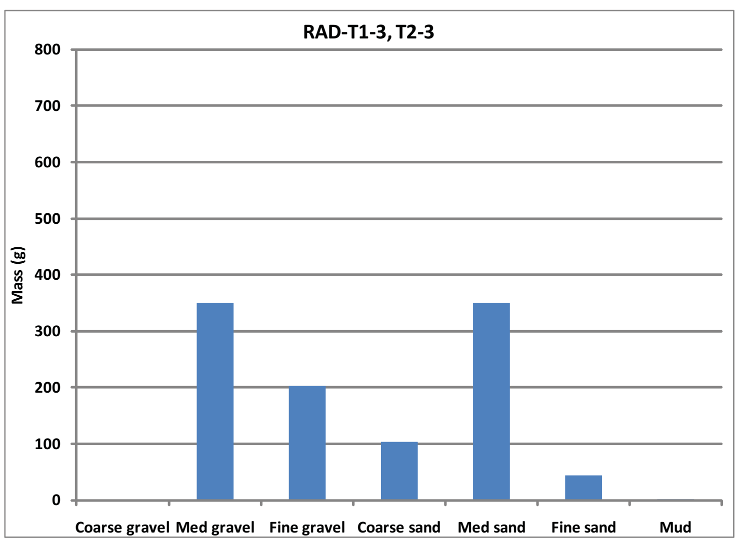
RADIO BEACH
TOPOGRAPHIC CROSS SECTIONS
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010	Project No. 1145

Graphic file: RAD-topography_2010-0225lee.ai
Data file: beach_transects_22july09_plots_2009-0907dag.xls





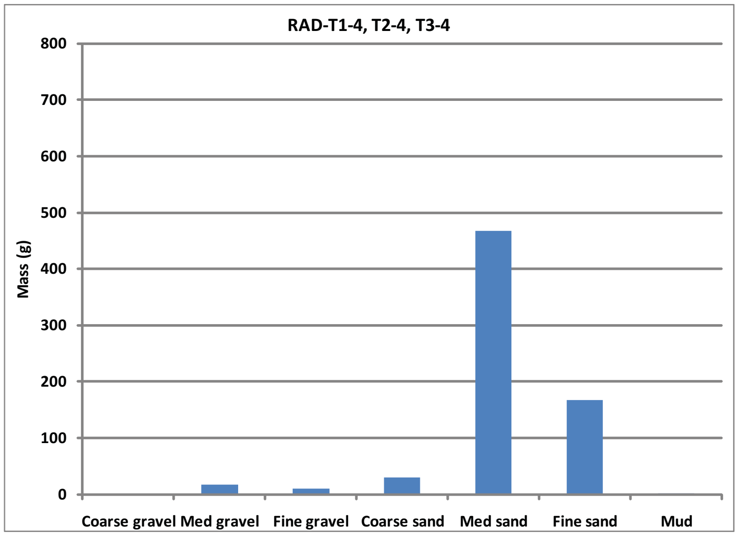


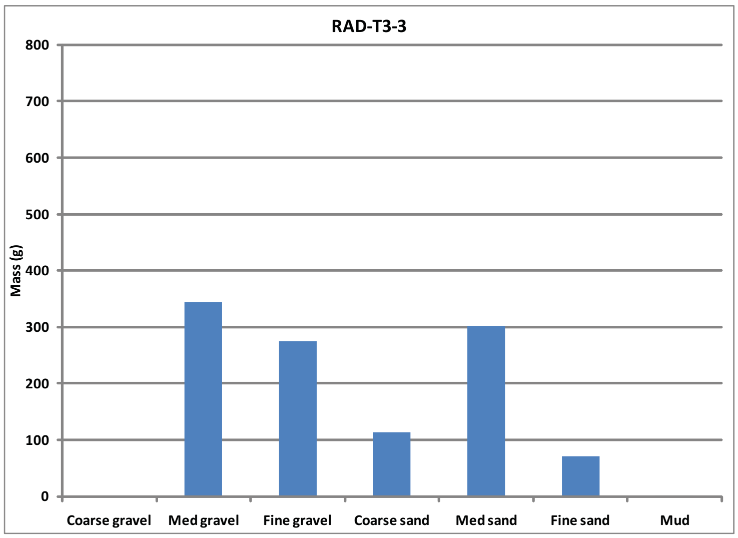
WETLANDS AND WATER RESOURCES

RADIO BEACH
GRAIN SIZE DATA-SHEET 1
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: RAD-grain-size-sheet-1_2010-0225lee.ai
Data file: RAD-grain-size-data_2009-0903dag.xls





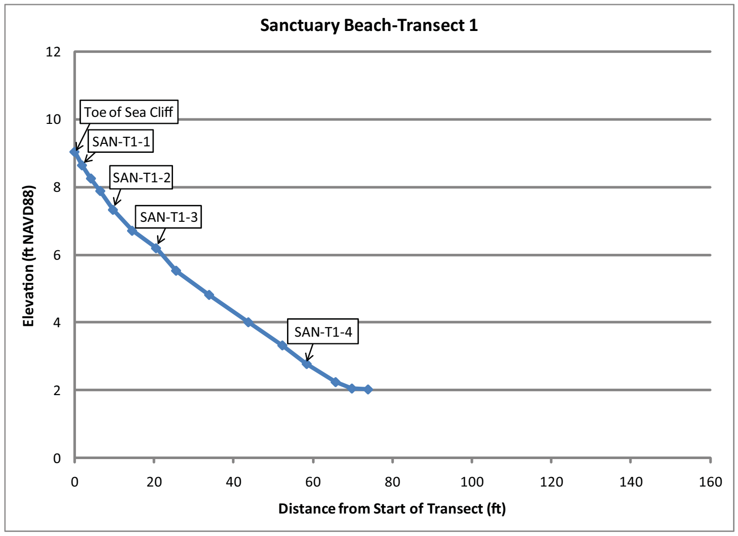
WETLANDS AND WATER RESOURCES

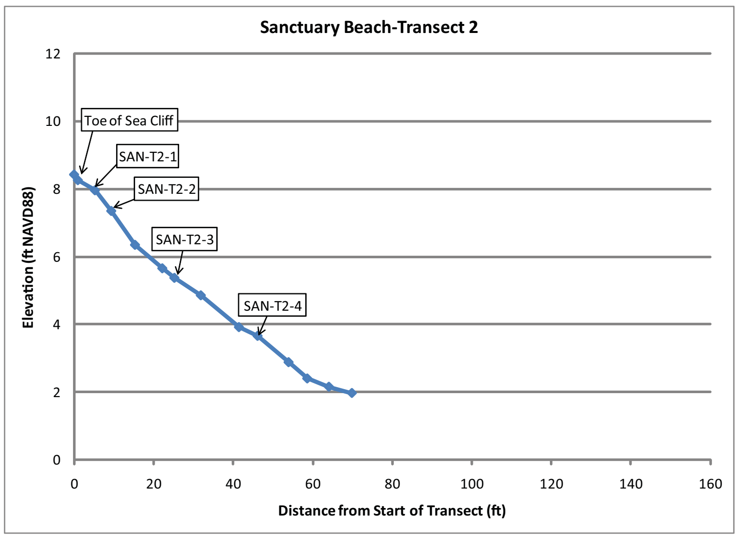
RADIO BEACH
GRAIN SIZE DATA-SHEET 2
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

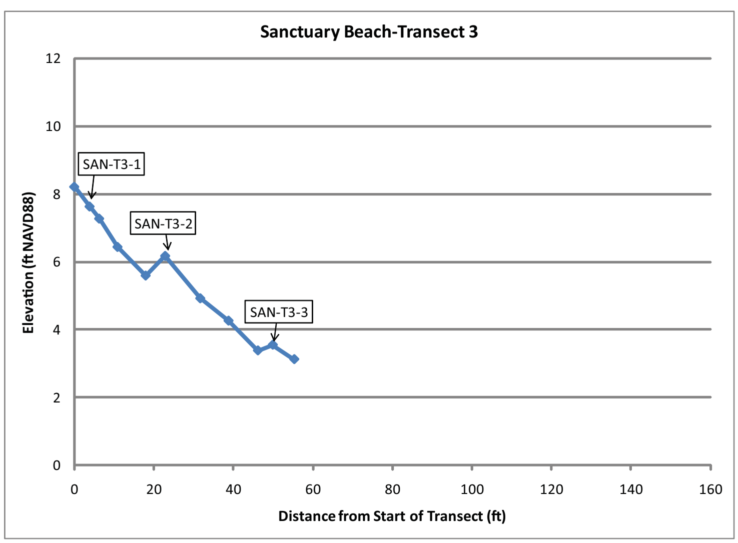
February 2010 | Project No. 1145

Graphic file: RAD-grain-size-sheet-2_2010-0225lee.ai
Data file: RAD-grain-size-data_2009-0903dag.xls

Sanctuary Beach







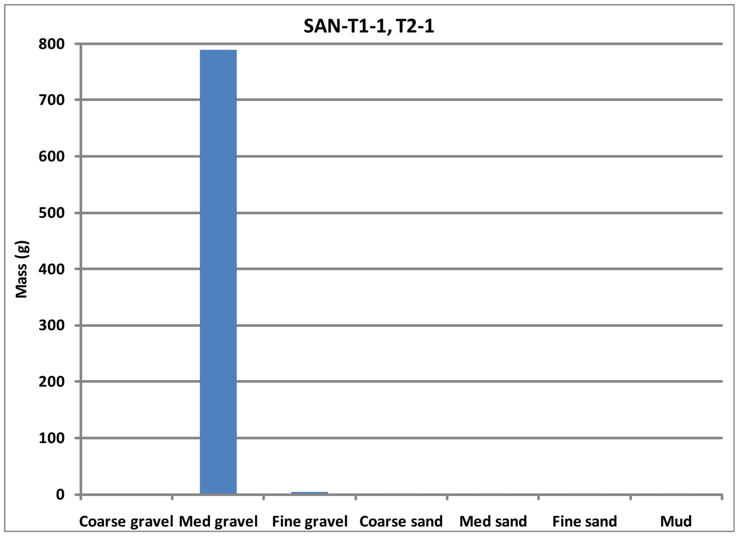
WETLANDS AND WATER RESOURCES

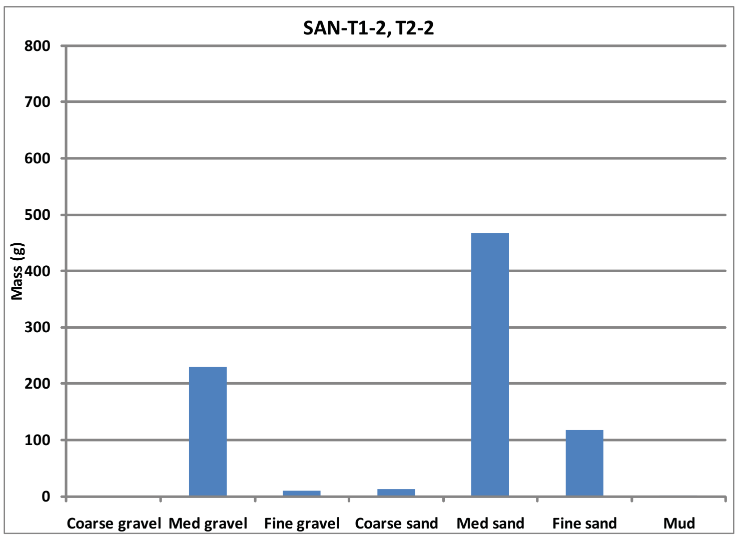
SANCTUARY BEACH
TOPOGRAPHIC CROSS SECTIONS

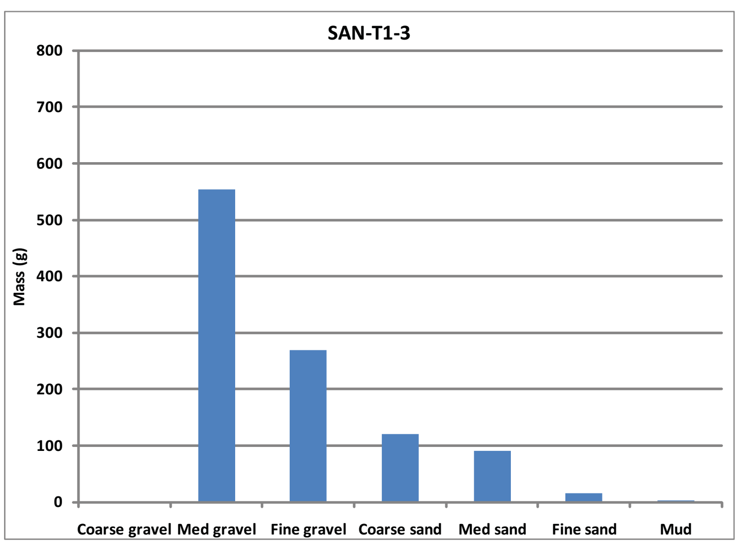
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: SAN-topography_2010-0225lee.ai
Data file: beach_transects_22july09_plots_2009-0907dag.xls







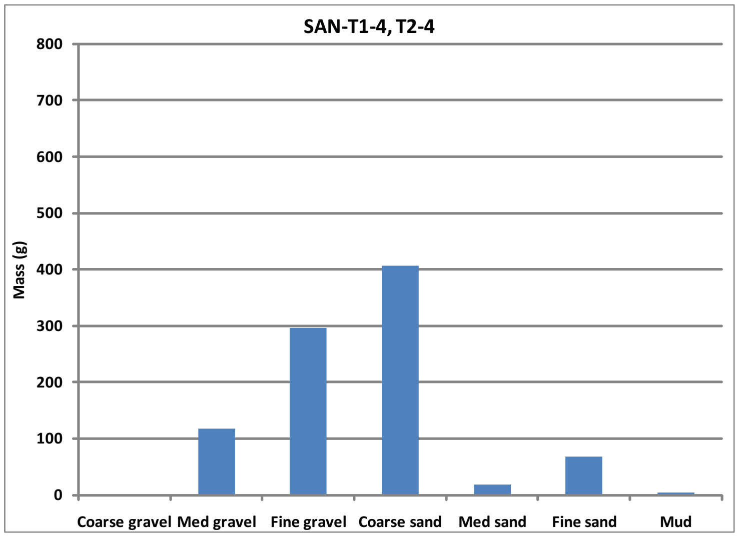
WETLANDS AND WATER RESOURCES

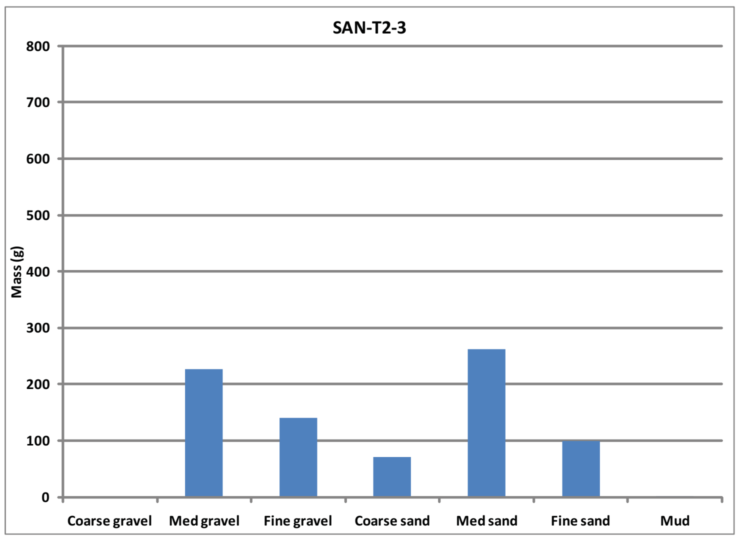
SANCTUARY BEACH
GRAIN SIZE DATA-SHEET 1

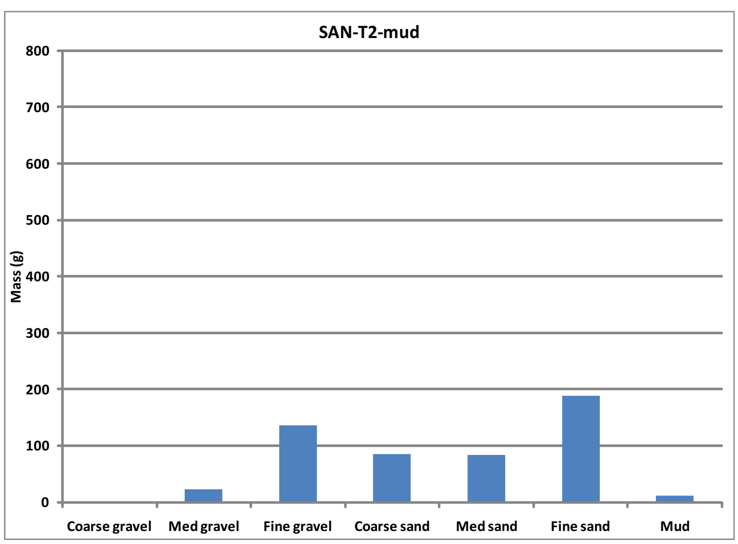
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: SAN-grain-size-sheet-1_2010-0225lee.ai
Data file: SAN-grain-size-data_2009-0903dag.xls





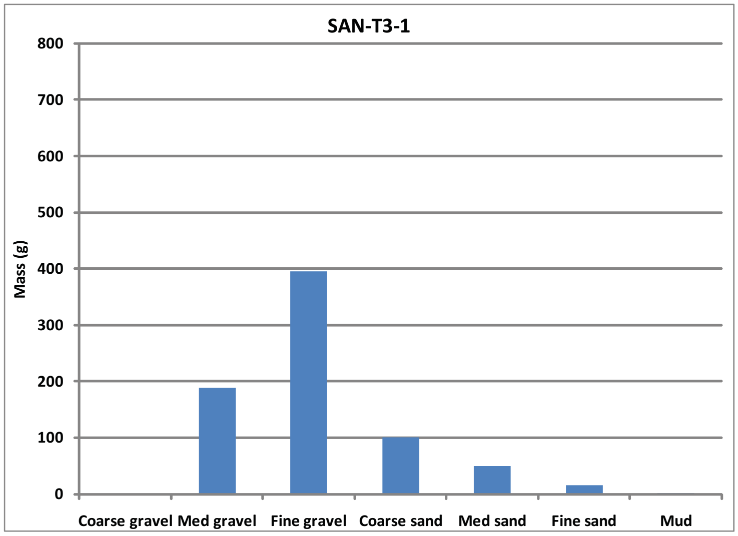


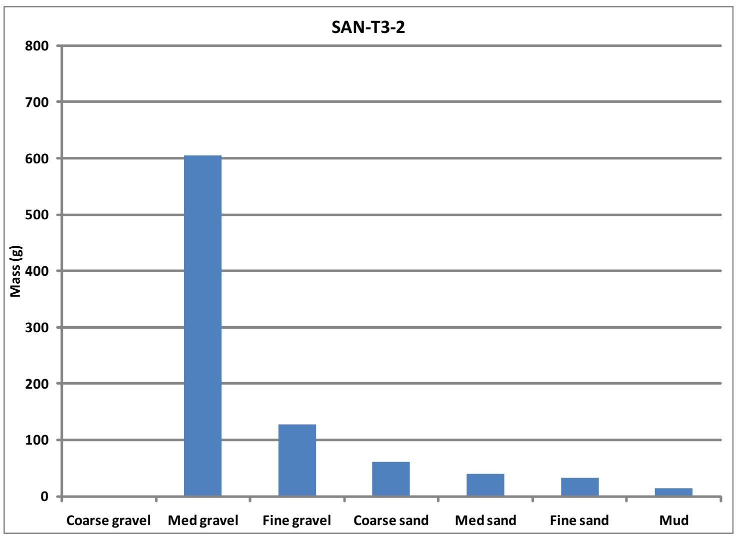
WETLANDS AND WATER RESOURCES

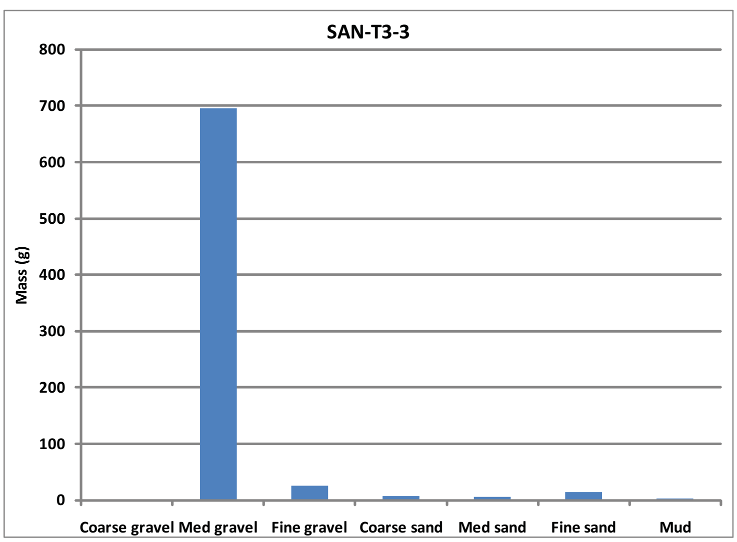
SANCTUARY BEACH
GRAIN SIZE DATA-SHEET 2
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: SAN-grain-size-sheet-2_2010-0225lee.ai
Data file: SAN-grain-size-data_2009-0903dag.xls







WETLANDS AND WATER RESOURCES

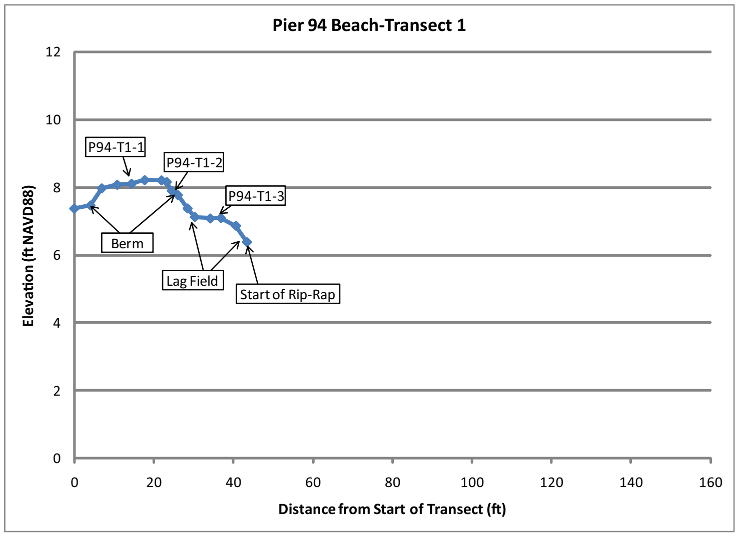
SANCTUARY BEACH
GRAIN SIZE DATA-SHEET 3

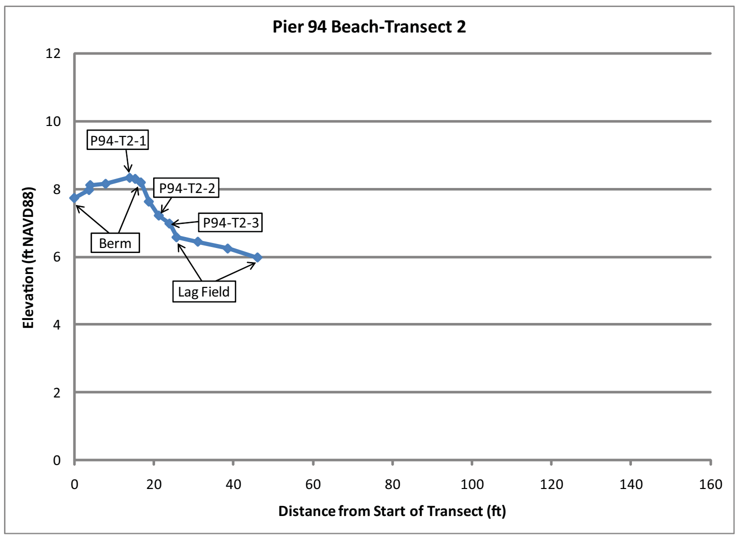
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

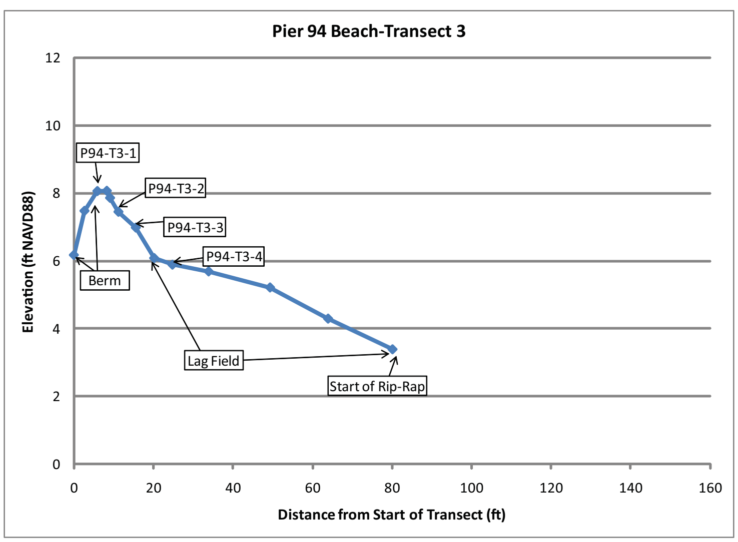
February 2010	Project No. 1145

Graphic file: SAN-grain-size-sheet-3_2010-0225lee.ai
Data file: SAN-grain-size-data_2009-0903dag.xls

Pier 94 Beach





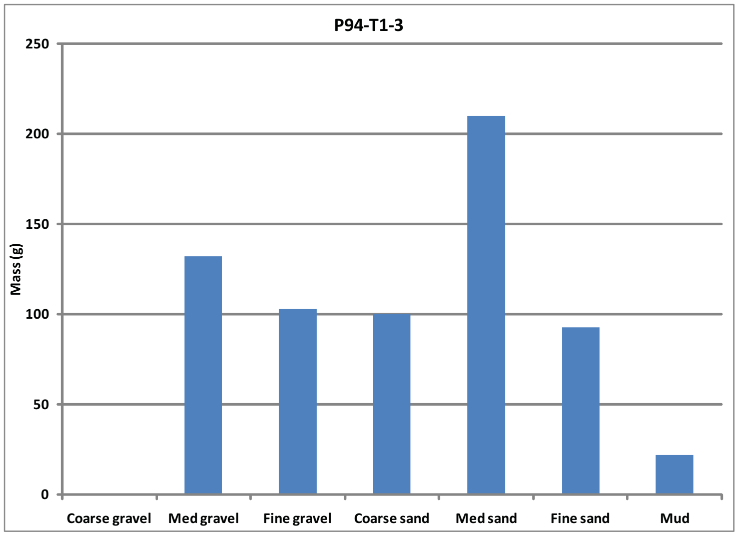


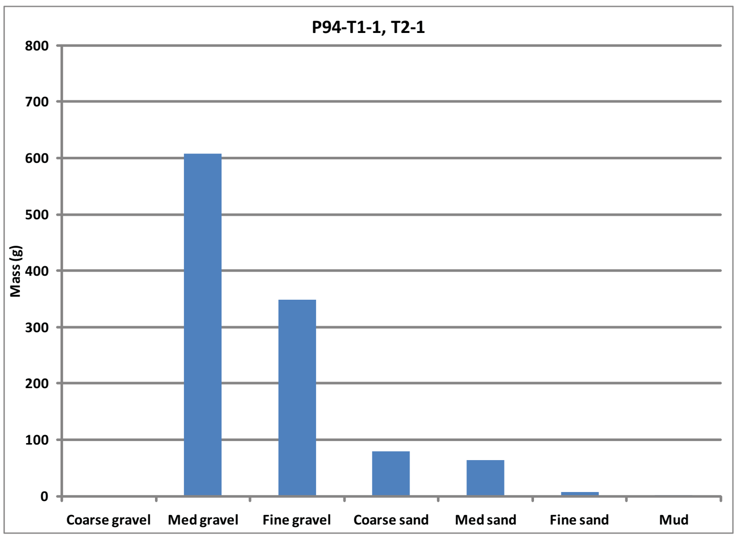
WETLANDS AND WATER RESOURCES

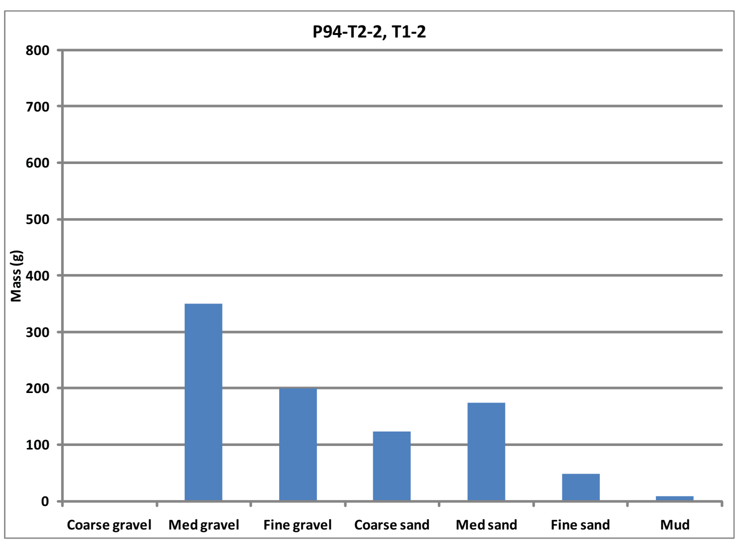
PIER 94 BEACH
TOPOGRAPHIC CROSS SECTIONS
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: P94-topography_2010-0225lee.ai
Data file: beach_transects_23jul09_plots_2009-0907dag.xls





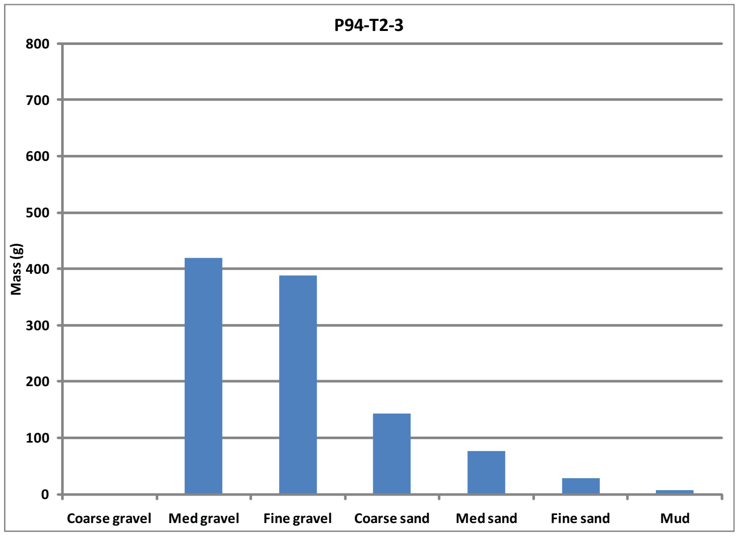


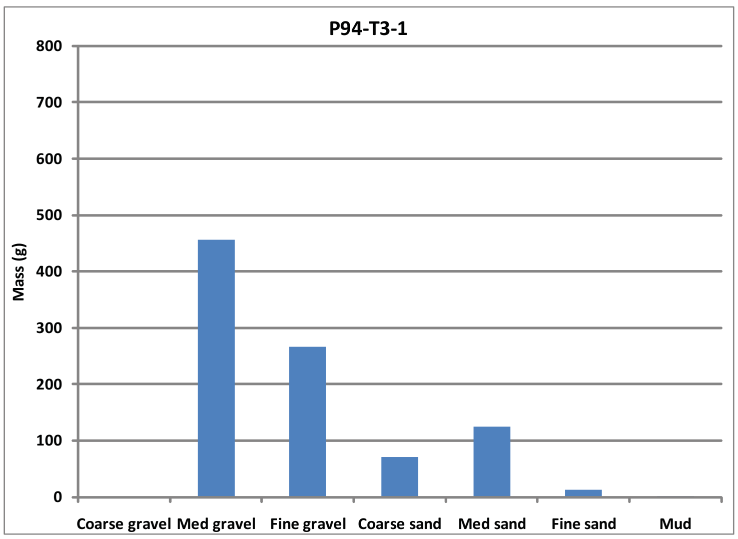
WETLANDS AND WATER RESOURCES

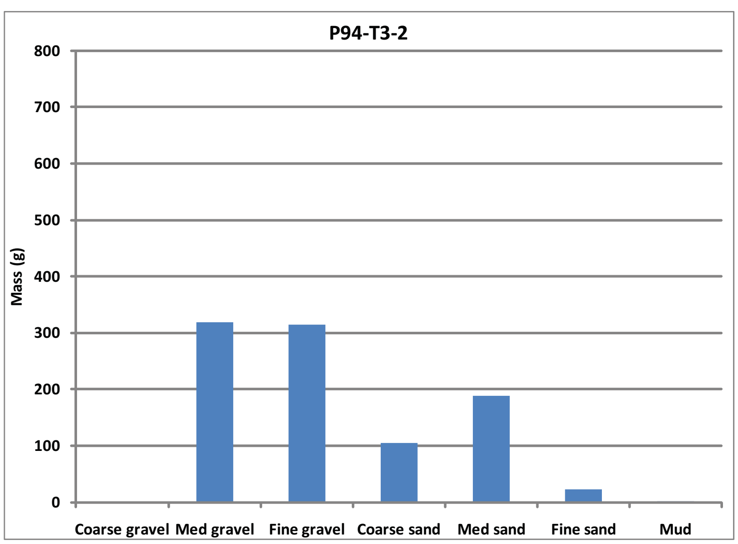
PIER 94 BEACH
GRAIN SIZE DATA-SHEET 1
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010	Project No. 1145

Graphic file: P94-grain-size-sheet-1_2010-0225lee.ai
Data file: p94-grain-size-data_2009-0903dag.xls





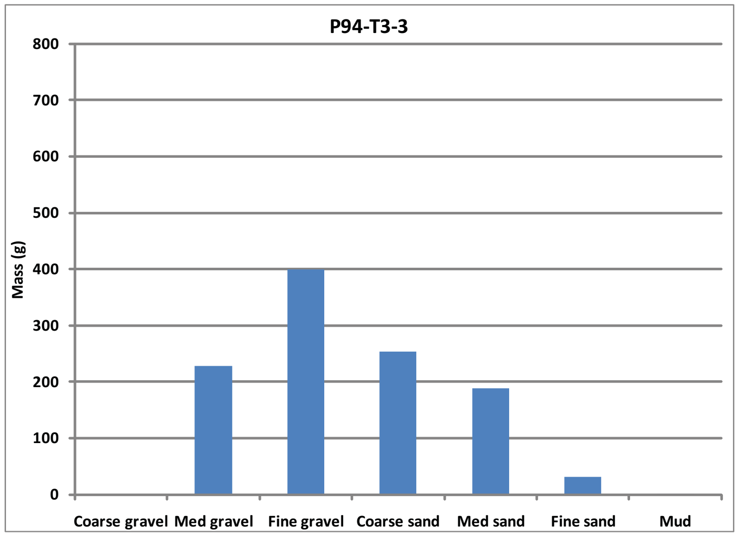


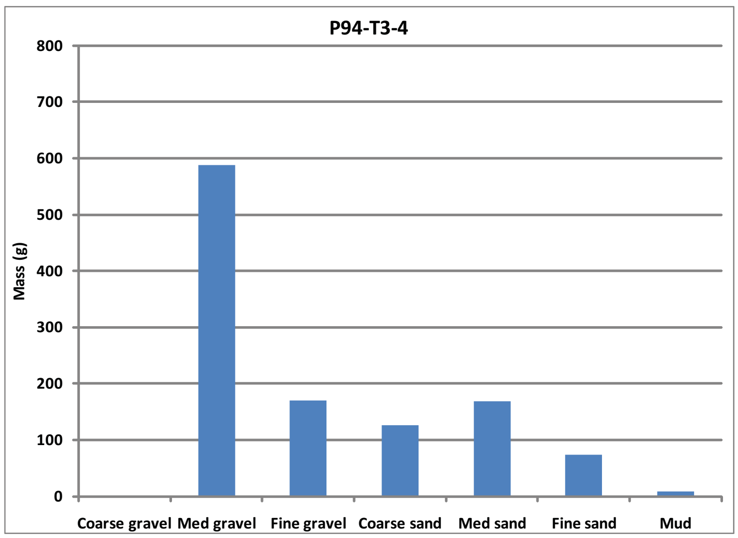
WETLANDS AND WATER RESOURCES

PIER 94 BEACH
GRAIN SIZE DATA-SHEET 2
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010	Project No. 1145

Graphic file: P94-grain-size-sheet-2_2010-0225lee.ai
Data file: p94-grain-size-data_2009-0903dag.xls





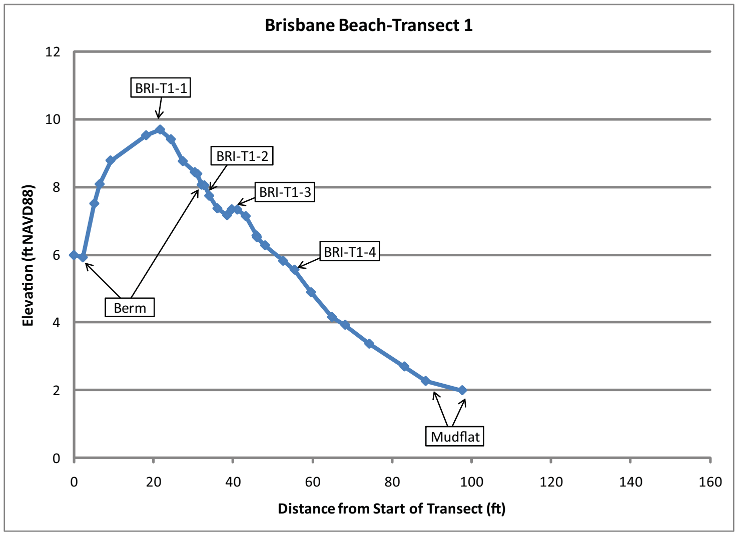
WETLANDS AND WATER RESOURCES

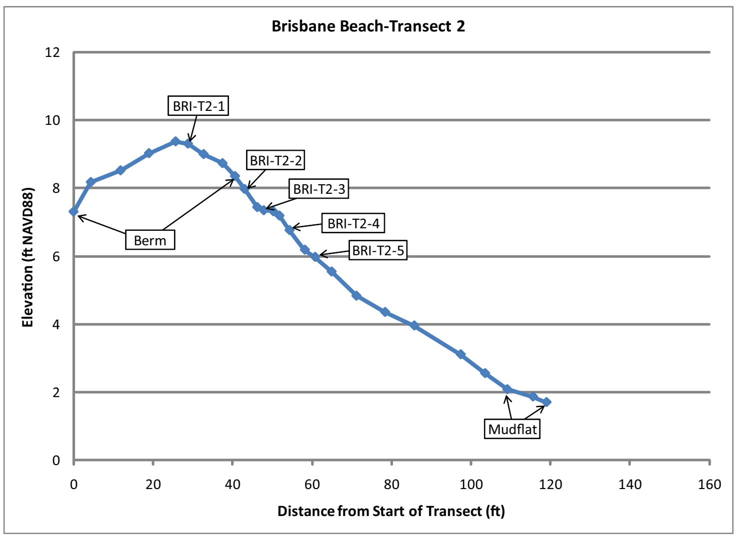
PIER 94 BEACH
GRAIN SIZE DATA-SHEET 3
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

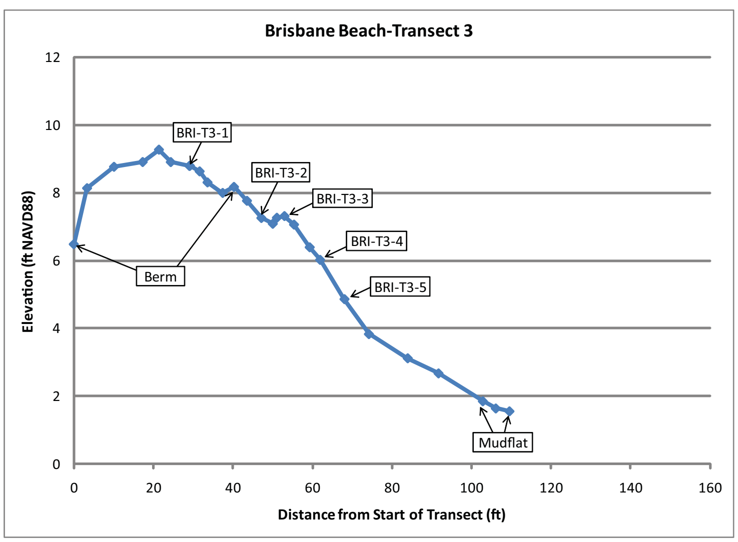
February 2010	Project No. 1145

Graphic file: P94-grain-size-sheet-3_2010-0225lee.ai
Data file: p94-grain-size-data_2009-0903dag.xls

Brisbane/Candlestick Beach







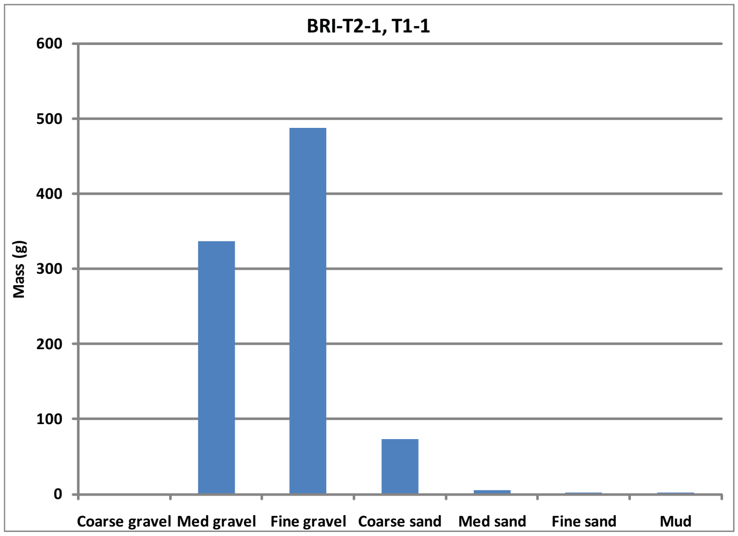
WETLANDS AND WATER RESOURCES

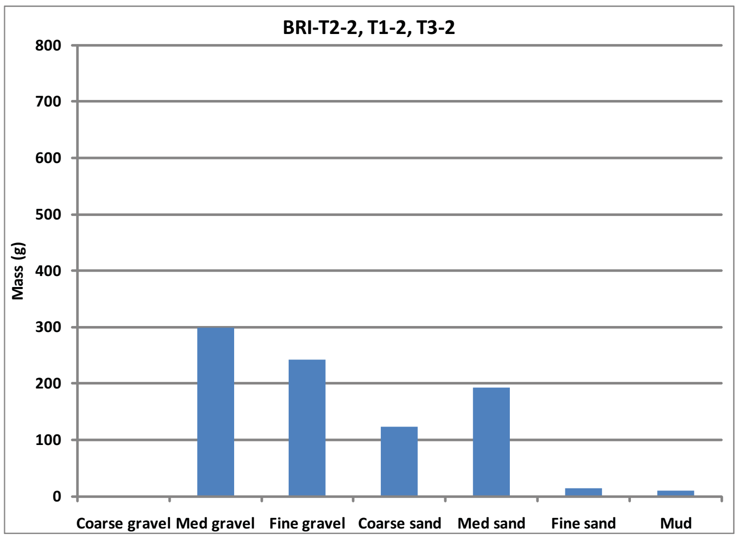
BRISBANE BEACH
TOPOGRAPHIC CROSS SECTIONS

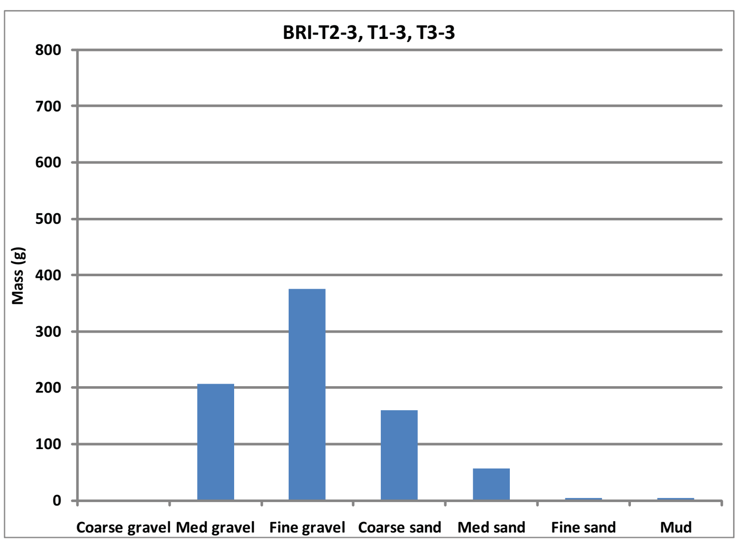
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: BRI-topography_2010-0225lee.ai
Data file: beach_transects_23jul09_plots_2009-0907dag.xls







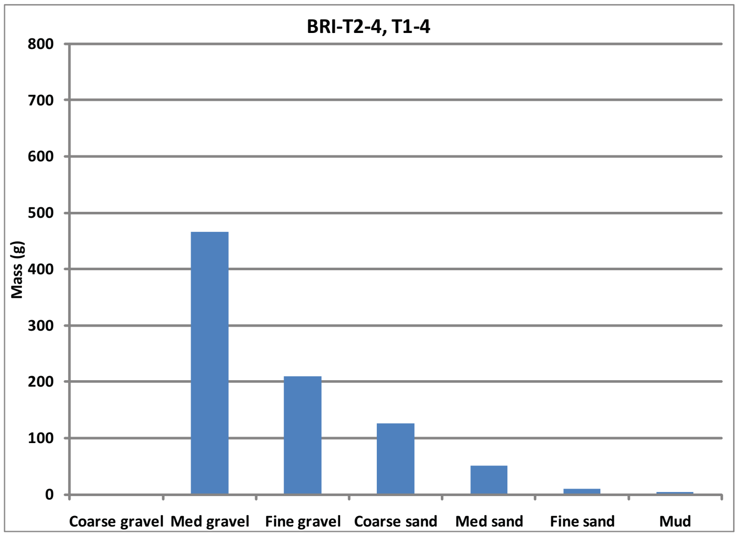
WETLANDS AND WATER RESOURCES

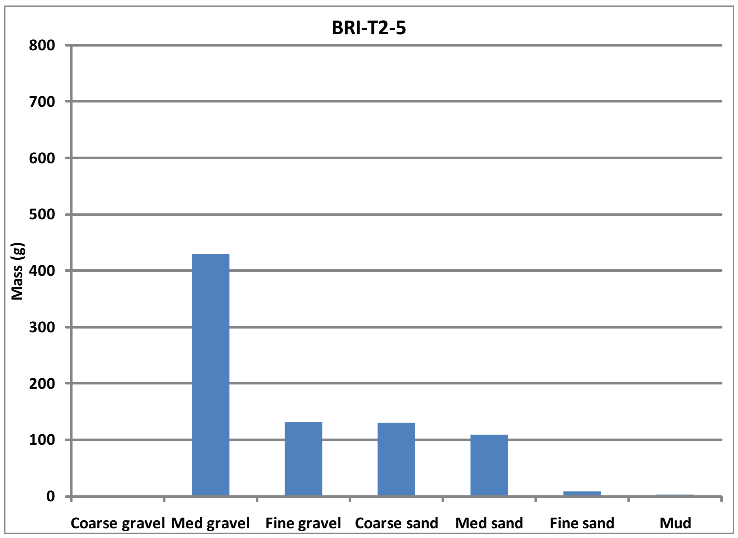
BRISBANE BEACH
GRAIN SIZE DATA-SHEET 1

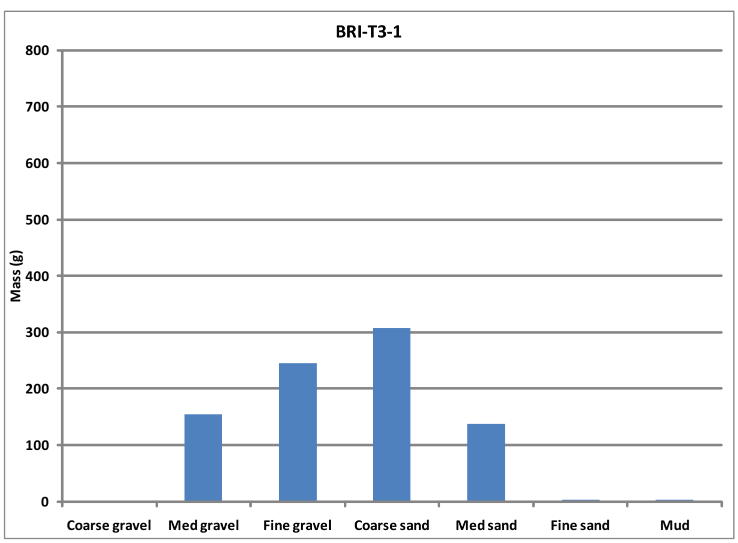
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: BRI-grain-size-sheet-1_2010-0225lee.ai
Data file: BRI-grain-size-data_2009-0903dag.xls







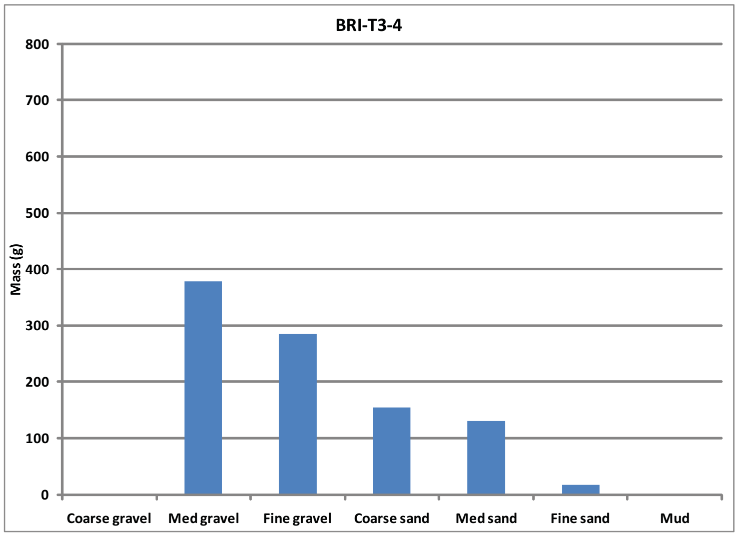
WETLANDS AND WATER RESOURCES

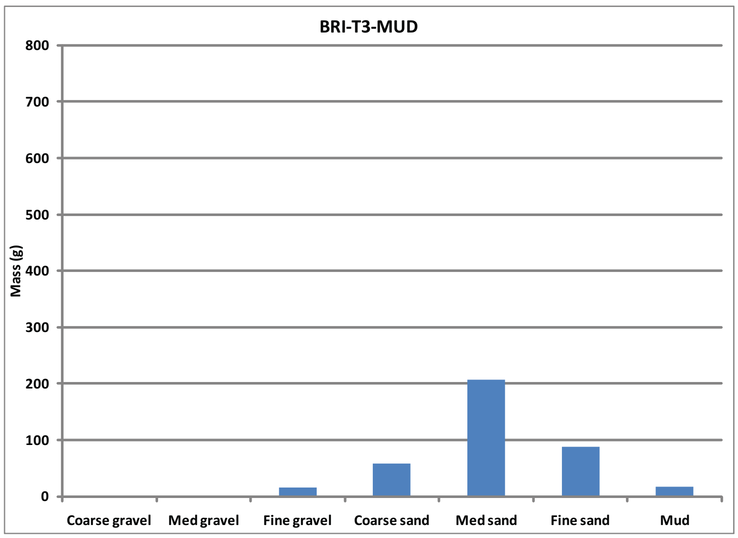
BRISBANE BEACH
GRAIN SIZE DATA-SHEET 2

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: BRI-grain-size-sheet-2_2010-0225lee.ai
Data file: BRI-grain-size-data_2009-0903dag.xls





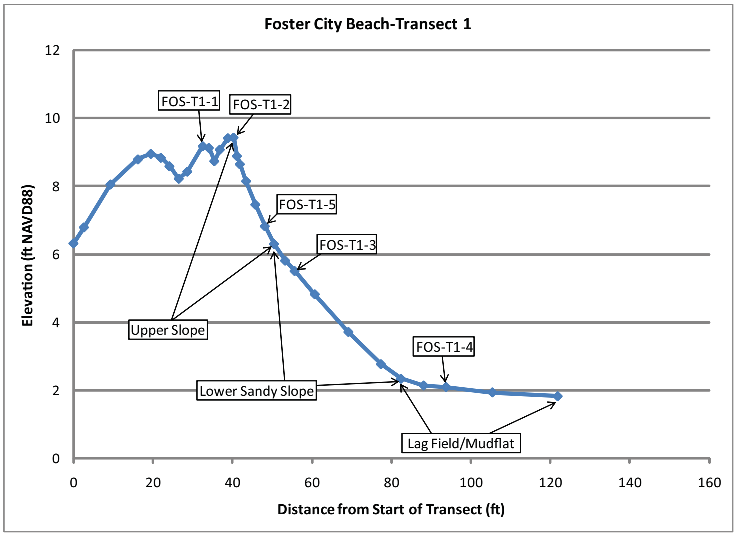
WETLANDS AND WATER RESOURCES

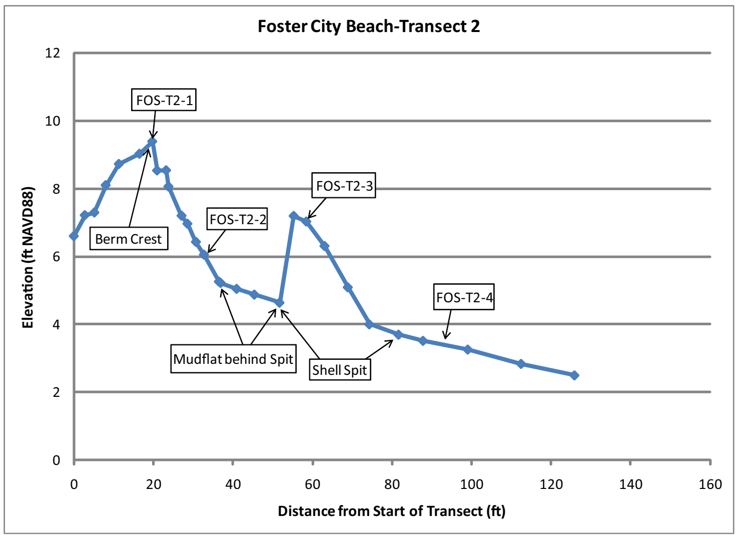
BRISBANE BEACH
GRAIN SIZE DATA-SHEET 3
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

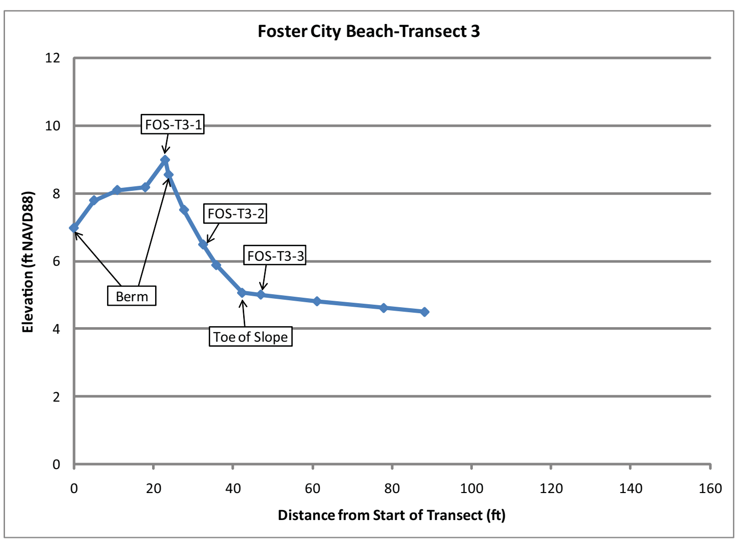
February 2010 | Project No. 1145

Graphic file: BRI-grain-size-sheet-3_2010-0225lee.ai
Data file: BRI-grain-size-data_2009-0903dag.xls

Foster City Beach







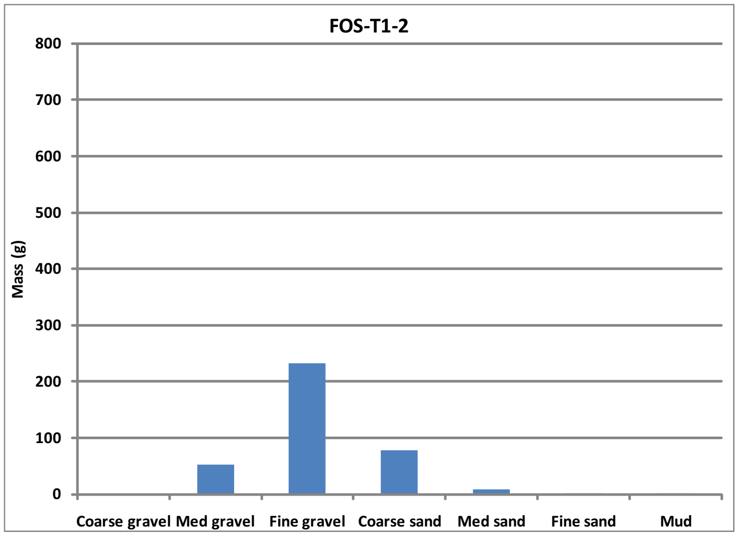
WETLANDS AND WATER RESOURCES

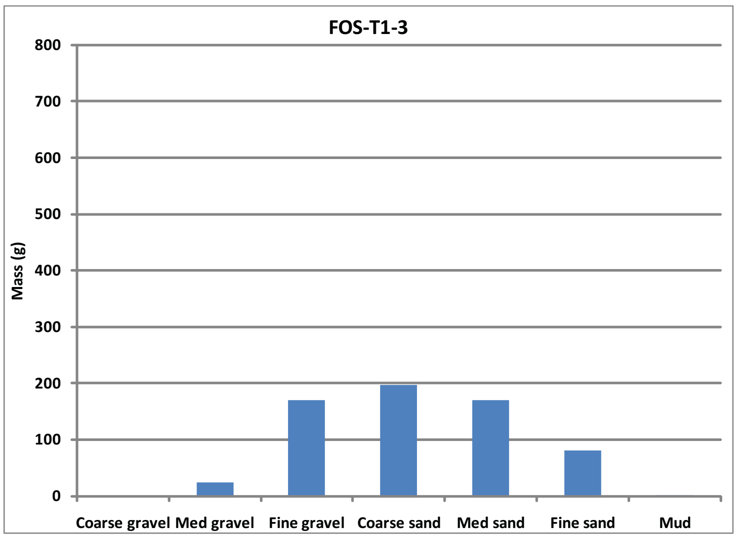
FOSTER CITY BEACH
TOPOGRAPHIC CROSS SECTIONS

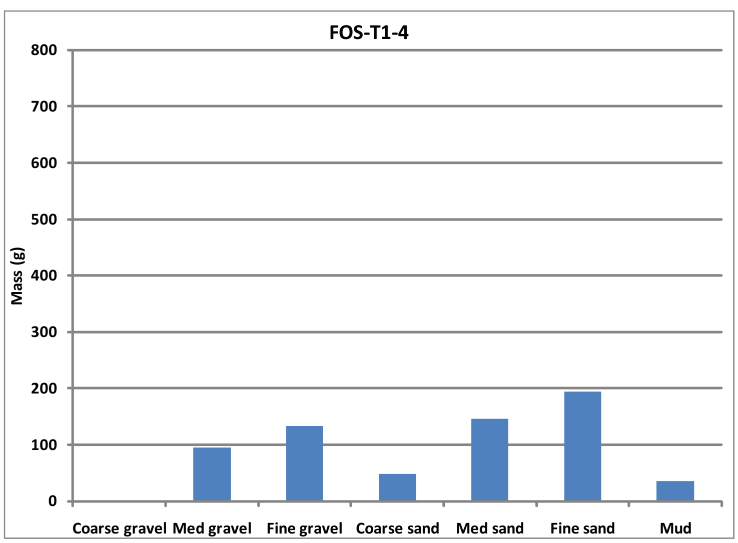
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010	Project No. 1145

Graphic file: FOS-topography_2010-0225lee.ai
Data file: beach_transects_23jul09_plots_2009-0907dag.xls





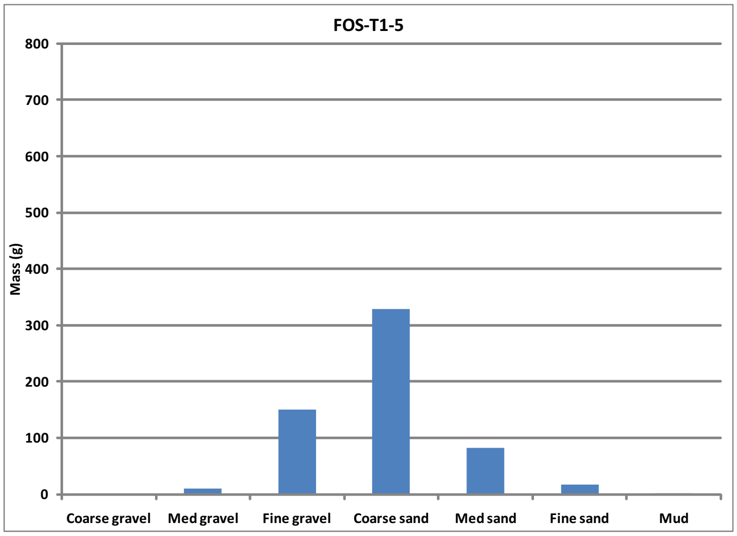


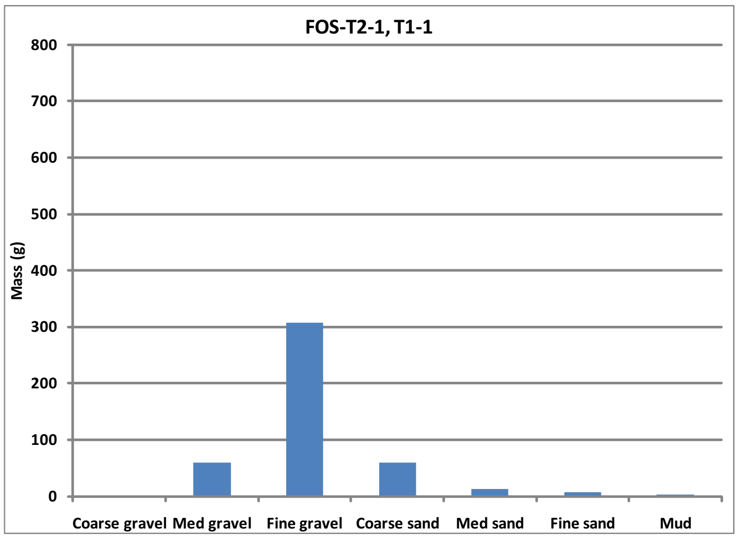
WETLANDS AND WATER RESOURCES

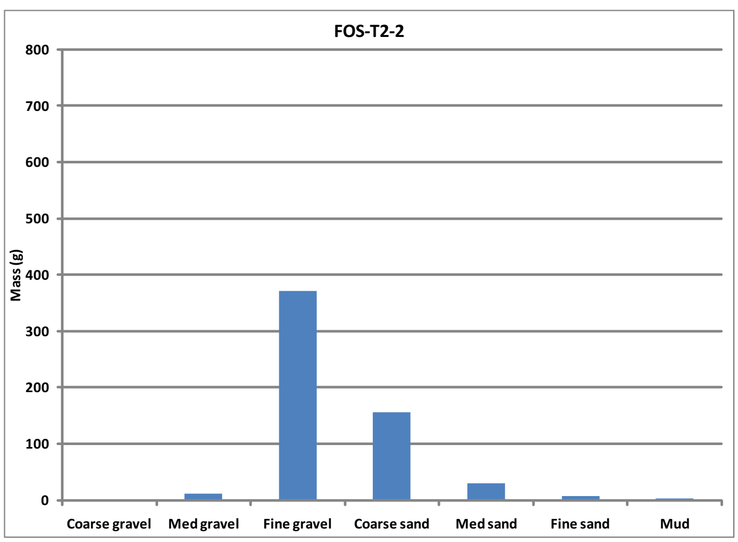
FOSTER CITY BEACH
GRAIN SIZE DATA-SHEET 1
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: FOS-grain-size-sheet-1_2010-0225lee.ai
Data file: FOS-grain-size-data_2009-0903dag.xls





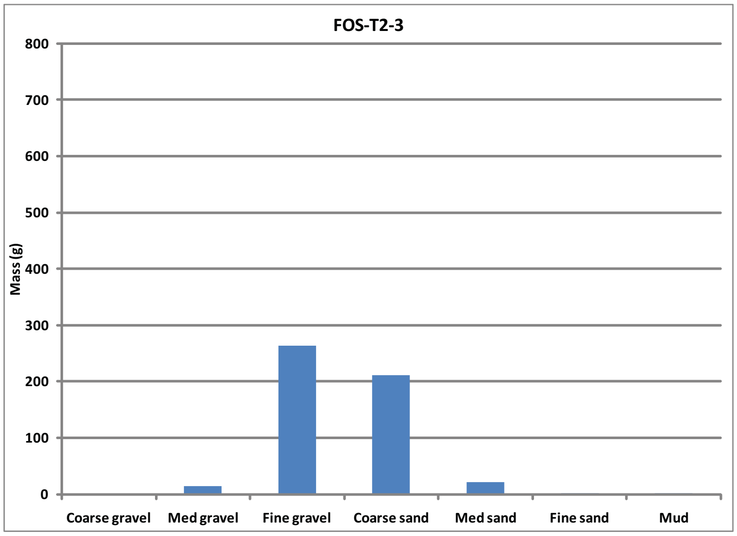


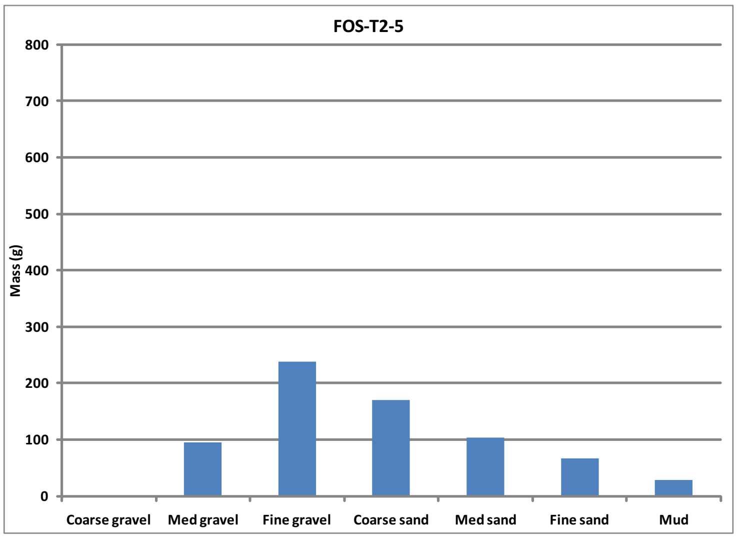
WETLANDS AND WATER RESOURCES

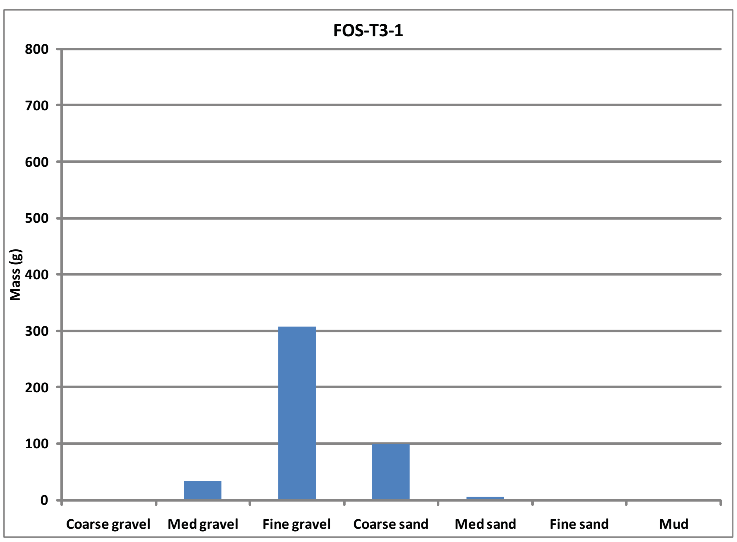
FOSTER CITY BEACH
GRAIN SIZE DATA-SHEET 2
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: FOS-grain-size-sheet-2_2010-0225lee.ai
Data file: FOS-grain-size-data_2009-0903dag.xls





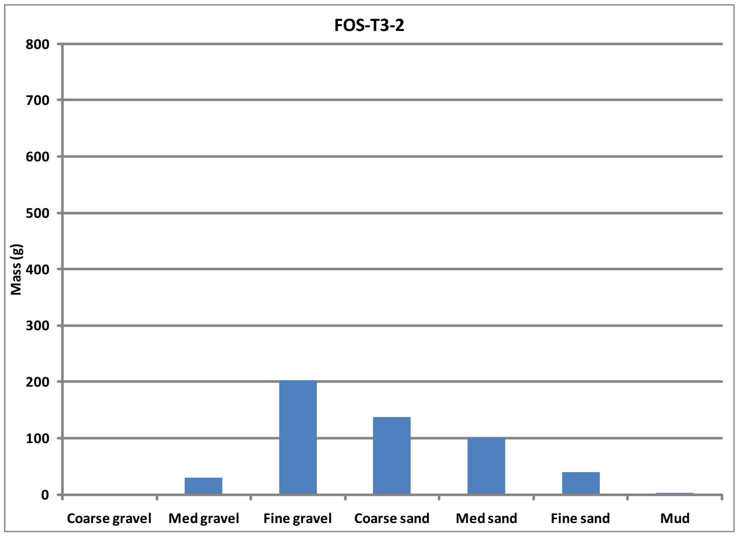


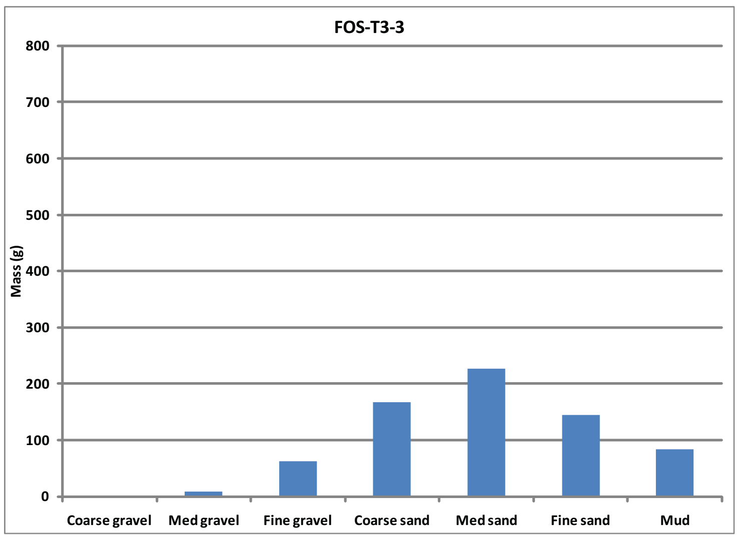
WETLANDS AND WATER RESOURCES

FOSTER CITY BEACH
GRAIN SIZE DATA-SHEET 3
Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010 | Project No. 1145

Graphic file: FOS-grain-size-sheet-3_2010-0225lee.ai
Data file: FOS-grain-size-data_2009-0903dag.xls





WETLANDS AND WATER RESOURCES

FOSTER CITY BEACH
GRAIN SIZE DATA-SHEET 4

Aramburu Island Enhancement Project
Richardson Bay Audubon Sanctuary
Marin County, CA

February 2010	Project No. 1145

Graphic file: FOS-grain-size-sheet-4_2010-0225lee.ai
Data file: FOS-grain-size-data_2009-0903dag.xls

Appendix:
NGS Benchmark Datasheets

DATASHEETS

The NGS Data SheetSee file dsdata.txt for more information about the datasheet.DATABASE = ,PROGRAM = datasheet, VERSION = 7.67
1 National Geodetic Survey, Retrieval Date = JULY 21, 2009
HT3533 ***
HT3533 DESIGNATION - F 1444
HT3533 PID - HT3533
HT3533 STATE/COUNTY- CA/MARIN
HT3533 USGS QUAD - POINT BONITA (1993)
HT3533
HT3533 *CURRENT SURVEY CONTROL
HT3533 ____
HT3533* NAD 83(1986)- 37 52 22. (N) 122 30 18. (W) SCALED
HT3533* NAVD 88 - 2.694 (meters) 8.84 (feet) ADJUSTED
HT3533 ____
HT3533 GEOID HEIGHT- -32.41 (meters) GEOID03
HT3533 DYNAMIC HT - 2.693 (meters) 8.84 (feet) COMP
HT3533 MODELED GRAV- 979,987.7 (mgal) NAVD 88
HT3533
HT3533 VERT ORDER - FIRST CLASS II
HT3533
HT3533.The horizontal coordinates were scaled from a topographic map and have
HT3533.an estimated accuracy of +/- 6 seconds.
HT3533
HT3533.The orthometric height was determined by differential leveling
HT3533.and adjusted in June 1991.
HT3533
HT3533.The geoid height was determined by GEOID03.
HT3533
HT3533.The dynamic height is computed by dividing the NAVD 88
HT3533.geopotential number by the normal gravity value computed on the
HT3533.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
HT3533.degrees latitude (g = 980.6199 gals.).
HT3533
HT3533.The modeled gravity was interpolated from observed gravity values.
HT3533
HT3533; North East Units Estimated Accuracy
HT3533;SPC CA 3 - 654,240. 1,823,620. MT (+/- 180 meters Scaled)
HT3533
HT3533 SUPERSEDED SURVEY CONTROL
HT3533
HT3533 NGVD 29 (10/21/93) 1.867 (m) 6.13 (f) ADJUSTED 1 2
HT3533
HT3533.Superseded values are not recommended for survey control.
HT3533.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT3533.See file dsdata.txt to determine how the superseded data were derived.
HT3533
HT3533_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG435918(NAD 83)
HT3533_MARKER: I = METAL ROD
HT3533_SETTING: 49 = STAINLESS STEEL ROD W/O SLEEVE (10 FT.+)
HT3533_SP_SET: STAINLESS STEEL ROD
HT3533_STAMPING: F 1444 1988
HT3533_MARK LOGO: NGS
HT3533_PROJECTION: FLUSH
HT3533_MAGNETIC: I = MARKER IS A STEEL ROD

HT3533_STABILITY: A = MOST RELIABLE AND EXPECTED TO HOLD
HT3533+STABILITY: POSITION/ELEVATION WELL
HT3533_SATELLITE: THE SITE LOCATION WAS REPORTED AS NOT SUITABLE FOR
HT3533+SATELLITE: SATELLITE OBSERVATIONS - 1988
HT3533_ROD/PIPE-DEPTH: 19.5 meters
HT3533
HT3533 HISTORY - Date Condition Report By
HT3533 HISTORY - 1988 MONUMENTED NGS
HT3533
HT3533 STATION DESCRIPTION
HT3533
HT3533'DESCRIBED BY NATIONAL GEODETIC SURVEY 1988
HT3533'IN SAUSALITO, AT THE INTERSECTION OF BRIDGEWAY BOULEVARD AND GATE 6
HT3533'ROAD, 15.0 M (49.2 FT) NORTHEAST OF THE CENTER OF THE NORTHBOUND LANES
HT3533'OF THE BOULEVARD, 9.2 M (30.2 FT) SOUTHEAST OF THE CENTER OF THE ROAD,
HT3533'3.7 M (12.1 FT) NORTH-NORTHEAST OF A TRAFFIC SIGNAL POST, 0.6 M
HT3533'(2.0 FT) NORTHWEST OF A UTILITY POLE, AND 0.3 M (1.0 FT) BELOW THE
HT3533'LEVEL OF THE BOULEVARD. NOTE--ACCESS TO DATUM POINT IS HAD THROUGH A
HT3533'5-INCH LOGO CAP.

*** retrieval complete.
Elapsed Time = 00:00:00

DATASHEETS

The NGS Data SheetSee file dsdata.txt for more information about the datasheet.DATABASE = ,PROGRAM = datasheet, VERSION = 7.67
1 National Geodetic Survey, Retrieval Date = JULY 21, 2009

```
 HT0562 ***********************************************************************
 HT0562  HT_MOD       -  This is a Height Modernization Survey Station.
 HT0562  TIDAL BM     -  This is a Tidal Bench Mark.
 HT0562  DESIGNATION -  TIDAL 1
 HT0562  PID          -  HT0562
 HT0562  STATE/COUNTY-  CA/SAN MATEO
 HT0562  USGS QUAD    -  SAN MATEO (1997)
 HT0562
 HT0562                         *CURRENT SURVEY CONTROL
 HT0562  ___________________________________________________________________
 HT0562* NAD 83(2007)-  37 35 22.69482(N)    122 19 06.15535(W)     ADJUSTED
 HT0562* NAVD 88     -         4.77   (meters)      15.6    (feet)  GPS OBS
 HT0562  ___________________________________________________________________
 HT0562  EPOCH DATE  -        2007.00
 HT0562  X           -  -2,705,365.675 (meters)                 COMP
 HT0562  Y           -  -4,276,428.007 (meters)                 COMP
 HT0562  Z           -   3,869,435.179 (meters)                 COMP
 HT0562  LAPLACE CORR-          -0.25  (seconds)                 DEFLEC99
 HT0562  ELLIP HEIGHT-         -27.853 (meters)         (02/10/07) ADJUSTED
 HT0562  GEOID HEIGHT-          -32.54  (meters)
 HT0562
 HT0562  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 HT0562  Type    PID    Designation                    North   East  Ellip
 HT0562  -------------------------------------------------------------------
 HT0562  NETWORK HT0562 TIDAL 1                          0.45   0.45   1.51
 HT0562  -------------------------------------------------------------------
 HT0562
 HT0562.The horizontal coordinates were established by GPS observations
 HT0562.and adjusted by the National Geodetic Survey in February 2007.
 HT0562
 HT0562.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 HT0562.See National Readjustment for more information.
 HT0562.The horizontal coordinates are valid at the epoch date displayed above.
 HT0562.The epoch date for horizontal control is a decimal equivalence
 HT0562.of Year/Month/Day.
 HT0562
 HT0562.The orthometric height was determined by GPS observations and a
 HT0562.high-resolution geoid model.
 HT0562.The orthometric height was determined by GPS observations and a
 HT0562.high-resolution geoid model using precise GPS observation and
 HT0562.processing techniques.
 HT0562
 HT0562.This Tidal Bench Mark is designated as VM 8118
 HT0562.by the Center for Operational Oceanographic Products and Services.
 HT0562
 HT0562.Photographs are available for this station.
 HT0562
 HT0562.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 HT0562
 HT0562.The Laplace correction was computed from DEFLEC99 derived deflections.
 HT0562
```

HT0562.The ellipsoidal height was determined by GPS observations
HT0562.and is referenced to NAD 83.
HT0562
HT0562
HT0562;   North   East   Units Scale Factor Converg.
HT0562;SPC CA 3   -   622,488.748 1,839,422.500   MT 0.99993313   -1 06 47.8
HT0562;SPC CA 3   - 2,042,281.83 6,034,838.65   sFT 0.99993313   -1 06 47.8
HT0562;UTM 10   - 4,160,504.389   560,177.025   MT 0.99964460   +0 24 56.9
HT0562
HT0562!   - Elev Factor x Scale Factor =   Combined Factor
HT0562!SPC CA 3   -   1.00000437 x   0.99993313 =   0.99993750
HT0562!UTM 10   -   1.00000437 x   0.99964460 =   0.99964897
HT0562
HT0562   SUPERSEDED SURVEY CONTROL
HT0562
HT0562 NAD 83(1998)- 37 35 22.69021(N)   122 19 06.15072(W) AD(2002.75) B
HT0562 ELLIP H (08/23/04) -27.788 (m)   GP(   ) 4 1
HT0562 NGVD 29 (??/??/92)   3.923 (m)   12.87   (f) ADJ UNCH   1 2
HT0562
HT0562.Superseded values are not recommended for survey control.
HT0562.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0562.See file dsdata.txt to determine how the superseded data were derived.
HT0562
HT0562_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG6017760504(NAD 83)
HT0562_MARKER: DB = BENCH MARK DISK
HT0562_SETTING: 32 = SET IN A RETAINING WALL OR CONCRETE LEDGE
HT0562_SP_SET: RETAINING WALL
HT0562_STAMPING: NO 1 1945
HT0562_MAGNETIC: N = NO MAGNETIC MATERIAL
HT0562_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
HT0562+STABILITY: SURFACE MOTION
HT0562_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
HT0562+SATELLITE: SATELLITE OBSERVATIONS - September , 2002
HT0562
HT0562 HISTORY   - Date   Condition   Report By
HT0562 HISTORY   - 1945   MONUMENTED   CGS
HT0562 HISTORY   - 1967   GOOD   NGS
HT0562 HISTORY   - 200209   GOOD   JOHFRA
HT0562
HT0562   STATION DESCRIPTION
HT0562
HT0562'DESCRIBED BY NATIONAL GEODETIC SURVEY 1967
HT0562'0.9 MI NE FROM SAN MATEO.
HT0562'0.3 MILE NORTHEAST ALONG PENINSULAR AVENUE FROM PENINSULAR
HT0562'AVENUE OVERPASS AT BAYSHORE FREEWAY, THENCE 0.6 MILE
HT0562'NORTHEAST AND NORTH ALONG AN ASPHALT ROAD TO THE HARBOR MASTERS
HT0562'OFFICE, 0.9 MILE NORTHEAST OF BENCH MARK J 476, IN THE TOP OF
HT0562'THE NORTH END OF A 2-FOOT HIGH CONCRETE RETAINING WALL, 25 FEET
HT0562'EAST OF THE CENTER LINE OF THE ROAD, 125 FEET SOUTHEAST AND
HT0562'ACROSS THE ROAD FROM TIDAL 2, 37.9 FEET NORTH-NORTHWEST OF THE
HT0562'NORTHWEST CORNER OF THE HARBOR MASTERS OFFICE, 46.5 FEET
HT0562'SOUTH-SOUTHWEST OF THE CENTER OF A FIRE HYDRANT, 0.6 FOOT
HT0562'SOUTH OF THE NORTH END OF THE WALL, ABOUT 2 FEET HIGHER THAN
HT0562'THE ASPHALT PAVING.
HT0562
HT0562   STATION RECOVERY (2002)
HT0562
HT0562'RECOVERY NOTE BY JOHNSON-FRANK 2002 (MSP)

HT0562'RECOVERED AS DESCRIBED WITH THE FOLLOWING REVISED DIRECTIONS. THE MARK
HT0562'IS NEAR THE SHORE BETWEEN BURLINGAME AND SAN MATEO. FROM THE
HT0562'INTERSECTION OF HWY 101 NORTHBOUND AND PENINSULA AVENUE, EXIT
HT0562'PENINSULA EAST TOWARD COYOTE POINT COUNTY RECREATION AREA. BEAR
HT0562'RIGHT ON COYOTE PT DRIVE AND THEN TURN LEFT GOING THROUGH ENTRANCE
HT0562'KIOSK. FROM THE KIOSK, FOLLOW THE ROAD THROUGH SEVERAL CURVES AND
HT0562'LOOK FOR SIGNS TO THE HARBORMASTER'S OFFICE. FROM THE INTERSECTION OF
HT0562'THE MAIN DRIVE AND THE OFFICE ROAD, DRIVE FOR ABOUT 0.2 MI TO THE
HT0562'MARK ON THE RIGHT.
HT0562'
HT0562'THE LOCAL MEASUREMENTS FOR THE MARK ARE GOOD. THE MARK IS A 9 CM (3.5
HT0562'IN) BRASS U.S. COAST AND GEODETIC SURVEY BENCH MARK DISK STAMPED 'NO 1
HT0562'1945' SET IN THE TOP OF THE NORTHERLY END OF A 0.7 M (2.3 FT) HIGH
HT0562'CONCRETE RETAINING WALL.
HT0562'
HT0562'THIS STATION WAS OBSERVED AS PART OF THE SOUTH SAN FRANCISCO BAY
HT0562'HEIGHT MODERNIZATION PROJECT.

*** retrieval complete.
Elapsed Time = 00:00:00

DATASHEETS

The NGS Data SheetSee file dsdata.txt for more information about the datasheet.DATABASE = ,PROGRAM = datasheet, VERSION = 7.67
1 National Geodetic Survey, Retrieval Date = JULY 21, 2009

```
 AE5207 ***********************************************************************
 AE5207  HT_MOD       -  This is a Height Modernization Survey Station.
 AE5207  DESIGNATION -  YACHT RM 4
 AE5207  PID         -  AE5207
 AE5207  STATE/COUNTY-  CA/ALAMEDA
 AE5207  USGS QUAD   -  OAKLAND WEST (1993)
 AE5207
 AE5207                         *CURRENT SURVEY CONTROL
 AE5207  ___________________________________________________________________
 AE5207* NAD 83(2007)-  37 51 50.75444(N)    122 18 56.24944(W)     ADJUSTED
 AE5207* NAVD 88     -         3.26   (meters)      10.7    (feet)  GPS OBS
 AE5207  ___________________________________________________________________
 AE5207  EPOCH DATE  -        2007.00
 AE5207  X           -  -2,695,195.147 (meters)                  COMP
 AE5207  Y           -  -4,260,804.135 (meters)                  COMP
 AE5207  Z           -   3,893,528.439 (meters)                  COMP
 AE5207  LAPLACE CORR-           1.79  (seconds)                 DEFLEC99
 AE5207  ELLIP HEIGHT-         -29.071 (meters)         (02/10/07) ADJUSTED
 AE5207  GEOID HEIGHT-         -32.33  (meters)                  GEOID03
 AE5207
 AE5207  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 AE5207  Type    PID    Designation                     North   East  Ellip
 AE5207  -------------------------------------------------------------------
 AE5207  NETWORK AE5207 YACHT RM 4                       0.82   1.06   4.74
 AE5207  -------------------------------------------------------------------
 AE5207
 AE5207.The horizontal coordinates were established by GPS observations
 AE5207.and adjusted by the National Geodetic Survey in February 2007.
 AE5207
 AE5207.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 AE5207.See National Readjustment for more information.
 AE5207.The horizontal coordinates are valid at the epoch date displayed above.
 AE5207.The epoch date for horizontal control is a decimal equivalence
 AE5207.of Year/Month/Day.
 AE5207
 AE5207.The orthometric height was determined by GPS observations and a
 AE5207.high-resolution geoid model.
 AE5207.The orthometric height was determined by GPS observations and a
 AE5207.high-resolution geoid model using precise GPS observation and
 AE5207.processing techniques.
 AE5207
 AE5207.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 AE5207
 AE5207.The Laplace correction was computed from DEFLEC99 derived deflections.
 AE5207
 AE5207.The ellipsoidal height was determined by GPS observations
 AE5207.and is referenced to NAD 83.
 AE5207
 AE5207.The geoid height was determined by GEOID03.
 AE5207
 AE5207;                   North         East     Units Scale Factor Converg.
```

```
AE5207;SPC CA 3     -   652,938.960 1,840,256.386   MT  0.99993112   -1 06 41.7
AE5207;SPC CA 3     - 2,142,183.90  6,037,574.49   sFT  0.99993112   -1 06 41.7
AE5207;UTM  10      - 4,190,957.310   560,197.382   MT  0.99964463   +0 25 12.3
AE5207
AE5207!             -  Elev Factor  x  Scale Factor =   Combined Factor
AE5207!SPC CA 3     -   1.00000456  x   0.99993112  =   0.99993568
AE5207!UTM  10      -   1.00000456  x   0.99964463  =   0.99964919
AE5207
AE5207|---------------------------------------------------------------------|
AE5207| PID    Reference Object                     Distance      Geod. Az  |
AE5207|                                                           dddmmss.s |
AE5207| HT2935 YACHT                                75.963 METERS 25615     |
AE5207|---------------------------------------------------------------------|
AE5207
AE5207                          SUPERSEDED SURVEY CONTROL
AE5207
AE5207  NAD 83(1992)-  37 51 50.74765(N)    122 18 56.24129(W) AD(1997.30) 1
AE5207  ELLIP H (07/10/98)  -29.049  (m)                       GP(1997.30) 4 1
AE5207  NAD 83(1992)-  37 51 50.74596(N)    122 18 56.24025(W) AD(1995.42) 1
AE5207  ELLIP H (12/22/97)  -29.002  (m)                       GP(       ) 4 1
AE5207
AE5207.Superseded values are not recommended for survey control.
AE5207.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
AE5207.See file dsdata.txt to determine how the superseded data were derived.
AE5207
AE5207_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG6019790957(NAD 83)
AE5207_MARKER: DH = HORIZONTAL CONTROL DISK
AE5207_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
AE5207_STAMPING: YACHT 1947 RM 4
AE5207_MARK LOGO: CGS
AE5207_MAGNETIC: N = NO MAGNETIC MATERIAL
AE5207_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
AE5207+STABILITY: SURFACE MOTION
AE5207_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
AE5207+SATELLITE: SATELLITE OBSERVATIONS - 1947
AE5207
AE5207  HISTORY     - Date     Condition        Report By
AE5207  HISTORY     - 1947     MONUMENTED       CGS
AE5207
AE5207                          STATION DESCRIPTION
AE5207
AE5207'DESCRIBED BY COAST AND GEODETIC SURVEY 1947
AE5207'SEE STATION FOR THE DESCRIPTION.

*** retrieval complete.
Elapsed Time = 00:00:00
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DATASHEETS

The NGS Data SheetSee file dsdata.txt for more information about the datasheet.DATABASE = ,PROGRAM = datasheet, VERSION = 7.67
1 National Geodetic Survey, Retrieval Date = JULY 21, 2009

```
 AB7679 ***********************************************************************
 AB7679  DESIGNATION -  HPGN D CA 04 GF
 AB7679  PID         -  AB7679
 AB7679  STATE/COUNTY-  CA/SAN MATEO
 AB7679  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 AB7679
 AB7679                         *CURRENT SURVEY CONTROL
 AB7679  ___________________________________________________________________
 AB7679* NAD 83(2007)-  37 42 22.14930(N)    122 23 36.90380(W)     ADJUSTED
 AB7679* NAVD 88     -         3.7    (meters)       12.     (feet)  GPS OBS
 AB7679  ___________________________________________________________________
 AB7679  EPOCH DATE  -        2007.00
 AB7679  X           -  -2,706,744.539 (meters)                  COMP
 AB7679  Y           -  -4,266,202.736 (meters)                  COMP
 AB7679  Z           -   3,879,673.773 (meters)                  COMP
 AB7679  LAPLACE CORR-          0.87  (seconds)                  DEFLEC99
 AB7679  ELLIP HEIGHT-        -28.907 (meters)         (02/10/07) ADJUSTED
 AB7679  GEOID HEIGHT-         -32.54  (meters)                  GEOID03
 AB7679
 AB7679  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 AB7679  Type    PID    Designation                    North   East  Ellip
 AB7679  -------------------------------------------------------------------
 AB7679  NETWORK AB7679 HPGN D CA 04 GF                 0.69   1.12   5.68
 AB7679  -------------------------------------------------------------------
 AB7679
 AB7679.The horizontal coordinates were established by GPS observations
 AB7679.and adjusted by the National Geodetic Survey in February 2007.
 AB7679
 AB7679.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 AB7679.See National Readjustment for more information.
 AB7679.The horizontal coordinates are valid at the epoch date displayed above.
 AB7679.The epoch date for horizontal control is a decimal equivalence
 AB7679.of Year/Month/Day.
 AB7679
 AB7679.The orthometric height was determined by GPS observations and a
 AB7679.high-resolution geoid model.
 AB7679
 AB7679.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 AB7679
 AB7679.The Laplace correction was computed from DEFLEC99 derived deflections.
 AB7679
 AB7679.The ellipsoidal height was determined by GPS observations
 AB7679.and is referenced to NAD 83.
 AB7679
 AB7679.The geoid height was determined by GEOID03.
 AB7679
 AB7679;                    North         East     Units Scale Factor Converg.
 AB7679;SPC CA 3     -   635,548.916 1,833,043.544   MT  0.99992948   -1 09 33.5
 AB7679;SPC CA 3     - 2,085,130.07  6,013,910.36   sFT  0.99992948   -1 09 33.5
 AB7679;UTM  10      - 4,173,385.868   553,453.666   MT  0.99963519   +0 22 15.2
 AB7679
```

AB7679!   - Elev Factor x Scale Factor =   Combined Factor
AB7679!SPC CA 3   -   1.00000454 x   0.99992948 =   0.99993402
AB7679!UTM 10   -   1.00000454 x   0.99963519 =   0.99963972
AB7679
AB7679   SUPERSEDED SURVEY CONTROL
AB7679
AB7679 NAD 83(1992)- 37 42 22.13446(N)   122 23 36.88949(W) AD(1991.35) 1
AB7679 ELLIP H (10/31/96) -28.817 (m)   GP(   ) 4 1
AB7679
AB7679.Superseded values are not recommended for survey control.
AB7679.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
AB7679.See file dsdata.txt to determine how the superseded data were derived.
AB7679
AB7679_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG5345473386(NAD 83)
AB7679_MARKER: DD = SURVEY DISK
AB7679_SETTING: 32 = SET IN A RETAINING WALL OR CONCRETE LEDGE
AB7679_SP_SET: SET IN TOP OF RETAINING WALL
AB7679_STAMPING: CA-HPGN-DENSIFICATION STA. 04-GF 1994
AB7679_MARK LOGO: CADT
AB7679_MAGNETIC: N = NO MAGNETIC MATERIAL
AB7679_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
AB7679+STABILITY: SURFACE MOTION
AB7679_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
AB7679+SATELLITE: SATELLITE OBSERVATIONS - 1994
AB7679
AB7679 HISTORY   - Date   Condition   Report By
AB7679 HISTORY   - 1994   MONUMENTED   CADT
AB7679
AB7679   STATION DESCRIPTION
AB7679
AB7679'DESCRIBED BY CALTRANS 1994 (DAN)
AB7679'THE STATION IS LOCATED ON THE EAST SIDE OF U.S. HIGHWAY 101 NEAR
AB7679'CANDLESTICK PARK, ABOUT 6 MI (9.7 KM) NORTH OF SAN FRANCISCO
AB7679'INTERNATIONAL AIRPORT AND 5 MI (8.0 KM) SOUTH OF DOWNTOWN SAN
AB7679'FRANCISCO. TO REACH THE STATION FROM THE JUNCTION OF U.S. HIGHWAY
AB7679'101 AND INTERSTATE HIGHWAY 380 IN SAN BRUNO, GO NORTH ON HIGHWAY 101
AB7679'FOR 5.0 MI (8.0 KM) TO THE OFF-RAMP FOR CANDLESTICK PARK. TAKE THE
AB7679'OFF-RAMP NORTHERLY FOR 0.3 MI (0.5 KM) TO A PAVED SERVICE ROAD WITH A
AB7679'DECORATIVE IRON GATE ON THE RIGHT. CONTINUE NORTHERLY ALONG THE
AB7679'SERVICE ROAD, PARALLEL WITH THE OFF-RAMP, FOR ABOUT 150 FT (45.7 M) TO
AB7679'THE STATION ON THE RIGHT ON TOP OF A RETAINING WALL ON THE EAST SIDE
AB7679'OF THE SERVICE ROAD. THE STATION IS LOCATED AT HIGHWAY 101 POST MILE
AB7679'25.9. THE STATION IS A SURVEY DISK SET IN A DRILL HOLE AND EPOXYED TO
AB7679'THE TOP OF THE RETAINING WALL, 136.0 FT (41.5 M) NORTH OF THE
AB7679'DECORATIVE IRON GATE, 111.9 FT (34.1 M) NORTH OF THE NORTHWEST CORNER
AB7679'OF A 15 FT (4.6 M) TALL CONCRETE STRUCTURE, 91.8 FT (28.0 M) NORTH OF
AB7679'THE CENTER OF A LARGE CIRCULAR CONCRETE AND TILE MOSAIC IN THE SERVICE
AB7679'ROAD NEAR THE GATE, 79.4 FT (24.2 M) SOUTH OF A SURVEY DISK STAMPED
AB7679'STA 32 PLUS 50 51-FT FROM M LINE SET ON TOP THE SAME RETAINING WALL AS
AB7679'THE STATION, 55.6 FT (16.9 M) EAST OF THE CENTERLINE OF THE ON AND
AB7679'OFF-RAMPS FOR NORTH-BOUND HIGHWAY 101, 32.0 FT (9.8 M) SOUTH OF A
AB7679'SEWER LINE MANHOLE, 4.9 FT (1.5 M) NORTH OF THE BEGINNING OF ASPHALT
AB7679'PAVING, 1.3 FT (0.4 M) WEST OF THE EAST EDGE OF THE RETAINING WALL AND
AB7679'LEVEL WITH THE SERVICE ROAD. THIS STATION WAS OCCUPIED AS PART OF A
AB7679'CALIFORNIA HPGN DENSIFICATION SURVEY IN 1994.

*** retrieval complete.
Elapsed Time = 00:00:00