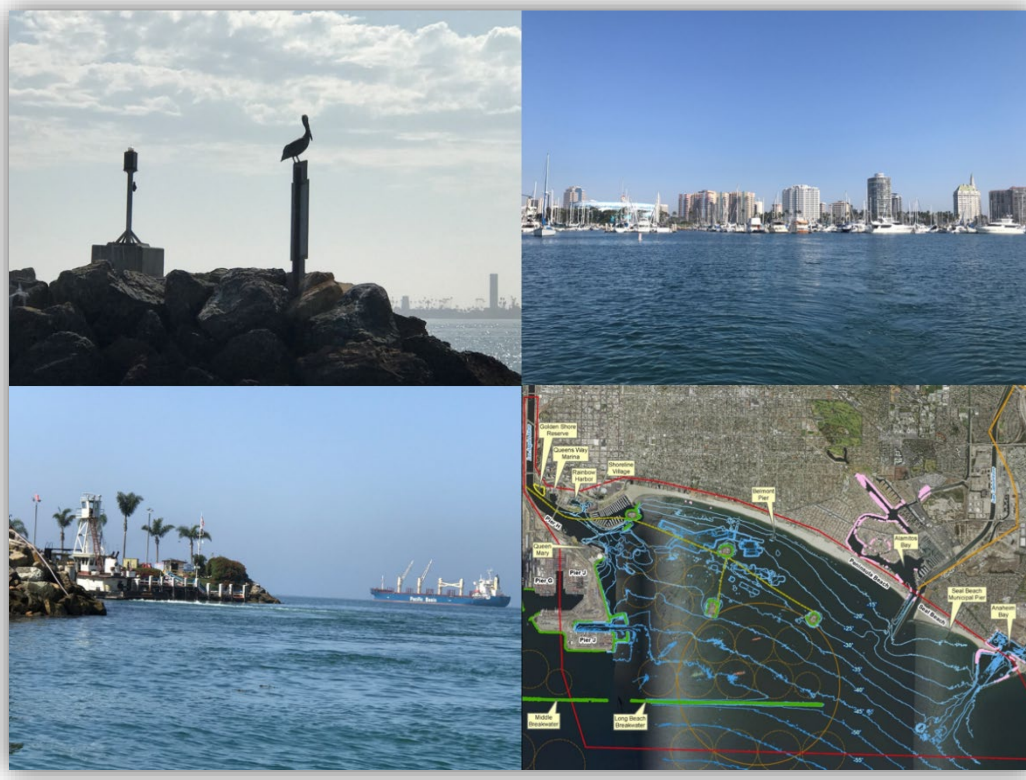
DRAFT INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT / ENVIRONMENTAL IMPACT REPORT (EIS/EIR)

APPENDIX I: GEOLOGY, GEOTECHNICAL, AND SOILS

EAST SAN PEDRO BAY
ECOSYSTEM RESTORATION STUDY
Long Beach, California

November 2019



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US Army Corps
of Engineers ®
Los Angeles District

Geotechnical Feasibility Report

East San Pedro Bay Ecosystem Restoration Feasibility Study
Long Beach, California

November 2019

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LIST OF ABBREVIATIONS AND ACRONYMS

CAD	Confined Aquatic Disposal
CEICA	Cost-Effectiveness and Incremental Cost Analysis
g	Gravitational Acceleration
H:V	Horizontal to Vertical
ERL	Effects Range Low
ERM	Effects Range Median
LARE	Los Angeles River Estuary
MLLW	Mean Lower Low Water
NER	National Ecosystem Restoration
NOAA	National Oceanic Atmospheric Agency
PED	Pre-construction, Engineering, and Design
PGA	Peak Ground Acceleration
POLB	Port of Long Beach
SC-DMMT	Southern California Dredged Material Management Team
THUMS	Texaco, Humbol, Mobile and Shell
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geologic Survey

1.0 INTRODUCTION

The purpose of the East San Pedro Bay Ecosystem Restoration Feasibility Study addresses the Corps' aquatic ecosystem restoration mission with the stated goal to restore and improve aquatic ecosystem structure and function for increased habitat biodiversity and ecosystem value of the Southern California Bight within the Proposed Project Area of East San Pedro Bay. A final array list of habitats alternatives studied are summarized in Table 1.1. The study's alternatives comprise of a combination of these habitats. From a gross geotechnical engineering viewpoint, the creation of these habitats will require a combination of hydraulic dredging, sediment placement, and/or stone placement. Furthermore, proposed modifications to the Long Beach Breakwater are no longer considered as part of the final array of alternatives.

A geotechnical exploration program was not completed as part of this feasibility study. Instead, reports from past geotechnical explorations were reviewed to gain insight on subsurface conditions and performance of existing structures within the vicinity of the study area.

The information presented in this geotechnical feasibility report is cursory and not intended to replace, wholly or in-part, design level efforts to be completed during pre-construction, engineering, and design (PED). Instead, the information presented in this geotechnical feasibility report is intended to inform an agency decision, primarily in support of feasibility-level cost estimation efforts. Ecological viability of habitat configurations are addressed elsewhere.

Table 1.1: List of Proposed Habitat Features

Habitat	Description
Nearshore Rocky Reef And *Open Water Rocky Reef	Construction of rocky reef shoal structures below ocean water surface Mean Lower Low Water (MLLW). *The "core" of Open Water Reef to be constructed of sand and silt mixture.
Kelp Beds	Placement and dumping of stone below ocean water surface (MLLW) in a random pattern to construct kelp bed habitat.
Emergent Sandy Islands	Construction of large to small island structures above ocean water surface (MLLW). Islands will require sandy sediment within top 2 feet of surface with core of structures composed of sand to silt mixtures with a reinforced perimeter made of large interlocking stone.
Oyster Beds	Planting of oysters at shallow backwater areas of project. Will require silt to clay sediment to induce oyster growth
*Long Beach Breakwater Removal	Removal of stone from breakwater and salvaged for construction of nearby or adjacent rocky reef. *This Habitat alternative is screened out of final array but is left herein for completeness.

Habitat	Description
Wetlands Estuary	Construction of flat marsh and estuary, subject to tide water covering and uncovering. Wetlands will require clay, sand and silt mixtures placed in specific thickness and pattern.

1.1 Study Area

The study area includes the entire San Pedro Bay from the Point Fermin on the Palos Verdes peninsula to Huntington Beach. However, most of this study is focused on the eastern portions of the Bay near Long Beach. The entire San Pedro Bay has been subject to habitat loss resulting from structural improvements to the shoreline and nearshore area.

1.2 Background

The study area is located offshore of the City of Long Beach, California, in East San Pedro Bay. It includes the area extending out from the Long Beach shoreline, including the Los Angeles River estuary, to the Middle and Long Beach Breakwaters. The study area represents the largest opportunity areas for restoration in open waters as well as in the intertidal zone of San Pedro Bay.

1.3 Tentatively Selected Plan

Alternative 4A is the National Ecosystem Restoration (NER) Plan, and is identified as the Tentatively Selected Plan (TSP) after evaluation of the three action alternatives based on Completeness, Effectiveness, Efficiency, and Acceptability.

1.4 Scope of Work

The purpose of this appendix is to support the overall East San Pedro Bay Ecosystem Restoration Feasibility Study and to draft a geotechnical feasibility report. Sources of This work is being developed in conjunction with the Los Angeles District U.S. Army Corps of Engineers (USACE), Soils Design and Materials Section and the Geology and Investigations Section.

2.0 AVAILABLE SUBSURFACE INFORMATION

A geotechnical exploration program was not completed as part of this feasibility study. Instead, information from past geotechnical explorations and study reports were reviewed to gain insight on subsurface conditions and performance of existing features within the study area. The descriptions of past geotechnical explorations are provided below and listed according to feature location. These features are listed with corresponding date of geotechnical exploration reference(s) in Table 2.1. The locations of the features and individual sample explorations are shown on the Existing Geotechnical Features map, Plate 1. The individual exploration locations for the Los Angeles River Estuary (LARE) and offshore borrow area Surfside Sunset are not shown because they are too numerous.

Table 2.1: Locations with Available Geotechnical Information and Corresponding Reference(s)

	LARE	East End Long Beach Breakwater	South Energy Island Borrow Pit	Long Beach Breakwater	POLB Marine Infrastructure (east side)	Long Beach Outer Habor Channel	Offshore Borrow Area, Surfside Sunset
USACE (1985)				X			
USACE (1994)						X	
USACE (2001)		X	X				X
USACE (1990-2013)	X						
POLB (1964 to 1985)					X		

2.1 Long Beach Breakwater

The USACE completed a comprehensive condition survey of the Long Beach Breakwater in 1985 (USACE, 1985). The study consisted of a visual inspect in November 1984 for material defects; available rock quality test data were reviewed; a sidescan surface geophysical survey was performed and rock quality tests were run on select samples of cap stone.

2.2 USACE Queens Gate Channel Deepening Investigation (1994)

Sea Surveyor Inc. completed a subsurface investigation in 1994 for the Queens Gate Dredging Project for the USACE. Sediments were collected at 45 locations to a depth of 20 feet each, in the vicinity of the Queens Gate entrance using a very heavy duty steel pneumatic vibratory corer. The sediments were also tested for bulk sediment chemistry and grain size.

According to grain size test results and visual observations, the sediments encountered were described as silty sand (SM) to Silt (ML) layer within the uppermost 15 feet and alternating layers of clay (CL), silt (ML) and sand (SP) within the bottommost 5 feet. The sediments were considered dredgeable and the uppermost coarser sediment considered compatible for placement as nearshore beach nourishment material. The bottommost finer sediment was not considered compatible for beach placement and was instead recommended for use as fill for construction of foundation material for marine infrastructure facilities at Long Beach and Los Angeles Harbors.

2.3 USACE South Energy Island Borrow Pit Investigation (2001)

Sediments were sampled and collected to approximately eight foot depths by diver cores in 2001 at four locations at the South Energy Island Borrow Pit as part of the offshore borrow site explorations task in support of the Stage 11 Surfside Sunset beach nourishment project.

The samples were located in areas of the South Pit to explore for suitable beach nourishment sediment. The explored areas were previously filled with dredged sediment placed there from the USACE's 1996 Long Beach Queens Gate channel deepening project and some of the material was subsequently removed and used a cover-capping material in 2001 for the LARE Confined Aquatic Disposal (CAD) site. The core testing results and descriptions indicated that the upper 1 foot layer of the sediment fill is loose to medium dense, semi-continuous, grey, slightly organic, very micaceous fine-grained silty sand. This upper layer is underlain by 6 foot layer of grey to dark grey, slightly organic, very micaceous silt. Grain size tests for the cores indicated that more than 50% of the sediment is smaller than a U.S. no. 200 sieve, which made the sediment physically incompatible for nearshore or onshore beach nourishment at Surfside Sunset beaches.

2.3.1 USACE Offshore Borrow Area Investigation at Surfside and Sunset Beaches (2001)

USACE conducted a subsurface investigation for the Stage 11 beach nourishment project at Surfside and Sunset Beaches, California in 2001. Sediments were collected at 77 borehole locations offshore of Surfside and Sunset Beaches to depths of 10 feet by diver core methods.

Chemical laboratory testing was conducted two sediment bulk samples composited from all boreholes. Physical grain size testing was also performed on all 77 cores. CPT testing was performed in additional locations within the offshore area. Approximate density and classification of the sediment was determined from the CPT results.

Results of the investigation indicated that sediments in the borrow area are composed of grain sizes of approximately 8% passing a U.S. no. 200 sieve. More than 92% of the sediment is larger than no. 200 sieve and consists of sand which makes them very compatible for nearby onshore and offshore beach nourishment. The sediments are described as a continuous, brown to grey, loose to very dense, fine to medium-grained, twenty-foot thick layer of poorly graded sand, overlain by a very thin (less than two inches) layer of silty sand and shell fragments. The overlying silty sand is dark grey and slightly organic. Large portions of the borrow area were subsequently dredged and placed onshore at Surfside Sunset beaches by the USACE in the years following 2001. Quality Control confirmation testing of all dredge material placed on the beaches to date indicates the borrow area contains sediment that is a consistent high quality fine to medium grained sand.

2.3.2 POLB Marine Infrastructure Investigation (east end) (1961, 1995, 2012 and 2013)

The sediment along the east side of was investigated numerous times in the past to collect geotechnical data of the foundations beneath the current marine infrastructure. Mud rotary and vibracore methods were used to sample boreholes and collect grain size, density and visually describe the sediment. The depths of the sediment sampled ranged from 10 to 20 feet and consisted of sand, silty sand, silt and minor amounts of clay and silty clay. The results of the investigations indicated that top 5 feet of sediment in this area is a silty sand (SM).

2.3.3 East End of Long Beach Breakwater Investigation (2001)

Sediment in the eastern portion of the Long Beach Breakwater was investigated by the USACE for borrow material as part of the 2001 Stage 11 Surfside Sunset beach nourishment project. Diver core methods were used to sample and collect sediment from fifteen locations. The range in lengths of sediment cores collected from diver locations was from 5 to 10 feet. The Top 5 feet of sediment from the cores was described and tested as a silty sand to silt with approximately 12% or more fine grain sizes passing a U.S. no. 200 sieve. The bottom foot of sediment varied from sand to silt. The presence of relatively low amount of fines made sediment from this area more suitable for nearshore beach placement only. Because of this and far distance of this area to Surfside Sunset beaches, the sediment from this area was considered unsuitable as a beach nourishment borrow source for Surfside Sunset beaches.

2.3.4 Los Angeles River Estuary (LARE) Investigations (1990-2013)

From 1990 to 2013, various investigations and testing have been conducted of the sediment within the Federal dredging footprint of LARE. Surface grab samples and vibratory cores samples were collected at various locations and tested for bulk sediment chemistry and grain size. Some of the sediment was tested and analyzed as compatible for nearshore beach nourishment, while other portions were found unsuitable. The unsuitable sediment was placed offshore at the U.S. Environmental Protection Agency (USEPA) LA-2 open ocean disposal site. Suitable sediment was placed in the vicinity at nearshore placement sites. LARE was last explored by vibratory core methods in 2013. Test results and descriptions of the sediment indicated suitable beach nourishment material was available from the Sand Trap area of the LARE footprint. Suitable sediment was tested and described as a silty sand, with some silt. Grain size test results indicated less than 20% fine sediment passing a U.S. no. 200 sieve. Sediment from the Sand Trap was dredged by the USACE in 2013 and placed nearshore at Cherry Avenue, near downtown Long Beach.

3.0 SITE CONDITIONS

3.1 Local Marine Geology

The study area is located entirely within the San Pedro Shelf, which is a relatively flat, isolated and narrow projection of the continental shelf. The bathymetry of the ocean surface at the shelf mimics this flat surface and slopes to the south at a rate of 10 feet per mile. The natural water depth of the Bay ranges from 20 to 50 feet. These depths have been increased from 50 to 70 feet locally due to dredging along the man-made channels and harbors and basins, as part of the creation of the marine infrastructure in the study area.

Based on background information, the uppermost 20 to 100 feet of the bay shelf sediment is unconsolidated and consists primarily of alternating layers of sand and silt, with very minor amounts of clay, gravel and sea-shells. The shelf sediment is consistently found across the study area and all of the man-made features in the study area are founded upon it. The thickness of the sand and silt layer vary in thickness 5 to 50 feet and increases in density with depth. Clay, gravel and sea-shells are relegated to the uppermost 50 feet of the sediment and are found as thin localized lenses mixed within the thicker layers of sand and silt. The very top of the ocean bottom sediment consists of a semi-floating, light layer of mud (suspended clay and silt) atop a very loose layer of sand to silt. The thickness of the floating layer is approximately 2 to 6 inches. The extent of the sediment is shown on the Local Marine Geology map, Plate 2.

3.2 Seismicity and Faulting

All of southern California including the study area is seismically active. The project study is located in the San Pedro Bay shelf, whose seismicity is characteristic of recurring small earthquakes with moment magnitudes less than 4.5.

Three major active faults of San Andreas, Palos Verdes and Newport-Inglewood, exist in the vicinity of the study area and are all capable of producing a moment magnitude 7 earthquake. The San Andreas is the largest principal active fault in Southern California and is located approximately 65 miles north-northeast of the study area. The Newport-Inglewood and Palos Verdes are located approximately 2 miles northeast and 2 miles southeast of the study area, respectively (USGS 2010). The THUMS Huntington Beach Thrust Fault and Compton Thrust Fault are located within the study area (shown on plate 1) and are both potentially active.

3.3 Liquefaction

As previously mentioned, much of the unconsolidated natural marine sediments in the study are composed of coarse sandy to fine silty materials, which become denser with depth. Because of the increasing density with depth, the liquefaction potential of such sediments is low, except for shallower deposits of small natural isolated lenses of loose coarse sandy and silty sandy materials. The liquefaction potential is higher for loose to less dense sandy to silty sandy materials that have been recently disturbed. High potential liquefiable materials are found in the various man-made marine structures in the vicinity of the study area whose foundations are composed of loose, dredged fill. Examples of such structures are Long Beach harbors and its ancillary jetties, slips and wharfs; San Pedro breakwater and THUMS islands.

3.4 Physical Character of Native Sediments (Subsurface Conditions)

The physical character of the sediments are the same as those described in the Local Marine Geology and is predominantly made up of thick alternating layers of silty sand (SM), sand (SP-SM) with some silt (SM). Minor thin layers and localized lenses of gravel and clays and some seashells exist within the sandy sediment and are found mostly within the upper 50 feet. The sediment is unconsolidated and increases in density with increasing depth.

A thin layer of semi-floating silt and mud (clay) exists atop the ocean bottom surface, in areas of less disturbance or where recent man-made activities (e.g., dredging and harbor modifications) have not altered the surrounding natural subsurface conditions. This layer is approximately 2 to 6 inches thick and overlies a very loose unconsolidated layer of sand or silt. Underlying this shallow surface sediment are the thicker alternating layers of silty sand to sand, as mentioned above.

3.5 Chemistry of Native Sediments

Bulk sediment chemistry testing has not been performed on the native sediments in the project site limits, except for the sediments dredged from nearby Queens Gate entrance channel. This sediment was sampled and tested in 1994 by the USACE. Test results indicated that this sediment was uncontaminated according to USEPA requirements at the time. Some of the sediments from this dredging event were placed at the South Energy Island Pit as uncontaminated fill. Some of this fill was later re-dredged and re-placed as capping material at North Energy Island pit, as part of the USACE CAD work performed in 2001.

3.6 Existing Geotechnical Features

3.6.1 Energy Islands

Four Texaco, Humble (now Exxon), Union Oil, Mobil, and Shell (THUMS) Islands occupy the study area: Island Freeman, Island Grissom, Island White, and Island Chaffee. The THUMS Islands were designed and constructed from 1965 to 1966 for the purpose of providing stable platforms for petroleum extraction. The islands are somewhat circular shaped and are constructed of sediment core surrounded by large stone revetment. The sediment for the core is composed of sediment dredged from the North and South Energy Islands Borrow Pits and the stone for the revetment was imported from Catalina Island Quarry. A general detail of a THUMS Island is shown in Figure 3.1.

The islands were built similar to that of White island. The general construction details of this island are shown below in the design build sketches and are described as follows: First, a large circular thin layer of dredged sediment was placed onto the Bay bottom in order fill in the natural contours and form a level platform for the foundation. Large diameter stone was then placed in interlocking circular fashion along the perimeter of the platform. Dredged sediment was then poured into the stone circle, leveled and then encircled again by more stone and repeated with poured sediment and process repeated until the island emerged. The details of the islands typical construction are shown in the example design as builds of White Island below. No additional geotechnical information is available.

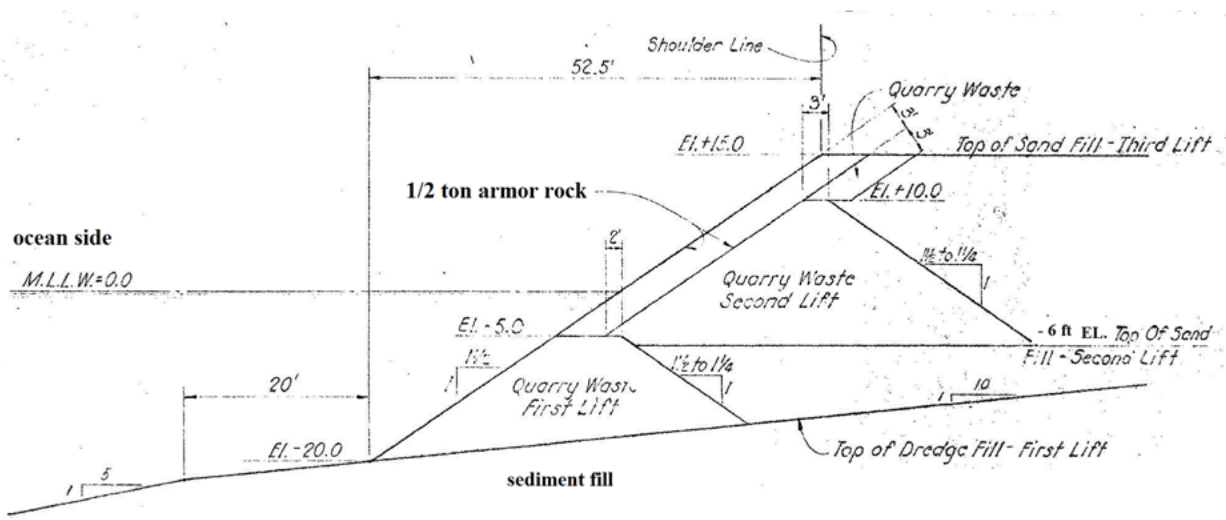


Figure 3.1: General Detail of THUMS Island (City of Long Beach)

3.6.2 Energy Island Borrow Pits

The North and South Energy Islands Borrow Pits are located in the vicinity of the THUMS Islands. They were formed after sediments were removed from them and used to construct the THUMS Islands.

The North Energy Islands Borrow Pit was partially filled with contaminated sediment dredged from the lower parts of the LARE and capped with sediment from the South Energy Islands Borrow Pit as part of the aquatic capping alternative of the Los Angeles County Regional Sediment Management Plan Pilot Studies in 1999. The cap area and the nearby ocean bottom area is off limits for development in accordance with California and Federal environmental regulatory requirements. As part of the requirements, the capping material is also periodically monitored and tested by the USACE for integrity and operability

The South Energy Island Borrow Pit was disturbed once since the completion of the THUMS Islands. Sediment from the Queens Gate deepening project was placed here in 1994 by the USACE. This sediment was again re-dredged and re-placed in 1999 and used as cover-capping material for the LARE-CAD site by the USACE.

3.6.3 Long Beach Breakwater

The Long Beach breakwater was designed and constructed during 1941 to 1949 by the USACE. The purpose for the structure is to provide a perimeter of physical protection for the inner harbors of Long Beach and Los Angeles against yearly marine derived storm erosion. The breakwater is of pyramid shape and was constructed from bottom of ocean floor and rises approximately 13 to 15 above the top of ocean water surface (+13 to +15 feet MLLW). From bottom to top, the breakwater material consists of a sand core bottom; followed by a mid-bottom core of clay mixed with class C stone; followed by a bottom cap of class B stone and a final top cap of class A stone. It is important to note that there are no stone sizes given for class A, B and C stone and no additional geotechnical foundation sampling and testing information available from the design and construction record. A design sketch of the typical to be constructed profile of the breakwater is shown below in Figure 3.2.

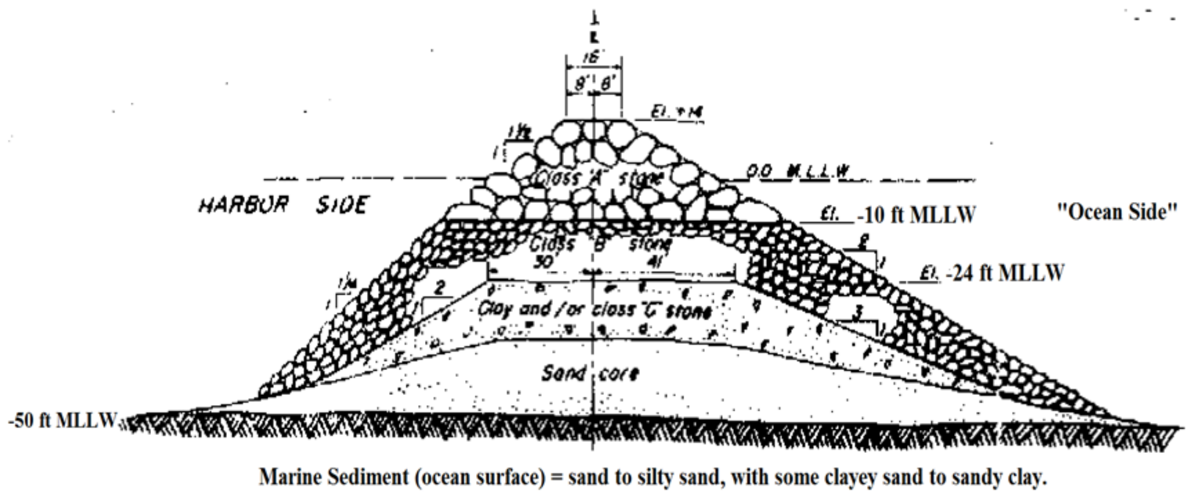


Figure 3.2: Profile of Long Beach Breakwater (USACE 2000, Condition Survey)

3.6.4 Los Angeles River Estuary (LARE)

The LARE is located at the mouth of the Los Angeles River and is part of the San Pedro Bay federal navigable channel. The footprint of this area is routinely dredged by the USACE as part of required federal channel maintenance for the area. LARE was last sampled, tested and dredged in 2013. Physical and chemical results indicated that a large portion of the sediment was contaminated and found suitable only for disposal offshore at USEPA LA-2 site.

4.0 GEOTECHNICAL ENGINEERING CONSIDERATIONS

The geotechnical engineering considerations presented in this section are preliminary and based on interpretations of available historic design reports and miscellaneous geotechnical investigation documentation for existing marine structures and dredging events within the vicinity of the study area. They will inform feasibility-level cost estimation efforts and assure habitat configurations are viable as related to the sediment foundations and materials they are constructed from. Refinements to the recommendations presented in this section will be made when geotechnical concerns impact an agency decision by significantly altering feasibility-level cost estimates.

As applicable, the geotechnical analyses and concerns herein are related to: a) Sediment foundation physical and chemical character and preparation costs; b) Sediment borrow material location, physical and chemical character, availability, dredgeability and cost; c) Stone borrow source location, availability and cost; and d) Constructability complexities and costs of the study's Tentative Selected Plan features. Recommendations are summarized in Table 5.1.

4.1 Sediment Borrow

Project criteria for suitable sediment have not been established. Therefore, specific physical and chemical requirements relating to suitability for sediment as borrow cannot be determined. The Surfside Sunset offshore borrow area is a consistent source of sand and has been used numerous times by the Corps of Engineers to re-nourish onshore beaches at Surfside Sunset. Therefore, this borrow area is identified as the main source of marine sediment borrow material for this study. However additional sources of marine sediment borrow are potentially listed as sources of sediment as well. These sources are: POLB dredged sediment; LARE and the North and South Energy Islands borrow pits. The sediment at these sources is not a consistent sand and is composed mainly of finer silt and silty sand. POLB dredged sediment has been used in recent past to supply fill for local marine construction projects. Sediment from LARE maintenance dredging was last placed offshore by the USACE at USEPA LA-2 site in 2015. Sediment from the Energy Islands borrow pits has never used as fill or beach nourishment.

The description, availability and condition of these borrow areas are discussed in the following sections. The location of the sediment borrow areas is shown on the Existing Geotechnical Features map, Plate 1.

4.1.1 Los Angeles River Estuary (LARE)

Based on past dredge history, small quantities of uncontaminated sediments from LARE can be considered as potentially suitable sediment for the project. The approximate quantity and availability of such sediments is unknown at this time. Availability and quantity is dependent on timing of future maintenance dredging by the USACE. The suitability of the sediment is based more specifically and the future chemical and physical character and their accompanying test results for each dredge event. In the past, LARE contaminated sediments have been dredged and placed both offshore at LA-2 and at the North Energy Island CAP site. Uncontaminated fine grained size sediments from LARE were placed by the USACE in 2015 at the USEPA LA-2 offshore open ocean disposal site. None of the sediments dredged from this event were placed as beach nourishment material because the amount of fine sediments was too high. North and South Energy Island Pits Both pits encompass approximately 25 acres each and are located between White and Grissom energy islands at depths ranging between -32 to -45 feet MLLW. As previously mentioned in section 4.3, the North pit is occupied with contaminated sediment placed at the bottom and capped over by uncontaminated sediment. This work was completed by the USACE as part of their LARE CAD site work performed in 1999. The CAD is monitored periodically for reliability by the USACE as part of environmental regulatory requirements. No sediment can be removed from this pit because the requirements entail that the CAD and the surrounding sediment from the North pit remain off limits to future disturbance, except that related to maintenance and monitoring of the cap. The South pit is not a CAD site but sediment was removed from it in 1999 and used as cover material for the nearby LARE CAD site. Prior to that time the South Pit had not been disturbed since sediment was first removed from it in the 1960s to supply fill for construction of the Energy Islands The use of the South Pit is reserved for future placement of clean sediment at the request of the City of Long Beach. The upper ten feet of sediment in this pit is sandy to silty sand. Sediment borrow material in this pit is dredgeable by hydraulic or mechanical methods, but is not available because of the reason previously mentioned.

4.1.2 Surfside Sunset

As previously mentioned, this borrow area is routinely used by the USACE to supply beach compatible sand to the nearshore areas of Surfside-Sunset. The last placement from the borrow area to these beaches occurred in 2011.

The area is very large and encompasses approximately 70 acres and lies between the depths of -30 to -40 feet MLLW. It is located approximately 1,500 feet directly offshore of the former Sunset pier. The upper 20 feet of the area is composed of sand to silty sand that is very compatible for onshore beach nourishment and is dredgeable by either hydraulic or cutterhead methods and is available for use as borrow material. Costs to use material from this area for use on the study project alternatives depends on the quantity needed for each alternative. The distance from this area to the study area is greater than sediment borrowed from the energy island pits and POLB therefore the overall costs for borrow sediment from Surfside Sunset are higher. Costs increases can be assumed of cutterhead methods of dredge removal because this method is slower and less efficient than hydraulic dredging methods.

4.1.3 POLB dredged sediment

Sediment borrow is potentially available from leftover dredge material from future POLB maintenance and marine infrastructure dredging activities. The actual quantity, quality and availability is dependent on the timing of the dredge event for each activity. The suitability of this sediment for use on the project is unknown because it is based specifically on its future physical and chemical character and accompanying test results. Past dredge sediment results indicate that most of this material is expected to be silt to silty sand.

4.2 Sediment placement

Sediment placement for the island and wetland habitat features can be accomplished by hydraulic fill methods. Sediments placed by hydraulic fill methods will require adequate time to consolidate and gain strength prior to successive hydraulic fill placement. It is recommended that hydraulic fill lift thicknesses be limited to ten feet and that twenty days elapse between successive lifts.

Where rock dike foundation structures are used to contain hydraulic fill, piece by piece stone placement costs and design considerations should be made. The semi-floating sediment layer of surficial San Pedro Bay mud and loose silt can be assumed to be approximately 6 inches thick across the study area. Prior to fill placement, minimal removal of this layer required within the foundation footprint. This will ensure rock is placed upon more competent weight bearing sediment. Further considerations should also be given to the disposal of the removed bay mud and loose silt because of its high fine grain size content. Its placement will be restricted to fill for planned wharf-marine construction sites, or other confined disposal areas in the study area that are open to acceptance of dredged sediment with high amounts of fine grained materials

The overall dredge volumes required for construction of the island and wetland habitat alternatives will depend on the fines content of the sediment borrow. When fine grain size content is high, the volume of material required to be dredged will be substantially more than the volume of sediment required to fill the total volume of these proposed structures. This occurs because of the substantial loss of fines washed away in the ocean water column during placement and from the significant reduction in volume of fines as they are compressed during and after placement. For sediments imported from the offshore borrow area of Surfside and Sunset, dredged volume and the volume of proposed structure can be assumed to equal because sediments from these sites have minimal fines content. Once a suitable sediment criteria is established for the project, more accurate dredging requirements can be estimated based on the maximum fines content required.

Safe slopes for placement of sediment onto the ocean bottom without reinforcement from rock dike containment structures is restricted to 3H:1V. This would apply to the submerged shoals and island habitat alternatives.

Important considerations should also be given to the placement dredged bay mud and loose silt because it is extremely fine grained.

4.3 Stone Borrow

Stone from Catalina Island and the surrounding areas of Riverside County, California have been successfully used on past USACE projects within the vicinity of the study area. Considerations will have to be made for the quality and size of stone to ensure it meets study project needs. It can be assumed that stone used for supporting foundations, such as creation of sandy islands, will need to meet USACE standards for quality-durability and will have to be properly sized to support the fill material. The standards of quality and size for creation of reef structures will be less rigorous and stone can be accepted of less quality-durability. In place unit costs for stone should be developed for both stone imported from Catalina Island and stone imported from Riverside County, California, with the greater of the two unit costs used to ensure suitable stone can be procured for this project.

The description and status of such stone sources is discussed in the following sections. The location of the stone source areas is shown on the Existing Geotechnical Features map, Plate 1.

4.3.1 Catalina Island Quarry

Catalina quarry is an active commercial stone producer and is located on Catalina Island, approximately 26 miles west of the study area. Sub angular to angular stone from this quarry is available in sizes ranging from 2 feet to 8 feet diameter and in quantities sufficient for use on the various study alternatives. The stone is a mixture of seven different extrusive igneous and metamorphic rock lithologies. Stone from this quarry has been successively used on numerous USACE and POLB marine projects, including repairs made to the LB Breakwater. The quality of the stone varies from poor to good, but good quality structural stone can be produced to meet higher quality standards of the project, as needed. The cost for use of this stone depends on the quantity and size needed. Because this is the closest quarry to the area, the cost is likely to be less expensive than the next closest quarries of Riverside County.

4.3.2 Riverside County Quarries

Numerous active producing quarries are located as a cluster of pits approximately 75 miles east of northeast of the study area in the western 1/4 of Riverside County and are all capable of producing commercial stone to support all of the project study alternatives. The stone is angular to sub-angular and poor to good quality and with sizes ranging from 3/4 inches to 8 feet diameter. Good quality stone can be produced to meet higher quality standards as need for the project. The stone type varies from igneous intrusive to extrusive rock to metamorphic rock. Stone from these quarries has been successively used on both terrestrial and marine type projects constructed in the past by the USACE. The cost for stone from these quarries depends on the quantity and size needed. Because their distance is 3 times more than the Catalina Quarry, the cost of transport of stone from these quarries to the project is higher than the costs for stone transported from Catalina. Therefore, the Riverside County quarries are assumed to be the most expensive source of stone for the project.

4.4 Stone placement

Stones placement can be accomplished by dumping in-place and piece by piece placement, with rearrangement of the stone as the proposed structure requires. Dumping in place is faster and less expensive but less accurate than slower piece by piece placement. Increased costs should be assumed for construction ofrocky reef structure as this work requires more precise placement by crane over barge to achieve the required shape of the structure. Construction may also have to be limited to summer months to avoid winter large storm events.. Stone placement for kelp reef can use push over method off of barge using a loader or bulldozer. This is a lower cost method of placement than the more precise placement required for rocky reef structure. Stone can be placed without additional bedding stone and foundation preparation. The surficial San Pedro bay semi-floating layer of clay and silt is assumed to be 2 to 6 inches thick across the study area. For cost estimation and design purposes, it should be assumed that approximately 6 inches of this low density sediment will be completely displaced during stone placement and there will be no need to add bedding stone. The recommended maximum slope for all stone structures considered for this project is 2H: 1V. Stone removal

Modification to the Long Beach Breakwater will require piece by piece stone removal and can be accomplished by a barge mounted excavator equipped with a rock bucket-clam-shell to efficiently modify the structure. This work may incorporate slower production rates.

5.0 REFERENCES

Dames & Moore. (1969). Report – Consultation and Soil Sampling, Proposed Hydraulic Dredging Project, Extension of Pier G and Pier J, Long Beach Harbor, Long Beach, California. Prepared for Long Beach Harbor Department.

Earth Mechanics. (2012). Geotechnical Data Report for Dredge Material Source Characterization, Phase 2 Vibracore Program, Middle Harbor Redevelopment Project, Port of Long Beach, California. Prepared for Moffat & Nichol.

Jennings, C.W., and Bryant, W.A. (2010). Fault Activity Map of California: California Geological Survey Geologic Data Map No. 6, Map Scale 1:750,000.

Moffat & Nichol. (1983). [Memorandum].

Moffatt & Nichol. (2015). CRC Islands – Rock Slope Protection Conditions Assessment (M&N File No. 6156-15) [Memorandum].

Port of Long Beach. (1995). Berths J260-J270, Pier J Breakwater. Prepared by Moffatt & Nichol.

Sea Surveyor. (1994). Final Report: Queens Gate Dredging, Geotechnical and Chemical Investigation. Prepared for Port of Long Beach.

THUMS Long Beach Company. (1965). Off-Shore Drilling Islands. Prepared by Moffatt & Nichol.

USACE. (1983). Emergency River and Harbor Improvement, Los Angeles and Long Beach Harbors, California: Restoration of Breakwaters.

USACE. (1985). Comprehensive Condition Survey, Geotechnical Appendix, Los Angeles-Long Breach Breakwaters, Los Angeles-Long Beach Harbor, Los Angeles County, CA.

USACE. (2001). Orange County Beach Erosion Control Project, San Gabriel River to Newport Bay, Orange County, California: Stage 11, Design Documentation Report

USACE. (2002). Los Angeles County Regional Dredged Material Management Plan Pilot Studies, Los Angeles County, California: Appendix A – Evaluation of Aquatic Capping Alternative.

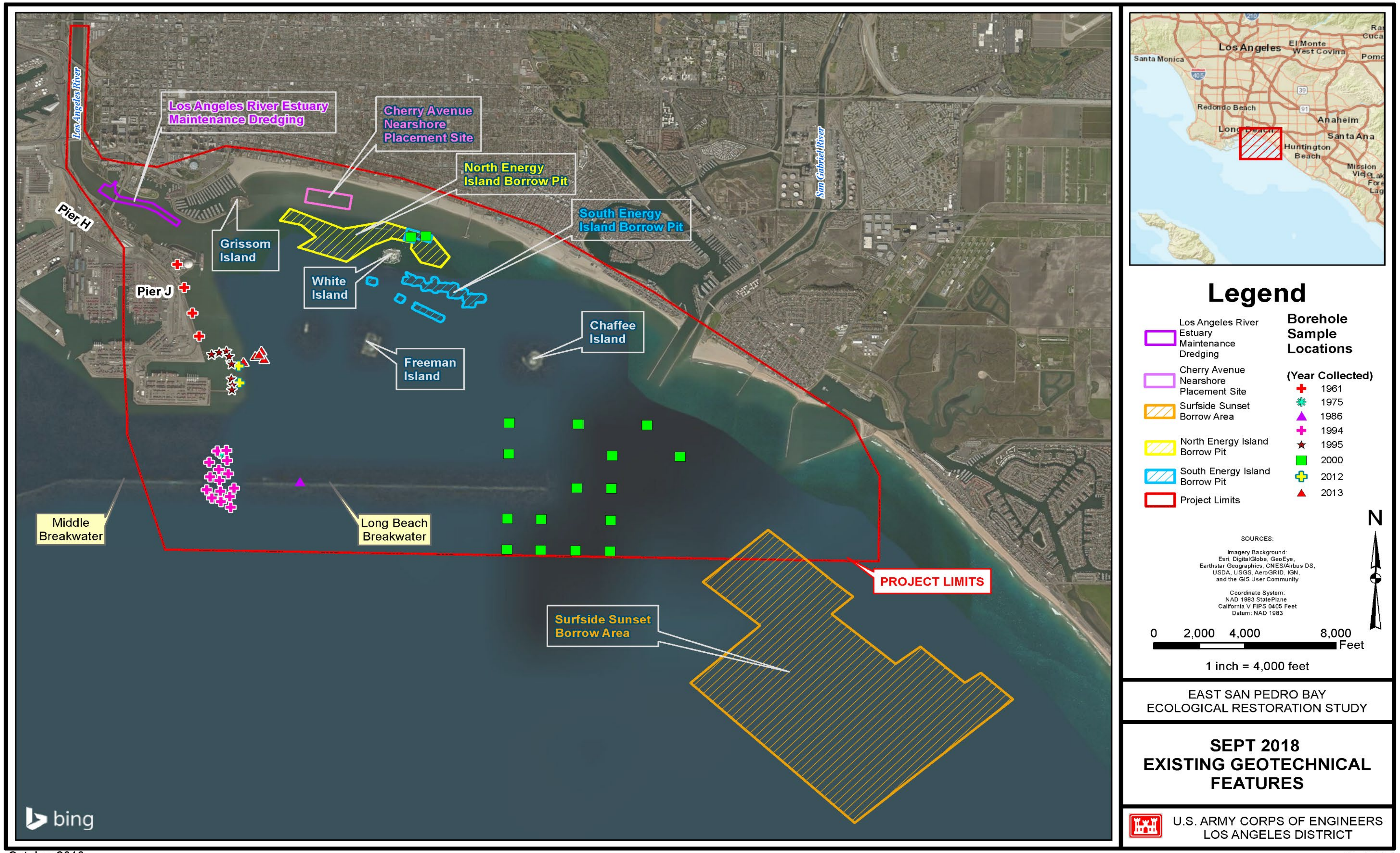
Yourman, A., Jr. and Diaz, G.M. (1991). Stability Analyses in the Ports of Long Beach and Los Angeles. International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics. Paper 26.

Yourman, A., Jr., Thurai, A., Nadeswaran, V. R., and Diaz, G.M. (2001). Review of Slope Stability Analysis in the Ports of Long Beach and Los Angeles. International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics. Paper 11.

Table 5.1: Geotechnical Recommendations

Habitat Type	Constructability		Material				Geotechnical Concerns	Geotechnical CostImpact	Total Cost
	Simple	Complex	Types	Location	Immediately Available	Proximity (one way distance)			
Submerged Reefs	X		Quarried stone or salvaged stone from LB Breakwater.	Stone = Catalina Island Quarry and LB Breakwater, or Riverside County Quarries.	Yes	Very close, < 5 miles for C Island & LB Breakwater. Very Far > 70 miles for Riverside County Quarries.	No major concerns.	Low = for stone chosen from locations very close. Medium to High = for stone chosen from locations far away.	Low.
Emergent Islands or Wetlands		X	Quarried stone or salvaged stone from LB Breakwater and Sediment.	Stone = Catalina Island Quarry and LB Breakwater, or Riverside County Quarries.	Yes	Very close, < 5 miles for C. Island & LB Breakwater. Very Far > 70 miles for Riverside County Quarries.	Some concerns: Stone should be placed with a maximum slope of 2H:1V to ensure stability of island sediment, which will require large amount of stone. Stone for existing stone structure projects within the vicinity of the study area has been placed with a maximum slope of 1.5H:1V. All sediment sources area must be tested for suitability according to amount, chemistry and grain size, prior to use. A high risk exists for suitability of sediment from study area because previous data exists on area wide basis. Past testing indicates small amounts of future LARE sediment may be suitable, while majority are very fine grain size and contaminated and unsuitable. Past testing also indicates majority of POLB sediments are suitable but all are very fine grain size, with some contaminated and unsuitable sediment. All sediment fill placement methods (hydraulic or mechanical dredging) must be approved by environmental regulatory agencies and Southern California Dredged Material Management Team (SC-DMMT) and will require turbidity and water chemistry monitoring and testing. Need to limit sediment fill thicknesses because fill for existing POLB harbor landfill projects has been successfully placed at limits of ten foot lifts,	Low = for stone chosen from locations very close. Medium to High = for stone chosen from locations far away.	Medium to High.
				Sediment = Surfside-Sunset offshore borrow area, or sediment from study area, or sediment dredged from POLB harbor or LARE.	Yes = S-Sunset. Yes = study area. No = POLB & LARE available at future dates, determined by dredge events planned according to POLB facility upgrades and USACE maintenance activities.	Very close, < 1 miles for study area & POLB. Far < 6 miles, for S-Sunset.		Medium to High = for S-Sunset sediment because far away. Low = LARE & POLB sediment because no cost for dredge removal. Medium = for study area sediment because close but unknown as to suitability (amount, grain size and chemistry).	

							with minimum of 20 to 30 days elapsed time between lifts to allow for proper settlement. Placement of sediment should be at slopes of 6H:1V for sandy sediment based on infinite slope stability analysis for a safety factor of greater than 1.5. For fine sediment the slopes may be steepened.		
Oyster Beds	X		Sediment.	Sediment = Surfside-Sunset offshore borrow area, or sediment from study area, or sediment dredged from POLB harbor or LARE.	Yes = S-Sunset. Yes = study area. No = POLB & LARE available at future dates, determined by dredge events planned according to POLB facility upgrades and USACE maintenance activities.	Very close, < 1 miles for study area & POLB. Far < 6 miles, for S-Sunset.	Some concerns: All sediment sources area must be tested for suitability according to amount, chemistry and grain size, prior to use. A high risk exists for suitability of sediment from study area because previous data exists on area wide basis. Past testing indicates small amounts of future LARE sediment may be suitable, while majority are very fine grain size and contaminated and unsuitable. Past testing also indicates majority of POLB sediments are suitable but all are very fine grain size, with some contaminated and unsuitable sediment. All sediment fill placement methods (hydraulic or mechanical dredging) must be approved by environmental regulatory agencies and SC-DMMT and will require turbidity and water chemistry monitoring and testing.	Medium to High = for S-Sunset sediment because far away. Low = LARE & POLB sediment because no cost for dredge removal.	Low.
Submerged Shoals	X		Quarried stone or salvaged stone from LB Breakwater and Sediment.	Same as Emergent Island or Wetlands.	Same as Emergent Island or Wetlands.	Same as Emergent Island or Wetlands.	Some concerns: Same as Emergent Islands and Wetlands, except: steeper slopes for stone and sediment are allowable because shoals are in shallow water and submerged. Stone and sediment quantities are lower because features are submerged.	Same as Emergent Island or Wetlands.	Low.
Removal of portions of LB Breakwater	X		Not applicable.	LB Breakwater.	Yes.	Very close, < 1 mile.	No major concerns.	Low = demolition of LB Breakwater involves simple removal of stone.	Low.



October 2018

PLATE 1

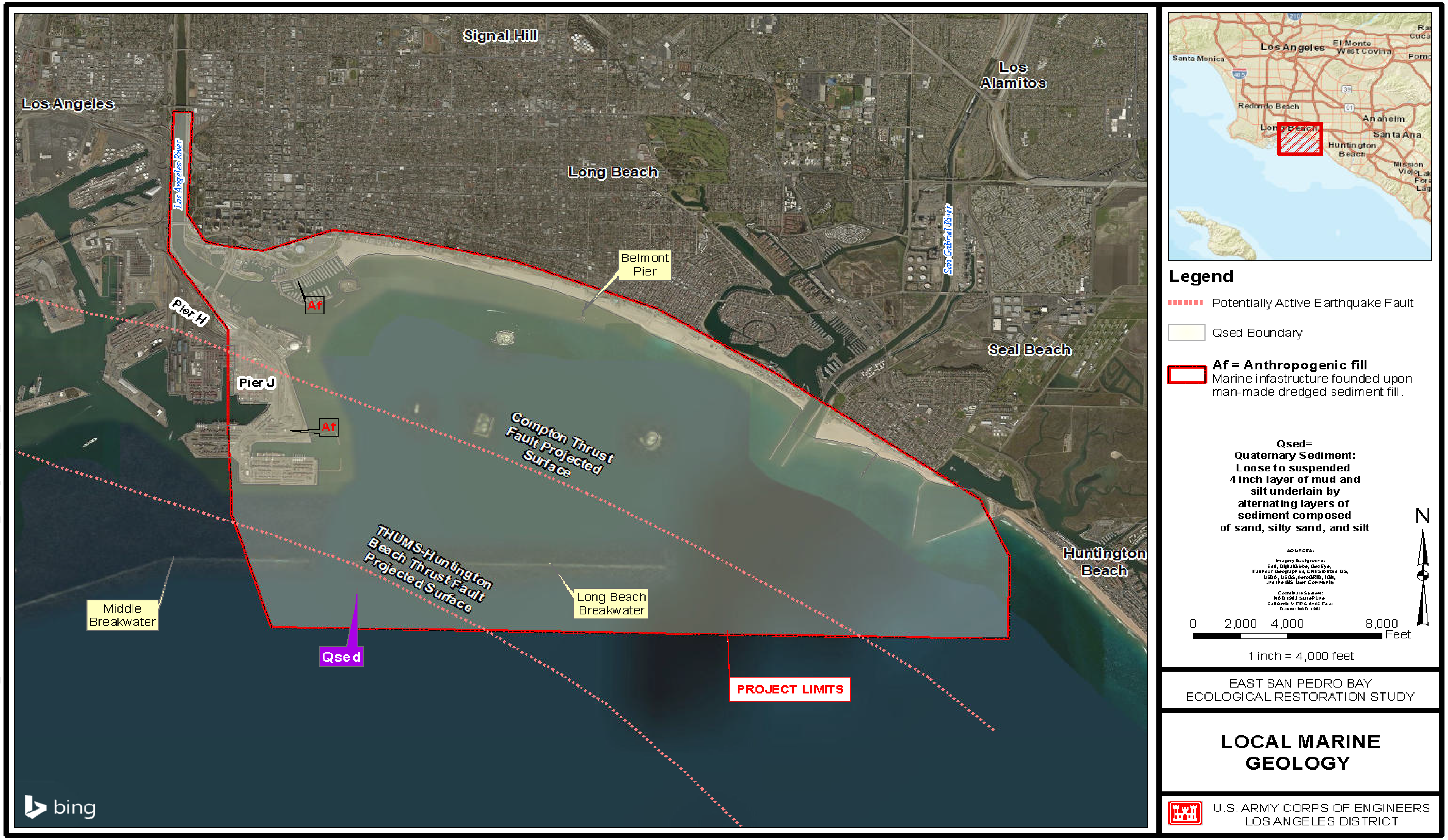

Signal Hill
Los Angeles
Los Alamitos
Long Beach
Los Angeles River
San Gabriel River
Belmont Pier
Pier H
Pier J
Af
Af
Seal Beach
Compton Thrust Fault Projected Surface
THUMS-Huntington Beach Thrust Fault Projected Surface
Huntington Beach
Middle Breakwater
Long Beach Breakwater
Qsed
PROJECT LIMITS
bing
Legend
Potentially Active Earthquake Fault
Qsed Boundary
Af = Anthropogenic fill
Marine infastructure founded upon man-made dredged sediment fill.
Qsed=
Quaternary Sediment:
Loose to suspended
4 inch layer of mud and
silt underlain by
alternating layers of
sediment composed
of sand, silty sand, and silt
N
0 2,000 4,000 8,000
Feet
1 inch = 4,000 feet
EAST SAN PEDRO BAY
ECOLOGICAL RESTORATION STUDY
LOCAL MARINE GEOLOGY
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 2