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2-21-0912 (SFPUC OCEAN BEACH ARMORING)

JUNE 13, 2024

EXHIBITS, Part 2

Table of Contents

EXHIBITS

OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT

Habitat Mitigation and Monitoring Plan

Prepared for
San Francisco Public Utilities Commission

April 2024

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CONTENTS

Ocean Beach Climate Change Adaptation Project – Habitat Mitigation and Monitoring Plan

Figures

Tables

Appendices

CHAPTER 1
Introduction and Purpose

This Habitat Mitigation and Monitoring Plan (HMMP; monitoring plan) was prepared by Environmental Science Associates (ESA) on behalf of the project applicant, the San Francisco Public Utilities Commission (SFPUC), for the Ocean Beach Climate Change Adaptation Project (project). Anticipated impacts from the project consist of temporary disturbance to 1.13 acres of coastal dunes within the South Ocean Beach project area, which the dune delineation indicated meeting the definition of environmentally sensitive habitat areas (ESHA). ESHAs are afforded protection under the California Coastal Act and the California Coastal Commission requires compensatory mitigation for impacts on such areas.

The SFPUC proposes to restore 9.36 acres coastal dune habitat along South Ocean Beach, consisting of three distinct zones: the Sacrificial Zone (3.36 acres), Vegetative Stabilization Zone (4.47 acres), and Stabilized Dune Zone (1.26 acres). The 8.1 acres which comprise the Sacrificial Zone and Vegetation Stabilization Zone are expected to compensate for the project's temporary coastal dune impacts. Although not proposed as mitigation, the Stabilized Dune Zone will be monitored for vegetation establishment and habitat functionality consistent with the other revegetation zones throughout the monitoring period. This monitoring plan provides a summary of the project design for creating coastal dune habitat, establishes monitoring methods and metrics for evaluating performance toward meeting mitigation objectives during the establishment period, and describes an adaptive management framework for responding to the dynamic coastal conditions affecting the project and created dunes. The monitoring plan was prepared to meet the anticipated monitoring requirements of the project's Coastal Development Permit 2-21-0291.

1.1 Project Location

The project is located along the coast of the Pacific Ocean in western San Francisco, California (**Figure 1-1**). Ocean Beach is a 4.5-mile stretch of north-south running sandy beach, separating the Pacific Ocean from the Great Highway. The primary project area is located along an approximately 1-mile stretch of Ocean Beach from Sloat Boulevard to Fort Funston known as "South Ocean Beach" and extending east along the Great Highway, between Sloat and Skyline Boulevards (**Figure 1-2**).

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2


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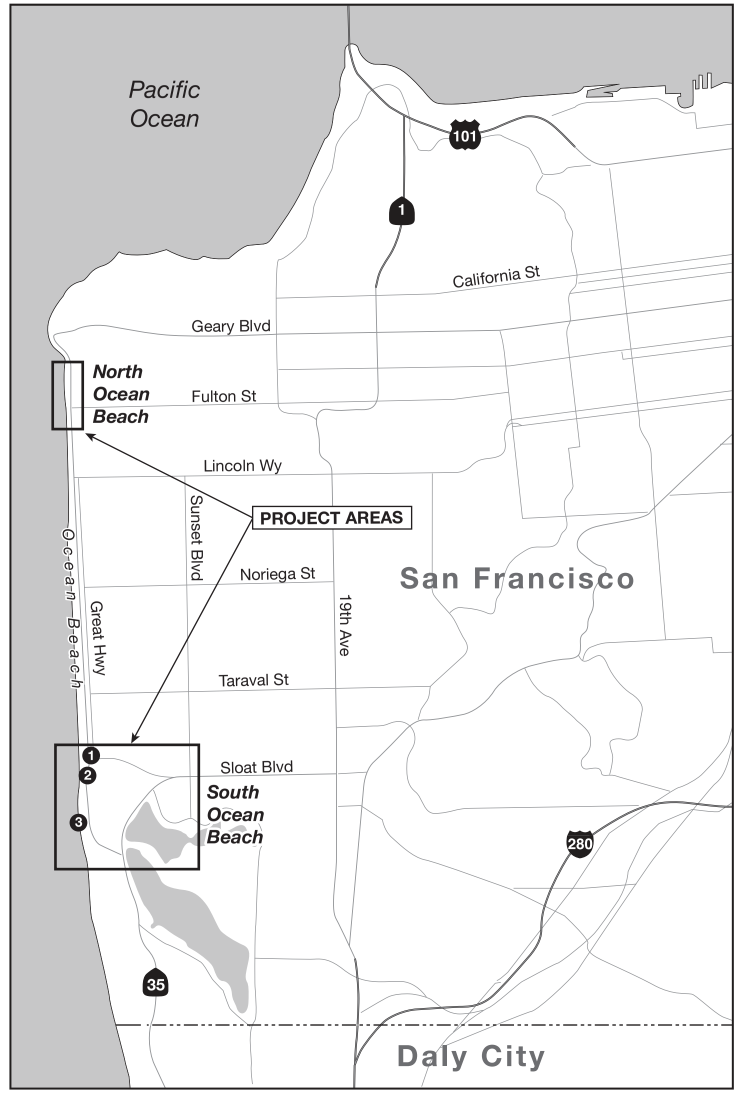

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SOURCE: ESA, 2020

Ocean Beach Climate Change Adaptation Project

Figure 1-1
Project Area and Photos

ESA

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SOURCE: ESA, 2019; Google Earth, 2019

Ocean Beach Climate Change Adaptation Project

Figure 1-2
Project Location and Existing Roadway Configuration

ESA

1.2 Project Overview

The City and County of San Francisco (the city) through the SFPUC is proposing the Ocean Beach Climate Change Adaptation Project (project) to address climate change-induced sea-level rise, shoreline erosion, and severe coastal storm and wave hazards, which threaten city infrastructure, coastal access, recreational use, and public safety.

Ocean Beach is an intensely energetic environment, frequently battered by powerful waves and storm surge. Currently, chronic erosion of the beach and bluffs by episodic coastal storms occurs at South Ocean Beach. Shoreline erosion has undermined and damaged National Park Service (NPS) beach parking lots, stormwater drainage facilities, and the Great Highway, and threatens existing underground wastewater system infrastructure.

The SFPUC's Oceanside Water Pollution Control Plant (OSP) and associated infrastructure are located along South Ocean Beach and provide treatment for wastewater and stormwater from the Oceanside watershed (Richmond, Sunset, and Lake Merced) which comprises about 35 percent of the total area of San Francisco. In addition to the OSP, critical components of the treatment system located along South Ocean Beach include the Westside Transport/Storage Box; the Westside Pump Station; the Lake Merced Transport and Storage Tunnel; the Southwest Ocean Outfall, and buried utilities that connect and support these facilities. This critical infrastructure is threatened by chronic coastal erosion of the beach and bluffs, caused by anthropogenic disturbance, wave action and episodic bluff failures (Barnard et al., 2012).

Dune habitats provide critical ecosystem services to coastal areas. Dunes dissipate waves and release (erode) sand during high wave conditions and limit the landward extent of wave runup. The dunes then trap sand and re-build with the assistance of dune plants. The beach, dune, and bluff natural infrastructure are essential components of the recreational and ecological attributes of the National Park Service's Golden Gate National Recreation Area which overlaps the project area. Because of the existing built environment and unique coastal processes affecting South Ocean Beach, historic dunes have eroded down to rubble (nonnative fill) which supports the great highway. Absent a functional dune system, the eroded shore is limited in its efficacy to absorb or buffer wind and wave action which threaten landward city infrastructure.

The project incorporates the guiding principles of the Ocean Beach Master Plan and the adopted policies of the Western Shoreline Plan (the city's certified local coastal program) (SPUR, et al. 2012). For example, the project includes a combination of managed retreat,[1] beach nourishment, and shoreline protection strategies. Through these measures, the city aims to preserve and enhance public access, coastal recreation, and scenic resources at South Ocean Beach, while protecting critical wastewater system infrastructure from damage due to coastal hazards.

1 Managed retreat refers to the planned movement of people and assets away from areas of potential hazard.

Major project components, which are shown in **Figure 1-3**, include:

- Permanently closing the Great Highway between Sloat and Skyline boulevards[2] to public vehicular traffic, reconfiguring affected intersections and San Francisco Zoo parking access, removing the existing NPS restroom and parking lot, and maintaining a service road to SFPUC facilities;
- Removing pavement, rock and sandbag revetments, rubble, and debris from the beach, and then recontouring the bluff and planting dune vegetation;
- Constructing a multi-use trail, beach access stairways, coastal access parking, and restrooms;
- Constructing a buried wall to protect existing wastewater infrastructure from shoreline erosion; and
- Providing long-term beach nourishment (sand replenishment).

1.3 Mitigation Goals and Objectives

The overarching purpose of the project is to implement a long-term coastal management strategy for South Ocean Beach that addresses shoreline erosion and climate-related sea level rise (San Francisco Planning, 2023). The specific project objectives identified in the project EIR are summarized as follows:

- Preserve and enhance coastal public access, recreation, habitat, and scenic quality at South Ocean Beach.
- Maintain current operational capacity of wastewater infrastructure to meet continued compliance with regulatory permits.
- Protect the Lake Merced Tunnel, Westside Transport Box, and Westside Pump Station and associated facilities from damage due to shoreline erosion and storm and wave hazards.
- Increase resilience to sea level rise.
- Maintain emergency vehicle access.
- Maintain dedicated service vehicle access to the Oceanside Treatment Plant, Westside Pump Station, and associated facilities.
- Maintain visitor access to the San Francisco Zoo.

The primary goal of the HMMP is to support the project's proposed creation of a high-functioning, ecologically valuable coastal dune habitat within the South Ocean Beach project area consistent with the broader project objectives of coastal resiliency, protection of infrastructure, and maintaining access and use of public amenities.

The project Habitat Restoration and Enhancement Plan (HREP) explains the basis for design of the created dunes within the South Ocean Beach project area (M&N/AGS JV, 2024). The HREP describes three zones which serve discrete functions in achieving the project objectives: 1) the Sacrificial Zone – unstable incipient foredune and backshore beach; 2) the Vegetative Stabilization Zone – artificial perched foredune; and 3) the Stabilized Dune Zone – stable

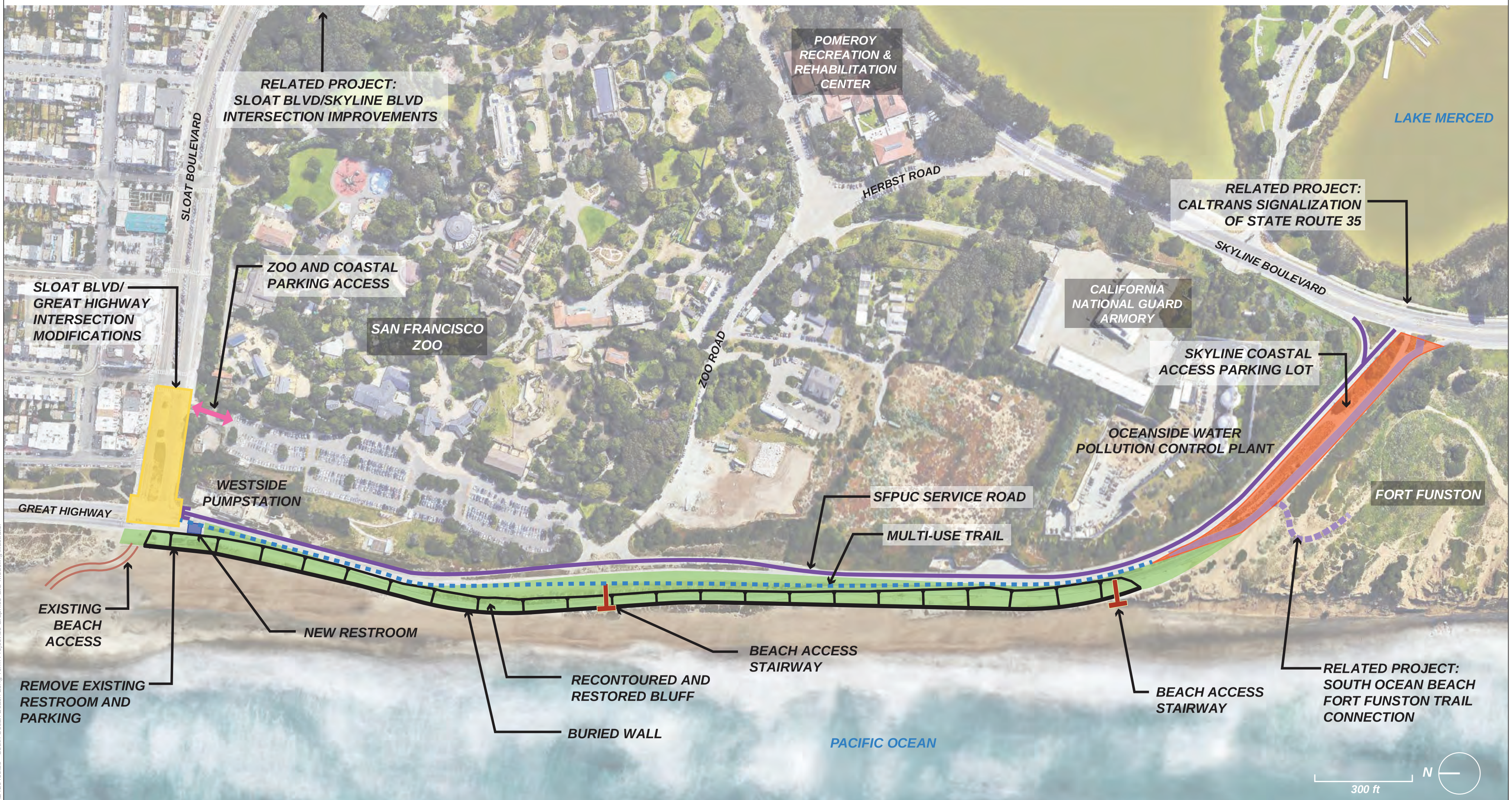
2 Skyline Boulevard is also State Route 35 at this location.

vegetated backdunes. The project Monitoring and Adaptive Management Plan (MAMP) establishes the long-term monitoring protocols and adaptive management strategies for these zones related to topographic surveying of South Ocean Beach and the North Ocean Beach sand borrow area, geomorphologic surveys of the dune zones, and wind-blown sand ingress onto pedestrian trails and other access areas. Monitoring under the MAMP will inform when adaptive management actions are implemented, such as sand replenishment events, brush placement to intercept, trap and stabilize onshore-blown sand from the beach, and maintenance removal of wind-blown sand into public recreational areas. The MAMP briefly describes surveys to assess performance of dune vegetation as it relates to the geomorphological functionality of the project. This HMMP is intended to supplement the MAMP during the initial vegetation establishment period by providing the framework for evaluating the ecological success of created habitat within the revegetated zones, focused on vegetative performance and wildlife use. After the establishment period, a simplified assessment of vegetation performance will be conducted biannually to inform adaptive management and maintain the ecological functionality of the project's coastal dune habitat.

The goals of the HMMP reflect project objectives and the unique functions of the three zones that informed their design:

1. Establish a Sacrificial Zone (SZ) which periodically erodes with wave action and is replenished by artificial beach nourishment (sand replenishment) events.
    a. Vegetation in the incipient foredune should be representative of an unstable foredune community and the *Leymus mollis* Herbaceous Alliance (Sea lyme grass patches).[3] A secondary *Abronia latifolia-Ambrosia chamissonis* Herbaceous Alliance (dune mat) community should also be present.
    b. Performance should consider the intended cyclical turnover of this zone and evaluate success of vegetation based on whether the zone is in a stable, eroded, or replenished/replanted state.
    c. Annual vegetative growth should trend in a positive direction when the zone is in a stable (growth) state.
    d. The SZ should support indicator species typical of backshore beach and unstable foredune habitats.
2. Establish a Vegetative Stabilization Zone (VSZ) which adequately intercepts, traps, and stabilizes onshore-blown sand from the beach to avoid or minimize dune sand encroachment on landward infrastructure and resist severe erosion during episodic storm events.
    a. Vegetation in the VSZ foredune should be representative of the *Leymus mollis* Herbaceous Alliance (Sea lyme grass patches) with a secondary *Abronia latifolia-Ambrosia chamissonis* Herbaceous Alliance (dune mat) community, each adapted to sand burial, winter overwash, fragmentation and dispersal.

[3] Alliances described herein are consistent with characterizations in the Manual of California Vegetation (online edition). Available at: https://vegetation.cnps.org.



Note: Long-term beach nourishment not shown.

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SOURCE: MN+AGS JV, Conceptual Engineering Report, Ocean Beach Long-term Improvements Project, September 2019

Ocean Beach Climate Change Adaptation Project

Figure 1-3
Project Components

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b. Annual vegetative growth should trend in a positive direction with the understanding that natural coastal processes and design constraints[4] of this artificial perched foredune will influence the condition and performance of vegetation within the VSZ.

c. The VSZ should support indicator species typical of foredune habitats.[5]

3. Establish a Stabilized Dune Zone (SDZ) which supports relatively continuous vegetative cover and resists wind deflation.

   a. Vegetation in the SDZ infiltration basins should be representative of San Francisco's stable backdunes and include assemblages of the *Lupinus chamissonis – Ericameria ericoides* Shrubland Alliance (silver dune lupine – mock heather scrub), *Eriophyllum, staechadifolium – Erigeron glaucus – Eriogonum latifolia* Herbaceous Alliance (seaside woolly-sunflower – seaside daisy – buckwheat patches), *Diplacus aurantiacus* Shrubland Alliance (brush monkeyflower scrub), or *Leymus mollis* Herbaceous Alliance (sea lyme grass patches).

   b. Annual vegetative growth should trend in a positive direction.

   c. The SDZ should support indicator species typical of backdune habitat.

Subsequent chapters of the HMMP include qualitative and quantitative metrics for evaluating the success of the created coastal dune habitat toward achieving these goals during the establishment period, primarily focused on performance of vegetation introduced to the mitigation areas. Wildlife use of the mitigation areas will also be documented as evidence of whether the created dune habitat is functioning as intended.

1.4 Responsible Parties

The SFPUC is responsible for ensuring that this monitoring plan is implemented, and that created dunes meet the performance criteria outlined in this document.

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4 The cementitious slope stabilization layer (SSL) will restrict root growth and access to groundwater. The design incorporates a subsurface irrigation system on top of the SSL to provide dune plantings within the VSZ with sufficient water in perpetuity.

5 Indicator species are plant or animal species that serve as a measure of the environmental or ecological conditions in a given area.

CHAPTER 2
Site Conditions and Project Impacts

This section describes the existing conditions within and surrounding the South Ocean Beach project area (study area) and characterizes anticipated impacts to coastal dunes under the project. This information is incorporated from the Dune Delineation Memorandum prepared for the project and provided to the Commission as the basis for identifying and distinguishing coastal dune ESHA from other non-dune sand deposits, and quantifying impacts to dune ESHA that the project is obligated to mitigate for (ESA, 2022). For a detailed discussion of the South Ocean Beach historic shoreline, dune morphology, and shoreline evolution see the HREP (MN+AGS JV, 2024).

2.1 Natural and Artificial Processes that Influence Sand Transport and Deposit

The following section provides background information on the natural and artificial processes generating the dune and dune-like sand deposits in the South Ocean Beach study area. The dunes and dune-like sand deposits along the Great Highway originate from a combination of natural eolian (wind transport) processes and external sediment sources. Sources that supply local wind-blown sand within the project area are dominated by recent (beginning regularly in 2013) artificially placed sand deposits related to ongoing beach nourishment for shoreline erosion protection. These sources include:

1. Trucked dry sand from North Ocean Beach,[6] referred to generally as the "sand backpass," and sand removed from the Great Highway north of Sloat Boulevard. Sand collected from these sources is stockpiled on the bluff top west (upwind) of the Great Highway and placed over the bluff edge as sacrificial sand berms.
2. Hydraulically placed dredged sand shaped into a sacrificial sand berm.[7]

The study area and locations and extent of placed sand originating from these sources is depicted in **Figure 2-1**. The sacrificial sand berms and trucked sand stockpile areas upwind of the Great Highway in the study area are generally not stabilized by vegetation or temporary surface stabilization measures to inhibit wind erosion (deflation) of sand deposits. These dry, high-relief unconsolidated, unstable sand deposits are now the primary source of dune sand transport into the study area. Prior to 2015 (the first year of prolonged, active wind-reworking of sacrificial sand

6 The San Francisco Public Utilities Commission's (SFPUC) sand backpass placement projects involve placement of beach sand obtained from North Ocean Beach.

7 The U.S. Army Corps of Engineers (USACE) Beneficial Use of Sand Dredged from the San Francisco Main Ship Channel for Storm-Damage Reduction at Ocean Beach, or Ocean Beach Sand Nourishment Project, involved placement of sand dredged from the San Francisco Main Ship Channel. Vertical wave-cut scarps in the sand berm are subject to rapid wind erosion, contributing sand that builds roadside dunes and dune-like deposits.

backpass berm placement), there was limited dune sand accretion along the study area segment of the Great Highway, bordered by wet, eroded intertidal beachface upwind.

During periods of high velocity, dry onshore winds, the dry exposed unprotected surface of the sacrificial sand berms erodes, and wind transports eroded fine to medium grain size sand across the Great Highway. Dune sand then deposits around obstacles, such as shore-parallel median barriers, K-rails, and guard rails along the Great Highway, as well as on vegetation of the project area, including pre-existing ice plant. Dune ramps deposit on the upwind side of barriers, and elongated tongue-like shadow dunes deposits extend downwind of barriers, often burying the road surface. These dune sand deposits encroach on the road surface until they are routinely removed by grading to permit vehicle use of the roadway. This necessary maintenance activity mixes the dune sand with roadside fill (e.g., gravel and soil), and incidentally re-deposits some of the mixed composite graded and dune sand from the margins of the graded roadside dunes elsewhere in the study area.

Dunes encroaching on the Great Highway within the study area also originate from natural sources in some areas. At the south end of the study area, wind erosion of the exposed high bluffs of Fort Funston (Golden Gate National Recreation Area [GGNRA]) transports weathered (iron oxide-stained, yellowish brown) sand from ancient uplifted beach and dune deposits (paleodunes) of the Colma formation. In addition, the eroded, wet intertidal beach face seaward of the study area (exposed during low tide) at times still supplies some unweathered (gray-white) wind-blown sand during high onshore wind events. The absence of a dry above-tide backshore beach south of Sloat Boulevard in the highly erosional, armored shoreline in this reach of the coast restricts natural onshore sand transport from beach to interior dune zones. The Colma paleodune sands contain traces of fine sediment from chemical weathering, and organic matter from past vegetation and soil development, unlike recent (modern) dunes, which distinguish the Colma sand dunes from others in the study area.

Other sandy soils and fills in the study area are remnants of past road construction (road base fill) and earthen slopes graded during construction of the Oceanside Water Pollution Control Plant east of the Great Highway, and earlier. These differ from dune sands in visible content of gravel, silt, clay from imported fill sources.

2.2 Coastal Dune Criteria and ESHA Evaluation

The methodology used to distinguish coastal dunes from artificial, non-dune sand deposits was based on physical substrate characteristics (the primary indicator) and vegetation (the secondary indicator) as observed during the field survey conducted by ESA biologists and Dr. Peter Baye on September 21, 2022. **Table 2-1** presents the criteria used to evaluate a feature and the basis of habitat determination.

A reference site for classifying the sand grain size range typical of dunes at Ocean Beach was also established during the field survey to support substrate comparison with potential dunes. The survey team examined 25 sampling plots within the study area to assess all possible dunes, and collected data to distinguish the qualifying dunes from surveyed areas that are not dunes.

SOURCE: ESA 2022

Ocean Beach Climate Change Adaptation Project

Figure 2-1
Dune Delineation Study Area and Sand Management Activities in the Vicinity

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TABLE 2-1
COASTAL DUNE CRITERIA AND BASIS OF HABITAT DETERMINATION

Coastal Dune Criteria

Physical Substrate (Primary Indicator)

- Medium to fine sand grain sizes transported and deposited by wind (surface and subsurface material). (Definition and necessary indicator).
- Absence of significant (more than trace) proportion of clay and/or silt; absence of gravel-sized sediments in most or all of deposit (surface and subsurface). (Definition and necessary indicator).
- Cross-bedding and other fine lamination structures in stratigraphic profile[1]indicating sand accumulation over several seasons. (If present, positive identification; if not present, neutral attribute).

Rejection criteria for substrate:

- More than trace proportion of clay and/or silt sediments in representative sand sample (sufficient to cause significant turbidity in aqueous suspension, relative to dune reference sample). Source material may explain presence of fines in the deposit (e.g., location downwind of placed dredge sand).

More than trace proportion of gravel or very coarse sand distributed in most of the deposit (not just surface deposits).

Vegetation (Secondary Indicator)

While not necessary to be considered coastal dune, if the preceding physical substrate criteria are met, a prevalence of native dune vegetation is a strong positive indicator of coastal dune habitat, as psammophytes (sand dune plants) select for conditions with relatively homogeneous sandy substrate where silt, clay, and gravel content in the sediment are low.

Basis of Habitat Detrermination

Observed Condition of Criteria	Habitat Determination
Dune substrate indicators met but no dune vegetation	Coastal Dune
Dune substrate indicators strong and dune vegetation indicator is weak or ambiguous (e.g., ice plant)	Coastal Dune
Dune substrate indicator is mixed positive/negative and weaker but still met, and vegetation indicator is strong (e.g., prevalence of obligate dune and beach native species like beach-bur or yellow sand-verbena or beach wildrye)	Coastal Dune
Substrate is mixed external material (significant gravel, silt, or clay content) and dune sand (substrate indicator not met), native vegetation present	Not Coastal Dune
Dune substrate indicators are not met and there is no dune vegetation	Not Coastal Dune

SOURCE: ESA 2022

NOTES:

1. Subsurface cut or column depicting sediment deposits over time.

Data collected from each sample plot included the following attributes:

- Sample plot height (maximum) above underlying ground surface;
- Presence/absence of surface sediment coarser than local pure reference dune sand (surface substrate particle size and type);
- Presence/absence of significant fine sediment (surface sample) compared with local pure reference dune sand (as determined by results of an aqueous suspension test);
- Homogeneity of subsurface substrate to 30 centimeters (stratigraphic profile). If subsurface substrate grain size exceeded the reference dune sand grain size (which is fine to medium grain size), an aqueous suspension test of surface sand was not performed;

- Presence/absence of vegetation and documentation of all taxa present, absolute and relative cover, native and non-native species; and
- Boundaries of potential dune associated with the sample plot.

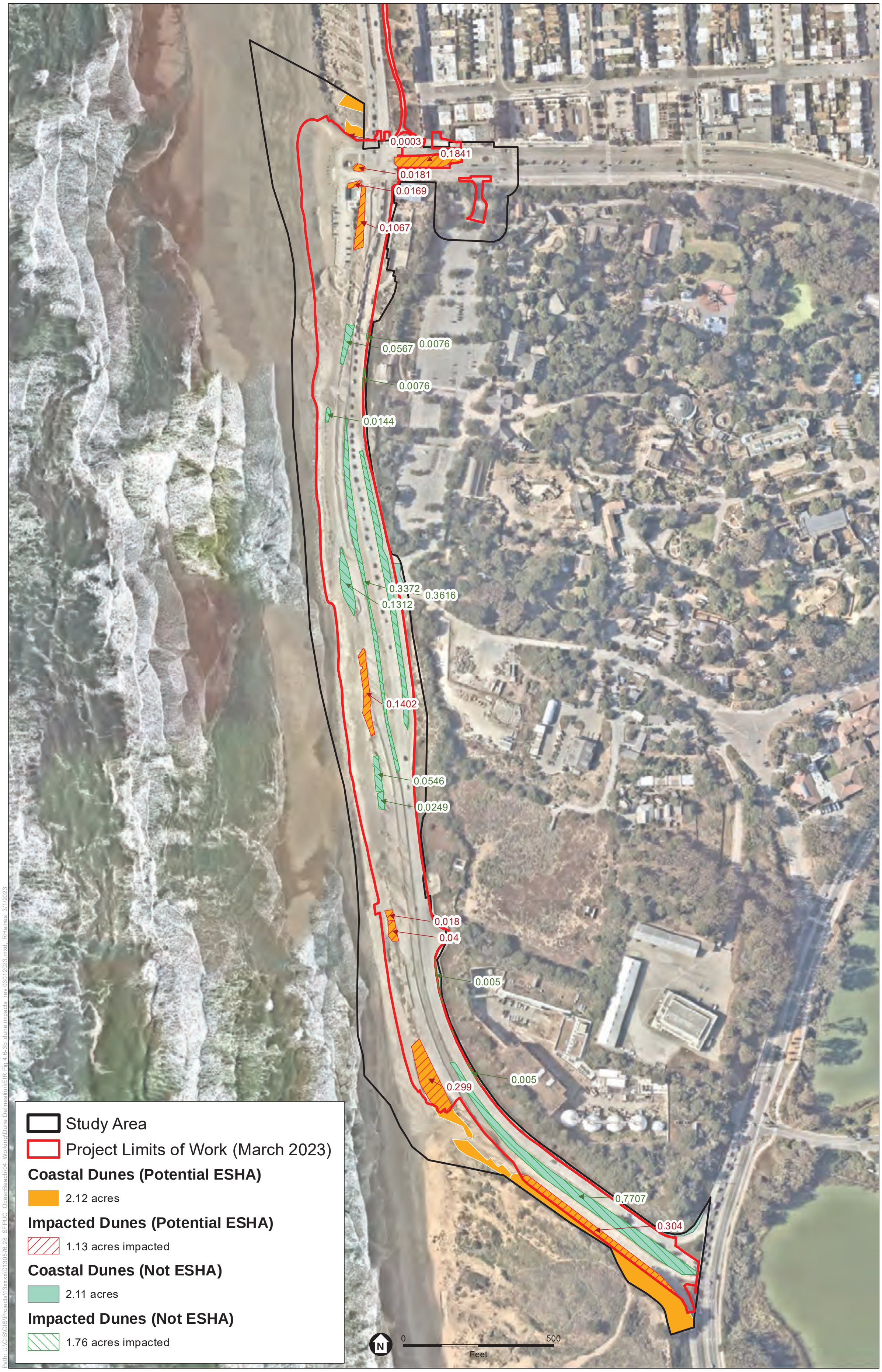
Qualifying coastal dunes were then assessed for whether they should be considered potential ESHA. The assessment evaluated environmental sensitivity based on the following objective traits:

- **Likely origin of the sample plot substrate** (e.g., beach sand or trucked, placed sand transported by wind or asphalt graded, collected, and deposited during roadside clearing);
- **Circumstances influencing sample plot** (e.g., historical sand removal maintenance). *Is the plot influenced by sand backpass project or USACE dredge sand placements or routinely manipulated by necessary maintenance clearing the accumulated sand from the Great Highway?*; and
- **Landscape context** (e.g., plot location and constraints). *Is the plot and associated polygon able to evolve or are there physical constraints (existing development or ongoing actions) that limit perennial growth and development as functioning dune habitat? Is the sample plot and associated polygon(s) connected to other dune habitat or is it isolated or constrained by existing development or ongoing actions?*

2.3 Project Impacts on Coastal Dune ESHA

The dune delineation identified 2.12 acres of coastal dunes as potential ESHA, 2.11 acres of mixed composite (non-ESHA) coastal dunes, and 1.72 acres of non-dune sand deposits within the 31.42-acre study area.[8] Project implementation is anticipated to impact 1.13 acres of coastal dunes identified as potential ESHA and 1.76 acres of mixed composite non-ESHA dunes. **Figure 2-2** depicts the location and extent of costal dunes and impacts within the South Ocean Beach project area.

[8] The remaining portions of the study area were beach, roadway or otherwise developed landcover.



SOURCE: ESA 2022

Notes: Project limits of work extend beyond the study area and figure boundary to the north and consist of repaving a pedestrian trail.

ESA

Ocean Beach Climate Change Adaptation Project

Figure 2-2
Location and Extent of Coastal Dunes and Impacts within the South Ocean Beach Project Area

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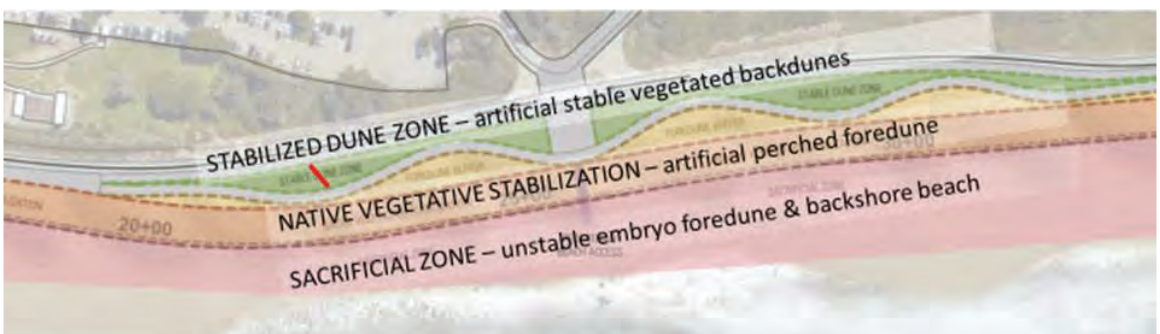
CHAPTER 3
Revegetation Design and Implementation

This section describes the revegetation of each restoration zone in the project area. This section is based on design basis and proposed design implementation described in detail in the Habitat Restoration and Enhancement Plan (HREP; MN+AGS JV, 2024). Detailed planting plans are provided in **Appendix A**.

3.1 Revegetation Design Overview

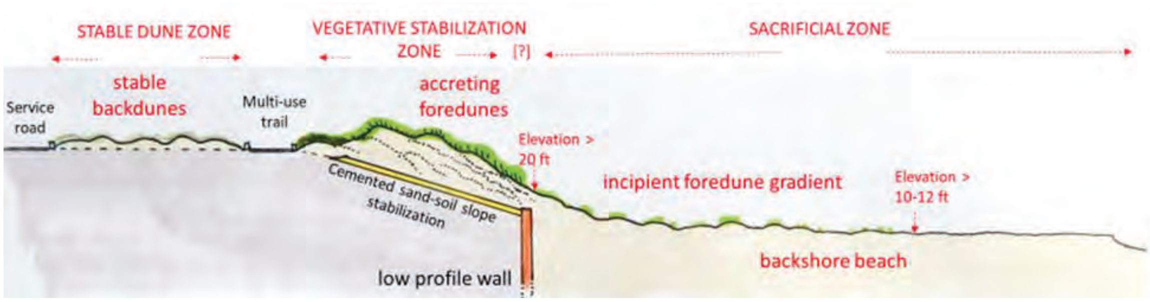
The revegetation of the project area is designed to accomplish multiple objectives, including to constructing coastal dune habitat along South Ocean Beach, and helping manage dune sand transport and infiltration of stormwater runoff within constructed infiltration basins.

The proposed revegetation comprises three unique zones based on a combination of ecology and desired function in relation to coastal processes and engineered structures. Moving from the beach inland, the revegetated project area, will consist of the Sacrificial Zone, the Vegetative Stabilization Zone, and the Stabilized Dune Zone. **Figures 3-1** and **3-2** below are extracted from the HREP to illustrate these dune planting zones (MN+AGS JV, 2024).



SOURCE: M&N/AGS JV, 2024 (HREP)

Figure 3-1
Generalized conceptual layout of the engineered beach and dune zones of the Ocean Beach Climate Change Adaptation Project.



SOURCE: M&N/AGS JV, 2024 (HREP)

Figure 3-2
Generalized cross-section view of the engineered beach and dune zones of the Ocean Beach Climate Change Adaptation Project.

Sacrificial Zone

The Sacrificial Zone is composed of the backshore beach and the incipient foredunes. This zone is designed not to be stable, but to have a high turnover of sand and vegetation. The Sacrificial Zone is intended to function as a buffer for storm wave erosion, and is expected to periodically become eroded, and replenished by placement of sand.

The seaward, lower elevations of the Sacrificial Zone are within reach of infrequent high tides during the spring-summer season, and is considered a naturally unvegetated dry backshore beach zone. No plantings are proposed in this sub-zone, but it may become intermittently vegetated by encroachment from plants in the incipient foredune during post-storm beach recovery and beach nourishment phases.

The incipient foredune at the inland edge of this zone may periodically support perennial beach and dune vegetation but is intended to alternate between partially vegetated and disturbed, post-storm recovery beach states. Perennial vegetation may persist between major storm events only at elevations greater than 10-12 ft NAVD88 or higher in most years. Vegetation planned for planting (and replanting) in this upper section of the sacrifice zone include native beach wildrye (*Leymus mollis*) with scattered patches of beach saltbush (*Atriplex leucophylla*), beach-bur (*Ambrosia chamissonis*), yellow sand-verbena (*Abronia latifolia*), and sea-rocket (*Cakile maritima*).

Vegetative Stabilization Zone

The Vegetative Stabilization Zone will be constructed on top of the cementitious slope stabilization layer on top of the low-profile wall. This zone is intended to mimic and function as a depositional foredune landform characterized by perennial vegetation that traps onshore wind-blown sand. Plantings in this zone will be dominated by beach wildrye, selected for its functional traits of efficient sand-trapping and dune stabilization. Two associate species, beach-bur (*Ambrosia chamissonis*) and yellow sand-verbena (*Abronia latifolia*), will also be planted in this zone, although in lower quantities, chosen for their historic presence in San Francisco foredunes.

Exhibit 4
2-21-0912
Page 26 of 95

Stabilized Dune Zone

The Stabilized Dune Zone on the landward side of the project's multi-use trail includes infiltration basins, intended to function as backdune habitat and drain stormwater runoff from adjacent trails and service roads. This zone will largely be protected from wind-blown sand that is intercepted by the Vegetative Stabilization Zone. Infiltration basins will be planted with native dune species that are tolerant of infrequent, ephemeral saturation or ponding of stormwater during precipitation events. The upper elevations will be planted with typical upland, backdune species and the lower elevations will be planted with dune slack vegetation.

3.2 Construction BMPs and Conservation Measures

The SFPUC has adopted standard construction measures (SCMs) to reduce potential environmental effects during construction of their projects. These SCMs apply to all SFPUC-sponsored projects and would be implemented for all project components throughout the construction phase. Relevant best management practices applicable to the mitigation area during the construction period are listed below. Discussion of BMPs characterized in the project EIR and mitigation measures related to biological resources beyond the scope of the SCMs that were determined necessary for the project to avoid significant environmental effects during construction is also provided.

SWPPP and Erosion Controls

- **SCM 3. Water Quality**: All projects will implement erosion and sedimentation controls to be tailored to the project site such as, fiber rolls and/or gravel bags around stormdrain inlets, installation of silt fences, and other such measures sufficient to prevent discharges of sediment and other pollutants to storm drains and all surface waterways, such as San Francisco Bay, the Pacific Ocean, water supply reservoirs, wetlands, swales, and streams. As required based on project location and size, a Stormwater Control Plan (in most areas of San Francisco) or a Stormwater Pollution Prevention Plan (SWPPP) (outside of San Francisco and in certain areas of San Francisco) will be prepared. If uncontaminated groundwater is encountered during excavation activities, it will be discharged in compliance with applicable water quality standards and discharge permit requirements.

- **SCM 5. Hazardous Materials**: Where there is reason to believe that site soil or groundwater that will be disturbed may contain hazardous materials, the SFPUC shall undertake an assessment of the site in accordance with any applicable local requirements (e.g., Maher Ordinance) or using reasonable commercial standards (e.g., Phase I and Phase II assessments, as needed). If hazardous materials will be disturbed, the SFPUC shall prepare a plan and implement the plan for treating, containing or removing the hazardous materials in accordance with any applicable local, State and federal regulations so as to avoid any adverse exposure to the material during and after construction. In addition, any unidentified hazardous materials encountered during construction likewise will be characterized and appropriately treated, contained or removed to avoid any adverse exposure. Measures will also be implemented to prevent the release of hazardous materials used during construction, such as storing them pursuant to manufacturer recommendation, maintaining spill kits onsite, and containing any spills that occur to the extent safe and feasible followed by collection and disposal in accordance with applicable laws. SFPUC will report spills of reportable quantity to applicable agencies (e.g., the Governor's Office of Emergency Services).

The following bullets include a discussion of BMPs that would be implemented during project construction, as characterized in the EIR.

- Excavation for the grade beam and tieback anchors associated with the buried wall may extend below groundwater, necessitating temporary groundwater dewatering. Active dewatering systems such as use of a sump pump may be required to maintain a dry working space in these excavations. The excavation may extend into the Colma Formation. Groundwater from dewatering activities could contain sediment and suspended solids. Groundwater pumped from the excavated areas would be discharged to the combined sewer system via existing manholes on the Great Highway. Discharge of groundwater produced during construction-related dewatering would be subject to a batch wastewater discharge permit issued in accordance with article 4.1 of the public works code, as supplemented by Public Works Order No. 158170, which regulates the quantity and quality of discharges to the combined sewer system. Accordingly, groundwater produced during the limited dewatering would be pumped to baker tanks or other containment, tested, and treated to ensure compliance with the discharge limitations of article 4.1 of the public works code and Public Works Order No. 158170. Treatment could include methods such as using settling tanks to remove sediments, filters to remove suspended solids, and other methods to meet chemical-specific discharge limitations. The chemical-specific treatment method used would depend on the chemicals that exceed the specified discharge limitation but could include methods such as filtration or activated carbon treatment to reduce chemical concentrations as necessary to meet permit requirements prior to discharge. Installation of meters to measure the volume of the discharge may also be required.

- The final design of the project would be required to comply with the San Francisco Stormwater Management Ordinance included in San Francisco Public Works Code article 4.2, section 147. The stormwater management ordinance requires projects that would add or replace 5,000 square feet or more of impervious surface to manage stormwater using green infrastructure (i.e., stormwater controls or BMPs considered to be of low-impact design) and to maintain that green infrastructure for the lifetime of the project. Compliance with the ordinance would require that the project prepare a stormwater control plan describing the BMPs that would be implemented, including a plan for post-construction operation and maintenance of the BMPs. Treatment BMPs would reduce the pollutant loads in stormwater via infiltration (for example, permeable pavement or infiltration basins or trenches), detention (in constructed wetlands, detention ponds or vaults, or wet ponds), bioretention (such as flow through planter or rain garden), or biofiltration (for example, vegetated areas; media, sand, or vegetated rock filters; swirl separators, water quality inlets, or drain inserts). One or more treatment BMPs could be required to address each of the potential stormwater pollutants of concern.

- Ongoing periodic maintenance of the beach through a beach nourishment program to replenish sand lost to sediment transport from coastal processes would be conducted in accordance with applicable authorizations or permits from the U.S. Army Corps of Engineers, Regional Water Quality Control Board, and Commission that would require standards for the quality of the sand being placed, and implementation of construction measures such as minimizing heavy equipment time in the water, storing materials in a dedicated area, and other BMPs that are protective of ocean water quality.

- The project would include stormwater management features as detailed in a stormwater control plan that would comply with the stormwater management ordinance. The project includes stormwater management infrastructure that would be installed alongside new or replaced impervious areas. The stormwater management infrastructure would incorporate operational BMPs and low-impact design concepts as required by the stormwater management ordinance to the extent that is applicable to the site conditions and project specifics. These required drainage control features would minimize the potential for erosion or siltation, and would adequately control stormwater volumes such that the potential for flooding onsite or offsite would also be minimized.

Biological Resources

- **SCM 7. Biological Resources**: All project sites and the immediately surrounding area will be screened to determine whether biological resources may be affected by construction. A qualified biologist will also carry out a survey of the project site, as appropriate, to note the general resources and identify whether habitat for special-status species and/or migratory birds, are present. In the event further investigation is necessary, the SFPUC will comply with all local, State, and federal requirements for surveys, analysis, and protection of biological resources (e.g., Migratory Bird Treaty Act, federal and State Endangered Species Acts, etc.). If necessary, measures will be implemented to protect biological resources, such as installing wildlife exclusion fencing, establishing work buffer zones, installing bird deterrents, monitoring by a qualified biologist, and other such measures. If tree removal is required, the SFPUC would comply with any applicable tree protection ordinance.

- **Mitigation Measure M-BI-2a: Nesting Bank Swallow Protection Measures**. This measure applies to construction activities and small sand placements. Nesting bank swallows, their eggs and their nests, and their young shall be protected during construction and during sand placement events through the implementation of the following measures:
  - If construction or beach nourishment activities within 650 feet of the bluffs used by the Fort Funston bank swallow colony are conducted during bank swallow nesting season (nesting is from April 1 to August 1), a qualified wildlife biologist shall conduct preconstruction surveys for nesting bank swallow within seven days prior to the start of construction, beach nourishment activities, and prior to reinitiating construction at this location after any construction breaks of 14 days or more.
  - If active bank swallow nest sites are located during the preconstruction nesting surveys, a 650-foot no-disturbance buffer shall be established around the burrow nest site and all project work shall halt within the buffer until a qualified biologist determines the nest is no longer in use.

- **Mitigation Measure M-BI-2b: Worker Environmental Awareness Program Training**. This measure applies to construction activities and small sand placements. A project-specific Worker Environmental Awareness Program training shall be developed by a qualified biologist for the project and attended by all construction personnel prior to beginning on site work. As part of the training, brochures may be given to provide reference material to contractors. The training may be provided by the qualified biologist or by designated SFPUC staff trained by the biologist to provide this training, using the materials developed by the qualified biologist, and may be administered via a video-recorded training produced specifically for the project by a qualified biologist. A more in-depth environmental training may be developed and provided for contractor supervisors in leadership roles. The environmental training shall generally include but not be limited to education about the following:
  - Applicable state and federal laws, environmental regulations, project permit conditions, and penalties for non-compliance;

- Special-status species with potential to occur on or in the vicinity of the project sites, avoidance measures, and a protocol for encountering such species including a communication chain;
- Preconstruction surveys and biological monitoring requirements associated with each phase of work and at each project site as biological resources and protection measures will vary depending on project component location and the corresponding land managers (see f, below);
- Known sensitive resource areas in the project vicinity that are to be avoided and/or protected, as well as approved project work areas, access roads, and staging areas;
- Best management practices and their location at various project sites for erosion control and species exclusion, in addition to general housekeeping requirements; and
- Specific requirements sanctioned by the National Park Service (NPS) that the project must comply with while working on NPS-managed lands.

3.3 Plant Material Sourcing and Installation

This section summarizes the restoration and revegetation plan for the coastal dune habitat mitigation areas.

Plant Palette & Material Sourcing

Each mitigation zone will be replanted with native species that have been selected based on ecology and desired function of each zone (M&N/AGS JV, 2024). A full list of species proposed for replanting is presented in Appendix A. Native plant seeds will be collected from known, stable populations from the coastal San Francisco Peninsula, and propagated for the quantities needed for mitigation. Native plant nurseries managed by the Parks Conservancy in the Presidio and Fort Funston have been propagating native plants from local source populations for dune restoration projects since the 1990s and will be likely sources of plant material for the project. It is expected to take at least two full growing seasons before construction is completed to get transplant-ready plants.

Plant Installation

Transplanting nursery stock into the mitigation areas should take place in late fall or early winter, in cool, moist weather, when sand has been fully wetted by rain. Transplants should be kept moist during handling, transport and throughout the transplanting process. Beach wildrye shoots should have the top half to two thirds of live leaves pruned, and be planted with their base at least 1-foot below the sand surface, and be firmly compacted in the moist sand after planting.

Organic tidal wrack such as seaweed can be buried in the sand directly below or around the rootball of the beach plantings, to provide a source of nutrients in otherwise low-nutrient holding sand. Other sources of commercially available composts may be locally applied as well.

During the early stages of replanting, the foredune planting areas will be especially vulnerable to erosion and sand deflation. Temporary surface stabilization measures to stabilize the surface sand are proposed. Such measures include straw plugs, coarse woody debris deposits, brush fencing, loose brush placement, or coarse pebbles or shell placement. Brushwood fencing is the primary stabilization measure proposed in the Vegetative Stabilization Zone. Blue gum eucalyptus slash, cut and stored from tree removals within San Francisco at 8-10 ft lengths and rapidly dried for increased roughness, will be laid in overlapping patterns to help trap sand and stabilize the dunes.

The Stabilized Dune Zone planting areas will also require temporary stabilization measures. In this zone, a thin surface layer of scattered woody debris or coarse sand lag veneers is the proposed stabilization method.

Irrigation

Vegetative Stabilization Zone

Beach wildrye is the primary species to be used for sand trapping and stabilization in the Vegetative Stabilization Zone. In order to maximize efficiency of these stability functions, it is ideal to mimic the volume and density only naturally found in populations of this species growing in seep-fed foredune systems. To achieve this desired density, and to combat the limitations of a restrictive root system formed upon the slope stabilization layer of the low-profile wall, supplemental sub-surface irrigation is proposed. Slow, low-level flows of freshwater will be used to irrigate plantings in the Vegetative Stabilization Zone via perforated pipes installed below the surface of the sand, on top of the cementitious slope stabilization layer of the low-profile wall. Upward capillary movement is expected to saturate the soil from below to adequately support plantings within the Vegetative Stabilization Zone.

Stabilized Dune Zone

Overhead irrigation is proposed for the vegetation in the infiltration basins within the Stabilized Dune Zone, during the vegetation establishment period. This establishment period is expected to take 2 years but adjusting or eliminating irrigation to these areas will depend on input from Restoration monitors during the annual assessments. If winter droughts cause dry sand repellency and restrict even infiltration of water to the root zone, surfactants can be applied to the irrigated sand surface to help mitigate this effect.

3.4 Invasive Species Control and Eradication Plan

Early control of weed invasions as seedlings or prior to flowering or seed set are recommended in all zones. Annual invasive species control efforts in the spring are recommended, until native vegetation is able to more effectively outcompete weed seedlings.

The Stabilized Dune Zone will be at the highest risk of weed invasion after planting, since there are existing large stands of invasive weeds in this area, and sand burial will not occur in this zone. It is also at high risk of new invasions from anthropomorphic activity via the trail and service roads which flank planting areas in this zone.

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CHAPTER 4

Performance Criteria, Monitoring Methods, and Adaptive Management

To verify that the project is performing as intended, assessments of vegetation establishment will be performed by a qualified professional (i.e., the Restoration Monitor[s]) for a period of five years, until performance criteria are met, unless otherwise approved by the Commission. Baseline monitoring will take place immediately following revegetation of the three zones (to document as-built conditions). Monitoring and reporting on establishment and performance of revegetation zones will be performed annually during the monitoring period. Monitoring will be conducted at approximately the same time annually, per the monitoring schedule in Section 4.2, *Monitoring Methods*.

4.1 Performance Criteria

The performance criteria will provide a basis for determining success of the revegetation zones and the need for possible adaptive management actions. Given the dynamic environmental conditions of the project area, failure to attain one or more of the performance criteria should not necessarily be interpreted as the mitigation areas failing to function as coastal dune habitat. Rather, the collective monitoring results will provide a basis for discussion with Commission staff as to whether remedial actions are warranted to improve ecological conditions consistent with the mitigation goals and objectives. Despite failure to attain one or more specific performance criteria, monitoring results may suggest that the mitigation areas are serving the ecological functions intended for the created dune habitat, overall performance goals are being met, and that no remedial intervention is warranted. Most importantly, the performance criteria are intended to be used and interpreted based on professional judgment of the Restoration Monitor(s) and Commission staff.

Sacrificial Zone

The performance criteria for the Sacrificial Zone mitigation area during any monitoring year in a stable state will be the following:

- On average, 5 – 10 percent absolute vegetative cover of native and non-invasive plant species in the incipient foredune sub-zone in any monitoring year;
  - Or an average 10 percent growth in area of patch size from the previous monitoring year (if alternative monitoring methods conducted);
- The absolute cover of invasive plants will be no more than 5 percent in any monitoring year. Invasive plants will be defined as species rated high by the California Invasive Plant Council.

Vegetative Stabilization Zone

The performance criteria for the Vegetative Stabilization Zone mitigation area will be the following:

- On average, 10 – 30 percent absolute vegetative cover of native and non-invasive plant species in any monitoring year;
  - OR an average 10 percent growth in area of patch size from the previous monitoring year (if alternative monitoring methods conducted)
- The absolute cover of invasive plants will be no more than 10 percent in any monitoring year. Invasive plants will be defined as species rated high by the California Invasive Plant Council.
- Species richness of at least 2 native species in any monitoring year.
- Minimal to no evidence of significant windblown sand erosion, accretion, or blowouts in any monitoring year.

Stabilized Dune Zone

Because of the intended multi-use function of the infiltration basins which comprise revegetation planting areas within the Stabilized Dune Zone, these areas are not proposed as compensatory mitigation for project impacts on coastal dune habitat; however, establishment and performance of vegetation planted in the infiltration basins will be monitored consistent with the mitigation areas to ensure health and vigor of plantings, backdune habitat functionality, and to determine when adaptive management actions are needed. The performance criteria for the Stabilized Dune Zone will be the following:

- On average, 50 – 70 percent absolute vegetative cover of native and non-invasive plant species in any monitoring year;
- The absolute cover of invasive plants will be no more than 10 percent in any monitoring year. Invasive plants will be defined as species rated high by the California Invasive Plant Council.
- Species richness of at least 15 native species in the infiltration basin backdune planting areas in any monitoring year.

4.2 Monitoring Methods

Restoration Monitor

A qualified botanist, biologist, ecologist, environmental scientist, or person with at least three years of experience implementing restoration plans would oversee and monitor implementation of this HMMP. The Restoration Monitor(s) would be responsible for:

- Supervising site preparation
- Directing plant harvest and planting
- Conducting annual monitoring for five years or the duration of the monitoring period
- Preparing annual reports

- Providing guidance and instruction to SFPUC for ongoing maintenance to ensure the long-term successful establishment of the plantings
- Guiding remedial actions as needed, so that performance standards and mitigation goals and objectives are met
- If necessary, the Restoration Monitor would train maintenance crews in the methods represented in this plan including, but not limited to, proper techniques and best management practices for weed control/removal and brush placement.

As-Built Drawings

Upon project completion, as-built drawings will be prepared to document final grades and map the final planting and seeding palette and layout. The as-built drawings will include sections showing existing, design, and constructed grades at the same sections as provided in the construction drawings. The as-built drawings will be reviewed by the Engineer of Record, with assistance from contributing project designers, for conformance with the construction drawings.

Monitoring Schedule

A summary of the monitoring schedule and assessment methods is provided in **Table 4-1**. Each of the assessments would be conducted annually during the monitoring period.

Aerial Survey

The MAMP includes aerial surveys of the project area and shoreline by an unmanned aerial vehicle (UAV) approximately every six months.

To maximize utility of these aerial surveys, high resolution aerial photographs will be collected during the surveys to aid in analysis of beach size and vegetative cover of coastal dune habitat. Methods for conducting this remote sensing analysis of vegetative cover in revegetation areas is discussed below under *Remote Sensing Growth Assessment.*

TABLE 4-1
MONITORING SCHEDULE

Survey Type	Zone	Method	Raw Data	Result
Spring Assessment (Conducted Annually)				
Aerial Survey	Entire project area and shoreline	UAV flight every 6 months in the spring and fall as specified in the MAMP	High-resolution aerial imagery of each zone	Seasonal and inter-annual variation of vegetative cover
Qualitative Assessment	• Sacrificial Zone • Vegetative Stabilization Zone • Stabilized Dune Zone	Visual observation	Visual assessment of vegetative quality and composition; observations of disturbance; location and extent of invasive plant populations; list of all plant species observed on site to document presence of spring annuals	Species richness per zone; Adaptive management recommendations; field verification of aerial imagery
Wildlife Surveys	• Sacrificial Zone • Vegetative Stabilization Zone • Stabilized Dune Zone	Visual observation of terrestrial species	List of wildlife observed	Wildlife use of the habitat, and presence of indicator species
Photodocumentation	• Sacrificial Zone • Vegetative Stabilization Zone • Stabilized Dune Zone	Photos taken at fixed photopoints, from same bearing and camera angle	Georeferenced photographs	Georeferenced photographs over time
Late Summer-Early Fall Assessment (Conducted Annually)				
Aerial Survey	Entire project area and shoreline	UAV flight every 6 months in the spring and fall as specified in the MAMP	High-resolution aerial imagery of each zone	Seasonal and inter-annual variation of vegetative cover
Quantitative Ground-Based Vegetation Surveys	• Sacrificial Zone • Vegetative Stabilization Zone • Stabilized Dune Zone	Quadrat-transect sampling	Absolute percent cover of plant species within each quadrat	Average percent cover of native and non-native plant species per zone; field verification of aerial imagery
Photodocumentation	• Sacrificial Zone • Vegetative Stabilization Zone • Stabilized Dune Zone	Photos taken at fixed photopoints, from same bearing and camera angle	Georeferenced photographs	Georeferenced photographs over time

Qualitative Assessment

Overall conditions within the mitigation areas will be assessed including: project state (i.e., stable, eroded, replenished/replanted), habitat characteristics (e.g., increase/decrease/new occurrence of invasive species, general health and productivity of vegetation, natural recruitment of native plants), wildlife observations, human disturbances, trash, and natural disturbances (e.g., wind or wave damage, significant sand accretion or erosion, and drought), all of which may affect vegetation performance. Restoration monitors will walk transects across each zone to visually assess overall conditions and field verify conditions documented in the aerial images of the revegetation areas from UAV surveys preceding the spring and fall assessments. Monitors will record all plant and animal species observed to document species richness in each zone. Any small occurrences of invasive (plant) species will be immediately removed by the Restoration Monitor; larger invasive species infestations will be recorded and mapped for follow-up treatment. All qualitative observations will be recorded in a field notebook or standardized data form in the same manner during each assessment and used to inform adaptive management recommendations.

Quantitative Ground-Based Vegetation Surveys

Project State Assessment

The project state at the time of the quantitative vegetation monitoring will determine whether and how the vegetative cover assessment is performed in a given year. If the project is in a severely eroded or recently replenished/replanted state, appropriate alternative assessment methods will be implemented to document current conditions. See the *Vegetative Cover Assessment* and *Remote Sensing Growth Assessment* sections below for description of assessment methods that could be implemented under this HMMP.

Stable State

The project stable (growth) state is when each zone is functioning as designed and the Sacrificial Zone has not been severely affected by natural coastal processes such that a sand replenishment event is triggered. The Vegetative Stabilization Zone is intended to be stable but could be affected by significant sand accretion soon after a replenishment event and wind and wave erosion during large storm events resulting in loss of the Sacrificial Zone. The Stabilized Dune Zone backdune infiltration basins are expected to maintain a constant stable state because of their upland location but could be periodically affected by wind-blown sand deposition and maintenance removal of accumulated sand. If the stable project state is maintained sequentially for several years, vegetation in all zones is expected to progressively expand with each year.

Eroded State

Episodic storm events with severe, erosive wave uprush are anticipated to periodically erode the Sacrificial Zone, resulting in loss of sand and vegetation. When the project is in an eroded state, quantitative vegetation assessment methods will still be performed to document the vegetative loss and inform replanting. The assessment and discussion of monitoring results in the annual report related to performance criteria will acknowledge the eroded state.

Replenished/Replanted State

Severe erosion of the Sacrificial Zone which triggers a beach nourishment event will initiate the replenishment state and replanting to project design. As-built conditions will be documented following any replanting in mitigation zones. When the project is in the replenished/replanted state, seasonal timing and distance from planting will inform whether a quantitative assessment of vegetation is appropriate. Scheduled sand placement events would initiate no earlier than June 1 and last an estimated six weeks (MN+AGS JV, 2024). Emergency sand placement would be implemented as needed, according to the triggers established in the MAMP. Refer to MAMP Section 4, *Maintenance and Adaptive Management*, for a complete description of the triggers for beach nourishment episodes (MN+AGS JV, 2024). Replanting the Sacrificial Zone and/or Vegetative Stabilization Zone following a nourishment event would occur in the late fall to mid-winter, contingent on timing of cool-wet winter weather sufficient to fully moisten the sand profile and optimize propagule transplant success. It is likely quantitative monitoring of the Sacrificial Zone will not occur in years when the project is in a replenished state because replanting will occur later in the fall/winter than the fall monitoring event.

Vegetative Cover Assessment

In monitoring years where a quantitative assessment of vegetation is appropriate, and dependent on the state of each revegetation zone, vegetative cover will be quantitatively estimated using the transect/quadrat method. The revegetation zones will be sampled at an appropriate, proportional density/frequency, will be sampled in representative areas, and the selection of sampling locations will include an element of randomness. Specific sampling methods are described in greater detail, by zone, below. Transects or other sampling locations will be identified using geographic coordinates.

The first vegetative cover assessment will be conducted immediately following revegetation (and with each subsequent replanting), so that a revised baseline condition can be documented. Vegetative cover assessments will be repeated annually throughout the monitoring period and conducted at the end of the growing season (late summer-early fall) to document maximum annual vegetative growth.

Vegetative Stabilization Zone and Sacrificial Zone

A quantitative assessment of vegetation cover in the Vegetative Stabilization Zone and in the vegetated incipient foredune sub-zone of the Sacrificial Zone will begin by dividing the combined area north-south into 4-8 macroplots. Each macroplot will be approximately equal in size and contain an east-west cross section of the Vegetative Stabilization Zone and Sacrificial Zone. A grid will be superimposed over the macroplots, and 4-6 transect locations will be selected within each macroplot, at set intervals.

Restoration monitors will navigate to the predefined transect locations, and lay a transect tape from start to end point. Each transect will be approximately 10-25 meters long. For each transect, 3-6 quadrat sampling locations, and their position (right or left of the transect tape) will be randomly generated. Transect start/end locations, quadrat locations and positions will be established prior to the first quantitative assessment following revegetation, and will be replicated during each subsequent monitoring event when quantitative monitoirng is performed.

At each quadrat sampling location, a 1-meter square quadrat will be placed on the ground, and used to visually estimate percent cover of each plant species (see pages 10-13 of the California Native Plant Society's [CNPS] Relevé Protocol for estimating vegetation cover).[9] All plant species observed are recorded, along with their total cover value. Cover will be estimated for each species and for total cover using the following relevé-type cover classes: 0-1%, 1-5%, 5-15%, 15-25%, 25-50%, 50-75%, and >75%. With cover information for each species, the data can later be summarized to provide the total vegetation cover, total cover of native species, total cover of invasive species, or any other classification that may be important for assessing the performance of the revegetated areas.

Stabilized Dune Zone

The four project infiltration basins planted with backdune species are located between the service road and multi-use trail and comprise the Stabilized Dune Zone. Four representative transects will be established within this zone – one in each infiltration basin. The start location of each transect can be randomly generated, but the orientation will be designed so that it spans a representative elevational gradient (i.e. from the bottom of the basin to the top) in order to ensure a representative sample.

For each transect, 3-6 quadrat sampling locations, and their position (right or left of the transect tape) will be randomly generated. Transect start/end locations, quadrat locations and positions will be established prior to the first quantitative assessment following revegetation, and will be replicated during each subsequent monitoring event. Vegetative cover will be assessed using visual estimations of plant cover as described above in the methods for the Vegetative Stabilization Zone and Sacrificial Zone.

Alternative Patch Growth Assessment

During the baseline monitoring event following revegetation of the mitigation areas, an alternative quantitative monitoring method will be conducted in the Vegetative Stabilization Zone and the Sacrificial Zone for tracking vegetation establishment. This method, focused on measuring growth of individual vegetation patches, may be an informative metric applicable to the patchy nature of these mitigation areas and appropriate to implement following sand replenishment events and significant sand accretion within the Vegetative Stabilization Zone. Depending on the state of these two zones during the quantitative assessment within the monitoring period, either the patch growth assessment method or the transect/quadrat method will be implemented. The selected method will consider planting density of the two zones and will be used in subsequent monitoring events to capture the quantitative vegetation performance metrics.

Within the macroplots established in the Vegetative Stabilization Zone and in the vegetated incipient foredune sub-zone of the Sacrificial Zone, 10-15 individual patches of vegetation will be

[9] California Native Plant Society. 2007. Relevé Protocol CNPS Vegetation Committee, Revised August 23, 2007. Available: http://www.cnps.org/cnps/vegetation/pdf/cnps_releve_protocol_20070823.pdf.

randomly selected for that year. Restoration monitors will navigate to each selected patch, and measure the perimeter of the patch. An area of consistent vegetative cover will be mapped and quantified for each patch, and the average size of vegetated patches in each zone can be compared across monitoring years to assess growth.

Remote Sensing Growth Assessment

Using the aerial imagery collected by a UAV every six months, remote sensing analysis will be used to supplement ground vegetation surveys and provide a more holistic approach to vegetation establishment and performance seasonally and inter-annually.

Vegetative cover for each revegetation zone (i.e., Sacrificial Zone, Vegetative Stabilization Zone, and Stabilized Dune Zone) will be evaluated using remote sensing and images captured during each aerial survey in the spring and late summer/fall. Qualitative and quantitative onsite surveys will document plant species assemblages in each zone to aid the remote sensing analysis. This ground-truthing effort will improve accuracy of the remote sensing approach. During the establishment period, remote sensing cover results will supplement the quantitative assessment methods already described.

Once vegetation is established and the mitigation areas are determined successful, remote sensing to evaluate vegetative cover in all zones will continue to be used throughout the long-term monitoring of the project area and shoreline to inform adaptive management actions (e.g., replanting), consistent with the description in the MAMP.

Photodocumentation

Photo monitoring point locations will be established during baseline monitoring to document as-built conditions. Photos will be taken during each monitoring event at the same position, bearing, and camera angle to provide visual documentation of change over time. At least 10 photo monitoring points will be established throughout the site to capture different, representative perspectives of the revegetation areas. In addition, photos will be taken at the start and end points of each vegetation monitoring transect. The locations and bearings of each photo monitoring point will be recorded during the baseline monitoring event following revegetation.

MAMP Geomorphic Assessments

Routine geomorphic assessments of dune integrity, beach width, and sand movement are described in great detail in the MAMP (MN+AGS JV, 2024). The MAMP describes methods for regular monitoring and topographic surveying of the beach at South Ocean Beach and the North Ocean Beach sand borrow area, monitoring of pedestrian trails and access with respect to ingress of wind-blown sand, and outlines adaptive management actions to address variability in beach response and borrow area recovery as a result of sand backpassing, and erosion, deflation or other geomorphic changes over time. Results of the geomorphic assessments documenting the condition of the South Ocean Beach project area will inform whether a beach nourishment event is triggered. See the MAMP for details on the monitoring approach and conditions that would initiate sand placement.

4.3 Adaptive Management

Information gathered during the annual qualitative and quantitative monitoring of the planting areas will be used to assess success of the revegetation areas with respect to performance criteria. These results will be used to inform an adaptive management approach, and certain management actions may be recommended to proactively address any concerns. The MAMP contains a detailed description of adaptive management triggers and remedial actions. Adaptive management actions may include:

- Replacement plantings in one of the revegetation zones in response to plant mortality or burial;
- Repair or extension of the subsurface irrigation system, or modifications to the irrigation schedule in response to changes in precipitation;
- Replacement or addition of sand-catch structures (e.g., brush fencing) to address erosion-prone areas;
- Removal of accumulated sand from pedestrian use areas and infiltration basins; and
- Invasive species control and removal efforts.

The MAMP includes guidance for implementing adaptive management actions within the Sacrificial Zone and Vegetative Stabilization Zone, as well as for management of wind-blown sand, as summarized below (MN+AGS JV, 2024).

Sacrificial Zone

Triggers for sand replenishment include:

- Fifty feet or less beach width over 500 feet total length of beach, measured between the mean high water line and the face of the low profile wall. Implement sand replenishment in the following year, with a 12-month window to complete operations.
- Five hundred feet or more total length of the low profile wall is exposed above mean high water elevation. Implement an emergency sand placement to conceal the exposed wall.

Vegetative Stabilization Zone

Triggers for installation of brush fencing include:

- Evidence of blowouts. Install brush fencing in blowout areas to prevent further loss of dune sand.
- Significant ingress of wind-blown sand into pedestrian areas. Excavate and relocate sand and consider if methods for mitigation of wind-blown sand need to be augmented.

Triggers for potential dune restoration and replanting include:

- Significant loss of dune sand due to erosion or slope failure.
- Significant loss of native vegetation. Consult with biologist to determine cause of loss and whether replanting should be initiated.

- Declining or stagnating plant growth. Consult with biologist to determine cause of decline (e.g., the subirrigation system needs to be maintained or augmented).
- Excessive influx of weeds or invasive species resulting in fragmentation and decline of native species. Consult with biologist and consider removal of invasives and replanting with native plant species.

Wind-Blown Sand Management

The MAMP prescribes surveys of wind-blown sand encroachment into pedestrian areas be conducted every six months. These assessments should also evaluate whether removal of sand accumulated in the infiltration basins of the Dune Stabilization Zone is needed.

Triggers for wind-blown sand removal:

- Accumulation of sand to a level that presents a significant nuisance or obstacle to pedestrian traffic and/or vehicle access, inhibits functionality of the infiltration basins, or buries vegetation such that survival is threatened.
  – Immediate mitigation will be in the form of excavation and removal/relocation of the accumulated quantities of sand.
  – Removal of sand from the infiltration basins will be conducted with hand tools and under the direction of the Restoration Monitor to avoid or minimize inadvertent damage to vegetation.
  – With Restoration Monitor's input, assess whether augmentation of the sand trapping ability of vegetation in the Vegetative Stabilization Zone can aid in reducing the level of and ingress into pedestrian areas. Potential mitigation to limit ingress of wind-blown sand may be in the form of improved beachgrass straw-punch placement, brush fencing, or adapted sand berm crests. May alternatively warrant consideration of jute netting, slat fencing, and shell/pebble lag treatment if necessary.

Adaptive management related to beach nourishment and other aspects of the physical dune structure are addressed in the MAMP (M&N/AGS JV, 2024).

CHAPTER 5
Reporting

5.1 Baseline Report

An initial baseline report will be prepared to document as-built conditions. This report will be submitted within 90 days after completion of monitoring activities following initial planting of the revegetation zones. Monitoring methods, analysis, and results will be described in a report to document conditions immediately following project implementation.

5.2 Annual Report

Annual monitoring reports will be prepared by the SFPUC and submitted to the Commission each monitoring year by January 31st, with the first monitoring year commencing in the spring the calendar year after completing revegetation of the mitigation areas. Each annual report will summarize the prior year's monitoring results and recommendations, including the need for, and implementation of, any adaptive management actions to achieve the performance criteria. The annual reports will compare data to previous monitoring years and describe progress towards meeting the mitigation goals and objectives. The final monitoring report will document how the created coastal dune habitat satisfies the mitigation goals and objectives sufficient to compensate for project impacts and will be submitted for the review and approval of the Commission's Executive Director.

Annual reports will include the following information:

- Summary description of the monitoring methods, including schedule, data collection and analysis;
- A qualitative assessment of the revegetated areas, including a general discussion of site conditions and changes since the previous report;
- Vegetative cover and species richness;
- Analysis of success in relation to performance criteria and mitigation goals and objectives; and
- A discussion of any 1) remedial actions undertaken during the monitoring and reporting period; 2) recommendations for additional remedial actions to be implemented during the next monitoring and reporting period, such as invasive species control, replanting, or erosion/sediment control measures needed to improve revegetation area performance.

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CHAPTER 6
References

Barnard, P.L., Hansen, J.E., and Erikson, L.H. (2012). Synthesis Study of an Erosion Hot Spot, Ocean Beach, California. Journal of Coastal Research, Vol. 28, Issue 4, p. 903-922.

Environmental Science Associates, 2022. Memorandum: Ocean Beach Climate Adaptation Project – Dune Delineation. Prepared for Julie Moore, San Francisco Planning Department, JT Mates-Muchin and Karen Frye, San Francisco Public Utilities Commission. December 28, 2022.

Moffatt & Nichol and AGS Joint Venture (M&N/AGS JV), 2024. Ocean Beach Climate Change Adaptation Project, Monitoring and Adaptive Monitoring Plan. Prepared for San Francisco Water Power Sewer. March 2024.

M&N/AGS JV, 2024. Ocean Beach Climate Change Adaptation Project, Habitat Restoration and Enhancement Plan. Prepared for San Francisco Water Power Sewer. February 2024.

San Francisco Planning, 2021. Ocean Beach Climate Change Adaptation Project. Case No. 2019-020115ENV. Draft Environmental Impact Report (DEIR). State Clearinghouse No. 2020090171. December 8, 2021.

San Francisco Planning, 2023. Ocean Beach Climate Change Adaptation Project. Case No. 2019-020115ENV. Draft EIR Responses to Comments. State Clearinghouse No. 2020090171. September 14, 2023.

San Francisco Public Utilities Commission (SFPUC), 2018. Alternatives Analysis Report for Coastal Adaptation Strategies for South Ocean Beach Wastewater Systems, February 15, 2018.

SPUR, AECOM, ESA PWA, Nelson\Nygaard, Sherwood Design Engineers, Phil D. King, PhD, 2012, Ocean Beach Master Plan, Prepared for State of California Coastal Conservancy, San Francisco Public Utilities Commission, and the National Park Service.

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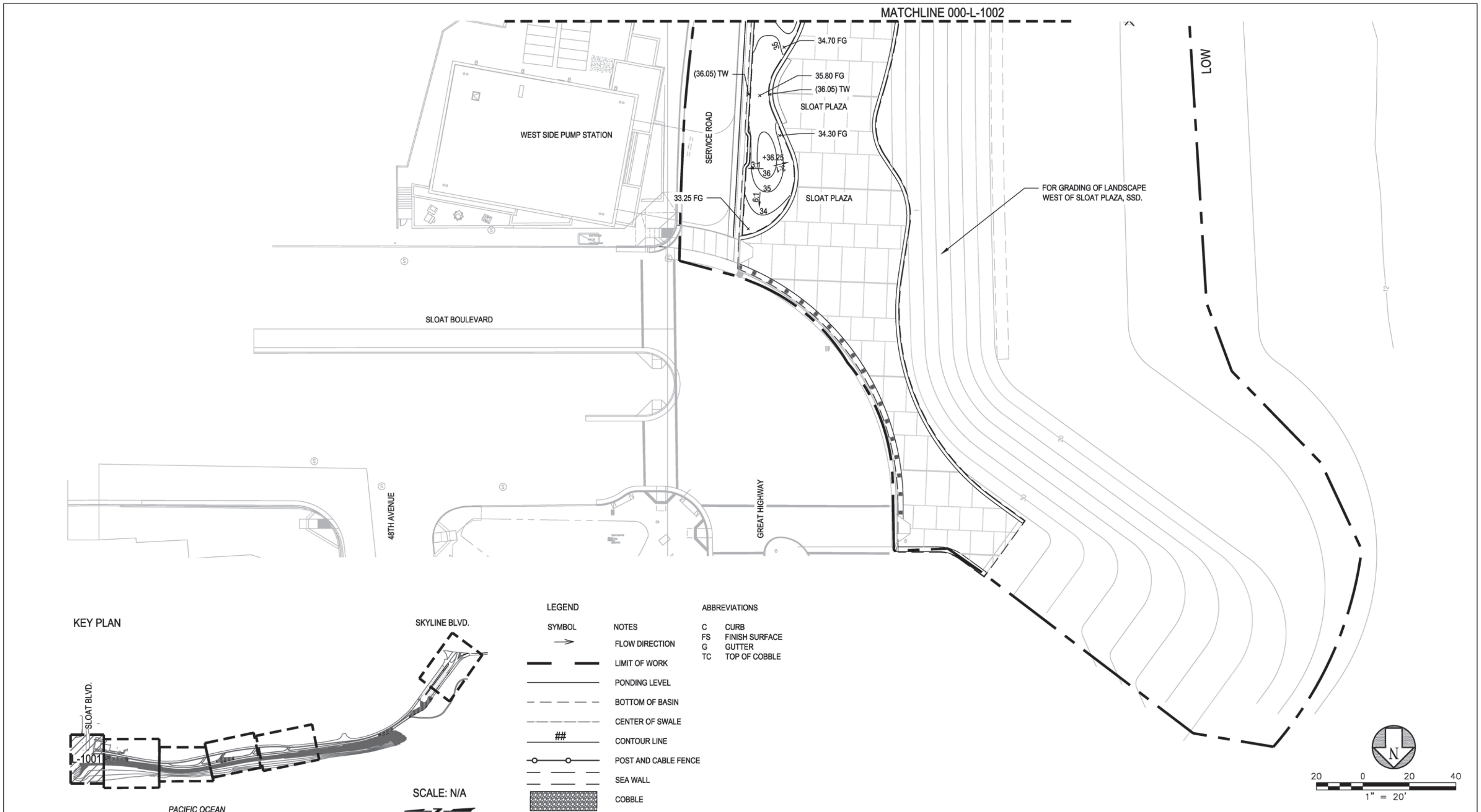
Appendix A
Planting Plan Set



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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: GRADING PLAN - SLOAT PLAZA
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-1001
Revision No. 0
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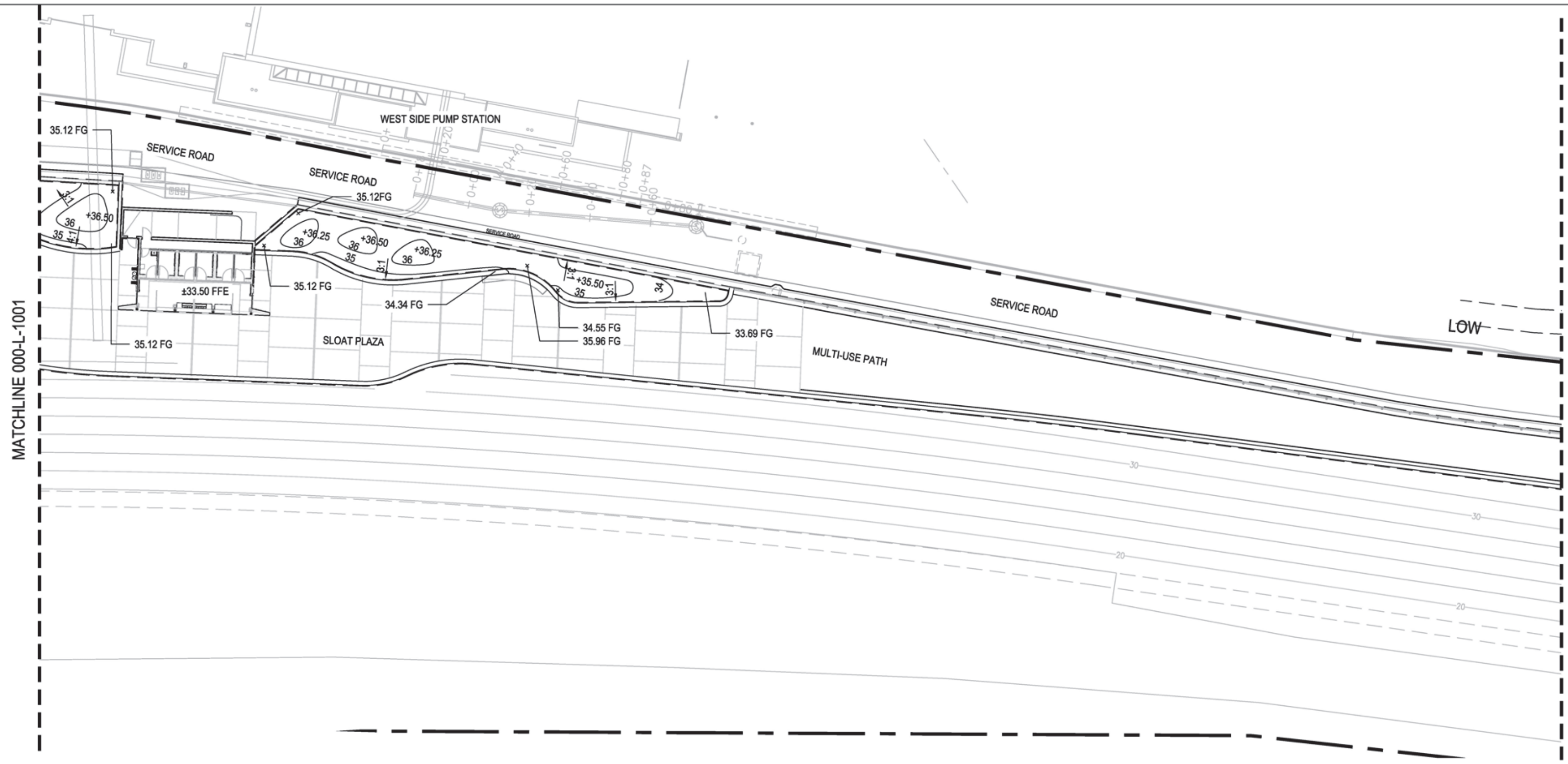

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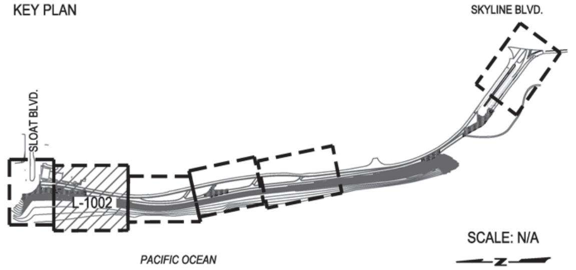

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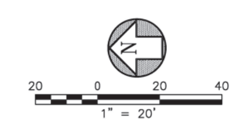

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WWE O&M Mgr.	Section Mgr. ANTHONY ESTERBROOKS		Plan No.
Section Mgr. HEATHER MANDERS	Proj. Engr.		Contract No WW-662
Designed	Designed SG		Drawing Title: GRADING PLAN - SLOAT PLAZA
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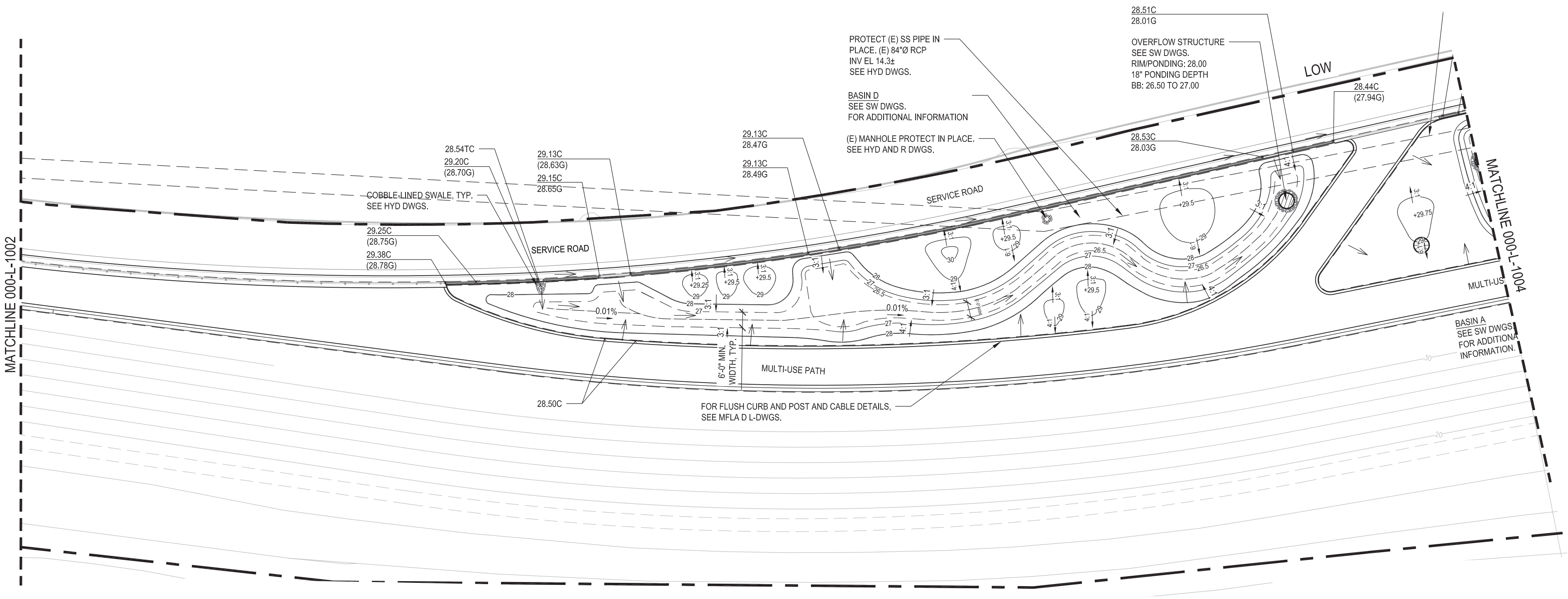

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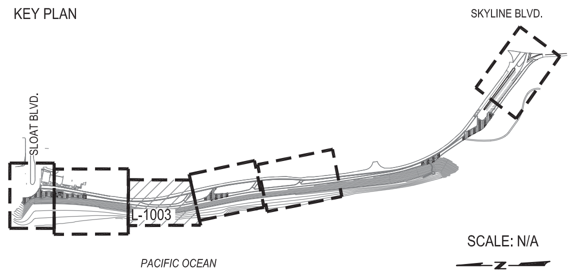

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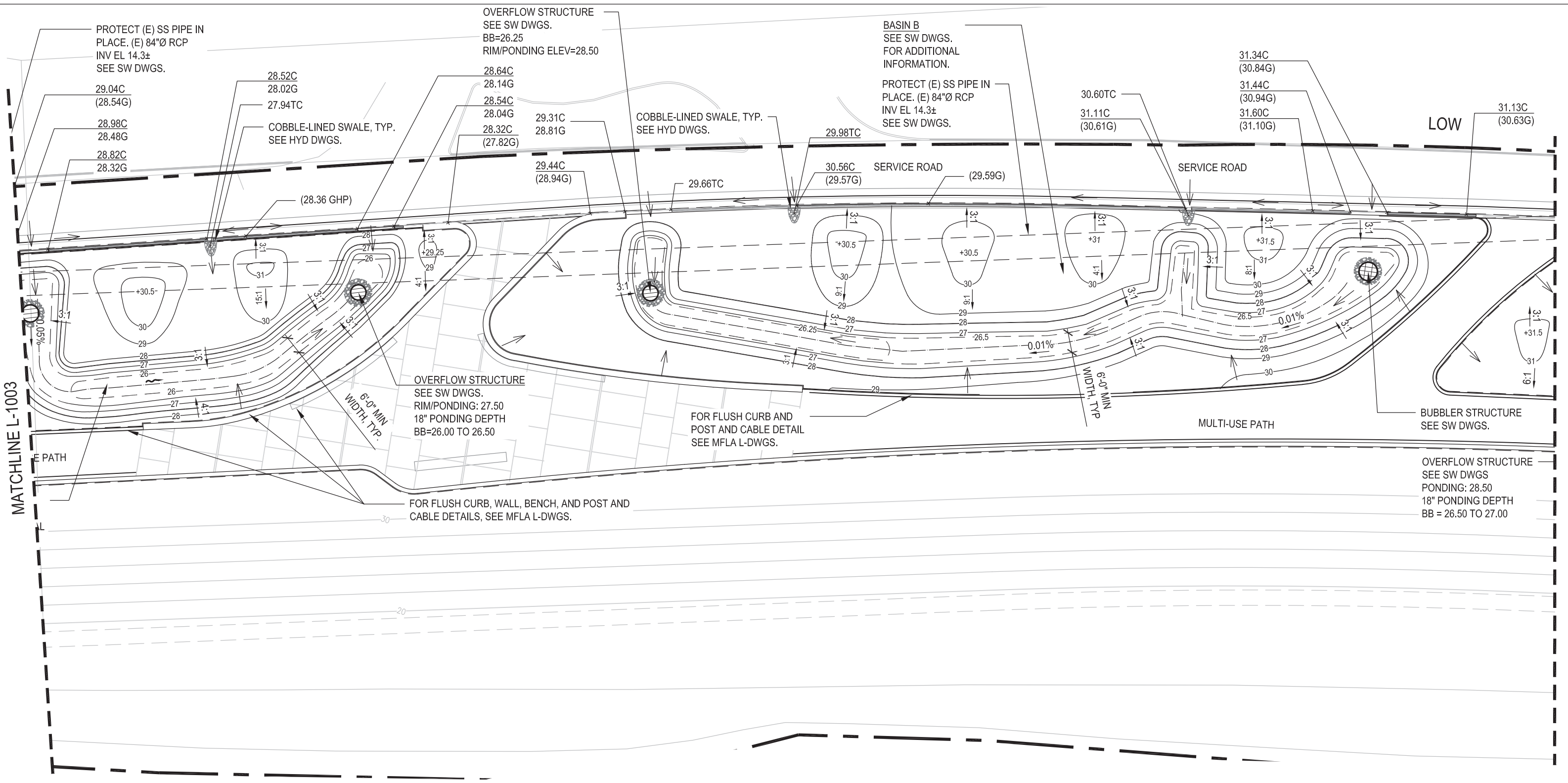

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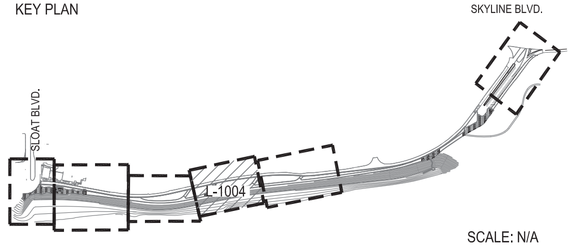

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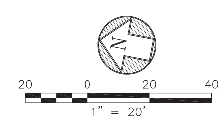

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Plan No.

Contract No: WW-662

Drawing Title: GRADING PLAN

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-1009

Revision No.: 0

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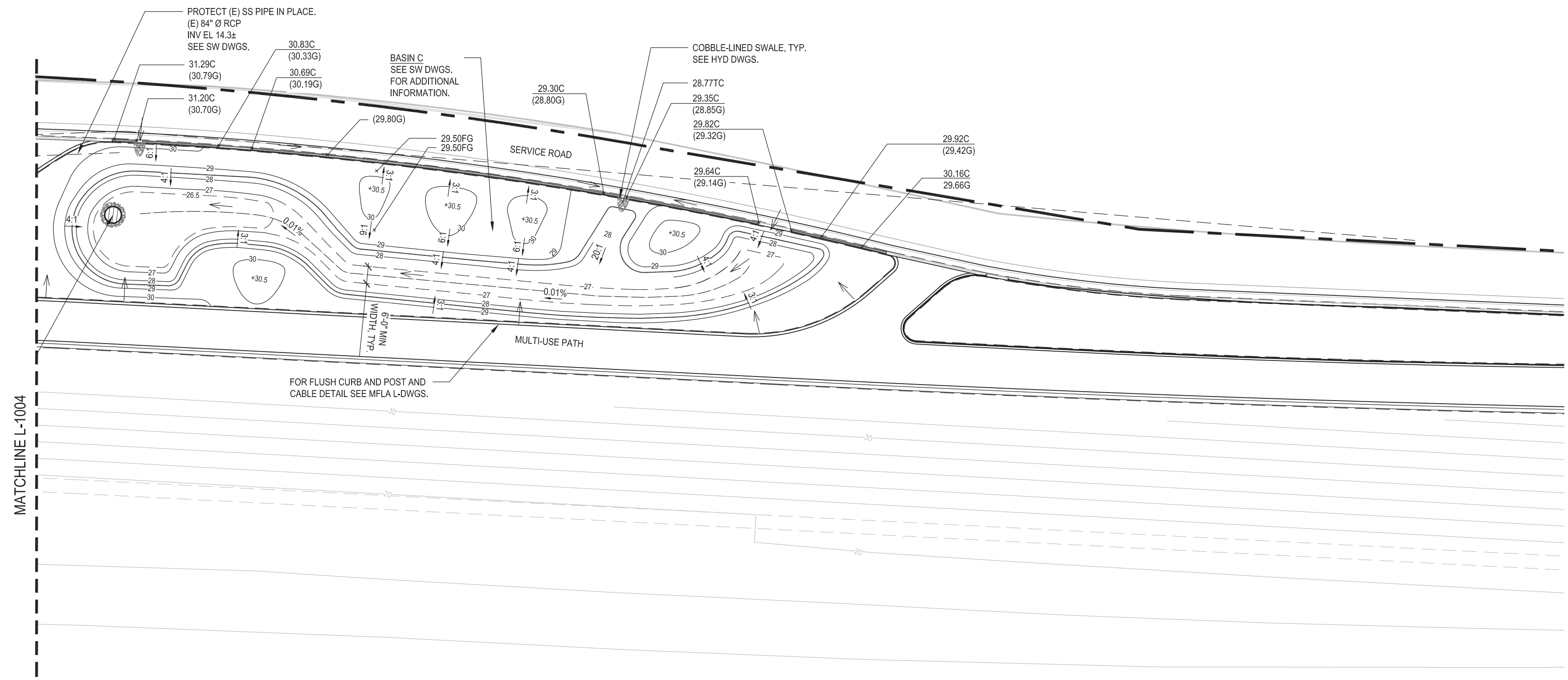

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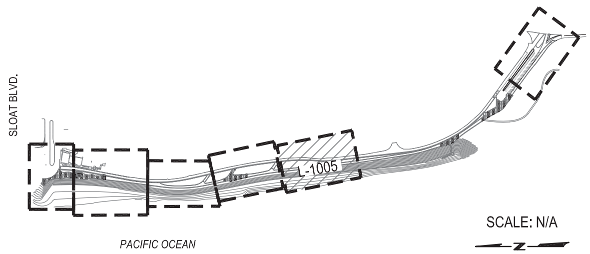

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Contract No: WW-662

Drawing Title: GRADING PLAN

Project No.: 1138I

Elevation Datum

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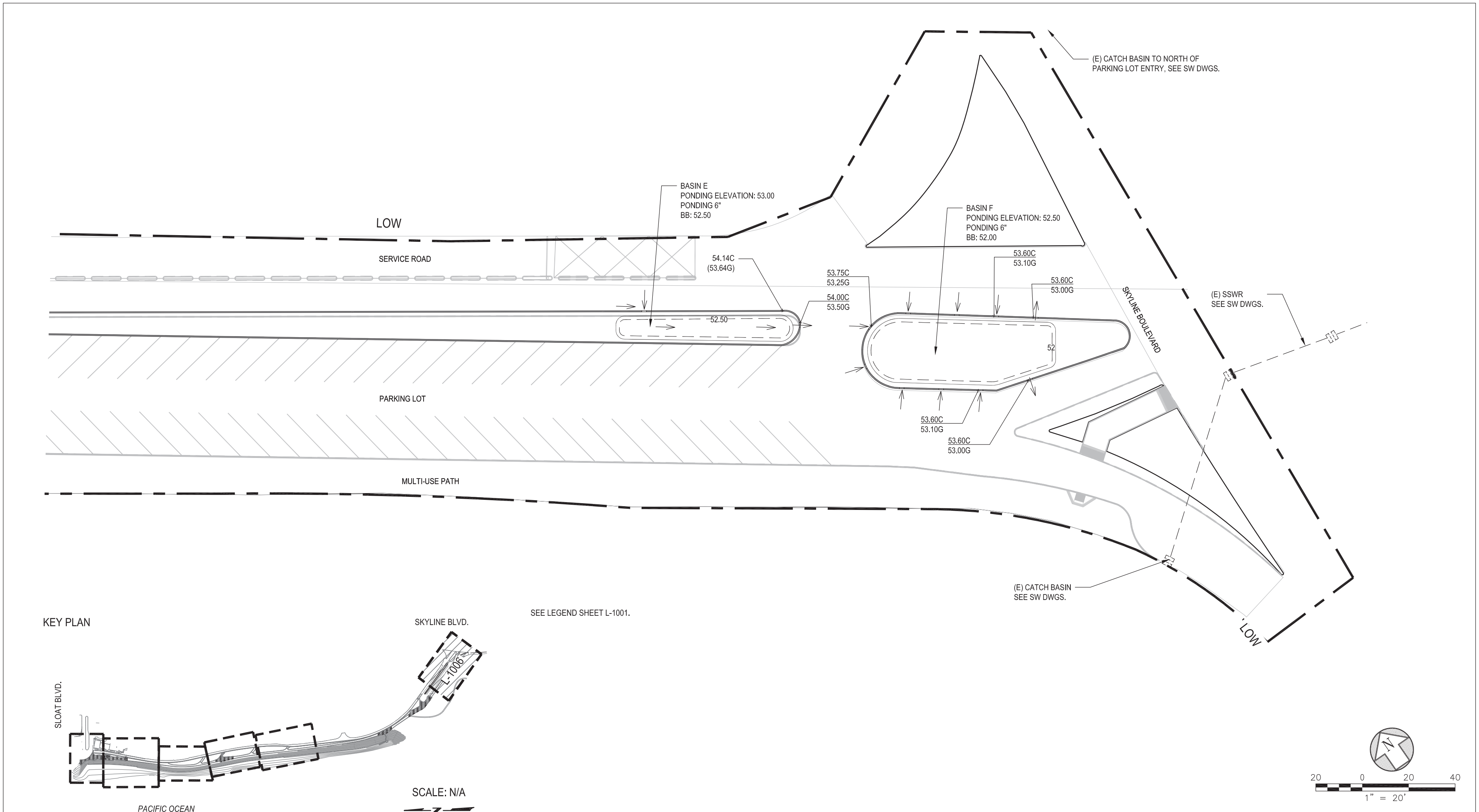
Exhibit 4
2-21-0912
Page 52 of 95



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Contract No: WW-662

Drawing Title: GRADING PLAN

Project No.: 1138I

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Exhibit 4
2-21-0912
Page 53 of 95

LATERAL PIPING SIZE SCHEDULE	
GPM	PIPE SIZE (NOMINAL SCH 40 PVC)
8 OR LESS	3/4" Ø
13	1" Ø
23	1 1/4" Ø
32	1 1/2" Ø
53	2" Ø
74	2 1/2" Ø
116 OR MORE	3" Ø

NOTE:
REFER TO THE IRRIGATION LEGEND FOR SPRINKLER FLOW RATES (GPM), NO PIPING DOWNSTREAM OF THE REMOTE CONTROL VALVE TO THE SPRINKLER SHALL BE SIZED SMALLER THAN THE SPRINKLER THREADED INLET SIZE.

KEY: 1 STATION NUMBER, 2 SIZE, 25 GPM

IRRIGATION LEGEND

SYMBOL	MFR	EQUIPMENT	DETAIL
WM	(N)	2" IRRIGATION ONLY WATER METER, SEE NOTES	
	MFR	EQUIPMENT	
	HUNTER	ECO-WRAP 12" DRIP TUBING	1 / L-X
C	HUNTER	ACC DUEL CONTROLLER WITH ET SENSOR, 48 STATIONS	
B	FEBCO	LEAD FREE BACKFLOW PREVENTER W/ SS ENCLOSURE	1 / L-X
	HUNTER	QUICK COUPLER HQ44 - LRC	5 / L-X
	HUNTER/NIBCO/ CHRISTY	1" REMOTE CONTROL VALVE ASSEMBLY: HUNTER IBZ-151-40-XL WITH NIBCO 1" LEAD FREE BRONZE FNPT BALL ISOLATION VALVE.	4 / L-X
	TORO	5/8" VALVE ASSEMBLY FOR DRIPTUBING	
	NIBCO	1" T-1013 BRASS GATE VALVE	2 / L-X
	-	2" HDPE MAINLINE	
	-	PVC IRRIGATION LATERAL; SEE PIPE LATERAL PIPE SIZING SCHEDULE	
	-	2" DIA PVC PERFORATED PIPE SURROUNDING 5/8" TORO AQUA TRAXX AGRICULTRUAL DRIPLINE	2.65 GPM/100 FT
FS	-	FLOW SENSOR	
	TORO	AIR RELIEF VALVE - 5/8" MPT CONNECTION	
	HUNTER	MP ROTATOR 3000, 2000, 1000	
	HUNTER	RZWS-36 (2 PER TREE)	

DUNE GRASS

UNPLANTED SACRIFICIAL DUNE

IRRIGATION NOTES:

1. THIS PLAN IS DIAGRAMMATIC.
2. ALL VALVES AND METERS TO BE HOUSED IN LOCKING BOXES W/ TOPS SET FLUSH TO ADJACENT PAVING OR MULCH.
3. IRRIGATION NOZZLE SPACING TO PROVIDE FULL COVERAGE OF PLANTING AREAS WITHOUT OVERSPRAY ONTO PAVING.
4. CONTRACTOR TO COORDINATE AND PAY FOR NEW WATER METER INSTALLATION
5. THESE NOTES AND IRRIGATION PLAN GOVERN IRRIGATION INSTALLATION ONLY AND ARE NOT INTENDED TO GOVERN OTHER WORK.
6. THE CONTRACTOR SHALL VERIFY LOCATIONS OF POINT OF CONNECTION, MAINLINES, AND PROPOSED CONTROLLERS, PRIOR TO COMMENCEMENT OF WORK. ANY DISCREPANCY BETWEEN THE DRAWING AND FIELD CONDITIONS SHALL BE BROUGHT TO THE ATTENTION OF THE ENGINEER PRIOR TO THE INSTALLATION OF ANY PIPE.
7. THE CONTRACTOR IS RESPONSIBLE FOR THE INSTALLATION OF AN IRRIGATION SYSTEM THAT PROVIDES 100% COMPLETE AND APPROPRIATE COVERAGE IN ALL PLANTING AREAS. THE WORK OF THE CONTRACT INCLUDES ADJUSTMENTS TO THE SYSTEMS INDICATED, INCLUDING QUANTITIES OF PIPING, HEADS, NOZZLES AND OTHER EQUIPMENT AS NECESSARY TO ASSURE COMPLETE COVERAGE.
8. THE IRRIGATION DRAWINGS ARE DIAGRAMMATIC, AND DO NOT SHOW EXACT LOCATIONS OF PIPING, VALVES OR CONTROL LINES. INSTALL THESE ITEMS IN PLANTING AREAS PARALLEL TO, AND AS CLOSE AS POSSIBLE TO CURBS, HEADERS OR PAVING EDGES UNLESS OTHERWISE INDICATED.
9. THE CONTRACTOR SHALL COORDINATE WORK WITH ALL APPROPRIATE TRADES FOR THE INSTALLATION OF PIPING, PIPE SLEEVES AND ELECTRICAL CONDUIT.
10. ALL PIPING AND CONTROL WIRING UNDER PAVING SHALL BE INSTALLED IN SCHEDULE 40 GALVANIZED STEEL PIPE SLEEVES OF SUFFICIENT SIZE TO ALLOW FOR EASY INSERTION AND REMOVAL. INSTALL EACH SOLENOID VALVE IN A SEPARATE VALVE BOX. SEE DETAILS AND SPECIFICATIONS.
11. IRRIGATION HEADS ARE INDICATED AS ACCURATELY AS POSSIBLE ON THE DRAWING. INSTALL HEADS AS SHOWN AT THE CENTERLINE OF THE SYMBOL, AND IN ACCORDANCE WITH INSTALLATION DETAILS.
12. THE PROPOSED CONTROLLER SHALL BE INSTALLED PER MANUFACTURER'S INSTRUCTIONS AND FINAL LOCATION SHALL BE FIELD LOCATED BY THE CITY REPRESENTATIVE

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Plan No.

Contract No WW-662

Drawing Title: IRRIGATION LEGEND AND NOTES

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-0002

Revision No. 0

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Contract No: WW-662

Drawing Title: IRRIGATION PLAN

Project No.: 1138I

Elevation Datum

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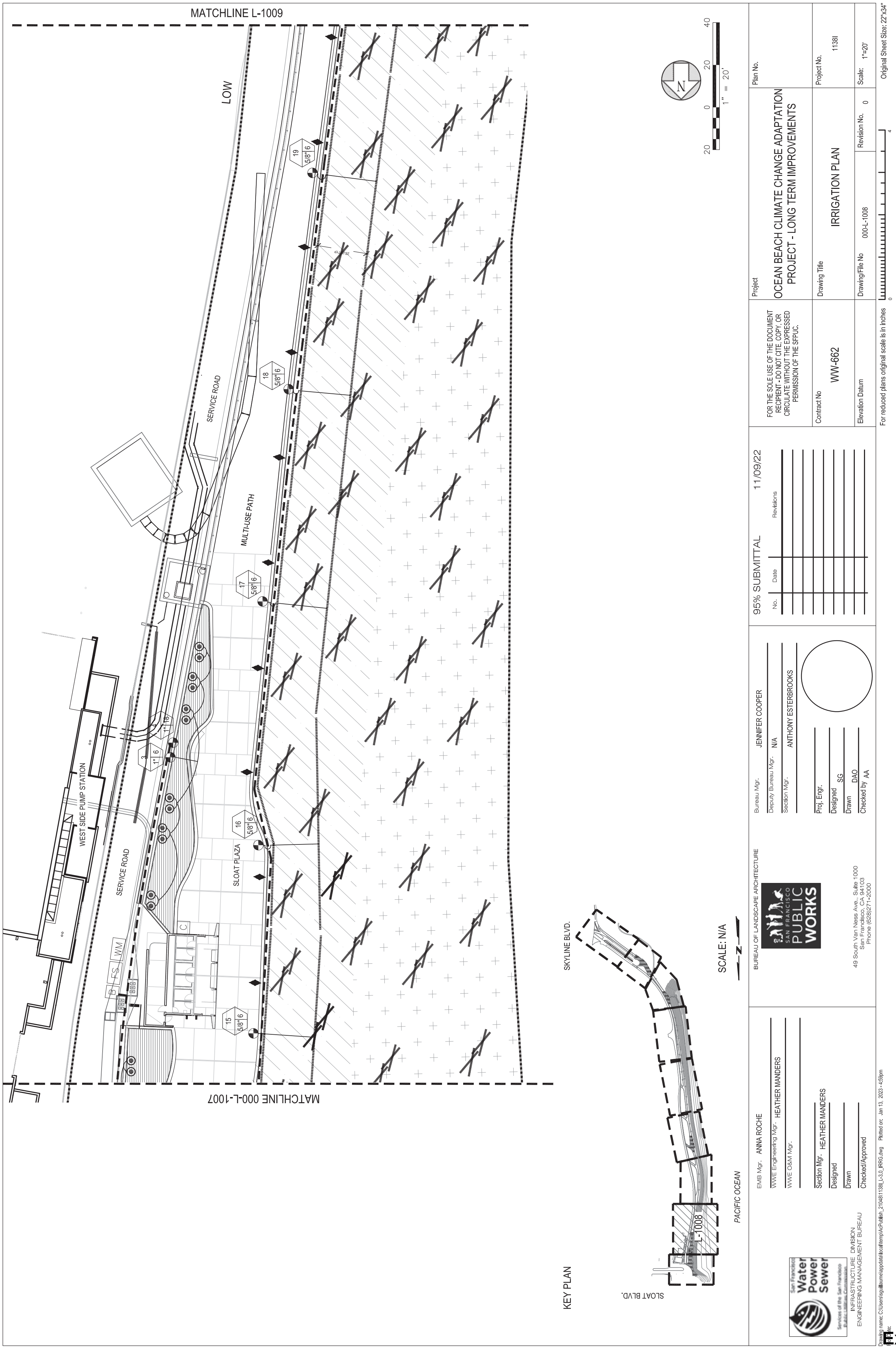
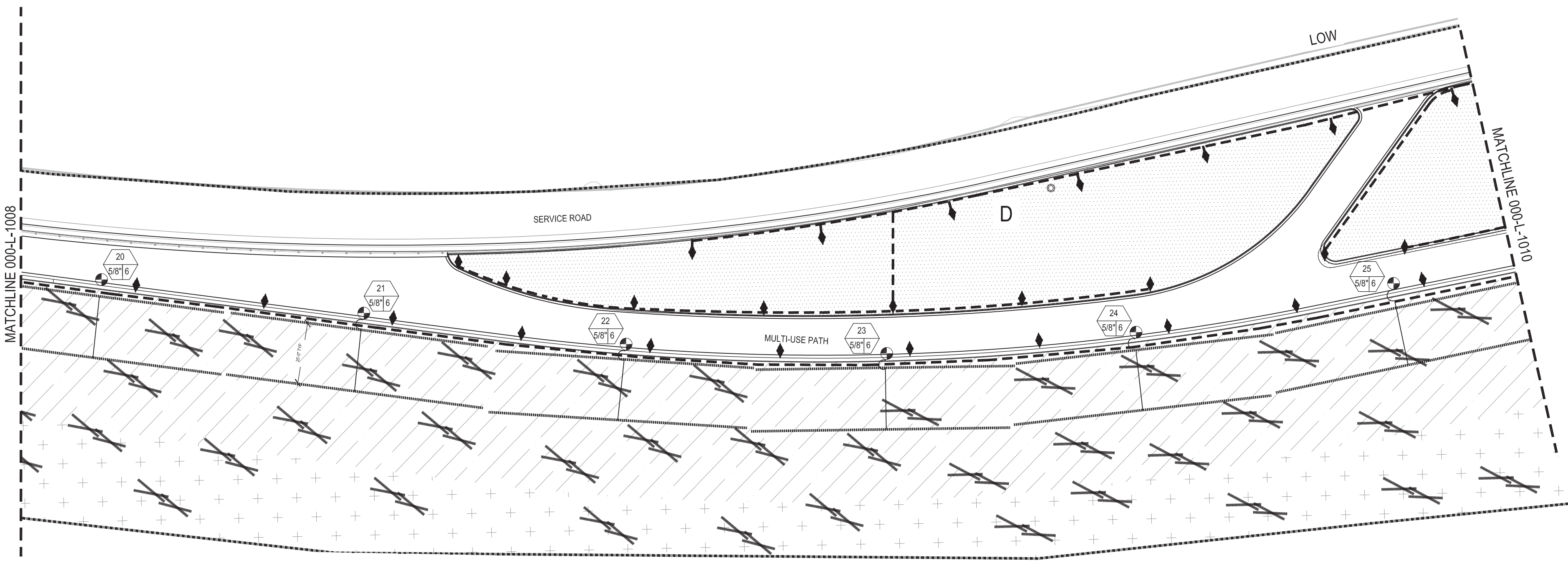


Exhibit 4
2-21-0912
Page 56 of 95



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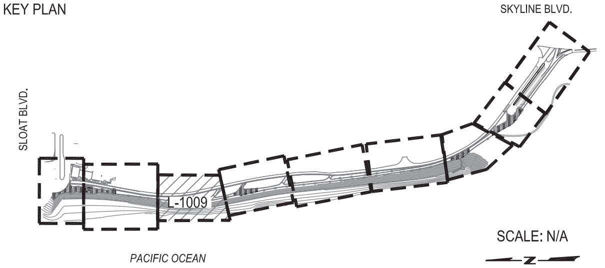

SCALE: N/A

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Plan No.

Contract No: WW-662

Drawing Title: IRRIGATION PLAN

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-1009

Revision No.: 0

Scale: 1"=20'

For reduced plans original scale is in inches

Original Sheet Size: 22"x34"

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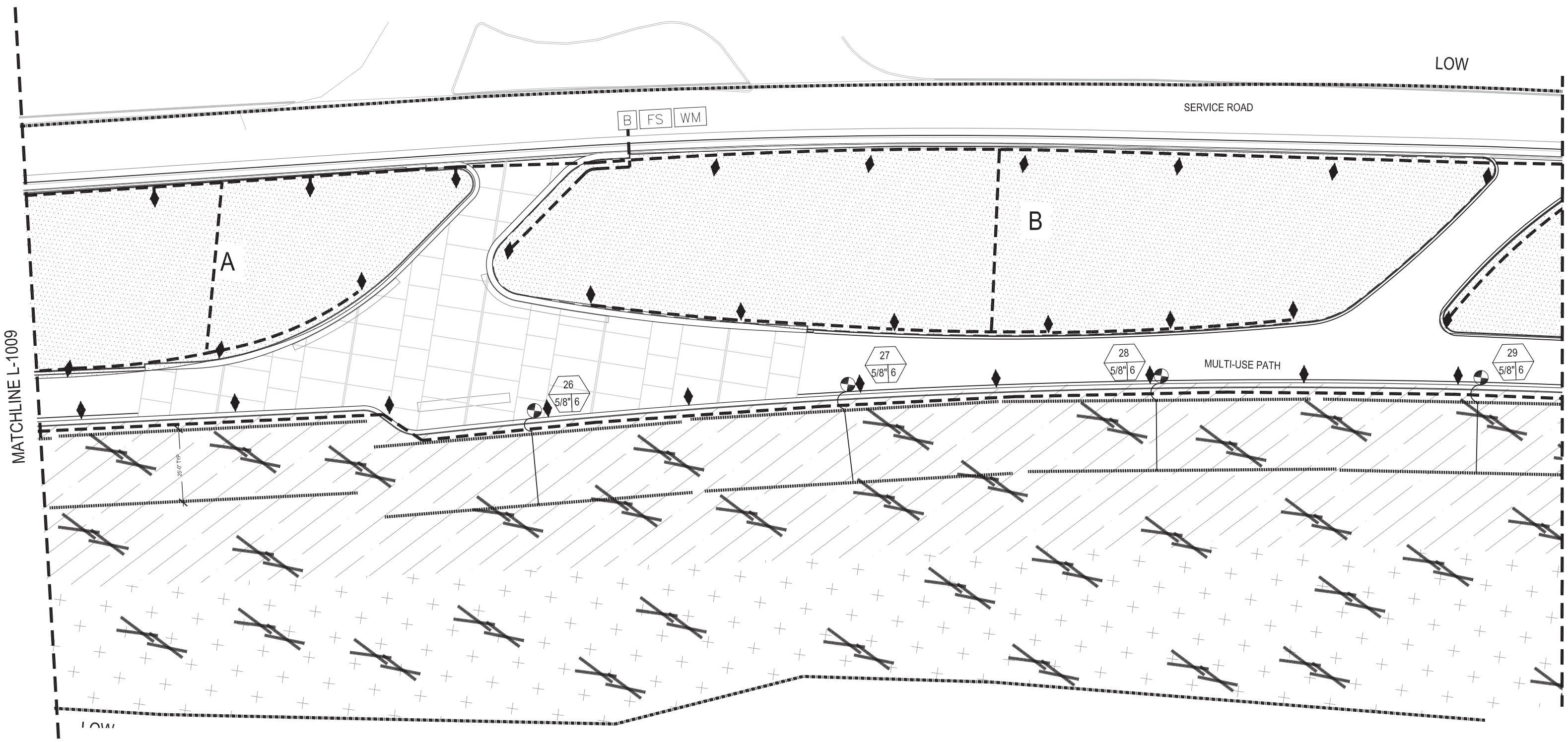

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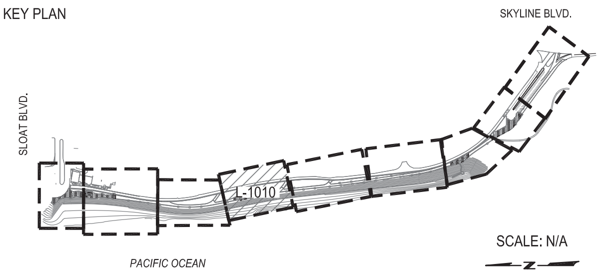

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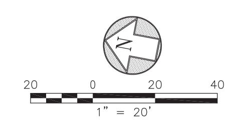

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Section Mgr.	HEATHER MANDERS
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Drawn	DAO
Checked by	AA

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No.	Date	Revisions

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: IRRIGATION PLAN

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-1010

Revision No.: 0

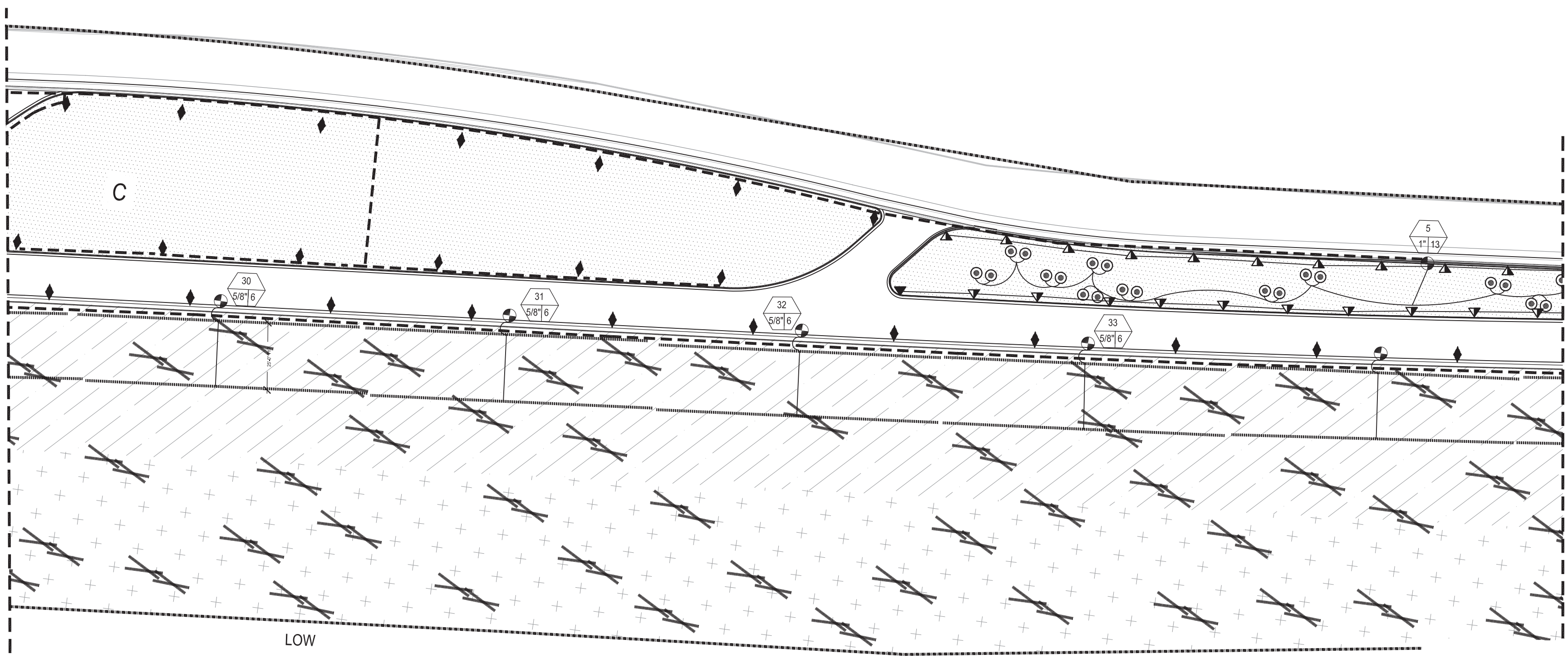
Scale: 1"=20'

For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-3.0_IRRG.dwg Plotted on: Jan 13, 2023 - 4:59pm



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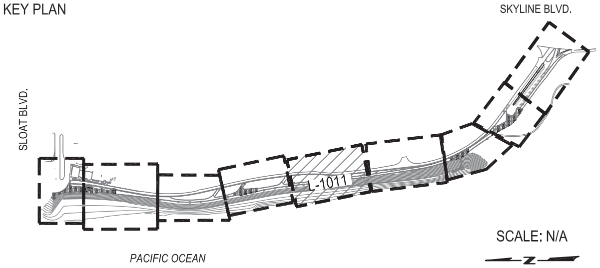

SCALE: N/A

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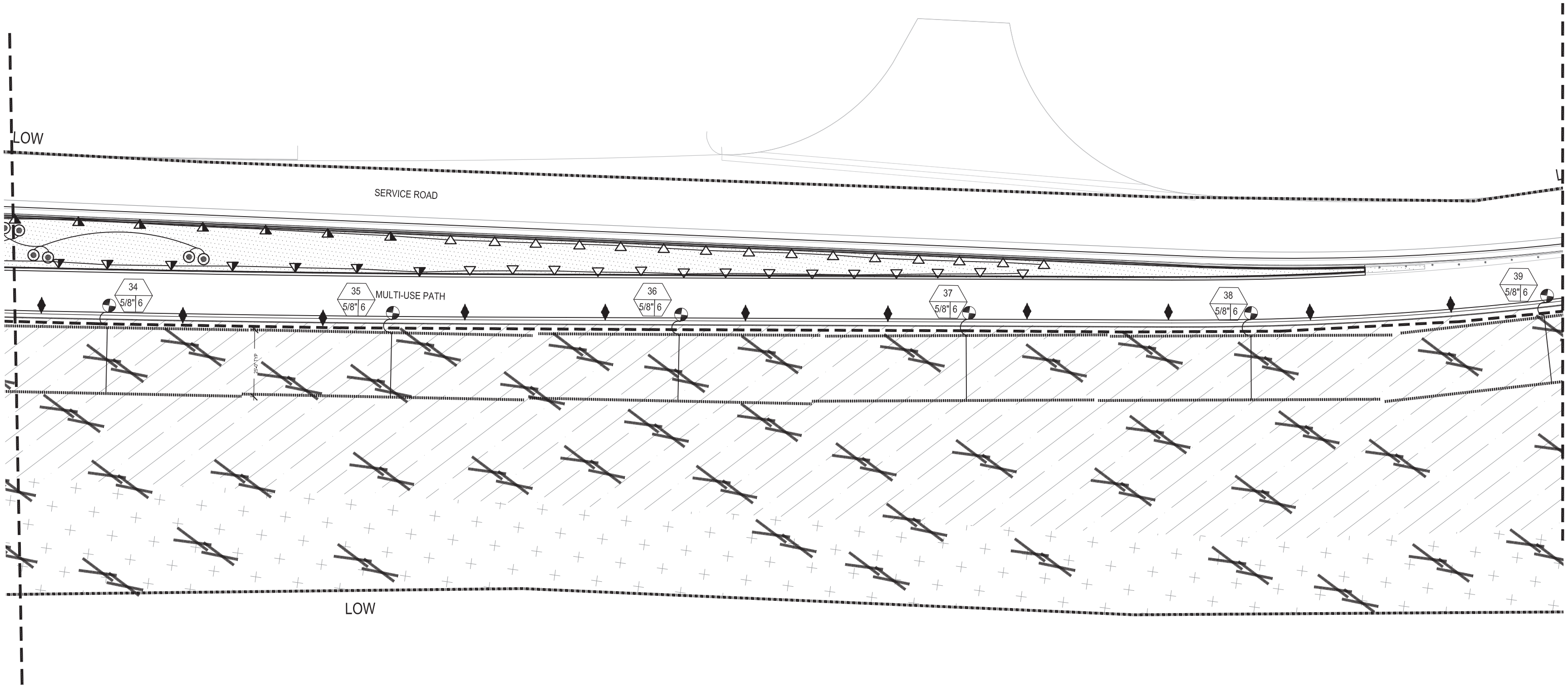
Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: IRRIGATION PLAN
Project No.: 1138I
Elevation Datum
Drawing/File No: 000-L-1011
Revision No.: 0
Scale: 1"=20'

For reduced plans original scale is in inches
Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-3.0_IRRG.dwg Plotted on: Jan 13, 2023 - 4:59pm

Exhibit 4
2-21-0912
Page 59 of 95



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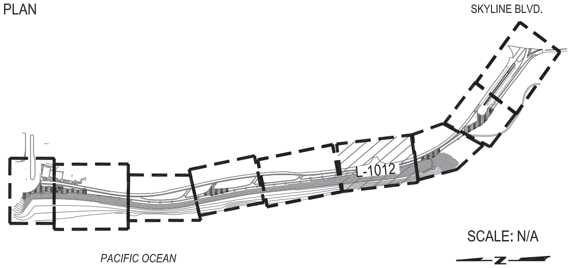

SCALE: N/A

20 0 20 40
1" = 20'

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: IRRIGATION PLAN

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-1012

Revision No. 0

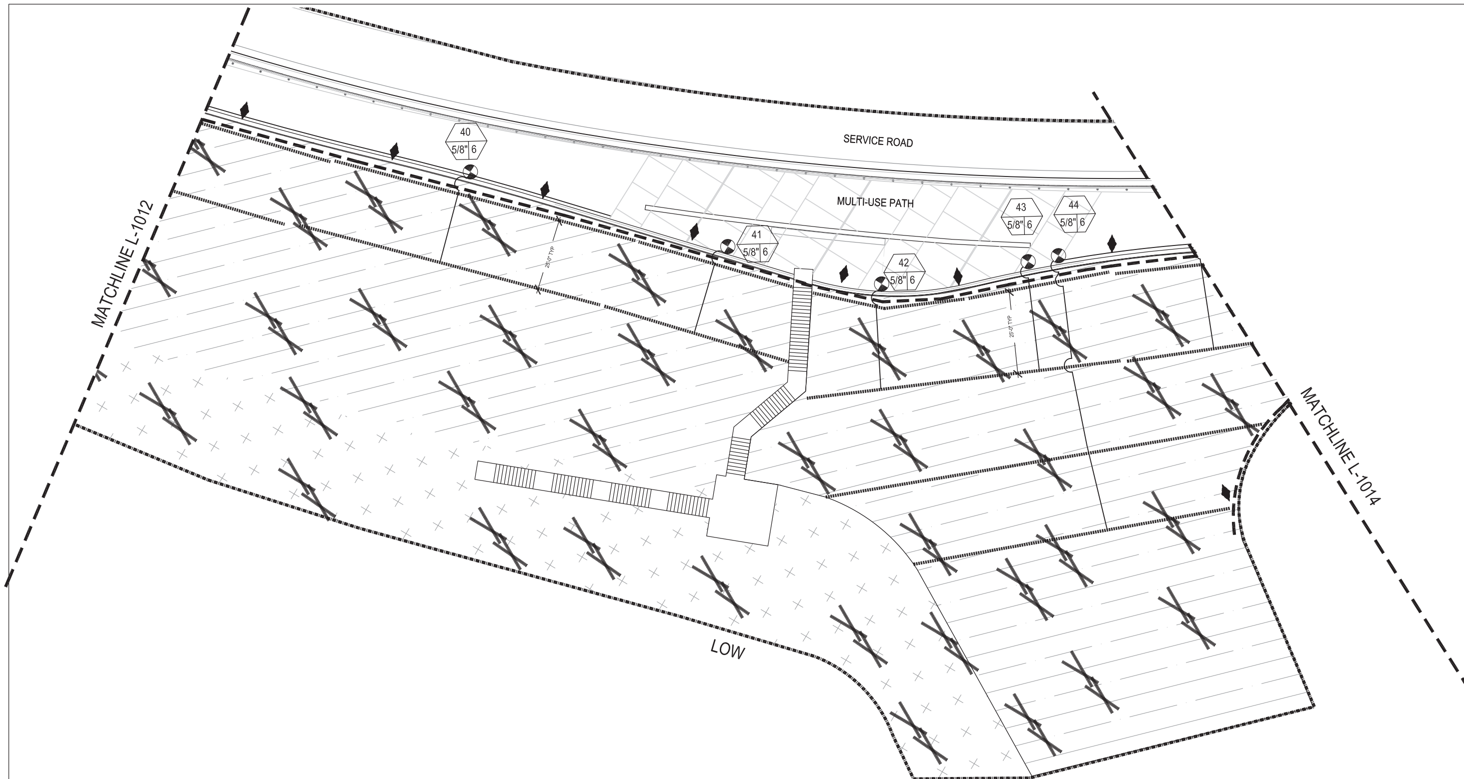
Scale: 1"=20'

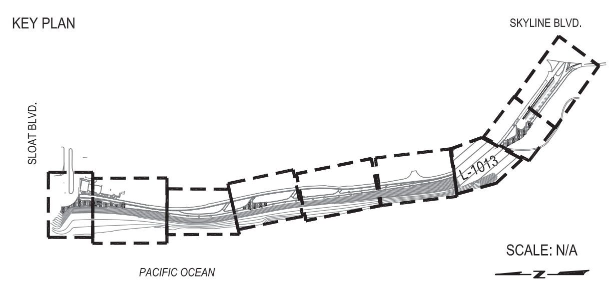
For reduced plans original scale is in inches

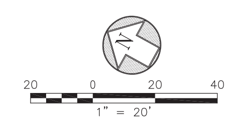
Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-3.0_IRRG.dwg Plotted on: Jan 13, 2023 - 4:59pm

Exhibit 4
2-21-0912
Page 60 of 95







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Plan No.

Contract No: WW-662

Drawing Title: IRRIGATION PLAN

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-1013

Revision No.: 0

Scale: 1"=20'

For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"

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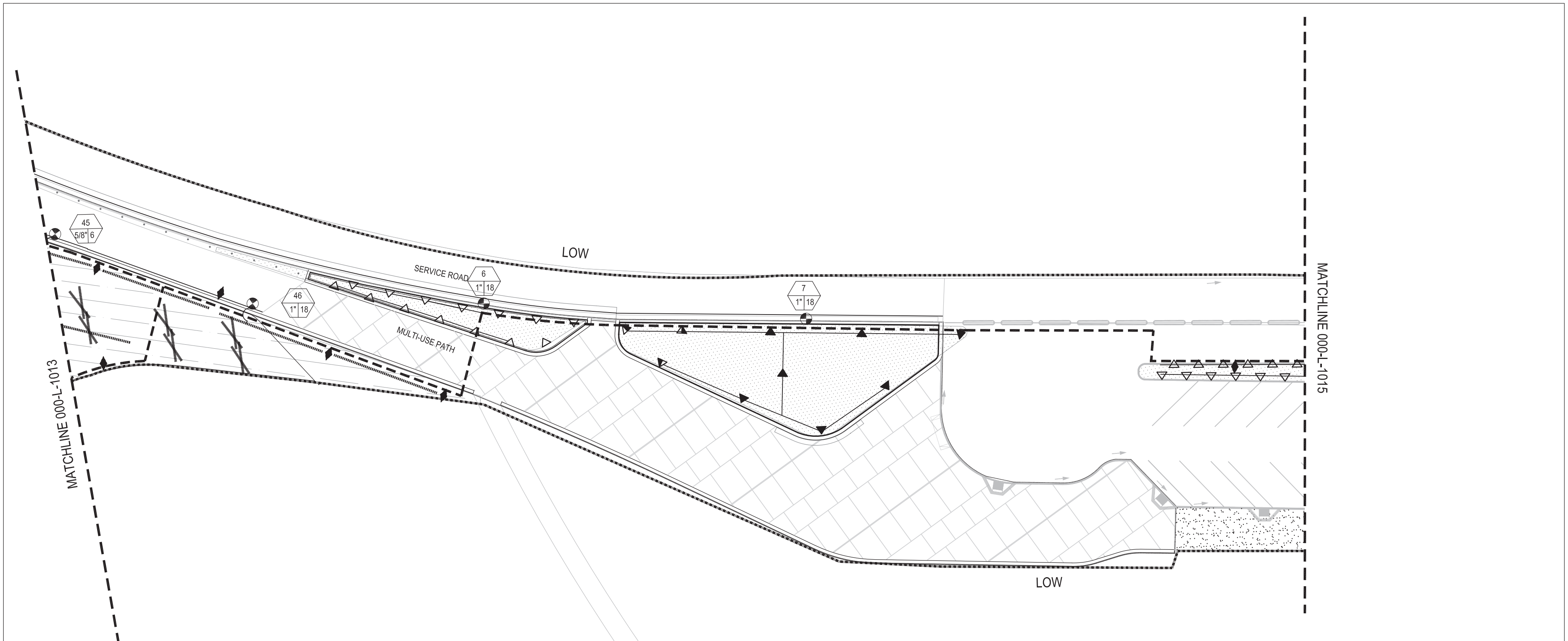
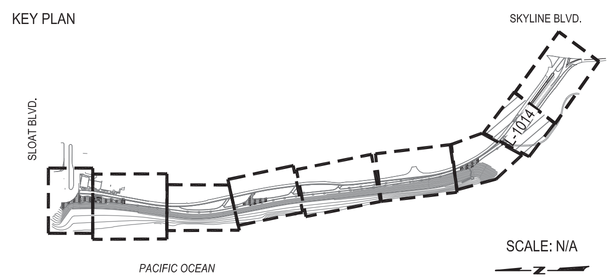
Exhibit 4
2-21-0912
Page 61 of 95





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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: IRRIGATION PLAN

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-1014

Revision No.: 0

Scale: 1"=20'

For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

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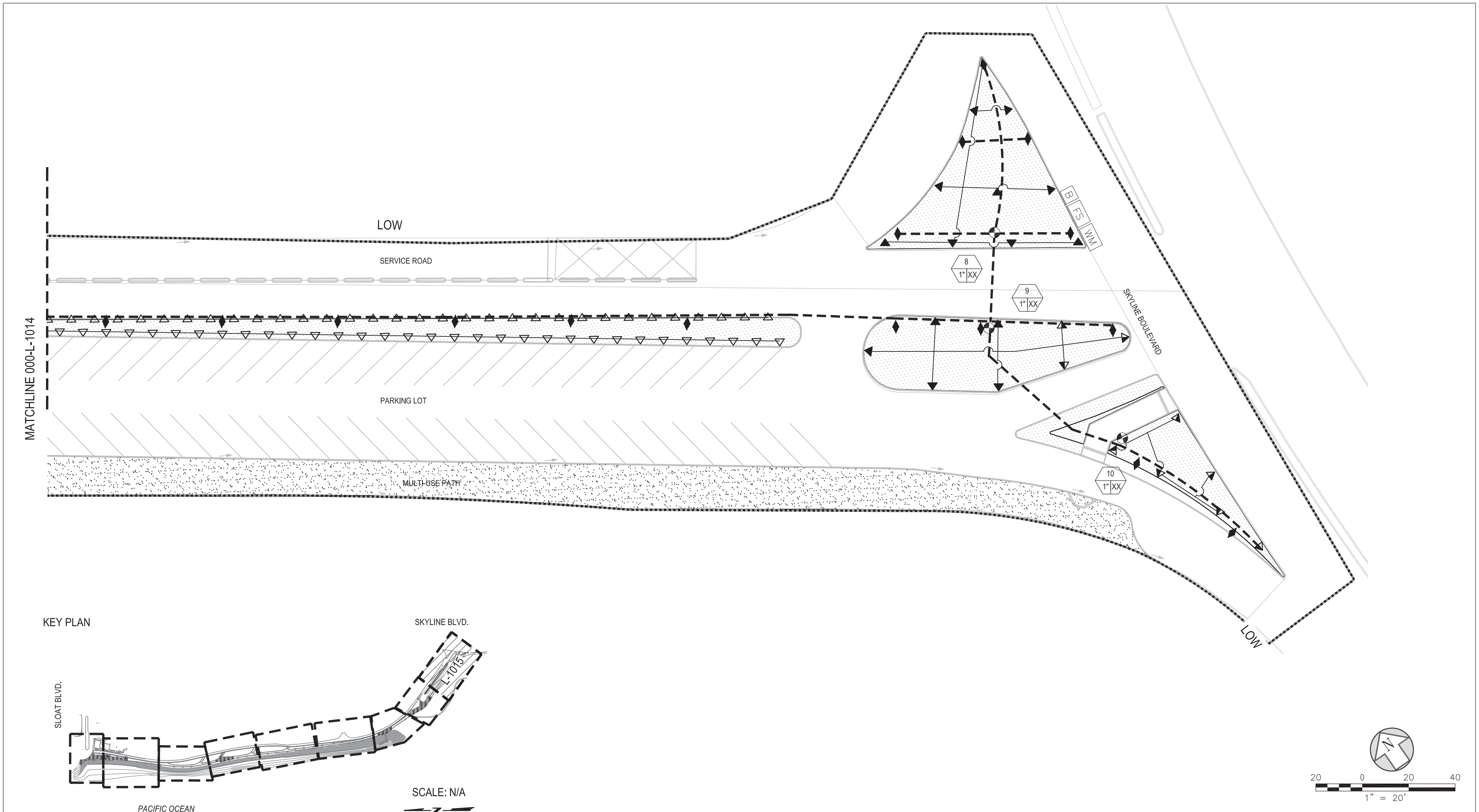
Exhibit 4
2-21-0912
Page 62 of 95



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Contract No
WW-662

Elevation Datum

Project
OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Drawing Title
IRRIGATION PLAN

Drawing/File No 000-L-1015
Revision No. 0

Plan No.

Project No. 1138I

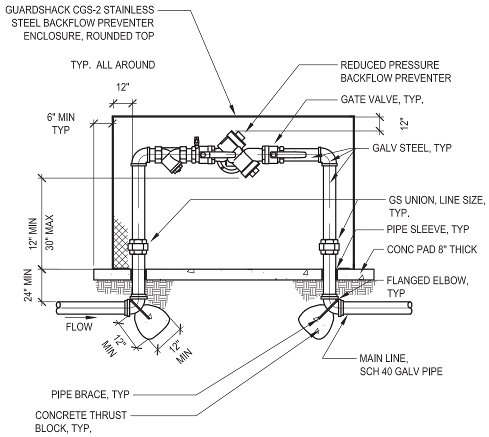
Scale: 1"=20'

For reduced plans original scale is in inches

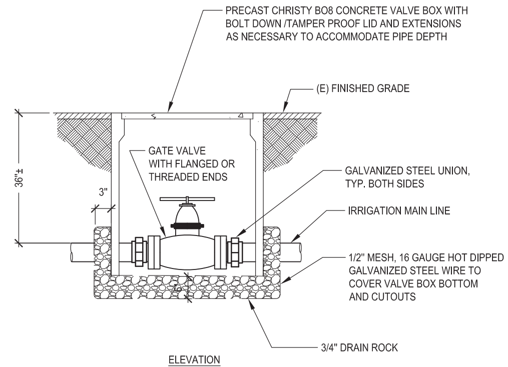
Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-3.0_IRRG.dwg Plotted on: Jan 13, 2023 - 5:01pm

Exhibit 4
2-21-0912
Page 63 of 95



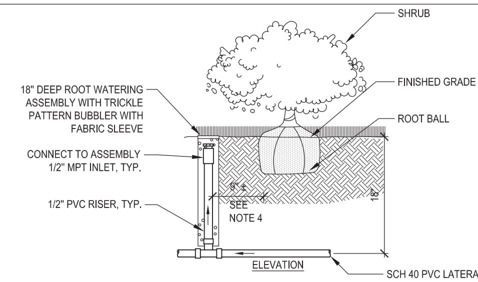
1 BACKFLOW PREVENTER
SCALE: NTS



NOTES:

1. LID SHALL HAVE CAST IN 1" HIGH LETTERS THE APPROPRIATE WORDING: "IRRIGATION" ON TOP SURFACE
2. PROVIDE A GALVANIZED STEEL UNION ON BOTH SIDES OF THREADED GATE VALVE

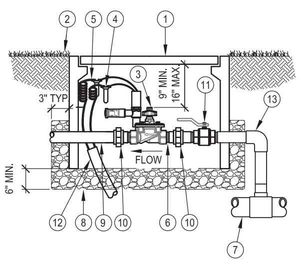
2 GATE VALVE
SCALE: NTS



NOTES:

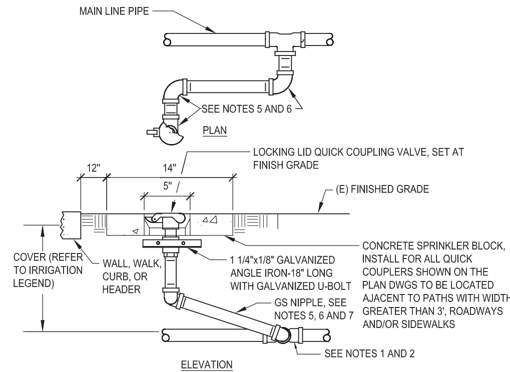
1. REFER TO LANDSCAPE DWGS FOR EXACT LOCATION OF SHRUBS TO BE WATERED.
2. FIELD ADJUST ASSEMBLY LOCATION AS REQUIRED.
3. SINGLE BUBBLERS SHALL BE LOCATED ABOVE THE SHRUB ROOT BALL WHEN SHRUB IS LOCATED ON A SLOPED GRADE.
4. F/I ONE (1) WATERING ASSEMBLY PER TWO (2) SHRUBS SPACED EQUAL DISTANCE BETWEEN ROOT BALLS WHEN INSTALLING IN SHRUB ROWS AND ONE (1) PER SHRUB WHEN IN SHRUB AREAS.

3 SHRUB WATERING ASSEMBLY
SCALE: NTS



1. CONCRETE VALVE BOX WITH BOLT DOWN/TAMPER PROOF LID
2. FINISHED GRADE
3. REMOTE CONTROL VALVE, SEE NOTE 1
4. WATERPROOF CONNECTORS, SEE NOTE 2
5. 18-24" COILED WIRE
6. BRASS NIPPLE, SEE NOTE 2
7. MAINLINE PIPE AND FITTINGS
8. 3/4' DRAIN ROCK, W/ 1/2" 16 GAUGE, GALV. WIRE MESH SURROUND
9. PVC LATERAL PIPING
10. GS UNION, LINE SIZE
11. BRASS BALL VALVE, LINE SIZE
12. CONDUIT WITH WATERTIGHT SEALED END
13. GALVANIZED STEEL PIPING

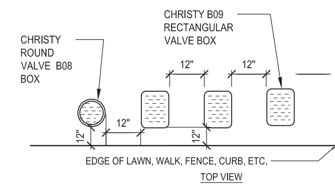
4 REMOTE CONTROL VALVE ASSEMBLY
SCALE: NTS



NOTES:

1. FOR 3 INCH DIA. OR SMALLER MAIN LINE CONNECTION, USE A THREADED TEE.
2. FINGER-TIGHTEN O-RING JOINTS AND BACK-OFF ONE FULL TURN TO ALLOW SWING ACTION. PROVIDE 10 INCHES BETWEEN CENTER LINES OF ELBOWS ON SWING ARM.
3. USE A 1-1/4" GS SWING JOINT (MIPT INLET X MIPT OUTLET), FOR QUICK COUPLING VALVE.
4. INSTALL THE SWING JOINT LAY ARM AT AN ANGLE BETWEEN 30° AND 45° OF THE MAIN IN ORDER TO ABSORB DOWNWARD IMPACT.

5 QUICK COUPLING VALVE
SCALE: NTS



NOTES:

1. CENTER BOX OVER VALVE TO FACILITATE SERVICING VALVE.
2. SET BOXES 1" ABOVE FINISH GRADE OR MULCH COVER IN GROUND COVER/SHRUB AREA AND FLUSH WITH FINISH GRADE IN TURF AREA.
3. SET VALVE BOX ASSEMBLY IN GROUND COVER/SHRUB AREA WHERE POSSIBLE.
4. SET BOXES PARALLEL TO EACH OTHER AND PERPENDICULAR TO EDGE.
5. AVOID HEAVILY COMPACTING SOIL AROUND VALVE BOX EDGES TO PREVENT COLLAPSE AND DEFORMATION OF VALVE BOX SIDES.
6. VALVE BOXES SHALL BE CONCRETE & HAVE BOLT DOWN/TAMPTER PROOF LIDS

6 VALVE BOX LAYOUT
SCALE: NTS

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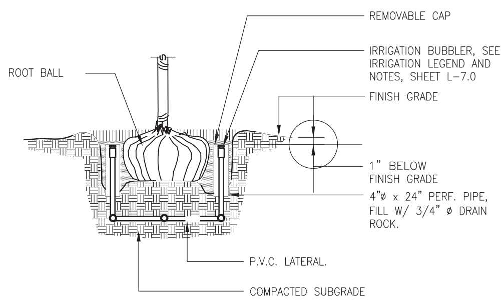
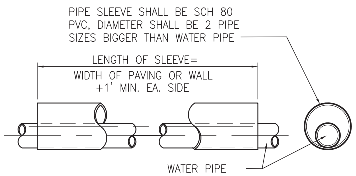
Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: IRRIGATION DETAILS
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-5001
Revision No. 0
Scale: AS NOTED

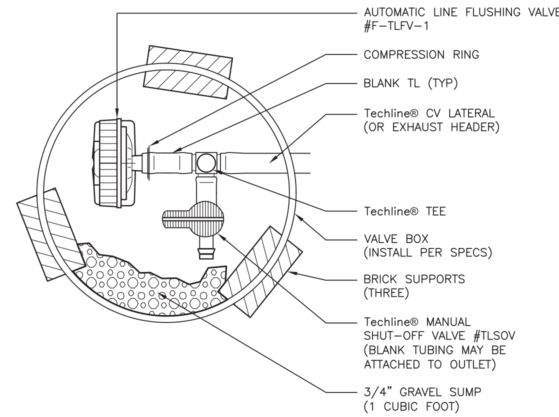
For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-3.1_IRRG_DETLS.dwg Plotted on: Jan 13, 2023 - 4:47pm



NOTE:
CONTRACTOR TO PROVIDE (2) BUBBLERS PER TREE.

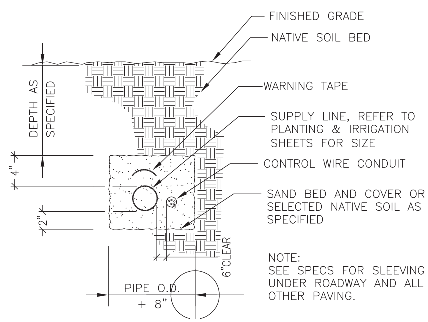




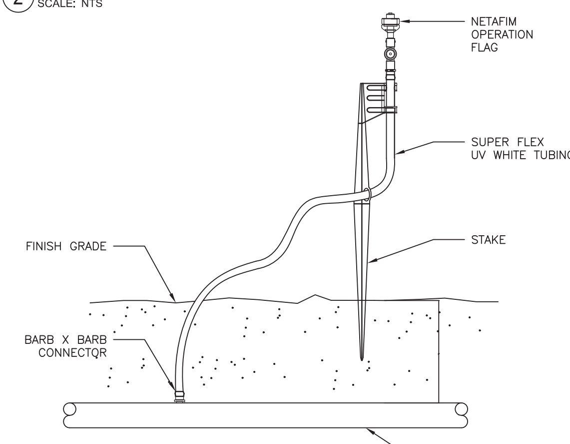
1 BUBBLER INSTALLATION @ TREE PIT
SCALE: NTS

2 PIPE SLEEVE
SCALE: NTS

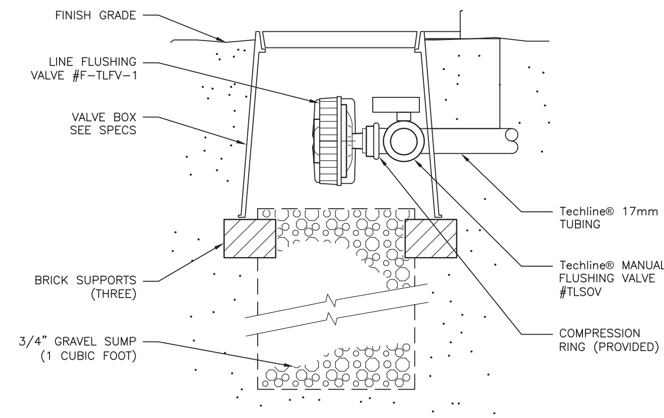
3 MANUAL LINE FLUSHING VALVE PLAN
SCALE: NTS



NOTE:
SEE SPECS FOR SLEEVING UNDER ROADWAY AND ALL OTHER PAVING.



NOTE:
LOCATE INDICATOR STAKE AT THE FARTHEST AND/OR HIGHEST POINT ON THE ZONE.



4 IRRIGATION SUPPLY LINE
SCALE: NTS

5 CV OPERATION PRESSURE INDICATOR FLAG
SCALE: NTS

6 MANUAL LINE FLUSHING VALVE SECTION
SCALE: NTS

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Plan No.
Contract No: WW-662
Drawing Title: IRRIGATION DETAILS
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-5002
Revision No. 0
Scale: AS NOTED

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-3.1_IRRG_DETLS.dwg Plotted on: Jan 13, 2023 - 4:47pm

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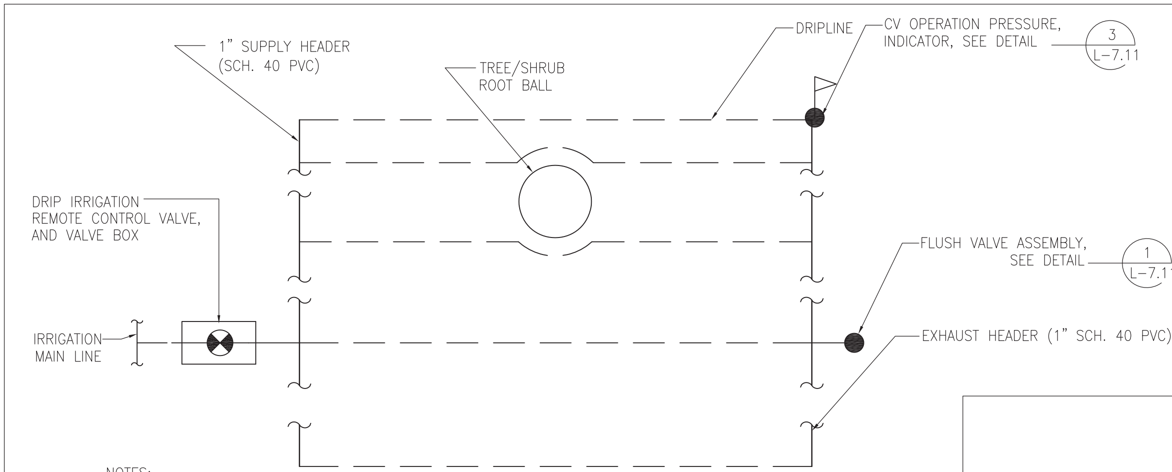
Exhibit 4
2-21-0912
Page 65 of 95

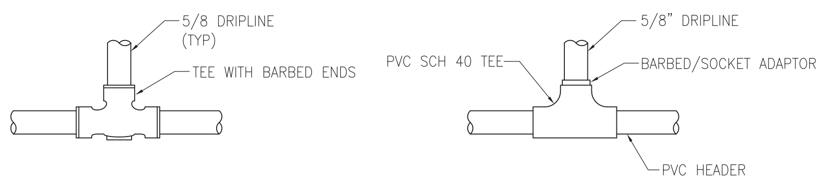


NOTES:

1. REFER TO RCV CALLOUT FOR SPACING BETWEEN EMITTERS ON DRIPLINE.
2. HEADER AND FOOTER LENGTHS VARY.
3. DRIP LINES SHALL PARALLEL CONTOUR LINES WHERE POSSIBLE.
4. ALL DRIPLINES AND SUPPLY/DISCHARGE HEADERS SHALL BE BURIED 6 INCHES BELOW THE FINISHED SURFACE (MULCH OR SOIL).

PLAN

1 DRIP IRRITATION TYPICAL LAYOUT DETAIL
SCALE: NTS



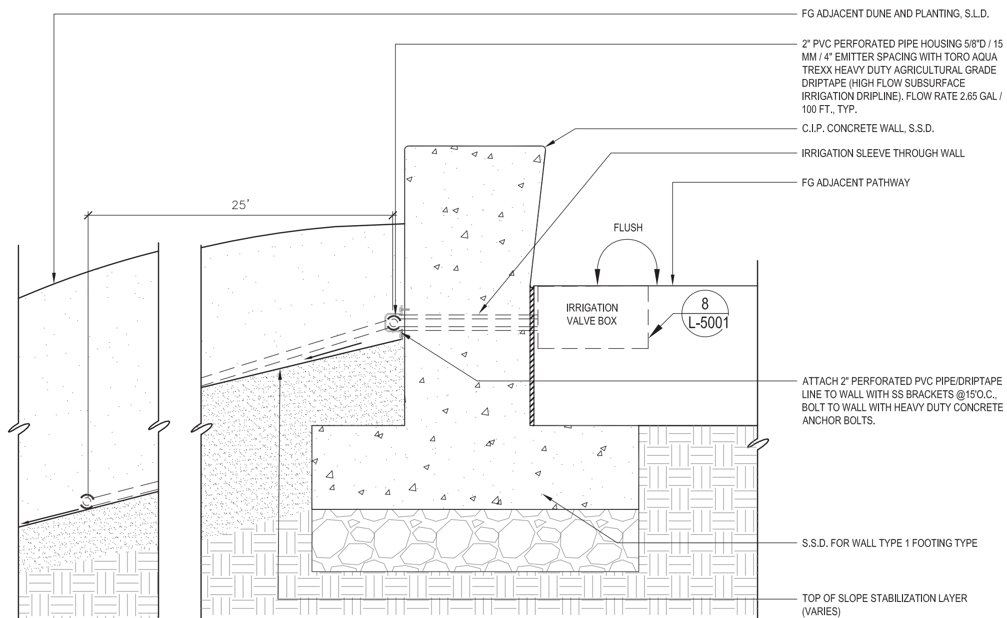
DRIPLINE TO DRIPLINE

DRIPLINE TO PVC MANIFOLD

NOTE:

1. ALL DRIPPERLINES SHALL BE SECURED TO BARBED ENDS WITH TYPE 316 SS PIPE CLAMPS. CONNECTORS SHALL BE THE SAME MANUFACTURER AS DRIPPERLINE, NETAFIM OR APPROVED EQUAL.

2 DRIPLINE CONNECTION DETAIL
SCALE: NTS



SECTION

3 SUBSURFACE IRRIGATION AT WALL
SCALE: 1 1/2"=1'-0"

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WWE O&M Mgr.
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Proj. Engr.
Designed SG
Drawn DAO
Checked by AA

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No.	Date	Revisions

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No WW-662

Drawing Title: IRRIGATION DETAILS

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-5003

Revision No. 0

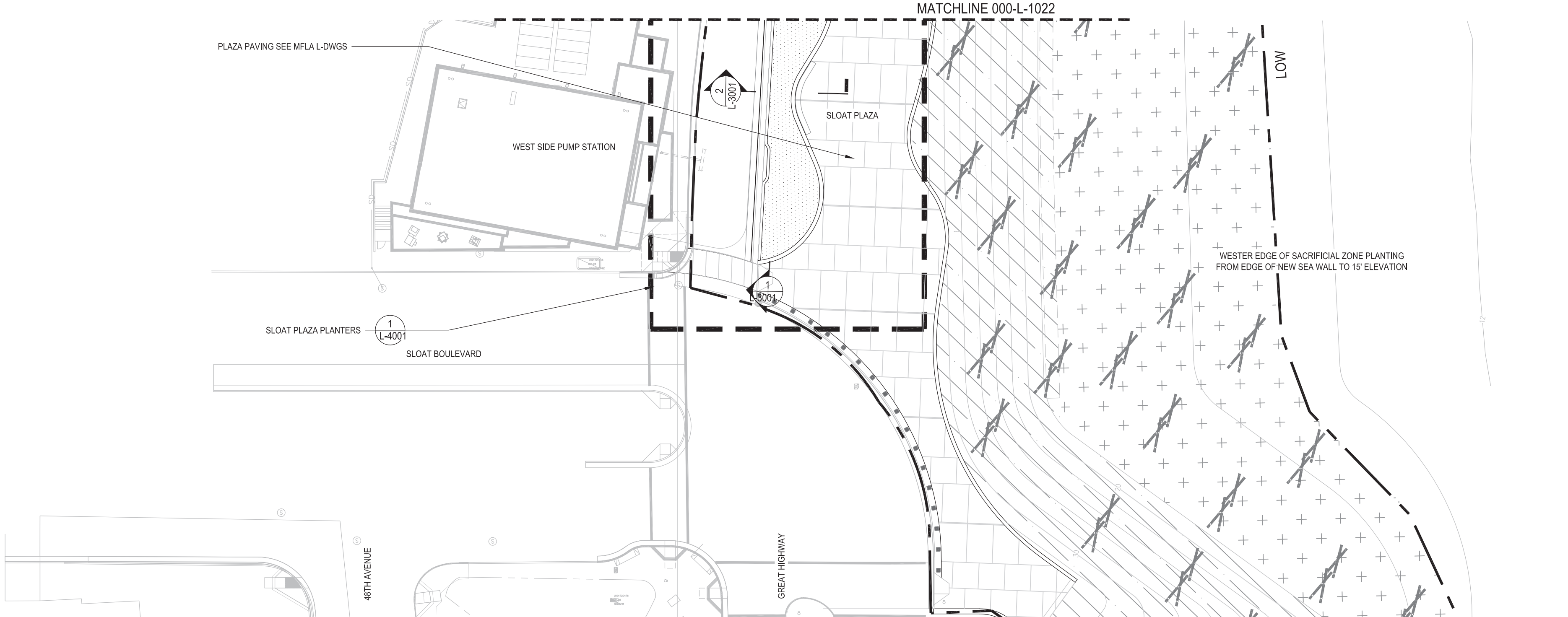
Scale: AS NOTED

For reduced plans original scale is in inches

Original Sheet Size: 22"x34"

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-3.1_IRRG_DETLS.dwg Plotted on: Jan 13, 2023 - 4:45pm

Exhibit 4
2-21-0912
Page 66 of 95



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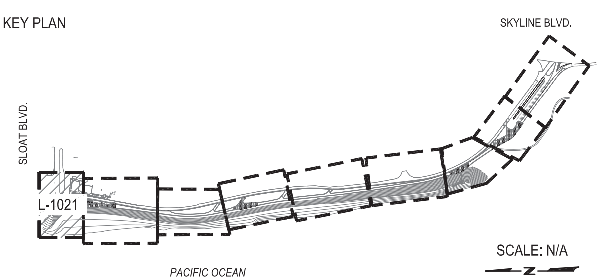

SCALE: N/A

LEGEND

SYMBOL	DESCRIPTION	DETAIL
	LIMIT OF WORK	
	MAJOR CONTOURS	
	MINOR CONTOURS	
	CUT BRUSH	000-L-5006
	SEA WALL	
	SLOAT PLAZA, INFILTRATION PLANTING, MEDIANS AND PARKING LOT PLANTING SEE ENLARGEMENT PLANS	000-L-4001 TO 000-L-4007
	VEGETATIVE STABILIZATION ZONE	000-L-4008
	SACRIFICIAL ZONE	000-L-4009

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: PLANTING PLAN
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-1016
Revision No. 0
Scale: 1"=20'

For reduced plans original scale is in inches
Original Sheet Size: 22"x34"

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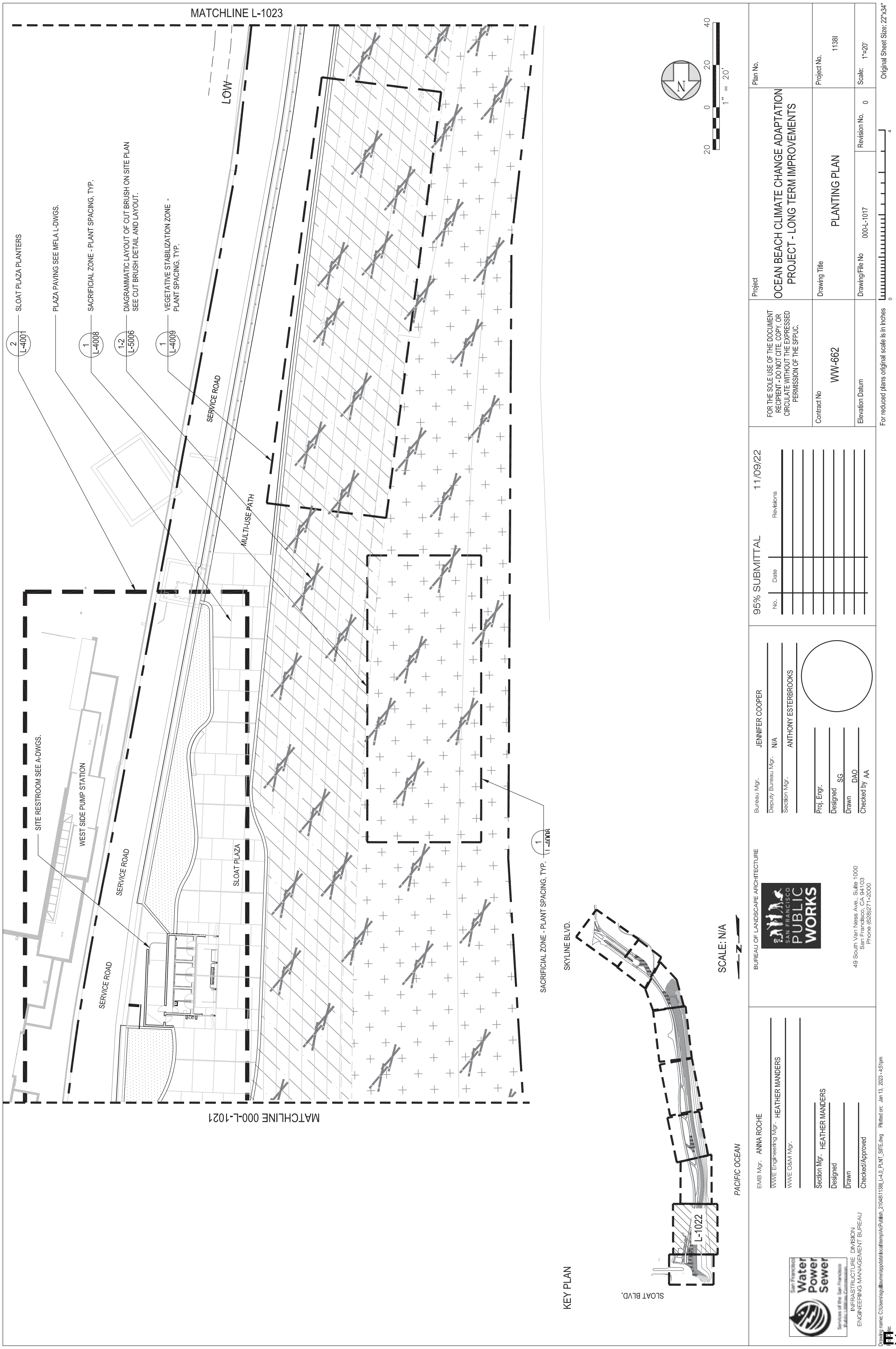
MATCHLINE L-1023
MATCHLINE 000-L-1021
LOW
SERVICE ROAD
MULTI-USE PATH
SLOAT PLAZA
WEST SIDE PUMP STATION
2 L-4001 SLOAT PLAZA PLANTERS
PLAZA PAVING SEE MFLA L-DWGS.
1 L-4008 SACRIFICIAL ZONE - PLANT SPACING, TYP.
1-2 L-5006 DIAGRAMMATIC LAYOUT OF CUT BRUSH ON SITE PLAN SEE CUT BRUSH DETAIL AND LAYOUT.
1 L-4009 VEGETATIVE STABILIZATION ZONE - PLANT SPACING, TYP.
SITE RESTROOM SEE A-DWGS.
1 L-4008 SACRIFICIAL ZONE - PLANT SPACING, TYP.
1" = 20'
KEY PLAN
SKYLINE BLVD.
SLOAT BLVD.
PACIFIC OCEAN
L-1022
SCALE: N/A
EMB Mgr. ANNA ROCHE
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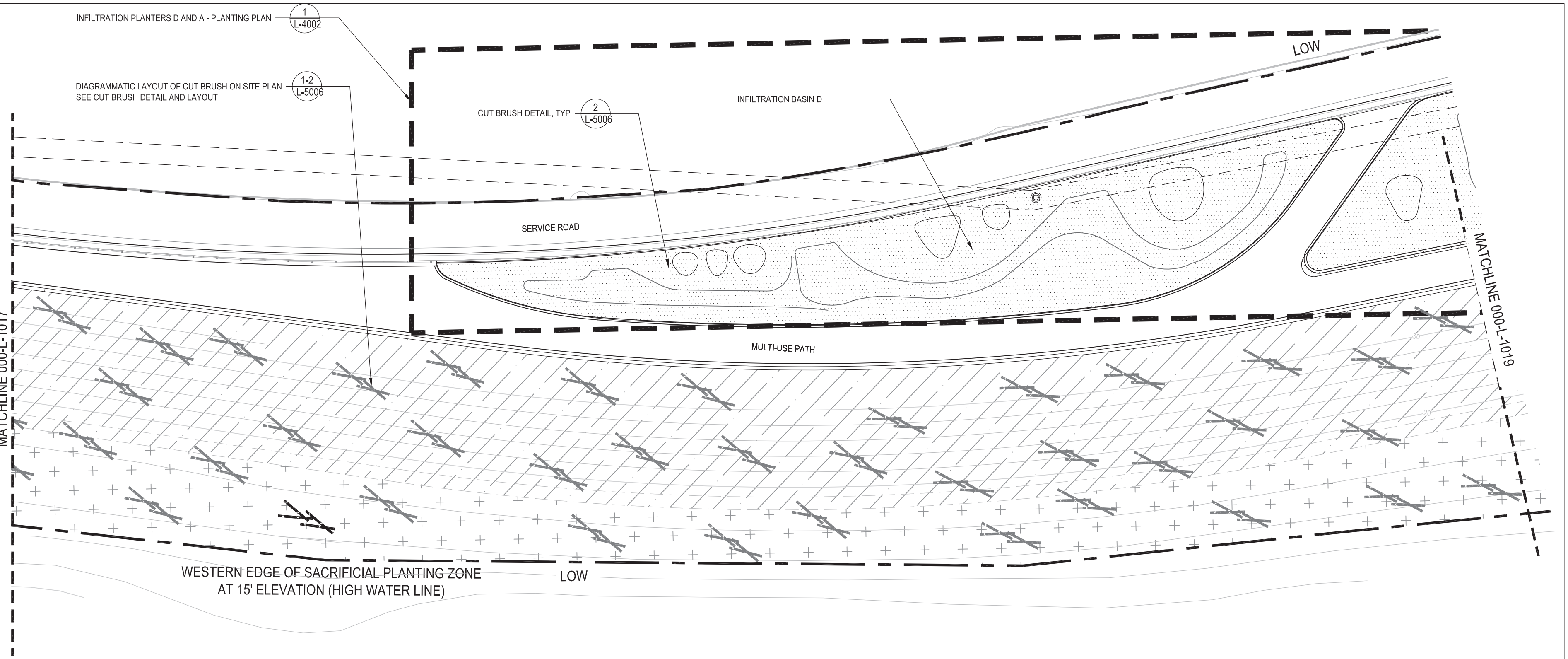
Contract No WW-662
Elevation Datum
Project
OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Drawing Title
PLANTING PLAN
Drawing/File No 000-L-1017
Revision No. 0
Plan No.
Project No. 11381
Scale: 1"=20'
Original Sheet Size: 22"x34"
For reduced plans original scale is in inches



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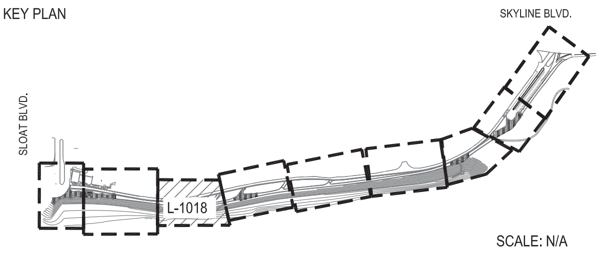

SCALE: N/A

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Project
OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No WW-662

Drawing Title
PLANTING PLAN

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-1018
Revision No. 0
Scale: 1"=20'

For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

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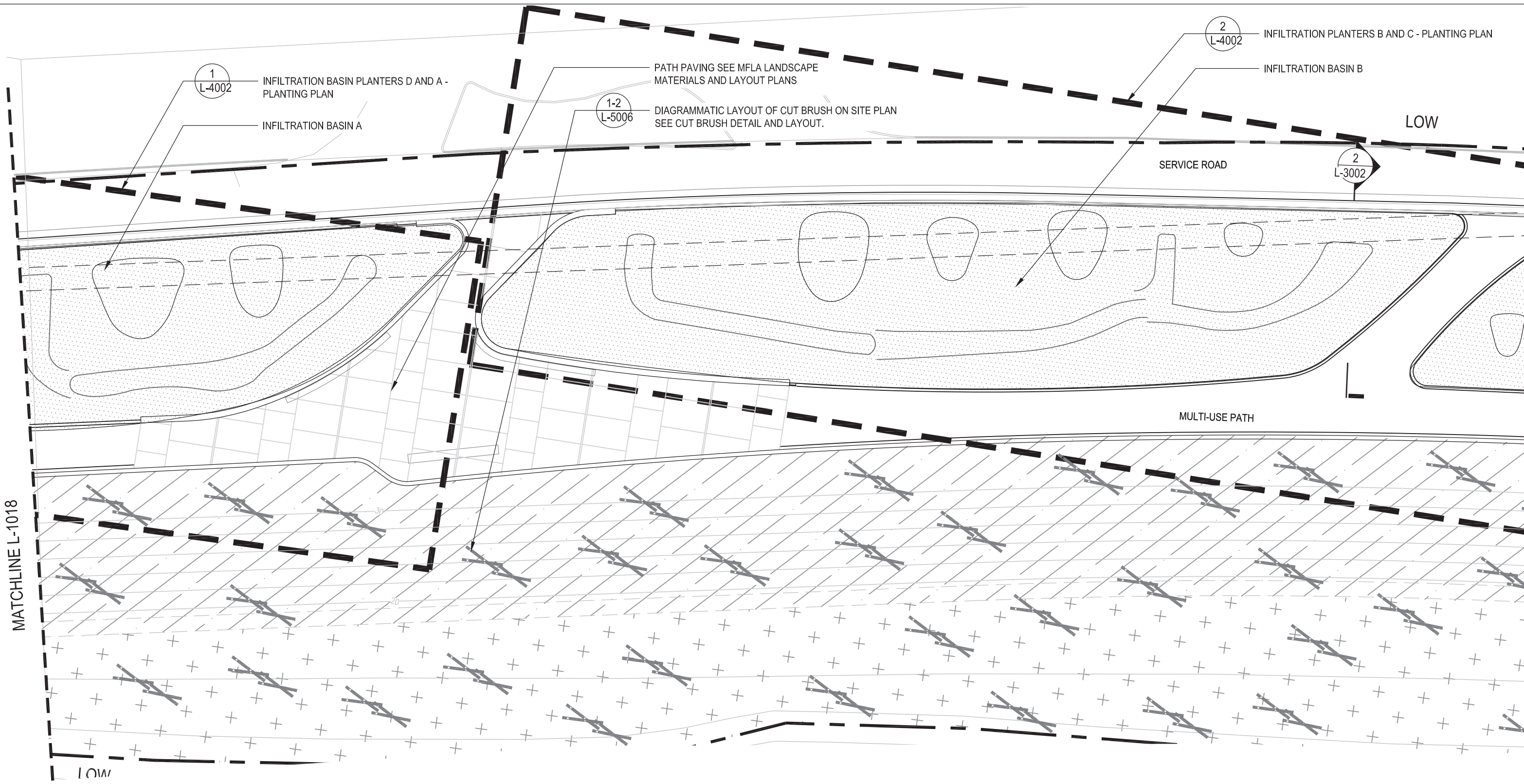

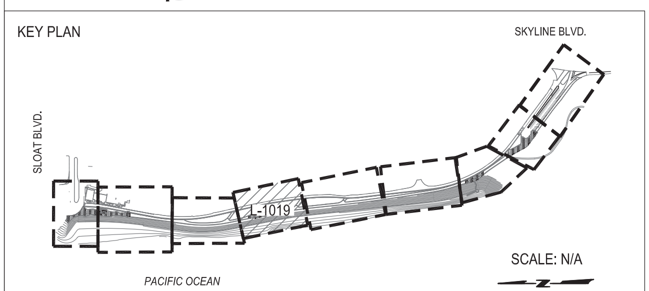

20 0 20 40
1" = 20'

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No.	Date	Revisions

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING PLAN

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-1019

Revision No.: 0

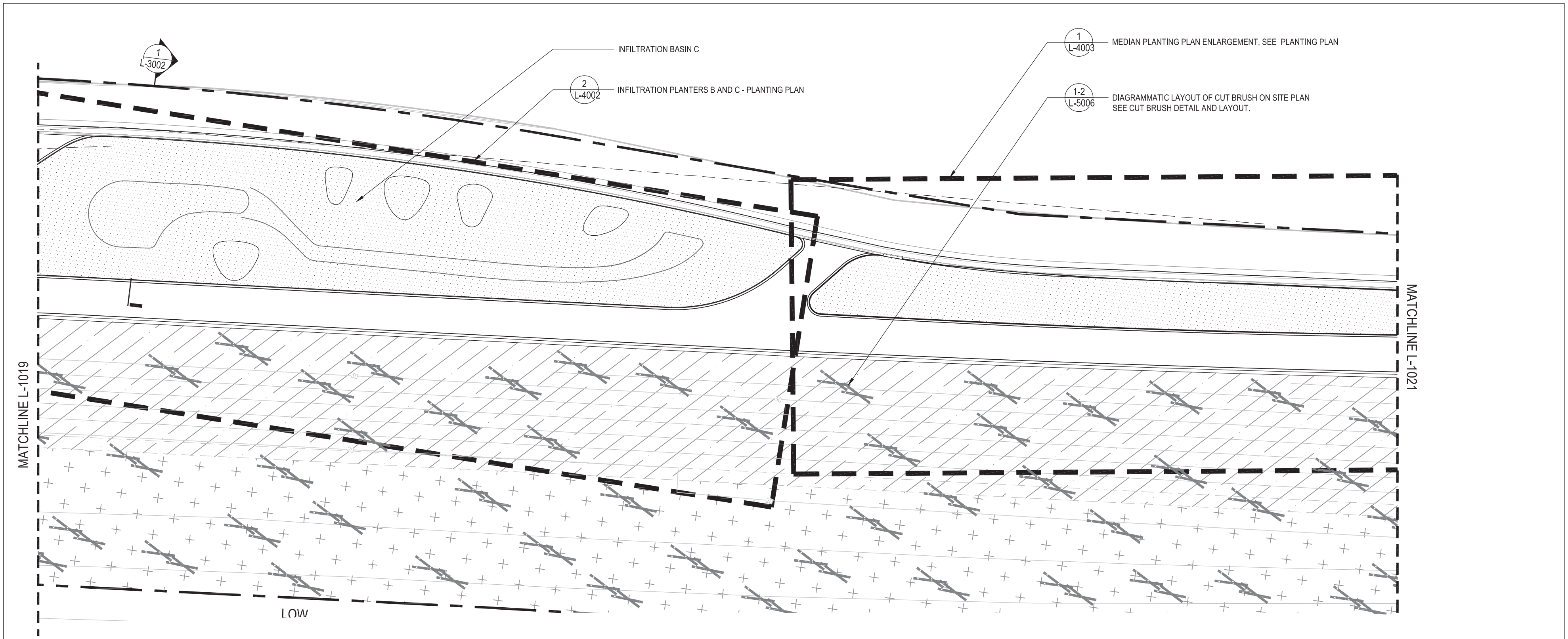
Scale: 1"=20'

For reduced plans original scale is in inches

Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.0_PLNT_SITE.dwg Plotted on: Jan 13, 2023 - 11:58am

Exhibit 4
2-21-0912
Page 70 of 95



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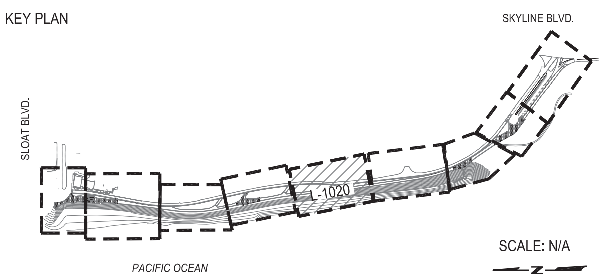

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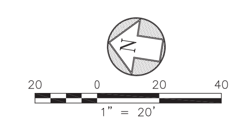

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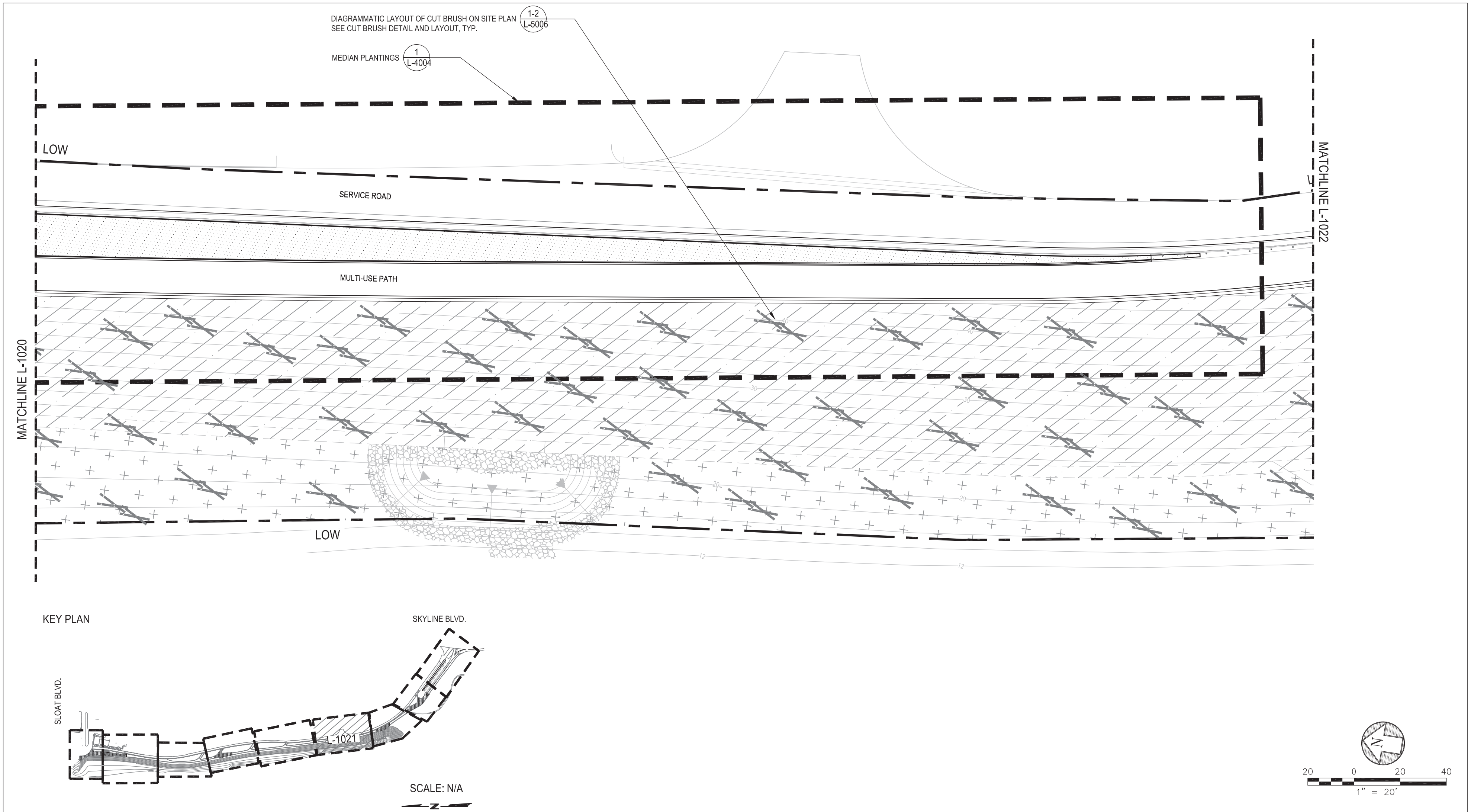
Contract No WW-662	Drawing Title PLANTING PLAN	Project No. 1138I
Elevation Datum	Drawing/File No 000-L-1020 / Revision No. 0	Scale: 1"=20'

For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.0_PLNT_SITE.dwg Plotted on: Jan 13, 2023 - 11:59am

Exhibit 4
2-21-0912
Page 71 of 95



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WWE Engineering Mgr. HEATHER MANDERS	SAN FRANCISCO PUBLIC WORKS	Deputy Bureau Mgr. N/A	No. / Date / Revisions	Contract No: WW-662	Drawing Title: PLANTING PLAN	Project No.: 1138I
WWE O&M Mgr.	49 South Van Ness Ave., Suite 1000, San Francisco, CA 94103, Phone (628)271-2000	Section Mgr. ANTHONY ESTERBROOKS		Elevation Datum	Drawing/File No: 000-L-1021	Revision No.: 0
Section Mgr. HEATHER MANDERS		Proj. Engr.				Scale: 1"=20'
Designed		Designed SG				
Drawn		Drawn DAO				
Checked/Approved		Checked by AA				

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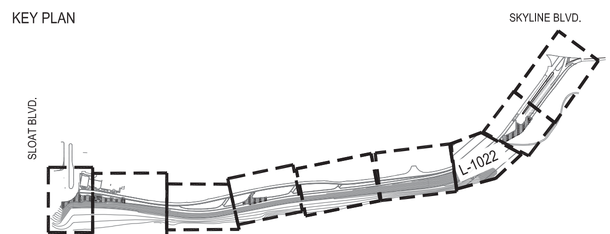
Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.0_PLNT_SITE.dwg Plotted on: Jan 13, 2023 - 12:05pm

For reduced plans original scale is in inches

Original Sheet Size: 22"x34"

KEY PLAN



SCALE: N/A

1" = 20'

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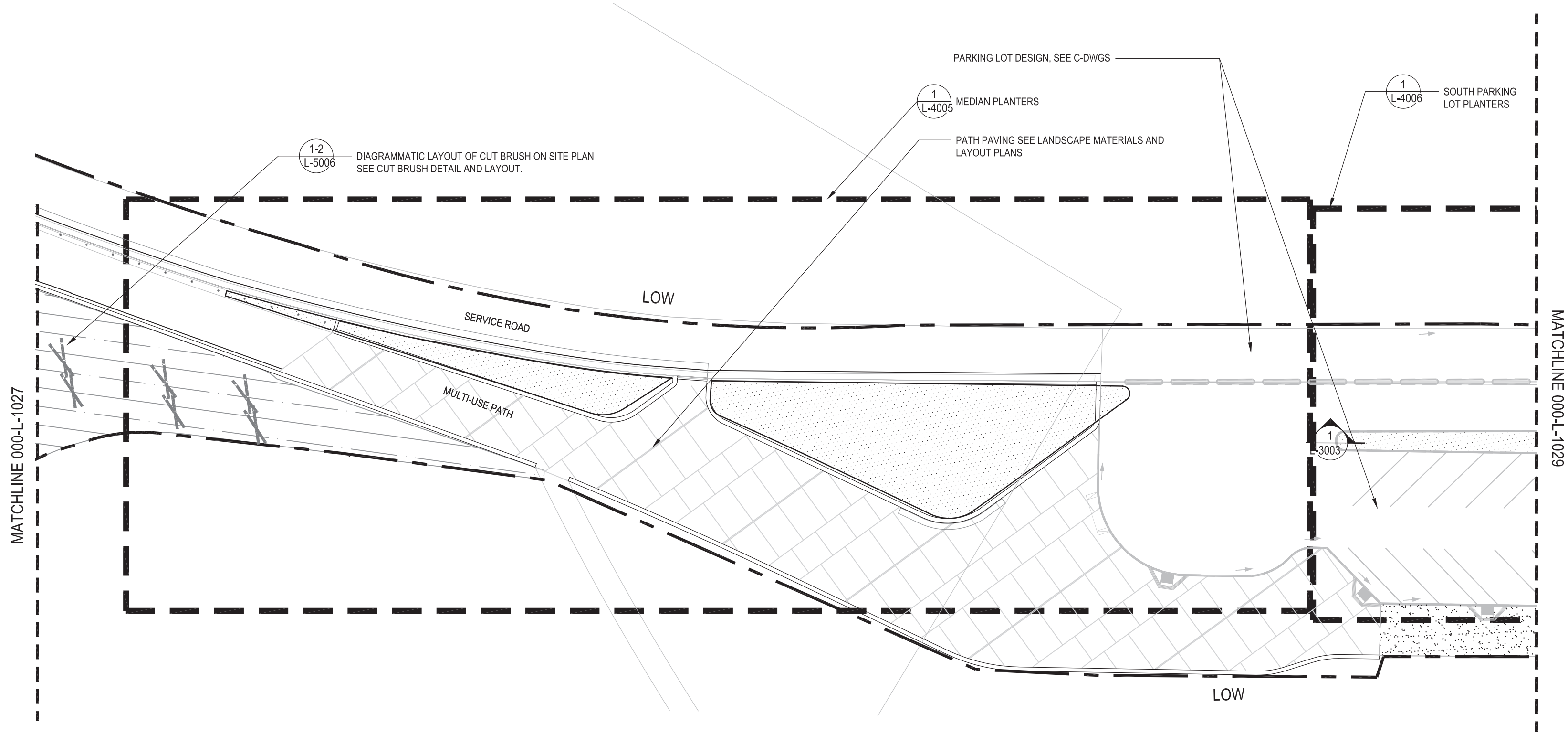
Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS		Plan No.
Contract No: WW-662	Drawing Title: PLANTING PLAN	Project No. 1138I
Elevation Datum	Drawing/File No 000-L-1022 — Revision No. 0	Scale: 1"=20'

For reduced plans original scale is in inches

Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.0_PLNT_SITE.dwg Plotted on: Jan 13, 2023 - 11:59am

Exhibit 4
2-21-0912
Page 73 of 95



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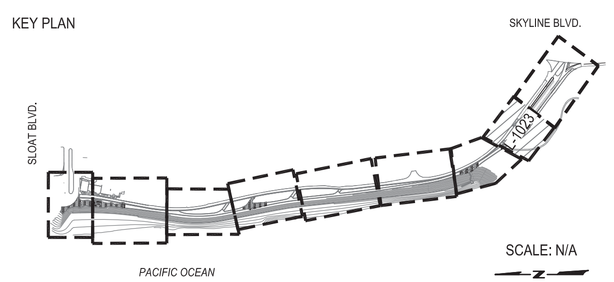

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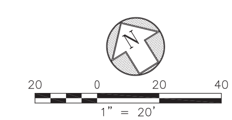

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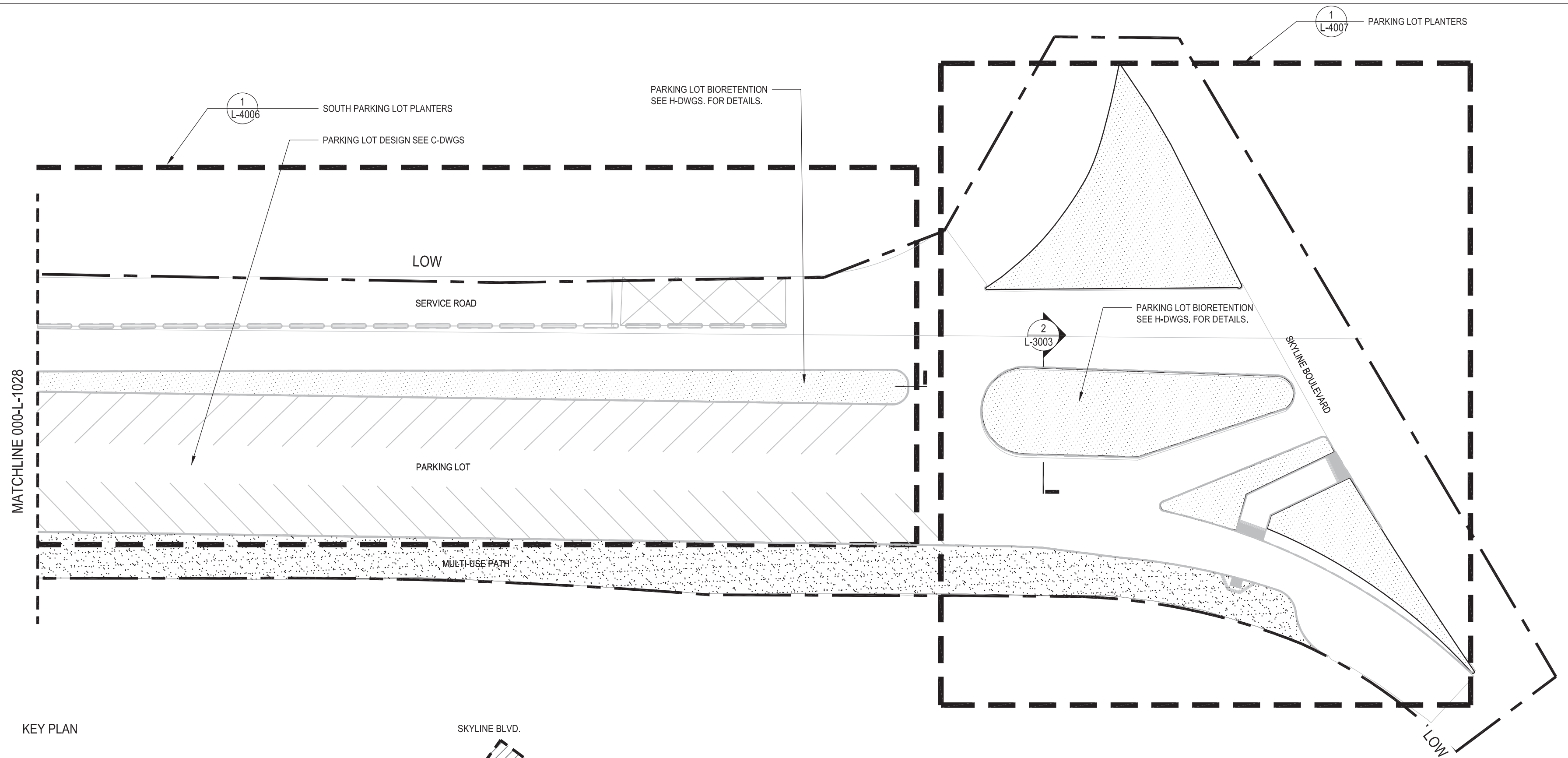
Project OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS		Plan No.
Drawing Title PLANTING PLAN		Project No. 1138I
Drawing/File No 000-L-1023	Revision No. 0	Scale: 1"=20'

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.0_PLNT_SITE.dwg Plotted on: Jan 13, 2023 - 11:59am

For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"

Exhibit 4
2-21-0912
Page 74 of 95



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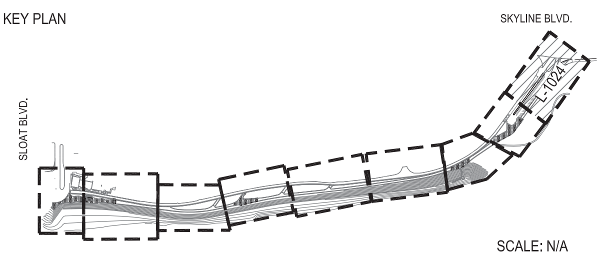

SCALE: N/A

20 0 20 40
1" = 20'

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Deputy Bureau Mgr.	N/A
Section Mgr.	ANTHONY ESTERBROOKS
Proj. Engr.	
Designed	SG
Drawn	DAO
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No.	Date	Revisions

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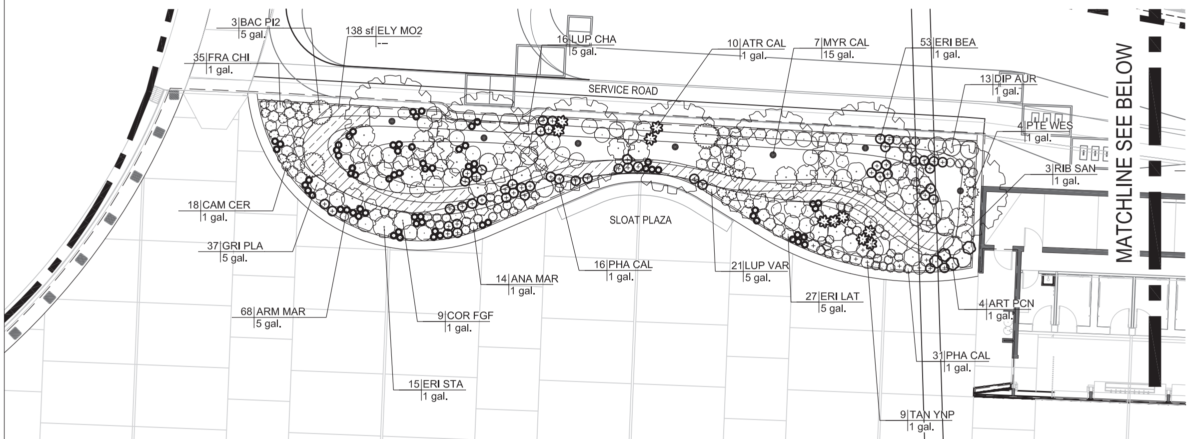
Project	OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS		Plan No.
Contract No WW-662	Drawing Title PLANTING PLAN		Project No. 1138I
Elevation Datum	Drawing/File No 000-L-1024	Revision No. 0	Scale: 1"-20'

For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"

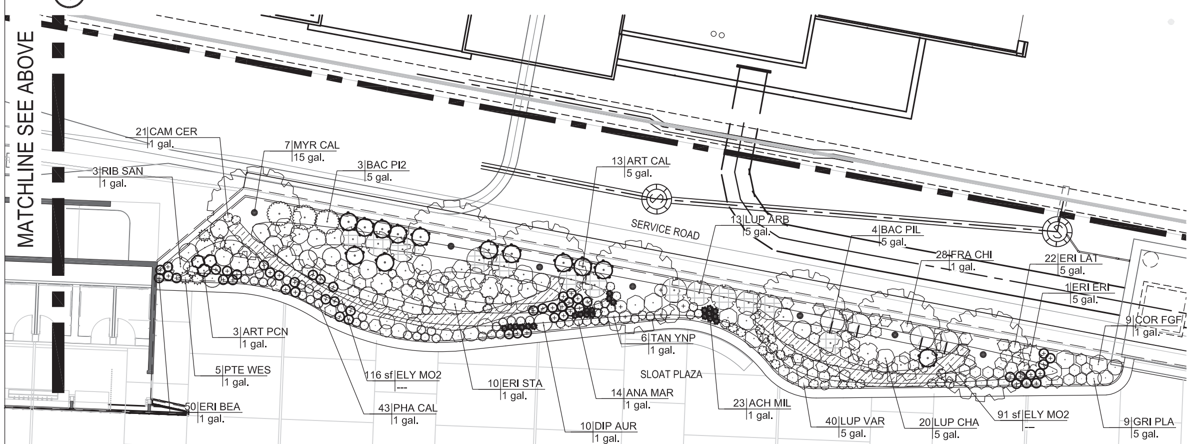
Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.0_PLNT_SITE.dwg Plotted on: Jan 13, 2023 - 11:59am

Exhibit 4
2-21-0912
Page 75 of 95



1 SLOAT PLAZA PLANTERS – PLANTING ENLARGEMENT

SCALE: 1"=10'



2 SLOAT PLAZA PLANTERS – PLANTING ENLARGEMENT

SCALE: 1"=10'

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No.	Date	Revisions

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING PLAN SLOAT PLAZA

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-4001

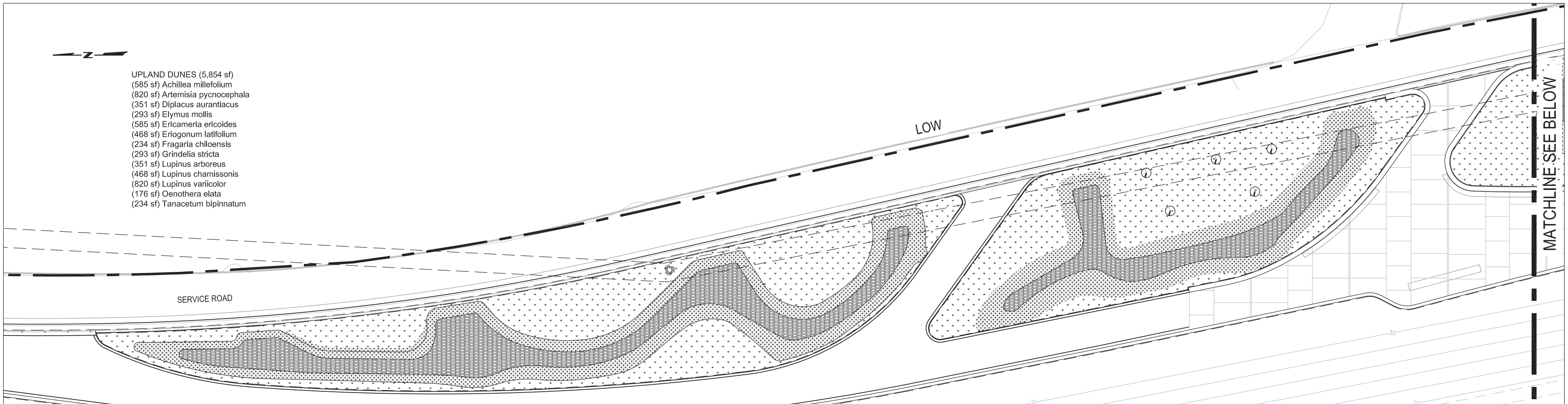
Revision No.: 0

Scale: 1"=10'-0"

For reduced plans original scale is in inches 0 4

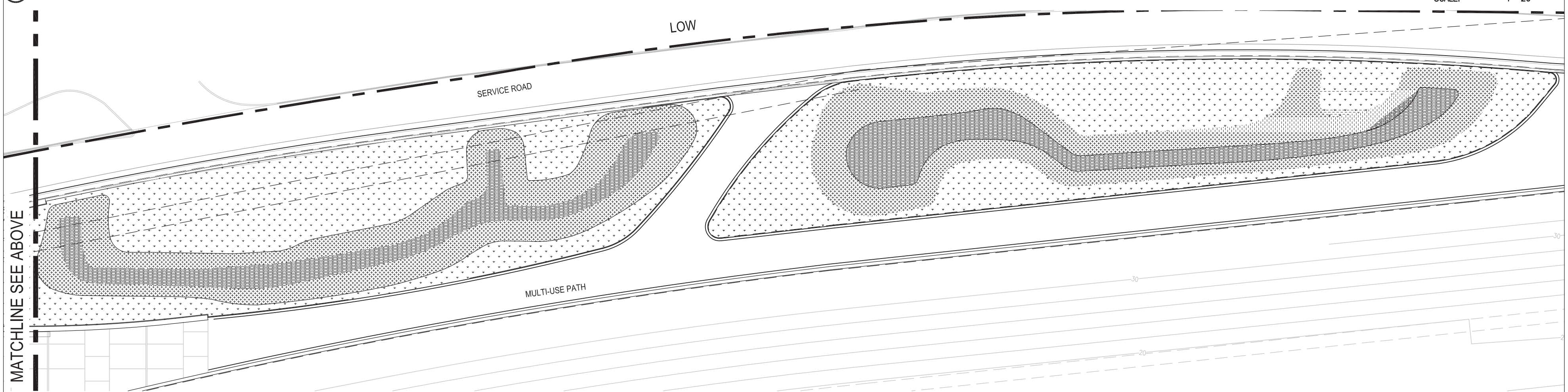
Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:22am



1 BIORETENTION PLANTERS D AND A – PLANTING PLAN

SCALE: 1"=20'



2 BIORETENTION PLANTERS B AND C – PLANTING PLAN

SCALE: 1"=20'

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WWE Engineering Mgr. HEATHER MANDERS
WWE O&M Mgr.
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No.	Date	Revisions

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING PLAN BIORETENTION PLANTERS

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-4002

Revision No.: 0

Scale: 1"=20'-0"

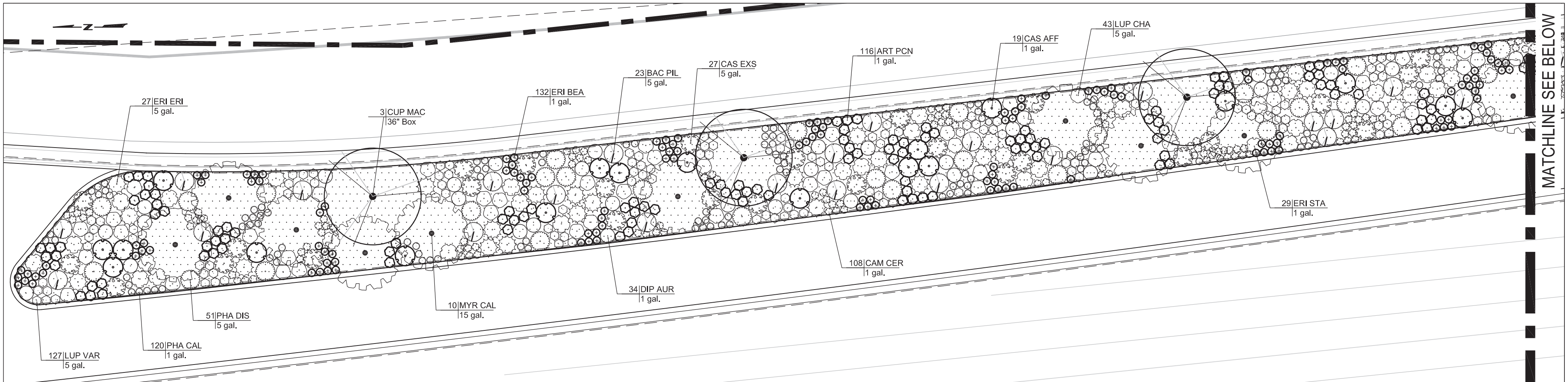
For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

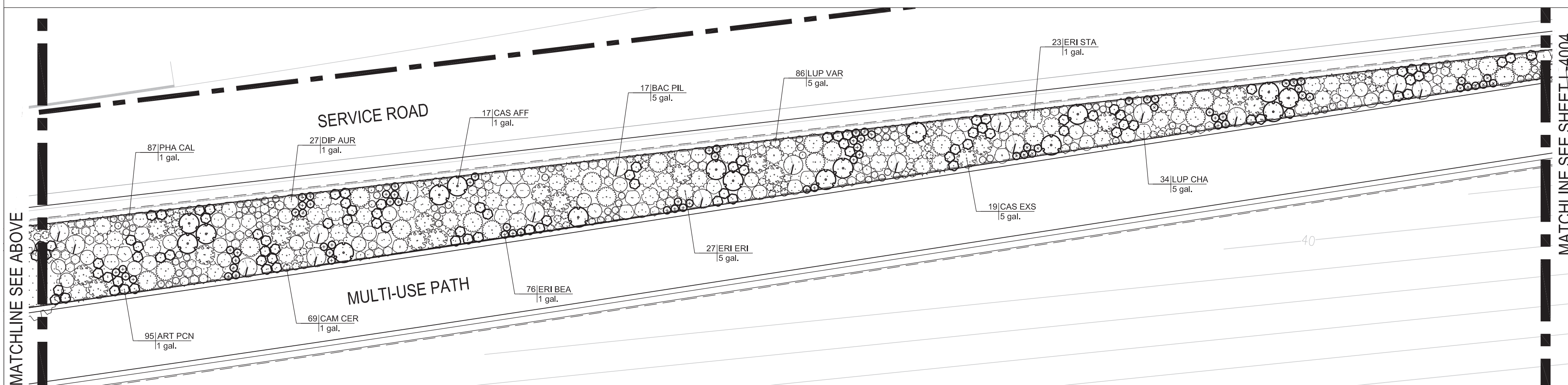
Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:22am

Exhibit 4
2-21-0912
Page 77 of 95



1 MEDIAN PLANTERS – PLANTING PLAN

SCALE: 1"=10'



2 MEDIAN PLANTERS – PLANTING PLAN

SCALE: 1"=10'

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission
INFRASTRUCTURE DIVISION
ENGINEERING MANAGEMENT BUREAU

EMB Mgr. ANNA ROCHE
WWE Engineering Mgr. HEATHER MANDERS
WWE O&M Mgr.
Section Mgr. HEATHER MANDERS
Designed
Drawn
Checked/Approved

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No.	Date	Revisions

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING PLAN MEDIAN

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-4003

Revision No. 0

Scale: 1"=10'-0"

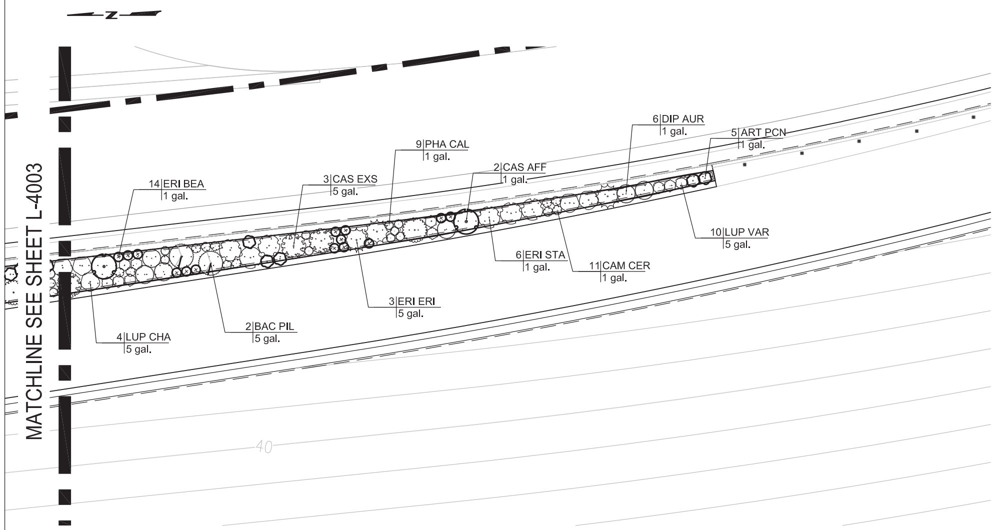
For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:22am

Exhibit 4
2-21-0912
Page 78 of 95



1 MEDIAN PLANTERS – PLANTING PLAN

SCALE: 1"=10'

San Francisco Water Power Sewer. Services of the San Francisco Public Utilities Commission. INFRASTRUCTURE DIVISION ENGINEERING MANAGEMENT BUREAU	EMB Mgr. ANNA ROCHE WWE Engineering Mgr. HEATHER MANDERS WWE O&M Mgr. Section Mgr. HEATHER MANDERS Designed Drawn Checked/Approved	BUREAU OF LANDSCAPE ARCHITECTURE SAN FRANCISCO PUBLIC WORKS 49 South Van Ness Ave., Suite 1000 San Francisco, CA 94103 Phone (628)271-2000	Bureau Mgr. JENNIFER COOPER Deputy Bureau Mgr. N/A Section Mgr. ANTHONY ESTERBROOKS Proj. Engr. Designed SG Drawn DAO Checked by AA	95% SUBMITTAL 11/09/22 No. Date Revisions	FOR THE SOLE USE OF THE DOCUMENT RECIPIENT - DO NOT CITE, COPY, OR CIRCULATE WITHOUT THE EXPRESSED PERMISSION OF THE SFPUC. Contract No WW-662 Elevation Datum

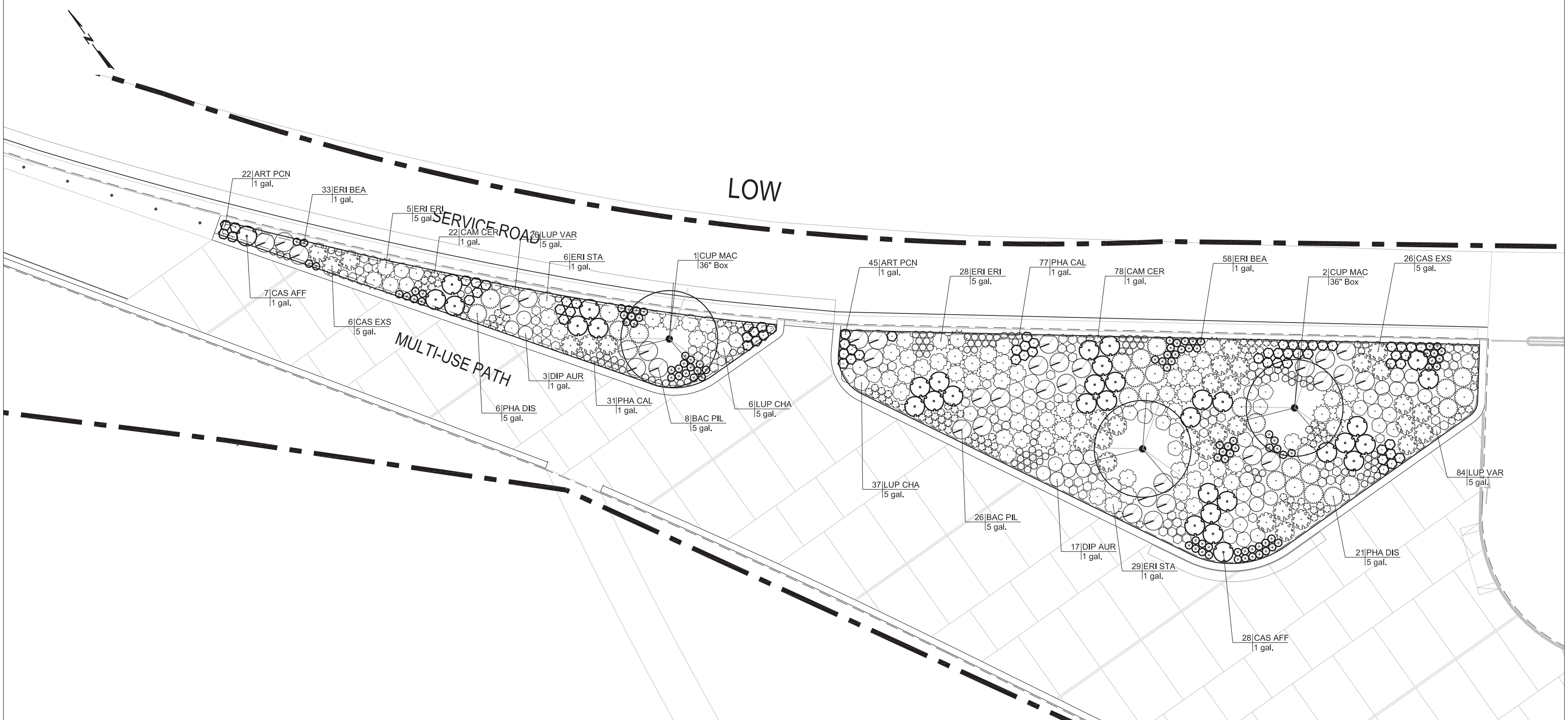
Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS		Plan No.
Drawing Title: PLANTING PLAN MEDIAN		Project No. 1138I
Drawing/File No 000-L-4004	Revision No. 0	Scale: 1"=10'-0"

For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:22am

Exhibit 4
2-21-0912
Page 79 of 95



1 MEDIAN PLANTERS – PLANTING PLAN

SCALE: 1"=10'

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INFRASTRUCTURE DIVISION
ENGINEERING MANAGEMENT BUREAU

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING PLAN MEDIAN

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-4005

Revision No. 0

Scale: 1"=10'-0"

For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

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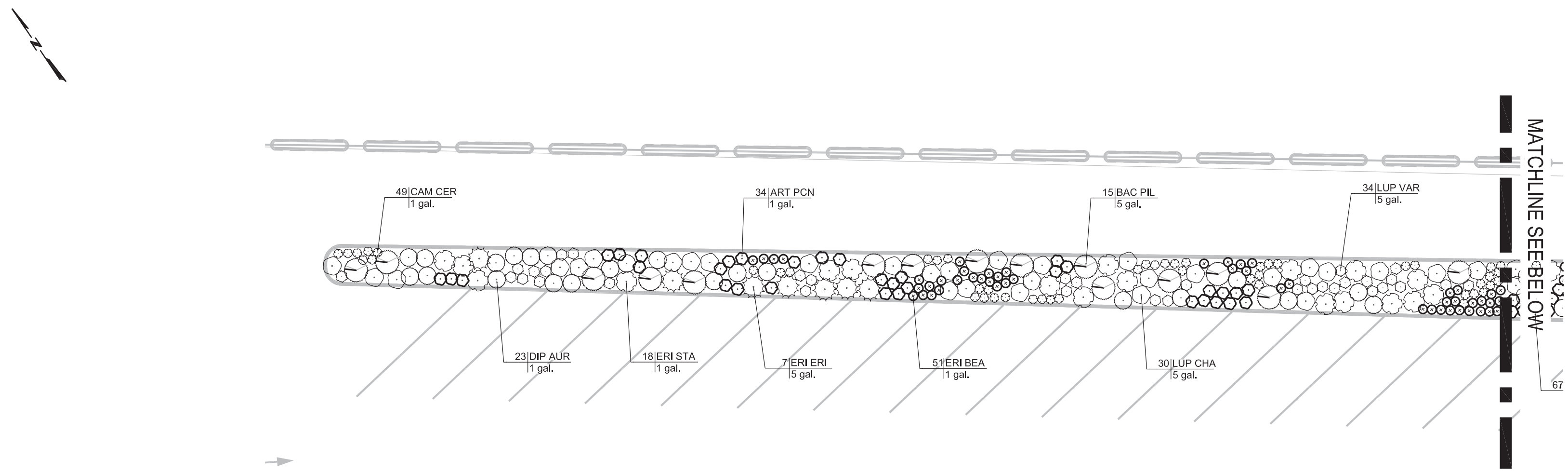
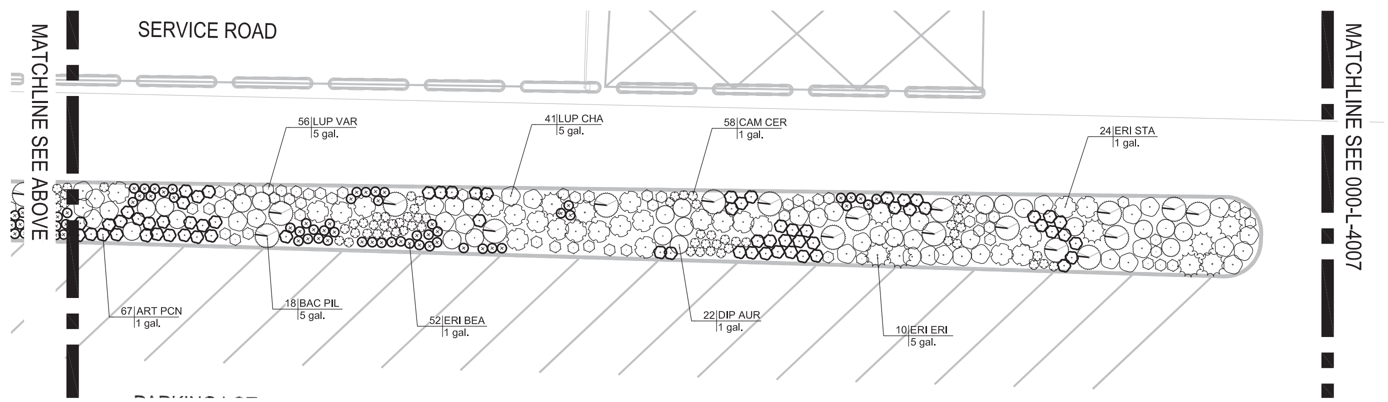
Exhibit 4
2-21-0912
Page 80 of 95



1 PARKING LOT PLANTERS

SCALE: 1"=10'



2 PARKING LOT PLANTERS

SCALE: 1"=10'

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING PLAN PARKING LOT

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-4006

Revision No. 0

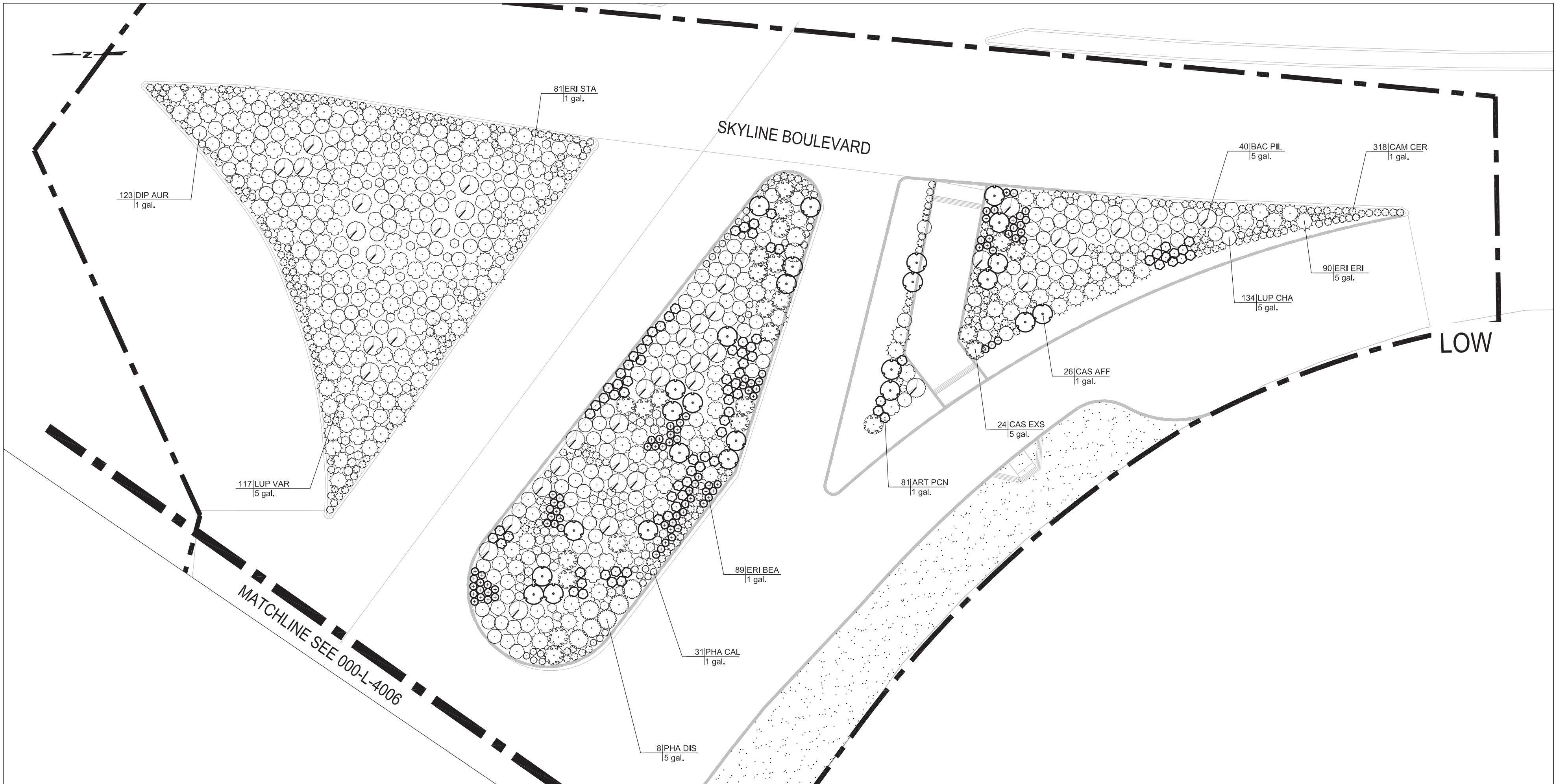
Scale: 1"=10'-0"

For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:22am



1 PARKING LOT PLANTERS

SCALE: 1"=10'

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: PLANTING PLAN PARKING LOT
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-4007
Revision No. 0
Scale: 1"=10'-0"

For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:22am

PLANT SCHEDULE SLOAT PLAZA

SHRUBS	CODE	BOTANICAL NAME	COMMON NAME	SIZE	SPACING	QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
	ACH MIL	ACHILLEA MILLEFOLIUM	COMMON YARROW	1 GAL.	12" o.c.	23			X	
	ANA MAR	ANAPHALIS MARGARITACEA	PEARLY EVERLASTING	1 GAL.	18" o.c.	28				
	ARM MAR	ARMERIA MARITIMA	SEA THRIFT	5 GAL.	12" o.c.	68				
	ART CAL	ARTEMISIA CALIFORNICA	CALIFORNIA SAGEBRUSH	5 GAL.	36" o.c.	13				
	ART PCN	ARTEMISIA PYCNOCEPHALA	BEACH SAGEWORT	1 GAL.	24" o.c.	7				
	ATR CAL	ATRIPLEX CALIFORNICA	CALIFORNIA SALTBUSH	1 GAL.	24" o.c.	10				
	BAC PIL	BACCHARIS PILULARIS	COYOTE BRUSH	5 GAL.	48" o.c.	4				
	BAC PI2	BACCHARIS PILULARIS	COYOTE BRUSH	5 GAL.	48" o.c.	6				
	CAM CER	CAMISSONIOPSIS CHEIRANTHIFOLIA	BEACH EVENING PRIMROSE	1 GAL.	18" o.c.	46				
	COR FGF	CORETHROGYNE FILAGINIFOLIA	CALIFONIA ASTER	1 GAL.	36" o.c.	18				
	DIP AUR	DIPLACUS AURANTIACUS	STICKY MONKEYFLOWER	1 GAL.	36" o.c.	23				X
	ERI ERI	ERICAMERIA ERICOIDES	CALIFORNIA GOLDENBUSH	5 GAL.	48" o.c.	1				
	ERI BEA	ERIGERON GLAUCUS	SEASIDE DAISY	1 GAL.	18" o.c.	105			X	
	ERI LAT	ERIOGONUM LATIFOLIUM	COAST BUCKWHEAT	5 GAL.	24" o.c.	49				
	ERI STA	ERIOPHYLLUM STAECHADIFOLIUM	LIZARD-TAIL	1 GAL.	42" o.c.	25				
	FRA CHI	FRAGARIA CHILOENSIS	BEACH STRAWBERRY	1 GAL.	24" o.c.	65				
	GRI PLA	GRINDELIA STRICTA PLATYPHYLLA	SPREADING GRINDELIA	5 GAL.	30" o.c.	50				
	LUP ARB	LUPINUS ARBOREUS	YELLOW TREE LUPINE	5 GAL.	48" o.c.	13				
	LUP CHA	LUPINUS CHAMISSONIS	DUNE LUPINE	5 GAL.	36" o.c.	37				
	LUP VAR	LUPINUS VARIICOLOR	LINDLEY'S VARIED LUPINE	5 GAL.	24" o.c.	67				
	MYR CAL	MYRICA CALIFORNICA	PACIFIC WAX MYRTLE	15 GAL.	180" o.c.	14		X		
	PHA CAL	PHACELIA CALIFORNICA	CALIFORNIA PHACELIA	1 GAL.	18" o.c.	66				
	PHA CA2	PHACELIA CALIFORNICA	CALIFORNIA PHACELIA	5 GAL.	18" o.c.	30				
	PTE WES	PTERIDIUM AQUILINUM	WESTERN BRACKENFERN	1 GAL.	24" o.c.	9				
	RIB SAN	RIBES SANGUINEUM	RED FLOWERING CURRANT	1 GAL.	36" o.c.	6		X	X	

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No.	Date	Revisions

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: PLANTING SCHEDULE SLOAT PLAZA
Project No.: 1138I
Elevation Datum
Drawing/File No: 000-L-6001
Revision No.: 0
Scale: N/A

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:28am

For reduced plans original scale is in inches
0 4
Original Sheet Size: 22"x34"

Exhibit 4
2-21-0912
Page 83 of 95

PLANT SCHEDULE INFILTRATION BASIN

SHRUBS	CODE	BOTANICAL NAME	COMMON NAME	SIZE	SPACING	QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
		BACCHARIS PILULARIS			48" o.c.	5				
	BAC PI3	BACCHARIS PILULARIS	COYOTE BRUSH	5 GAL.	0" o.c.	5				

GROUND COVERS	CODE	BOTANICAL NAME	COMMON NAME	SIZE	SPACING	QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
		UPLAND DUNES				51,189 SF				
	ACH MI2	ACHILLEA MILLEFOLIUM	COMMON YARROW	—		5,119 SF			X	
	ART PC2	ARTEMISIA PYCNOCEPHALA	BEACH SAGEWORT	—		7,167 SF				
	DIP AU2	DIPLACUS AURANTIACUS	STICKY MONKEYFLOWER	—		3,071 SF				X
	ELY MOL	ELYMUS MOLLIS	AMERICAN DUNEGRASS	—		2,559 SF				
	ERI MRI	ERICAMERIA ERICOIDES	MOCK HEATHER	—		5,119 SF				
	ERI KSF	ERIOGONUM LATIFOLIUM	SEASIDE BUCKWHEAT	—		4,095 SF				
	FRA CH2	FRAGARIA CHILOENSIS	BEACH STRAWBERRY	—		2,048 SF				
	GRI STR	GRINDELIA STRICTA	COASTAL GUM PLANT	—		2,559 SF				
	LUP BBR	LUPINUS ARBOREUS	YELLOW BUSH LUPINE	—		3,071 SF				
	LUP CBH	LUPINUS CHAMISSONIS	DUNE BUSH LUPINE	—		4,095 SF				
	LUP VA2	LUPINUS VARIICOLOR	LINDLEY'S VARIED LUPINE	—		7,167 SF				
	OEN ELA	OENOTHERA ELATA	HOOKER'S EVENING PRIMROSE	—		1,536 SF				
	TAN PIY	TANACETUM BIPINNATUM	DUNE TANSY	—		2,048 SF				
		INTERMEDIATE BASIN				19,161 SF				
	ACH MI3	ACHILLEA MILLEFOLIUM	COMMON YARROW	—		1,533 SF			X	
	AMS SPE	AMSINCKIA SPECTABILIS	SEASIDE FIDDLENECK	—		1,150 SF				
	EXT CAL	EXTRIPLEX CALIFORNICA	CALIFORNIA SALTBUSH	—		1,341 SF				
	FRA CH3	FRAGARIA CHILOENSIS	BEACH STRAWBERRY	—		2,299 SF				
	GRI PL2	GRINDELIA STRICTA PLATYPHYLLA	SPREADING GRINDELIA	—		1,916 SF				
	JUN LO2	JUNCUS LESCURII	SAN FRANCISCO RUSH	—		958 SF				
	LEY SRF	LEYMUS PACIFICUS X TRITICOIDES	PACIFIC WILDRYE	—		3,449 SF	LEYMUS TRITICOIDES, INTERMEDIATE WITH L. PACIFICUS			
	LEY XV3	LEYMUS X VANCOUVERENSIS	VANCOUVER WILDRYE	—		3,449 SF				
	OEN HOE	OENOTHERA ELATA HOOKERII	CALIFORNIA EVENING PRIMROSE	—		1,533 SF				
	TAN PI2	TANACETUM BIPINNATUM	DUNE TANSY	—		1,533 SF				
		BOTTOM BASIN				9,314 SF				
	LEY RNW	LEYMUS PACIFICUS INTERMEDIATES WITH L. TRITICOIDES	PACIFIC WILD RYE	—		9,314 SF	TRANSPLANT FROM PROPAGATION SITE			

San Francisco Water Power Sewer
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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: PLANTING SCHEDULE BIORETENTION AND PARKING PLANTERS
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-6002
Revision No. 0
Scale: N/A

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:23am

For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

PLANT SCHEDULE MEDIAN1

TREES	CODE	BOTANICAL NAME	COMMON NAME	SIZE		QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
	CUP MAC	CUPRESSUS MACROCARPA	MONTEREY CYPRESS	36" BOX		3				

SHRUBS	CODE	BOTANICAL NAME	COMMON NAME	SIZE	SPACING	QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
	ART PCN	ARTEMISIA PYCNOCEPHALA	BEACH SAGEWORT	1 GAL.	24" o.c.	216				
	BAC PIL	BACCHARIS PILULARIS	COYOTE BRUSH	5 GAL.	48" o.c.	42				
	CAM CER	CAMISSONIOPSIS CHEIRANTHIFOLIA	BEACH EVENING PRIMROSE	1 GAL.	18" o.c.	188				
	CAS AFF	CASTILLEJA AFFINIS	COAST INDIAN PAINTBRUSH	1 GAL.	48" o.c.	38				
	CAS EXS	CASTILLEJA EXSERTA	PURPLE OWL'S CLOVER	5 GAL.	48" o.c.	49				
	DIP AUR	DIPLACUS AURANTIACUS	STICKY MONKEYFLOWER	1 GAL.	36" o.c.	67				X
	ERI ERI	ERICAMERIA ERICOIDES	CALIFORNIA GOLDENBUSH	5 GAL.	48" o.c.	57				
	ERI BEA	ERIGERON GLAUCUS	SEASIDE DAISY	1 GAL.	18" o.c.	222			X	
	ERI STA	ERIOPHYLLUM STAECHADIFOLIUM	LIZARD-TAIL	1 GAL.	42" o.c.	58				
	LUP CHA	LUPINUS CHAMISSONIS	DUNE LUPINE	5 GAL.	36" o.c.	81				
	LUP VAR	LUPINUS VARIICOLOR	LINDLEY'S VARIED LUPINE	5 GAL.	24" o.c.	223				
	MYR CAL	MYRICA CALIFORNICA	PACIFIC WAX MYRTLE	15 GAL.	180" o.c.	10		X		
	PHA CA2	PHACELIA CALIFORNICA	CALIFORNIA PHACELIA	5 GAL.	18" o.c.	216				
	PHA DIS	PHACELIA DISTANS	DISTANT PHACELIA	5 GAL.	48" o.c.	51				

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: PLANTING SCHEDULE MEDIAN PLANTERS
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-6003
Revision No. 0
Scale: N/A

For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:23am

Exhibit 4
2-21-0912
Page 85 of 95

PLANT SCHEDULE MEDIAN2

TREES	CODE	BOTANICAL NAME	COMMON NAME	SIZE		QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
	CUP MAC	CUPRESSUS MACROCARPA	MONTEREY CYPRESS	36" BOX		3				

SHRUBS	CODE	BOTANICAL NAME	COMMON NAME	SIZE	SPACING	QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
	ART PCN	ARTEMISIA PYCNOCEPHALA	BEACH SAGEWORT	1 GAL.	24" o.c.	67				
	BAC PIL	BACCHARIS PILULARIS	COYOTE BRUSH	5 GAL.	48" o.c.	34				
	CAM CER	CAMISSONIOPSIS CHEIRANTHIFOLIA	BEACH EVENING PRIMROSE	1 GAL.	18" o.c.	100				
	CAS AFF	CASTILLEJA AFFINIS	COAST INDIAN PAINTBRUSH	1 GAL.	48" o.c.	35				
	CAS EXS	CASTILLEJA EXSERTA	PURPLE OWL'S CLOVER	5 GAL.	48" o.c.	32				
	DIP AUR	DIPLACUS AURANTIACUS	STICKY MONKEYFLOWER	1 GAL.	36" o.c.	20				X
	ERI ERI	ERICAMERIA ERICOIDES	CALIFORNIA GOLDENBUSH	5 GAL.	48" o.c.	33				
	ERI BEA	ERIGERON GLAUCUS	SEASIDE DAISY	1 GAL.	18" o.c.	91			X	
	ERI STA	ERIOPHYLLUM STAECHADIFOLIUM	LIZARD-TAIL	1 GAL.	42" o.c.	35				
	LUP CHA	LUPINUS CHAMISSONIS	DUNE LUPINE	5 GAL.	36" o.c.	43				
	LUP VAR	LUPINUS VARIICOLOR	LINDLEY'S VARIED LUPINE	5 GAL.	24" o.c.	110				
	PHA CA2	PHACELIA CALIFORNICA	CALIFORNIA PHACELIA	5 GAL.	18" o.c.	108				
	PHA DIS	PHACELIA DISTANS	DISTANT PHACELIA	5 GAL.	48" o.c.	27				

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No WW-662
Drawing Title: PLANTING SCHEDULE MEDIAN 2 PLANTERS
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-6004
Revision No. 0
Scale: N/A

For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:23am

Exhibit 4
2-21-0912
Page 86 of 95

PLANT SCHEDULE PARKING LOT

SHRUBS	CODE	BOTANICAL NAME	COMMON NAME	SIZE	SPACING	QTY	REMARKS	ATTRACTS BIRDS	ATTRACTS BUTTERFLIES	ATTRACTS HUMMINGBIRDS
	ART PCN	ARTEMISIA PYCNOCEPHALA	BEACH SAGEWORT	1 GAL.	24" o.c.	182				
	BAC PIL	BACCHARIS PILULARIS	COYOTE BRUSH	5 GAL.	48" o.c.	73				
	CAM CER	CAMISSONIOPSIS CHEIRANTHIFOLIA	BEACH EVENING PRIMROSE	1 GAL.	18" o.c.	425				
	CAS AFF	CASTILLEJA AFFINIS	COAST INDIAN PAINTBRUSH	1 GAL.	48" o.c.	26				
	CAS EXS	CASTILLEJA EXSERTA	PURPLE OWL'S CLOVER	5 GAL.	48" o.c.	24				
	DIP AUR	DIPLACUS AURANTIACUS	STICKY MONKEYFLOWER	1 GAL.	36" o.c.	168				X
	ERI ERI	ERICAMERIA ERICOIDES	CALIFORNIA GOLDENBUSH	5 GAL.	48" o.c.	107				
	ERI BEA	ERIGERON GLAUCUS	SEASIDE DAISY	1 GAL.	18" o.c.	192			X	
	ERI STA	ERIOPHYLLUM STAECHADIFOLIUM	LIZARD-TAIL	1 GAL.	42" o.c.	123				
	LUP CHA	LUPINUS CHAMISSONIS	DUNE LUPINE	5 GAL.	36" o.c.	205				
	LUP VAR	LUPINUS VARIICOLOR	LINDLEY'S VARIED LUPINE	5 GAL.	24" o.c.	207				
	PHA CA2	PHACELIA CALIFORNICA	CALIFORNIA PHACELIA	5 GAL.	18" o.c.	31				
	PHA DIS	PHACELIA DISTANS	DISTANT PHACELIA	5 GAL.	48" o.c.	8				

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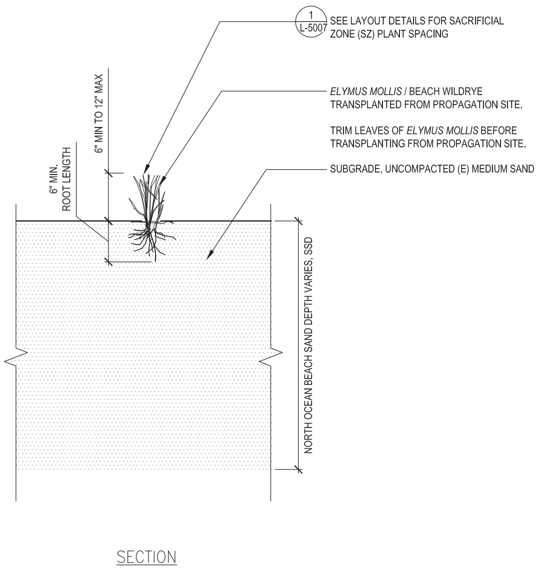
Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: PLANTING SCHEDULE PARKING LOT
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-6005
Revision No. 0
Scale: N/A

For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

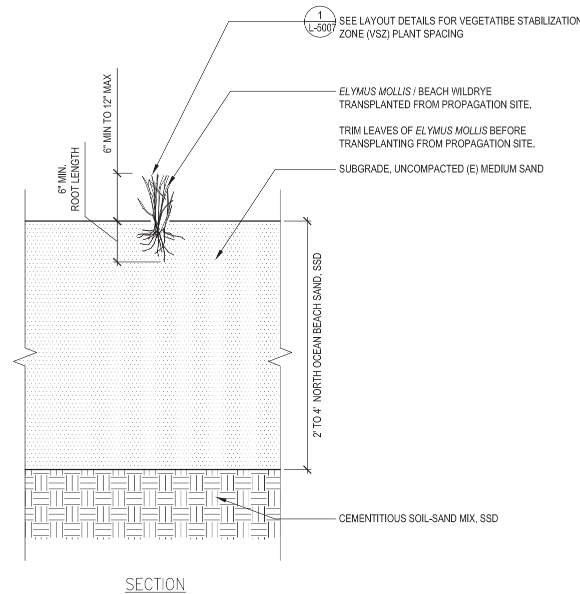
Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_21048\1138I_L-4.1_PLNT_ENLG_PLAN.dwg Plotted on: Jan 18, 2023 - 9:23am



CONSTRUCTION NOTES:

1. PLANT LOCATIONS TO BE STAKED IN THE FIELD AND APPROVED BY LANDSCAPE ARCHITECT PRIOR TO PLANTING.
2. ELYMUS MOLLIS IN THIS DETAIL APPLIES TO TRANSPLANTED GRASSES AT SLOAT PLAZA AND THE SACRIFICAL ZONE PLANTING AREA, SEE SITE PLANTING PLANS.

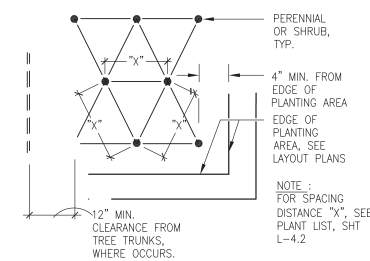
1 PLANTING DETAIL - TRANSPLANTED GRASSES SACRIFICIAL ZONE
SCALE: 1" = 1'-0"



CONSTRUCTION NOTES:

1. PLANT LOCATIONS TO BE STAKED IN THE FIELD AND APPROVED BY LANDSCAPE ARCHITECT PRIOR TO PLANTING.
2.

2 PLANTING DETAIL - TRANSPLANTED GRASSES AT VSZ
SCALE: 1" = 1'-0"



3 TRIANGULAR PLANTING
SCALE: NTS

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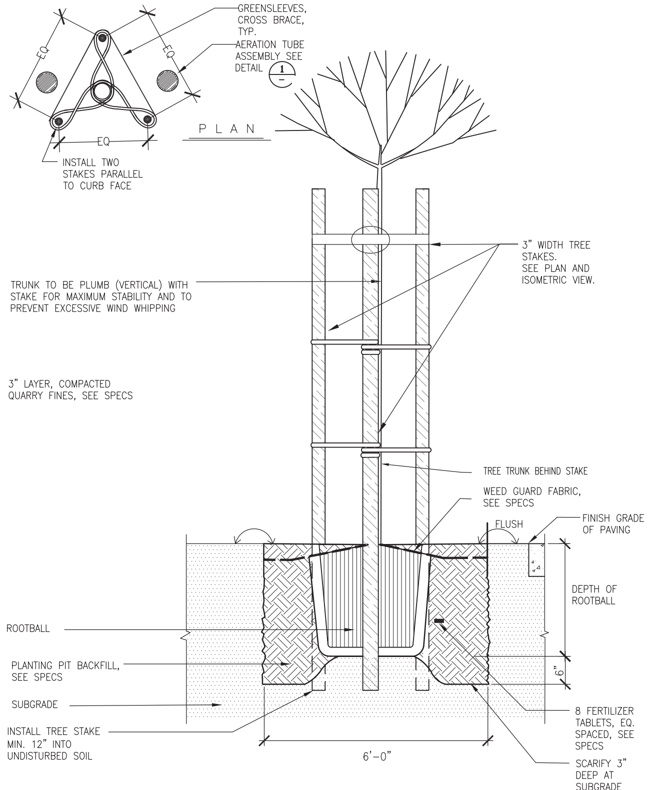
Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS
Plan No.
Contract No: WW-662
Drawing Title: PLANTING DETAILS
Project No. 1138I
Elevation Datum
Drawing/File No 000-L-5004
Revision No. 0
Scale: AS NOTED

For reduced plans original scale is in inches 0 4
Original Sheet Size: 22"x34"

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.2_PLNT_DETL.dwg Plotted on: Dec 20, 2022 - 9:48am



NOTE:

1. TREE STAKE TO BE LOCATED ON PREVAILING WIND SIDE.
2. TREES SHALL BE PRUNED UNDER THE DIRECTION OF ENGINEER.
3. ALL TREES TO RECEIVE COMPACTED QUARRY FINES AND WEED
4. GUARD FABRIC AND BE CENTERED WITHIN 3'X4' PLANTING PIT. STAKES TO BE PAINTED. COLOR: BLACK.
5. BRACE SLEEVES, CROSS BRACE, TIES SLEEVES AND STRAPS TO BE BLACK IN COLOR.

1 TREE PLANTING

SCALE: 1" = 1'-0"

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING DETAILS

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-5005

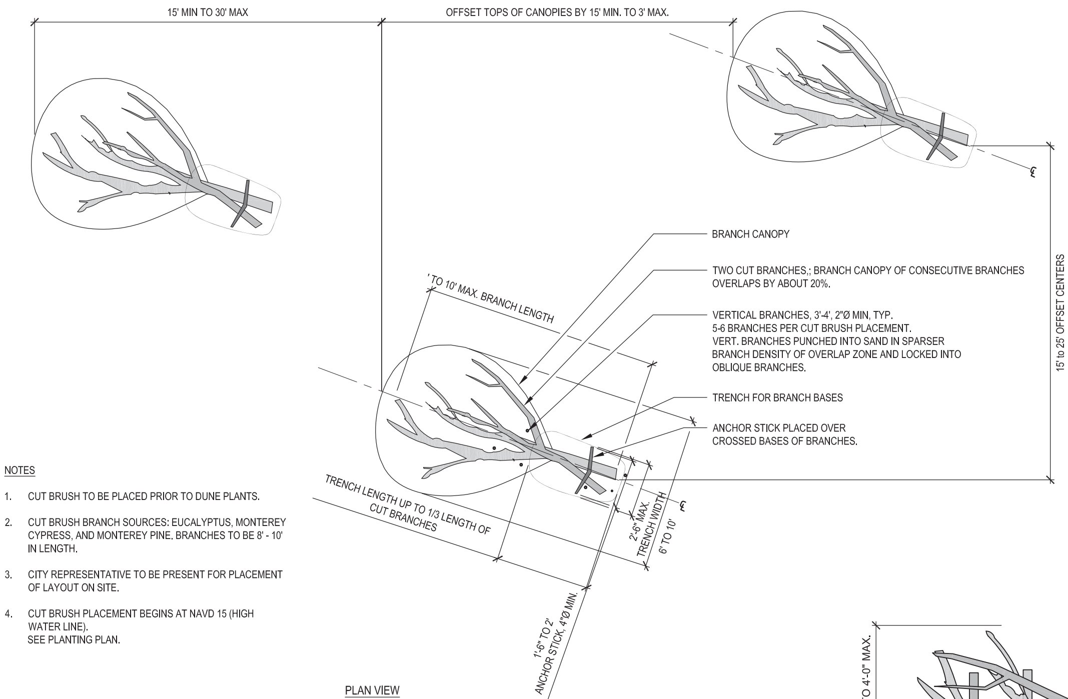
Revision No. 0

Scale: AS NOTED

For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"

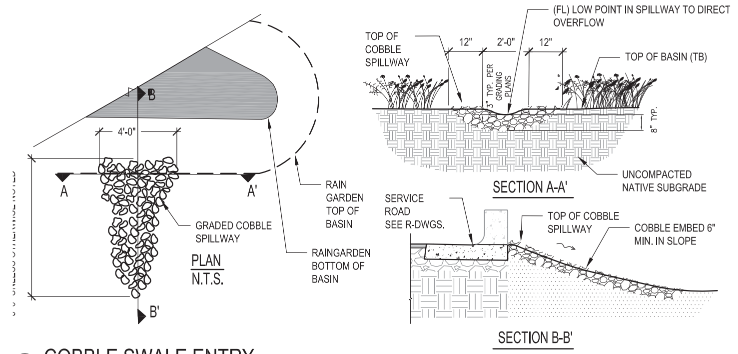
Drawing name: C:\Users\sguillaume\appdata\local\temp\AcPublish_24580\1138I_L-4.2_PLNT_DETL.dwg Plotted on: Dec 20, 2022 - 9:44am



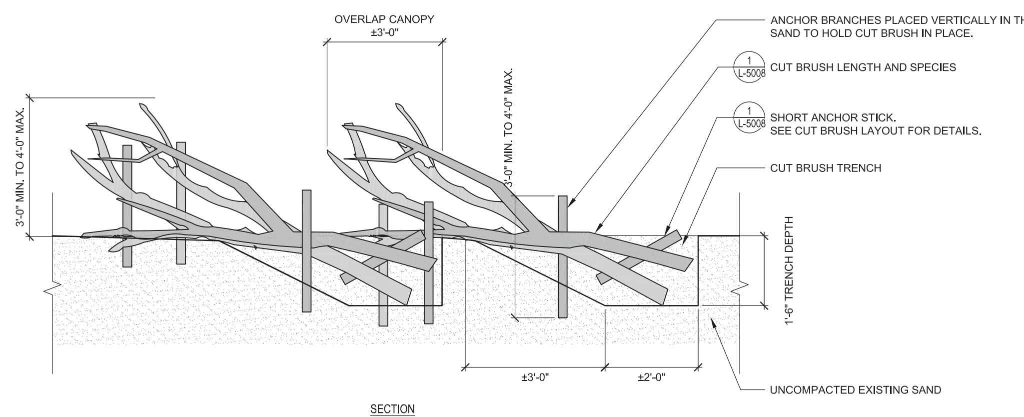
NOTES

1. CUT BRUSH TO BE PLACED PRIOR TO DUNE PLANTS.
2. CUT BRUSH BRANCH SOURCES: EUCALYPTUS, MONTEREY CYPRESS, AND MONTEREY PINE. BRANCHES TO BE 8' - 10' IN LENGTH.
3. CITY REPRESENTATIVE TO BE PRESENT FOR PLACEMENT OF LAYOUT ON SITE.
4. CUT BRUSH PLACEMENT BEGINS AT NAVD 15 (HIGH WATER LINE). SEE PLANTING PLAN.

1 CUT BRUSH - LAYOUT
SCALE: 3/8" = 1'-0"



3 COBBLE SWALE ENTRY
SCALE: NTS



2 CUT BRUSH - CONSTRUCTION
SCALE: 3/4" = 1'-0"

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING DETAILS CUT BRUSH DETAILS

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-5006

Revision No.: 0

Scale: AS NOTED

For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.2_PLNT_DETL.dwg Plotted on: Jan 13, 2023 - 6:37pm

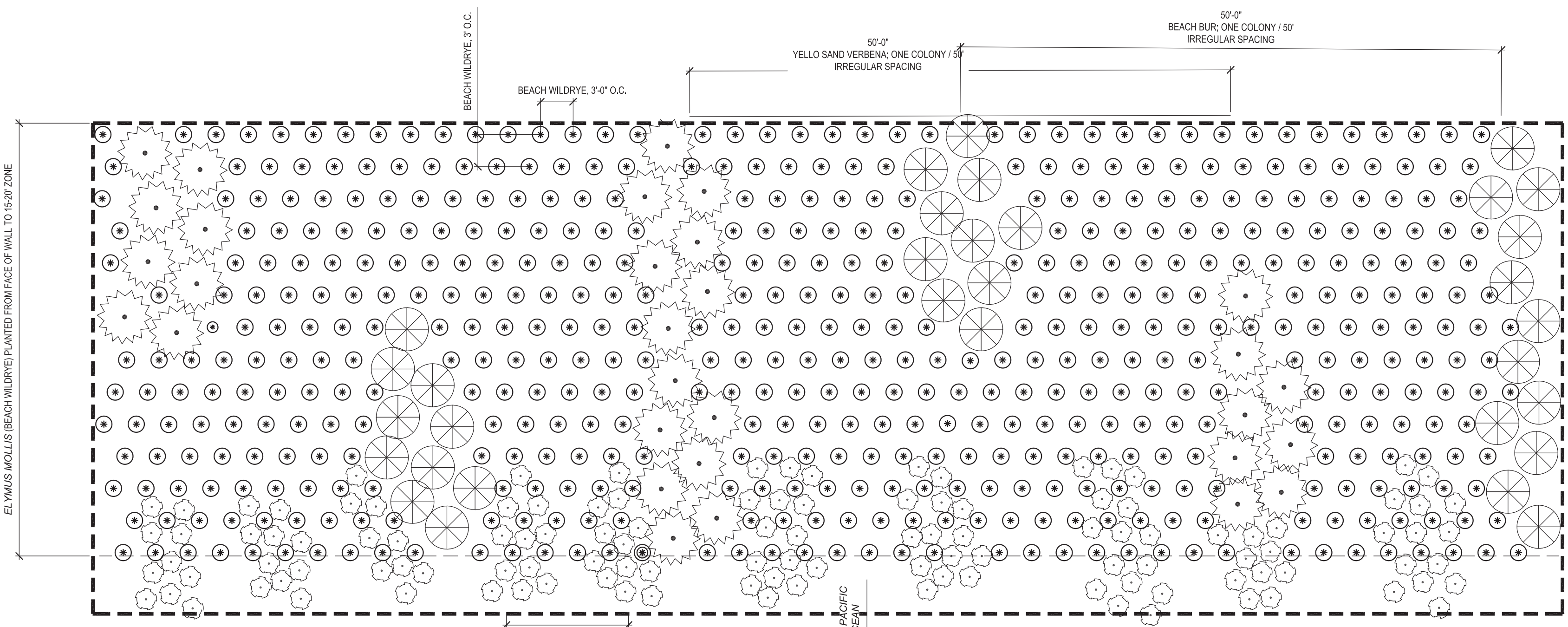
Exhibit 4
2-21-0912
Page 90 of 95

KEY

- BEACH WILDRYE (LEYMUS MOLLIS)
- YELLOW SAND–VERBENA (ABRONIA LATIFOLIA)
- BEACH–BUR (AMBROSIA CHAMISSONIS)
- CALIFORNIA SALTBUSH (ATRIPLEX CALIFORNICA)

NOTE:

APPLY ALTERNATING PATTERN OF ABRONIA AND AMBROSIA TO ENTIRE SACRIFICIAL PLANTING ZONE.



1 SACRIFICIAL ZONE - PLANT SPACING

SCALE: 3/16"=1'-0"

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING DETAILS SACRIFICIAL ZONE PLANT SPACING

Project No.: 1138I

Elevation Datum

Drawing/File No: 000-L-4008

Revision No.: 0

Scale: AS NOTED

For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

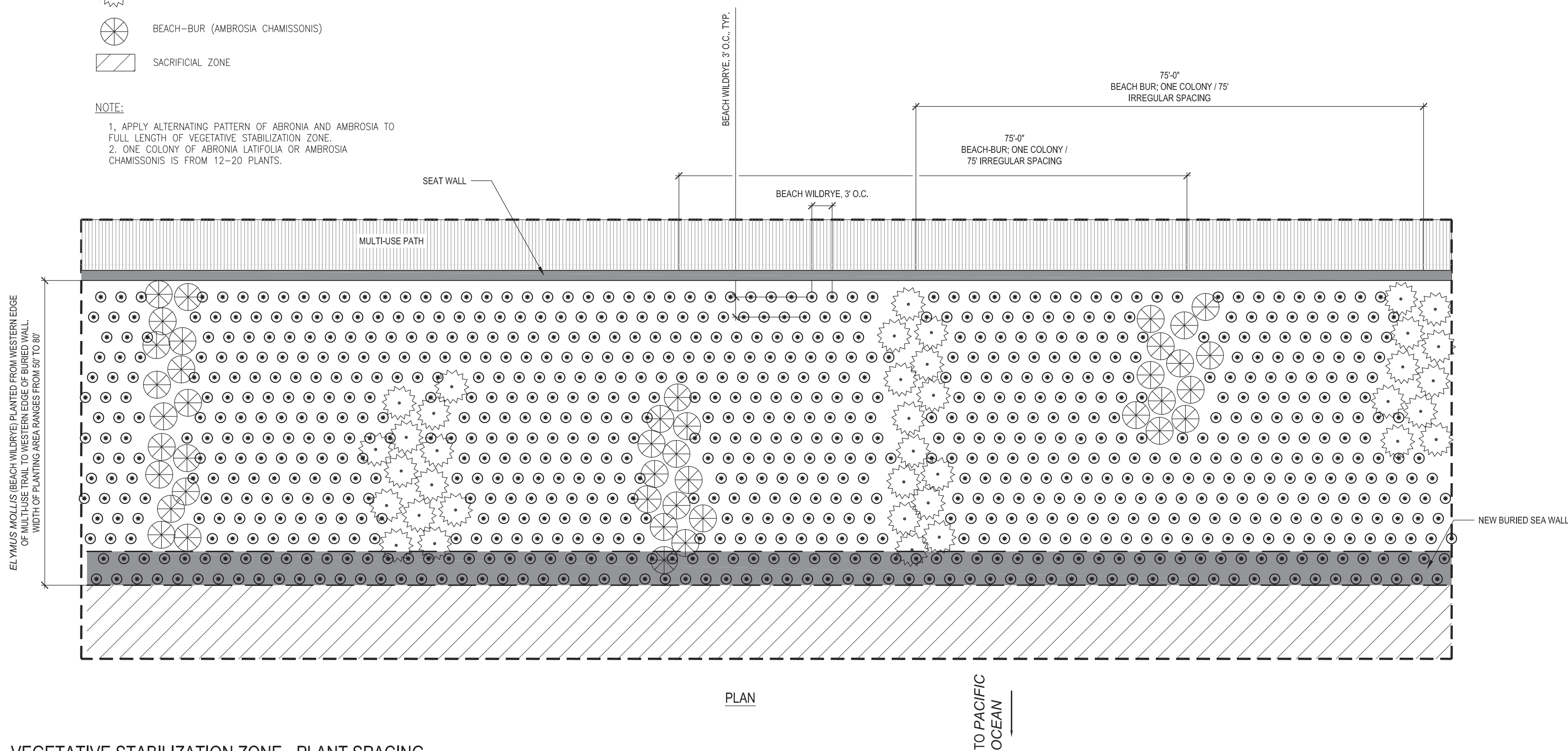
Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.2_PLNT_DETL.dwg Plotted on: Jan 13, 2023 - 6:38pm

KEY

SYMBOL	NOTES
⊙	BEACH WILDRYE (LEYMUS MOLLIS)
(sand-verbena symbol)	YELLOW SAND-VERBENA (ABRONIA LATIFOLIA)
(beach-bur symbol)	BEACH-BUR (AMBROSIA CHAMISSONIS)
(hatched box)	SACRIFICIAL ZONE

NOTE:

1. APPLY ALTERNATING PATTERN OF ABRONIA AND AMBROSIA TO FULL LENGTH OF VEGETATIVE STABILIZATION ZONE.
2. ONE COLONY OF ABRONIA LATIFOLIA OR AMBROSIA CHAMISSONIS IS FROM 12-20 PLANTS.



1 VEGETATIVE STABILIZATION ZONE - PLANT SPACING

SCALE: 1/8"=1'-0"

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING DETAILS VEGETATIVE STABILIZATION ZONE PLANT SPACING

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-4009

Revision No. 0

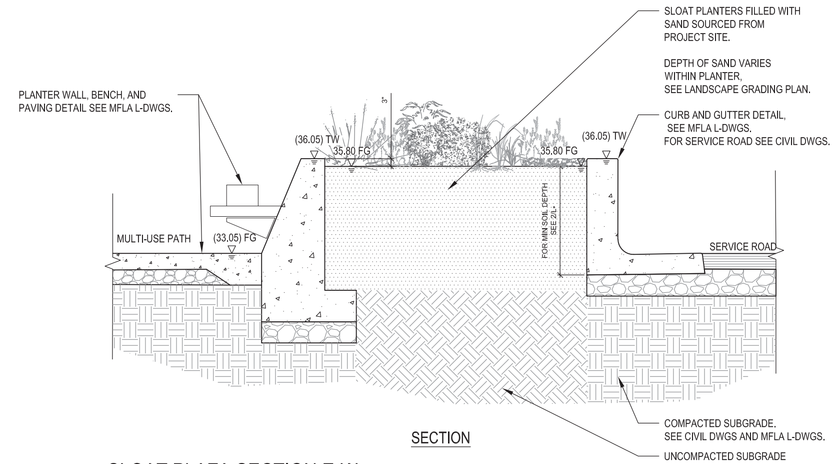
Scale: AS NOTED

For reduced plans original scale is in inches

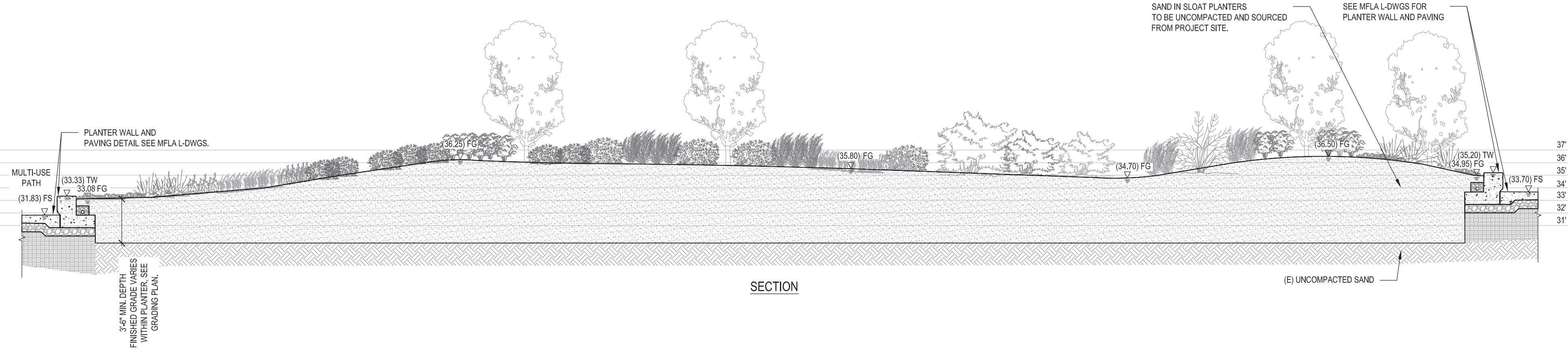
0 4

Original Sheet Size: 22"x34"

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.2_PLNT_DETL.dwg Plotted on: Jan 13, 2023 - 6:39pm



1 SLOAT PLAZA SECTION E-W
SCALE: 1" = 1'-0"



2 SLOAT PLAZA SECTION N-S
SCALE: 1/4" = 1'-0"

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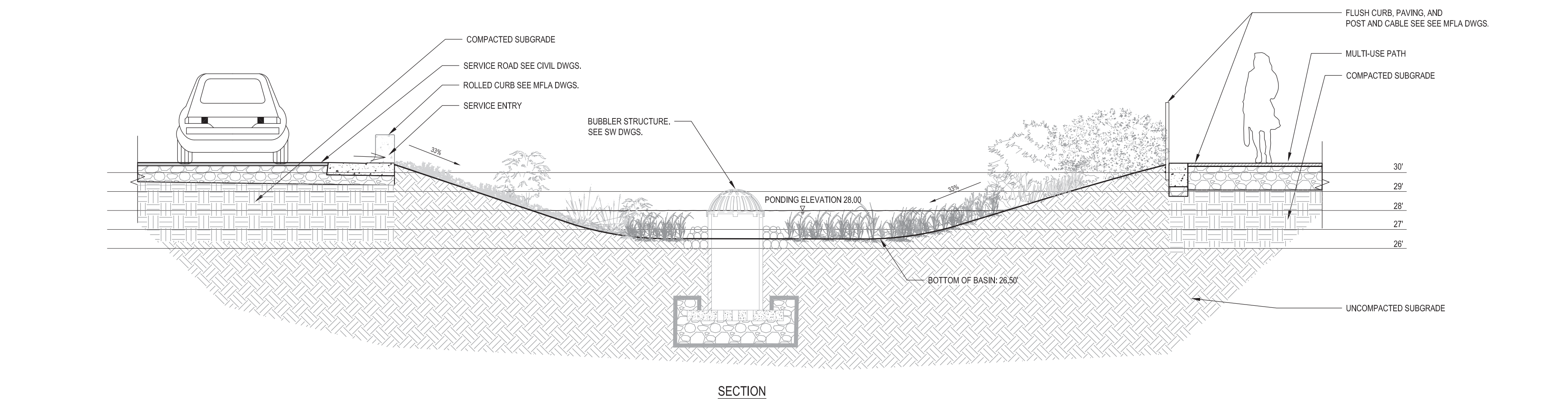
Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS		Plan No.
Contract No: WW-662	Drawing Title: PLANTING DETAILS	Project No.: 1138I
Elevation Datum	Drawing/File No: 000-L-3001 — Revision No.: 0	Scale: AS NOTED

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.2_PLNT_DETL.dwg Plotted on: Jan 13, 2023 - 3:21pm

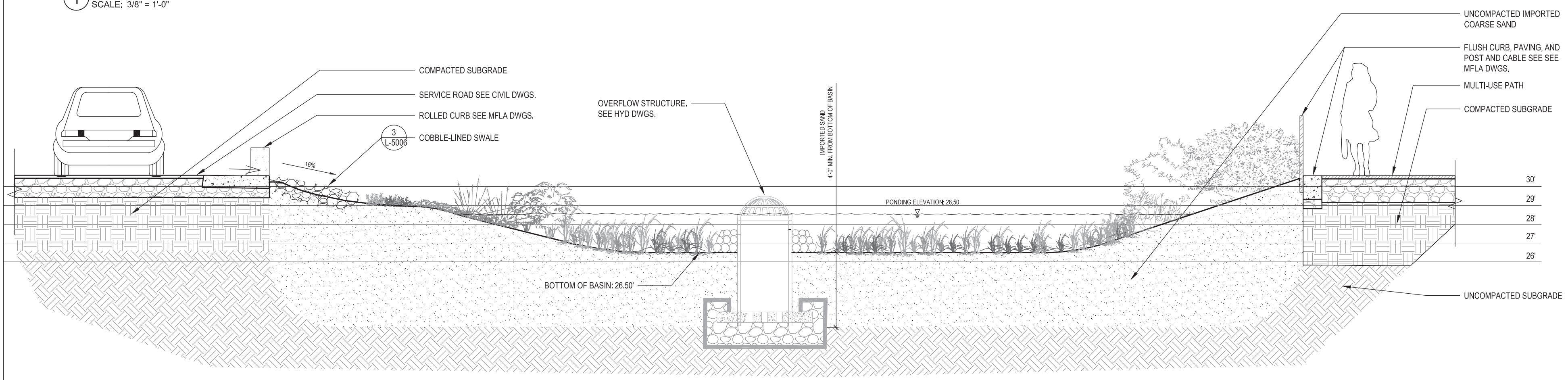
For reduced plans original scale is in inches 0 4

Original Sheet Size: 22"x34"



1 BIORETENTION BASIN B

SCALE: 3/8" = 1'-0"



SECTION

2 BIORETENTION BASIN C

SCALE: 3/8" = 1'-0"

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Project: OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT - LONG TERM IMPROVEMENTS

Plan No.

Contract No: WW-662

Drawing Title: PLANTING DETAILS BIORETENTION BASIN SECTIONS

Project No. 1138I

Elevation Datum

Drawing/File No 000-L-3002

Revision No. 0

Scale: AS NOTED

For reduced plans original scale is in inches

0 4

Original Sheet Size: 22"x34"

Drawing name: V:\1138I_Ocean_Beach_Long_Term_Improvement_Project_10015554\2_Design\Working_Drawings\ALA\Sheets\1138I_L-4.2_PLNT_DETL.dwg Plotted on: Dec 22, 2022 - 2:39pm

Exhibit 4
2-21-0912
Page 94 of 95

PARKING LOT INFILTRATION
BASINS TO BE REVISED

(1) PARKING LOT INFILTRATION BASIN - SECTION 1
SCALE: 1" = 1'-0"

PARKING LOT INFILTRATION
BASINS TO BE REVISED

(2) PARKING LOT INIFILTRATION BASIN - SECTION 2
SCALE: 1" = 1'-0"

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OCEAN BEACH CLIMATE CHANGE ADAPTATION PROJECT

Habitat Restoration and Enhancement Plan

Prepared By:

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Prepared for:

San Francisco Water Power Sewer

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Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Purpose

This report provides the design basis and proposed design for components of the Ocean Beach Climate Change Adaptation Project (OBCCAP) related to construction of coastal dunes, management of dune and beach vegetation, dune sand transport, and infiltration of storm runoff within constructed infiltration basins (dune slacks). These project components are fitted to engineering designs for the South Ocean Beach shoreline as outlined in the project Conceptual Engineering Report Draft (M&N/AGS JV, 2019) and Sand Management Plan for Ocean Beach Climate Change Adaptation Project (M&N/AGS JV, 2020). This report integrates, updates and expands prior technical memoranda individually covering preliminary assessment and conceptual design of dune vegetation, wind-blown sand management, infiltration basins in stabilized backdune zones, and sub-irrigation of the vegetative stabilization zones (Baye 2020, 2021)

1.2. Scope of Document

The design basis for dune vegetation and sand management applies a “nature-based” approach through focused assessment of natural remnant coastal dunes of the San Francisco Peninsula, analogous coastal California dune systems retaining components now lost in San Francisco, and incorporation of specific functional elements of these systems to the reconstructed, engineered bluff and coastal dunes that are designed for resilience to climate change – specifically erosion caused by sea level rise in combination with extreme storms, extreme droughts, and extreme rainfall events.

The design report is framed by review of the historic shoreline, including its dune forms and processes, and the historic native vegetation in the project vicinity. Selected components of the native dune ecosystem are applied to resilient designs for establishment of planted native vegetation after beach nourishment and construction of slopes, walls, and dunes along with management of vegetation across a wind-blown sand transport gradient. The dune sand transport gradient itself is in turn influenced by active management of vegetation, adapted to the spatial constraints of the project infrastructure.

The sand transport gradient and vegetation are also adapted to anticipated cycles of beach erosion and beach nourishment that drive pulses of wind-blown (eolian) sand deposition to the foredune zone. The dune sand transport gradient that frames the design ranges from stable, landward infiltration basins to dynamic foredunes. The basic premise of the design is for most onshore wind-blown sand to be intercepted and trapped in the managed, vegetated foredune zone and then released to the beach during erosional beach phases.

Additional ecosystem services designed for the constructed dune system include nature-based analogs of stable vegetated dune depressions such as dry dune slacks, basins, flats, or hollows that detain and rapidly infiltrate stormwater runoff from roads and trails. The design basis and conceptual designs for modifications of the constructed dune system are also provided in the report.

Adaptive management measures, contingent on storm erosion and post-storm beach recovery supported by beach nourishment, are included in site management plans. These cover placement of temporary nature-based physical sand surface stabilization features (brush fencing, woody debris, coarse lag materials, etc.) that are compatible with ecosystem, aesthetic, recreational coastal uses of the project area.

2. Physical Setting

2.1. Coastal Processes and Shoreline Management

Ocean Beach is strongly affected by tidal currents from the adjacent Golden Gate entrance as well as wave refraction around the ebb-tidal delta at the mouth of San Francisco Bay (USGS, 2007).

In 2004, the U.S. Geological Survey (USGS) initiated a two-year coastal processes monitoring program at Ocean Beach and provided scientific data to better understand and mitigate the long-term erosion problem at the South Ocean Beach (USGS, 2007). Field data collection included beach topographic mapping, nearshore bathymetric profile surveying, image monitoring, offshore and surf-zone current and wave measurements, grain size mapping, and development of numerical modeling. Major findings related to coastal processes are:

- Beach volume varies seasonally over a maximum envelope of 520,000 cubic yards (CY).
- Single storm events can cause an average shoreline retreat of over 33 ft and remove over 130,000 CY of sand from the beach.
- Preliminary findings from storm response surveys indicate a potentially strong correlation between wave height and wave direction with beach response.
- Comparisons of bathymetric profiles show patterns of seasonal bar migration onshore in the summer and offshore in the winter. Bars can be as high as 6.6 ft and move over 1,000 ft in the cross-shore direction.
- A shorter-term survey after one month suggests that a few winter storms can force offshore bar migration on the order of 300 ft.
- Four rip currents occurred seasonally at the northern Ocean Beach with a spacing of 500 ft to 650 ft.
- Analysis of time-stack runup data shows that the beach was dissipative under typical summer conditions, with infragravity conditions dominating and swash periods on the order of a minute.
- Erosion of the shoals offshore of South Ocean Beach has made the adjacent beach more susceptible to wave attack.

2.1.1. Human Alterations

The Ocean Beach area has had human alterations since the late 19th century including highway construction, seawall construction, dune stabilization, dune removal, rip-rap emplacement, beach nourishment, and inlet fill. The most significant man-made feature is the 1 mile long O'Shaughnessy Seawall at the northern end of the beach, built between 1915 and 1929 to protect the Great Highway. The 665 ft long Taraval Seawall was constructed in 1941 to protect the pedestrian underpass at Taraval Street and the Great Highway. In 1983, the City and County of San Francisco constructed the Westside Sewer Transport Box under the Great Highway to treat urban effluent. In March of 1988, construction of another seawall/promenade was initiated to protect the Great Highway and sewer box between Noriega and Santiago Streets from major storms, completed in 1993 (USGS, 2007; USACE, 1996).

Beach and dune fill activities started as early as the 1870's when dune stabilization and road improvements affected the shoreline position and shape (M&N, 1995*)*. Significant beach and dune fill occurred in the period from 1900 to 1929 when the O'Shaughnessy Seawall was constructed. Between the years 1900 and 1956 a total volume of 2.35 million CY of sand was placed as beach and dune fill. Since 1956 over one million CY of sand was placed, primarily south of Lincoln Way. Additional sand may have been dumped on the beach and dunes in the late 1940's and early 1950's when nearby residential development peaked, requiring removal of sand dunes from lots. About 100,000 CY of sand was mined between 1963 and 1967, with mining initiated in 1953. Since completion of the Great Highway in 1929, significant beach and dune nourishment has taken place while sand mining rates have remained relatively low. The net volume increase to the beach and dunes by human alteration since 1929 is estimated to be about 1.3 million CY (M&N/AGS JV, 2019).

2.1.2. Sand Backpass History

Short-term erosion protection measures have been carried out at South Ocean Beach since 2012 (M&N/AGS JV, 2020). These measures include sand backpass events, windblown sand mitigation measures, bluff failure response, and sandbag placement to bolster integrity. Table 2-1 summarizes the approximate quantity of sand placement and Figure 2-1 shows the location of placement.

Table 2-1: Summary of sand backpass events since 2012.

Date	Placement Amount (CY)	Placement Location
Aug/Sep 2012	73,300	
	~ 17,000 (est.)	Reach 2
	~ 56,000 (est.)	North Lot & Reach 3
Nov/Dec 2014	25,000	Reach 2
Feb/Mar 2016	25,000	Reach 2
Nov/Dec 2016	70,000	
	~ 25,000 (est.)	Reach 2
	~ 45,000 (est.)	North Lot & Reach 3
Apr 2018	65,000	
	~ 25,000	Reach 2
	~ 40,000	North Lot & Reach 3
Nov/Dec 2019	65,000	
	~ 25,000	Reach 2
	~ 40,000	North Lot & Reach 3

Figure 2-1: Sand backpass placement areas

2.2. Historic Shoreline and Dune Morphology in Project Area

Prior to development and shoreline engineering, the most seaward dunes of Ocean Beach were continuous with the bare sand of the backshore beach, only sparsely vegetated in discrete mounds with mostly unimpeded wind-blown sand transport from the beach to waves of transverse dunes extending far inland (Cooper 1967, Ramaley 1918) (Figure 2-2). Ramaley (1918) observed the foredune zone when a road was already constructed parallel to shore, and described its condition in 1917 as

> "…large areas, often 500 meters square, with no vegetation whatever. Then there are still more extensive tracts with only occasional mounds crowned with plants. In low places, especially in the shelter of high dunes, a fairly close plant community may occur, but elsewhere where there is always much bare ground."

Ramaley's "low places in the shelter of high dunes" with a "fairly close plant community" refer to dune slacks, either wetland or drained. Ramaley noted that marram grass (*Ammophila arenaria*, European beachgrass), which was introduced to stabilize inland Presidio and Golden Gate Park dunes over four decades prior to his visit, was only locally established near the beach in 1917. The primary pioneer foredune plants in 1917 were two prostrate, dune mound-forming perennial broadleaf plants, beach-bur (*Ambrosia chamissonis*) and yellow sand-verbena (*Abronia latifolia*). Cooper (1967), who also visited the San Francisco dunes in the in 1919 and 1927, reviewed historical descriptions of the dunes by early explorers and navigators, especially W.P. Blake's 1857 account, and concluded that the original, pre-colonization condition of the outer dunes was desert-like and principally unvegetated, unstable mobile dunes consistent with Ramaley's (1918) description.

Most relevant to the Ocean Beach Climate Change Adaptation Project, there is no historical evidence of any significantly vegetated, continuous, linear foredune ridges landward of the beach in San Francisco. There is, however, clear historical botanical evidence that the obligate beach-dune plant species like beach wildrye (*Leymus mollis*), which can form low vegetated foredune ridges, were originally present in San Francisco's seaward dunes, known from remnant populations collected in 1921 (Howell *et al.* 1958).

Figure 2-2: Examples of sparse, isolated vegetated dune mounds (hummocks) of the outer San Francisco dunes landward of Ocean Beach in 1917, indicative of original pre-reclamation conditions (from Ramaley 1918)

Aerial photographs of Ocean Beach from the 1940s-1960s exhibit discontinuous, shore-parallel patterns of marram grass foredunes aligned with outcrops of eroded fill placed seaward of Great Highway, above filled backshore portions of Ocean Beach. Since Ramaley (1918) described "an automobile highway parallels the ocean shore at the west but has had no influence upon the dunes or their vegetation" in 1917, it is apparent that the artificial fill platform of the linear marram foredune ridge of the mid-20th century was a later development. The eroded remnants of the Great Highway fill platform and eroded marram foredunes were replaced by construction of an artificial foredune ridge extending from Lincoln to Sloat Boulevards in 1984-1985 (Figure 2-3). The project was completed by the City of San Francisco and was newly planted by March 1985. The ridge was constructed from imported non-dune sandy fill materials, but most of its surface became mantled with dune sand by the late 1980s-1990s.

Figure 2-3: The newly constructed and planted Ocean Beach artificial foredune ridge in March 1985, with incipient dune sand accretion confined to the toe of the steep seaward slope.

The historic San Francisco dune sheet in the project vicinity is distinguished by two outstanding geologic features: the historic outlet of Lake Merced, a beach-impounded, non-tidal coastal freshwater lagoon and overlap with northward dipping slopes of Pleistocene (ice-age) uplifted Colma Formation sands composed of raised beaches and ancient dunes near the former Lake Merced outlet (Figure 2-4). The recent surface dune of Fort Funston, however, was deposited in the historic era. The recent dunes of Fort Funston are distinct from those of south Ocean Beach in composition, composed of iron-stained (ochre) weathered ancient sands recently eroded by wind from the high bluff face (scarp) rather than unweathered wave-washed grayish beach sand blown from the backshore. The transition between recent Ocean Beach dunes and Colma bluff-top (perched) modern dunes occurs at the south end of the project site, where Colma Formation scarps still outcrop behind recent boulder armoring.

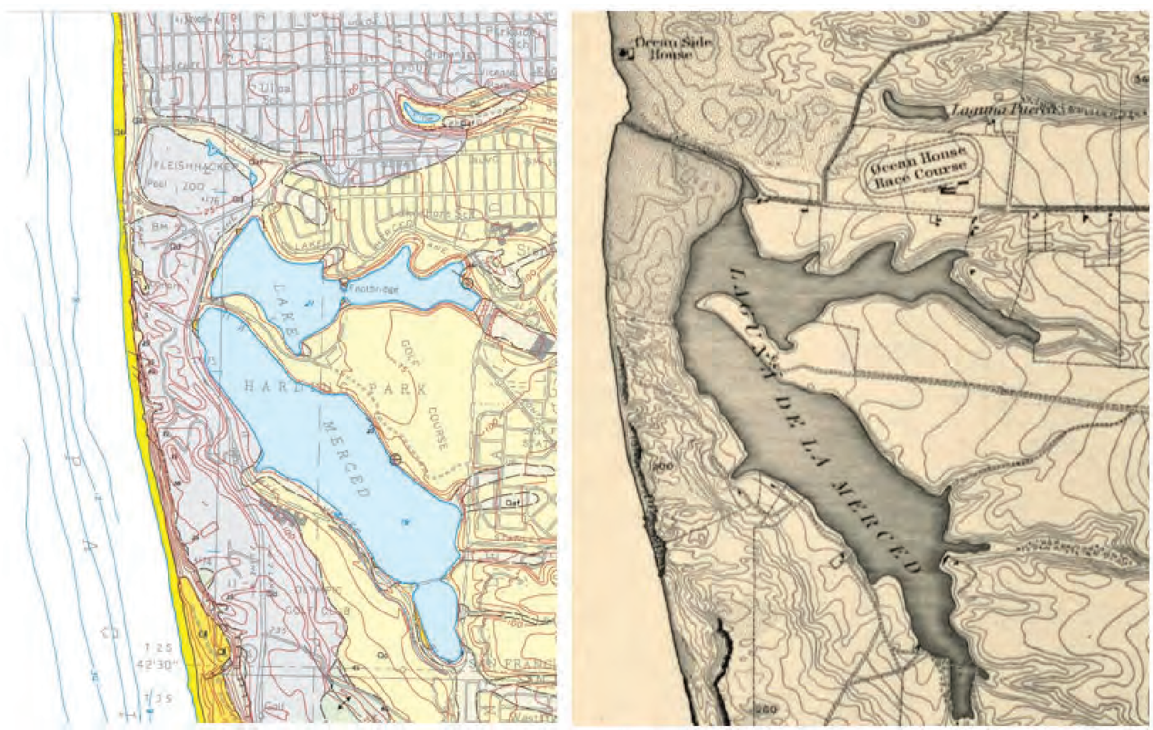

Figure 2-4: Historic topography and surface geology of the south Ocean Beach project area, and adjacent Lake Merced and north Fort Funston. (a) Excerpt from U.S. Geologic Survey Map Open File Report 98-354, Bonilla, M.G. Preliminary

Geologic Map of the San Francisco South 7.5' Quadrangle (1998). Qaf – artificial fill. Qd = Quaternary (Holocene) dune sand, gray. Qb – beach deposits, dark yellow. Qc – Colma Formation, pale yellow. (b) Excerpt 1:40,000 U.S. Coast Survey map of San Francisco Peninsula, with 1850-1857 topography. Note linear outlet channel of North Lake Merced through south Ocean Beach (artificially extended after a seismic event outlet breach).

2.2.1. Shoreline Evolution

The USGS continues to monitor beach profiles at Ocean Beach and provides valuable data on the short-term beach profile fluctuations and long-term shoreline change rates. Figure 2-5 presents the time series of 16-year beach profiles at the project and the surrounding areas. The data demonstrates that the beach experiences both seasonal and interannual variations.

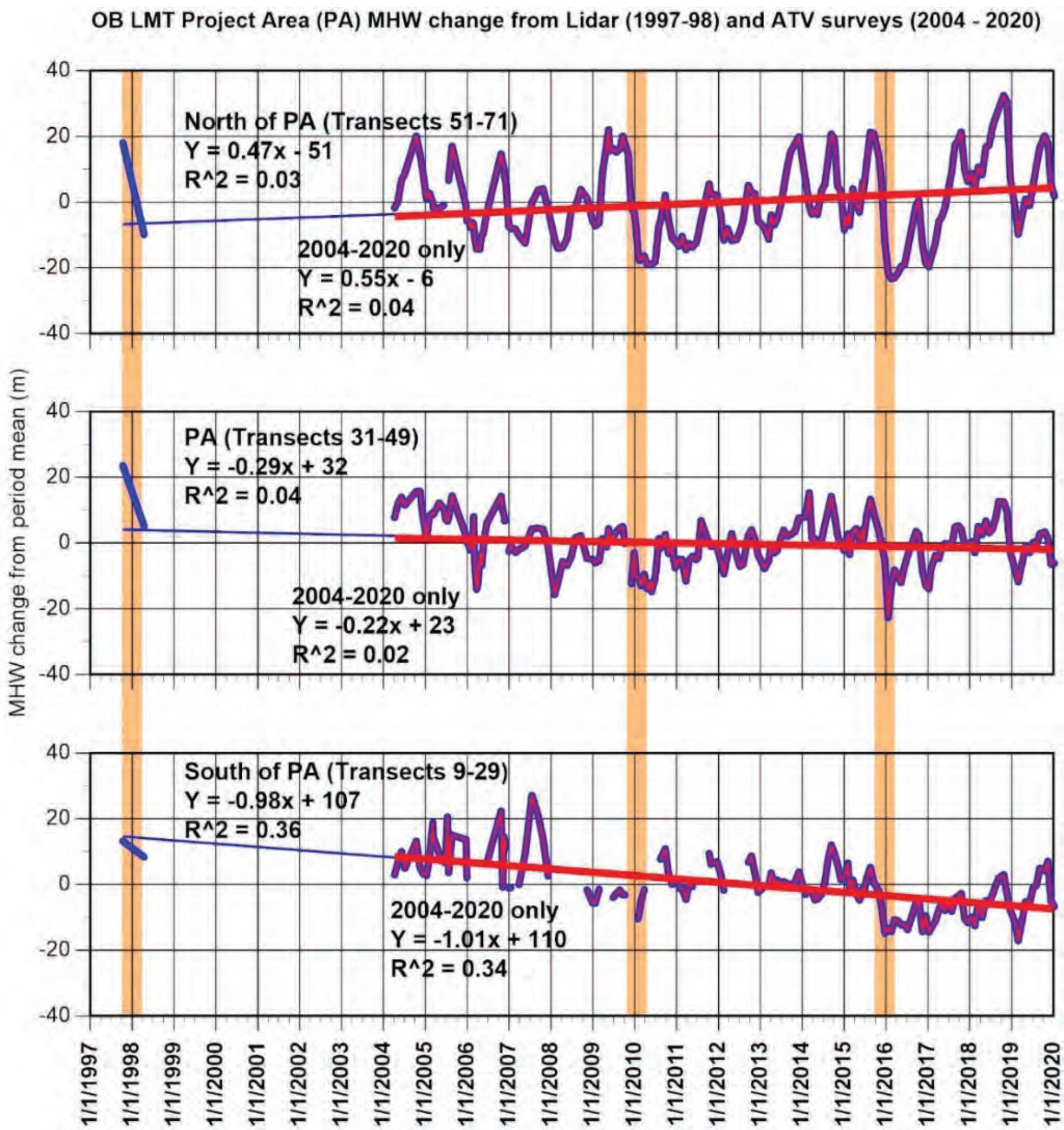

Figure 2-5: Time series of MHW shoreline change near the project area (USGS, 2020). Provisional USGS data subject to revision.

Figure 2-6 shows an average erosion rate of 0.7 m/year (2.3 ft/year) and up to 1.3 m/year (4.3 ft/year) at the Project area. The largest erosion rate at the south end agrees well with the bluff erosion rate in the same area estimated at 4.7 ft/year, based on USGS Dr. Warrick's unpublished data. Concurrently, the northern Ocean Beach experiences an average accumulation rate of 4 to 5 m/year (13 to 16 ft/year).

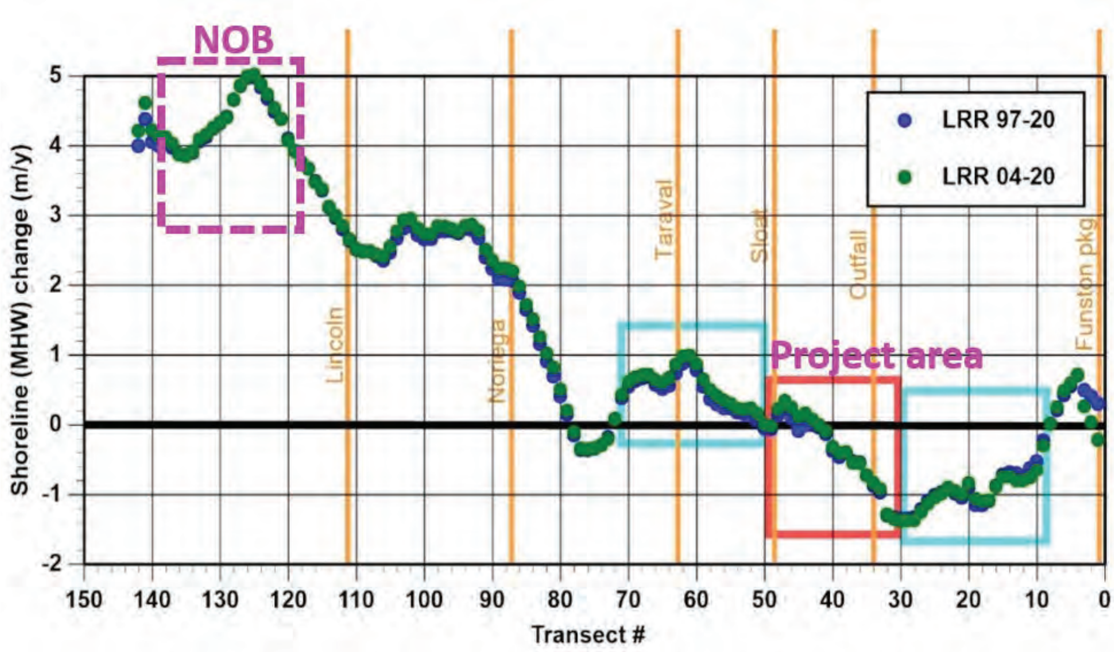

Figure 2-6: MHW shoreline change rates by transect (USGS, 2020). Provisional USGS data subject to revision.

3. Restoration Design Basis

3.1. Overview

Coastal dune systems of Central California develop highly variable “typical” profiles depending on the degree of past or present influence by marram grass (*Ammophila arenaria*, the European beachgrass), which often forms high, narrow, and steep foredune ridge topography with sharply defined vegetation and sand transport zones. In contrast, the foredune topographic patterns established by native California foredune vegetation usually develop as broad, irregular undulating mounds or semi-open mobile dunes with relatively large gaps and blowouts.

The low, semi-open structure of natural Central California foredunes under native vegetation usually facilitates potential high rates of wind-blown sand transport landward. The OBCCAP design requires a marram-type artificial foredune ridge similar to the 1980s Ocean Beach constructed foredune ridge and an interior stable backdune area to restrict onshore wind-blown sand transport in a narrow zone. Since the planting of invasive non-native marram grass is discouraged or prohibited by resource agencies, OBCCAP designs must use only native foredune vegetation to achieve sand-trapping functions and efficiency to the greatest extent feasible. This will require active management to sustain vegetation performance beyond typical thresholds.

The backdune infiltration basin zone, landward of significant wind-blown sand transport that would be intercepted by the managed vegetation canopy of foredunes, also must include native vegetation to perform specific, managed ecosystem services. Infiltration basins require capacity to drain and rapidly infiltrate stormwater runoff from trails and service roads in dry (non-wetland) dune depressions, or dune slacks, using a subset of dune vegetation that can tolerate infrequent, ephemeral saturation or flooding during extreme rainfall events. The convex backdunes, however, are available to support relatively natural native dune plant assemblages typical of stable dune restoration sites with park visitor access in San Francisco, such as Lobos Dunes and inner Crissy Field lagoon dunes of the Presidio.

The conceptual generalized plan form and cross-sections of the engineered foredune and backdune infiltration basin zones of South Ocean Beach are shown in Figure 3-1 and Figure 3-2 below. The zones correspond with a combination of engineered structures and natural, uncontrollable processes rather than natural zonation of beaches and foredunes. Their form, dynamics, composition, and aspects of management are described below.

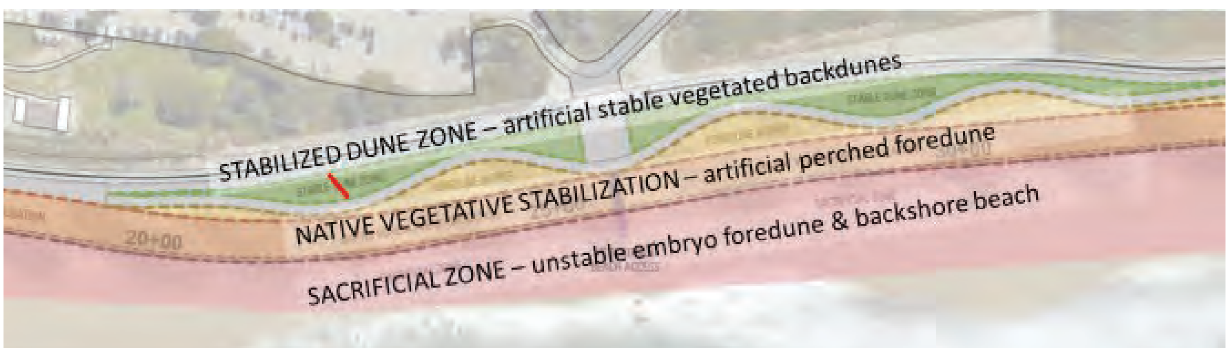

Figure 3-1: Generalized conceptual layout of the engineered beach and dune zones of the Ocean Beach Climate Change Adaptation Project.

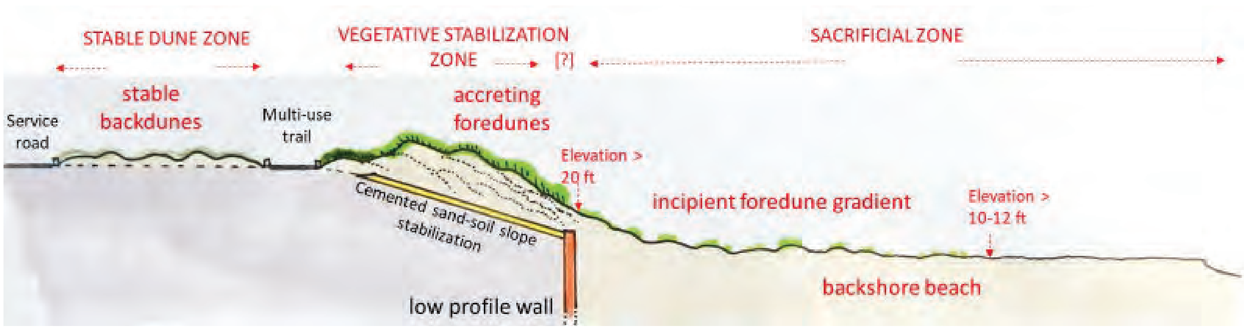

Figure 3-2: Generalized cross-section view of the engineered beach and dune zones of the Ocean Beach Climate Change Adaptation Project.

3.2. Vegetative Stabilization Zone

3.2.1. Foredunes, Wind-blown Sand Accretion, and Native Vegetation

The basic aim of the Vegetative Stabilization Zone (VSZ) concept is to manage vegetation of constructed foredunes on the seaward slope to intercept, trap, and stabilize onshore-blown sand from the beach so that dune sand does not significantly encroach upon landward infrastructure, constructed backdunes, and dune slacks (topographic dune depressions) functioning as infiltration basins for stormwater runoff.

Foredunes are the most seaward persistent depositional dune landforms formed by perennial vegetation that traps onshore blown sand, accreting as the foredune cycles through vegetation canopy regrowth and renewed sand trapping phases. The dominant natural native vegetation of historic foredunes in San Francisco were two prostrate herbaceous species with massive deep taproots and swollen crowns, beach-bur (*Ambrosia chamissonis*) and yellow sand-verbena (*Abronia latifolia*), not the native dune grasses that were also present in the dune flora but occurred sporadically or locally. Prostrate herbaceous species are inefficient dune-builders, trapping only shallow layers of wind-blown sand, mostly in the 10-20 cm range, before they are completely buried.

The most efficient, higher-capacity plant morphology for sand trapping in foredunes is that of tall beach and dune grasses. Only one native species, beach wildrye (*Leymus mollis*), exhibits all essential functional traits of rapid emergence and vegetative recovery from sand burial as well as rapid growth and lateral spread in nutrient-poor dune sand. It is typically confined to a narrow zone in the beach and foredune where deposition of salt spray, sea foam, fog, dew, marine wracks, and wind-blown sand occur together with shallow groundwater. It has an extensively spreading root system, not a deep taproot morphology. This species does form locally dominant vegetation in California foredunes outside of San Francisco, where it has not been excluded by invasive marram grass. For the OBCCAP, it is selected because of its functional traits as the dominant native foredune vegetation of the VSZ.

Naturally formed foredunes under grass vegetation develop an internal structure of interbedded sand layers from rapid deposition events and fabric-like mats of roots and rhizomes (horizontal stems). The internal structure of layered residual fibrous rootmats imparts greater shear strength to dune sand than unconsolidated sand alone. Artificially constructed, graded foredunes lack internal structure and are more vulnerable to rapid erosion than even beach sand with embedded driftwood and coarse woody debris. Partial surrogates for internal rootmat structure of foredunes may include embedded or buried brush, such as coarse woody debris, graded into sand during construction of artificial foredunes.

The surface stability and sand-trapping capacity of the grass-dominated foredune is not related to the rootmat below ground. It is a function of the height, density, and area of the leafy shoot canopy including residual dead, persistent, erect grass culms as well as live ones. Beach wildrye shoot height and density is positively related to sand moisture content and nutrient status. The highest density and vigor of beach wildrye in natural foredune vegetation occurs near freshwater seeps of bluffs, springs, or stream mouths. The sand burial tolerance of beach wildrye has not been quantitatively analyzed, but the maximum capacity of its shoot structure to trap sand is approximately 25-35 cm per deposition event, a likely threshold above which shoot density declines under sustained high deposition rates.

Typically, foredune sand deposition events are episodic, with weeks or months of low or interrupted sand accretion allowing vegetation to regenerate between active deposition events. Foredunes also naturally cycle through episodes of storm erosion and accretion, with long-term trends of landward retreat as sea level rises. Foredune plant species are adapted to sand burial, winter overwash, and occasional fragmentation and dispersal with beach erosion and deposition processes. Dune forms also influence local rates and patterns of sand transport. Wind-shadow dunes (elongated lobes or tongues of sand formed in the lee of obstacles), dune ramps (concave wedges of sand filling cliffed profiles), and blowouts (troughs that concentrate windflow and sand transport) can focus dune drifting into irregular “hot spots” or breakthrough areas, usually associated with irregularities in vegetation or topography that often occur following storm erosion.

3.2.2. Local Ocean Beach Native Foredune Model

An outstanding example of long-term dynamic stability of a beach wildrye-dominated foredune occurs at Ocean Beach near Irving St, where the foredune has accreted and expanded since the early 1990s (Figure 3-3). This foredune segment developed from unmanaged founder colonies of beach wildrye established in the backshore beach below the marram-planted foredune slope, filling a hollow area in the seaward slope and later merging with the flanking marram foredunes. Marram has not encroached the beach wildrye foredune in the decades since it formed and expanded, without any active management or maintenance by GGNRA or the City of San Francisco.

The beach wildrye foredune intercepted enough onshore-blown sand that the original 1985 graded sand surface of the artificial dune ridge landward of the foredune west of Great Highway remains unburied and exposed at the surface, covered with iceplant. This native-dominated segment of Ocean Beach foredunes, as well as the beach wildrye-dominated lower foredune at Pacifica State Beach (Figure 3-4), serve as reference foredunes for the design of the VSZ vegetation and dynamic management.

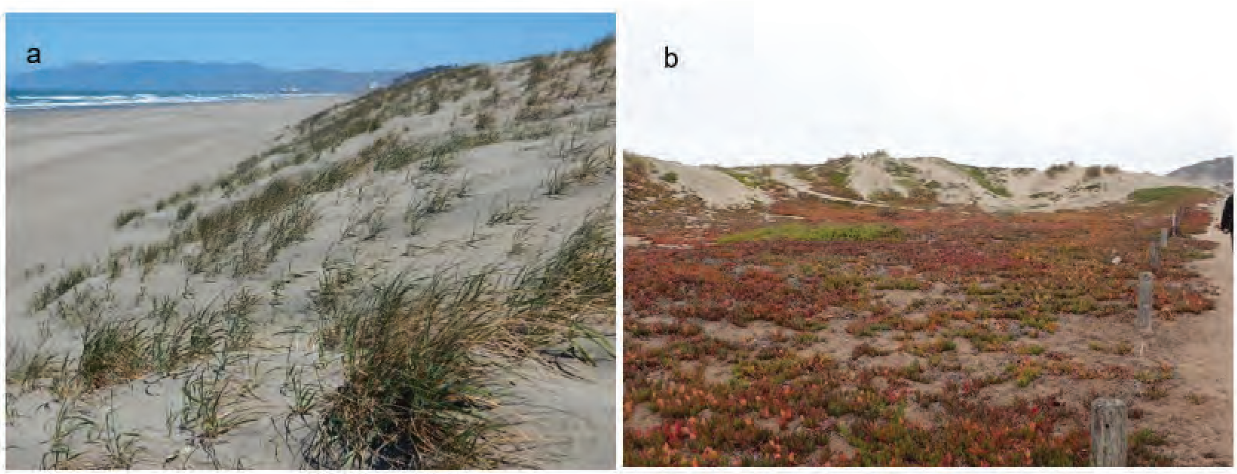

Figure 3-3: (a) Native beach wildrye-dominated foredunes of North Ocean Beach opposite Irving St trap abundant wind-blown sand supplied by NW winds eroding the wide backshore beach, March 2022. (b) Sheltered iceplant flats landward of the sand-trapping beach wildrye foredune shown in (a), remain unburied by gray-white Ocean Beach sand of the foredune. The flats expose the original brownish sandy soil fill graded in the 1985 artificial foredune construction project, indicating nearly four decades of dynamic stability of the foredune, despite high rates of sand accretion.

Figure 3-4: A low, wide foredune dominated by beach wildrye (*Leymus mollis*) reference site at Pacifica State Beach (2019) was naturalized from artificial plantings, and naturally developed geomorphically under moderate rates of onshore wind-blown sand transport. vegetation development in the "sacrificial zone" of South Ocean Beach following beach nourishment.

The primary constraint for establishing a beach wildrye-dominated foredune perched on the cemented sand slope is the likely impact of the cemented sand slope on foredune vegetation root depth. The cemented surface is likely to act as a restrictive layer, similar to a hardpan, for fibrous beach wildrye roots that would be confined to a shallow, dry dune sand volume. Both the spreading fibrous roots of dune grasses, and the tougher, thicker roots of dune forbs are adapted to penetrating unconsolidated sand with no significant cementation between grains. Shallow rooting and limited moisture storage in thin dune strata would be expected to reduce beach wildrye cover, density, and shoot height compared with the deep sand of reference site foredunes, which rest above shallow groundwater and support deep internal sand moisture storage. This design constraint for the VZM is proposed to be offset by subsurface irrigation, emulating natural freshwater seep-fed foredunes that sustain maximum density and vigor of beach wildrye to maximize sand-trapping capacity.

3.3. Sacrificial Zone

The sacrificial zone (SZ) comprises the nourished backshore beach, embryo foredunes (incipient dune mounds or hummocks, shadow dunes, formed by vegetation and driftwood), and the most seaward foredunes above the low-profile wall, all of which are anticipated to erode periodically and be replenished by reconstruction of artificial sand berms. The Sacrificial Zone is expected to have the highest turnover of sand and vegetation and is not designed to be stabilized. It serves as a buffer for storm wave erosion of the lower foredune slope and the beach itself. The sacrificial zone includes two backshore beach sub-zones with variable duration, width, and elevation:

Incipient foredune (embryo foredune) and winter drift-line zone

This zone lies above highest wave runup during the spring-summer growing season but is within reach of winter storm wave runup and wrack deposition most years. This sub-zone periodically supports perennial beach and dune vegetation in low-relief young foredunes about 1-4 ft above adjacent unvegetated beach level in a gradient with bare sand backshore beach. The vegetated embryo foredune zone alternates in between partially vegetated gradients, and bare, disturbed post-storm recovery beach states.

At South Ocean Beach, the perennial vegetation zone may be expected to persist between major storm events only above elevations greater than about 10-12 ft NAVD88 or higher most years. The embryo foredune zone is also a zone of winter storm wrack and driftwood deposition. Vegetation planted and replanted for intermittent establishment of embryo foredunes in the upper, landward SZ would include extensive colonies of native beach wildrye (*Leymus mollis*) with scattered patches of beach saltbush (*Atriplex leucophylla*), beach-bur (*Ambrosia chamissonis*), and yellow sand-verbena (*Abronia latifolia*) in unstable, erosion-prone populations. Sea-rocket (*Cakile maritima*) is a very common to abundant non-native short-lived perennial forb that also occurs in this zone.

Naturally unvegetated dry backshore zone

This beach zone is above normal spring high tides but within reach of infrequent high wave overtopping during the spring-summer growing season. This is the high tide beach zone typically occupied by recreational beach visitors and wildlife. It includes high tide roosts of many shorebird species and high tide foraging areas of western snowy plovers as well as many native sand and detritus-dwelling beetle species. The elevation threshold between persistently unvegetated and intermittently vegetated backshore at Ocean Beach varies among storm years but is usually above about 10-12 ft NAVD88.

The term “sacrificial zone” refers to the inherently temporary, dynamic condition of sand placement, perennial native foredune/beach vegetation, and foredune topography occurring in this zone. This zone is expressly not intended for vegetative stabilization but is compatible with potential growth of embryo foredunes during post-storm beach recovery and nourishment phases. In the last two decades the topographic relief of incipient foredunes (seaward of seawalls and constructed dune/bluff scarps) has generally not exceeded 5 ft above backshore beach elevations before storm wave erosion eliminates them. Only in areas of chronic beach stability or slight progradation (e.g. Irving-Judah shoreline) have incipient foredunes grown into landforms continuous with the primary constructed foredune.

3.3.1. Beach Nourishment

The proposed beach nourishment will serve as a buffer against wave energy and will help with the project goals of increasing recreational and habitat values. While not exclusive, three basic schemes of beach nourishment can be identified:

- Placement of material, generally sand, offshore with the goal of attenuating wave energy and reducing wave impacts on the shoreline.
- Placement of material on the beach with a focus on the intertidal and dry-beach zones, thereby constructing a wider and/or higher beach to act as a buffer between waves and the upland infrastructure. Only this scheme can provide a wider beach with significant recreational uses.
- Placement of material on dunes above the dry beach, again to provide a buffer between the waves and upland infrastructure.

In 2007, M&N assisted the CCSF and the USACE in formulating a Section 933 Beach Nourishment Study (M&N, 2017) to address the ongoing erosion at South Ocean Beach under the authority of Section 933 of the Water Resources Development Act of 1986. The Section 933 program is intended to further the beneficial reuse of dredged material, including beach quality sand, by providing for the USACE to participate in the additional costs of placing dredged material on a beach as opposed to the least costly acceptable alternative.

Since 2012, beach nourishment through episodic sand backpass events was carried out at the south Ocean Beach. Figure 3-5 documents the field conditions before and after the backpass event performed in April 2018.

Photo Source: ESA

Figure 3-5: Photos before/after April 2018 sand backpass event (ESA, 2018).

4. Proposed Restoration and Enhancement Plan

4.1. Vegetative Stabilization Zone

4.1.1. Dune and Vegetation Establishment

The Vegetative Stabilization Zone (VSZ) is an artificially initiated, vegetated foredune perched on the lightly cemented sand slope above the low-profile wall along the backshore beach. The initial foundation or core of constructed foredunes would be a minimum 2 ft and up to 4 ft thick layer of clean beach or dune sand, with no dirt or fines and no physiologically significant residual salinity. If available, loose coarse woody debris may be incorporated in the upper foot of the foredune core to provide roughness and resistance to sand deflation prior to native perennial vegetation establishment and spread. The graded sand foundation should be smooth to gently undulating with no notches or gaps that may concentrate wind erosion or catalyze blowouts.

While the graded foredune foundation is newly planted or in early stages of vegetative spread, with sparse vegetative cover, it will be prone to deflation unless temporary surface stabilization measures are applied. Compatible, efficient sand surface stabilization treatments compatible with beach wildrye transplanting include straw plugs, coarse woody debris scatter deposits, brush fencing (see Section 4.1.5) or loose brush placement, or coarse lag armor veneers such as coarse sand/small pebbles, or shell (e.g. commercial sand refining “screening” by-products). Temporary surface stabilization materials would be buried by accreted dune sand after sand-trapping vegetative cover is established.

The minimum expected time to develop effective surface-stabilizing vegetative cover, depending on initial planting density, is two growing seasons, typically Feb/March-November for beach wildrye in San Francisco. The time required to achieve effective surface stabilization will depend on the initial planting density, constrained by planting stock quantities available, and subsequent environmental conditions, especially the seasonal distribution and amount of rainfall before and after transplanting.

The proposed native foredune vegetation is composed and managed primarily to maximize the capacity of the foredune to intercept, trap and stabilize onshore wind-blown sand eroded from beach nourishment or exposed wave-cut scarps in the beach below the low-profile wall. The dominant vegetation proposed is the local San Francisco population of beach wildrye (*Leymus mollis*), diversified by associated, compatible species such as silvery beach pea (*Lathyrus littoralis*), a low-growing, nitrogen-fixing perennial forb that can enhance the nitrogen nutrient status of foredune sand and also provide additional roughness at the ground level below the beach wildrye foliar canopy. Beach wildrye would be planted at a minimum nearest neighbor distance of 5 ft, with a goal of 2 ft planting centers if stock availability allows. Clonal spread (creeping underground stems and rhizomes) will fill gaps between transplants in 1-3 years.

In addition to surface stabilization treatments applied after grading, the VSZ is also proposed for initial placement of temporary brush fencing (see Figure 4-6) to physically trap sand before foredune vegetation is established. Brush fencing is also recommended for adaptive management of pulses of foredune sand accretion if foredune vegetation canopies become saturated (fully buried) by sand in infrequent, extreme short-term sand transport events. Sand-trapping brush fencing would be a relatively low-cost, effective control of blowing sand landward of the VSZ before the foredune vegetation regenerates by emerging from burial by dune sand deposits. Two lines of brush fencing, one seaward of the top of slope and one above the low-profile wall should be embedded in the initial sand foundation of the slope.

The co-management of VSZ vegetation and brush fencing may prevent significant wind-blown sand deposition landward of the crest trail and service road. However, the beach wildrye vegetation, when well-established, is likely to provide ample stabilization of dune sand most years, just as the intact Irving Street foredune beach wildrye dominant segment has intercepted dune sand and prevented dune migration over the landward iceplant flats and Great Highway roadsides since 1985.

The excessively high rates of dune accretion during 2022 in the project area along Great Highway south of Sloat Blvd are an artifact of sand berm placement in the absence of significant dune vegetation or any temporary surface stabilization treatments for dry, bare sand placed upwind of Great Highway. It does not represent a natural or long-term condition of dune accretion rates for the 50-70 ft wide VSZ as there is no significant foredune vegetation between the erodible artificial sacrificial sand berm fills and Great Highway. The wind-blown sand transport volumes and rates here depend on the absence of extensive, wide zones of sand-trapping and stabilizing vegetation and a perpetually replaced source of dry, bare, erodible sand. Minor patches of prostrate non-native iceplant, marram grass, and isolated native dune plant patches have negligible influence on wind-blown sand eroded from the high sacrificial sand berm.

VSZ structure and function

The design of the vegetated foredune perched on the cemented sand slope is to intercept all significant volumes of onshore wind-blown sand, and trap it within the leafy canopy while new grass shoots elongate through the accreted sand and raise a new leafy canopy above the newly deposited sand surface. The leafy canopy and foredune sand deposits rise in about 20-40 cm increments – close to the temporary limit of "sand saturation" for the dominant native dune grass canopy of beach wildrye. To maintain high resilience and rapid vegetative recovery after wind-blown sand deposition events that saturate the vegetation canopy, the growth rate and vigor of the vegetation must be maximized as much as feasible for the local environment.

Initial VSZ transplanting – essential techniques for survivorship

The initial density of transplants will likely be constrained by availability of stock plants. Transplanting of bare-root, dormant beach wildrye must occur in moist, cool late fall-winter weather (November-February) after the sand profile is fully wetted by rains. Winter droughts and unseasonable heat waves may restrict transplanting schedules; transplanting before persistent warm, dry weather is a high risk for significant transplant injury or mortality. Transplants must be maintained with continuous moisture during harvest, handling, transport, and transplanting. The top half to two-thirds of the live leaves should be pruned at the time of transplanting. Beach wildrye shoots should be planted obliquely, not vertically, with their bases at least 1 foot below the sand surface, and most attached remaining leaf area buried, not exposed to sun and wind. Transplants should be firmly recompacted in moist sand by foot.

Localized organic matter and nutrient amendments

Growth rates and plant size of foredune plant species is usually high in the drift-line zone of the backshore where organic wrack is deposited by storms and buried by sand. Buried decaying wrack provides sources of nutrients and nutrient-holding capacity in low-nutrient sand, and relatively low elevations of the beach provide root access to permanent sand moisture above the shallow groundwater table above Mean High Water. These natural subsidies for foredune plant growth should be emulated in the VSZ transplanting as the initial growth of beach wildrye transplants is limited by sand moisture availability and nutrient availability – primarily nitrogen.

Localized addition of nutrient-rich, moisture-retaining organic matter and low doses of nitrogen-rich fertilizer to transplants in the VSZ would significantly increase initial plant growth rates, colony size (lateral spread), and for dune grasses, canopy height and density. These are the primary vegetation variables influencing sand-trapping capacity in the foredunes. "Localized" addition of organic matter means manual placement of organic matter directly below or around the root zone of the transplant, not broadcast soil amendments or fertilizer applications.

Localized placement of commercially available, clean, and pathogen-free composts such as composted steer or horse manure with decomposed sawdust/wood shavings directly below foredune transplants at a rate of approximately 1- lb fresh weight per transplant would significantly augment the effects of fertilizer application. Fertilizer application at a rate of approximately 10-20 g (20-20-20 fertilizer) per transplant, mixed in compost, is recommended. Localized nutrients may also be applied during or before transplanting by dipping transplant shoot bases in a slurry of clayey sediment with added dissolved nitrogen fertilizer such as high-N turfgrass fertilizer with no herbicides. Subsequent broadcast applications of nitrogen fertilizers should be evaluated on an annual, as-needed basis if beach wildrye stands exhibit symptoms of potential nitrate deficiency or growth limitation.

4.1.2. Dune Sand Source and Composition

The sand excavated during wall construction is expected to be remnant Colma formation sand that is weathered, highly variable, and poorly sorted with trace fines. This would not be a suitable root zone for the proposed planting for the VSZ and Infiltration Basin dune slack communities, as it would likely result in non-native seedling invasion. However, it can be used as a base over the SSL layer, over which sand from North Ocean Beach areas that have been used in past sand backpassing efforts could be placed. Sand from North Ocean Beach is a mix of wave-washed, unweathered, quartz-rich sand that is suitable for establishing native foredune species while discouraging non-native invasive species. The Sand Management Plan (MN, 2020) includes a description of prior backpassing efforts and grain size of sand from North Ocean Beach, and replenishment volumes of sand for this area.

The VSZ and Infiltration Basin dune slack communities will therefore be constructed using sand excavated from the bluff recontouring that will serve as a foundation/base, covered with 2 feet of sand from North Ocean Beach.

4.1.3. Source Plant Location and Description

Most native San Francisco dune plants have been propagated from local source populations since the 1990s, when native dune plant community restoration projects in the Presidio, GGNRA, and San Francisco parks began. Stock populations, both vegetative and seed stock, of most of these species are available from native plant nurseries managed by Parks Conservancy in the Presidio and Fort Funston. Several of the proposed dominant species needed for foredune stabilization functions and some ecologically related essential species, however, are not available in large quantities needed for mass revegetation of the 3500 ft long proposed foredunes and infiltration basins.

These species must be collected from the field, propagated, and amplified for quantities needed following construction, with at least 2 full growing seasons estimated advance time before the year of project construction completion. The locations of either local San Francisco populations or the nearest known recently confirmed San Francisco Peninsula coastal populations are listed in Table 4-1 for these relatively unavailable species. Reintroduction of populations currently extirpated in San Francisco is expected to require authorization from GGNRA if they are planted in GGNRA jurisdiction. Preparation of precise GPS locations of populations and permission to sample propagules (mostly vegetative; seed often sterile or absent) would be developed as project implementation tasks.

Table 4-1: Locations of coastal plant populations.

Species/taxon	OBCCAP zone, functions	Local or nearest known San Francisco Peninsula coastal population source
BEACH WILDRYE *Leymus mollis*	VSZ, SZ. Dominant foredune vegetation, principal sand trapping functions.	1. Largest stable SF foredune population occurs at Ocean Beach above the beach in vicinity of Irving St, presumed GGNRA land. 2. Large population occurs on and above the beach at the extreme north end of Fort Funston bluffs next to the south end of the project site, on GGNRA. 3. Fort Funston bluff-top climbing dune colonies between north end of Fort Funston and Great Highway descending slope to Skyline Blvd, GGNRA. 4. Small population at Sutro Baths relict climbing dunes, GGNRA 5. Crissy Field Beach population (reintroduced), GGNRA/Presidio Trust 6. North Pacifica bluff-top dunes above Manor Beach, end of W Manor Drive at Esplanade Ave. Ownership unknown. 7. Sharp Park, Pacifica (City of San Francisco ownership), remnant natural population of sand

		washover fan above seaward lagoon shore. SFRPD land.
PACIFIC WILDRYE *Leymus pacificus* (ecotype or local form; intermediate *L. triticoides*)	Stabilized backdunes, backdune slacks of infiltration basins	1. Relict population in flat sandy turf (trampled) at summit of Sutro Heights overlook, GGNRA; the only western SF/Ocean Beach population known. 2. Crissy Field Beach turfgrass landforms (planted; origin = vicinity Wherry Housing to Lobos Dunes, Presidio. GGNRA/Presidio Trust.
CREEPING WILDRYE *Leymus triticoides* (dune ecotype or local form; intermediate *L. pacificus)*	Backdune slacks (stormwater infiltration basins)	1. North Pacifica remnant climbing bluff-top dunes below Palmetto Ave (land ownership unknown)
VANCOUVER WILDRYE *Leymus* X*vancouverensis*	Backdune slacks (stormwater infiltration basins)	1. South Pacifica, Linda Mar, backshore at mouth of San Pedro Creek. City of Pacifica. 2. (?) undetermined historical localities at south Lake Merced; possibly remnant. SFRPD.
SILVERY BEACH PEA *Lathyrus littoralis*	VSZ, SZ: foredune and embryo foredune/backshore beach, nitrogen fixing associate of beach wildrye	1. Last known population from project site, 1990s, propagated by Presidio native plant nursery. Status unknown. 2. Recent population (possibly extirpated) at North Pacifica bluff-top dunes above Manor Beach, end of W Manor Drive at Esplanade Ave. Ownership unknown. 3. Half Moon Bay beach at mouth of Pilarcitos Creek, California State Parks. In commercial cultivation (Go Native, Montara, CA).
CURLYLEAF COYOTE-MINT OR MONARDELLA (*Monardella undulata*)	Stable backdunes, spring/summer-flowering annual forb	1. Point Reyes National Seashore, multiple populations, extensive in west shore backdunes. NPS.
BROADLEAF PURPLE OWL'S-CLOVER (*Castilleja exserta* ssp. *latifolia*)	Stable backdunes, annual forb hemiparasitic on dune sage	1. Point Reyes National Seashore, few populations, locally abundant in bluff-top dune scrub north of Lighthouse, and sparse along Abbott's Lagoon trail. NPS National Seashore. 2. Reported from Milagra Ridge, Pacifica, GGNRA (2018) 3. San Bruno Mt; current localities unknown.

4.1.4. Irrigation

The narrow foredune zone perched on the sloping SSL (slightly cemented layer) is required to intercept and stabilize dune sand during phases of dune building and peak rates of onshore wind-blown sand transport. Completely natural patterns of patchy, prostrate foredune vegetation with scattered mounds of beach wildrye would allow large volumes of dune sand to migrate inland from the beach, the condition of the historic San Francisco dune sheet. High shoot density of burial-tolerant, tall foredune vegetation capable of high growth rates after burial is needed to keep pace with high rates of dune sand accretion.

In the 1985 SFDPW Ocean Beach foredune construction project, non-native invasive marram grass (European beachgrass, *Ammophila arenaria*) was planted for this purpose, as it is globally superior in its capacity of sand trapping, stabilization, and burial tolerance. Since this invasive dune grass species is no longer permitted to be planted on the California coast, the nearest functionally equivalent native species, beach wildrye (*Leymus mollis*) is proposed as the dominant sand-trapping foredune grass. Beach wildrye, however, naturally grows with lower shoot density than marram in most dry foredune conditions, and it has higher sand moisture requirements for vigorous growth. It grows at high density and rates near freshwater seeps below coastal bluffs or zones of high beach groundwater (Figure 4-1). Natural occurrences of foredune seeps below marine terrace scarps and bluffs occur at Franklin Point and Ano Nuevo in San Mateo County, Point Reyes National Seashore north of Abbott's Lagoon, MacKerricher State Park in Mendocino County, and near Manchester State Park in Mendocino County.

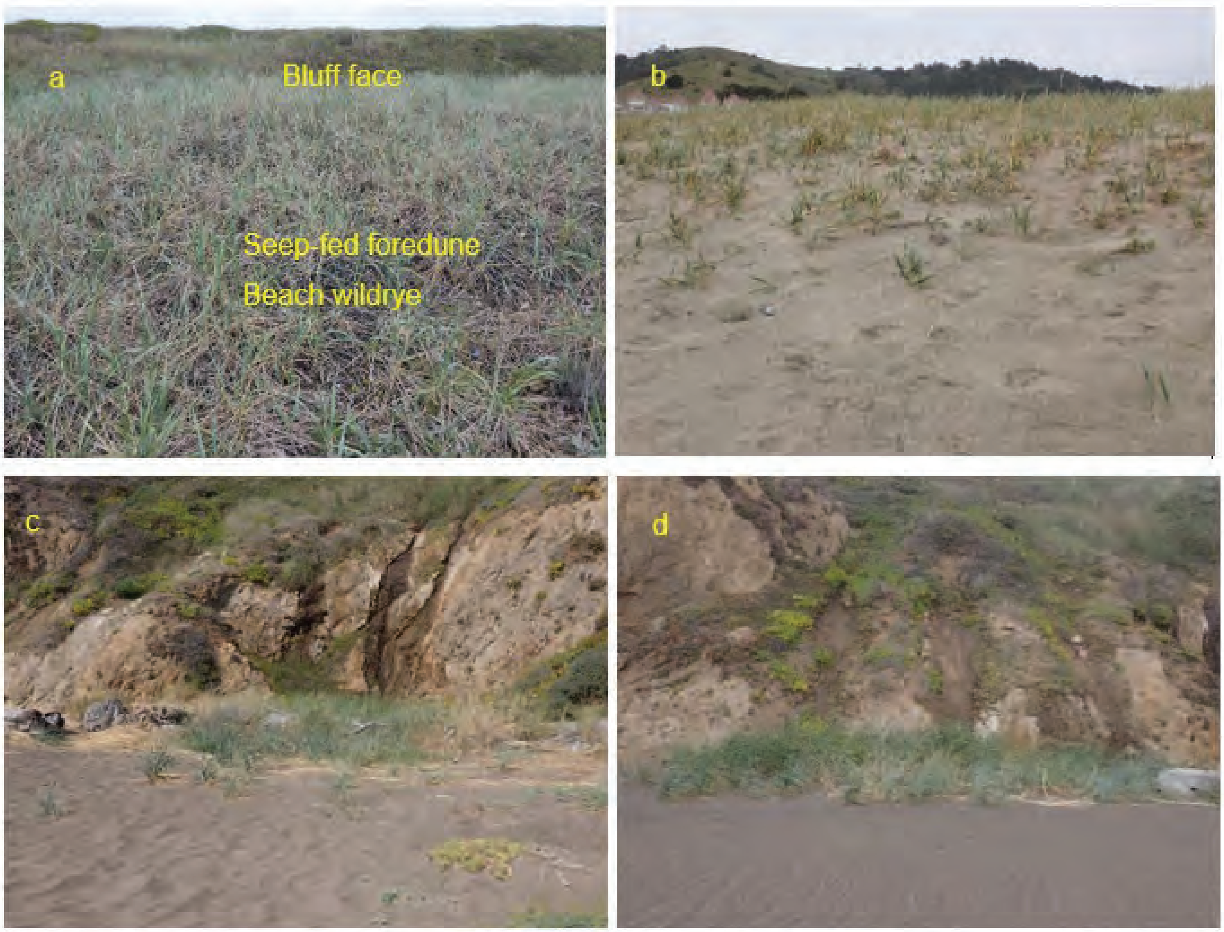

Figure 4-1: Beach wildrye shoot density and canopy cover increases near freshwater seeps. (a) Beach wildrye forms a natural dense, closed canopy stand almost exclusively below bluff seeps and bordering drainages at Ward Avenue, Cleone, north of Fort Bragg, Mendocino County. (b) Beach wildrye forms an open canopy with moderate shoot density in well-drained low foredunes at Pacifica State Beach, San Mateo County, where wind-blown sand transport rates are low compared with Ocean Beach. (c-d), Beach wildrye rapidly expands in one year as a vigorous, dense, closed-canopy stand beach locally sub-irrigated by a visible freshwater seep near Alder Creek, Mendocino County (August 2021 and 2022).

The cemented sand surface layer above the low-profile wall is likely to restrict the root zone depth of beach wildrye in the foredune zone, even if the degree of cementation is structurally low. Sand depth above the SSL will range from 2-4'. Beach wildrye roots are adapted to penetrate only loose sand and are easily obstructed by harder soil substrates such as naturally cemented iron oxide layers, lithified older dunes, clay pans, hard pans, or buried high-density marine terrace soils. The root systems of beach wildrye are shallow, fibrous, short-lived, and spread laterally over wide distances to acquire moisture and nutrients. They do not dive deep into sand like tap-rooted perennial broadleaf dune plants and shrubs that can access permanent moisture at greater depth and penetrate dense soils that may exist below loose dune sand. Restriction of rooting depth within the dunes deposited above the resistant, cemented layer are likely to constrain growth of beach wildrye during the dry season and expose it to higher risk of dieback or mass mortality during extreme droughts or heat waves. Significant drought dieback or growth inhibition of beach wildrye in the

Vegetative Stabilization Zone would significantly impair its ability to trap and intercept wind-blown sand from the beach and destabilize the foredunes if mass mortality occurs during droughts.

To develop drought-resilient, efficient sand-trapping stands of beach wildrye with high shoot density and tall high-roughness canopy cover, a mesic foredune vegetation analogous with natural freshwater seep-fed foredunes should be developed above the cemented sand layer. A slow, low-level seep should be artificially sub-irrigated at the contact between the cemented sand layer and the foredunes perched on them. This stratified dune/impermeable layer profile is analogous to a hardpan of soil on a sloped marine terrace supporting climbing dunes such as Franklin Point and Ten Mile Dunes at MacKerricker State Park. This structure is generalized in Figure 4-2, corresponding with the foredune seep examples shown in Figure 4-3.

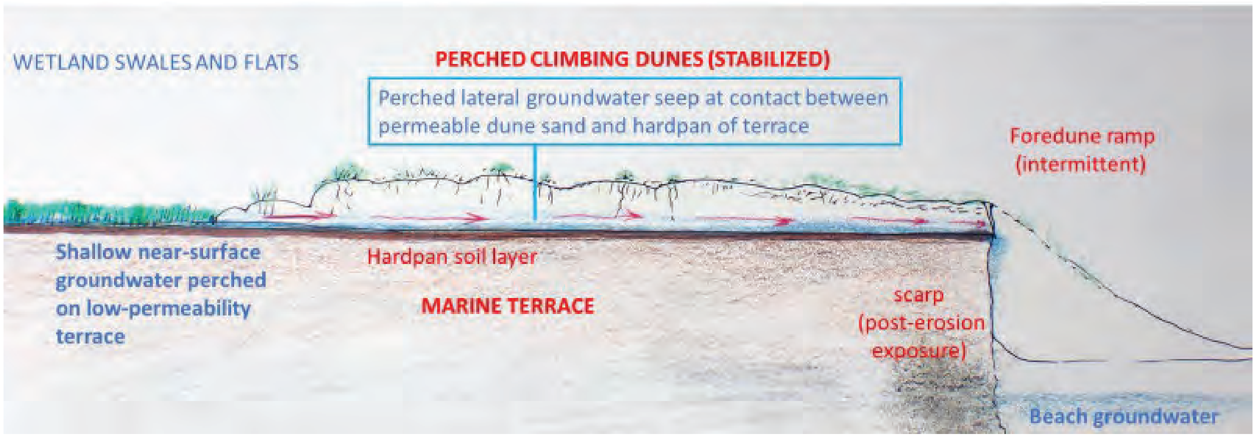

Figure 4-2: Simplified typical cross-section of shallow perched dune field on marine terrace with perched groundwater seepage. This represents "sub-irrigation" of the thin dune field, supporting dune, riparian, and wetland vegetation despite shallow sand over buried impermeable root-restrictive hardpan soil layers. (Based on Franklin Point-Ano Nuevo dunes, south Ten Mile dunes).

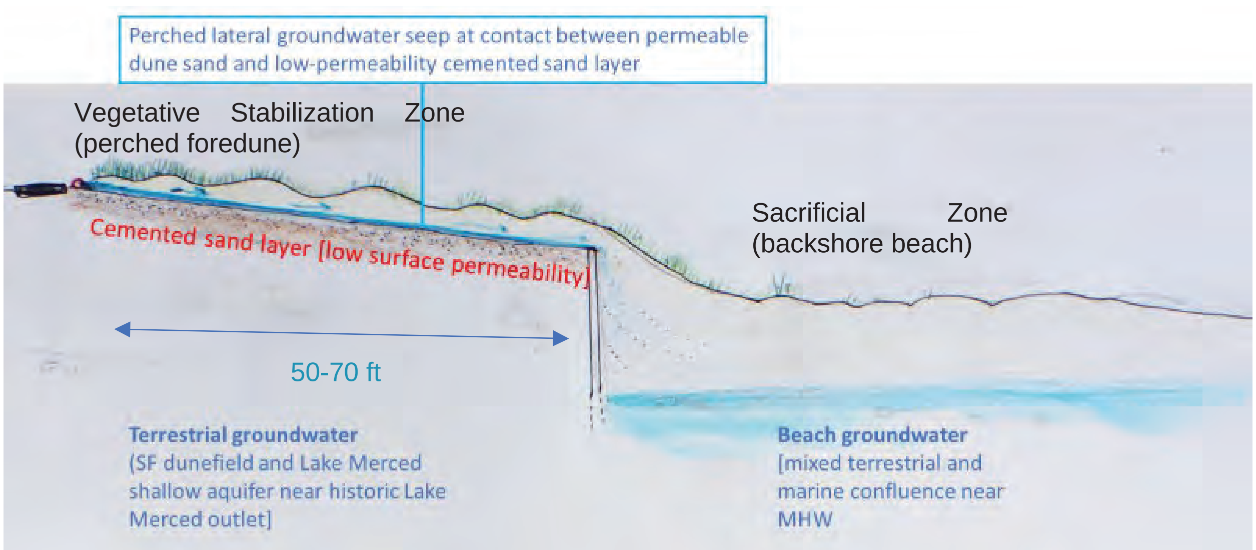

Figure 4-3: Cross section from trail-side discharge zone (swale) to subsurface irrigation below perched foredune, above backshore beach foredunes connected to beach groundwater.

Surface or overhead irrigation of dry dune sand is not a feasible alternative to subsurface seep irrigation over a restrictive layer below dune sand. Dry dune sand is highly water-repellent (Dekker *et al*. 2001), with strong capillary forces that resist infiltration and cause irregular "fingers" of wetting around dry sand, in contrast with moist sand. Overhead irrigation of dune sand in the dry season results in very uneven penetration of moisture to the root zone, or a shallow surface wetted layer that rapidly evaporates before it infiltrates. Conversely, upward capillary movement of saturated dune sand porewater of the groundwater table is predictable. It may also contribute to upward water vapor flow and adsorption on sand of the root zone above, adding to water vapor absorption of sand from saturated marine airflow (Kohfahl *et al*. 2019, 2017, Agam and Berliner 2006).

Plants within the VSZ will be irrigated sub-irrigated via perforated pipes located below the surface of the sand and adjacent to the sea wall on the western side of the new multi-use trail. The source for this irrigation will be municipal potable water. Irrigation from these perforated pipes will pass through permeable sand and seep laterally downslope towards the beach along the contact between accreted dune sand and the buried cemented sand surface, analogous with a buried marine terrace hardpan soil layer. The potential vertical capillary rise of water above the saturated contact zone would likely be on the order of 8-12 inches. Water vapor transport and internal adsorption on sand, transport along a water potential gradient from perched groundwater to the root zone above, would be additional potential pathways for root zone uptake in dune sand above the cemented layer.

4.1.5. Plant Community Management

Backdune and dune slack vegetation will be located near massive stands of invasive weeds adapted to sand dunes around Fort Funston and Great Highway, so weed seed dispersal by wildlife should be expected to occur at significant rates. Principal invasive weed threats to stable backdunes include upright veldtgrass (*Ehrharta erecta*), iceplant (*Carpobrotus* spp.) and narrow-leaf iceplant (*Conicosia pugioniformis*). These weeds are relatively difficult to control after establishment, but relatively efficient to control before they set seed or establish well-rooted mature plants. Therefore, weed management must focus on well-timed, pre-emptive removal of new colonies at early stages of development, especially during early stages of native backdune vegetation establishment. Over time, as annual and perennial native backdune populations grow and capture more available dune surface area, native vegetation competition with weed seedlings is likely to increase and inhibit invasions.

Temporary physical dune surface stabilization measures will be required immediately after project construction, before vegetation is established, and probably also after major storm wave erosion or completion of beach nourishment activities in the Sacrificial Zone. Many dune stabilization methods would be incompatible with nature-based methods suitable for an urban recreational coastal park setting because of esthetic or ecological conflicts. The range of compatible methods reviewed here include driftwood analogs for the beach, brush fencing, embedded brush, straw punch, coarse surface mulch, and coarse lag armoring with natural materials such as shell or granular sand.

Vineyard staking of plastic or wood slat fencing used for large-scale dune stabilization is not recommended as compatible with this project and setting because it would be placed in high storm wave erosion hazard zones that would deposit tangles of corroded metal wire, broken wood slats, plastic mesh, and metal stakes on an urban beach with high visitor use. Removal of vineyard stakes after complete sand burial is also labor-intensive. Wood slat and plastic mesh fences are also prone to vandalism and deterioration. For these reasons, staked wood slat or plastic mesh fence for physical temporary stabilization of dunes is excluded from detailed review and description.

Long-term sand management must include pedestrian access pathways through vegetated dunes. Chronic small-scale trampling damage causes barren path networks that initiate foredune blowouts and large-scale dune instability over decades, evidenced by the massive blowouts of Ocean Beach foredunes at Judah Street and Noriega Street evolved from funnel-shaped foot trails during the 1990s-2000s, reaching thresholds of complete dune destabilization by the 2010s.

Figure 4-4: Multiple lines of wood slat fencing, oriented perpendicular to dominant onshore winds, was used in combination with jute netting to stabilize a wide artificial blowout in dunes at Marina, Monterey Bay. The lack of upwind sand supply from the coarse-grained beach allowed stabilization without formation of shadow dunes in lee of any of the fences. Note the vandalism and degeneration of the outer fenceline bordering public access. Interior fences are intact. April 2013.

Figure 4-5: Plastic porous fences are used as less expensive substitutes for wood slat fencing, but are prone to breakage and vandalism, and are a high risk for debris (plastic pollution) on beaches. Sand City, Monterey Bay, 2009.

Brushwood Fencing

Brushwood fencing is among the oldest techniques used for rapid dune surface stabilization on blowouts, deflation plains, and washover fans both in the United States and Europe. Brushwood fencing typically consists of cut limbs or large branches of trees and shrubs with the basal end embedded in sand at oblique angles and bases set about 2 feet deep below the surface. Overlapping limbs or branches are interwoven to anchor one another as a complex porous fence of variable width. Additional anchoring may be provided by driving wooden stakes behind or over the limb bases. The interior of the porous canopy becomes a zone of reduced wind velocity and increased deposition, and the matrix of branches undergoes “self-burial” through episodes of high eolian sand transport rates. Driftwood jams on beaches naturally produce this pattern and process of dune formation on beaches near river mouths with high loads of coarse woody debris, as in the Pacific Northwest and northern California coasts. Brushwood fences, depending on the size, spacing, and structure of the materials used, are generally very efficient sand trapping devices and have been found to be superior to wood slat fencing in most respects except with respect to costs due to greater labor of installation (Woodhouse 1978).

Brushwood fencing may easily be installed iteratively as sand accretes and buries initially installed brushwood fencing. Additional limbs and branches can be inserted in the matrix of partially dune-buried brushwood and rely on the foundation brushwood and dune to anchor added materials. Initial brushwood fence height over 4 ft is likely to enable greater sand trapping capacity in a narrow zone and would facilitate formation of desirable lee precipitation slopes (slipfaces at angle of repose of dry sand), avoiding the problematic attenuated shadow dunes ('tongue dunes' of Cooper 1958). Low precipitation dunes formed by high, dense, wide brushwood fencing would likely store larger volume of wind-blown sand in a smaller footprint than conventional 4 ft slat fencing after major windstorms. When the brushwood interior volume is saturated with sand, the steep lee slope slipface itself may become a sand-trapping landform that migrates only a short distance downwind for each unit volume of sand deposited. In contrast, convex (pyramidal, elongated) shadow dunes that form in the lee of wood slat fence rapidly attenuate downwind when slat fences saturate with sand (fill to near the fence top).

Eucalyptus brushwood fencing would be feasible to install as a "backstop" for eolian sand deposition landward of the foredune crest/VSZ during initial construction. The width and height of the brush fence zone would be adjusted to accommodate the estimated or measured maximum annual onshore eolian transport of sand per unit length of shoreline measured following ongoing sand backpass operations that do not include any revegetation or sand surface stabilization.

Post-storm dispersal of brushwood during major winter beach erosion events would generate relatively natural types of coarse woody debris on the beach and would not introduce hazardous metal from wires or stakes.

Brushwood fencing would be aligned parallel with the shoreline except at the north end of the project near Sloat Blvd, which faces NW and protrudes into the beach. Brushwood fencing can also be used to provide barriers, along with symbolic cord and cable fence, to guide pedestrian access paths. Eucalyptus brush fencing (flexible wood matrix of interwoven branches and limbs) is relatively difficult to vandalize or breach. Exposed branches are gradually self-buried with sand and decay very slowly, providing below-ground resistance to renewed dune erosion.

Brushwood fencing should be composed of blue gum eucalyptus slash (cut branches) from tree removals within San Francisco, dried and stockpiled for reserved use as brush fencing. Brushwood lengths of 8-10 feet, and (cut end) basal diameter should be prepared prior to site delivery for installation. Rapid drying of green eucalyptus branches help retain dried leaves on branchlets, increasing roughness. Individual brushwood units should be installed in an overlapping, imbricate pattern end to end, for continuous cover of brush. Brush should be embedded in sand with cut ends facing dominant (NW) winds. The cut brush should be embedded in trenches at least 1.5 ft deep to secure the limb and brush. The bases should be anchored in place with buried, crossed wood stakes (cut branch segments) to discourage vandalism for beach firewood. The minimum target height for brush above sand surface level is 3 feet; brush height can be adjusted by altering the angle of brush insertion.

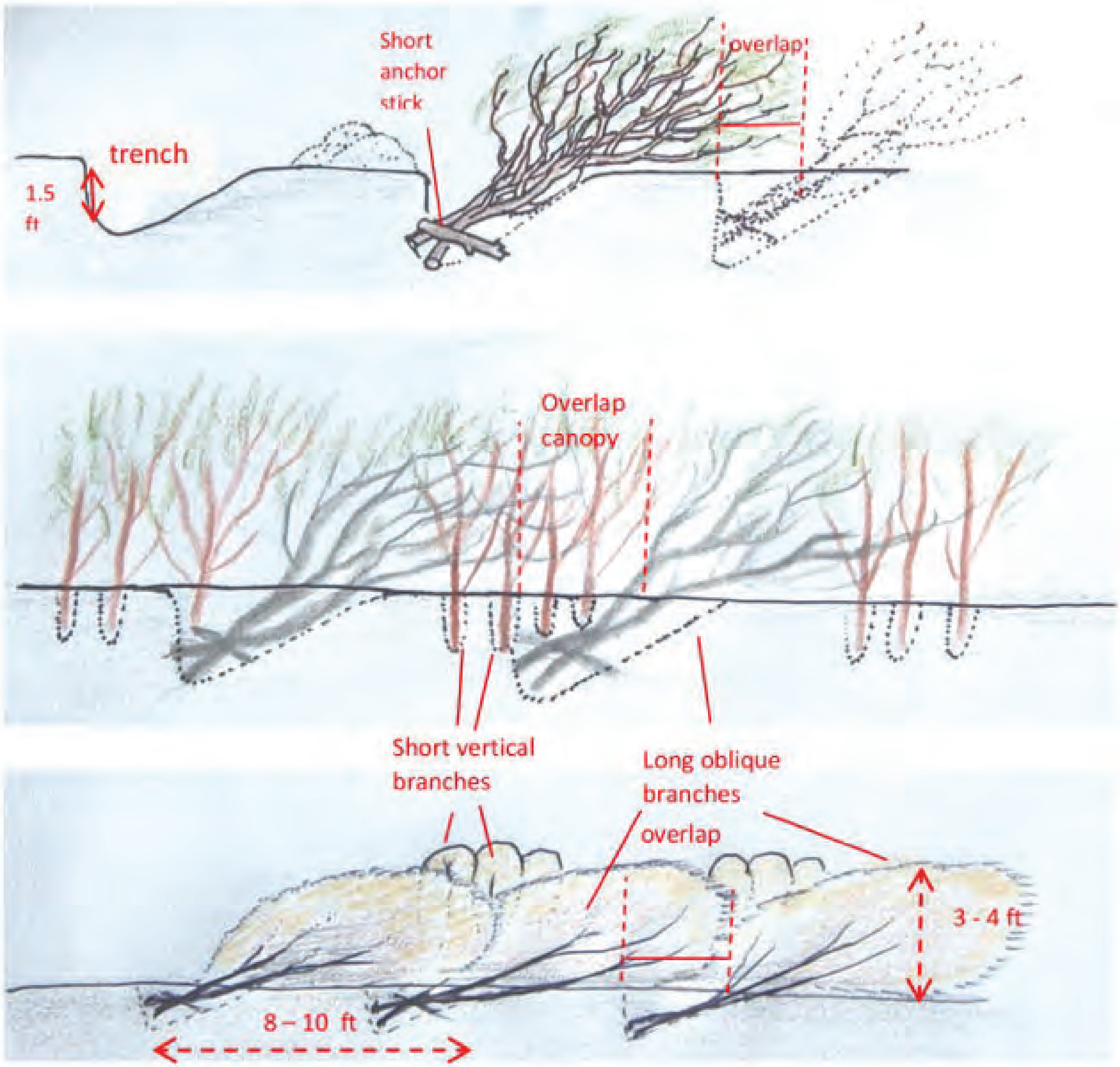

Figure 4-6: Brushwood fencing illustration.

Artificial driftwood (large woody debris) placement in nourished backshore beach

Large woody debris (LWD; logs, large-diameter limbs) plays an important role in trapping wind-blown sand within the beach and initiation of backshore dunes (Grilliot *et al*. 2019). It can build shadow dunes and raise beach roughness, intercepting and storing highly significant volumes of sand on the beach upwind of the foredune. LWD is abundant on beaches below forested California watersheds of the North Coast and Santa Cruz mountains. Urban coastal watersheds generate large volumes of waste wood from treefall removal as over-aged, temperature-injured, or drought-weakened planted Monterey cypress and Monterey pine hazard trees die and fall, or when blue gum eucalyptus trees are removed.

Placement of sectioned logs or limbs of trees from urban tree removal projects during beach nourishment operations may provide immediate significant increase in backshore beach trapping and storage capacity for wind-blown sand (intercepting up to 99% of wind-blown sand; Grilliot *et al*. 2019), and attenuate eolian sand transport to the foredune. Wind-blown sand trapping by LWD also buries the LWD, reducing its cover at the beach surface and minimizing aesthetic impacts. Wildlife benefits of beach habitat surface roughness and complexity, especially during high onshore winds (velocity refuges), may be ecologically important, but no local studies are available to confirm this.

Figure 4-7: Natural driftwood (Large Woody Debris, LWD) on North Coast beaches trap significant volumes of dune sand upwind of foredunes. (a) A driftwood jam (including weathered logging debris) on the beach at the mouth of Ten Mile River, Mendocino, self-buried by windblown sand after a week of high onshore winds, The shadow dune crest height is over 3 ft above the adjacent beach. Beach grain size distribution is similar to Ocean Beach. June 2013. (b) Driftwood-nucleated embryo foredunes accrete below a marram-dominated foredune, Manchester Beach, Mendocino County (California State Parks) 2007.

Figure 4-8: Natural coarse driftwood deposition at the backshore of San Gregorio Creek lagoon (west of Highway 1), intermixed with patchy native pioneer foredune vegetation, nucleates foredune deposition in a recreational California State Park Central Coast ocean beach setting. Beach grain size distribution is similar to Ocean Beach. April 2009.

Public access management for dune building and stabilization

The primary cause of vegetated foredune degeneration along Ocean Beach is unconfined trampling that causes loss of vegetation cover and root/rhizome matrix in the dune. Footpaths cross dune areas at locations convenient to visitors for efficient shoreline access, scenic viewing, and recreational uses that are largely unregulated. Footpaths generally develop fan-like, seaward-radiating patterns of vegetation disturbance or destruction along the dune/beach interface. Wind funneling in footpaths causes blowout incision and enlargement, with expanding erosional blowout throats and accreting dune lobes downwind (Schwartz *et al.* 2019). These patterns are likely to occur also at Sloat where deflation-resistance or sand-trapping features are installed, defeating their function. Well-defined and publicly acceptable public access compatible with functioning of sand stabilization should be incorporated in the overall project design to prevent its degeneration.

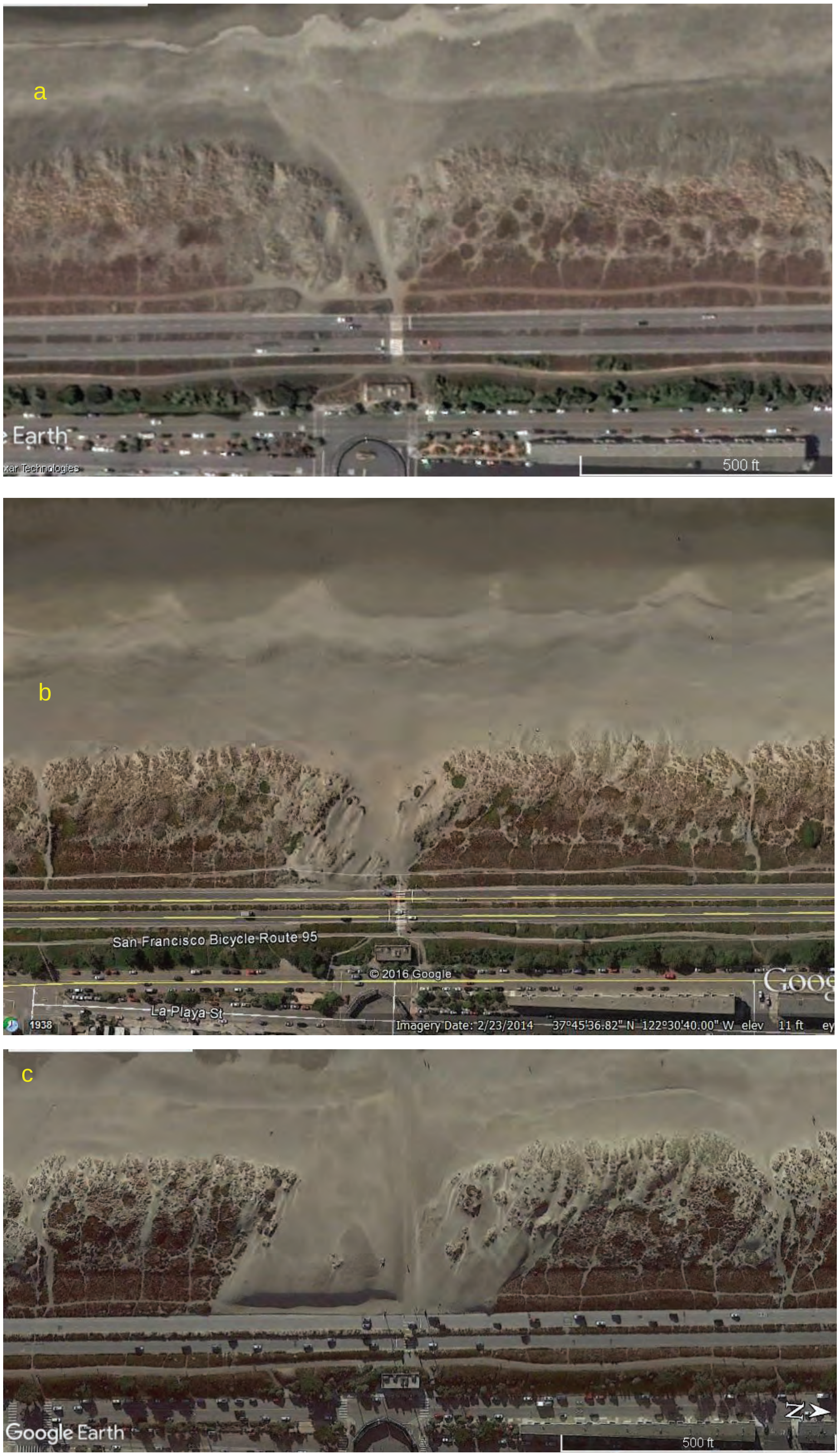

Figure 4-9: Evolution of the massive Judah St/Great Highway foredune blowout from a funnel-shaped major foot trail crossing between 2008-2021. Note NW wind alignment of blowouts, and relative stability of adjacent vegetated foredunes with minor foot trail networks. (a) September 2008. (b) Feb 2014. (c) September 2021. Google Earth image excerpts.

Symbolic cable fencing, or combined cable fencing and brush fencing, is recommended for guiding foot access through vegetated foredunes. California State Park beaches and dunes have achieved a high degree of compliance with well-located foot trail corridors defined by symbolic rope fencing (metal stake and cable or rope) and interpretive signage at frequent intervals, such as that found at Marina State Park and Morro Sand Spit. Rope fencing does not accrete sand and can be rapidly removed before storm erosion occurs in winter. Orientation of foot trails away from dominant winds at Ocean Beach (i.e., sloping southwest rather than due west or northwest), or establishing slight curves in foot trails would minimize potential wind-funneling and blowouts in trails. Trail mouths at the beach should avoid NW orientation and extend past the seaward line of beach and foredune vegetation.

Structural trails (boardwalks, sand ladders) across dunes are generally unsuitable for mobile dune areas. They quickly become useless when they are truncated by steep active dune lobes, and may require high maintenance in years of frequent high winds and dune deposition events.

Figure 4-10: Active dune transgression over wood boardwalk, Marina Dunes State Park, Monterey Bay. Structural pedestrian walkways in mobile dunes are seldom stable, and rarely feasible to retrieve or rehabilitate after burial. April 2013.

Figure 4-11: Symbolic cable fencing guides foot trails that are oriented perpendicular to dominant winds at Marina State Park, Monterey Bay. Cable fencing is transparent to eolian sand transport, erosion and deposition processes. Footprint patterns here indicate a high degree of compliance in conjunction with signage, despite ordinarily high visitor use. April 2009.

4.2. Sacrificial Zone

4.2.1. Risk-Based Probabilistic Modeling

Critical wastewater infrastructure located along South Ocean Beach has been threatened by chronic bluff erosion caused by storm waves and episodic bluff failures. The erosion would be further exacerbated with sea level rise (SLR). Historically, federal, state, and local agencies have focused on erosion mitigation measures aimed at protecting the existing shoreline and hence the wastewater infrastructure behind it. Given the increasing difficulty in securing approvals for armoring type of solutions, a multi-agency effort led by San Francisco Public Utilities Commission (SFPUC) resulted in the development of a long-term vision that culminated in the Ocean Beach Master Plan (OBMP). The OBMP (SPUR, 2012) outlined coastal protection strategies for the future and recommended a robust long-term beach nourishment with a low-profile wall (LPW) as a last line of defense, along with a multi-use recreational trail along the reach. A Sand Management Plan (SMP) for long-term beach nourishment therefore became a crucial requirement for obtaining approvals, which informed frequency and scale of replenishment episodes, identified sustainable sand sources, and defined triggers for action. In 2020, M&N assisted the SFPUC with preparing the SMP (M&N/AGS JV, 2020).

For the SMP, it is important to understand how oceanographic conditions could vary over time, including incoming wave energy, Oceanic El Niño conditions, SLR, and more importantly how the beach in front of the LPW would respond to such complex interactions. Because these oceanographic parameters are highly unpredictable in nature, they typically cannot be described with a singular value but rather a function based on probabilities of occurrence or levels of risk. As a result, a risk-based probabilistic model was developed for the SMP to allow consideration of a wide range of possible combinations of events that would influence beach morphology.

The risk-based probabilistic model included process-based longshore and cross-shore transport equations that are computationally efficient and were validated with past field observations of shoreline position. In addition, long-term data on oceanographic and geomorphic conditions at the site and long-term surveys of shoreline positions conducted by the USGS were utilized in the analysis. The analysis then utilized the Monte Carlo technique to normalize and statistically characterize the results, e.g. a total of 1,000 runs was conducted for each model scenario. Finally, various “what if” scenarios were evaluated to address the model’s uncertainty, including model inputs, El Niño intensity, increased storminess, and SLR.

Four beach nourishment scenarios were investigated to allow a trade-off between periodic sand replenishment quantity and placement intervals, two characterized as small plan (85,000 and 120,000 CY replenishment) and two as large plan (300,000 and 500,000 CY replenishment). The small plan is based on the current practice of sand backpass events from the northern Ocean Beach by trucking to the southern end. The large plan is based on the long-proposed concept of placing dredged material from the maintenance of the SF Main Ship Channel onto South Ocean Beach and requires partnering agreements with the USACE.

Using the 85,000 CY scenario as an example, the average frequency of replenishments is one episode every 4 years. When SLR follows a larger projection, more replenishments are required. In eighty years, the average number of low-profile wall exposures down to MHW is 4 times. All wall exposures occur during the forecasted “Very Strong El Niño” years, when greater erosion is expected. The model also keeps track of hourly beach width, which is found greater than 50 feet about 91% of the time per the established rules. The narrowest beach width occurs between March and April as it is approximately the end of the winter erosive season. The widest beach width occurs between September and October as it marks the end of the summer accretive season as well as any sand replenishments that may have occurred. Figure 4-12 illustrates an example of one simulation run under the 85,000 CY scenario. The overall results are presented in Table 4-2.

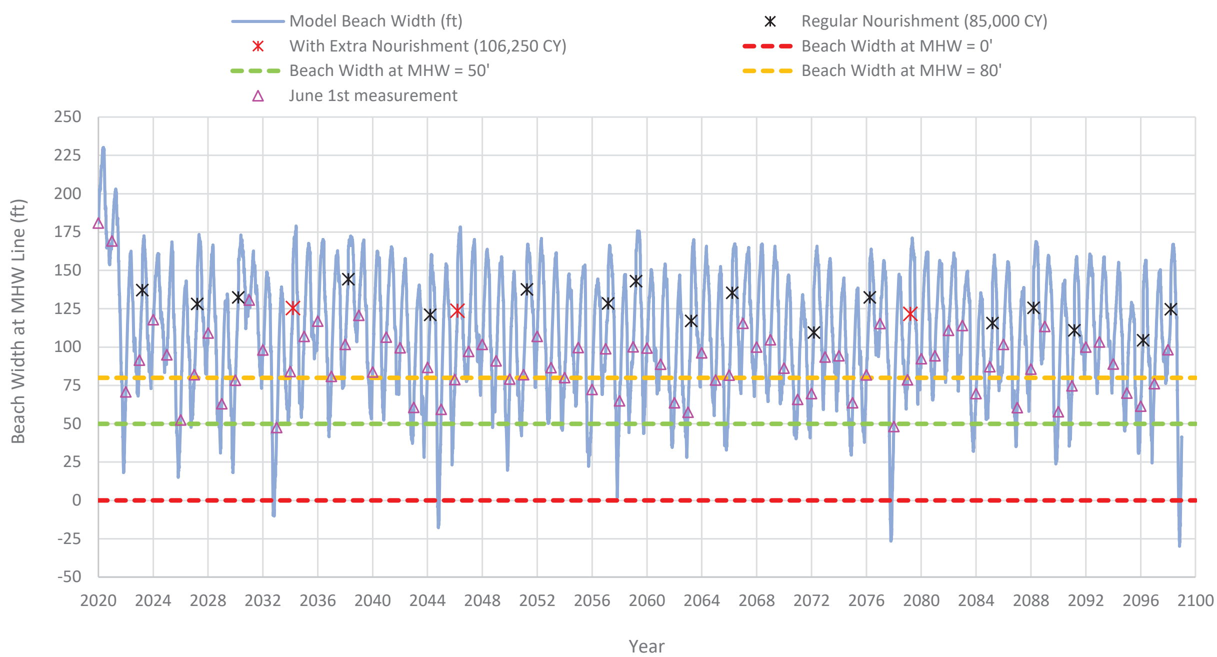

Figure 4-12: Example of one simulation run (projected SLR 4.4' in year 2100.

Table 4-2: Performance of beach nourishment scenarios.

Parameters		Nourishment Volume (CY)			
		85,000	120,000	300,000	500,000
Number of Nourishment in 80 years	Max	26	17	14	9
	95th Percentile	22	16	12	8
	Avg	20	14	11	8
	5th Percentile	18	13	9	7
	Min	16	11	8	5
Number of Full Wall Exposure at MHW in 80 years	Max	11	9	9	10
	Avg	4	3	3	3
	Min	0	0	0	0
Average Percent of Time Beach Width Distributions (%)	Width ≤ 25'	3%	2%	2%	2%
	25' < Width ≤ 50'	6%	5%	4%	4%
	50' < Width ≤ 80'	17%	14%	13%	11%
	80' < Width ≤ 160'	68%	66%	63%	57%
	160' < Width ≤ 230'	6%	13%	18%	24%
	Width > 230'	0%	0%	0%	2%

Average Beach Width at MHW (ft)	Jan	95	103	109	118
	Feb	75	83	89	98
	Mar	63	70	76	85
	Apr	60	68	74	82
	May	76	83	89	97
	Jun	96	103	108	116
	Jul	115	122	127	135
	Aug	135	143	148	157
	Sep	149	157	164	173
	Oct	151	159	165	174
	Nov	141	149	155	164
	Dec	119	127	133	142

In addition, seven additional cases with the 85,000 CY scenario were assessed. The intent is to address the model's uncertainty as well as to provide better understanding for the SMP's implementation. These cases include a greater longshore transport, a nominal 5% increase of offshore wave heights to address the potential increased storminess, a flatter beach slope of 60H:1V, a greater background erosion, a trigger beach width of 80 feet, a mixed beach nourishment scenario (combined two 85,000 CY replenishments, followed by one 300,000 CY replenishment), and adding the wave run-up calculation to take into account the 'dry beach' width. The results are presented in Table 4-3.

Table 4-3: Summary of model uncertainty analysis.

Parameters		Base	Greater Longshore Diffusivity	5% Wave Height Increase	60H:1V Beach Slope	Greater Background Erosion (-4.3 ft/yr)	Greater Trigger Width (80')	Mixed Scenarios (85k+300k)	Include Wave Run-up (1)
Number of Nourishment in 80 years		22	24	23	28	28	27	16	22
Number of Full Wall Exposure at MHW in 80 years		5	6	6	7	6	1	4	5
First Nourishment Following LPW Completion (yrs)		5	5	5	5	5	3	5	5
Average Percent of Time Beach Width Distributions (%) (1)	Width ≤ 25'	3%	3%	3%	5%	4%	1%	1%	8%
	25' < Width ≤ 50'	6%	8%	8%	11%	11%	2%	4%	11%
	50' < Width ≤ 80'	22%	23%	22%	24%	24%	7%	17%	25%
	80' < Width ≤ 160'	66%	64%	63%	59%	59%	64%	64%	55%
	160' < Width ≤ 230'	3%	2%	4%	1%	1%	27%	14%	2%
	Width > 230'	0.2%	0.0%	0.0%	0.2%	0.2%	0.2%	0.2%	0.1%
Average Beach Width (ft) (1)	Jan	88	85	87	78	78	116	102	69
	Feb	68	65	65	58	58	96	82	53
	Mar	57	53	53	47	47	85	70	47
	Apr	57	53	53	46	46	85	70	49
	May	72	68	70	61	61	100	85	64
	Jun	91	88	91	80	81	119	105	81
	Jul	110	106	111	99	99	138	123	96
	Aug	130	127	133	120	120	158	143	114
	Sep	144	142	149	136	136	173	159	128
	Oct	147	144	151	138	138	175	161	128
	Nov	136	133	139	127	127	164	150	115
	Dec	112	109	113	103	103	140	126	91

(1) Average Beach Width and Beach Width Distributions for all cases except "Include Wave Run-up" are defined by the MHW shoreline;
Average Beach Width and Beach Width Distribution for the "Include Wave Run-up" is defined by the line of wave runup above the still water level.

The SMP considers the historical cycle of El Niño oceanographic conditions to provide the best estimate overall of the replenishment quantity and interval to satisfy long-term requirements. The plan addresses more severe conditions during strong El Niño years that trigger non-scheduled sand replenishments and less severe conditions in milder years that allow deferral of a scheduled replenishment. Exceptionally severe conditions could result in exposure of portions of the LPW, which the plan also addresses. Table 4-4 summarizes the SMP based on the results of the model scenarios.

Table 4-4: Sand management plan model scenario results summary.

Sub Plan Option	Scale of Operation	Source of Sand	Transport Method	Scheduled Sand Placement (CY)	Est. No. of Placements in 80 Years[A]	Est. First Placement (Years) Following LPW Completion[A]	Trigger[B] - Beach Width (ft)	Trigger[C] - LPW Exposure Length (ft)
S1	Small	• Northern Ocean Beach	Truck	85,000	20	5	50[1]	500[2]
S2	Small			120,000	14	5		
L1	Large	• Entrance navigation channel • SF-8 disposal site • SF Bay sand lease site	Hopper dredge equipped for beach placement	300,000	11	5	50[1]	500[2]
L2	Large			500,000	8	8		

(A) Estimate based on sand transport modeling described in SMP and represent statistical average values; see text for confidence intervals.
(B) Placement of 125% of scheduled sand quantity in the next summer season; upon completion of a triggered nourishment, reset interval schedule.
(C) Placement of sandbags in sufficient quantity to conceal exposed wall.

Notes:
(1) 50 ft or less beach width, measured between MHW and the face of LPW over 500 ft total length on June 1 of the year.
(2) 500 ft or more total length of LPW exposure, measured above MHW elevation on June 1 of the year.

4.2.2. Sand Source

The northern portion of Ocean Beach had been used as the sand source for the sand backpass events since year 2012. However, it is important to determine if the northern Ocean Beach could be sustainable for the sub-plan “S” series in the long-term. A preliminary analysis indicated that the northern Ocean Beach could be sustainable if the sand was borrowed infrequently and if there is not any recent extreme event. However, it should be acknowledged that the San Francisco Bay littoral system is a complex environment and the knowledge of sediment transport is still not fully understood; e.g. some recent studies suggest that sand along Ocean Beach moves from the north to south, as opposed to the previous consensus (Barnard et al., 2013). Therefore, it is important to continuously monitor the shoreline at northern Ocean Beach and confirm it is sustainable as the past records suggest.

4.2.3. Placement Location, Frequency, and Templates

The planned location of sand placement is anticipated seaward of the wall to cover any exposed portion of the wall. The slope stabilization area is above the mean high tide and is being design as a stable vegetation layer. If plants and sand wash away above the slope stabilization layer, then sand will also be replaced and the area replanted Figure 4.13 and 4.14 is an example of what a placement template might look like including plan view and cross sections showing the amount of sand that maybe required for sand placement.

The frequency of a trigger being reached would vary depending upon intensity of storm activity and beach widths in preceding years. As sand placements would be expected to occur when a trigger is reached, Table 4-4 above, Frequency and Duration of Sand Placements, is representative of the anticipated frequency of a trigger being reached. The frequency of a trigger being reached would vary depending upon intensity of storm activity and beach widths in preceding years. Sand would be placed as soon as possible after a trigger is reached, generally within one year. In practice, if either trigger is reached, the SFPUC would most likely implement a sand placement in late spring of the following year. Placement is proposed in late spring, instead of within a certain period of time after the trigger is reached (such as one month or less), because sand placed between late summer and early spring could wash away during winter/spring storm events and have minimal public benefit during higher use periods (i.e., summer/fall), given the shoreline dynamics at South Ocean Beach. Supplemental sand placements could occur between triggered placement events and would be sourced from North Ocean Beach, a commercial vendor, or sand cleared from the Great Highway and multi-use trail.

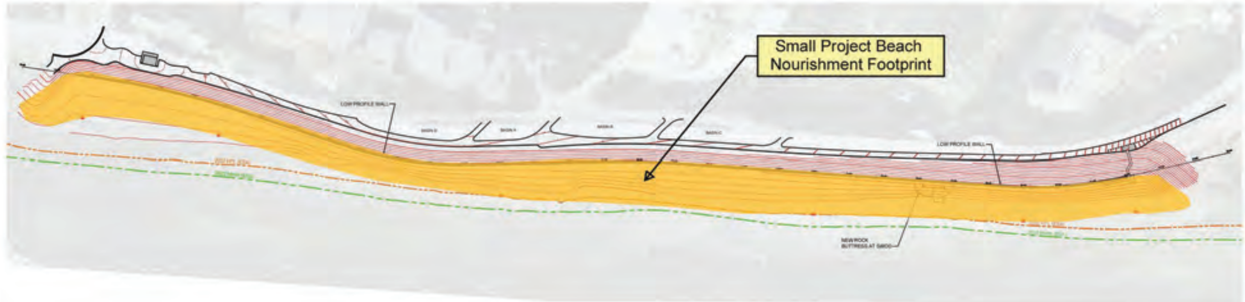

Figure 4.13. Small Beach Nourishment Footprint

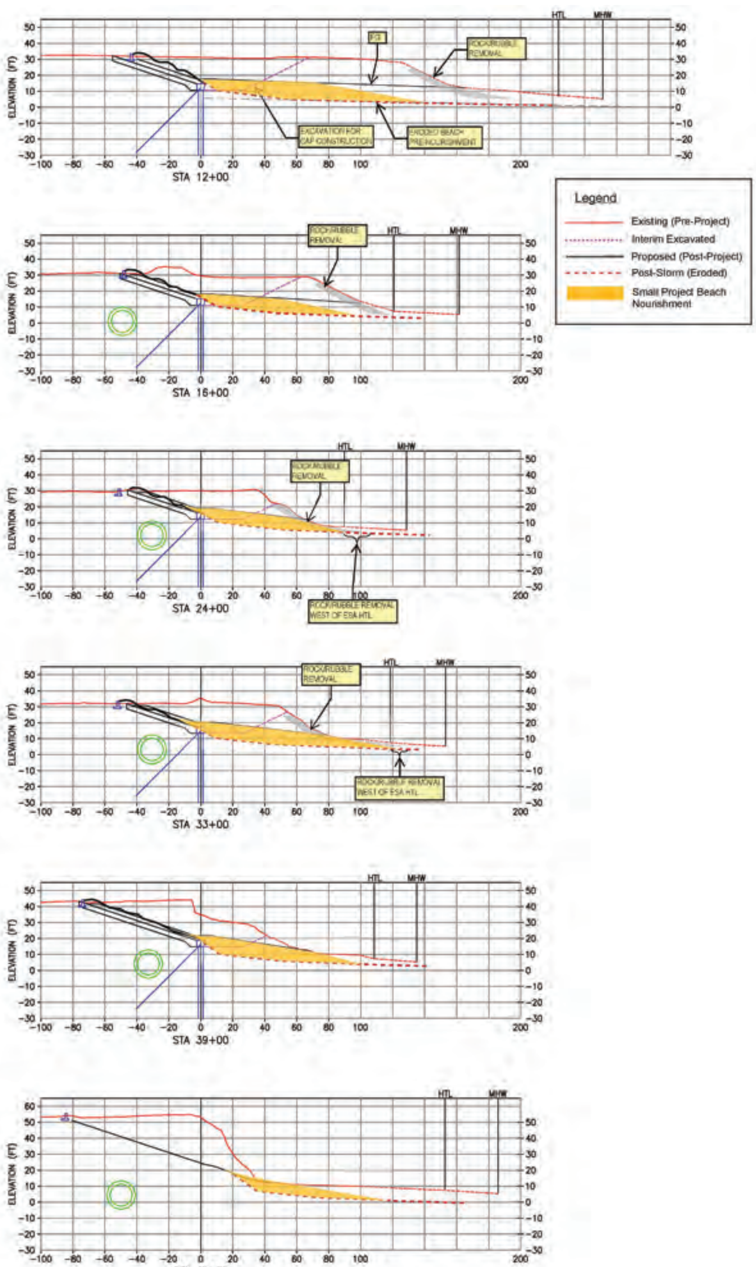

Figure 4.14. Finish grade and sand placement required to restore the beach to Finish grade after an erosion event.

5. Restoration Area Management

The basic premise of the vegetation and dune sand management designs for the VSZ is that the constructed, nourished artificial beach and dune system will cycle between a sequence of transitional, dynamic states driven by storm wave erosion, post-storm beach profile, vegetative recovery stages, and beach nourishment cycles.

The beach erosion/accretion state is the primary control of onshore wind-blown sand rates to the VSZ. Wind-blown (eolian) sand transport patterns and rates would vary with the state of the beach profile, vegetation structure, and the timing of high onshore wind events. The conceptual model of beach-foredune sand transport described below has a direct practical use for dune sand management and project design: it should allow qualitative rapid assessments of beach states to provide managers a basis for short-term and near-term forecasts of major changes in foredune sand mobility. For project design, it provides a basis for designs to adapt to pulsed, episodic high and low (or interrupted) rates of foredune sand accretion rather than long-term average rates. This conceptual model is drawn from long-term (multi-decade) observations of Ocean Beach foredunes, supported by review of the contemporary global literature on foredune geomorphic processes and beach-dune dynamics.

Wide, high backshore beach areas with sparse or no vegetation provide the highest potential for sand deflation, or surface erosion by wind, to supply onshore wind-blown sand to foredunes at high rates. High rates of wind-blown sand transport are associated with relatively few, infrequent days each year with very strong, dry onshore winds, usually northwest, and eolian sand transport is an exponential function of wind velocity. High rates of onshore wind transport of sand occur when high onshore winds cross beach profiles with wide, dry backshore beaches and wide, high relatively well-drained intertidal beach faces or beach-welded intertidal sand bars (Aagard *et al.* 2004). Low rates of onshore wind transport of sand or interruption of onshore wind transport of sand occur when the intertidal beach is low and moist to wet (cohesive, relatively resistant to sand deflation), and the dry backshore beach is narrow, scarped, or absent.

Some intermediate stages of beach and foredune erosion, such as rapid removal of stabilizing vegetation and sand dune slope failure, can also rapidly expose bare dry sand surfaces to rapid deflation and onshore transport. In general, however, high rates of onshore wind transport of sand are associated with wide, high, dry beach profiles and positive sand budgets.

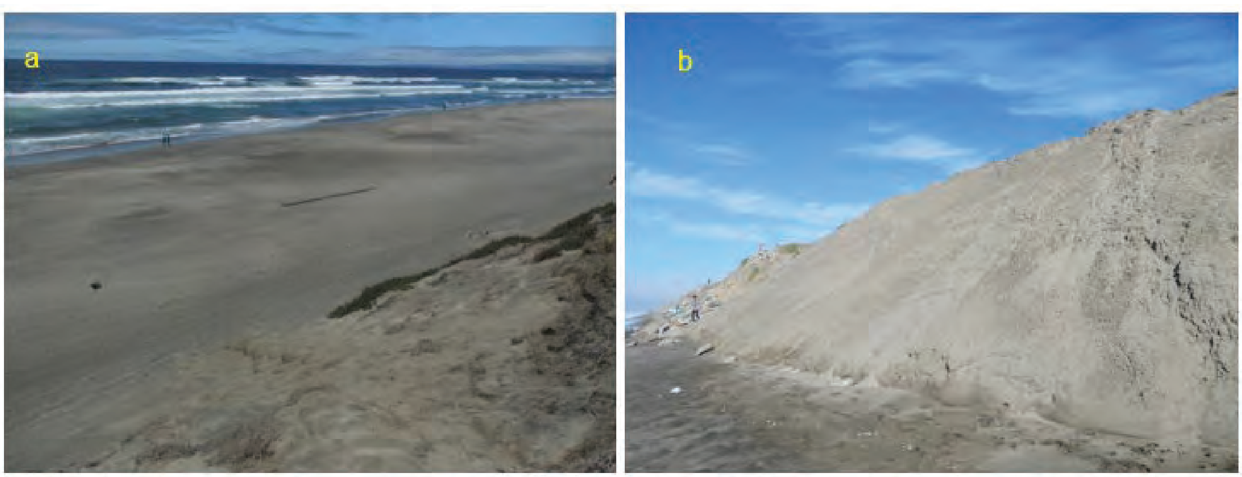

Figure 5-1: Ocean Beach profile states conducive to high rates of onshore wind transport of sand. (a) Wide, high, dry backshore beach profiles are conducive to high rates of onshore wind transport of sand to foredunes during brief periods of intensive high onshore winds at South Ocean Beach, 2014. (b) Placement of high-relief unvegetated sand berms, or rapid high-volume extensive backshore beach nourishment, can also provide exposed, dry steep sand profiles conducive to rapid wind erosion and onshore dune sand transport.

Significantly reduced or interrupted onshore transport of wind-blown sand is associated with very narrow dry backshore beach widths, complete erosion of the backshore, and extensive, low, wet intertidal beachfaces that resist sand deflation. This condition is prevalent following severe storm erosion events, or when nearshore troughs or rip channels move to positions that cause chronic severe local beach erosion. Foredunes can become sand-starved when the upper intertidal beachface remains low and wet or saturated at low tide.

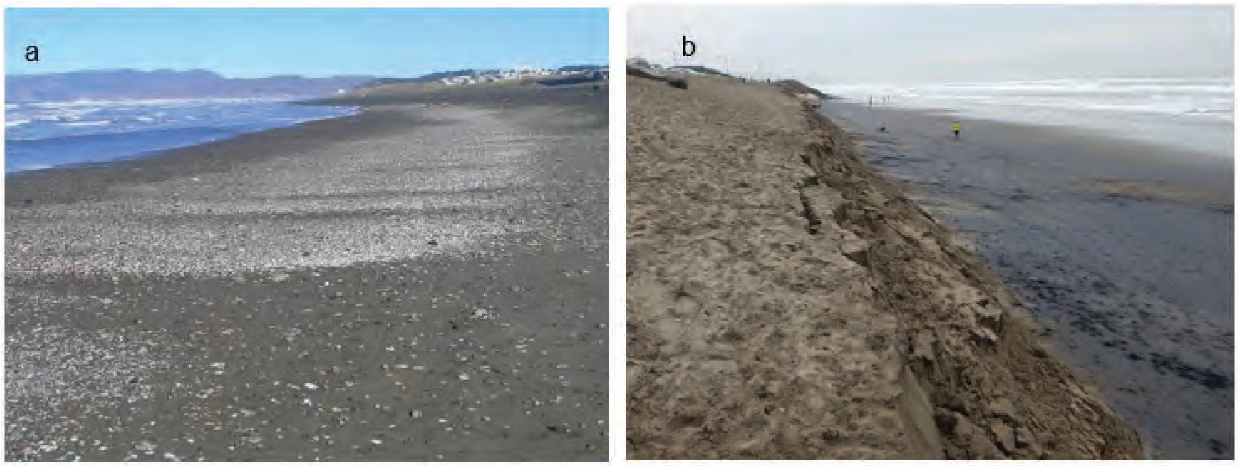

Figure 5-2: Intertidal beachface conditions can restrict onshore wind transport of sand at Ocean Beach. (a) Wet, low intertidal beachface with shell and pebble lag surface, narrow dry backshore beach, January 2007. (b) Wet heavy mineral lag beachface with no dry backshore beach below artificial Sloat sand berm, January 2016. Onshore wind-blown sand supply during these wet, low shoreface phases is limited to the wind erosion of the dry backshore beach or artificial sand berms.

Beach profile conditions that are associated with very low or high rates of onshore wind-transport of dune sand vary significantly among years and alongshore at Ocean Beach. Therefore, dune sand management would be expected to follow patterns of oscillating pulses of eolian sand transport that temporarily coincide with beach nourishment and storm erosion cycles, rather than hold at or near average condition. The cycle of transitions between beach states driving onshore wind-blown sand rates to the VSZ are shown as a conceptual diagram of Figure 5-3, and summarized in below with the target managed condition of the proposed project added for context.

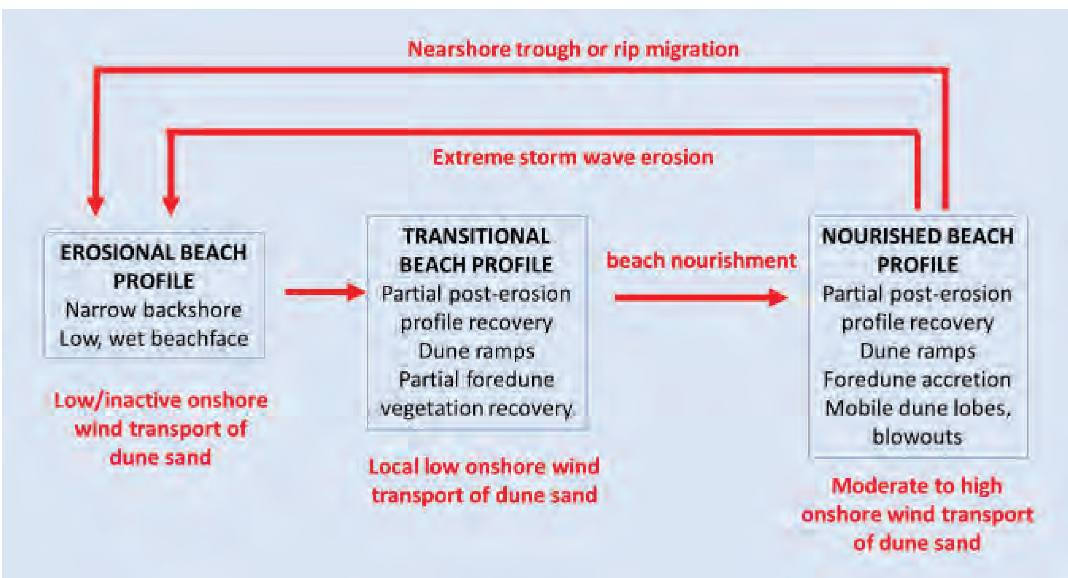

Figure 5-3: Conceptual diagram of transitions between beach states that drive states of onshore wind-blown sand rates and processes in the VZM foredunes (based on Ocean Beach foredune long-term observations, Aagard *et al.* 2004, Arens 1996, Christiansen and Davidson-Arnott 2004, Bauer *et al*. 2012).

Steep, eroded beach/interrupted onshore eolian sand transport: When the beach profile is steep and eroded (low backshore beach or beachface, vertical beach scarp or exposure of the low-profile wall), onshore wind transport of sand is expected to be negligible or nil; wind-blown sand is subject to topographic steering, deflected alongshore at the base of the beach or dune scarp (Arens 1996, Christiansen and Davidson-Arnott 2004) or exposed low-profile wall. Onshore wind transport rates of sand from the moist or wet intertidal beachface are relatively low (Aagard *et al*. 2004, Aagard 2014). Most sand transport in the VSZ in this condition would derive from internal erosion of the exposed, drying foredune scarp.

Partial backshore beach profile recovery, unvegetated/sparse beach vegetation: Intermediate post-storm beach recovery stage. Most onshore-blown sand eroded from the beach is deposited at the base of the foredune or residual beach scarp as a low dune ramp and transported alongshore rather than onto the windward face of the vegetated foredune or foredune crest. Low rates of foredune sand accretion are prevalent.

Replenished sand berm, unvegetated or sparsely vegetated beach: This transient phase of wide, dry backshore beach and sparse to negligible vegetation roughness represents the window of maximum potential onshore wind transport. Following post-storm beach recovery or artificial placement of a wide backshore sand berm (beach nourishment), wind deflation and onshore sand transport rates of the dry, wide backshore beach rapidly increase. Dune ramps deposit at the base of the scarp or wall (Arens 1996). When ramps reach the crest of the scarp or wall, high rates of onshore sand transport into the foredune/VSZ resume (Christiansen and Davidson-Arnott 2004, Arens 1996). High intertidal beachface elevations or welding of bars to the beach, with low surface moisture at low tide, will significantly increase net onshore wind transport of sand to the foredunes (Aagard *et al.* 2004).

Managed target state - fully vegetated foredune and backshore beach embryo dunes: Proposed adaptive management vegetation of foredune vegetation after beach nourishment). Backshore beach is replanted with beach wildrye in the wet winter season, and coarse woody debris and brush fencing are replaced at the toe of the dune ramp/back of the beach, to increase beach roughness and sand trapping while perennial beach wildrye spreads vegetatively over 2-3 years. The dune ramp revegetates and coalesces with the foot of the foredunes above the low-profile wall. Onshore-blown sand is deposited and trapped primarily in the seaward portion of the vegetated foredune slope and embryo foredunes on the beach.

5.1. Response to Storm Erosion

The primary response to storm erosion is replanting of the VSZ. Following severe storm erosion with significant erosive wave uprush above the low-profile wall, lower portions of the foredune slope may require reconstruction through sand placement, temporary stabilization though brush fence or brush placement, and revegetation to maintain dynamic stability of the VSZ. The initial adaptive management response to erosion of the lower foredune slope should be to stabilize the exposed perched foredune scarp with brush placement and revegetate the re-nourished landward zone of the backshore beach with beach wildrye to nucleate embryo foredunes that may spread up accreted dune ramps and regenerate the lower foredune by the same natural processes that foredune scarps undergo. If this natural process does not have time to complete before the next major erosion event, direct sand placement and replanting on the eroded slope may be needed as a last resort.

5.2. Response to Wind-Blown Sand Accumulation

Wind-blown sand transport, also referred to as eolian transport, plays a major role in dune formation and stability along Ocean Beach. Active eolian transport, which is a loss of sediment to the Ocean Beach system, moves sediment across the Great Highway driven by prevailing northwesterly and westerly winds (USGS, 2007).

An analytical method was used to estimate eolian transport. A time series of over-water wind measurements at NOAA's offshore buoy 46026 was first converted to shore-normal over-land wind speeds. Once the threshold to initiate aeolian transport (depending on grain size) is exceeded, the transport rate per foot of beach was calculated. Figure 5-4 presents the estimated monthly aeolian transport rates for two grain sizes. As shown in the figure, the smaller grain size results in a larger aeolian transport rate.

Wind-blown sand mitigation measures incorporated in the sand backpass events were found effective to reduce the amount of nuisance sand passed to the Great Highway (ESA, 2018). The measures included placement of a coarse sand layer (reducing sand mobilization) over the top of the placed berms and installation of interlocking brushwood fencing on the crest of the sand berms to trap sand. The trapped sand can then be collected and re-used for the nourishment or sandbags.

The spatial distribution, frequency and magnitude of wind-blown sand deposition in the VZM is expected to fluctuate between two extreme conditions controlled by the beach profile erosion and recovery cycle, driven by storm erosion, beach sand replenishment, and vegetation re-establishment in the embryo foredune zone seaward of the low-profile wall. The alternate states of wind-blown sand conditions are expected to switch abruptly and predictably from the following beach conditions that will occur cyclically but at variable rates.

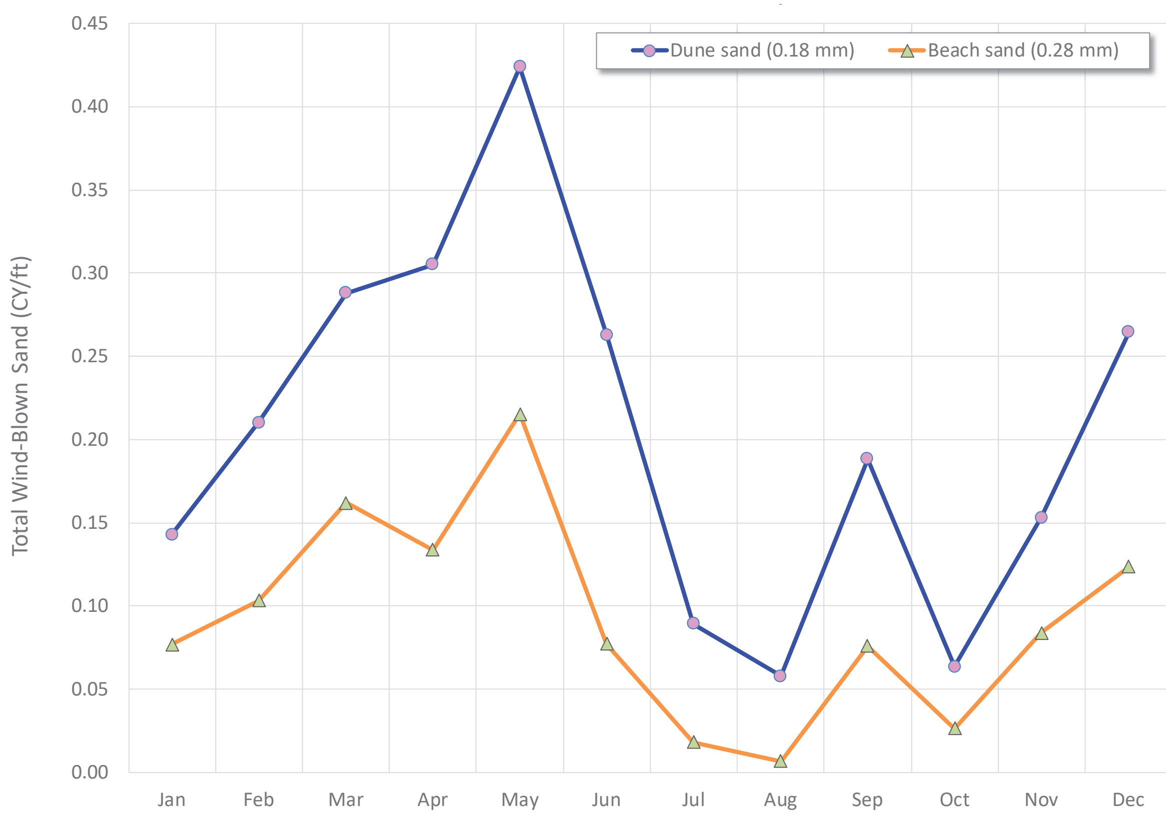

Figure 5-4: Estimated monthly aeolian transport per foot of beach.

Following beach nourishment, wide backshore beach areas may provide unstable dry sand sources for wind erosion to supply foredune vegetation of the VSZ with overwhelming rates of sand accretion, saturating the beach wildrye canopy (full burial to leaf tips). If the lobes of new dunes or the dune sand burial front (sand wave) migrate within 20-30 ft of the foredune crest, brush fencing materials should be mobilized to be placed as needed. Brush fencing or unsecured brush should be set at least 15 ft upwind (NW) of the trail or road edge to be protected from sand deposition. Brush can be placed loosely within beach wildrye canopies, to at least 3 feet above ground surface.

The vegetation of the dune slacks is tolerant of moderate sand burial. If sand removal maintenance of roads or trails generates small volumes (3-5 cubic yards) of sand to be disposed, it may be deposited as a thin layer averaging 0.25 ft thick, and not exceeding 0.5 ft thick, over standing vegetation. Buried patches of rhizomatous dune grasses in the slack should be able to regenerate through the sand layer within weeks or months, and fully recover in the following growing season. Dormant (winter or fall) sand burial has lower impact on grass regrowth than burial during active growth.

6. Landscape Areas

6.1. Infiltration Basins

6.1.1. Purpose and Structure

The four infiltration basins included in this project are designed to capture storm water coming from the project's service road and adjacent multi-use trail. Due to the projected increase in storm intensity over the coming years, the basins have been designed to accommodate infiltration of a 100-year storm event. In the event of a storm of this magnitude, the basins are designed to have a small percentage of overflow sent to the storm water system of the San Francisco Zoo.

The ponding area of storm water takes up about 38% of the total acreage set aside for the infiltration basins. The remainder acreage of the basin area is devoted to stable backdune vegetation, see 6.1.2 below. Three of the four basins are designed with existing sand as their soil media. The fourth basin, due to low infiltration of existing sand at its site location, will require imported sand from the overall project site.

The basins are designed to hold 18" of ponding depth. The lowest elevations of these basins will be planted with dune slack vegetation. The upper elevations will contain backdune species. See details about species selection and placement below.

6.1.2. Stable Backdunes and Native Vegetation

Stable backdunes are coastal dunes landward of the foredune, where they are located beyond the zone of active sand transport from the foredune and support relatively continuous vegetative cover (only small vegetation gaps) that resist wind deflation and blowout development. Stable backdune vegetation can become unstable where large vegetation gaps expose bare, wind-erodible sand patches facing dominant winds. Blowouts in stable backdune vegetation are likely to form where chronic trampling denudes vegetation in foot trails, especially where they cross dune crests. Otherwise, native backdune vegetation, including native dune annuals, are likely to re-colonize small vegetation gaps.

The internal structure of naturally formed stable backdunes reflects their origin and evolution from earlier phases as active, accreting vegetated dunes. Backdunes, like foredunes, are typically composed of interbedded layers of accreted sand from active deposition episodes and buried, accumulated root mats and plant litter layers formed during phases of dune surface stabilization. The residual stratified internal sand and buried relict root mats provide some resistance to wind erosion when the surface cover of vegetation is disturbed. In contrast, artificially constructed stabilized dunes have no internal structure as they are composed of unconsolidated sand. Unless supplied with embedded coarse fibrous or woody debris in subsurface sand layers, they are directly exposed to wind deflation if surface vegetation gaps due to factors such as trampling, animal burrowing, or drought dieback open.

Stable native backdune vegetation in western San Francisco was historically composed of various dune scrub assemblages of prostrate and tall upright growth habits and dune grassland consisting of herbaceous broadleaf plants and grasses, often with low-growing or prostrate growth habits. Some native backdune perennial plant species are tolerant of moderate sand burial rates that occur when dunes destabilize due to blowouts or landward encroachment of foredunes, but many are intolerant of significant sand burial. Local important stands of restored backdune vegetation that correspond with historic types occur at Fort Funston, where most stabilized dunes are otherwise dominated by non-native Australian or South African vegetation (iceplant, blue gum eucalyptus, acacia species). Related, similar relict backdune vegetation stands with mixed native and non-native vegetation, with variable stability and blowout activity, occur on cliff-top perched dunes in North Pacifica.

Table 6-1, Table 6-2, and Table 6-3 summarize a recommended, representative selection of native San Francisco perennial forb, subshrub, and shrub species of stable backdunes based on historical records (Howell *et al.* 1958, and Consortium of California Herbaria record searches) and recent decades of observations. Their proposed distribution and abundance in managed, constructed dunes of the project are included in the tables, reflecting natural patterns but also modified for project purposes. Species are presented according to life-form (shrub, subshrub and perennial forb, perennial grasses and grass-like plants, and annual forbs), rather than designated assemblages since populations assemble themselves in variable gradients and assemblages in annually variable backdune environments. Only tall woody dune scrub species, which can overtop and outcompete prostrate or low-stature forbs, subshrubs, and grasses, require some separation of patches to prevent over-dominance or competitive exclusion of more diverse grassland and forb assemblages.

Table 6-1: Native grasses and forbs of active (depositional) foredunes in San Francisco.

Foredune Species	Growth habit, life-form	Proposed abundance and distribution	Ecological and geomorphic traits
BEACH WILDRYE (*Leymus mollis*, syn. *Elymus mollis;* American dunegrass)	Perennial tall widely creeping coarse grass	Frequent extensive large colonies; proposed dominant species. 3-5 ft center transplants across whole VSZ.	High tolerance to sand burial, storm overwash; root/rhizome mat increases sand/soil shear strength. Tall canopy traps and stabilizes relatively thick deposits of blowing sand in foredunes
YELLOW SAND-VERBENA (*Abronia latifolia*)	Taprooted perennial prostrate forb	Infrequent in gaps between beach wildrye colonies; subdominant. Average one colony/50-100 ft, lower seaward slope.	Rapid lateral spread stabilizes sand surface, traps thin, broad deposits of blowing sand in foredunes. Taproot provides no significant below-ground shear strength. Bee pollination.
BEACH-BUR (*Ambrosia chamissonis*)	Taprooted perennial prostrate forb	Infrequent in gaps between beach wildrye colonies; subdominant. Average one colony/50-100 ft, lower seaward slope.	Rapid lateral spread stabilizes sand surface, traps thin, broad deposits of blowing sand in foredunes. Taproot provides no significant below-ground shear strength.
SILVERY BEACH PEA (*Lathyrus littoralis*)	Perennial creeping forb	Common in lower seaward slope. Average one colony/20-30 ft, irregular spacing.	Nitrogen fixing roots are likely to enhance growth of adjacent beach wildrye. Vegetation roughness near sand surface. Bee pollination.

Table 6-2: Native dune shrubs (woody plants branched at base) of San Francisco backdunes, dominants of dune scrub vegetation.

Backdune Shrub Species	Growth habit, life-form	Proposed abundance and distribution
COYOTE-BRUSH (*Baccharis pilularis*)	Prostrate to low mounding shrub	Restricted, local (strongly colonial; “native invasive species”
MOCK-HEATHER (*Ericameria ericoides*)	Erect shrub	Discrete large patches, landward/interior
SEASIDE WOOLLY SUNFLOWER (*Eriophyllum staechadifolium*)	Erect subshrub	Discrete large patches with other shrubs
BUSH LUPINE (*Lupinus arboreus*)	Erect nitrogen-fixing colonial shrub	Discrete large patches; seaward buffer zone bordering VSZ
CHAMISSO’S LUPINE (*Lupinus chamissonis*)	Erect nitrogen-fixing colonial shrub	Discrete large patches; seaward buffer zone bordering VSZ

Table 6-3: Native dune forbs and subshrubs (herbaceous broadleaf and semi-woody plants) of San Francisco backdunes, widespread in dune grassland and forb assemblages, as well as dune scrub gaps. Note: stable backdune species may occur in active foredune positions due to shoreline and foredune retreat landward.

Backdune Perennial Forb and Subshrub Species	Growth habit, life-form	Proposed abundance and distribution
DUNE SAGE (*Artemisia pycnocephala)*	Taprooted perennial forb	Widespread, common, and abundant
VIRGATE NUTTALL'S MILK-VETCH (*Astragalus nuttallii* var. *virgata*)	Taprooted prostrate perennial forb	Occasional colonies
CALIFORNIA SALTBUSH (*Extriplex californica*)	Taprooted perennial forb	Occasional colonies in gaps
PAINTBRUSH (*Castilleja affinis, C. wightii*)	Hemiparasitic perennial forb/subshrub	Widespread local patches associated with dune sage, coyote-brush
COMMON SANDASTER (*Corethrogyne filaginifolia*)	Perennial summer-fall flowering prostrate forb	Occasional local patches
SHRUB MONKEY-FLOWER (*Diplacus aurantiacus*)	Erect shrub	Infrequent individuals (esp. mesic)
BLUFF-LETTUCE (*Dudleya farinosa*)	Taprooted low-growing rosette-forming succulent perennial forb	Local patches in sparse prostrate vegetation or gaps
SEASIDE DAISY (*Erigeron glaucus*)	Prostrate colonial perennial forb	Widespread patches
FRANCISCAN WALLFLOWER (*Erysimum franciscanum*)	Taprooted perennial/subshrub	Widespread, infrequent patches
COAST BUCKWHEAT (*Eriogonum latifolium*)	Prostrate to mounding taprooted perennial forb/subshrub	Widespread, common
BEACH STRAWBERRY (*Fragaria chiloensis*)	Stoloniferous (widely spreading colonies) prostrate perennial forb	Local large patches, occasional in vegetation gaps
BROADLEAF GUMPLANT (*Grindelia stricta* var. *platyphylla*)	Taprooted prostrate perennial forb	Widespread, small colonies
*SAN FRANCISCO LESSINGIA (**Lessingia germanorum*, listed endangered species)	Annual summer-fall flowering taprooted forb	Local colonies in sparse prostrate vegetation or gaps (under MOA; see text)
VARIED LUPINE (*Lupinus variicolor*)	Taprooted prostrate forb/subshrub	Occasional, small colonies
CALIFORNIA MANROOT (*Marah fabacea*)	Massive long-lived taprooted (caudex) perennial forb, sprawling or vining	Occasional
DUNE KNOTWEED (*Polygonum paronychia*)	Prostrate taprooted subshrub	Occasional, small colonies
CALIFORNIA PHACELIA (*Phacelia californica*)	Low mounded perennial forb	Occasional, small colonies
BRACKEN FERN (*Pteridium aquilinum*)	Perennial colonial fern	Among coyote-brush, mock-heather
DUNE TANSY (*Tanacetum bipinnatum*, syn. *T. camphoratum*)	Coarse tall creeping perennial forb	Infrequent, large colonies

6.1.3. Backdune Annual Forbs

The annual herbaceous species component of stable backdune vegetation, despite low abundance in mature vegetation, is highly important for establishment of new, restored backdunes. Annual backdune forbs are adapted to rapidly colonizing and spreading over bare sand in gaps among perennial or shrub vegetation where sand surface movement (erosion or deposition) has become insignificant or has ceased. In contrast, native perennial and shrub species of stable backdunes are relatively stress-tolerant and slow-growing. Newly graded sand surfaces of constructed dunes are equivalent to early successional stages of stabilizing blowout dunes, where annuals may be temporarily abundant or dominant.

The functional role of coastal dune annuals in natural backdune vegetation is often colonization of bare sand gaps left by dieback of dominant perennial or shrub species, local erosion or deposition, or animal burrows. The functional role of coastal dune annuals in newly restored or constructed backdunes is analogous to a cover crop in agriculture. Broadcast seeding of annual dune forbs over new graded sand surfaces contributes to rapid stabilization of the sand surface and competition against seedlings of non-native weeds. There are also wildflowers, many of which provide conspicuous bright, colorful patches of flower displays with variable duration from brief to long seasons. Most grow in open sun and sand. One species grows only in association with a host on which it is weakly parasitic (broad-leaf purple owl's-clover, on dune sage). Two annual species are primarily shade-dependent winter annuals that require shelter from direct sun under shrubs, often among mosses and lichens, where moisture is high in winter (miner's lettuce, woodland threadstem).

Table 6-4: Perennial native grasses of stable backdunes in San Francisco.

Backdune Grass species	Growth habit, life-form, life-history	Proposed abundance and distribution
MARITIME BROME (Bromus sitchensis var. maritimus)	Tufted, sprawling to upright perennial grass	Widespread, patchy in mesic slacks and dry dune slopes
PACIFIC WILDRYE (*Leymus pacificus* and intermediates with *L. triticoides*)	Low-growing creeping perennial grass	Widespread, large colonies in dune slopes and mesic to dry dune slacks; also moderately burial-tolerant, trampling-tolerant
DUNE (DOUGLAS') BLUEGRASS (*Poa douglasii*)	Low-growing creeping perennial grass	Widespread, large colonies in dune slopes and mesic to dry dune slacks; also moderately burial-tolerant

Table 6-5: Native annual forbs of stable San Francisco backdunes.

Backdune Annual Forb Species	Growth habit, life-form, life-history	Proposed abundance and distribution
ROUND-LEAF HEERMAN'S LOTUS (*Acmispon heermanii* var. *orbiculatus*)	Annual spring-flowering prostrate forb	Widespread colonies in vegetation gaps; pioneer native cover crop
COAST FIDDLENECK (*Amsinckia spectabilis*)	Annual spring-flowering forb	Widespread colonies in vegetation gaps; pioneer native cover crop
BEACH EVENING-PRIMROSE (*Camissoniopsis cheiranthifolia* ssp. *cheiranthifolia*)	Prostrate taprooted short-lived perennial or annual	Widespread in gaps; source populations from interior SF only
BROADLEAF PURPLE OWL'S-CLOVER (*Castilleja exserta* ssp. *latifolia*)	Hemiparasitic annual forb	Local patches associated with dune sage, on which it is dependent for a host plant
MINER'S-LETTUCE (*Claytonia perfoliata*)	Annual winter forb	Shaded ground layer below coyote-brush, mock-heather
AMERICAN WILD CARROT (*Daucus pusillus*)	Annual taprooted spring/early summer-flowering forb	Widepread colonies in vegetation gaps; pioneer native cover crop
DUNE GILIA (*Gilia capitata* var. *chamissonis*)	Taprooted spring-flowering annual forb	Local patches in sparse prostrate vegetation or gaps
*SAN FRANCISCO LESSINGIA (**Lessingia germanorum*, listed endangered species)	Annual summer-fall flowering taprooted forb	Local colonies in sparse prostrate vegetation or gaps (under MOA; see text)
CURLYLEAF COYOTE-MINT OR MONARDELLA (*Monardella undulata*)	Taprooted spring/summer-flowering annual forb	Occasional, large sparse colonies
DUNE PHACELIA (*Phacelia distans*)	Annual spring-flowering forb	Widespread colonies in vegetation gaps; pioneer native cover crop
WOODLAND THREADSTEM (*Pterostegia drymarioides*)	Annual prostrate forb	Shaded ground layer below coyote-brush, mock-heather

6.1.4. Dune Slacks and Native Vegetation

Dune slacks are flats or hollows eroded by wind during mobile dune phases that are stabilized by vegetation during either moist or low wind climate phases or when erosion depths approach permanently moist, cohesive sand near the capillary fringe of groundwater. They are the topographic low areas forming basins within stabilized backdunes. They are a special sub-type of backdune landforms and vegetation of particular relevance to stormwater runoff management of OBCCAP.

California dune slacks that contact fluctuating groundwater levels are wetlands, either seasonal (dry in summer dry, moist to saturated in winter) or perennial (dune lakes, ponds, willow-waxmyrtle riparian groves, or marshes). True wetland dune slacks were envisioned for the Zoo/Sloat vicinity in the Ocean Beach Master Plan (SPUR *et al*. 2012), but they are incompatible with the OBCCAP substrate and drainage requirements. Dry (drained) dune slacks, however, support vegetation that is compatible with the stormwater management needs of OBCCAP. Dry dune slacks are basins that may undergo ephemeral flooding or long moist periods without prolonged wetland soil hydrology (anaerobic soil conditions) and their native plant assemblages are adapted to this intermediate, dry-mesic hydrology. They are often associated with transition zones between wetland dune slacks and dune slopes along the north-central and north California coast.

Because of their importance for stabilizing the dune depressions serving as stormwater runoff infiltration basins, a selection of native dry dune slack plant species is assembled (Table 6-6) based on plant functional traits rather than specific reference sites of vegetation. Since some of the species have been reduced to relatively isolated, small, or rare regional populations, there are no known examples of natural dune slacks where they all occur together in association, but they are all historically native to San Francisco and all still have populations on the San Francisco Peninsula coast between Pacifica and San Francisco.

Table 6-6: Dry (non-wetland) dune slack dominant grasses and forbs of San Francisco. Graminoid refers to grasses and grass-like herbaceous plants.

Dry/mesic dune slack graminoid and forb species	**Growth habit, life-form, life-history**	**Proposed abundance and distribution**
BROADLEAF GUMPLANT (*Grindelia stricta* var. *platyphylla*)	Tap-rooted prostrate perennial forb	Widespread, small colonies
COAST FIDDLENECK (*Amsinckia spectabilis*)	Annual spring-flowering forb	Widespread colonies in vegetation gaps; pioneer native cover crop
SALT RUSH (*Juncus lescurii*)	Perennial colonial grass-like rush	Typically dominant in seasonally wet slacks, but marginal in dry slacks
PACIFIC WILDRYE (*Leymus pacificus* and intermediates with *L. triticoides*)	Low-growing creeping perennial grass	Widespread, large colonies; moderately high tolerance for sand burial, trampling, ephemeral flooding
VANCOUVER WILDRYE (*Leymus Xvancouverensis*)	Tall creeping perennial grass	Widespread, large colonies moderately high tolerance for sand burial and ephemeral flooding
CREEPING WILDRYE -dune ecotype (*Leymus triticoides*, intermediate with *L. pacificus*)	Tall creeping perennial grass	Widespread, large colonies; local ecotype from N Pacifica remnant dunes tolerant of sand burial, presumably ephemeral flooding
EVENING-PRIMROSE (*Oenothera elata* var. *hookeri*)	Tall, short-lived perennial forb; prolific seed colonization, often colonial	Widespread, patchy large colonies. Conspicuous summer-fall wildflower
DUNE (DOUGLAS') BLUEGRASS (*Poa douglasii*)	Low-growing creeping perennial grass	Widespread, large colonies. moderately high tolerance for sand burial,
DUNE TANSY (*Tanacetum bipinnatum*, syn. *T. camphoratum*)	Coarse tall creeping perennial forb	Infrequent founder plants, forming extensive clonal colonies

6.1.5. Initial Establishment and Maintenance

As with foredunes, backdune transplanting will require at least two growing seasons of advance propagation to build up sufficient seed and vegetative stock for transplanting. Transplanting time and conditions for backdunes are also contingent on the timing of cool, wet weather from late fall to mid-winter, sufficient to fully moisten the sand profile (root zone) prior to transplanting. Winter droughts, dry sand, and elevated temperatures in coastal dunes cannot be compensated by overhead irrigation because of dry sand repellency of water and interactions with irregular and impeded infiltration of sloping or undulating sand surfaces. Transplants may be bare-root or, if container-grown, in sandy growing medium with minimal amendments. Backdunes will be at high risk of weed invasion after transplanting, since sand burial will not exclude weeds as in foredunes. Weed invasions must be controlled at the seedling stage or seedling-juvenile transition stage, long before flowering or seed set.

Backdunes will also require temporary surface stabilization after grading to prevent rapid deflation. Thin coarse sand lag veneers or thin surface scatters of coarse woody debris may be the most cost-effective and inconspicuous treatments. In the absence of sand surface stabilization, sand deflation after transplanting will expose roots and shoot crowns to desiccation, and undermine seedlings, potentially causing excessive transplant and seedling mortality.

The dry dune slack grass-dominated vegetation would be established by the same transplanting techniques as for beach wildrye. Transplant density, however, should be increased to a minimum 1-2 ft center layout with large single-species patches as opposed to interspersed species. Unlike the sloping, undulating backdune surfaces, the flat or depressional basins would likely be feasible for temporary overhead irrigation, especially if it is initiated after transplanting during the rainfall season. Dry sand repellency during winter droughts may cause restricted or very uneven infiltration of water to the root zone, but this effect may be mitigated by applying surfactants to the irrigated sand surface (Dekker *et al*. 2005)

6.2. Sloat Plaza

The planters at Sloat Plaza are built with above-ground concrete walls and are open to the underlying existing sand below. They include a selection of backdune shrubs and forbs as well as beach wildrye *elymus mollis*, featured in the Vegetative Stabilization Zone.

As planters at one of the entry points of the site, the plants here will be designed to showcase dune plants, providing seasonal color and a point of focus for the visitors. Additionally, these planters will include Pacific wax myrtle *myrica californica* to provide a scenic and visual buffer between the service road and the plaza space.

6.3. Parking Lot and Medians

The OBCCAP Parking Lot is located adjacent to Skyline Boulevard at the southeast end of the project site. To the immediate north of the parking lot is a rise in terrain that serves as the effective high point of the OBCCAP site. Because of this elevated terrain and because the service road connected to the parking lot veers eastward from the beach, plants within the parking lot are more sheltered from ocean wind and sand than other areas of the site.

Medians separating the service road and multi-use trail extend down either side of this high point. Some medians are exposed to ocean winds and others more sheltered. Medians will include both dune vegetation and dispersed placement of Monterey cypress *cupressus macrocarpa*.

The parking lot contains three infiltration basins to manage storm water from the service road and parking stalls. These basins contain the majority of plants within the parking area. Ponding depths of these infiltration basins is 6”. Due to the sheltered nature of this space, sand accumulation is less of a concern than at the infiltration basins to the north of this site.

Planting within the parking lot basins and at-grade planters will include a selection of backdune vegetation as described in Tables 6-2 and 6-5. Plants that can handle greater storm water inundation will be located within the infiltration basin bottoms. Those that are more sensitive to inundation will be located in the higher elevations of above-ground planters. In one of the above-ground planters, existing Monterey cypress will remain adjacent to an infiltration basin.

7. References

Aagaard, T., Davidson-Arnott, R., Greenwood, B. and Nielsen, J., 2004. Sediment supply from shoreface to dunes: linking sediment transport measurements and long-term morphological evolution. Geomorphology, 60:205-224.

Agam, N. and Berliner, P.R., 2006. Dew formation and water vapor adsorption in semi-arid environments—a review. Journal of Arid Environments 65: 572-590.

Arens, S.M., 1996. Patterns of sand transport on vegetated foredunes. Geomorphology, 17(4), pp.339-350.

Barnard, P.L., Schoellhamer, D.H., Jaffe, B.E. and McKee, L.J., 2013. Sediment transport in the San Francisco Bay coastal system: an overview. Marine Geology, Special Issue San Francisco Bay, Volume 345, p. 3-17.

Bauer, B.O., Davidson-Arnott, R.G., Walker, I.J., Hesp, P.A. and Ollerhead, J., 2012. Wind direction and complex sediment transport response across a beach–dune system. Earth Surface Processes and Landforms, 37:1661-1677.

Baye, P. 2020. Preliminary assessment and conceptual design of dune vegetation and wind-blown sand management for the South Ocean Beach coastal erosion and wastewater infrastructure protection project. August 2020.

Baye, P. 2021. Ocean Beach Climate Change Adaptation – runoff infiltration and flood detention basin in constructed dune landscape. Technical memorandum for MN+AGS JV, MFLA, San Francisco Public Utilities Commission, July 2021.

Baye, P. 2022. Ocean Beach Climate Change Adaptation – conceptual natural analog model (basis for concept design) and conceptual description of subsurface summer irrigation for perched Sloat foredune vegetation above the proposed low-profile wall and cemented sand layer. Technical memorandum for MN+AGS JV, MFLA, San Francisco Public Utilities Commission.

Cooper, W.S. 1967. The Coastal Dunes of California. Geol. Soc. Amer. Mem. 72.

Christiansen, M.B. and Davidson-Arnott, R., 2004. Rates of landward sand transport over the foredune at Skallingen, Denmark and the role of dune ramps. Geografisk Tidsskrift-Danish Journal of Geography, 104:1-43.

de Jong, T.M., 1979. Water and salinity relations of Californian beach species. Journal of Ecology 67:647-663.

Dekker, L.W., Doerr, S.H., Oostindie, K., Ziogas, A.K. and Ritsema, C.J., 2001. Water repellency and critical soil water content in a dune sand. Soil Science Society of America Journal, 65:1667-1674.

Drexler, J.Z., Anderson, F.E. and Snyder, R.L., 2008. Evapotranspiration rates and crop coefficients for a restored marsh in the Sacramento–San Joaquin Delta, California, USA. Hydrological Processes: An International Journal, 22:725-735.

ESA, 2018. Ocean Beach short-term erosion protection measures project, 2017-2018 monitoring report. Prepared for San Francisco Public Utilities Commission. Final Report: September, 2018.

Grilliot, M.J., Walker, I.J. and Bauer, B.O., 2019. Aeolian sand transport and deposition patterns within a large woody debris matrix fronting a foredune. Geomorphology 338:1-15.

Grilliot, M.J., Walker, I.J. and Bauer, B.O., 2019. The Role of Large Woody Debris in Beach-Dune Interaction. Journal of Geophysical Research: Earth Surface, 124(12):2854-2876.

Howell, J.T, P.H. Raven, and P. Rubtzoff. 1958. A Flora of San Francisco. Wassman Journal of Biology 16 (1). University of San Francisco.

Kohfahl, C., Molano-Leno, L., Martínez, G., Vanderlinden, K., Guardiola-Albert, C. and Moreno, L., 2019. Determining groundwater recharge and vapor flow in dune sediments using a weighable precision meteo lysimeter. Science of the Total Environment 656:550-557.

Kohfahl, C., Saaltink, M.W. and Bermudo, F.R., 2021. Vapor flow control in dune sediments under dry bare soil conditions. Science of The Total Environment 786:147404.

Marchi, A.M. and Carrick, H.J., 2006. Variation in water quality and phytoplankton nutritional status in an urbanized lake system (Lake Merced, California, USA). Lake and Reservoir Management, 22:33-43.

McLaughlin, W.T., 1942. Controlling coastal sand dunes in the Pacific Northwest. Circular No. 660, U.S. Department of Agriculture.

M&N, 1995. Sediment transport processes study. Ocean Beach, San Francisco, California. Prepared for: U.S. Army Corps of Engineers, San Francisco District. Final Report: July 31, 1995.

M&N, 2007. Guidance for a beach nourishment study under Section 933, Ocean Beach, California. Prepared for: City & County of San Francisco. July, 2007.

M&N/AGS JV, 2019. Conceptual engineering report, Ocean Beach long-term improvements project. Prepared for: San Francisco Public Utilities Commission. Final Report: September 30, 2019.

M&N/AGS JV, 2020. Sand management plan. Ocean Beach climate change adaptation project, long-term improvements. Prepared for: San Francisco Public Utilities Commission. Final report: July 2, 2020.

Pavlik, B.M., 1985. Water relations of the dune grasses *Ammophila arenaria* and *Elymus mollis* on the coast of Oregon, USA. Oikos 45:197-205.

Phillips, S.P., Hamlin, S.N. and Yates, E.B., 1993. Geohydrology, water quality, and estimation of ground-water recharge in San Francisco, California, 1987-92 (Vol. 93, No. 4019). U.S. Geological Survey.

Ramaley, F., 1918. Notes on dune vegetation at San Francisco, California. The Plant World, 21(8):191-201.

Reckendorf, F., Leach, D., Baum, R. and Carlson, J., 1985. Stabilization of sand dunes in Oregon. Agricultural History, 59:260-268.

Schwarz, C., Brinkkemper, J. and Ruessink, G., 2018. Feedbacks between biotic and abiotic processes governing the development of foredune blowouts: a review. Journal of Marine Science and Engineering 7:2.

Smith, O.W, Jacquot, H.D. and R.L. Brown. 1947. Stabilization of Sand Dunes in the Pacific Northwest. State College of Washington Institute of Agricultural Sciences, Pullman WA, Bulletin No. 492. 16 pp.

SPUR, 2012. Ocean Beach master plan. Prepared by: SPUR with AECOM, ESA PWA, Nelson/Nygaard, Sherwood Design Engineers, and Phil D. King, PhD. May 2012.

USACE, 1996. Ocean Beach storm damage reduction feasibility study, San Francisco District, Final Feasibility Study for the City and County of San Francisco.

USGS, 2007. Coastal processes study at Ocean Beach, San Francisco, CA: summary of data collection 2004-2006. Open-File Report 2007–1217, 171 p. Prepared by: Patrick L. Barnard, Jodi Eshleman, Li H. Erikson, and Daniel M. Hanes.

USGS, 2020. Ocean Beach LMT seawall project area erosion rates. Processed and provided by Dan Hoover, PhD. Unpublished data. February 5, 2020.

Woodhouse, W.W., 1978. Dune building and stabilization with vegetation. U.S. Army Corps of Engineers, Coastal Engineering Research Center Special Report No. 3. Fort Belvoir, VA.

Yates, E.B. S. N. Hamlin, L. Horowitz McCann. 1990. Geohydrology, water quality, and water budgets of Golden Gate Park and the Lake Merced area in the Western part of San Francisco, California. U.S. Geological Survey Water-Resources Investigations Report 90-4080

Sand Management Plan

Ocean Beach Climate Change Adaptation Project, Long-Term Improvements

PREPARED FOR:

San Francisco
Water Power Sewer
Services of the San Francisco Public Utilities Commission

JULY 2020

PREPARED BY:

MN+AGS JV

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Approvals

People listed in the table below have signed and approved the information provided in this report.

Table 1: Signatures

Department/ Bureau	Name	Signature	Date

Rev	Date	Reason	Originator	Initials	Project Engineer	Initials
1						

Document Verification

Project name	Ocean Beach Climate Change Adaptation Project, Long-Term Improvements
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A	Working Draft	C-F. Tsai/R. Dornhelm	11/18/2019	M. Jorgensen
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Produced by:

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AGS

McMillen Jacobs Associates

CHS Consulting Group

San Francisco Public Works

Table of Contents

Figures

Tables

Glossary

AAR	Alternatives Analysis Report
CCSF	City & County of San Francisco
CER	Conceptual Engineering Report
CY	Cubic Yards
DHI	Danish Hydraulic Institute
ENSO	El Niño Southern Oscillation
GGNRA	Golden Gate National Recreation Area
H:V	Horizontal:Vertical (Slope)
LiDAR	Light Detection and Ranging
LMT	Lake Merced Transport and Storage Tunnel
LPW	Low-Profile Wall
M&N	Moffatt & Nichol
MHW	Mean High Water
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OBMP	Ocean Beach Master Plan
ONI	Oceanic Niño Index
OPC	Ocean Protection Council
Project	Ocean Beach Climate Change Adaptation Project, Long-Term Improvements
RMS	Root-Mean-Squared
SF	San Francisco
SFPUC	San Francisco Public Utilities Commission
SLR	Sea-Level Rise
SPUR	San Francisco Planning and Urban Research Association
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Executive Summary

Introduction

In 2012, the San Francisco Planning and Urban Research Association (SPUR) completed the Ocean Beach Master Plan (OBMP), a vision document that emerged from an in-depth interagency and public planning process. The overall goal of the OBMP was: ”to knit the unique assets and experiences of Ocean Beach into a seamless and welcoming public landscape, planning for environmental conservation, sustainable infrastructure and long-term stewardship.” The OBMP recommended management and protection measures for the existing essential wastewater infrastructure at Ocean Beach, in conjunction with increasing local access to the beach, improving aesthetics, and improving the beach’s ecological functions (SPUR, 2015; SPUR, 2012).

The MN + AGS JV team is developing a design for the protection of the essential wastewater infrastructure, along with a *Sand Management Plan* that will be used for monitoring beach widths and for the management of sand placement after the initial construction. This Sand Management Plan provides recommendations for beach replenishment and sand management at South Ocean Beach in conjunction with the Ocean Beach Climate Change Adaptation Project, Long-Term Improvements. The goals of sand management are:

- To maintain an effective, year-round recreational beach within the Project area over the Project life, utilizing scheduled sand replenishment actions;
- To increase resilience of the shoreline within the Project area to future sea level rise;
- To accomplish the sand replenishment based on beach width triggers in a cost-effective manner; and
- To minimize disruption to shoreline ecology, from a habitat protection standpoint, and to beach users, from a recreational perspective.

Although the design and permits for the Project are expected to cover the Project through the year 2060, the *Sand Management Plan* is intended to establish a sustainable long-term sand management framework for South Ocean Beach extending to the end of century. It is also recognized that the *Sand Management Plan* builds upon current state-of-the-art research in coastal processes and as understanding of the processes advances the adaptive management provisions of the plan will allow it to evolve as well.

Analysis Approach and Model Results

To develop the *Sand Management Plan* and guide the decision-making process for stakeholders, it is important to understand how oceanographic conditions could vary over time, including incoming wave energy, Oceanic El Niño conditions, and sea level rise and how the beach in front of the wall would respond. Because these oceanographic parameters are highly unpredictable in nature, they typically cannot be described with a singular value, but rather a function based on probabilities of occurrence or levels of risk. Therefore, a risk-based probabilistic approach was used in this study to allow consideration of a wide range of possible combinations of events that influence beach morphology. A large number of model runs using Monte Carlo simulation were performed for this study. The risk-based probabilistic model utilized a software program that is computationally efficient, with input that was developed based on oceanographic and geomorphic conditions at the site and results of process-based models that were developed by the USACE and the USGS. This approach allowed a reduced complexity of sand transport equations (e.g. longshore and cross-shore transport process-based models) and a simplified representation of coastal morphology.

Four replenishment scenarios were evaluated in this study, two characterized as small plan (85,000 and 120,000 CY replenishment) and two as large plan (300,000 and 500,000 CY replenishment). Using the 85,000 CY scenario as an example, the average number of replenishments in eighty years is 20 events. The average number of low-profile wall exposures down to the MHW elevation is about 4. The average first replenishment occurs about 5 years after the project construction is completed. Results also show that the beach width is less than 50 feet only 9% of the time. Results are summarized in Table E-1.

Figure E-1 illustrates average beach widths by month, along with the 90% confidence interval (90% of beach widths over all model runs for the scenario lie within the interval). The narrowest beach width occurs between March and April as it is approximately the end of the winter erosive season. The widest beach width occurs between September and October as it marks the end of the summer accretive season and includes any sand replenishments that may have occurred that year.

In addition, seven additional cases were run for the 85,000 CY replenishment scenario, in order to address the model's uncertainty as well as to provide a better understanding of the model's sensitivity for the plan implementation.

Table E-1: Results of Numerical Simulations

Parameters		Nourishment Volume (CY)			
		85,000	120,000	300,000	500,000
Number of Nourishment in 80 years	Max	26	17	14	9
	95th Percentile	22	16	12	8
	Avg	20	14	11	8
	5th Percentile	18	13	9	7
	Min	16	11	8	5
Number of Full Wall Exposure at MHW in 80 years	Max	11	9	9	10
	Avg	4	3	3	3
	Min	0	0	0	0
First Nourishment Following LPW Completion (yrs)	Max	8	8	8	10
	Avg	5	5	5	8
	Min	2	3	4	4
Probability Distribution of Beach Widths (%)	Width ≤ 25'	3%	2%	2%	2%
	25' < Width ≤ 50'	6%	5%	4%	4%
	50' < Width ≤ 80'	17%	14%	13%	11%
	80' < Width ≤ 160'	68%	66%	63%	57%
	160' < Width ≤ 230'	6%	13%	18%	24%
	Width > 230'	0%	0%	0%	2%
Average Beach Widths in feet (MHW to LPW)	Jan	95	103	109	118
	Feb	75	83	89	98
	Mar	63	70	76	85
	Apr	60	68	74	82
	May	76	83	89	97
	Jun	96	103	108	116
	Jul	115	122	127	135
	Aug	135	143	148	157
	Sep	149	157	164	173
	Oct	151	159	165	174
	Nov	141	149	155	164
	Dec	119	127	133	142

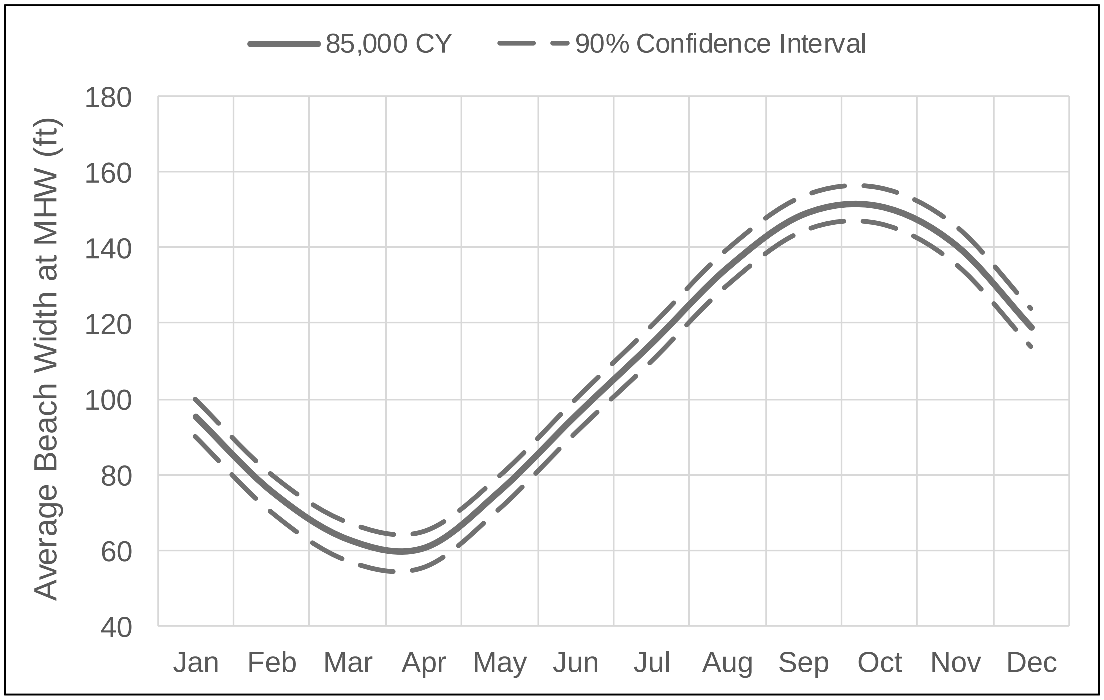

Figure E-1: Seasonal Fluctuation of Beach Widths

When the beach width becomes zero in the model, the shoreline has receded to the LPW – that is, the wall is exposed down to MHW elevation. The beach erosion may continue when this happens, and the model shows increasing negative beach widths until the mobile sand layer is completely gone and the erosion resistant marine terrace is exposed. However, the wall is designed to withstand such extreme erosion events and continues to protect the Wastewater infrastructure. In addition, the "emergency" sandbag placement of Trigger B is designed to minimize the impact of wall exposure and reduce wave reflection and wave run-up hazard for the public.

The four replenishment scenarios are characterized under two sub-plans, each with two replenishment quantity options to allow trade-off between the periodic sand replenishment quantity and placement intervals as follows:

- Sub-plan series 'S' is based on the current practice of 'back-passing' sand from the northern end of Ocean Beach by trucking to the Erosion Hot-Spot at the southern end. It has the principal advantage that implementation can be both certain and immediate since it has been functioning for several years in addressing the current sand management needs along Ocean Beach. The technical details and costs are well documented. Furthermore, environmental review of the work is complete and permits have been obtained, which are expected to be renewed to meet future needs. This sub-plan can be implemented in a relatively straight-forward manner to allow the Project to proceed as scheduled.

- Sub-plan series ‘L’ is based on the practice common on the U.S. East Coast and in Southern California of harvesting sand offshore by means of a dredge that is equipped to deposit the dredged material directly onto the beach. It incorporates the long-proposed concept of placing dredged material from the maintenance of the SF Main Ship Channel onto South Ocean Beach. The harvesting of sand offshore and placing the material directly onto the beach as required by this sub-plan would need to undergo additional environmental review and secure permits, as well as conclude partnering agreements with the USACE. The schedule and the outcome of these proposals are not certain. Therefore, the sub-plan is not included at this time as part of the Project. However, it is included in this *Sand Management Plan* because of its future potential to provide beach replenishment that is more cost-effective with less disruption for beach users and greater ecologic benefits as construction disturbance would be less frequent.

The sand management plan considers the historic cycle of El Niño oceanographic conditions to provide the best estimate overall of the replenishment quantity and interval to satisfy long-term requirements. The plan addresses more severe conditions during strong El Niño years that trigger non-scheduled sand replenishments, and less severe conditions in milder years that allow deferral of a scheduled replenishment. Exceptionally severe conditions could result in exposure of portions of the LPW, which the plan also addresses.

The frequency of placement episodes for Sub-plan ‘S’ sand replenishment is based on model results and varies between an interval of 2 to 8 years. The actual frequency of sand replenishment will vary depending on beach width trigger criteria and oceanographic conditions actually encountered.

Two triggers are proposed for initiating a non-scheduled Sand Replenishment or LPW Exposure Management episode:

- **Trigger A – Sand Replenishment:** 50 feet or less beach width over 500 feet total length of beach, measured between the MHW line and the face of LPW on June 1 of the year requires that a sand replenishment be implemented in the following year, allowing about 12 months to complete preparations. Although the model allows over 12 months for the City to prepare for a replenishment, it should be noted that this model assumption is not a strict rule but is mainly to foster an orderly budgeting, contracting, environmental protection and public notification process. The MHW line was chosen because it is a widely recognized definition of the 'shoreline' and often used for the measurement of beach width, though it is not the only definition in case another water level datum is desired. The effect of including wave run-up in the measurement of beach width was evaluated in the analysis.

- **Trigger B – LPW Exposure Management:** 500 feet or more total length of LPW exposure above MHW elevation also measured on June 1 of the year requires that the exposed portion of wall be concealed by sandbags using materials stockpiled for this purpose. This "emergency" placement is to reduce the wave run-up hazard and reduce wave reflection off the wall when the sand fronting the wall is depleted.

Although the intent of the Sand Management Plan is to avoid or minimize the current practice of emergency responses at South Ocean Beach, it does not preclude an *Ad-Hoc* placement of a reduced volume of sand if required.

The trigger distance of 50 feet serves as a buffer to reduce the risk of wall exposure in case storms occur during the preparation for a replenishment event. The value of 50 feet was selected because it allows for dry beach fronting the wall even during a King High Tide. In addition, if a non-scheduled replenishment has been triggered, it may not be implemented if the beach recovers naturally during the 12 months between the June 1 trigger and the subsequent June 1 measurement.

If the non-scheduled sand replenishment trigger is not activated, the regular sand replenishment should proceed per schedule, unless the beach width measured between MHW and the face of the LPW is greater than 80 feet over the entire length of the beach on June 1 of the year preceding the scheduled replenishment.

The plan also allows placing a coarse sand layer atop the sand replenishment berms to reduce the amount of nuisance wind-blown sand transport. Local sand mining operations in the Central San Francisco Bay are identified as potential sources for this coarser material. It should be noted that this mitigation measure will have little effect on wave-driven erosion.

Beach Monitoring

The plan is dependent on a beach and dune monitoring program that provides regular input on beach and dune condition and will guide the SFPUC in decision-making for the implementation of the sand management activities. As noted, the sand quantities and replenishment intervals in the *Sand Management Plan* are based on maintaining the beach and dune system under long-term conditions, so the monitoring program is intended to document both the expected seasonal variations as well as the inter-annual variations. The normal erosion and accretion cycles of beaches should not be allowed to compromise the critical Lake Merced Transport and Storage Tunnel (LMT) the LPW is designed to protect, nor to diminish the long-term ecologic and recreational values that the *Sand Management Plan* is intended to safeguard. The design of the LPW and the Plan recognizes that LPW exposure and reduced beach width are to be expected from time to time and that there is a commitment to replenish the beach sand to the extent that the natural process of beach accretion does not restore the minimum beach width in a timely manner.

The monitoring program consists of the following elements:

A) At South Ocean Beach Replenishment Site

- Bi-monthly reports, based on visual observations by a qualified engineer/scientist of the 3200 foot-long beach and dune system to detect conditions that suggest beach width or LPW exposure are near or past trigger stage, or the dune encroachment on the public trail is reaching nuisance levels. Bi-monthly monitoring would be coordinated with quarterly and annual monitoring.
- Quarterly reports, based on beach and dune profile surveys at low tide for a minimum of 12 transects extending beyond the north and south limits of the project to report quantitatively on beach width, LPW exposure and depth of (dune) sand covering the trail.
- Annual reports, due by the end of June each year to tally the results of the prior year's observations/measurements, summarize the occurrence of trigger actions, and to conclude on the need to conduct a scheduled (or unscheduled) sand replenishment in the following summer season, or the need to conceal exposed portions of the LPW.

B) At North Ocean Beach Borrow Site

- June and December beach profile surveys at low tide for a minimum of 10 transects covering the extent of the borrow site. Report in the Annual Report under A) in order to confirm the availability of sufficient sand quantity in the event a sand replenishment event is scheduled or triggered.

The scope of the monitoring for beach biologic/ecologic parameters or the sand borrow or replenishment operation itself is to be developed within the environmental review process.

Summary of Recommendations

The *Sand Management Plan* recommendations are summarized in Table E-2 below. See Section 4 for details of the plan.

Table E-2: Sand Management Plan – Ocean Beach Climate Change Adaptation Project, Long-Term Improvements

Sub Plan Option	Scale of Operation	Source of Sand	Transport Method	Scheduled Sand Placement (CY)	Est. No. of Placements in 80 Years[A]	Est. First Placement (Years) Following LPW Completion[A]	Trigger[B] - Beach Width (ft)	Trigger[C] - LPW Exposure Length (ft)
S1	Small	• Northern Ocean Beach	Truck	85,000	20	5	50[1]	500[2]
S2	Small			120,000	14	5		
L1	Large	• Entrance navigation channel • SF-8 disposal site • SF Bay sand lease site	Hopper dredge equipped for beach placement	300,000	11	5	50[1]	500[2]
L2	Large			500,000	8	8		

[A] Estimate based on sand transport modeling described in Section 3 and represent statistical average values; see text for confidence intervals.
[B] Placement of 125% of scheduled sand quantity in the next summer season; upon completion of a triggered nourishment, reset interval schedule.
[C] Placement of sandbags in sufficient quantity to conceal exposed wall.

Notes:
[1] 50 ft or less beach width, measured between MHW and the face of LPW over 500 ft total length on June 1 of the year.
[2] 500 ft or more total length of LPW exposure, measured above MHW elevation on June 1 of the year.

1. Introduction

1.1. Purpose and Need

Currently, the existing wastewater infrastructure within the South Ocean Beach Project area (see Figure 1-1 and Figure 1-2) is threatened by chronic coastal erosion of the beach and bluffs, caused by wave action and episodic bluff failures. The Lake Merced Transport and Storage Tunnel (LMT) is located immediately behind the bluff and is in jeopardy of structural failure without some form of protection. Failure of the LMT would cripple the functionality of the Oceanside Wastewater Infrastructure.

Over the years, federal, state, and local agencies have adopted erosion mitigation measures, aimed at protecting the existing shoreline and beach. These efforts have included depositing sand along the bluffs and/or offshore areas and the construction of rock and sandbag revetments (under emergency permit order). However, the permit only allows for the placement of sandbags, maintenance of rock, and sand backpass activities as temporary protection measures while the long-term solution is being developed and implemented (CCC, 2015).

Efforts in recent years have focused on the development of the Ocean Beach Master Plan (OBMP), which outlines coastal protection strategies along Ocean Beach through mid-century. The overall goal of the OBMP was: "to knit the unique assets and experiences of Ocean Beach into a seamless and welcoming public landscape, planning for environmental conservation, sustainable infrastructure and long-term stewardship." The OBMP recommended management and protection measures for the existing essential wastewater infrastructure at Ocean Beach (including the LMT) in conjunction with increasing local access to the beach, improving aesthetics, and improving the beach's ecological functions (SPUR, 2015; SPUR, 2012).

In 2018, the San Francisco Public Utilities Commission (SFPUC) produced an Alternatives Analysis Report (AAR), entitled: "Alternative Analysis Report for Coastal Adaptation Strategies for South Ocean Beach Wastewater System." The AAR analyzed ten (10) alternatives to address the threat of chronic erosion to the LMT and associated Oceanside facilities. With the intent to protect the LMT, each alternative was evaluated against eight criteria concerning cost, environmental impact, resilience to sea level rise, and operational complexity and all alternatives included ongoing beach nourishment. Alternative A, a low-profile wall (LPW), ranked highest among the alternatives and was carried forward in the subsequent conceptual design. Given the long-term erosion that characterizes the shoreline fronting the LMT, the vision of the Project is to provide LMT protection while enhancing the recreational opportunity and shoreline ecology in the Project area in a prudent, cost effective manner.

The Conceptual Engineering Report (CER) develops Alternative A into a 10% design level. Figure 1-3 and Figure 1-4 present the conceptual plan view and one typical section for Alternative A. The wall extends about 200 ft beyond the LMT's northern limit because of the need to protect the intersection of the Great Highway and Sloat Boulevard's essential role in the revised traffic pattern that will accompany the LPW construction and facilitate the public beach access in the area. Similarly the wall extends about 100 ft beyond the LMT's southern limit to provide a more secure LPW terminus with greater accommodation for public access and safety due to the fragile nature of the coastal bluffs in the area. The report also presents conceptual designs for other elements of the Project including traffic, landscaping, modified access to the zoo, modified access to the OSP and WSP facilities for SFPUC employees, and public recreational access to the beach and proposed relocated parking lot, bathroom, multi-use trail and beach. The CER additionally considers aspects of constructability, operations and maintenance, right-of-way, and environmental review. The CER follows the OBMP guidance and focuses on a solution in the form of managed retreat of the Ocean Beach shoreline in response to chronic erosion and future sea-level rise (M&N and AGS, 2019).

Beach replenishment is one of the important considerations in Alternative A. Development of a sand management plan is required by the Environmental Team, the Coastal Commission, the National Park Service and other stakeholders to have sufficient information for assessing the Project's performance. The goals of the *Sand Management Plan* are:

- To maintain an effective, year-round recreational beach within the Project area over the Project life, utilizing scheduled sand replenishment actions;
- To increase resilience of the shoreline within the Project area to future sea level rise;
- To accomplish the sand replenishment based on beach width triggers in a cost-effective manner; and
- To minimize disruption to shoreline ecology, from a habitat protection standpoint, and to beach users, from a recreational perspective.

This *Sand Management Plan* supersedes the high-level desktop analysis prepared in the CER.

1.2. Scope of Work

This document provides the background information, supplemental beach nourishment analysis, and the sand management plan. The subjects outlined in the sand management plan include the following:

- Sand replenishment sources;
- Sand replenishment volume and placement;
- Sand replenishment frequency and triggers;
- Sand replenishment methods, equipment, staging, access;
- Sand replenishment beach/dune closure needs;
- Wind-blown sand management;
- Effect of sea level rise and increased storminess;
- Risk of LPW exposure; and
- Pre and post construction monitoring needs.

Figure 1-1: South Ocean Beach Location

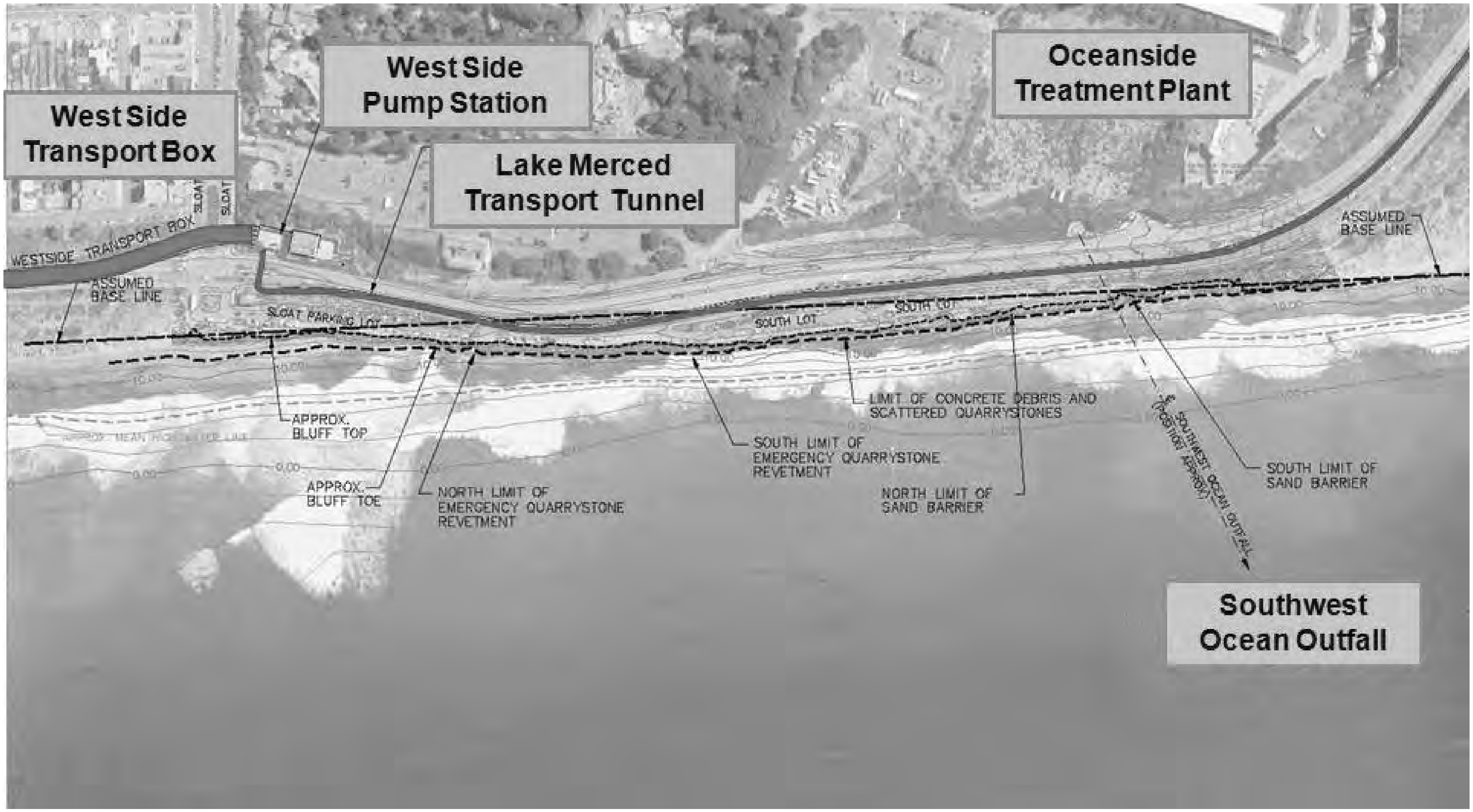

Figure 1-2: San Francisco West Wastewater Facilities

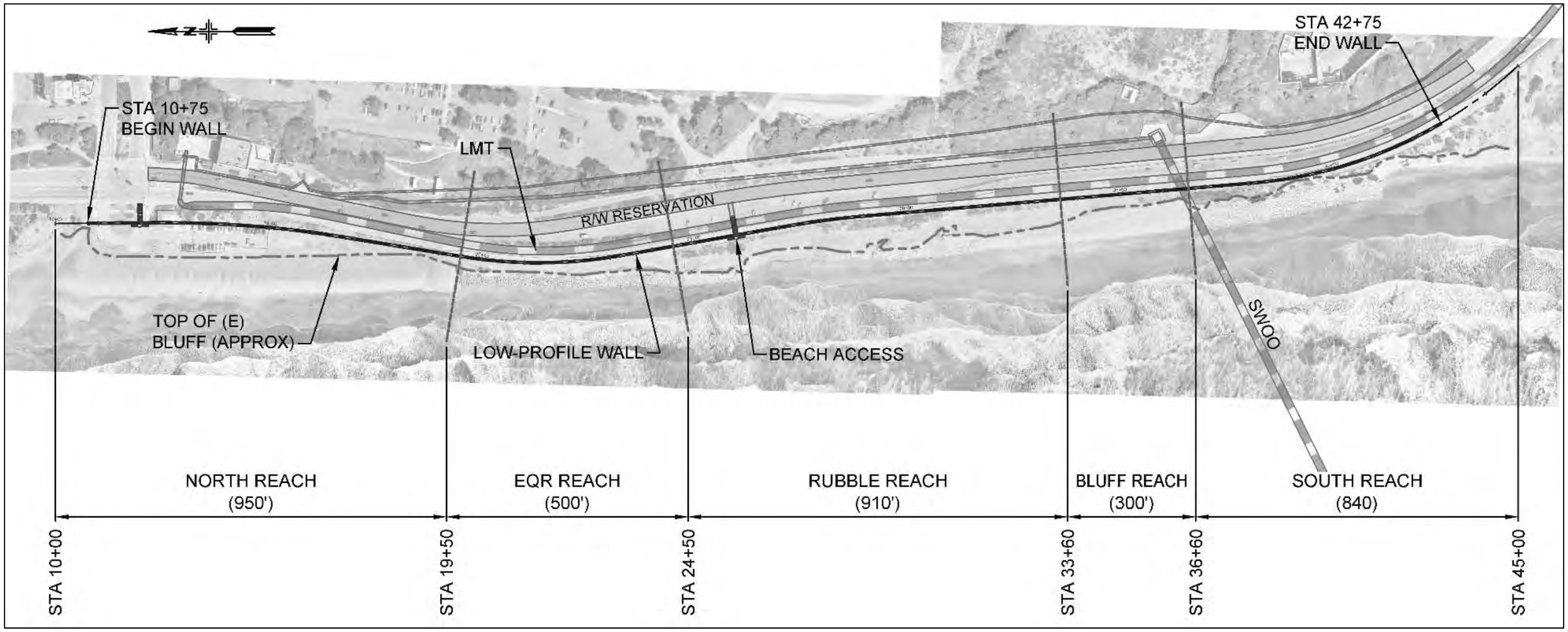

Figure 1-3: Conceptual Plan of Low-Profile Wall

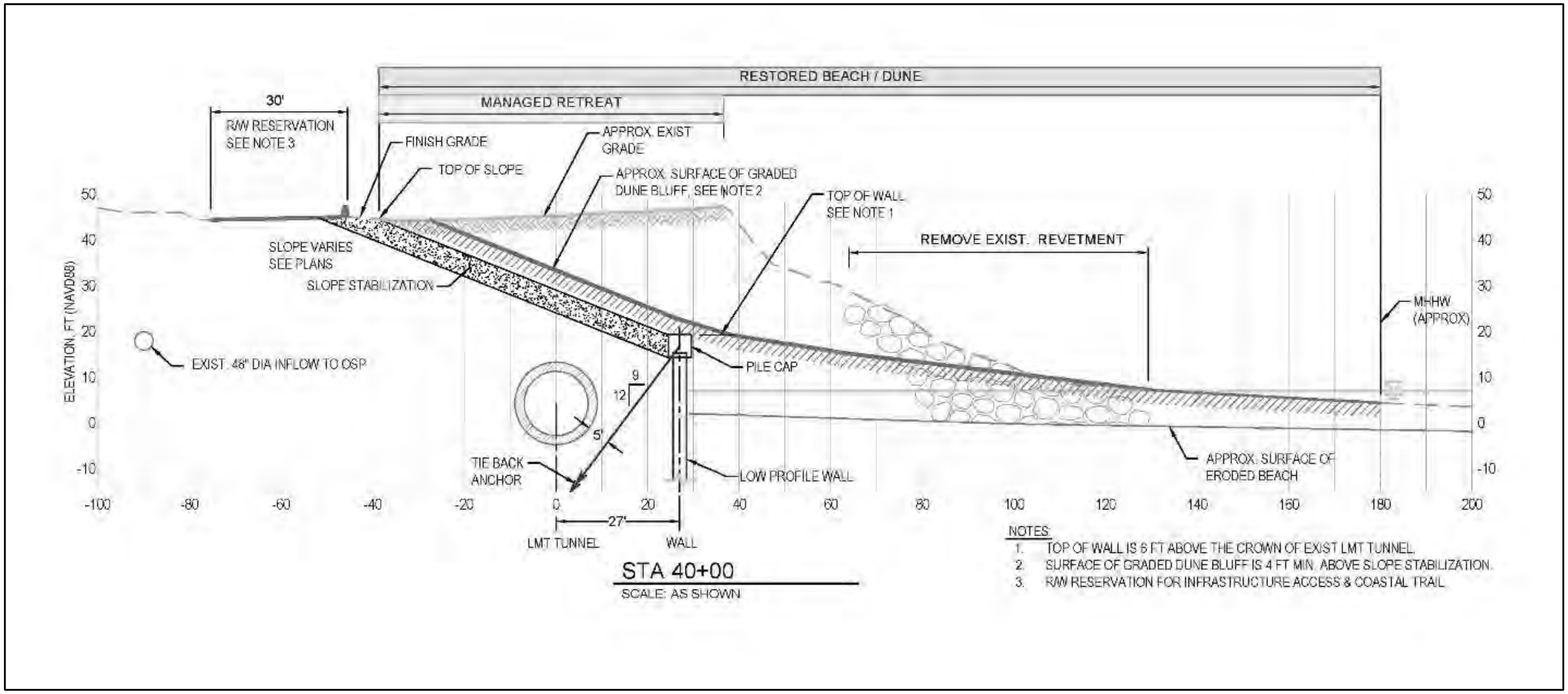

Figure 1-4: Conceptual Typical Section (Shown at STA 40+00)

Exhibit 6
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Page 22 of 107

2. Background Studies

This chapter summarizes some background studies used as the basis for the beach nourishment analysis and the sand management plan.

2.1. National Park Service Guidance

Because Ocean Beach is located within the jurisdiction of the Golden Gate National Recreation Area (GGNRA), the placement of sand on the beach is subject to the guidance outlined by the National Park Service (NPS). In 2012, the NPS published the *Beach Nourishment Guidance* in support of technical designs and best management practices in beach nourishment to avoid or minimize potential adverse impacts within its park system (Dallas et al., 2012). This guidance provides the framework for the sand management plan. Some highlights from the report are:

- Any sediment placement should be carried out in a way that ensures that park resources and values remain unimpaired.
- Any sediment placement should minimize human impacts on native plants, animals, populations, communities, and ecosystems, and the processes that sustain them.
- Soils or sediments imported from inside or outside park boundaries must be compatible with existing soils or sediments. Sediment used for beach nourishment should ideally be indistinguishable from native site sediment in terms of grain size (the most important), color, shape, mineralogy, compaction, organic content, and sorting. If the fill material does not exactly match the native sediment, a compatibility analysis is necessary.
- Nearshore placement is an alternative to direct beach placement that can be implemented when cost or environmental impacts discourage placement directly on the beach. Regional and local sediment transport patterns must be considered in the selection of nearshore placement sites in order for placed sand to benefit the littoral and beach sediment budget.
- The evaluation of offshore borrow sources should consider sediment compatibility and the effects of dredging on wave transformation and sediment transport in the borrow area. In addition, offshore borrow areas should be in water depths greater than the zone of active sediment transport to avoid any reduction in cross-shore or alongshore sediment transport.
- To reduce environmental impacts, common factors for design considerations include turbidity, placement geometry, volume, coverage, compaction, construction-related impacts, native species, and the timing of the project.

- Physical and biological monitoring should occur before, during, and after nourishment activities. If a borrow area is used in the project, pre- and post-project monitoring in the borrow area should be included.

2.2. Prior Beach Management Plan

As a condition of constructing and operating the Westside sewer projects, the City & County of San Francisco (CCSF) was required to submit a *Beach Management Plan* to the Coastal Commission. The plan was prepared by the San Francisco Clean Water Program and was approved unanimously by Coastal Commission in 1986.

Although the 1986 *Beach Management Plan* provides a solid framework and much useful information, it is outdated. One primary reason is since mid-1990, severe shoreline erosion focused south of Sloat Blvd. has damaged and continues to threaten the Westside sewer infrastructure and the recreational value of the Southern Ocean Beach (USGS, 2007). Because Ocean Beach is such a dynamic coastal environment and new scientific data has become available since the 1986 document, a new sand management plan is needed.

In addition, the proposed actions for this *Sand Management Plan* are based on a practical monitoring program and trigger levels. With these well-defined metrics, the new plan is expected to be feasible and implementable by the City.

2.3. USGS Coastal Processes Study

In 2004, the U.S. Geological Survey (USGS) initiated a two-year coastal processes monitoring program at Ocean Beach and provided scientific data to better understand and mitigate the long-term erosion problem at the southern portion (USGS, 2007). The wide range, state-of-the-art field data collection included beach topographic mapping, nearshore bathymetric profile surveying, image monitoring, offshore and surf-zone current and wave measurements, grain size mapping, development of numerical modeling, etc. The findings from the USGS study are used in this study as noted in the relevant sections.

The USGS continues to monitor beach profiles at Ocean Beach after the initial program and continues to provide valuable data on the short-term beach profile fluctuations and long-term shoreline change rates. Figure 2-1 presents the time series of beach profiles at the project and the surrounding areas (USGS, 2020). The location of each area is provided in Figure 3-4.

One important conclusion from the USGS 2007 study and other ongoing studies is summarized below. The shape of the ebb-tidal delta, especially the precise location of the longitudinal bar, corresponds with the location of increased beach slopes at Ocean Beach, as well as a shift from a decadal accretional to erosional trend. It is likely due to wave focusing on the crest of the bar, which in turn produces variations in littoral drift magnitude and direction through this area. If the current trend of ebb-tidal delta contraction continues, then it's possible that the erosional trend in the southern portion of Ocean Beach will migrate northward (USGS, 2007; Barnard et al., 2012).

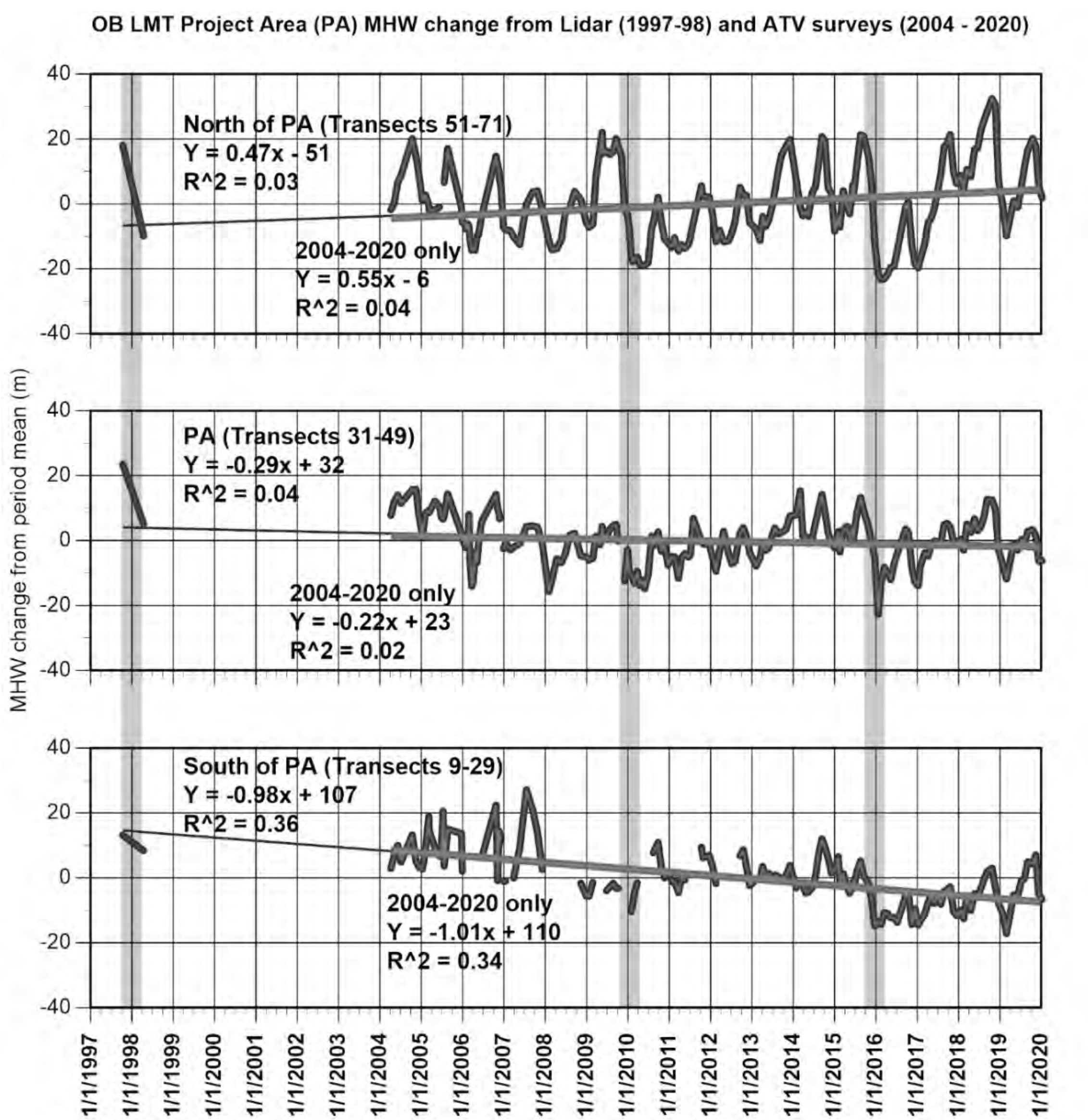


Figure 2-1: Time Series of MHW Shoreline Change near the Project Area (USGS, 2020). Provisional USGS Data Subject to Revision

2.4. M&N Beach Nourishment Study

In 2007, Moffatt & Nichol (M&N) assisted the CCSF and the U.S. Army Corps of Engineers (USACE) with formulating a Section 933 Beach Nourishment Study to address the ongoing erosion at Ocean Beach, under the authority of Section 933 of the Water Resources Development Act of 1986 (Public Law 99-662). The Section 933 program is intended to further the beneficial reuse of dredged material (beach quality sand) by providing for the USACE to participate in the additional costs of placing dredged material on a beach, as opposed to the least costly acceptable alternative. When all local cooperation requirements are met, the USACE may provide a 65 percent cost share of the additional costs.

2.5. Characteristics of Ocean Beach Sand

The ESA study concludes that sand at Ocean Beach is considered fine to medium size sand with a nominal diameter of about 0.3 mm. Patches of coarser sand are located near the water line, whereas finer sand is located along the landward parts of wider beaches and in dunes (ESA, 2016a).

Per the Section 933 report, an overview of the relationship between median grain size and beach face slope is given in Figure 2-2, as well as the typical grain size and associated beach face slope found in Ocean Beach.

- D_{50} = 0.5 mm to 0.7 mm: corresponding to the coarsest sand in the vicinity of the Main Ship Channel, generally at depths below the maintenance dredging depth of -55 feet MLLW.
- D_{50} = 0.25 mm to 0.35 mm: corresponding to the majority of the sand on the beach.
- D_{50} = 0.15 mm to 0.21 mm: corresponding to the majority of the sediment in the regularly dredged areas of the Main Ship Channel.

Consistently, the USGS 2007 study concluded that the median grain size in the swash along Ocean Beach averages 0.28 mm, with no significant alongshore variation except for localized coarse lags where median grain size can exceed 0.5 mm (USGS, 2007). Sediment placed in the nearshore disposal site has a median size of 0.18 mm, broadly consistent with nearshore bar and dune sediment found at Ocean Beach. Figure 2-3 illustrates the grain size distribution at the mouth of San Francisco Bay.

A detailed discussion of potential sediment sources is provided in Section ・.

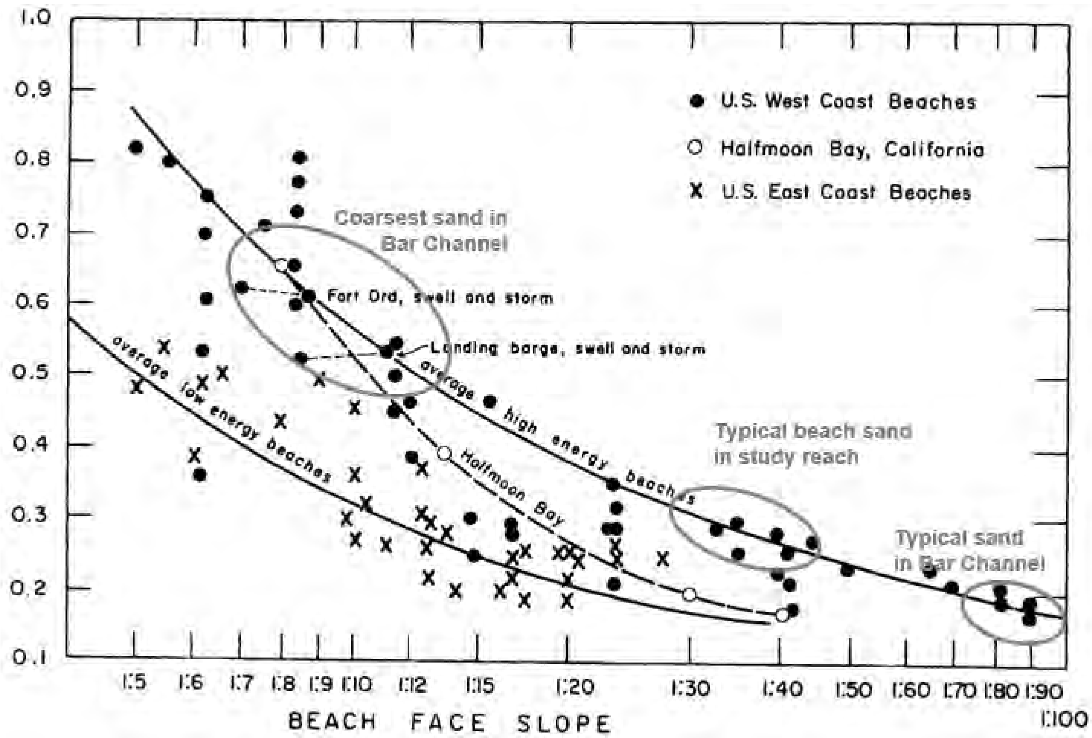


Figure 2-2: Empirical Relationship between Median Grain Size and Beach Slope (Revised from Komar, 1998)

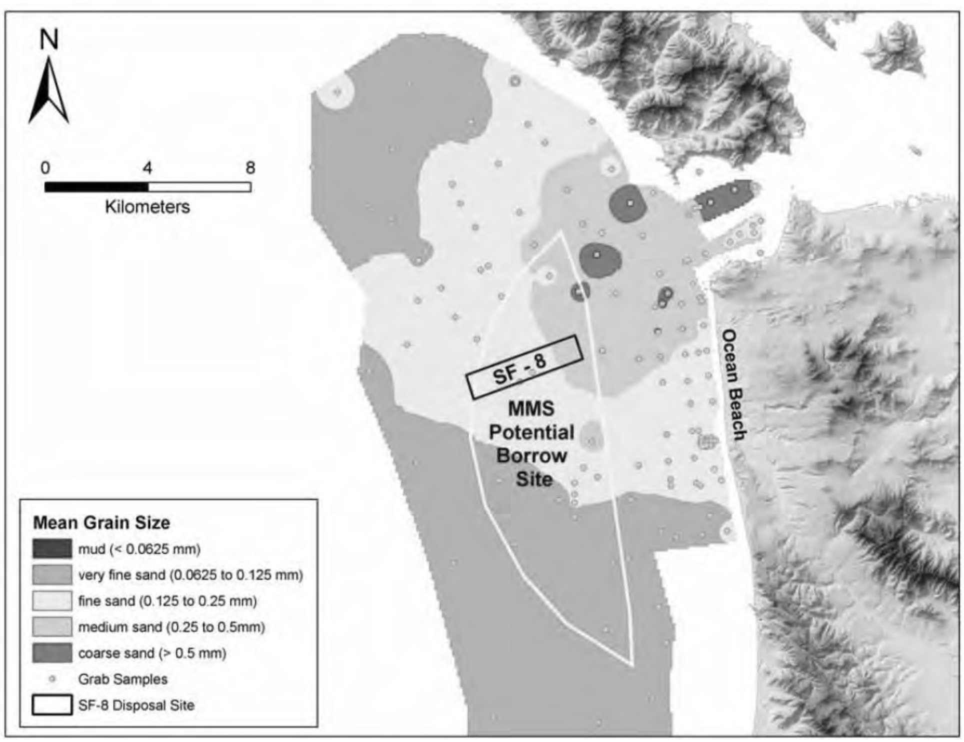


Figure 2-3: Distribution of Sediment Grain Size at the Mouth of San Francisco Bay (USGS, 2007)

2.6. Recent Sand Backpass Events

Short-term erosion protection measures were carried out at the South Ocean Beach Erosion Hot-Spot since 2012 (M&N, 2014, 2015; ESA, 2016b, 2017, 2018, 2019). These measures include sand backpass events, windblown sand mitigation measures, bluff failure response, sandbags integrity, etc. Table 2-1 summarizes the approximate quantity of sand placement and Figure 2-4 shows the location of placement. Figure 2-5 and Figure 2-6 illustrate two beach profiles located at Reach 2 between November 2016 and April 2019 and include profiles immediately after the backpass events.

Table 2-1: Summary of Sand Backpass Events since Year 2012

Date	Placement Amount (CY)	Placement Location
Aug/Sep 2012	73,300 ~ 17,000 (est.) ~ 56,000 (est.)	 Reach 2 North Lot & Reach 3
Nov/Dec 2014	25,000	Reach 2
Feb/Mar 2016	25,000	Reach 2
Nov/Dec 2016	70,000 ~ 25,000 (est.) ~ 45,000 (est.)	 Reach 2 North Lot & Reach 3
Apr 2018	65,000 ~ 25,000 ~ 40,000	 Reach 2 North Lot & Reach 3
Nov/Dec 2019	65,000 ~ 25,000 ~ 40,000	 Reach 2 North Lot & Reach 3

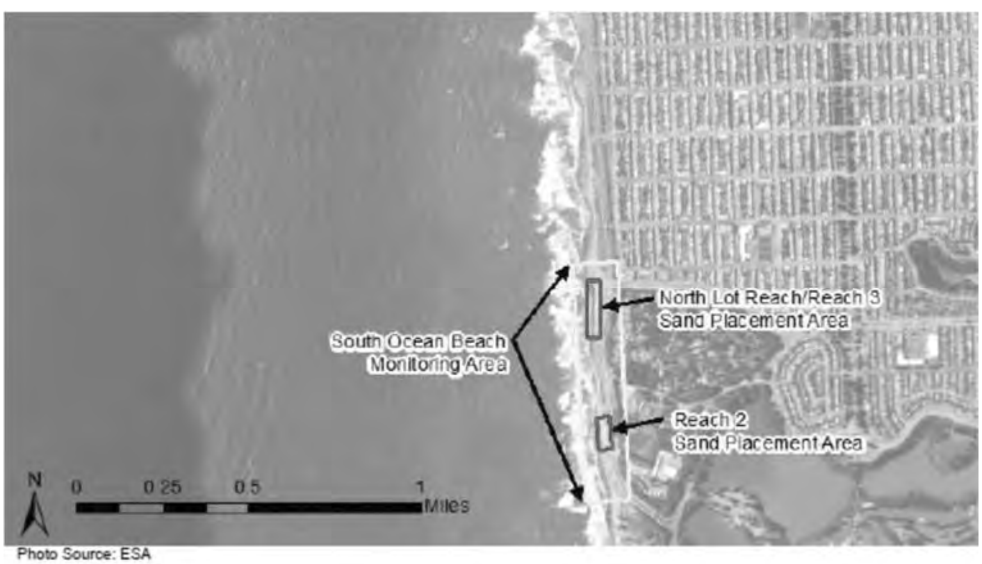


Figure 2-4: Map Showing Sand Backpass Placement Area (ESA, 2017)

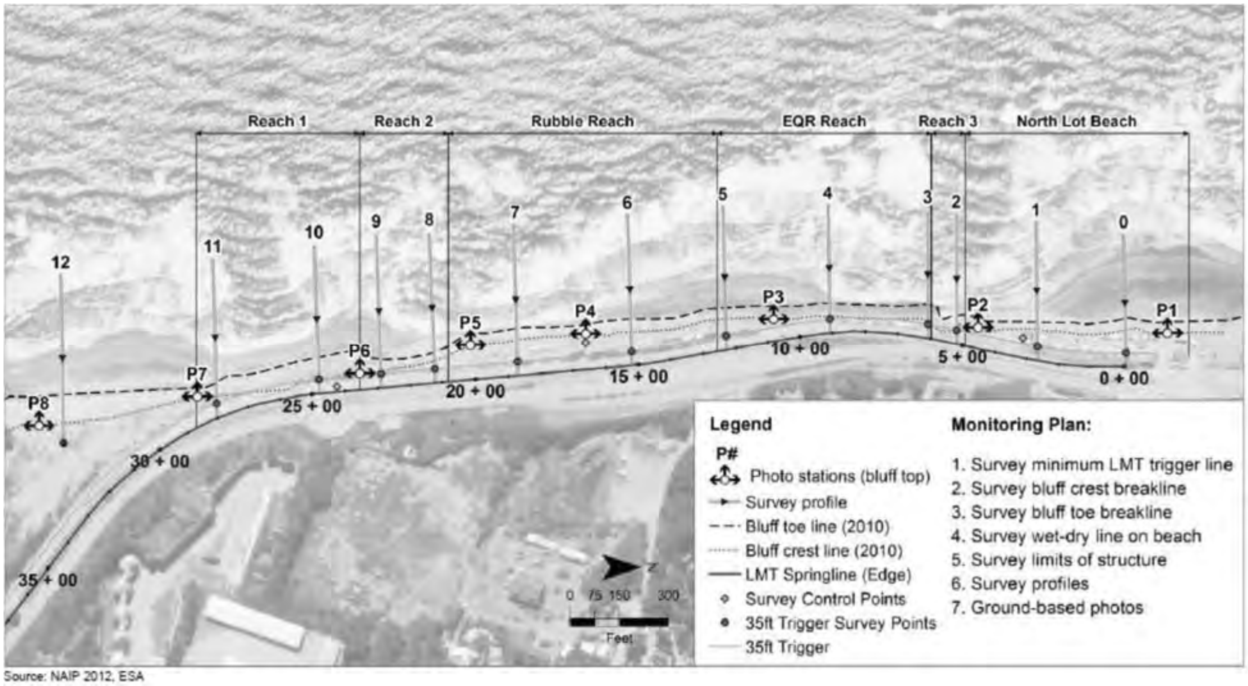


Figure 2-5: Monitoring Profile Location (ESA, 2017)

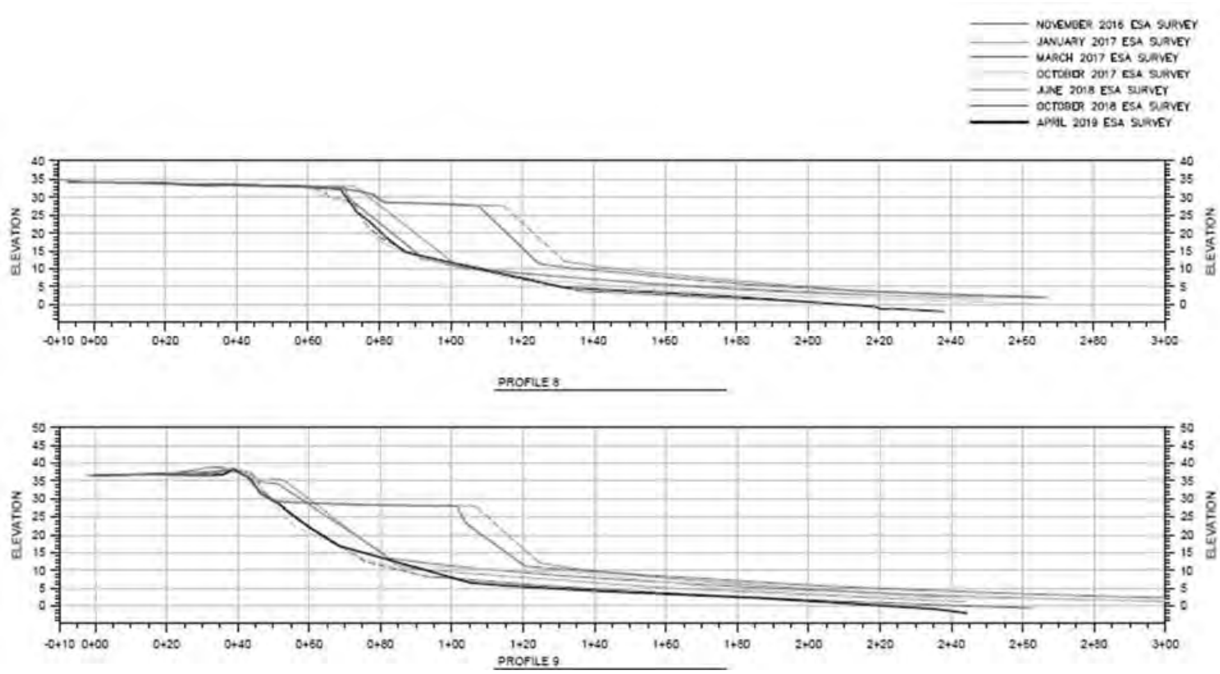


Figure 2-6: Variations of Beach Profile (Elevation in NAVD88) at Profiles 8 & 9 (ESA, 2019)

2.7. Current Ocean Beach Climate Change Adaptation Project

The Conceptual Engineering Report (CER) summarizes existing conditions at South Ocean Beach in terms of the beach and bluff topography, geology and stratigraphy, and natural hazards including erosion and coastal related hazards, and addresses the main engineering disciplines involved in the development of the conceptual design, which include geotechnical, civil, structural, and coastal engineering. A summary of guidance with respect to constructability, operations and maintenance, and right-of-way is also provided along with a status on the project environmental review. The planned timeline for project execution and construction is provided in a project schedule and an estimate of project costs for construction, a list of project specifications, and concept-level drawings are also provided (M&N and AGS, 2019).

The Project elements considered in the CER include:

1) Installing a low-profile secant pile wall seaward of the LMT.
2) Re-contouring the bluff at South Ocean Beach and providing sand nourishment for the beach as-needed for increased recreational access and ecological value.
3) Removing the Great Highway between Sloat and Skyline Boulevards and completing intersection improvements at Sloat and the Great Highway and Skyline and the Great Highway to accommodate changed traffic flows.
4) Relocating the existing parking lot and restroom, currently located along the Great Highway, south of Sloat Boulevard.
5) Creating a multiuse recreational trail and an access road for the SFPUC facilities in place of the existing Great Highway.
6) Providing access points to the beach for the public.
7) Modifying the entrance to the zoo to accommodate changed traffic flows.
8) Modifying MTA bus turn-around at Sloat and Great Highway to account for changed traffic flows.
9) Providing landscaping and sand management strategies for the re-contoured bluff and the beach.
10) Removing the existing shoreline revetments and rubble.

3. Supplemental Beach Nourishment Analysis

A beach nourishment project represents a perturbation to natural environment, which under wave action, will spread out along the shoreline by longshore transport and move offshore to create an equilibrium profile by cross-shore transport (Dean, 2002). Figure 3-1 illustrates these two important processes. Because the cross-shore profile evolution occurs on a shorter time scale (e.g. days to weeks) than the longshore planform evolution (e.g. several weeks to months), it is customary to consider them separately in beach nourishment design.

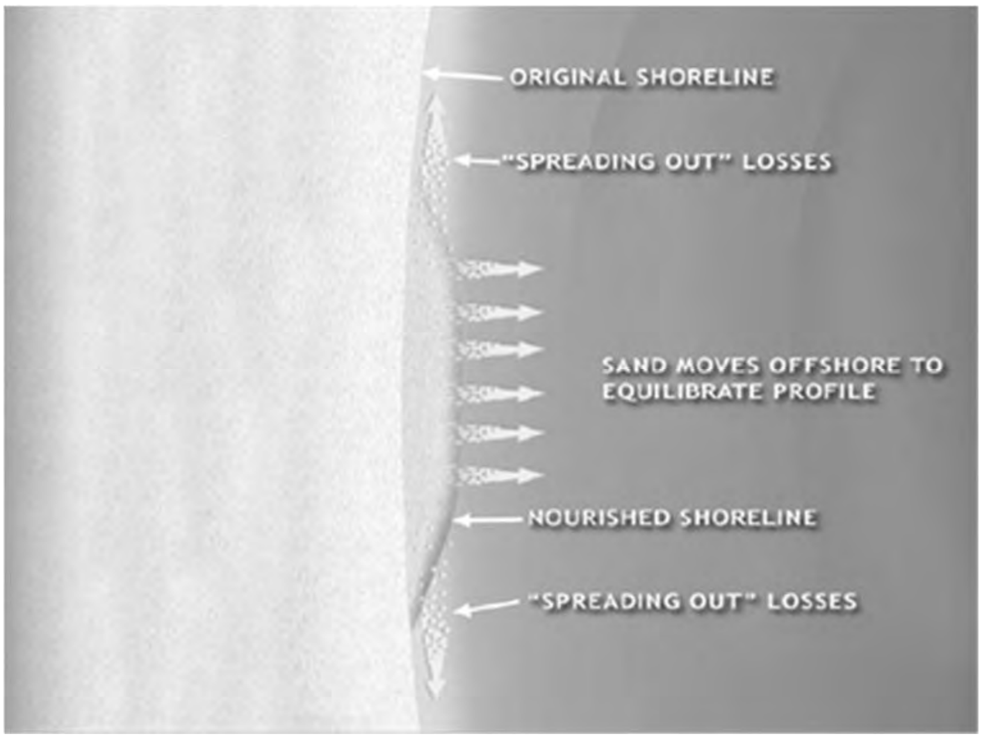


Figure 3-1: Planform Evolution Process

3.1. Study Methods

Vitousek et al. generalize two methods for predicting shoreline evolution. The computationally onerous, physics-based numerical models can be used for coastal hazards mapping and shoreline change due to extreme events, but on large-scale (e.g. 100 m to 100 km length scale) or long-term (e.g. years to decades) they do not necessarily provide improved results over the simplified, process-based models. On the contrary, the process-based models are often applied to predict chronic shoreline change because they are computationally efficient and have been proven (in most cases) reliable on inter-annual timescale (Vitousek et al., 2017). Although the process-based models typically account for a single dominant physical process, they can be improved if additional processes are resolved.

In this study two process-based models, one for longshore transport and one for cross-shore transport, are resolved separately and are coupled successively over a defined time step. Details of each model are provided below.

3.1.1. Longshore Transport

The longshore transport-induced planform evolution is estimated using the process-based Pelnard-Considère model (Dean, 2002). This equation describes the planform evolution in the classical linear diffusion equation. Because of its linearity, solutions can be superposed. The basic equation is:

$$\frac{\partial y}{\partial t} = G\frac{\partial^2 y}{\partial x^2} \quad \text{(Eq. 1)}$$

where *y(x,t)* is the shoreline position at a distance *x* alongshore and time t after placement, and *G* is the longshore diffusivity. Figure 3-2 provides a sketch of basic geometric parameters, including nourished length l; beach width w; native beach slope S_0; nourished beach slope S, berm height B, depth to the toe of nourishment h_t; and depth of closure h_*.

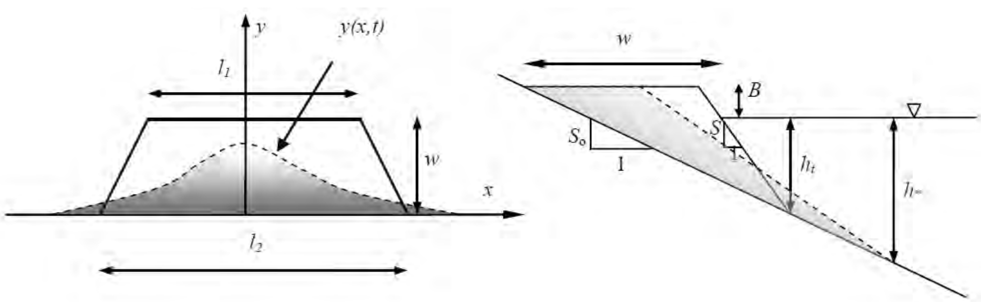


Figure 3-2: Sketch of Nourished Planform and Profile Geometric Parameters (Work et al., 2010)

Assuming an initial placement is rectangular with beach width Y, and length L, on an infinitely long shoreline, the solution yields:

$$y(x,t) = \frac{Y}{2}\left\{erf\left[\frac{L}{4\sqrt{Gt}}\left(\frac{2x}{L}+1\right)\right] - erf\left[\frac{L}{4\sqrt{Gt}}\left(\frac{2x}{L}-1\right)\right]\right\} \quad \text{(Eq. 2)}$$

$$M(t) = \frac{2\sqrt{Gt}}{L\sqrt{\pi}}\left(e^{-\left(\frac{L}{2\sqrt{Gt}}\right)^2} - 1\right) + \mathrm{erf}\left(\frac{L}{2\sqrt{Gt}}\right) \quad \text{(Eq. 3)}$$

where M(t) is the proportion of sand remaining in the placed location after time t, and “erf” is the error function. In this study, the alongshore location x was assumed as 0, the center of Project area.

3.1.2. Cross-Shore Transport

The cross-shore transport-induced shore response is estimated using the process-based Yates et al. equilibrium model, hereafter referred as Yates' model. Following Wright et al. (1985), the Yates' model relates the rate of beach change toward equilibrium to the current wave conditions and the disequilibrium of the wave conditions with the present beach configuration and calibrates using the observations from Ocean Beach (Yates et al., 2011). The basic equations are:

$$\frac{dS}{dt} = C^{\pm}E^{\frac{1}{2}}\Delta E \quad \text{(Eq. 4)}$$

$$\Delta E(S) = E - E_{eq}(S) = E - (aS + b) \quad \text{(Eq. 5)}$$

where E is the hourly averaged wave energy, ΔE is the wave energy disequilibrium, S is the present shoreline position, and $C^{\pm}$, a, and b are model free parameters. Figure 3-3 provides three of the model free parameters at Ocean Beach. Although the actual "b" parameter was not provided in Yates et al. (2011), it was calculated by relating the shoreline changes to the temporal mean shoreline position in USGS surveys. With these model free parameters, a time series of shoreline changes was estimated using the Yates' model.

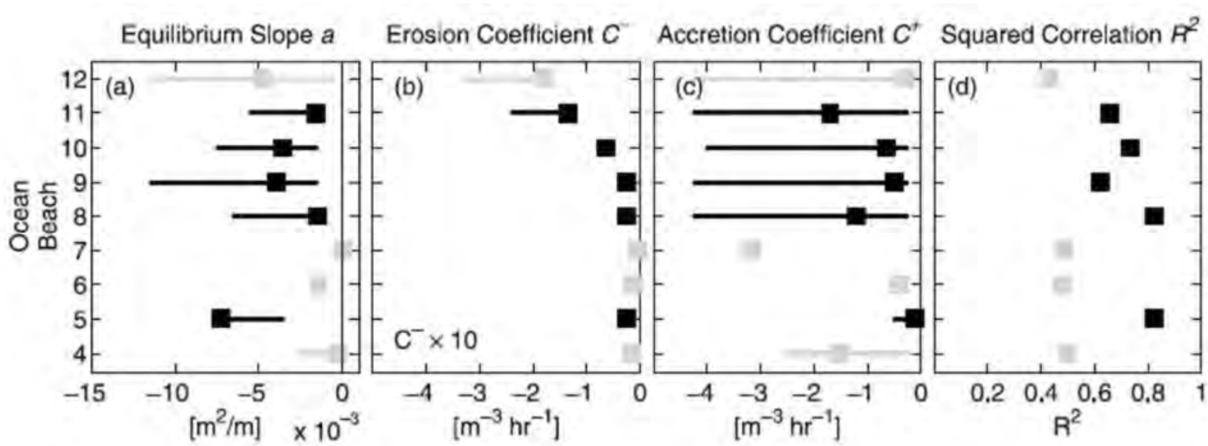


Figure 3-3: Best-Fit Model Free Parameters at Ocean Beach (Excerpted from Yates et al., 2011)

3.1.3. Risk-Based Probabilistic Approach

Because this study intends to develop a sand management plan and guide the decision-making process for the stakeholders, it is important to forecast the environmental conditions in the future. These environmental elements include incoming wave energy (see Section 3.2.3), Oceanic Niño conditions (see Section 3.2.4), and sea level rise projections (see Section 3.2.5), and have one thing in common, which is their highly unpredictable nature. As a result, they typically cannot be described with a singular value, but rather a function based on probability of occurrence or level of risk. In addition, there exists an even wider range of possible outcomes when two or more probabilistic functions are combined.

This study adopts the risk-based probabilistic approach, as opposed to the conventional, deterministic approach. The developed model is computationally efficient due to reduced complexity in transport equations (e.g. longshore and cross-shore transport process-based models) and a simplified representation of the coastal morphology, which makes it suitable for probabilistic approach. With the probabilistic approach, a unique initial state is applied and the above-mentioned environmental functions are combined randomly in each run realization. If sufficient number of runs are performed, a statistically-sound outcome can be developed. This process, which involves conducting many runs of random initial state and process functions, and analyzing outcomes statistically, is also known as the Monte Carlo simulation.

3.2. Model Inputs

This section summarizes the model inputs used in the beach nourishment analysis.

3.2.1. Longshore Diffusivity

In the Pelnard-Considère equation, the longshore diffusivity is arguably the most significant calibration factor and should be derived from field measurements. However, it is known that representative prototype or field data are difficult to obtain (Schoonees and Theron, 1995). Alternatively, numerical models on littoral transport (both longshore and cross-shore) may be used.

The USACE used the Coastal Modeling System (CMS) numerical model to assess the performance of a hypothetical, 300,000 cubic yards (CY) of beach fill placed along a 1-km length of shoreline at the Erosion Hot-Spot (USACE, 2012). The total volume of beach fill material removed from the placed location is around 80,000 CY for a case of “normal year” (e.g. 26.7% beach fill removed after a year). Using Equation 3 in Section 3.1.1, the longshore diffusivity is approximately 0.02 square feet per second. The USACE study also assessed a case of “weak El Niño” and the total volume of beach fill removed is around 96,000 CY (e.g. 32% beach fill removed after a year). The corresponding longshore diffusivity is approximately 0.028 square feet per second. This study adopts the longshore diffusivity for the normal year, and conducts a sensitivity test with the weak El Niño condition.

It is noted that the beach fill in the USACE's numerical study is composed of fine sand of 0.2 mm, which is broadly consistent with the nearshore bar and dune sediment found at Ocean Beach (USGS, 2007). If a larger, beach-compatible sand size is placed (e.g. 0.28 mm), the longshore diffusivity can be smaller.

3.2.2. Background Erosion

Beach nourishment is usually carried out in areas characterized by historical erosion. Unless the nourishment project includes effective measures to alter the cause(s) of such background erosion, it is typically assumed that the background erosion remains (Dean, 2002).

USGS conducts beach profile surveys at Ocean Beach regularly and provides a 16-year duration (e.g. 2004 through 2020) of shoreline changes by transect (USGS, 2020). Figure 3-4 shows an average erosion rate of 0.7 m/year (e.g. 2.3 ft/year) and up to 1.3 m/year (4.3 ft/year) at the Project area and is used for the background erosion. The largest erosion rate at the south end agrees well with the bluff erosion rate in the same area estimated at 4.7 ft/year, based on USGS Dr. Warrick's unpublished data.

Simultaneously, the Northern Ocean Beach shows an average accumulation rate of 4 to 5 m/year (e.g. 13 to 16 ft/year).

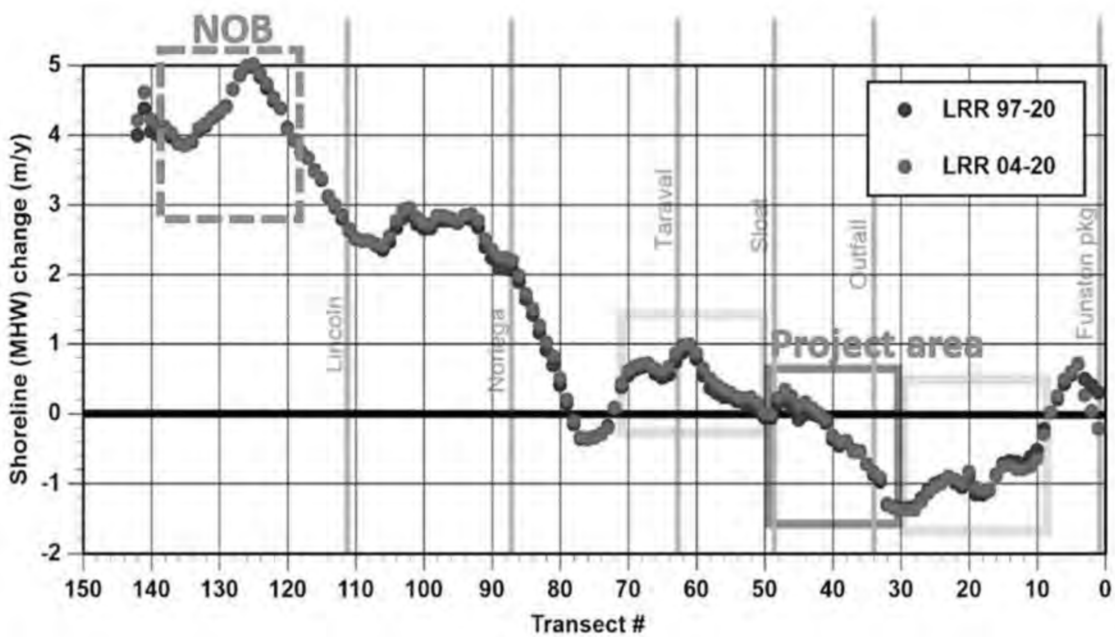


Figure 3-4: MHW Shoreline Change Rates by Transect (USGS, 2020). Provisional USGS Data Subject to Revision

3.2.3. Incoming Wave Energy

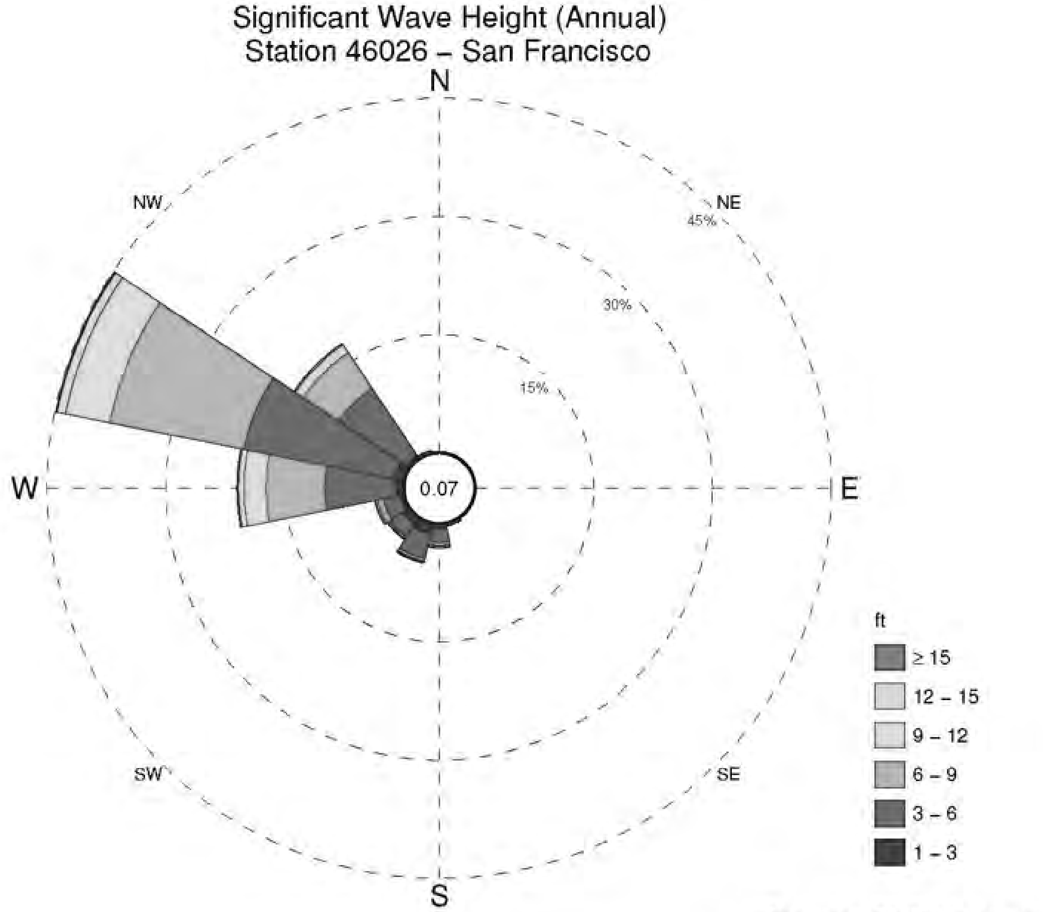
Waves are possibly the most dominant force to reshape the short-term shoreline configuration. To drive the Yates' model for cross-shore shore response, incoming waves and resultant wave energy are required.

National Oceanic and Atmospheric Administration (NOAA) operates an offshore buoy (e.g. 46026 San Francisco) about 15 nautical miles west of Ocean Beach. Wave height and period have been measured since the 1980s, while wave direction and spectral data have been measured since 2007. Figure 3-5 shows the annual wave rose at the buoy. Predominant waves are from the west to northwest direction, with approximately 83.5% of the time. However, the winter season may experience some larger waves (exceeding 15 feet) from the south quadrant. Additionally, the Scripps Institution of Oceanography operates a nearshore buoy (e.g. 46237 SF Bar) about 6 nautical miles west of Ocean Beach. All wave parameters are available since 2008.

Given there is no publicly-available nearshore wave data, the Danish Hydraulic Institute (DHI) Spectral Wave model (e.g. DHI MIKE-21 SW) was developed to transform offshore waves to the nearshore location. The SW model resolves wave growth due to wind power, shoaling and refraction due to bottom variations, diffraction and reflection near structures, wave breaking in the surf zone, wave dissipation, and some wave-current interactions. Bathymetry was obtained from NOAA's 1/3 arc-second Coastal Digital Elevation Model for San Francisco Bay and was originally developed from multi-agency's hydrographic surveys (NOAA, 2011). The bathymetry is referenced to North American Vertical Datum of 1988 (NAVD88) datum. Figure 3-6 illustrates the modeling domain and bathymetry.

Using wave measurements at NOAA's 46026 buoy as boundary conditions, the simulated significant wave heights and peak wave periods were compared with the measurements at Scripps' 46237 buoy during December 2015. This winter is characterized as "very strong El Niño". Figure 3-6 indicates that the SW model performs well in comparison with the field measurements.

In this study, a long-term time series (e.g. 1956-2019) of offshore wave dataset was compiled. Using the SW model, offshore waves are transformed to the nearshore location at the center of Project area. Figure 3-7 presents wave transformation coefficients for three approaching directions.



Direction FROM is shown
Center value indicates calms below 1 ft
Total observations 103592, calms 77
About 6.04% of observations missing

Percentage of Occurrence

Significant Wave Height, ft	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total								0.41	3.10	5.21	3.38	3.78	21.07	44.85	17.57	0.39	99.93
≥ 15													0.21	0.18			0.49
12 – 15									0.13				0.70	1.06	0.21		2.25
9 – 12									0.19	0.17		0.25	2.79	5.70	1.19		10.40
6 – 9									0.37	0.35	0.28	0.75	7.41	17.27	5.45		31.98
3 – 6								0.26	1.66	3.20	2.06	2.21	9.04	19.38	10.19	0.30	45.36
1 – 3									0.71	1.40	0.93	0.47	0.94	1.27	0.52		6.43

Figure 3-5: Annual Wave Rose at Buoy 46026

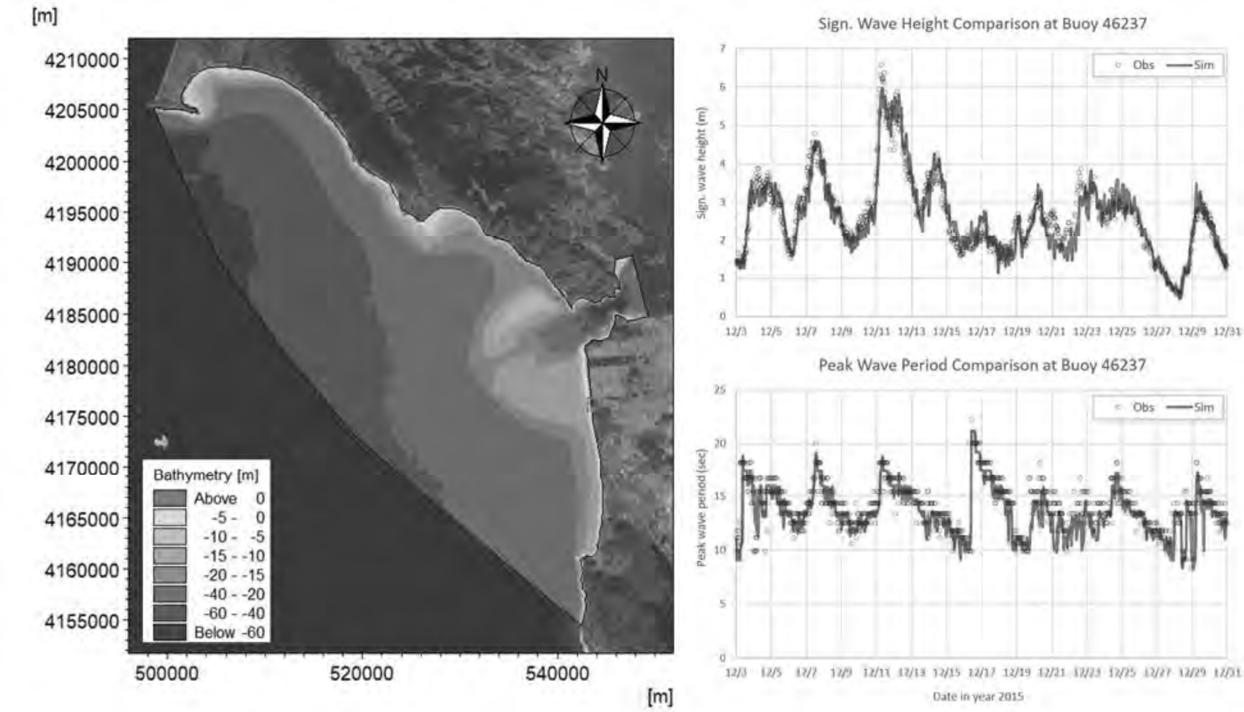


Figure 3-6: SW Wave Model Bathymetry and Performance

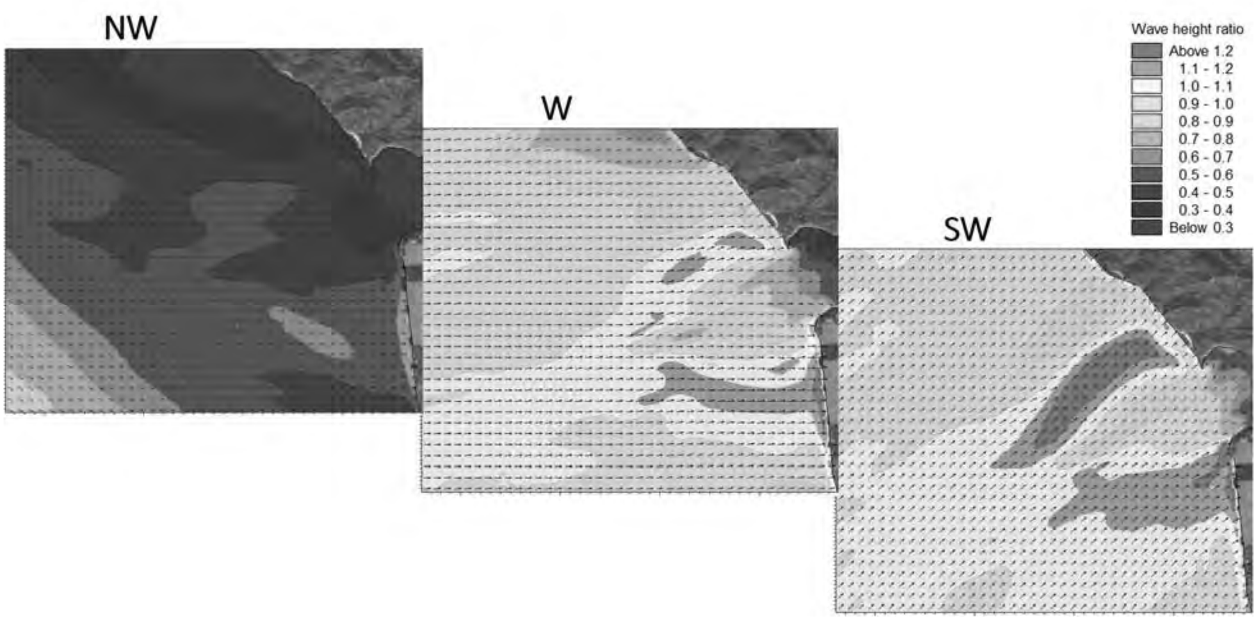


Figure 3-7: Wave Transformations from Northwest, West, and Southwest Direction (1.5-m Offshore Waves)

3.2.4. Oceanic Niño Conditions

Below is primarily excerpted from the CER (M&N and AGS, 2019).

The El Niño Southern Oscillation (ENSO) reflects irregular variations of the sea surface temperature in the Eastern Pacific. The warming phase is termed El Niño while the cooling phase is named La Niña.

Since 1950, the oceanographic community has used the Oceanic Niño Index (ONI) to characterize ENSO ocean temperatures (Figure 3-8). When warming of the ocean exceeds +0.5˚C, the El Niño conditions prevail. If the ocean temperature cools below -0.5˚C, the La Niña conditions are present. Within the range of +/-0.5˚C, conditions are termed "ENSO-neutral". The ENSO cycle affects temperatures and rainfall worldwide. Because the El Niño conditions are associated with greater storm activity in the Eastern Pacific, greater erosion is expected on Ocean Beach during El Niño.

El Niño and La Niña cycles typically last 9 to 12 months. They often commence in June or August and reach their peak during December through April, and subsequently, decay over May through July of the following year. Their periodicity is irregular, occurring every 3 to 5 years on average.

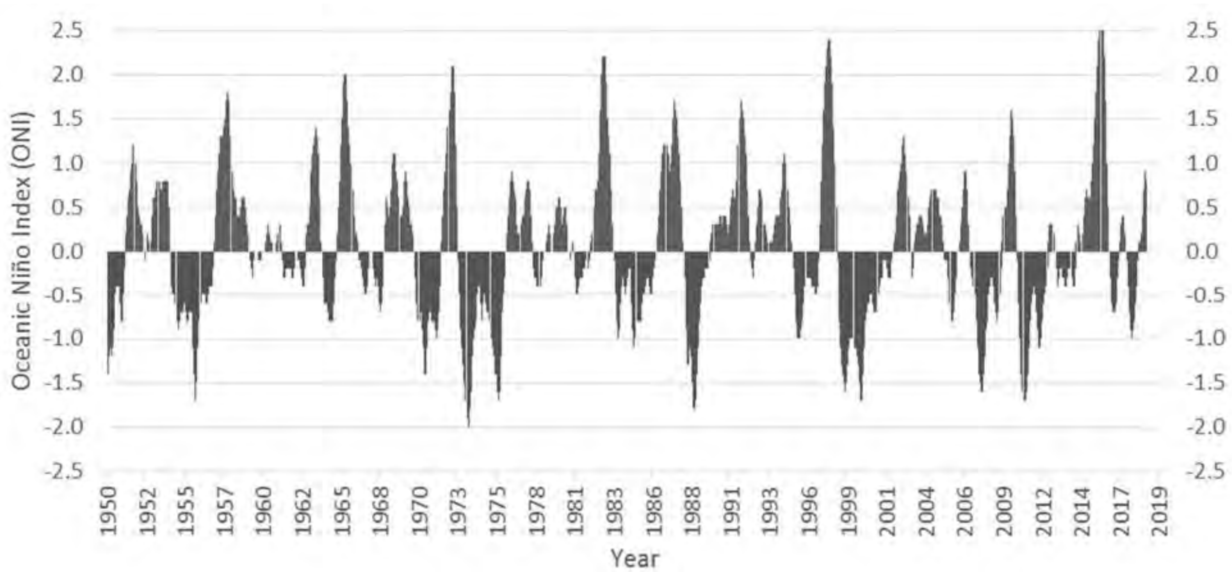


Figure 3-8: ONI Index Since 1950

Table 3-1 lists the ENSO characterization by year, except the years identified as "ENSO-neutral". Therefore, the compiled offshore wave dataset (see Section 3.2.3) can be paired with the corresponding ENSO characterization. Section 3.3 describes the application of this pairing in detail.

Since 1950, three "Very Strong El Niño (VSE)" years were identified, equivalent to a 4.3% chance of occurrence during a 69-year period of record. Similarly, Figure 3-9 presents the frequency of occurrence for each ENSO characterization.

Table 3-1: List of ENSO Characterization by Year

El Niño				La Niña		
Very Strong "VSE"	**Strong "SE"**	**Moderate "ME"**	**Weak "WE"**	**Weak "WL"**	**Moderate "ML"**	**Strong "SL"**
1982-83	1957-58	1951-52	1952-53	1954-55	1955-56	1973-74
1997-98	1965-66	1963-64	1953-54	1964-65	1970-71	1975-76
2015-16	1972-73	1968-69	1958-59	1971-72	1995-96	1988-89
	1987-88	1986-87	1969-70	1974-75	2011-12	1999-00
	1991-92	1994-95	1976-77	1983-84		2007-08
		2002-03	1977-78	1984-85		2010-11
		2009-10	1979-80	2000-01		
			2004-05	2005-06		
			2006-07	2008-09		
			2014-15	2016-17		
			2018-19	2017-18		

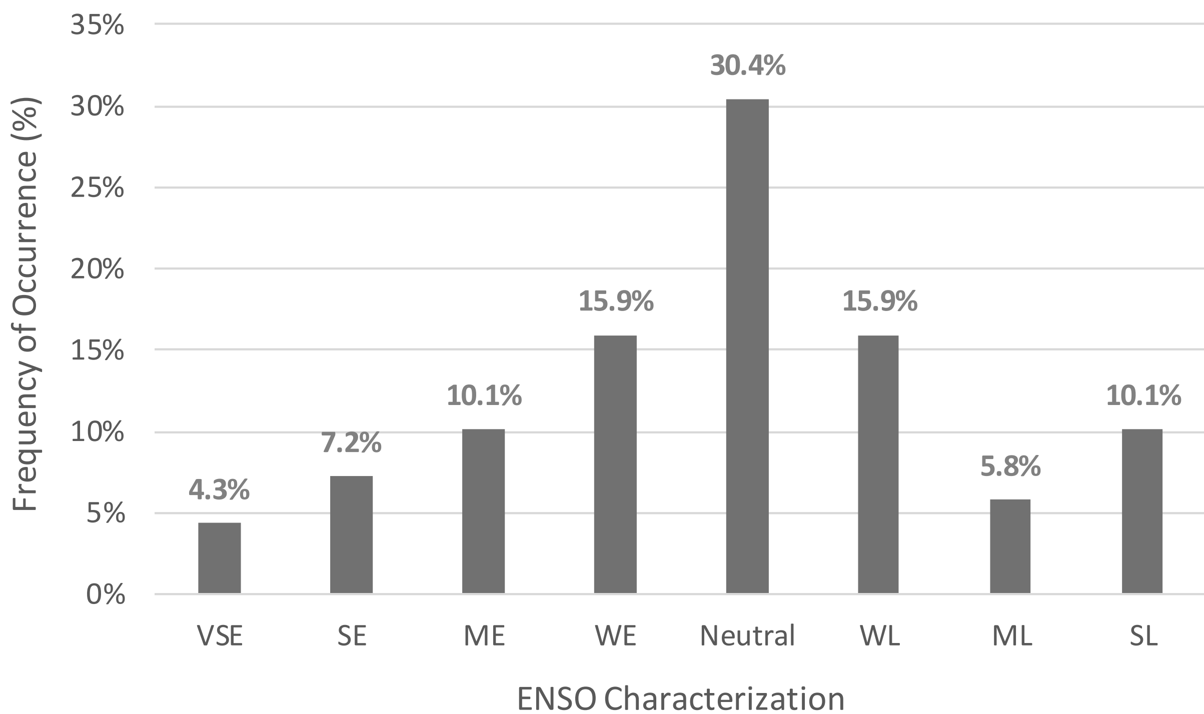


Figure 3-9: Frequency of Occurrence by ENSO Characterization

3.2.5. Sea-Level Rise Projections

Current guidance on sea-level rise (SLR) projections for California recommends using a risk-based approach. The most recent guidance is provided in OPC (2018) and has been addressed in the CER (M&N and AGS, 2019).

Table 3-2 summarizes SLR projections for San Francisco per OPC (2018). Each column represents a defined probability of risk associated with SLR, and each row separates the time horizons by low/high greenhouse gas emissions scenarios. Assuming a high emissions scenario (a.k.a. RCP8.5), Figure 3-10 converts the table to year 2100 in a graphical form.

Table 3-2: Sea-Level Rise Projections for San Francisco, California (OPC, 2018)

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds…	66% probability sea-level rise is between…		5% probability sea-level rise meets or exceeds…	0.5% probability sea-level rise meets or exceeds…	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.4	0.3 -	0.5	0.6	0.8	1.0
	2040	0.6	0.5 -	0.8	1.0	1.3	1.8
	2050	0.9	0.6 -	1.1	1.4	1.9	2.7
Low emissions	2060	1.0	0.6 -	1.3	1.6	2.4	
High emissions	2060	1.1	0.8 -	1.5	1.8	2.6	3.9
Low emissions	2070	1.1	0.8 -	1.5	1.9	3.1	
High emissions	2070	1.4	1.0 -	1.9	2.4	3.5	5.2
Low emissions	2080	1.3	0.9 -	1.8	2.3	3.9	
High emissions	2080	1.7	1.2 -	2.4	3.0	4.5	6.6
Low emissions	2090	1.4	1.0 -	2.1	2.8	4.7	
High emissions	2090	2.1	1.4 -	2.9	3.6	5.6	8.3
Low emissions	2100	1.6	1.0 -	2.4	3.2	5.7	
High emissions	2100	2.5	1.6 -	3.4	4.4	6.9	10.2
Low emissions	2110*	1.7	1.2 -	2.5	3.4	6.3	
High emissions	2110*	2.6	1.9 -	3.5	4.5	7.3	11.9
Low emissions	2120	1.9	1.2 -	2.8	3.9	7.4	
High emissions	2120	3	2.2 -	4.1	5.2	8.6	14.2
Low emissions	2130	2.1	1.3 -	3.1	4.4	8.5	
High emissions	2130	3.3	2.4 -	4.6	6.0	10.0	16.6
Low emissions	2140	2.2	1.3 -	3.4	4.9	9.7	
High emissions	2140	3.7	2.6 -	5.2	6.8	11.4	19.1
Low emissions	2150	2.4	1.3 -	3.8	5.5	11.0	
High emissions	2150	4.1	2.8 -	5.8	5.7	13.0	21.9

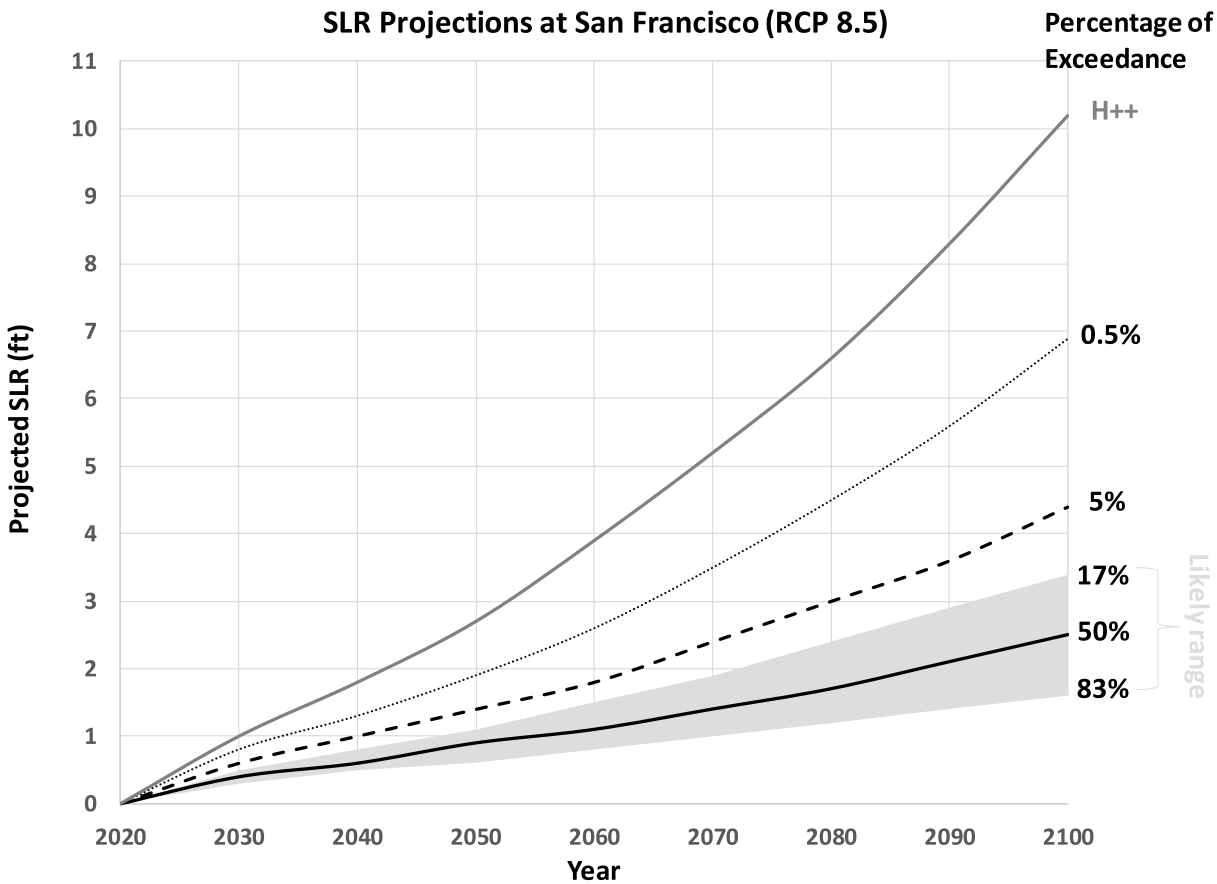


Figure 3-10: SLR Projections at San Francisco for RCP8.5

There are several different ways SLR can affect shorelines. Along shorelines subject to wave action, the typical shoreline response to SLR is to recede inland. This happens as the shoreline profile rebalances itself around the new higher mean sea level. This effect was first described by Per Bruun in 1962 and is known as the *Bruun Rule* (see Figure 3-11). The *Bruun Rule* assumes that the upland material is eroded as the shore profile moves landward, and that the volume of eroded material is deposited offshore, resulting in a rise of the nearshore bottom. In a simple mathematical form, the amount of shoreline recession “s” equals to the ratio of the amount of SLR “a” and the average slope of the active beach profile “$\frac{h}{l}$”.

$$s = \frac{a \times l}{h} \quad \text{(Eq. 6)}$$

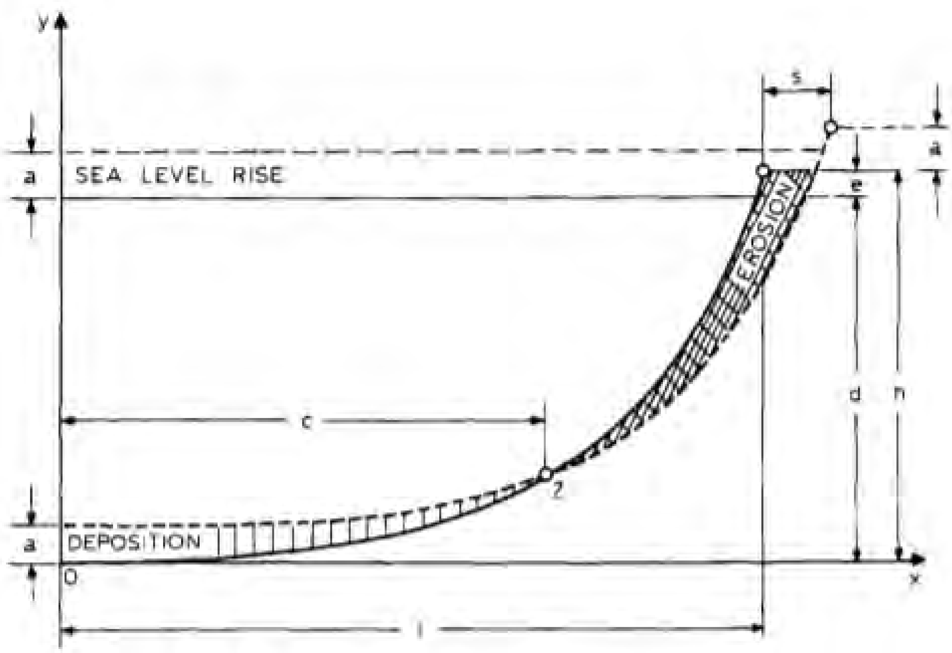


Figure 3-11: Sketch of the *Bruun Rule* (Bruun, 1983)

3.2.6. Closure Depth, Berm Height and Beach Slope

The seaward limit of effective seasonal profile fluctuations is a useful coastal engineering concept and is referred to as the closure depth (Dean, 2002; USACE, 2002). Based on USGS's coastal data collection, the closure depth ranges from 10 meters (e.g. 30 feet) in the central and southern portions of Ocean Beach to a depth of 15 meters or greater at the northern end (USGS, 2007). In addition, the beach berm is about +12 feet NAVD88 per the monitoring profiles shown in Figure 2-6. Therefore, the active sand movement in the vertical is approximately between -30 feet and +12 feet NAVD88.

The equilibrium beach slope is approximately 20 Horizontal:1 Vertical (20H:1V). This nominal beach slope was selected based on a recent cross-beach survey, conducted by Dr. Daniel Hoover of the USGS in February 2020. The beach slope surveyed varies between 19H:1V and 34H:1V. In comparison, Figure 2-6 shows the equilibrium beach slope is estimated between 15H:1V to 25H:1V.

3.2.7. Beach Width Advancement

If beach nourishment will be constructed from the land-side, the shoreline advancement (depicted as "w" in Figure 3-2) after placement is found to correlate well with the initial beach width. For the same nourished volume and project extent, Figure 3-12 gives such correlation for the typical conditions at South Ocean Beach.

If beach nourishment will be placed from the water-side (e.g. dredged material placement), the shoreline advancement is calculated per Dean (2002):

$$w = \frac{Volume}{L(B+h_*)} \qquad \text{(Eq. 7)}$$

where the symbols are as used in Section 3.1.1.

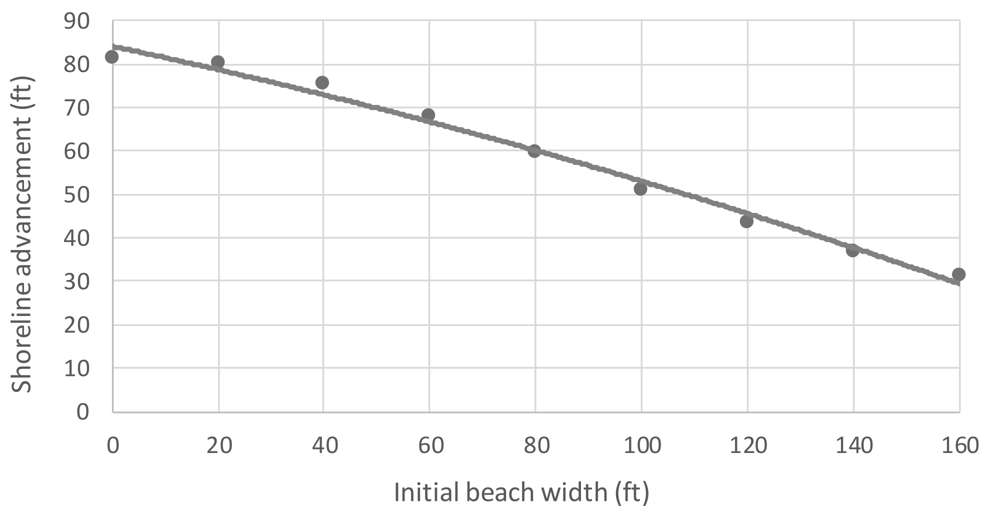


Figure 3-12: Shoreline Advancement vs. Initial Beach Width

3.2.8. Project Extent and Trigger Distance

Per the SFPUC's Alternatives Analysis Report (AAR), the exterior low-profile wall alternative was carried forward. As shown in Figure 1-3 and Figure 1-4, the alternative includes restoration of beach and dune fronting the low-profile wall, which extends a length of 3,200 feet.

The minimum beach width which triggers a non-scheduled nourishment event is proposed at 50 feet, measured between the wall and the mean high water (MHW) line. Per NOAA, in areas affected by tidal fluctuations the shoreline is represented by the line of contact between the land and the MHW datum plane (NOAA, 2020). However, it should be noted that this definition of shoreline is used to measure beach width for the purpose of establishing the triggers for the *Sand Management Plan* and may not be the best measure of 'usable beach' for the purpose of public recreation when wetted bound and wave runup are considered, but it does provide a stable, well defined boundary for the purpose of consistent plan implementation. The effect of the wetted bound and wave runup on the usable beach width is investigated in the next section.

USGS found that the shoreline position retreated at an average of 10 meters (e.g. 30 feet) in a typical winter season and also concluded that large storms can erode the beach at the same scale as the seasonal trends (USGS, 2007). Therefore, the proposed trigger distance of 50 feet will provide some buffer if storms hit during the preparation for the nourishment event, and represents a practical tradeoff between beach nourishment, beach access and potential wall exposure.

3.2.9. Wave Run-up and Wave Reflection

Although the shoreline is typically defined by the MHW line, the term “dry beach” is also frequently used in the coastal profession. Because the irregular wave run-up on the beach could extend the uprush of water (e.g. total water level) landward, the width of dry beach is less than the distance to the stillwater (SWL) line. Figure 3-13 shows the wave run-up limit.

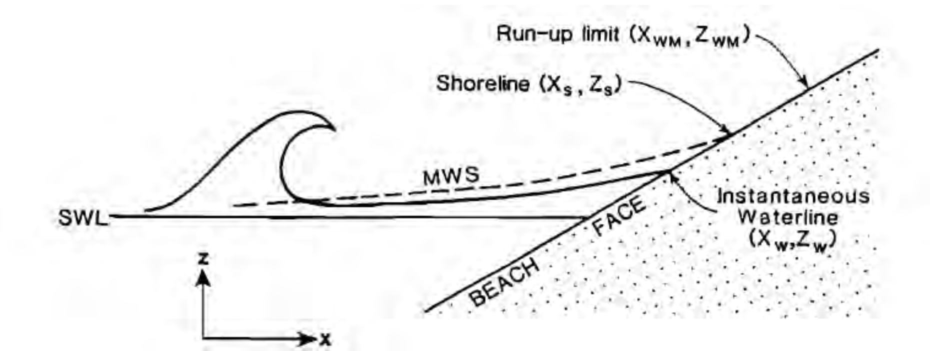


Figure 3-13: Sketch of Wave Run-up on Beach Face (Nielsen and Hanslow, 1991)

Extensive field data have been collected for wave run-up distributions on natural beaches (Nielsen and Hanslow, 1991). The following formulae were proposed for the beaches with flatter slopes similar to those at South Ocean Beach:

$$L_{zwm} = 0.05(H_{orms}L_o)^{0.5} \ \ for\ beach\ slope \leq 0.1 \qquad \text{(Eq. 8)}$$

$$\bar{z}_{wm} = SWL + 0.89L_{zwm} \qquad \text{(Eq. 9)}$$

Where H_{orms} and L_o are the offshore root-mean-square wave height and wavelength, respectively. $\bar{z}_{wm}$ is the average level reached by the waves above the still water level.

It should be noted that by including wave run-up in the model the beach profile remains the same, only the dry beach width changes, now defined by the wave run-up line instead of the MHW line. In this study, the effect of wave run-up was evaluated by including it in the model uncertainty analysis to allow comparison of the two beach width definitions.

Wave reflection due to wall exposure to waves is not considered in the model because the effect can be ignored as long as the beach is present (e.g. dissipative). It may only intensify when the wall is exposed, and the provision of the wall exposure trigger to require placement of sandbags is intended to minimize the wall exposure and wave reflection (not to protect the LPW, which is designed to withstand direct wave loads).

3.2.10. Sand Replenishment Scheme

The development of the Sand Management Plan is an iterative process. A set of sand replenishment rules was developed and analyzed, and the result was used to further refine the rules. Figure 3-14 provides the flow chart of the rules and reflects the sand replenishment scheme as it currently stands.

Although the model allows over 12 months for the City to prepare for a replenishment between the June 1 monitoring date and the actual placement the following year, it should be noted that this model assumption is not a strict rule but is mainly to foster an orderly budgeting, contracting, environmental protection and public notification process. The intent of the *Sand Management Plan* is to avoid or minimize the current practice of ad-hoc emergency responses at South Ocean Beach, but it does not preclude emergency placement of a reduced volume if required.

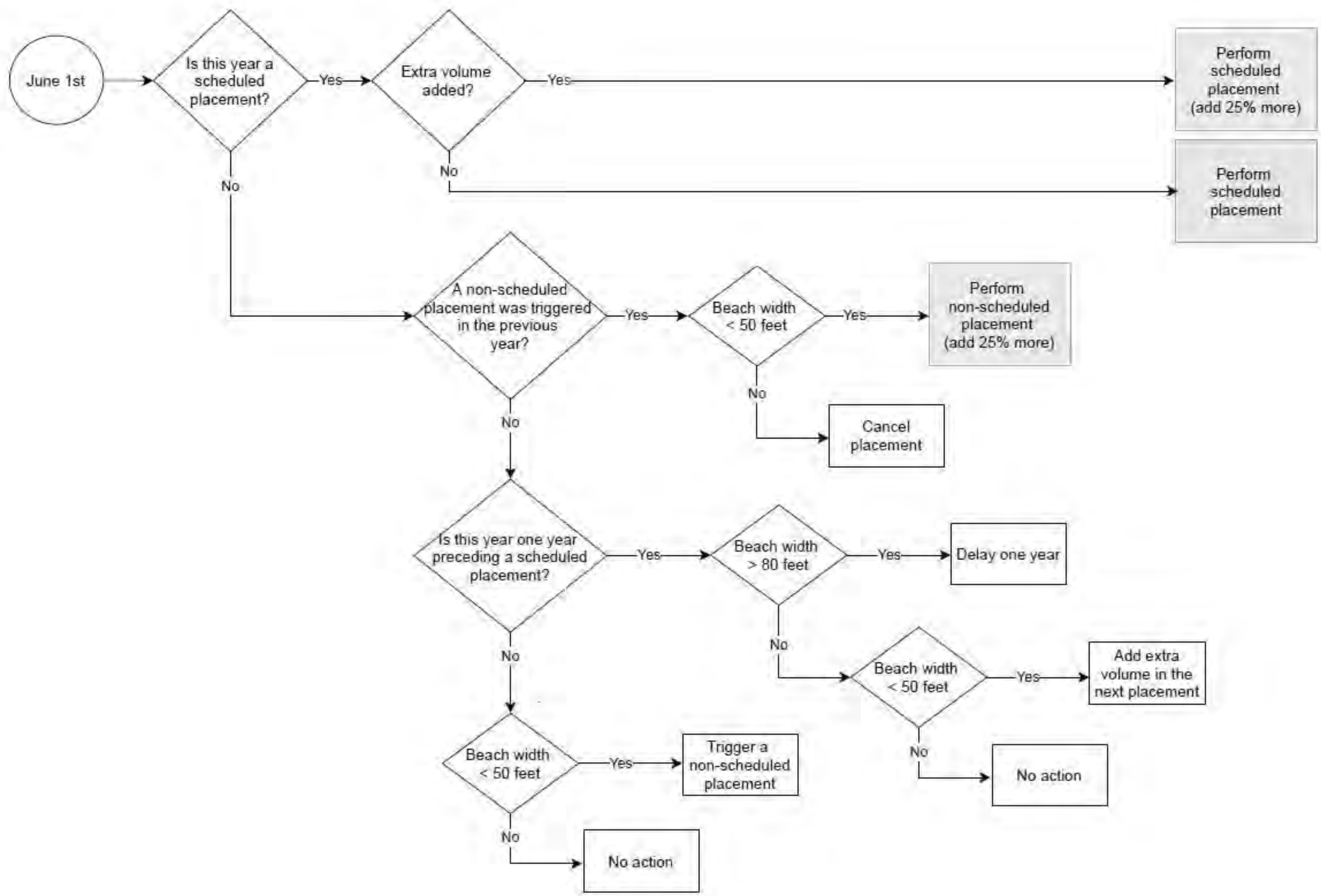


Figure 3-14: Flow Chart of Sand Replenishment Scheme

3.3. Model Procedures

The Monte Carlo simulation was carried out with the software ExtendSim®. It is an easy-to-use, yet extremely powerful, tool for understanding complex systems by creating a simplified, logical representation of the system processes (Imagine That Inc., 2013).

When a run is initiated, a SLR projection curve is first randomly selected from the distribution shown in Figure 3-10. Then, the ENSO condition is selected on an annual basis according to the frequency of occurrence, which in term pairs with the associated offshore waves pool. For instance, assuming a "Weak EL Niño" year is selected, a time series of offshore waves could be constructed from the November of 2006, the December of 2018, the January of 1970, the February of 2005, etc. All these months came from the identified "Weak EL Niño" year wave pool, as listed in Table 3-1. Subsequently, this synthetic offshore wave dataset is transformed to the nearshore location using the SW model and is used in the Yates' model. Finally, the resultant beach width is updated daily between year 2020 and 2100 (a span of 80 years) and takes into account the longshore spreading per the Pelnard-Considère diffusion equation, cross-shore response per the Yates' model, background erosion, and the SLR loss per the *Bruun Rule*. The decision to proceed with a sand replenishment is governed by the rules illustrated in Figure 3-14. If a sand replenishment is implemented, the advancement of beach width is assumed as a step increase and will occur randomly between August 1 and August 31 of the year of placement.

Figure 3-15 presents an example of one simulation run, with a projected SLR of 2.5 feet in year 2100. Also shown in the figure are the annual June 1 beach width measurements and the timing of 17 replenishments.

When the beach width becomes zero, the shoreline has receded to the LPW – that is the wall is exposed down to MHW. The beach erosion may continue increasing negative beach widths until the mobile sand layer is completely gone and the erosion resistant marine terrace is exposed. However, the wall is designed to withstand such extreme erosion events and continue to protect the Wastewater infrastructure. In addition, the "emergency" sandbag placement of Trigger B (see Section 4.2) is designed to minimize the impact of wall exposure and reduce wave reflection and wave run-up hazard for the public.

To normalize and statistically characterize the results, a total of 1,000 runs was conducted for each model scenario. The model scenario corresponded to the various sand management sub-plans.

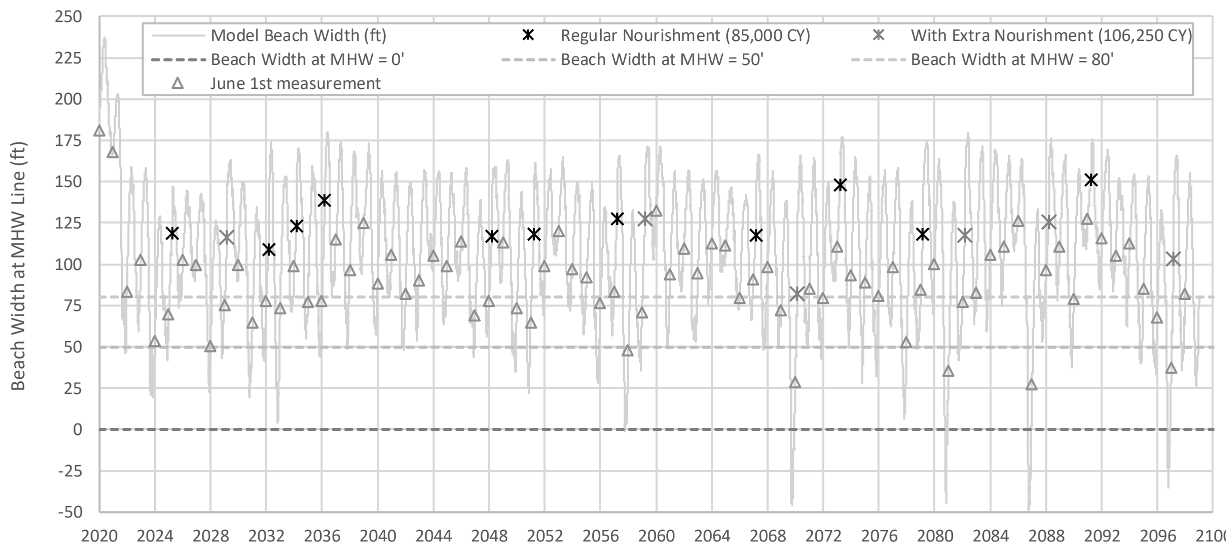


Figure 3-15: Example of One Simulation Run (SLR 2.5' in Year 2100)

3.4. Model Validation

Sand backpass events have been performed at North Lot & Reach 3 and at Reach 2. Table 2-1 provides a complete list of the recent sand backpass events and Figure 2-4 shows their locations. Figure 3-16 documents the field conditions before/after the backpass event performed in April 2018.

To evaluate the model's underlying methods and calibration parameters, two sites were modeled separately using recorded input data, and the results compared to observed conditions. Figure 3-17 and Figure 3-18 compare the model results and the USGS field observations, as well as the approximate timing of actual replenishments.

Two statistical parameters were used to quantify the goodness of fit between measurements and model predictions.

- Root-Mean-Squared (RMS) Error: $\varepsilon_{RMS} = \sqrt{\overline{(x-y)^2}}$

Where, x and y represent the measured and modeled data, respectively.

The ability of the model to predict the outcome can be estimated using the index of agreement (Willmott et al., 1985). An index close to 1 indicates a good prediction by the model.

- Index of Agreement (d): $d = 1 - \dfrac{\sum (x-y)^2}{\sum \left(\left| x - \bar{x} \right| + \left| y - \bar{x} \right| \right)^2}$, $0 \le d \le 1$

At North Lot & Reach 3 (about 900 feet placement extent), the estimated RMS error is 24 ft and an index of agreement of 0.85. At Reach 2 (about 350 feet placement extent), the estimated RMS error increases to 31 ft while the index of agreement decreases to 0.61. Some limitations may influence the model's goodness of fit. For instance, it is noted that the process-based models may not respond promptly and accurately in the short-term, when compared to the physics-based models. In addition, the underlying assumptions may not be directly applicable to the validation cases (e.g. the derived longshore diffusivity was based on a longer extent) and the adopted process-based models have their deviation of accuracy (e.g. the Yates' model has less goodness of fit in the Project area). Lastly, Figure 2-1 illustrates that the seasonal change of shoreline can be up to 40 m (e.g. 130 ft) at Ocean Beach, indicating it is a complex and constantly changing environment.

Even with these limitations, the model is considered acceptable for use in developing the long-term *Sand Management Plan*. To better understand the impacts of the model's uncertainty, several test cases were run (see Section 3.6).

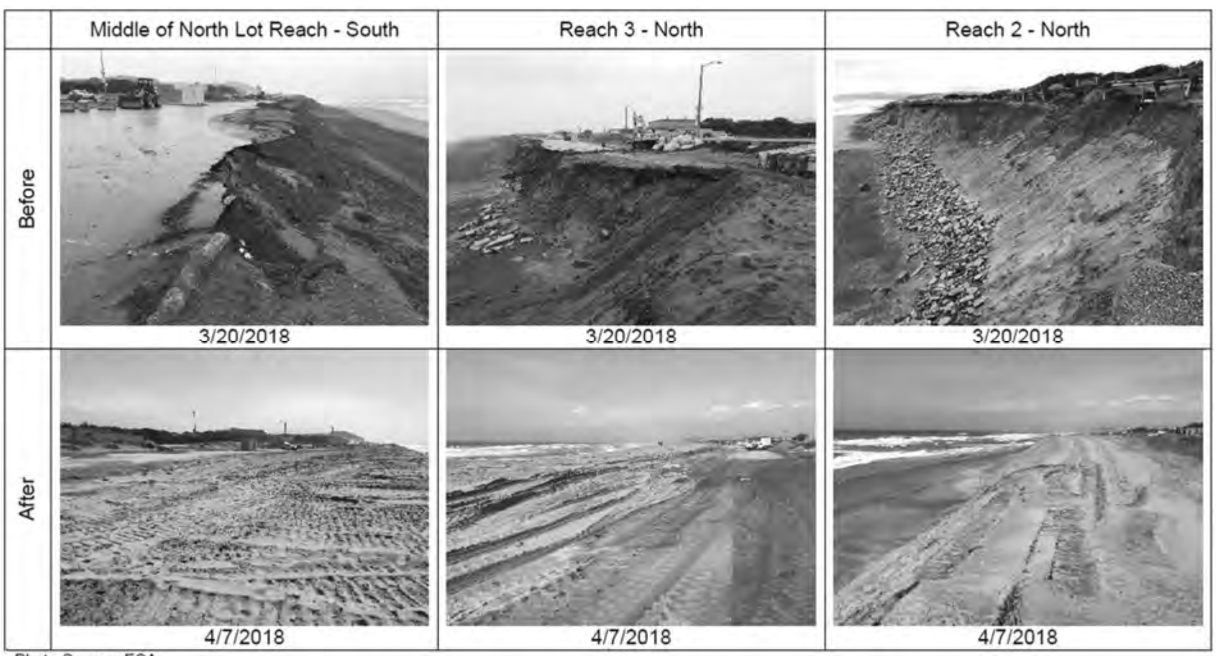


Photo Source: ESA

Figure 3-16: Photos Before/After April 2018 Sand Backpass Event (ESA, 2018)

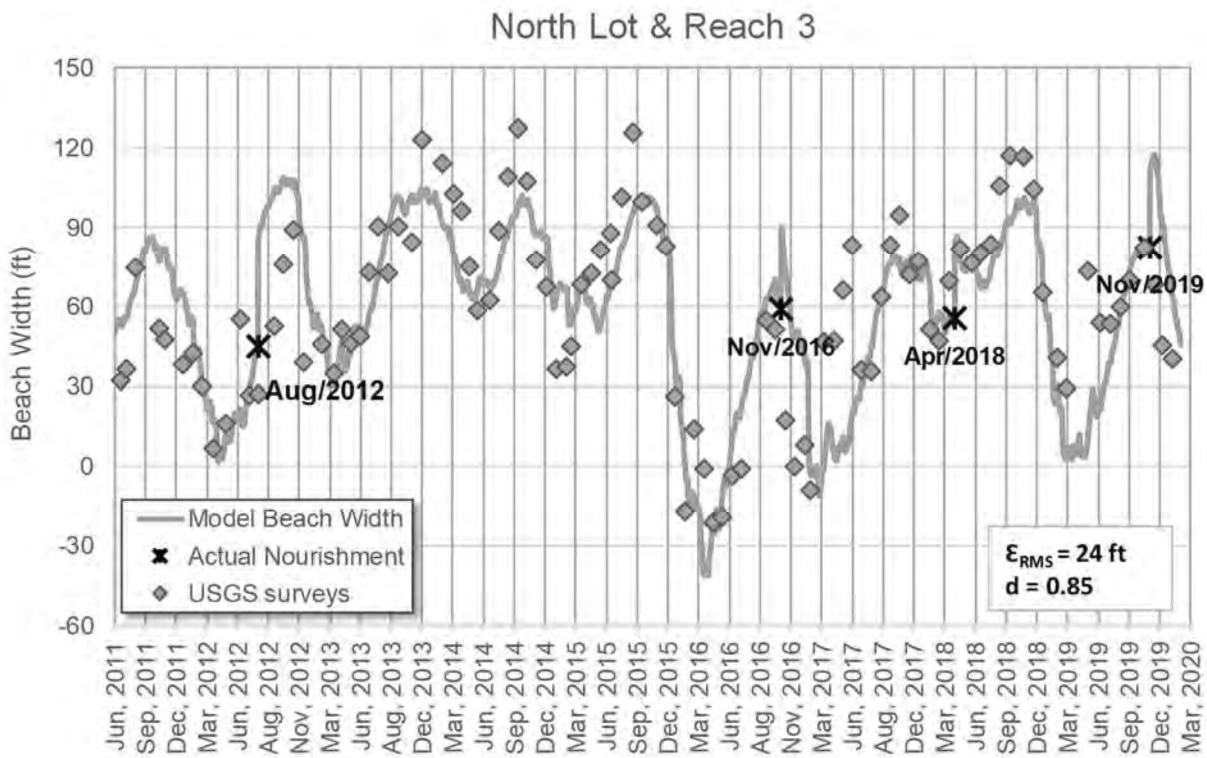


Figure 3-17: Model Validation - North Lot & Reach 3 Case

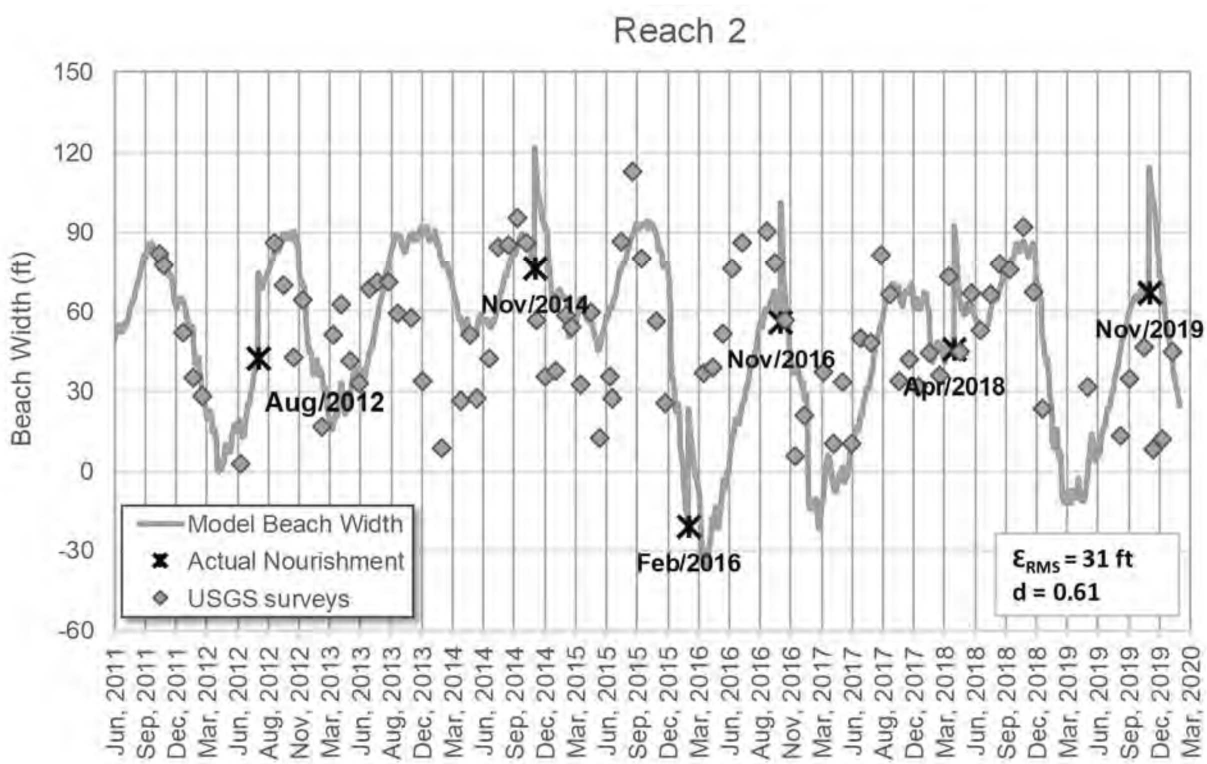


Figure 3-18: Model Validation - Reach 2 Case

3.5. Model Scenarios

Four scenarios were evaluated in this study, two characterized as small plan (85,000 and 120,000 CY replenishment) and two as large plan (300,000 and 500,000 CY replenishment). Table 3-3 summarizes the performance of each scenario.

Using the 85,000 CY replenishment as an example, the average number of replenishments in eighty years is 20 events, or equivalent to approximately one event every 4 years. When a larger SLR projection is forecasted, more replenishments are required. The run with the maximum 26 events has a SLR of 8.1 feet forecasted in year 2100. In eighty years, the average number of low-profile wall exposures down to MHW is 4 times. All wall exposures occur during the forecasted "Very Strong El Niño" years, when greater erosion is expected. The average first replenishment occurs about 5 years after the project construction is completed. The model also keeps track of the hourly beach width between the LPW and MHW shoreline and summarizes the result as the percent of time beach width distribution. Per the established sand replenishment rules (Figure 3-14), the beach width is less than 50 feet only 9% of the time. Figure 3-19 illustrates the average beach width by month and the range of its 90% confidence interval (90% of the beach width values over all model runs for the scenario lie with the interval). The narrowest beach width occurs between March and April as it is approximately the end of the winter erosive season. The widest beach width occurs between September and October as it marks the end of the summer accretive season as well as any sand replenishments that may have occurred.

Table 3-3: Performance of Model Scenario

Parameters		Nourishment Volume (CY)			
		85,000	120,000	300,000	500,000
Number of Nourishment in 80 years	Max	26	17	14	9
	95th Percentile	22	16	12	8
	Avg	20	14	11	8
	5th Percentile	18	13	9	7
	Min	16	11	8	5
Number of Full Wall Exposure at MHW in 80 years	Max	11	9	9	10
	Avg	4	3	3	3
	Min	0	0	0	0
First Nourishment Following LPW Completion (yrs)	Max	8	8	8	10
	Avg	5	5	5	8
	Min	2	3	4	4

Average Percent of Time Beach Width Distributions (%)	Width ≤ 25'	3%	2%	2%	2%
	25' < Width ≤ 50'	6%	5%	4%	4%
	50' < Width ≤ 80'	17%	14%	13%	11%
	80' < Width ≤ 160'	68%	66%	63%	57%
	160' < Width ≤ 230'	6%	13%	18%	24%
	Width > 230'	0%	0%	0%	2%
Average Beach Width at MHW (ft)	Jan	95	103	109	118
	Feb	75	83	89	98
	Mar	63	70	76	85
	Apr	60	68	74	82
	May	76	83	89	97
	Jun	96	103	108	116
	Jul	115	122	127	135
	Aug	135	143	148	157
	Sep	149	157	164	173
	Oct	151	159	165	174
	Nov	141	149	155	164
	Dec	119	127	133	142
95th Percentile Beach Width at MHW (ft)	Jan	100	109	118	133
	Feb	80	88	97	113
	Mar	68	76	84	100
	Apr	65	73	81	97
	May	80	88	96	112
	Jun	100	108	116	132
	Jul	119	127	135	151
	Aug	140	148	156	172
	Sep	154	162	172	187
	Oct	156	164	174	189
	Nov	146	154	163	179
	Dec	124	132	141	157
5th Percentile Beach Width at MHW (ft)	Jan	90	98	102	107
	Feb	70	78	82	87
	Mar	57	65	69	74
	Apr	56	63	66	71
	May	71	78	82	86

	Jun	91	98	101	106
	Jul	110	117	120	124
	Aug	130	138	141	146
	Sep	144	152	156	162
	Oct	146	154	158	164
	Nov	136	144	148	153
	Dec	114	121	125	131

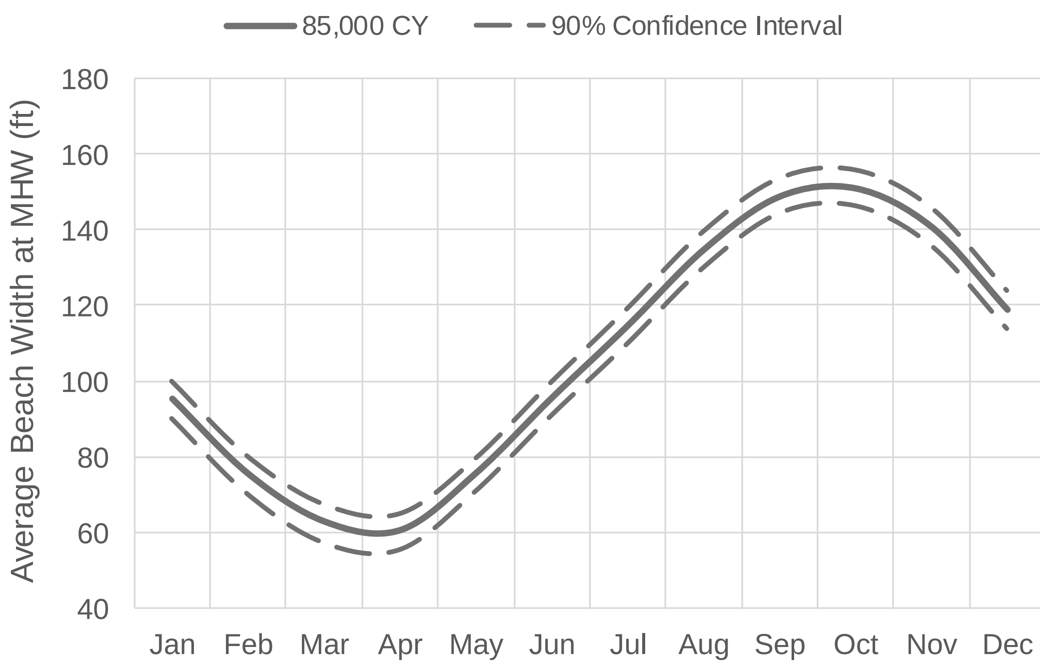


Figure 3-19: Average Beach Width by Month for 85,000 CY Scenario

3.6. Model Uncertainty

Seven additional cases were run for the 85,000 CY replenishment scenario, with the intent to address the model's uncertainty as well as to provide better understanding for the plan's implementation. These cases include a greater longshore diffusivity (G=0.028 per Section 3.2.1), a nominal 5% increase of offshore wave heights to address the potential increased storminess, a flatter beach slope of 60H:1V, a greater background erosion (4.3 ft/year per Section 3.2.2), a trigger beach width of 80 feet, a mixed replenishment scenario (combined scheme of two 85,000 CY replenishments, followed by one 300,000 CY replenishment), and adding the wave run-up calculation to model the 'dry beach' width (though the trigger beach width remains based on the MHW shoreline). It should be recognized, however, that combinations of the above factors could also be modeled if necessary.

Table 3-4 compares the results of the additional cases with the 'base' 85,000 CY scenario using the default settings. The comparison cases utilize a single run each and have used the same initial state (e.g. the same random seed number) to initiate the probabilistic analysis.

With a greater longshore diffusivity, an increase of loss due to longshore transport causes the beach width to reduce 3-4 feet per month. With larger offshore waves, a reduction of beach width in the winter season results from larger incident wave power to remove sands from the Project area. Similarly, an increase of beach width in the summer-fall season is also attributed to larger waves returning sands onshore. Both the flatter slope and the greater background erosion case have very similar outcomes, increased number of nourishments (e.g. a 27% increase) and reduced average beach width.

With a greater trigger width, it becomes a tradeoff between more replenishment events and a substantial increase of average beach width. Only 3% of the time beach width is less than 50 ft while 27% of the time it is greater than 160 ft. Clearly, this case is appealing from a recreational beach perspective.

Currently, the SFPUC has a cooperation agreement with the USACE to place dredged material on Ocean Beach for the upcoming channel dredging episode, which is scheduled in year 2021. Because the cooperation may continue in the future, the mixed scenarios case was evaluated. Results of the mixed case are in between the uniform 85,000 or 300,000 CY scenarios. Practically, the mixed case can combine the benefits from both the small scale (e.g. shorter response time) and the large scale replenishments (e.g. less disruption to shoreline ecology and beach users) into one.

Adding wave run-up in the beach width calculation to better define the wetted bound or 'dry beach' width only changes the beach width distribution slightly. Results indicate that the probability of a beach width narrower than 50' is now 19% using the wave run-up line to define beach width. However, other replenishment statistics and average beach width at MHW are the same.

Table 3-4: Summary of Model Uncertainty Analysis

Parameters		Base	Greater Longshore Diffusivity	5% Wave Height Increase	60H:1V Beach Slope	Greater Background Erosion (-4.3 ft/yr)	Greater Trigger Width (80')	Mixed Scenarios (85k+300k)	Include Wave Run-up [1]
Number of Nourishment in 80 years		22	24	23	28	28	27	16	22
Number of Full Wall Exposure at MHW in 80 years		5	6	6	7	6	1	4	5
First Nourishment Following LPW Completion (yrs)		5	5	5	5	5	3	5	5
Average Percent of Time Beach Width Distributions (%) [1]	Width ≤ 25'	3%	3%	3%	5%	4%	1%	1%	8%
	25' < Width ≤ 50'	6%	8%	8%	11%	11%	2%	4%	11%
	50' < Width ≤ 80'	22%	23%	22%	24%	24%	7%	17%	25%
	80' < Width ≤ 160'	66%	64%	63%	59%	59%	64%	64%	55%
	160' < Width ≤ 230'	3%	2%	4%	1%	1%	27%	14%	2%
	Width > 230'	0.2%	0.0%	0.0%	0.2%	0.2%	0.2%	0.2%	0.1%
Average Beach Width (ft) [1]	Jan	88	85	87	78	78	116	102	69
	Feb	68	65	65	58	58	96	82	53
	Mar	57	53	53	47	47	85	70	47
	Apr	57	53	53	46	46	85	70	49
	May	72	68	70	61	61	100	85	64
	Jun	91	88	91	80	81	119	105	81
	Jul	110	106	111	99	99	138	123	96
	Aug	130	127	133	120	120	158	143	114
	Sep	144	142	149	136	136	173	159	128
	Oct	147	144	151	138	138	175	161	128
	Nov	136	133	139	127	127	164	150	115
	Dec	112	109	113	103	103	140	126	91

[1] Average Beach Width and Beach Width Distributions for all cases except "Include Wave Run-up" are defined by the MHW shoreline;
Average Beach Width and Beach Width Distribution for the "Include Wave Run-up" is defined by the line of wave runup above the still water level.

4. Sand Management Plan

This section provides the details of the *Sand Management Plan* that calls for periodic sand replenishment to maintain the beach and dunes, which are an essential element of the proposed Project. The goals of the sand management plan are:

- To maintain an effective, year-round recreational beach within the Project area over the Project life, utilizing scheduled sand replenishment actions;
- To increase resilience of the shoreline within the Project area to future sea level rise;
- To accomplish the sand replenishment based on beach width triggers in a cost-effective manner; and
- To minimize disruption to shoreline ecology, from a habitat protection standpoint, and to beach users, from a recreational perspective.

Although the design and permits for the Project are expected to cover the Project through the year 2060, the *Sand Management Plan* is intended to establish a sustainable long-term sand management framework for South Ocean Beach extending to the end of century. It is also recognized that the *Sand Management Plan* builds upon current state-of-the-art research in coastal processes and as understanding of the processes advances the adaptive management provisions of the plan will allow it to evolve as well.

The plan provides two sub-plans, each with a series of options to allow trade-off between the periodic sand replenishment quantity and the replenishment interval as follows:

- Sub-plan series ‘S’ is based on the current practice of ‘back-passing’ sand from the northern end of Ocean Beach by trucking to the Erosion Hot-Spot at the southern end. This sub-plan has 2 replenishment quantity/interval options. It has the principal advantage that implementation can be both certain and immediate since it has been functioning for several years in addressing the current sand management needs along Ocean Beach. The technical details and costs are well documented. Furthermore, environmental review of the work is complete and permits have been obtained, which are expected to be renewed to meet future needs. This sub-plan can be implemented in a relatively straight-forward manner to allow the Project to proceed as scheduled.

- Sub-plan series ‘L’ is based on the practice common on the U.S. East Coast and in Southern California of harvesting sand offshore by means of a dredge that is equipped to deposit the dredged material directly onto the beach. This sub-plan also has 2 replenishment interval options, though longer intervals could be considered as well. It incorporates the long-proposed concept of placing dredged material from the maintenance of the SF Main Ship Channel onto South Ocean Beach. The harvesting of sand offshore and placing the material directly onto the beach as required by this sub-plan would need to undergo additional environmental review and secure permits, as well as conclude partnering agreements with the USACE. The schedule and the outcome of these proposals are not certain. Therefore, the sub-plan is not included at this time as part of the Project. However, it is included in this *Sand Management Plan* because of its future potential to provide beach replenishment that is more cost-effective with less disruption for beach users and greater ecologic benefits as construction disturbance would be less frequent.

Table 4-1 summarizes the *Sand Management Plan* based on the results of the model scenarios. For ease of reference, the sub-plan option assigned in Table 4-1 is used throughout this section. Details are provided in the following sections.

4.1. Sand Replenishment Volume and Location

Table 4-1 lists the estimated scheduled sand quantity varying between 85,000 CY and 500,000 CY, increasing to 125% of the scheduled quantity if a non-scheduled replenishment is triggered.

- S1 – 85,000 CY scheduled sand quantity or 105,000 CY non-scheduled quantity; sand placed over entire 3,200 feet project length.
- S2 – 120,000 CY scheduled sand quantity or 150,000 CY non-scheduled quantity; sand placed over entire 3,200 feet project length.
- L1 – 300,000 CY scheduled sand quantity or 375,000 CY non-scheduled quantity; sand placed over entire 3,200 feet project length.
- L2 – 500,000 CY scheduled sand quantity or 625,000 CY non-scheduled quantity; sand placed over entire 3,200 feet project length.

Table 4-1: Sand Management Plan

Sub Plan Option	Scale of Operation	Source of Sand	Transport Method	Scheduled Sand Placement (CY)	Est. No. of Placements in 80 Years[A]	Est. First Placement (Years) Following LPW Completion[A]	Trigger[B] - Beach Width (ft)	Trigger[C] - LPW Exposure Length (ft)
S1	Small	• Northern Ocean Beach	Truck	85,000	20	5	50[1]	500[2]
S2	Small			120,000	14	5		
L1	Large	• Entrance navigation channel • SF-8 disposal site • SF Bay sand lease site	Hopper dredge equipped for beach placement	300,000	11	5	50[1]	500[2]
L2	Large			500,000	8	8		

[A] Estimate based on sand transport modeling described in Section 3 and represent statistical average values; see text for confidence intervals.
[B] Placement of 125% of scheduled sand quantity in the next summer season; upon completion of a triggered nourishment, reset interval schedule.
[C] Placement of sandbags in sufficient quantity to conceal exposed wall.

Notes:
[1] 50 ft or less beach width, measured between MHW and the face of LPW over 500 ft total length on June 1 of the year.
[2] 500 ft or more total length of LPW exposure, measured above MHW elevation on June 1 of the year.

4.2. Sand Replenishment Frequency and Triggers

Table 4-1lists the average number of replenishments in 80 years and the number of years to the first replenishment following LPW completion.

- S1 – Average 20 replenishments (range 16 – 26); 5 years to first replenishment (range 2 – 8 years).
- S2 – Average 14 replenishments (range 11 – 17); 5 years to first replenishment (range 3 – 8 years).
- L1 – Average 11 replenishments (range 8 – 14); 5 years to first replenishment (range 4 – 8 years).
- L2 – Average 8 replenishments (range 5 – 9); 8 years to first replenishment (range 4 – 10 years).

The *Sand Management Plan* considers the historical cycle of El Niño oceanographic conditions to provide the best estimate overall of the replenishment quantity and interval to satisfy long-term requirements. The plan addresses more severe conditions during strong El Niño years that trigger non-scheduled sand replenishments, and less severe conditions in milder years that allow deferral of a scheduled replenishment. Exceptionally severe conditions could result in exposure of portions of the LPW, which the plan also addresses.

The scheduled Sub-plan ‘S’ sand replenishment interval is based on the model results and varies between 2 and 8 years. The actual frequency of sand replenishment varies depending on the beach width trigger criteria and the oceanographic conditions actually encountered.

Two triggers are established for initiating a non-scheduled sand replenishment or LPW exposure procedure:

- Trigger A – 50 feet or less beach width over 500 feet total length of beach, measured between the MHW line and the face of LPW on June 1 of the year requires that a sand replenishment be implemented in the following year, allowing about 12 months to complete preparations. The MHW line was chosen because it is a widely recognized definition of the ‘shoreline’ and often used for the measurement of beach width, though it is not the only definition in case another water level datum is desired.
- Trigger B – 500 feet or more total length of LPW exposure above MHW elevation also measured on June 1 of the year requires that the exposed portion of wall be concealed by sandbags using materials stockpiled for this purpose. This “emergency” placement is to reduce

the wave run-up hazard and reduce wave reflection off the wall when the sand fronting the wall is depleted.

The trigger distance of 50 feet serves as a buffer to reduce the risk of wall exposure in case storms occur during the preparation for a replenishment event. In addition, if a non-scheduled replenishment has been triggered, it may not be implemented if the beach recovers naturally during the 12 months between the June 1 trigger and the subsequent June 1 measurement.

If the non-scheduled sand replenishment trigger is not activated, the regular sand replenishment should proceed per schedule, unless beach width measured between MHW and the face of the LPW is greater than 80 feet over the entire length of the beach on June 1 of the year preceding the scheduled replenishment.

4.3. Sand Replenishment Sources

An important consideration in the selection of a beach replenishment sand source is the compatibility of the sand source material with the material on the beach, in particular the grain sizes. Moffatt & Nichol (2007) provides a discussion of the topic and grain size data for various potential sources which were screened in developing the following proposed sources. Performance of the beach fills may be enhanced by appropriate grain size selection so a near match of grain sizes is not necessarily the best replenishment option. Sand mineralogy and color is also a consideration.

For the Sub-plan “S” series:

- North Ocean Beach – Beach sand with near match of grain sizes, mineralogy, and color. The rate of accretion is sufficient to ensure a long-term supply based on current estimates per Section 4.3.1.

For the Sub-plan “L” series:

- SF Bay Main Ship Channel – As shown in Figure 2-3, sediment at the mouth of San Francisco Bay is highly variable, ranging from very fine sand on the outer reaches of the ebb tidal delta, to coarse sand and gravel in the inlet throat (USGS, 2007). Outer reaches have a median size of 0.18 mm sand that is finer than the beach sand of 0.28 mm, but still a good match.

- SF-08 Dredged Material Disposal Site – Used from about 1971 to the present for disposing of dredged material from the maintenance of the SF Bay Main Ship Channel. Originally envisioned as a ‘dispersive’ site that could accept an unlimited quantity of dredged material, it apparently has accumulated millions of cubic yards of dredged material that would be suitable for beach nourishment at Ocean Beach. The site is currently experiencing capacity constraints that limit the USACE's use of the site, hence their current practice directs the disposal of the channel dredged material to the SF-17 disposal site off Ocean Beach. Included with this site is the ebb tidal delta that has grown up around the southern lobe of the SF Bay entrance bar. This potential source has a median size of 0.18 mm and pockets of somewhat coarser material than found at Ocean Beach. Selective use of this source could make for a longer interval between nourishment operations. In all respects, the sand is a good match.

- SF-17 Dredged Material Disposal Site – Used since 2005 on an irregular basis, partly as a 'demonstration project for beach nourishment' and partly to dispose of channel maintenance material due to capacity constraints at SF-08, it has produced a reservoir of dredged material off Ocean Beach. While the mound is gradually dispersing, the water depth at the location of the mound is such that nourishment of the beach is very limited.
- SF Bay Sand Lease Sites – Currently under term lease from the State to Bay Area construction aggregate supply firms, the sites primarily in the central bay closest to the Golden Gate though controversial on account of the sand resource depletion aspect, can provide a wide range of sand sizes to allow greater control of the sand nourishment interval. The City may work with these private suppliers to secure sand from these sites.

In addition, the plan recommends placing a coarse sand layer atop the constructed sand berms to reduce the amount of nuisance wind-blown sand transport, similar to the mitigation measures incorporated in the sand backpass projects. A two-foot thick layer of medium-sized sand (e.g. 0.5 mm) across the top and extending down the seaward slope four feet was implemented and was found effective (ESA 2016a). Local sand mining operations in the Central San Francisco Bay were identified as potential sources and the sand product was found to be compatible in sand quality, color, and size to the coarser sands that naturally occur at Ocean Beach (ESA, 2016a).

Overall, the proposed sand sources for small and large sub-plans are from within the San Francisco Bay littoral system. Coarse sand veneer, if proposed, would also comply with in-situ characteristics.

4.3.1. Northern Ocean Beach

The Northern Ocean Beach, between USGS' transect #119 and #139, had been used as the sand source for the sand backpass events since year 2012. However, it is important to determine if the Northern Ocean Beach could be sustainable for the sub-plan "S" series in the long-term.

The USGS' beach profile surveys provide shoreline changes by transect (USGS, 2020). To understand the impacts on the Northern Ocean Beach shoreline when the sand was borrowed by the backpass events, the analysis of shoreline changes was conducted for the period between year 2012 and early 2020 (grey dash line in Figure 4-1). However, it was found that a singular extreme event, the Very Strong El Niño (VSE) 2015-16, significantly affects the trend of the shoreline changes because the event occurs in the middle of the analysis period. Alternatively, two periods were evaluated, before and after the VSE. Before the VSE, which includes a total of 98,300 CY sand removal (see Table 2-1), the beach width at the Northern Ocean Beach increases, when compared with the long-term trend. After the VSE, which includes a total of 225,000 CY sand removal (e.g. 4 events in 4 years), the trend of beach width is stable in the middle of the Northern Ocean Beach, but decreases on both ends.

Results indicate that the Northern Ocean Beach could be sustainable if the sand was borrowed infrequently and if there is not any recent extreme event. However, it should be acknowledged that the San Francisco Bay littoral system is a complex environment and the knowledge of sediment transport is still not fully understood; e.g. some recent studies suggest that sand along Ocean Beach moves from the north to south, as opposed to the previous consensus (Barnard et al., 2013). Therefore, it is important to continuously monitor the shoreline at Northern Ocean Beach and confirm it is sustainable as the past records suggest.

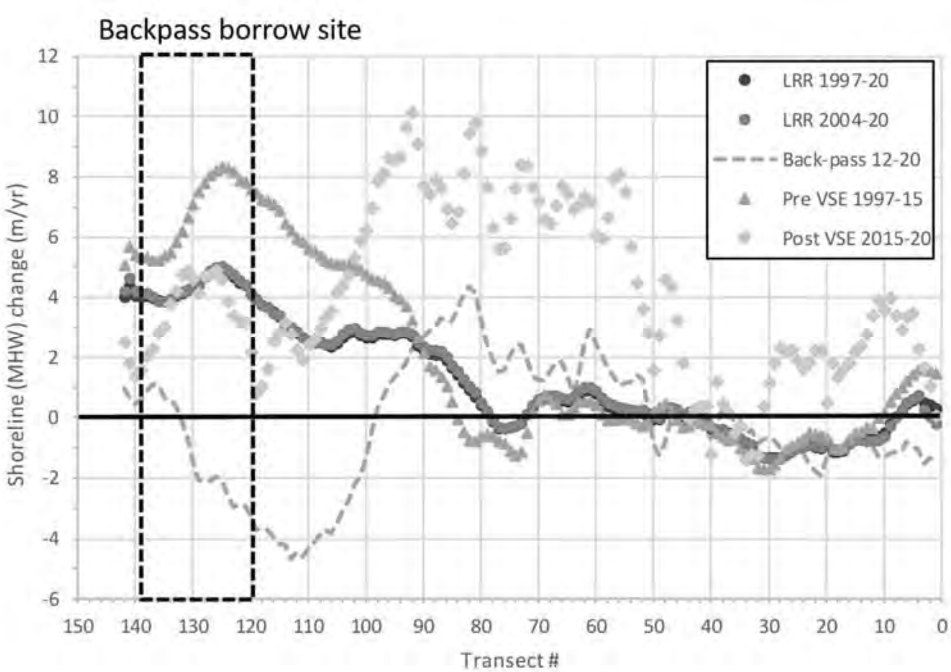


Figure 4-1: MHW Shoreline Change Rates by Transect (Revised from USGS, 2020). Provisional USGS Data Subject to Revision

4.4. Sand Replenishment Methods, Equipment, Staging, and Access

Associated with the sub-plan series sources are series specific sand harvesting, transport modes and replenishment methods, equipment, staging and access, as follows:

- For the "S" series, harvesting from Northern Ocean Beach involves land-based loaders, trucks to haul the material, and dozers for spreading the material along the South Ocean Beach shoreline. The operation is more fully described in Appendix A with considerable detail based on the 2012 experience by Power Engineering Contractors. This nourishment consisted of harvesting about 90,000 CY of sand and placing it at the Erosion Hot-Spot just south of Sloat Blvd. (about 1,000 ft of shoreline). The field work required about 6 weeks to complete, allowing 1 week for site preparation and equipment setup, about 3 weeks of continuous production (about 30,000 CY/week), and 1 week for equipment removal and site restoration. The hauling was done by off-road articulated dump trucks that had exclusive use of the Great Highway southbound lanes for the contract duration. In addition, the north and south ends of Ocean Beach were closed to the public. The operation took place during late summer (August-September) and cost approximately $10/CY (escalated to 2019 costs). A series of winter storms in late 2013 dispersed the mounded material along the Southern beaches, most of which 'disappeared'. The Northern beaches were apparently not adversely affected since the source of material had been the accumulated sand piled high against the seawall in the area. In the future depending on the reconfiguration of the Great Highway roadway and limitations on vehicle access to the beach south of Sloat Boulevard from the realigned roadway, truck access to the beach will probably be provided by a ramp at the north end of the Project and travel over the beach.

- For the "L" series, harvesting from the underwater sites and transporting the material would be accomplished using hopper dredges equipped with pump-off capability to deliver the dredged material from a mooring site off Ocean Beach to the shoreline, where it would be conditioned behind a temporary containment dike for spreading along the beach by dozers. The USACE hopper dredge that performs the maintenance of the SF Bay Main Ship Channel is not equipped with pump-off capability and so would not be able to perform the required nourishment unless it was retrofitted for this purpose. However, the USACE Portland District that is responsible for the maintenance of the federal channels in SF Bay contracts for private industry hopper dredges to provide this service where needed (periodically on the Richmond and Oakland Harbor channels to off-load material at certain upland dredged material beneficial reuse sites). Currently there are three ocean-going private industry hopper dredges that compete for this work and could conceivably compete for the sand nourishment work at South Ocean Beach. Development of a funding and contracting strategy for the work would involve considerable planning effort with a host of Federal and State agencies, as would resolving a myriad of technical, environmental and permit issues, but the reward even if it took a decade to realize, would potentially be seen in operational cost savings, air emissions reduction, and reduced frequency of nourishment impacts on beach users and ecology.

4.5. Beach/Dune Closure

For the Sub-plan “S” series, both the borrow site at Northern Ocean Beach and the Project area should be closed to the public during the sand harvesting and replenishment. For the Sub-plan “L” series, the Project area should be closed to the public.

4.6. Wind-Blown Sand Management

Although dunes are an essential element of the proposed Project (see Figure 1-4 typical cross-section), it should be recognized that dunes may not be viable in the long-term because of the complex formation process and unpredictable anthropogenic activities.

Wind-blown sand transport, also referred to as aeolian transport, plays a major role in dune formation and stability along Ocean Beach. Active aeolian transport, which is a loss of sediment to the Ocean Beach system, moves sediment across the Great Highway driven by prevailing northwesterly and westerly winds (USGS, 2007).

The analytical method presented in the *Coastal Engineering Manual* (USACE 2002) was used to calculate aeolian transport. A time series of over-water wind measurements at NOAA’s offshore buoy 46026 was first converted to shore-normal over-land wind speeds. Once the threshold to initiate aeolian transport (depending on grain size) is exceeded, the transport rate per foot of beach was calculated. Figure 4-2 presents the monthly aeolian transport rates for two grain sizes. As shown in the figure, the smaller grain size results in a larger aeolian transport rate.

Wind-blown sand mitigation measures incorporated in the sand backpass projects, were found effective to reduce the amount of nuisance sand passed to the Great Highway (ESA, 2017, 2018, 2019). The measures included placement of a coarse sand layer (reducing sand mobilization) over the top of the placed berms and installation of interlocking brushwood fencing (trapping sand) on the crest of the sand berms. Then, the trapped sand can be collected and re-used for the nourishment or sandbags.

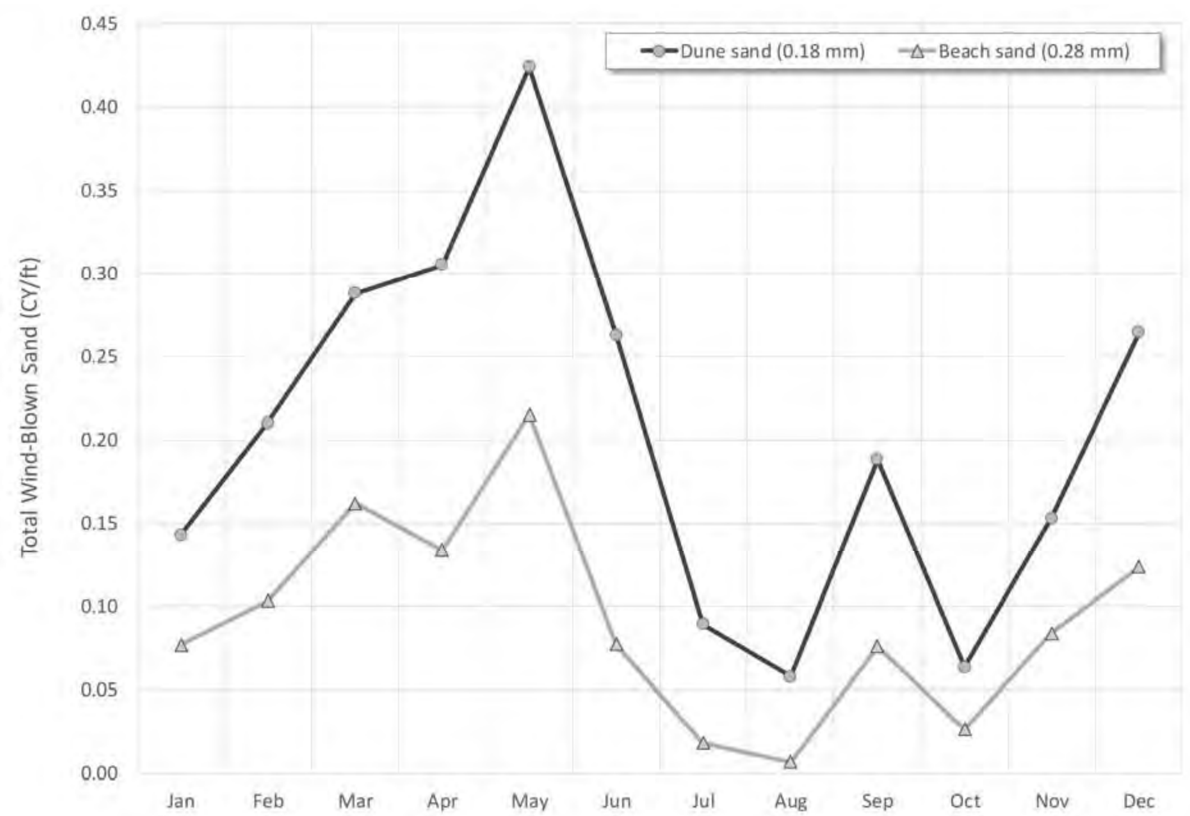


Figure 4-2: Monthly Aeolian Transport Per Foot of Beach

4.7. Effect of Sea-Level Rise and Increased Storminess

This study considers the full spectrum of the SLR projections for San Francisco per OPC (2018). Result indicates that if a larger SLR projection is forecasted, more nourishments are required.

Increased storminess was assessed as a model uncertainty case by applying a nominal 5% increase of offshore wave heights. Results show that with larger offshore waves, a reduction of beach width in the winter season results from larger incident wave power to remove sands from the Project area. Similarly, an increase of beach width in the summer-fall season is also attributed to larger waves pushing sands onshore.

4.8. Risk of Wall Exposure

As described in Section 4.2, the trigger distance of 50 feet for non-scheduled replenishments is used to reduce the risk of LPW exposure. However, it should be acknowledged that the risk of LPW exposure exists. For instance, the USGS 2007 study found that the very strong El Niño of the 1997-98 winter season caused an average of 72 feet (22 m) of erosion for the entire beach and localized pockets of over 230 feet (70 m). As a result, an emergency protection (e.g. Trigger B) using sandbags to conceal the exposed portion of wall, is designed to respond to such risk. Result indicate that in eighty years, the average number of low-profile wall exposure down to MHW is 3-4 times.

4.9. Monitoring

Sand Management Plan monitoring is designed to provide the data that is needed to drive the plan actions and to gauge the effectiveness of the plan in maintaining the desired beach and dune system. These monitoring requirements are intended to serve the needs of the *Sand Management Plan* only and are in addition to monitoring requirements that may be imposed to follow a beach replenishment operation itself or the construction of the LPW. Monitoring shall be performed under the supervision of licensed Civil or Geotechnical engineer with a minimum of 10 years' experience in coastal process evaluation. Alternatively the USGS has provided beach monitoring and scientific interpretation of the results for nearly 2 decades at Ocean Beach and would be in an excellent position to undertake the monitoring required by the plan. The monitoring shall be performed on a regular basis and reports shall be prepared and submitted to the City within 30 days of completion of the field work as follows:

A) At South Ocean Beach Replenishment Site

- Bi-monthly reports, based on visual observations by a qualified engineer/scientist of the 3200 foot-long beach and dune system to detect conditions that suggest beach width or LPW exposure are near or past trigger stage, or the dune encroachment on the public trail is reaching nuisance levels. Bi-monthly monitoring would be coordinated with quarterly and annual monitoring.
- Quarterly reports, based on beach and dune profile surveys at low tide for a minimum of 12 transects extending beyond the north and south limits of the project to report quantitatively on beach width, LPW exposure and depth of (dune) sand covering the trail.
- Annual reports, due by the end of June each year to tally the results of the prior year's observations/measurements, summarize the occurrence of trigger actions, and to conclude on the need to conduct a scheduled (or unscheduled) sand placement in the following summer season, or the need to conceal exposed portions of the LPW.

B) At North Ocean Beach Borrow Site

- June and December beach profile surveys at low tide for a minimum of 10 transects covering the extent of the borrow site. Report in the Annual Report under A) in order to confirm the availability of sufficient sand quantity in the event a sand placement event is scheduled or triggered.

5. References

Abeysirigunawardena, D.S., Gilleland, E., Bronaugh, D., and Wong, P. (2009). *Extreme Wind Regime Responses to Climate Variability and Change in the Inner South Coast of British Columbia, Canada*. Journal of Atmosphere-Ocean, 47:1, p. 41-62.

Barnard, P.L., Schoellhamer, D.H., Jaffe, B.E. and McKee, L.J. (2013). *Sediment Transport in the San Francisco Bay Coastal System: an Overview*. Marine Geology, Special Issue San Francisco Bay, Volume 345, p. 3-17.

Barnard, P.L., Hansen, J.E., and Erikson, L.H. (2012). *Synthesis Study of an Erosion Hot Spot, Ocean Beach, California.* Journal of Coastal Research, Vol. 28, Issue 4, p. 903-922.

Bruun, P. (1983). *Review of Conditions for Uses of the Bruun Rule of Erosion.* Coastal Engineering, Vol. 7, p. 77-89.

Bruun, P. (1962). *Sea-Level Rise as a Cause of Shore Erosion.* American Society of Civil Engineers, Journal of the Waterways and Harbors Division, Vol. 88, Issue 1, p. 117-132.

California Coastal Commission (2015). *Staff Report, Coastal Development Permit Application 2-15-1357*. Applicant: San Francisco Public Utilities Commission.

Dean, R.G. (2002). *Beach Nourishment: Theory and Practice.* Advanced Series on Ocean Engineering, Volume 18. Published by World Scientific Publishing Ltd. ISBN 981-02-1547-9.

Dallas, K.L., Eshleman, J., and Beavers, R. (2012). *National Park Service Beach Nourishment Guidance.* Natural Resource Technical Report NPS/NRSS/GRD/NRTR-2012/581. National Park Service, Fort Collins, Colorado, U.S. Department of the Interior.

ESA (2019). *Ocean Beach Short-Term Erosion Protection Measures Project, 2018-2019 Monitoring Report.* Prepared for San Francisco Public Utilities Commission. Final Report: July, 2019.

ESA (2018). *Ocean Beach Short-Term Erosion Protection Measures Project, 2017-2018 Monitoring Report.* Prepared for San Francisco Public Utilities Commission. Final Report: September, 2018.

ESA (2017). *Ocean Beach Short-Term Erosion Protection Measures Project, 2016-2017 Monitoring Report.* Prepared for San Francisco Public Utilities Commission. Final Report: October, 2017.

ESA (2016a). *Implementation Guidance of Wind-Blown Sand Mitigation Measures, South Ocean Beach Short-Term Erosion Protection Measures Project.* A Memorandum Prepared for San Francisco Public Utilities Commission. February 16, 2016.

ESA (2016b). *Ocean Beach Short-Term Erosion Protection Measures Project, 2015-2016 Monitoring Report.* Prepared for San Francisco Public Utilities Commission. Final Report: October, 2016.

ESA, Kearns & West, Peter R. Baye, PhD, and Philip King, PhD (2016). *San Francisco Littoral Cell Coastal Regional Sediment Management Plan.* Prepared for The California Coastal Sediment Management Workgroup. Draft Report. January 2016.

Imagine That Inc. (2013). *ExtendSim 9 User Guide.* ISBN: 978-0-9825040-4-8.

Komar, P.D. (1998). *Beach Processes and Sedimentation.* 2nd Edition. Simon & Schuster, Upper Saddle River, NJ.

M&N & AGS (2019). *Conceptual Engineering Report, Ocean Beach Long-Term Improvements Project.* Prepared for: San Francisco Public Utilities Commission. Prepared by: Moffatt & Nichol and AGS Joint Venture. Final Report: September 30, 2019.

M&N (2015). *Ocean Beach – 2014 Sand Backpass Project Monitoring.* Prepared for: San Francisco Public Utilities Commission. Memorandum: November 17, 2015.

M&N (2014). *Ocean Beach – Sand Backpass Monitoring, February 2014 Survey.* Prepared for: San Francisco Department of Public Works. Memorandum: May 13, 2014.

M&N (2007). *Guidance for A Beach Nourishment Study Under Section 933, Ocean Beach, California.* Prepared for: City & County of San Francisco. July, 2007.

M&N (2005). *Ocean Beach – Great Highway Storm Damage Protection Project.* Prepared for: San Francisco Department of Public Works, U.S. Army Corps of Engineers. Final Report: May 31, 2005.

Nielsen P. and Hanslow, D.J. (1991). *Wave Runup Distributions on Natural Beaches.* Journal of Coastal Research, 7(4), p.1139-1152.

NOAA (2020). *NOAA Shoreline Website*. A Guide to National Shoreline Data and Terms. https://shoreline.noaa.gov/glossary.html.

NOAA (2011). *Digital Elevation Models of Central California and San Francisco Bay: Procedures, Data Sources and Analysis.* NOAA Technical Memorandum NESDIS NGDC-52. August 2011.

Ocean Protection Council (2018). *State of California Sea-Level Rise Guidance.* 2018 Update.

Schoonees, J.S. and Theron, A.K. (1995). *Evaluation of 10 Cross-Shore Sediment Transport/Morphological Models.* Journal of Coastal Engineering 25 (1995) p.1-41.

San Francisco Clean Water Program (1986). *Ocean Beach – Beach Nourishment Plan.* Prepared for: California Coastal Commission. November 1986.

SFPUC (2018). *Alternatives Analysis Report for Coastal Adaptation Strategies for South Ocean Beach Wastewater Systems.* Project No. CWWFAC01. Prepared for: Wastewater Enterprises, San Francisco Public Utilities Commission. Prepared by: Engineering Management Bureau. February 2018.

SPUR (2015). *Coastal Protection Measures & Management Strategy for South Ocean Beach.* Prepared for San Francisco Public Utilities Commission. Prepared by SPUR with ESA PWA, Moffatt & Nichol, McMillen Jacobs Associates, and AGS, Inc. April 24, 2015.

SPUR (2012). *Ocean Beach Master Plan.* Prepared by: SPUR with AECOM, ESA PWA, Nelson/Nygaard, Sherwood Design Engineers, and Phil D. King, PhD. May 2012.

USACE (2012). *Littoral Transport Modeling for Ocean Beach and San Francisco Bight, California.* Prepared by: Lihwa Lin, Honghai Li, Frank Wu, and Lisa C. Andes. Coastal Engineering Proceedings 1(33). December 2012.

USACE (2002). *Coastal Engineering Manual*. EM 1110-2-1100. August 1, 2008 (Change 2).

USGS (2020). *Ocean Beach LMT Seawall Project Area Erosion Rates.* Processed and Provided by Dan Hoover, PhD. Unpublished Data. February 5, 2020.

USGS (2008). *The Performance of Nearshore Dredge Disposal at Ocean Beach, San Francisco, California, 2005-2007*. Open-File Report 2008–1347, 99 p. Prepared by: Patrick L. Barnard, Li H. Erikson, Jeff E. Hansen, and Edwin Elias. U.S. Department of the Interior, U.S. Geological Survey.

USGS (2007). *Coastal Processes Study at Ocean Beach, San Francisco, CA: Summary of Data* Collection 2004-2006. Open-File Report 2007–1217, 171 p. Prepared by: Patrick L. Barnard, Jodi Eshleman, Li H. Erikson, and Daniel M. Hanes. U.S. Department of the Interior, U.S. Geological Survey.

Vitousek, S., Barnard, P.L., Limber, P., Erikson, L., and Cole, B. (2017). *A Model Integrating Longshore and Cross-Shore Processes for Predicting Long-Term Shoreline Response to Climate Change.* Journal of Geophysical Research: Earth Surface, 122, p. 782-806.

Willmott, C.J., Ackleson, S.G., Davis, R.E., Feddema, J.J., Klink, K.M., Legates, D.R., O'Donnell, J., and Rowe, C.M., 1985. Statistics for the evaluation and comparison of models. Journal of Geophysical Research 90.C5 (1985): 8995-9005.

Work, P.A., Karasu, S., Cambazoğlu, M.K., and Srisuwan, C. (2010). *Sediment Size Influence on Beach Nourishment Evolution.* 9th International Congress on Advances in Civil Engineering.

Wright, L.D., Short, A.D., and Green, M.O. (1985). *Short-Term Changes in the Morphodynamic States of Beaches and Surf Zones: An Empirical Predictive Model.* Journal of Marine Geology, 62, p. 339-364.

Yates, M.L., Guza, R.T., O'Reilly, W.C., Hansen, J.E., and Barnard, P.L. (2011). *Equilibrium Shoreline Response of a High Wave Energy Beach.* Journal of Geophysical Research, Vol. 116, C04014.

6. Bibliography

The USGS has been studying and analyzing coastal processes along Ocean Beach over the past several decades. They have also been collecting and maintaining an extremely valuable data set of beach and bluff conditions for Ocean Beach. A partial list of publications related to coastal processes for the study is listed below.

1. Barnard, P.L. and Hanes, D.M., 2005. Integrating field research, modeling and remote sensing to quantify morphodynamics in a high-energy coastal setting, Ocean Beach, San Francisco, California. *5th International Conference on Coastal Dynamics 2005 Conference Proceedings*, Barcelona, Spain, American Society of Civil Engineers, CD-ROM, 14 pp., http://walrus.wr.usgs.gov/reports/reprints/Barnard_ASCE.pdf
2. Barnard, P.L. and Hanes, D.M., 2006. Coastal monitoring of the May 2005 dredge disposal offshore of Ocean Beach, San Francisco, California. U.S. Geological Survey, Open-File Report 2006-1140, 27 pp., http://pubs.usgs.gov/of/2006/1140/
3. Barnard, P.L. and Kvitek, R.G., 2010. Anthropogenic influence on recent bathymetric change in west-central San Francisco Bay. *San Francisco Estuary and Watershed Science*, Volume 8 (3), 13 pp., http://escholarship.org/uc/item/6k3524hg
4. Barnard, P.L., Allan, J., Hansen, J.E., Kaminsky, G.M., Ruggiero, P. and Doria, A., 2011. The impact of the 2009-10 El Niño Modoki on U.S. West Coast beaches. *Geophysical Research Letters*, Volume 38, L13604, 7 pp., http://dx.doi.org/10.1029/2011GL047707
5. Barnard, P.L., Erikson, L.H. and Hansen, J.E., 2009. Monitoring and modeling shoreline response due to shoreface nourishment on a high-energy coast. *Journal of Coastal Research*, Special Issue 56, p. 29-33, http://e-geo.fcsh.unl.pt/ICS2009/_docs/ICS2009_Volume_I/29.33_P.L.Barnard_ICS2009.pdf
6. Barnard, P.L., Erikson, L.H., Elias, E.P.L. and Dartnell, P., 2013. Sediment transport patterns in the San Francisco Bay Coastal System from cross-validation of bedform asymmetry and modeled residual flux. *Marine Geology*, Special Issue San Francisco Bay, Volume 345, p. 72-95, http://dx.doi.org/10.1016/j.margeo.2012.10.011
7. Barnard, P.L., Erikson, L.H., Hansen, J.E. and Elias, E., 2009. The performance of nearshore dredge disposal at Ocean Beach, San Francisco, California, 2005-2007. U.S. Geological Survey Open-File Report 2008-1347, 93 pp., http://pubs.usgs.gov/of/2008/1347/
8. Barnard, P.L., Erikson, L.H., Rubin, D.M., Dartnell, P. and Kvitek, R.G., 2012. Analyzing bedforms mapped using multibeam sonar to determine regional bedload sediment transport patterns in the San Francisco Bay coastal system. *Sedimentology*, In: Li, M.Z., Sherwood, C.R., and Hill, P.R. (Eds.), Sediments, Morphology and Sedimentary Processes on Continental Shelves: Advances in technologies, research and applications. Special Publication 44 of the International Association of Sedimentologists (IAS), p. 273-294, http://dx.doi.org/10.1002/9781118311172.ch13
9. Barnard, P.L., Eshleman, J.L., Erikson, L.H. and Hanes, D.M., 2007. Coastal processes study at Ocean Beach, San Francisco, CA: summary of data collection 2004-2006. U.S. Geological Survey Open-File Report 2007-1217, 165 pp., http://pubs.usgs.gov/of/2007 /1217/
10. Barnard, P.L., Foxgrover, A.C., Elias, E.P.L., Erikson, L.H., Hein, J.R., McGann, M., Mizell, K., Rosenbauer, R.J., Swarzenski, P.W., Takesue, R.K., Wong, F.L. and Woodrow, D.L., 2013. Integration of bed characteristics, geochemical tracers, current measurements, and numerical modeling for assessing provenance of beach sand in the San Francisco Bay Coastal System.

Marine Geology, Volume 336, p. 120-145, http://dx.doi.org/10.1016/j.margeo.2012.11.008, and Special Issue San Francisco Bay, Volume 345, p. 181-206, http://dx.doi.org/10.1016/j.margeo.2013.08.007

11. Barnard, P.L., Hanes, D.M., Kvitek, R.G. and Iampietro, P.J., 2006. Sand waves at the mouth of San Francisco Bay, California. U.S. Geological Survey, Scientific Investigations Map 2006-2944, 5 map sheets, http://pubs.usgs.gov/sim/2006/2944/
12. Barnard, P.L., Hanes, D.M., Lescinski, J. and Elias, E., 2007. Monitoring and modeling nearshore dredge disposal for indirect beach nourishment, Ocean Beach, San Francisco. In: Smith, J.M. (Ed.), *Coastal Engineering 2006, Proceedings of the 30th International Conference*, San Diego, CA, USA, 3-8 September 2006, Volume 4, p. 4192-4204, http://dx.doi.org/10.1142/9789812709554_0352
13. Barnard, P.L., Hanes, D.M., Rubin, D.M. and Kvitek, R.G., 2006. Giant sand waves at the mouth of San Francisco Bay. *Eos Transactions of the American Geophysical Union*, Volume 87 (29), p. 285, 289, http://dx.doi.org/10.1029/2006EO290003
14. Barnard, P.L., Hansen, J.E. and Erikson, L.H., 2012. Synthesis study of an erosion hot spot, Ocean Beach, California. *Journal of Coastal Research*, Volume 28 (4), p. 903-922. http://dx.doi.org/10.2112/JCOASTRES-D-11-00212.1
15. Barnard, P.L., Hoover, D. and Hansen, J.E., 2011. Nearshore bathymetric evolution on a high-energy beach during the 2009-10 El Niño winter. In: Wang, P., Rosati, J.D. and Roberts, T.M. (Eds.) *Coastal Sediments '11, Proceedings of the 7th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes*, American Society of Civil Engineers, Miami, FL, p. 1390-1403, http://dx.doi.org/10.1142/9789814355537_0105
16. Barnard, P.L., Hoover, D.J., Hubbard, D.M., Snyder, A., Ludka, B.C., Allan, J., Kaminsky, G.M., Ruggiero, P., Gallien, T.W., Gabel, L., McCandless, D., Weiner, H.M., Cohn, N., Anderson, D.L. and Serafin, K.A., 2017. Extreme oceanographic forcing and coastal response due to the 2015-2016 El Niño. *Nature Communications*, Volume 8 (14365), 8 pp., http://dx.doi.org/10.1038/ncomms14365
17. Barnard, P.L., Rubin, D.M., Harney, J. and Mustain, N., 2007. Field test comparison of an autocorrelation technique for determining grain size using a digital 'beachball' camera versus traditional methods. *Sedimentary Geology*, Volume 201 (1-2), p. 180-195, http://dx.doi.org/10.1016/j.sedgeo.2007.05.016
18. Barnard, P.L., Schoellhamer, D.H., Jaffe, B.E. and McKee, L.J., 2013. Sediment transport in the San Francisco Bay Coastal System: an overview. *Marine Geology*, Special Issue San Francisco Bay, Volume 345, p. 3-17, http://dx.doi.org/10.1016/j.margeo.2013.04.005
19. Barnard, P.L., Short, A.D., Harley, M.D., Splinter, K.D., Vitousek, S., Turner, I.L., Allan, J., Banno, M., Bryan, K.R., Doria, A., Hansen, J.E., Kato, S., Kuriyama, Y., Randall-Goodwin, E., Ruggiero, P., Walker, I.J. and Heathfield, D.K., 2015. Coastal vulnerability across the Pacific dominated by El Niño/Southern Oscillation. *Nature Geoscience*, Volume 8, p. 801-807, http://dx.doi.org/10.1038/ngeo2539
20. Collins, B. D. & Sitar, N. Processes of coastal bluff erosion in weakly lithified sands, Pacifica, California, USA. *Geomorphology* 97, 483–501 (2008).
21. Dallas, K. and Barnard, P.L., 2009. Linking human impacts within an estuary to ebb-tidal delta evolution. *Journal of Coastal Research*, Special Issue 56, p. 713-716, http://e-geo.fcsh.unl.pt/ICS2009/_docs/ICS2009_Volume_I/713.716_K.L.Dallas_ICS2009.pdf

22. Dallas, K. and Barnard, P.L., 2011. Anthropogenic influences on shoreline and nearshore evolution in the San Francisco Bay coastal system. *Estuarine, Coastal and Shelf Science*, Volume 92 (1), p. 195-204, http://dx.doi.org/10.1016/j.ecss.2010.12.031

23. Danielson, J.J., Poppenga, S.K., Brock, J.C., Evans, G.A., Tyler, D.J., Gesch, D.B., Thatcher, C.A., and Barras, J.A., 2016, Topobathymetric elevation model development using a new methodology—Coastal National Elevation Database: Journal of Coastal Research, SI no. 76, p. 75–89, at http://dx.doi.org/10.2112/SI76-008

24. Elias, E.P.L., Hansen, J.E., 2013. Understanding processes controlling sediment transports at the mouth of a high-energetic inlet system (San Francisco Bay, CA). Marine Geology, Special Issue San Francisco Bay, Volume 345, p. 207-220, http://dx.doi.org/10.1016/j.margeo.2012.07.003

25. Erikson, L., Hanes, D.M., Barnard, P.L. and Gibbs, A.E., 2007. Swash zone characteristics at Ocean Beach. In: Smith, J.M. (Ed.), *Coastal Engineering 2006, Proceedings of the 30th International Conference*, San Diego, CA, USA, 3-8 September 2006, Volume 1, p. 909-921, http://dx.doi.org/10.1142/9789812709554_0078

26. Erikson, L.H., Barnard, P.L., O'Neill, A.C., Wood, N., Jones, J., Finzi-Hart, J., Vitousek, S., Limber, P.W., Fitzgibbon, M., Hayden, M., Lovering, J. and Foxgrover, A.C., 2018. Projected 21st Century coastal flooding in the Southern California Bight. Part 2: tools for assessing climate change driven coastal hazards and socio-economic impacts. *Journal of Marine Science and Engineering*, Volume 6 (Issue 3), Article 76, 19 pp., http://dx.doi.org/10.3390/jmse6030076

27. Erikson, L.H., O'Neill, A., Barnard, P.L., Vitousek, S., Limber, P., 2017. Climate change-driven cliff and beach evolution at decadal to centennial time scales. *Coastal Dynamics 2017*, Paper No. 210, p. 125-136, http://coastaldynamics2017.dk/proceedings.html

28. Eshleman, J.L., Barnard, P.L., Erikson, L.H. and Hanes, D.M., 2007. Coupling alongshore variations in wave energy to beach morphologic change using the SWAN wave model at Ocean Beach, San Francisco, CA. *10th International Workshop on Wave Hindcasting and Forecasting*, Oahu, Hawaii, November 11-16, 2007, Paper F4, 20 pp., http://www.waveworkshop.org/10thWaves/Papers/Eshlemanetal_Waves2007_final.pdf

29. Hanes, D.M, Barnard, P.L., Erikson, L.H., Shi, F., Elias, E., Hsu, T.J., Hansen, J.E. and Dallas, K., 2011. Recent scientific advances and their implications for sand management near San Francisco: the influence of the ebb tidal delta. In: Wang, P., Rosati, J.D. and Roberts, T.M. (Eds.) *Coastal Sediments '11, Proceedings of the 7th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes*, American Society of Civil Engineers, Miami, FL, p. 472-483, http://dx.doi.org/10.1142/9789814355537_0036

30. Hanes, D.M. and Barnard, P.L., 2007. Morphological Evolution in the San Francisco Bight. *Journal of Coastal Research*, Special Issue 50, p. 469-473, http://www.griffith.edu.au/conference/ics2007/pdf/ICS090.pdf

31. Hansen, J.E. and Barnard, P.L., 2009. The observed relationship between wave conditions and beach response: a tool for coastal management. *Journal of Coastal Research*, Special Issue 56, p. 1771-1775, http://e-geo.fcsh.unl.pt/ICS2009/_docs/ICS2009_Volume_II/1771.1775_J.E.Hansen_ICS2009.pdf

32. Hansen, J.E. and Barnard, P.L., 2010. Sub-weekly to interannual variability of a high-energy shoreline. *Coastal Engineering*, Volume 57 (11-12), p. 959-972, http://dx.doi.org/10.1016/j.coastaleng.2010.05.011

33. Hansen, J.E., Elias, E., and Barnard, P.L., 2013. Changes in surf zone morphodynamics driven by multi-decadal contraction of a large ebb-tidal delta. *Marine Geology*, Special Issue San Francisco Bay, Volume 345, p. 221-234, http://dx.doi.org/10.1016/j.margeo.2013.07.005

34. Hansen, J.E., Elias, E., List, J.H. and Barnard, P.L., 2011. A numerical model investigation of the formation and persistence of an erosion hot spot. In: Wang, P., Rosati, J.D. and Roberts, T.M. (Eds.) *Coastal Sediments '11, Proceedings of the 7th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes*, American Society of Civil Engineers, Miami, FL, p. 1769-1782, http://dx.doi.org/10.1142/9789814355537_0134

35. Hansen, J.E., Elias, E., List, J.H., Erikson, L.H. and Barnard, P.L., 2013. Tidally influenced alongshore circulation at an inlet-adjacent shoreline. *Continental Shelf Research*, Volume 56, p. 26-38, http://dx.doi.org/10.1016/j.csr.2013.01.017

36. Hansen, J.E., Janssen, T.T., Raubenheimer, B., Shi, F., Barnard, P.L. and Jones, I.S., 2014. Observations of surfzone alongshore pressure gradients onshore of an ebb-tidal delta. *Coastal Engineering*, Volume 91, p. 251-260, http://dx.doi.org/10.1016/j.coastaleng.2014.05.010

37. Hein, J.R., Mizell, K. and Barnard, P.L., 2013. Sand sources and transport pathways for the San Francisco Bay coastal system, based on X-ray diffraction mineralogy. *Marine Geology*, Special Issue San Francisco Bay, Volume 345, p. 154-169, http://dx.doi.org/10.1016/j.margeo.2013.04.003

38. Limber, P., Barnard, P.L., Vitousek, S. and Erikson, L.H., 2018. A model ensemble for projecting multi-decadal coastal cliff retreat during the 21st century. *Journal of Geophysical Research-Earth Surface*, Volume 123, p.1566-1589, http://dx.doi.org/10.1029/2017JF004401

39. McGann, M., Erikson, L., Wan, E., Powell II, C., Maddocks, R.F., 2013. Distribution of biologic, anthropogenic, and volcanic constituents as a proxy for sediment transport in the San Francisco Bay Coastal System. Marine Geology, Special Issue San Francisco Bay, Volume 345, p. 113-142, http://dx.doi.org/10.1016/j.margeo.2013.05.006

40. O'Neill, A.C., Erikson, L.H., Barnard, P.L., Limber, P.W., Vitousek, S., Warrick, J.A, Foxgrover, A.C. and Lovering, J., 2018. Projected 21st century coastal flooding in the Southern California Bight. Part 1: Development of the third generation CoSMoS model. *Journal of Marine Science and Engineering*, Volume 6 (Issue 2), Article 59, 31 pp., http://dx.doi.org/10.3390/jmse6020059

41. Rosenbauer, R.J., Foxgrover, A.C., Hein, J.R., Swarzenski, P.W., 2013. A Sr-Nd isotopic study of sand-sized sediment provenance and transport for the San Francisco Bay Coastal System. Marine Geology, Special Issue San Francisco Bay, Volume 345, p. 143-153, http://dx.doi.org/10.1016/j.margeo.2013.01.002

42. Serafin, K.A., Ruggiero, P., Barnard, P.L. and Stockdon, H.F., 2019. The influence of shelf bathymetry and beach topography on extreme total water levels: linking large-scale changes of the wave climate to local coastal hazards. *Coastal Engineering*, Volume 150, p. 1-17, http://dx.doi.org/10.1016/j.coastaleng.2019.03.012

43. Shi, F., Hanes, D.M., Kirby, J.T., Erikson, L., Barnard, P.L. and Eshleman, J., 2011. Pressure gradient-dominated nearshore circulation on a beach influenced by a large inlet-tidal shoal system. *Journal of Geophysical Research-Oceans*, Volume 116, C04020, 18 pp., http://dx.doi.org/10.1029/2010JC006788

44. Splinter, K.D., Turner, I.L., Davidson, M.A., Barnard, P.L., Castelle, B. and Oltman-Shay, J., 2014. A generalized equilibrium model for predicting daily to interannual shoreline response. *Journal of Geophysical Research-Earth Surface*, Volume 119 (9), p. 1936-1958, http://dx.doi.org/10.1002/2014JF003106

45. Splinter, K.D., Turner, I.L., Davidson, M.A., Barnard, P.L., Castelle, B. and Oltman-Shay, J., 2014. A generalized equilibrium model for predicting daily to interannual shoreline response. *Journal of*

Geophysical Research-Earth Surface, Volume 119 (9), p. 1936-1958, http://dx.doi.org/10.1002/2014JF003106

46. Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface*, Volume 122, p. 782-806

47. Warrick, J.A., Ritchie, A.C., Adelman, G., Adelman, K. and Limber, P.W., 2017. New techniques to measure cliff change from historical oblique aerial photographs and Structure-from-Motion photogrammetry. *Journal of Coastal Research*, Volume 33 (1), p. 39-55, https://doi.org/10.2112/JCOASTRES-D-16-00095.1

48. Wong, F.L., Woodrow, D.L., McGann, M., 2013. Heavy mineral analysis for assessing the provenance of sandy sediment in the San Francisco Bay Coastal System. Marine Geology, Special Issue San Francisco Bay, Volume 345, p. 170-180, http://dx.doi.org/10.1016/j.margeo.2013.05.012

49. Yates, M.L., Guza, R.T., O'Reilly, W.C., Hansen, J.E. and Barnard, P.L., 2011. Equilibrium shoreline response of a high wave energy beach. *Journal of Geophysical Research-Oceans*, Volume 116, C04014, 13 pp., http://dx.doi.org/10.1029/2010JC006681

Appendix A:
Sub-Plan "S" Series Operations
(2012 Sand Backpass by Power Engineering Contractors)

Ocean Beach Shoreline Protection – Sand Management Project
(North End of Ocean Beach to South of Sloat Blvd.)

SUMMARY

The San Francisco Department of Public Works (SFDPW) and the San Francisco Public Utilities Commission (SFPUC) have been contacted by the National Parks Service (NPS) to evaluate and consider moving large quantities of sand from the North end of Ocean Beach to the area South of Sloat Blvd. The O'Shaughnessy seawall has been inundated with sand and is blowing onto the Great Highway. This is creating a considerable maintenance problem for NPS and, to a lesser degree, City infrastructure in the general area. The City will be partnering with NPS to provide a means of moving the sand via the SFPUC Job Order Contract process.

The following is a conceptual outline of the proposed sand maintenance project using aerial photos to provide a general scope of work, identify site and access constraints, and describe options to consider in moving sand from the North end of Ocean Beach to the area South of Sloat Blvd.

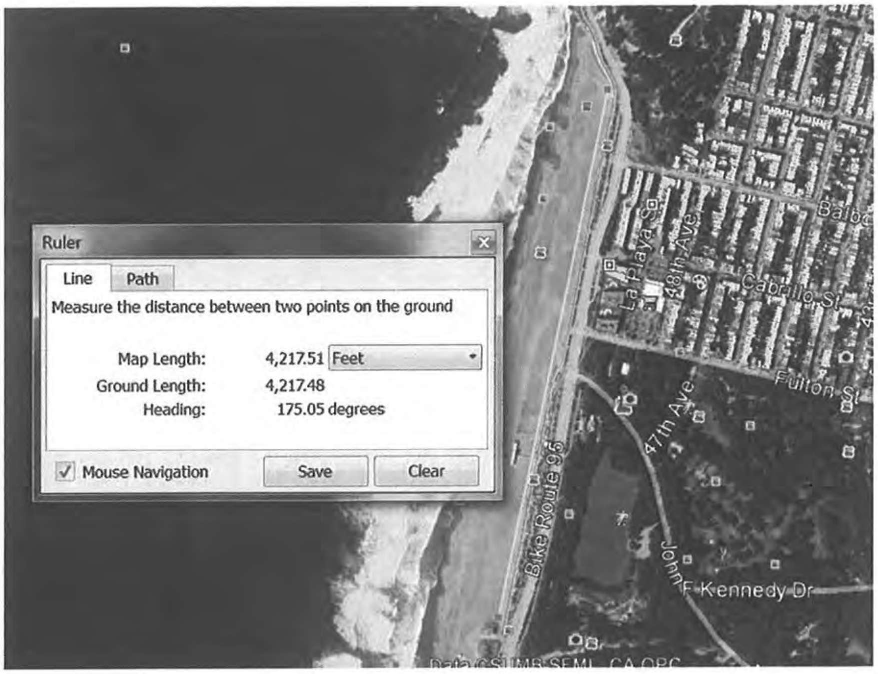
The City is proposing to move anywhere from 90,000 to upwards of 200,000 cuyd of sand, depending on site logistics and costs involved. Moving this large a volume of sand may require a combination of excavators, articulated off-road trucks, motor graders and dozers. This is a time and motion exercise. The actual amount of sand to be move is a function of how quickly and efficiently the Contractor can move material from one end of the Great Highway to the other. The simpler the exercise the more material can be moved.

PROPOSED BEACH ACCESS (Off Lincoln Way & The Great Highway)

Point of entrance and exit from beach. This is where the Contractor will enter/exit the Beach.

There is no easy entrance onto Ocean Beach. The closest point is at the south end of the Sea Wall where the NPS equipment accesses the beach. This would put the Contractor onto Ocean Beach from the Great Highway southbound lanes.

NORTH END SAND SOURCE

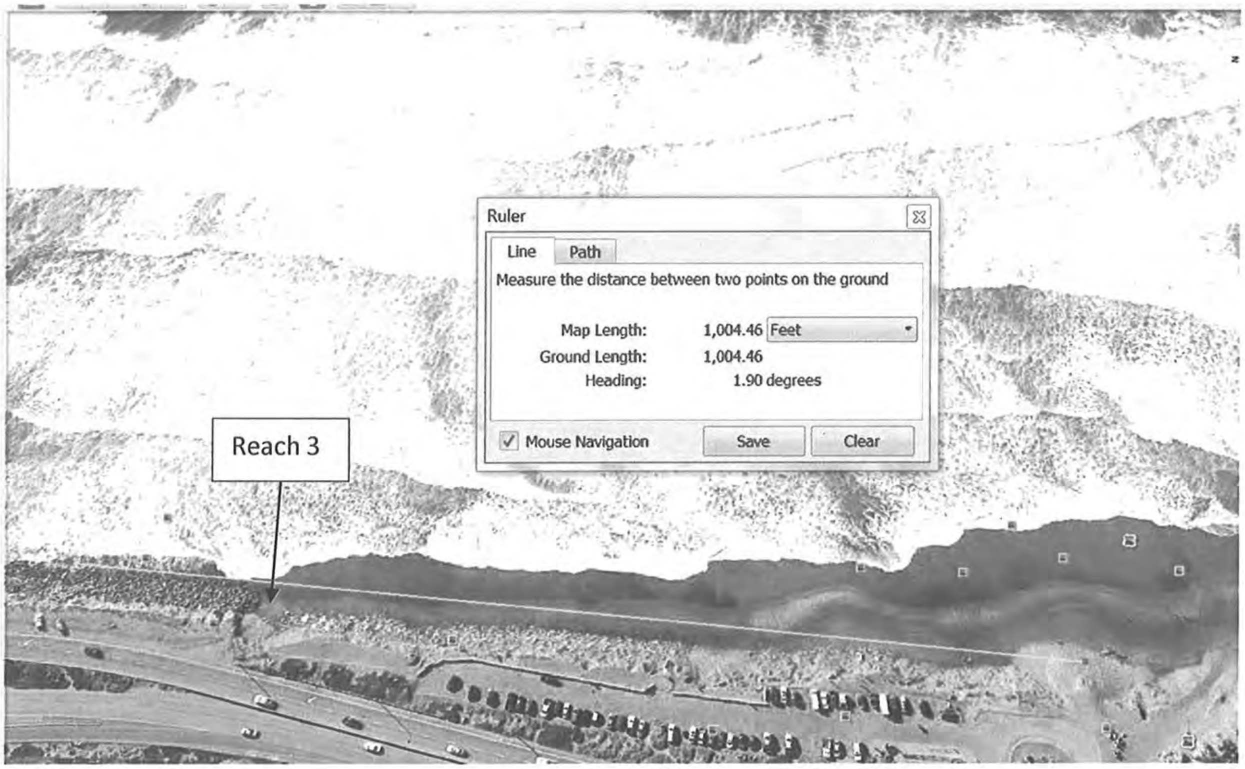


The beach is approximately 4,200 feet long but anything south of Stairwell 21 is Plover habitat. There are 28 stairwells from North to South with a narrow access ramp at Stairwell 15 near JFK Drive.

Excavation width approximately 20 - 30 feet or greater depending on the depth.

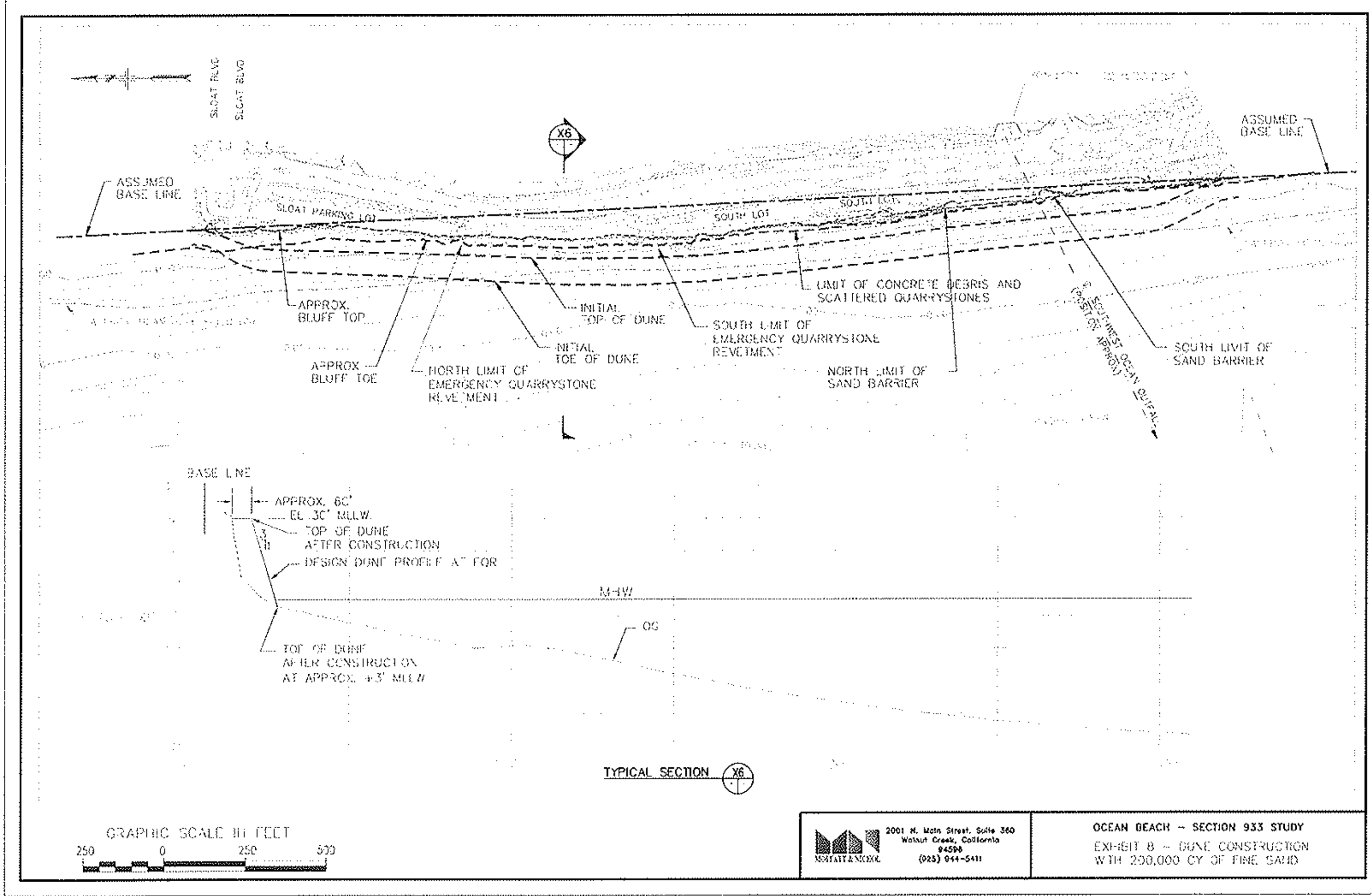
The intent is to excavate the sand down past the stairs to lower the back beach profile about 5 to 10 feet or more for a width of 20 to 30 feet or more. The actual depth and width to be determined in the field. For example an excavation of 90' by 10' by 3000' is 100,000 cubic yards. The beach width in this aerial photo is in excess of 600 feet.

SOUTH END SAND PLACEMENT



Place sand as directed in the field by the City Representative to cover a portion of the EQR, the recently installed large-capacity sand bags at Reach 3, the (E) rubble along the westerly side of the parking lot, and create a sand ladder at the Reach 3 area. A sand ladder at the MUNI turnaround area could allow access for larger vehicles. Priority for placing the sand will start in and around the Reach 3 sand bag area and proceed north to the MUNI turnaround area. The area south of the Reach 3 sandbags (i.e. on top of the EQR) will be the next level priority for sand placement, cost permitting.

SIZE AND TYPES OF EQUIPMENT TO MOVE AND GRADE SAND



SLOAT BLVD
ASSUMED BASE LINE
SLOAT PARKING LOT
SOUTH LOT
APPROX. BLUFF TOP
APPROX BLUFF TOE
INITIAL TOP OF DUNE
INITIAL TOE OF DUNE
NORTH LIMIT OF EMERGENCY QUARRYSTONE REVETMENT
SOUTH LIMIT OF EMERGENCY QUARRYSTONE REVETMENT
LIMIT OF CONCRETE DEBRIS AND SCATTERED QUARRYSTONES
NORTH LIMIT OF SAND BARRIER
SOUTH LIMIT OF SAND BARRIER
SOUTHWEST OCEAN OUTFALL
BASE LINE
APPROX. 60'
EL 30' MLLW.
TOP OF DUNE AFTER CONSTRUCTION
DESIGN DUNE PROFILE AT FOR
MHW
OG
TOE OF DUNE AFTER CONSTRUCTION AT APPROX. +3' MLLW
TYPICAL SECTION X6
GRAPHIC SCALE IN FEET
250 0 250 500
2001 N. Main Street, Suite 360
Walnut Creek, California 94596
(925) 944-5411
MOFFATT & NICHOL
OCEAN BEACH – SECTION 933 STUDY
EXHIBIT 8 – DUNE CONSTRUCTION WITH 200,000 CY OF FINE SAND

San Francisco Water Power Sewer

SAN FRANCISCO PUBLIC UTILITIES COMMISSION

Project Initiation Form

Job Order Contract

Project Information:

Project Manager: Ryan Cayabyab Office Ph: 415-554-0721 Cell: 415-760-0391

Project Title: Ocean Beach Shoreline Protection - Sand Management Project (North End of Ocean Beach to South of Sloat Blvd.)

Location: Ocean Beach Area County of Work: San Francisco

Brief Project Description: Move large quantities of sand from north end of Ocean Beach to the shoreline area South of Sloat Blvd. Refer to attached document for more information.

Construction Estimate: $ 250,000 - 350,000 + / - Funding Index Code: TBD

Liquidated Damages: $ 500.00 (Default LD Value is $500.00 / Day Unless Noted Otherwise)

Schedule: Estimated Construction Start Date: 05/21/12 Completion Date: 07/20/12

Request for Specific JOC Contractor: Power Engineering

Will Specialty Subcontractor be added? No ☒ Yes ☐ Est. Specialty Subcontractor $: N/A

If Yes, state name of Specialty Subcontractor: N/A Is Specialty Subcontractor LBE? N/A

COMPLETE PAGE 2 QUESTIONNAIRE FOR TASK ORDER SPECIFIC ADDITIONAL INSURANCE COVERAGES

Obtain Signatures only for Projects *Over* $400,000 **

***San Francisco Administration Code, Sec.6.62 (H) JOB ORDER CONTRACTS: No work order shall exceed $400,000, including all modifications. A department may issue or modify any work orders(s) to exceed the foregoing limits only upon the department head's written determination establishing the urgency of the work and the justification for proceeding under this Section 6.62 rather than by formal competitive process.*

Please Attach Letter of Justification if Task Order Exceeds $400,000

Approval Signatures:

1)	Ryan Cayabyab	04/17/12		4)		
	Project Manager	Date			General Manager, SFPUC	Date
2)				5)		
	Bureau / Division Manager	Date			JOC Manager	Date
3)						
	AGM Infrastructure	Date				

(Complete and Attach to Project Initiation Form. This form designates additional insurance coverage for the Task Order, beyond the standard contract coverage of Worker's Compensation for $1 million, Commercial General Liability $1 million, Commercial Auto Liability $1 million)

☐**YES** ☒**NO** Does the contract involve construction of a building or other facility, or substantial renovation of existing facilities? *(A YES answer will add requirement for Builder's Risk coverage. Builder's Risk covers only damage to new construction work. Builder's Risk is appropriate where a sudden or accidental event such as a fire has the potential to destroy the entire contract work. For example, Builder's Risk would be appropriate to building projects but is not appropriate for long underground water lines. Default deductible is $25,000. Check with Risk Manager.)*

☐**YES** ☒**NO** Does Contractor have City equipment in its care, custody or control for set up or installation on City premises? *(A YES answer will add requirement for Installation Floater coverage for the contractor. The default deductible is $25,000. Check with Risk Manager.)*

☐**YES** ☒**NO** Are hazardous or contaminated materials known to exist on the site? *(Answer YES if a hazardous materials survey was performed for the site, and the Contractor will perform the abatement work. If the Contractor will not perform abatement work, answer NO.)*

☐**YES** ☒**NO** Does the contract include hazardous materials abatement or remediation work, or other work where there is a substantial likelihood of encountering hazardous materials? *(A YES answer will add requirement for Contractor's Environmental Pollution Insurance coverage. The default insurance limit is $1,000,000. Circumstances of the job may require a higher limit. Check with Risk Manager.)*

☐**YES** ☒**NO** Does Contractor have City personal property or equipment (other than motor vehicles) in its care, custody or control, off City premises for storage, repair, modification, painting, etc? *(A YES answer will add requirement for Bailee's Insurance. The default deductible is $25,000. Check with Risk Manager.)*

☒**YES** ☐**NO** Enter the name of any non-City agency to be covered by Contractor's liability insurance: *(List all Agency names separated by commas. Leave the default as "None".)*

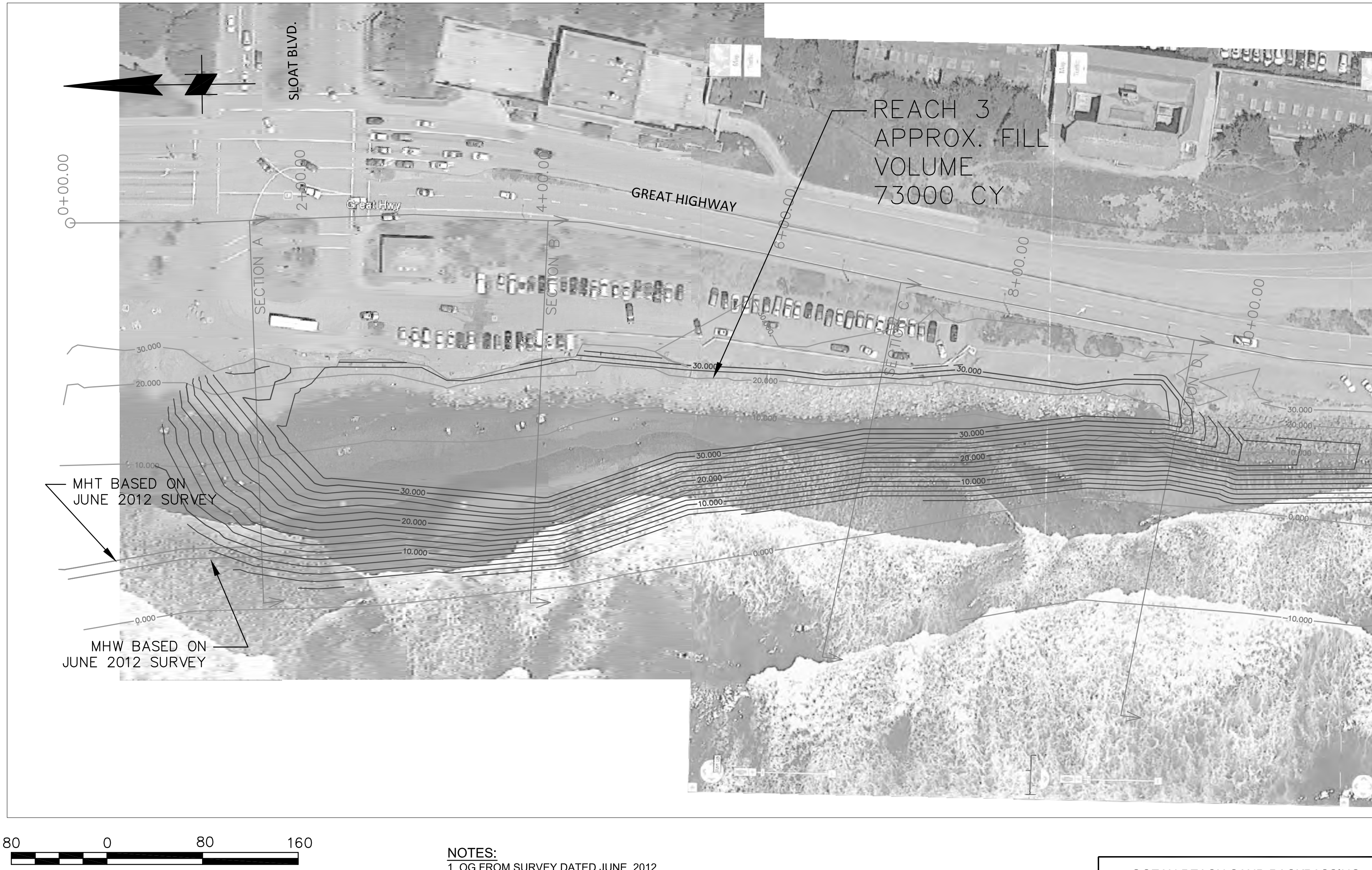
Golden Gate National Recreation Area (U.S. National Park Service)

☐**YES** ☒**NO** Does Contractor have employees who are railroad workers? *(A YES answer will add requirement for "Federal Employers Liability Act Coverage".)*

☐**YES** ☒**NO** Does Contractor have employees who work on or over navigable waters? *(A YES answer will add requirement for "U.S. Long Shore and Harbor Workers' Act Benefits".)*

☐**YES** ☒**NO** Does Contractor have employees who operate boats? *(A YES answer will add requirement for "Jones Act Benefits".)*

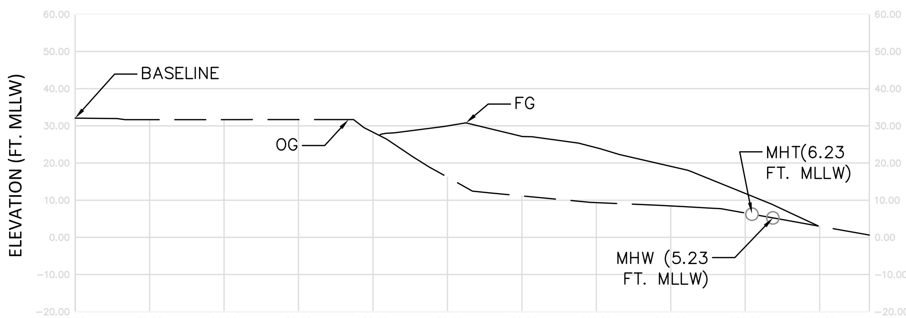
☒**YES** ☐**NO** Is there during the contract potential for explosion, blasting, excavation, damage to foundations or underground structures or utilities? *(A YES answer will add requirement for "explosion, collapse, and underground (XCU) under the Commercial General Liability Insurance.)*



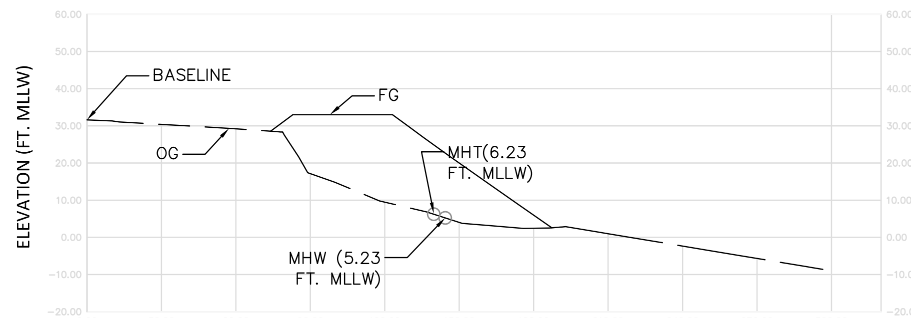
DRAFT - NOT FOR CONSTRUCTION

NOTES:
1. OG FROM SURVEY DATED JUNE, 2012
HORIZONTAL DATUM: CALIFORNIA ZONE 3 - NAD1983 (CORS96)
VERTICAL DATUM: ORIGINALLY CITY OF SAN FRANCISCO DATUM, ADJUSTED TO MLLW IN DRAWINGS
2. TO CONVERT FROM MLLW TO CITY DATUM, SUBTRACT 11.666 FT

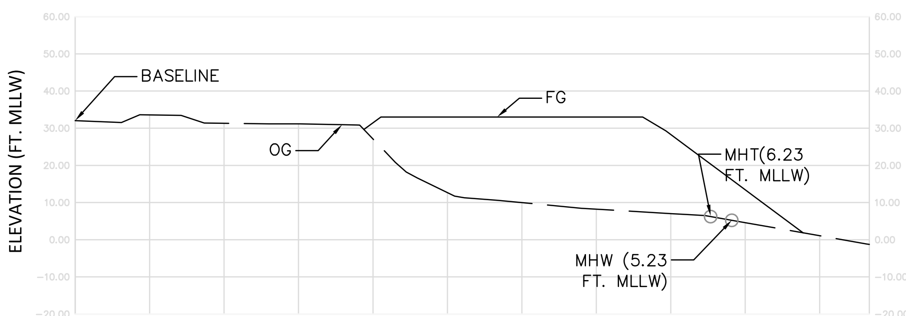
OCEAN BEACH SAND BACKPASSING PROJECT		FIG 1
moffatt & nichol	PROPOSED PLACEMENT PLAN	



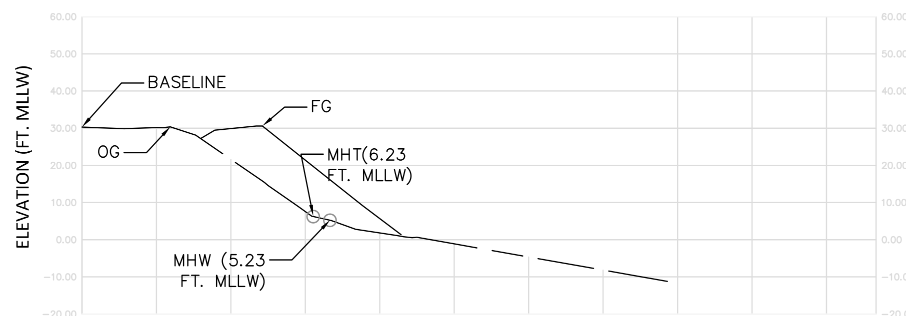
SECTION A
STATION 1+50.00



SECTION C
STATION 7+00.00



SECTION B
STATION 4+00.00



SECTION D
STATION 9+50.00

DRAFT - NOT FOR CONSTRUCTION

NOTES:
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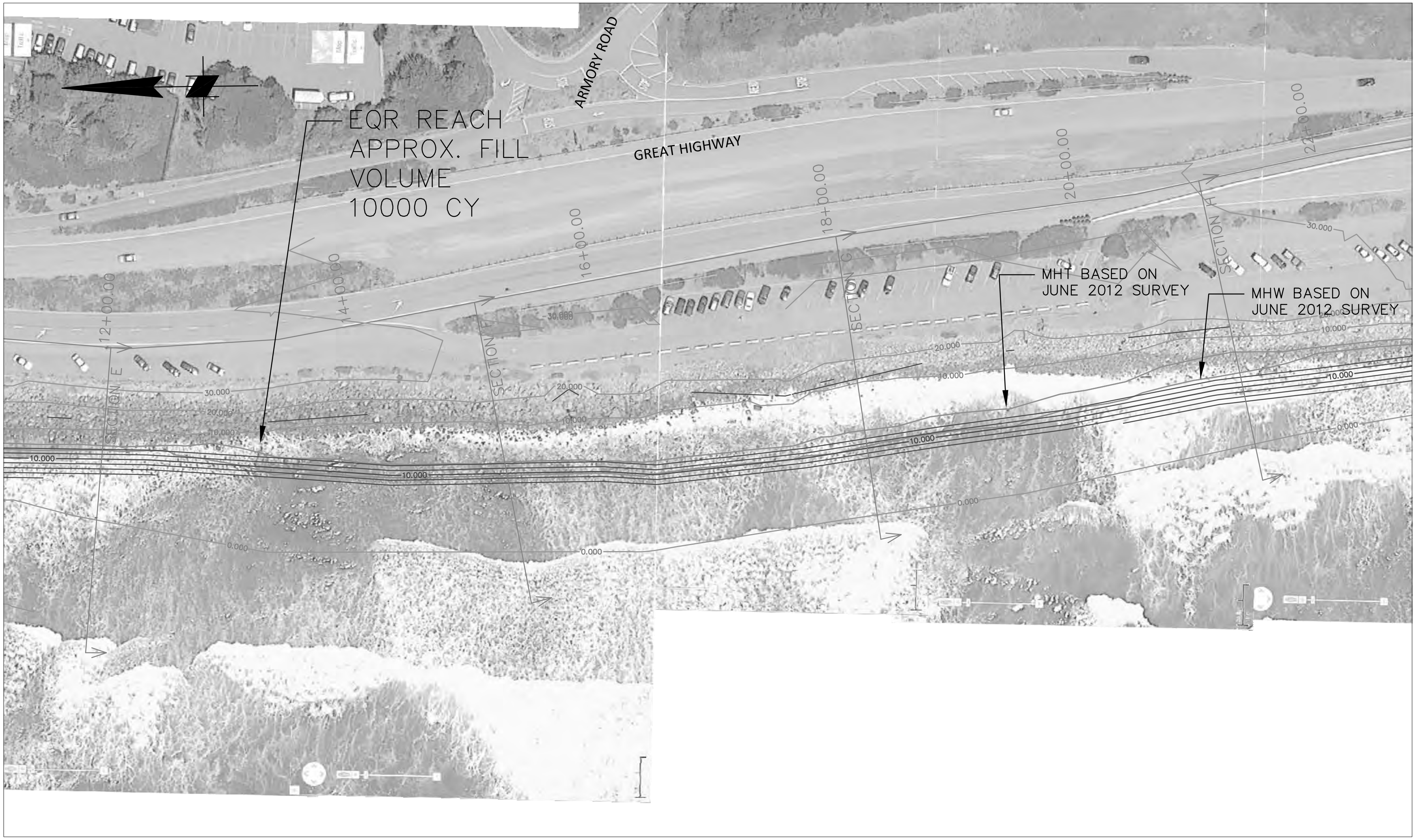
VERTICAL DATUM: ORIGINALLY CITY OF SAN FRANCISCO DATUM, ADJUSTED TO MLLW IN DRAWINGS
2. TO CONVERT FROM MLLW TO CITY DATUM, SUBTRACT 11.666 FT

OCEAN BEACH SAND BACKPASSING PROJECT

moffatt & nichol

PROPOSED PLACEMENT PLAN

FIG 2



80 0 80 160

1"=80'

DRAFT - NOT FOR CONSTRUCTION

NOTES:
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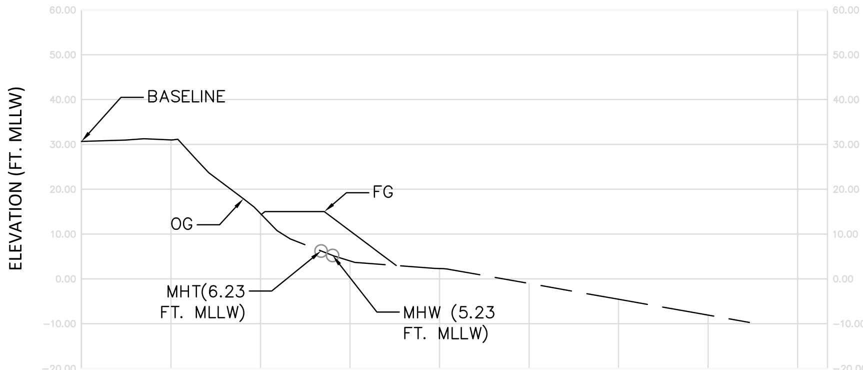
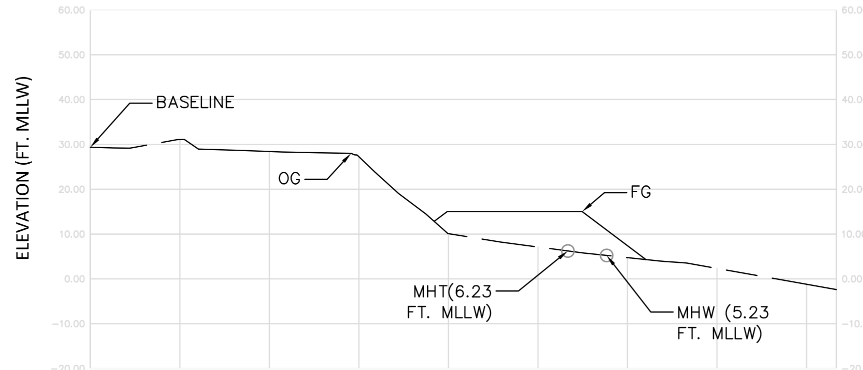
2. TO CONVERT FROM MLLW TO CITY DATUM, SUBTRACT 11.666 FT

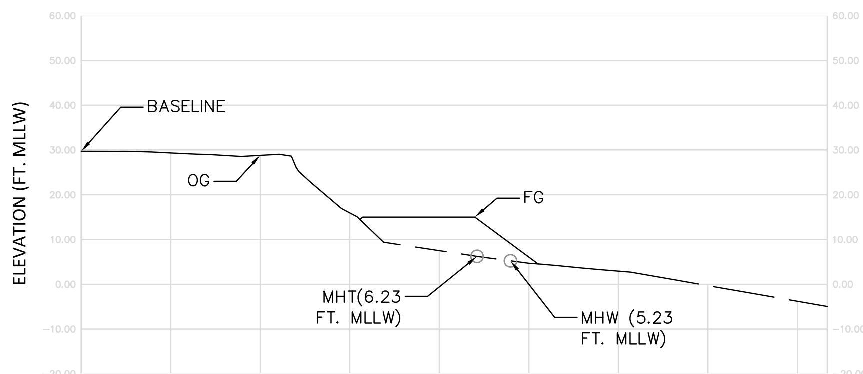
OCEAN BEACH SAND BACKPASSING PROJECT		FIG 3
moffatt & nichol	PROPOSED PLACEMENT PLAN	



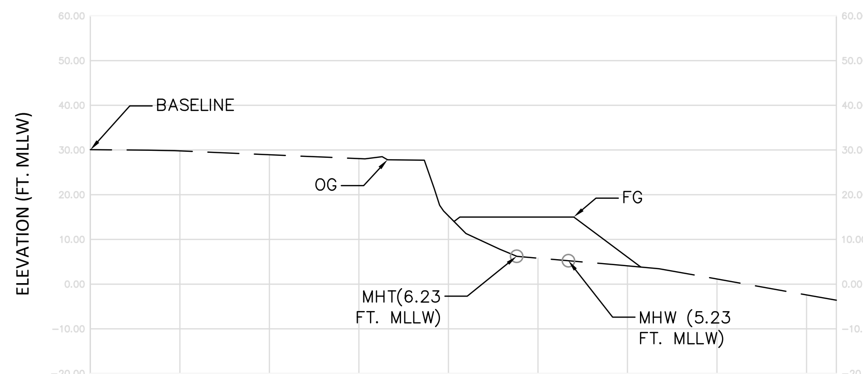
SECTION E
STATION 12+00.00



SECTION G
STATION 18+00.00



SECTION F
STATION 15+00.00



SECTION H
STATION 21+00.00

DRAFT - NOT FOR CONSTRUCTION

NOTES:
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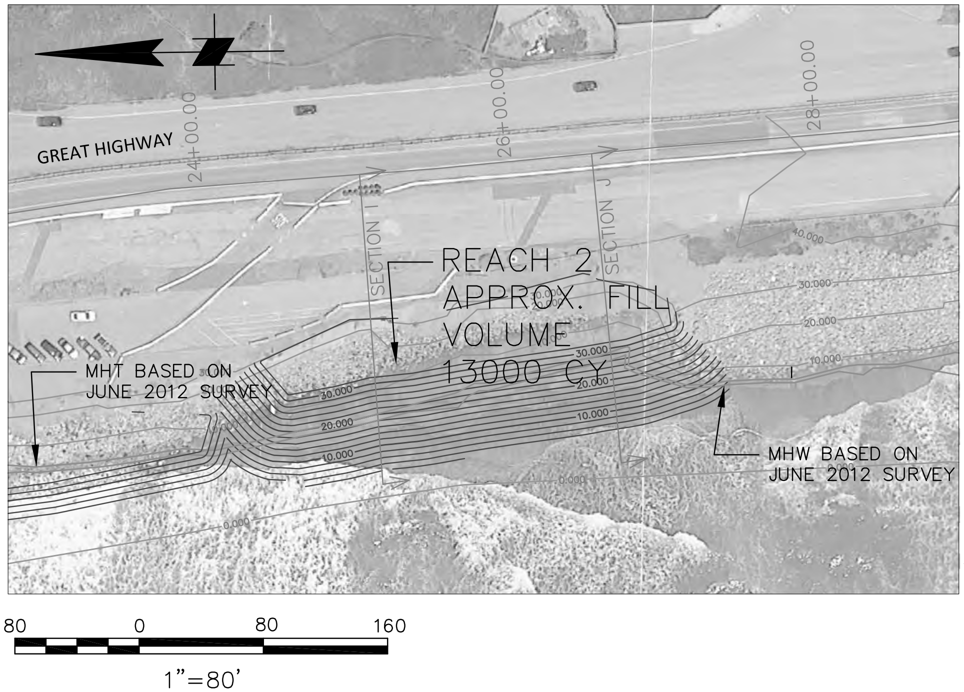
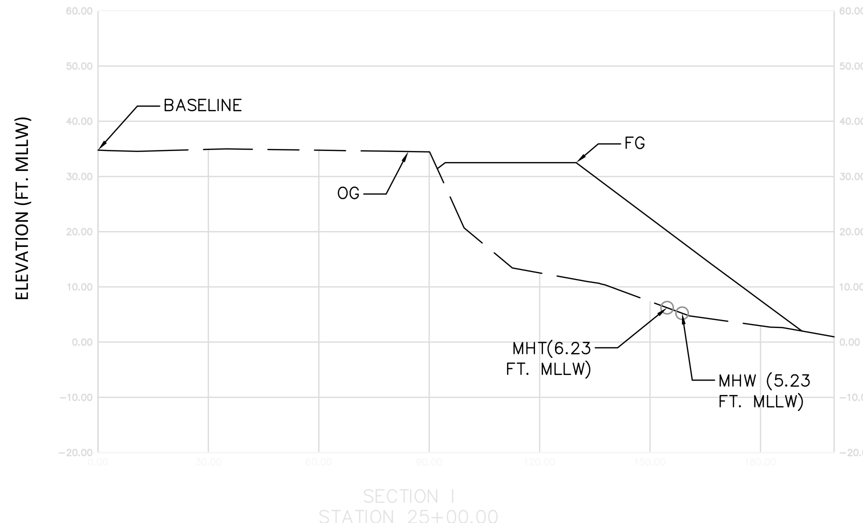
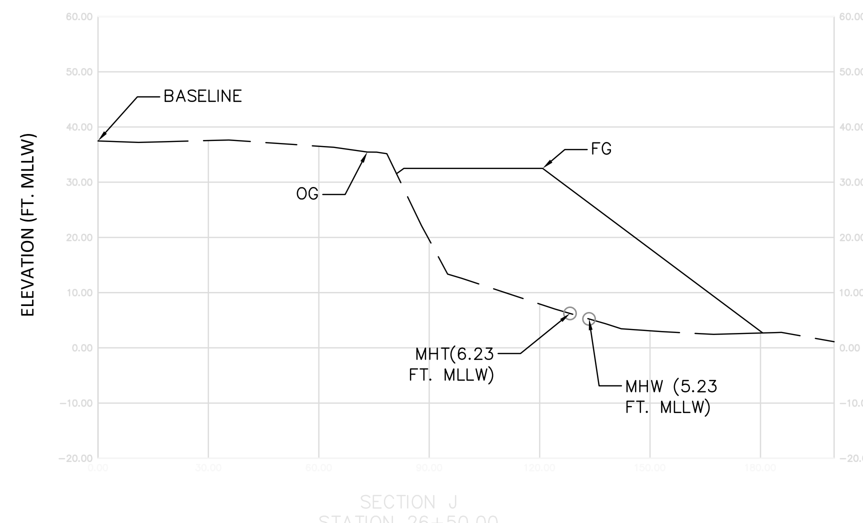
VERTICAL DATUM: ORIGINALLY CITY OF SAN FRANCISCO DATUM, ADJUSTED TO MLLW IN DRAWINGS
2. TO CONVERT FROM MLLW TO CITY DATUM, SUBTRACT 11.666 FT

OCEAN BEACH SAND BACKPASSING PROJECT		FIG 4
moffatt & nichol	PROPOSED PLACEMENT PLAN	







DRAFT - NOT FOR CONSTRUCTION

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HORIZONTAL DATUM: CALIFORNIA ZONE 3 - NAD1983 (CORS96)
VERTICAL DATUM: ORIGINALLY CITY OF SAN FRANCISCO DATUM, ADJUSTED TO MLLW IN DRAWINGS
2. TO CONVERT FROM MLLW TO CITY DATUM, SUBTRACT 11.666 FT

OCEAN BEACH SAND BACKPASSING PROJECT

moffatt & nichol

PROPOSED PLACEMENT PLAN

FIG 5

CONSTRUCTION PHASING

Construction Phase	North End Activities	South End Activities	Detours
Phase 1	Sand will be excavated starting at north end, working southward. An approx. 100'-wide work area/truck route along the seawall will be delineated by orange plastic fencing to keep pedestrians and equipment separated. Fencing will be removed at the north end, as work is completed. Two pedestrian crossings of the work zone will be allowed at Stairwells 15 and 21 and protected by flaggers; all other stairwells to be closed during work hours. Stairwells will be reopened beginning on the north end, as work is completed. Trucks will access Great Hwy. at the south end of seawall and through the Lincoln Way intersection.	South half of Sloat parking lot to be closed for work activities; north half will be open to the public via the existing Sloat entrance. Work will also include a sand ladder needed for Phase 2 pedestrian access to the beach. Trucks will access the site from Great Hwy. south of Sloat intersection. Trucks will have to cross traffic at the Sloat signal, but traffic will only be allowed to access the Sloat parking lot and will not be allowed to follow trucks southward on Great Hwy.	Southbound Great Hwy closed from Lincoln to Hwy 35; detour along Sunset Blvd. and Skyline Blvd. Northbound traffic unaffected. Muni bus stops unaffected.
Phase 2		Entire Sloat parking lot to be closed to the public for work activities, including the entrance turn-around. Trucks will access the site through the Sloat intersection. The south-bound outside lane will be closed adjacent to the Sloat parking lot, and on-street parking allowed. Pedestrians will be directed along the road shoulder adjacent to the parking lot to the new sand ladder at the south end of the parking lot.	Southbound Great Hwy closed from Lincoln to Sloat; detour along Sunset Blvd. Northbound traffic unaffected. Muni bus stop at Great Hwy. & Sloat to be relocated by SFMTA.
Phase 3		All of Sloat parking lot will be open to the public. The parking lot at Armory Road will be closed to the public for work activities. Trucks will access the site from Great Hwy. Trucks will have to cross traffic at the Sloat signal, but traffic will only be allowed to access the Sloat parking lot and will not be allowed to follow trucks southward on Great Hwy.	Southbound Great Hwy closed from Lincoln to Hwy 35; detour along Sunset Blvd. and Skyline Blvd. Northbound traffic unaffected. Muni bus stops unaffected.

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

REFERENCE INFORMATION & FILE NO. OF SURVEYS

SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

DRAFT

DESIGNED	S.L.	DATE 07/12
DRAWN	A.G.	DATE 07/12
CHECKED	S.L.	DATE 07/12

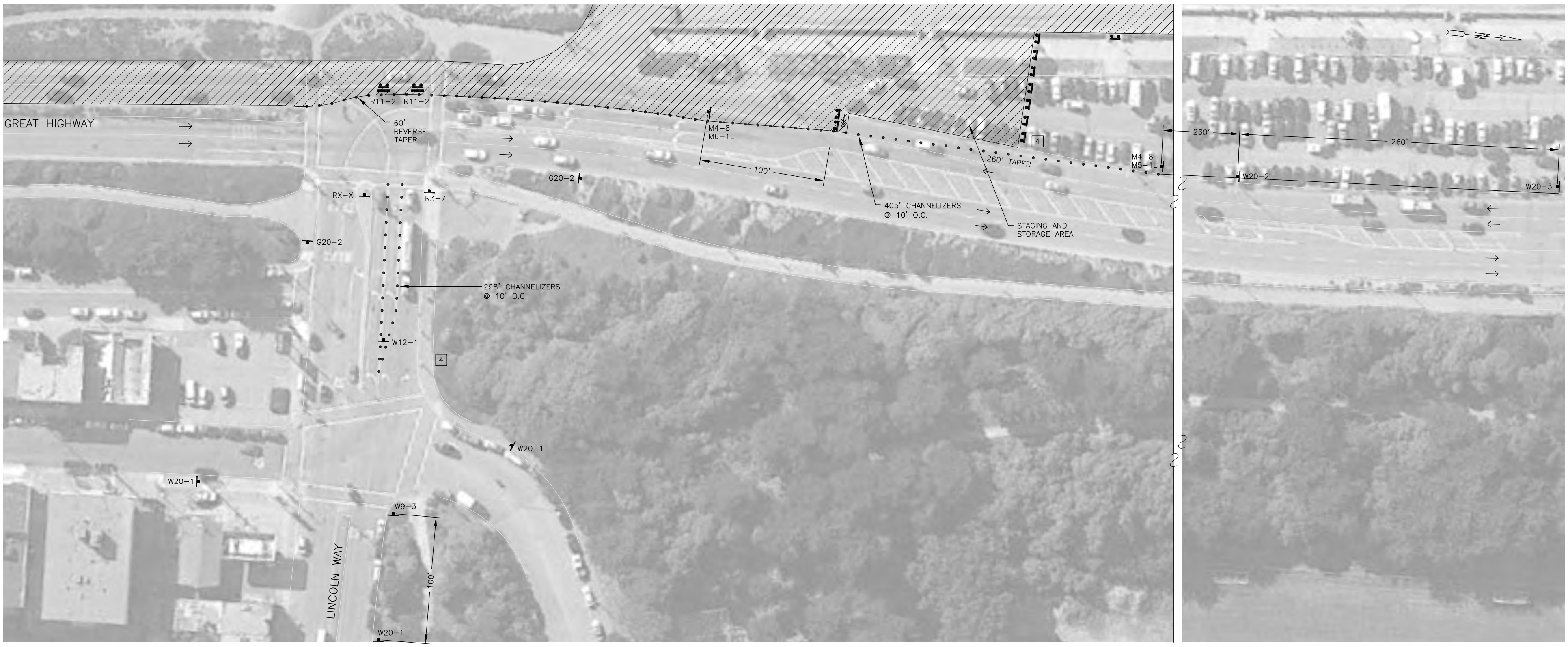
APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE 1" = 40'
SHEET OF SHEETS OF 7

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
CONSTRUCTION PHASING
PHASES 1 THRU 3

JOB ORDER NO. -
DRAWING NO. TCP-1
FILE NO. -
REV. NO.



PLAN
1"=40'

NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.
2. WORK AREA/TRUCK ROUTE ON THE BEACH WILL BE DELINEATED BY ORANGE PLASTIC FENCING TO KEEP PEDESTRIANS AND EQUIPMENT SEPARATED. FENCING WILL BE REMOVED AT THE NORTH END, AS WORK IS COMPLETED.
3. TWO PEDESTRIAN CROSSINGS OF THE WORK ZONE WILL BE ALLOWED AT STAIRWELLS 15 AND 21 AND PROTECTED BY FLAGGERS. CLOSE ALL OTHER STAIRWELLS WITH BARRICADES DURING WORK HOURS. STAIRWELLS WILL BE REOPENED BEGINNING ON THE NORTH END AS WORK IS COMPLETED.

4. ONE WEEK IN ADVANCE OF SOUTHBOUND LANE CLOSURE, PLACE CHANGEABLE MESSAGE SIGNS INFORMING MOTORISTS OF THE DATES AND TIME OF WORK.

LEGEND AND SYMBOLS

(hatched)	WORK AREA
• • • •	CHANNELIZERS
	TEMPORARY SIGN
←	DIRECTION OF TRAFFIC FLOW
	BARRICADE
	BARRICADE WITH SIGN(S)
	FLASH ARROW, TYPE (B)

TEMPORARY TRAFFIC CONTROL SIGNS

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

REFERENCE INFORMATION & FILE NO. OF SURVEYS

SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

DRAFT

DESIGNED A.L.	DATE 07/12	
DRAWN A.L.	DATE 07/12	
CHECKED S.L.	DATE 07/12	

APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE 1" = 40'
SHEET OF SHEETS — OF 7

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT LINCOLN WAY
PHASES 1 THRU 3

JOB ORDER NO. -
DRAWING NO. TCP-2
FILE NO. -
REV. NO.

Xrefs: Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\TITLEBLOCK\X-BOE-Std-TTLB-22x34.dwg
Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Plans\Ocean beach plan.dwg
Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Plans\TrafficControlPlan1.dwg

Drawing Path: \\Sf-files\chs-files\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Sheets\TCP-2.dwg Login: dlewis
Plot Time: Wed, 25 Jul 2012 - 1:33pm
Measurement Units are English
Model Units: Inches

PLAN
1"=40'

LEGEND AND SYMBOLS

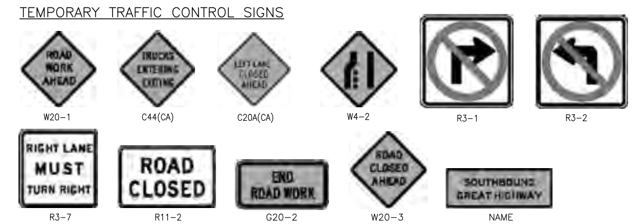
- WORK AREA
- CHANNELIZERS
- TEMPORARY SIGN
- DIRECTION OF TRAFFIC FLOW
- BARRICADE
- BARRICADE WITH SIGN(S)

NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.

2. ONE WEEK IN ADVANCE OF SOUTHBOUND LANE CLOSURE PLACE CHANGEAGE MESSAGE SIGN INFORMING MOTORISTS OF THE DATES AND TIME OF WORK.

TEMPORARY TRAFFIC CONTROL SIGNS



NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

REFERENCE INFORMATION & FILE NO. OF SURVEYS

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

DRAFT

DESIGNED	A.L.	DATE 07/12
DRAWN	A.L.	DATE 07/12
CHECKED	S.L.	DATE 07/12

APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE 1" = 40'
SHEET OF SHEETS OF 7

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT SLOAT BLVD
PHASE 1

JOB ORDER NO. -
DRAWING NO. TCP-3
FILE NO. -
REV. NO.

Exhibit 6
2-21-0912
Page 92 of 107

PLAN
1"=40'

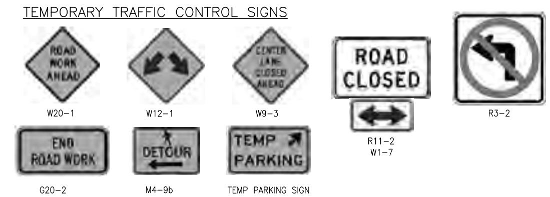
LEGEND AND SYMBOLS

- WORK AREA
- TEMPORARY PARKING AND PED ACCESS
- CHANNELIZERS
- TEMPORARY SIGN
- DIRECTION OF TRAFFIC FLOW
- BARRICADE
- BARRICADE WITH SIGN(S)

NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.
2. MUNI BUS STOP TO BE RELOCATED BY SFMTA.
3. COVER EXISTING "NO PARKING" SIGNS WITHIN THE TEMPORARY PARKING AREA FOR THE DURATION OF THIS CONSTRUCTION PHASE.

TEMPORARY TRAFFIC CONTROL SIGNS



NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

REFERENCE INFORMATION & FILE NO. OF SURVEYS

SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

DRAFT

DESIGNED A.L.	DATE 07/12	APPROVED
DRAWN A.L.	DATE 07/12	SECTION MANAGER DATE
CHECKED S.L.	DATE 07/12	DEPUTY BUREAU MANAGER DATE
		BUREAU MANAGER DATE

SCALE S.L.
SHEET OF SHEETS OF 7

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT SLOAT BLVD
PHASE 2

JOB ORDER NO. -
DRAWING NO. TCP-4
FILE NO. -
REV. NO.

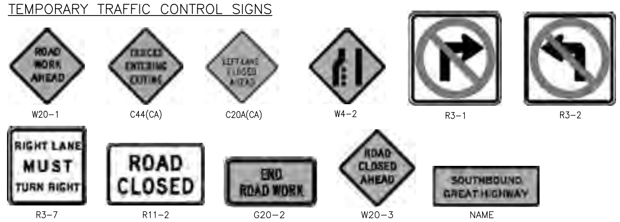
Xrefs: Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\TITLEBLOCK\X-BOE-Std-TTLB-22x34.dwg
Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Plans\TrafficControlPlan2.dwg
Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Plans\Ocean beach plan.dwg

Drawing Path: \\Sf-files\chs-files\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Sheets\TCP-4.dwg Login: dlong
Plot Time: Wed, 25 Jul 2012 - 1:51pm
Measurement Units are English
Model Units: Inches

Exhibit 6
2-21-0912
Page 93 of 107

PLAN
1"=40'

TEMPORARY TRAFFIC CONTROL SIGNS



NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.

2. ONE WEEK IN ADVANCE OF SOUTHBOUND LANE CLOSURE PLACE CHANGEABLE MESSAGE SIGN INFORMING MOTORISTS OF THE DATES AND TIME OF WORK.

LEGEND AND SYMBOLS

- WORK AREA
- CHANNELIZERS
- TEMPORARY SIGN
- DIRECTION OF TRAFFIC FLOW
- BARRICADE
- BARRICADE WITH SIGN(S)

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
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SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

DRAFT

DESIGNED	DATE
A.L.	07/12
DRAWN	DATE
A.L.	07/12
CHECKED	DATE
S.L.	07/12

APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE 1" = 40'
SHEET OF SHEETS OF 7

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT SLOAT
PHASE 3

JOB ORDER NO. -
DRAWING NO. TCP-5
FILE NO. -
REV. NO.

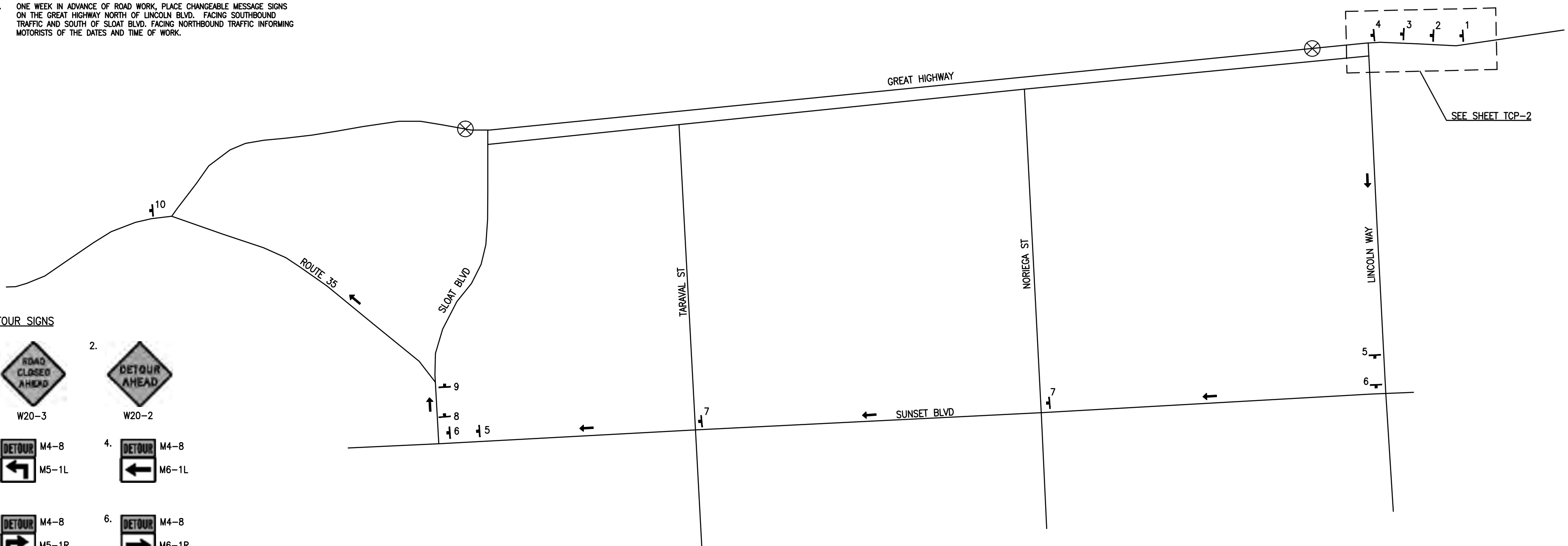
LEGEND

- TEMPORARY SIGN ASSEMBLY
- BARRICADE (TYPE III)
- DETOUR ROUTE
- SOUTHBOUND ROAD CLOSURE

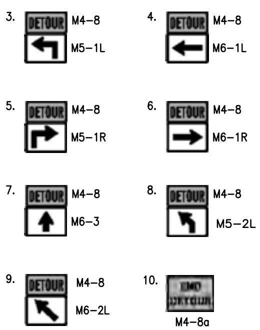
NOTES

1. ONE WEEK IN ADVANCE OF ROAD WORK, PLACE CHANGEABLE MESSAGE SIGNS ON THE GREAT HIGHWAY NORTH OF LINCOLN BLVD. FACING SOUTHBOUND TRAFFIC AND SOUTH OF SLOAT BLVD. FACING NORTHBOUND TRAFFIC INFORMING MOTORISTS OF THE DATES AND TIME OF WORK.

NOT TO SCALE



DETOUR SIGNS



1. W20-3
2. W20-2
3. M4-8 M5-1L
4. M4-8 M6-1L
5. M4-8 M5-1R
6. M4-8 M6-1R
7. M4-8 M6-3
8. M4-8 M5-2L
9. M4-8 M6-2L
10. M4-8a

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
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REFERENCE INFORMATION & FILE NO. OF SURVEYS

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

DRAFT

DESIGNED	DATE	APPROVED	SCALE
A.G.	07/12	SECTION MANAGER DATE	N.T.S.
DRAWN A.G.	07/12	DEPUTY BUREAU MANAGER DATE	SHEET OF SHEETS 6 OF 7
CHECKED S.L.	07/12	BUREAU MANAGER DATE	

OCEAN BEACH
SAND BACK PASSING

PARTIAL STREET CLOSURE DETOUR
GREAT HIGHWAY, SOUTHBOUND
PHASE ONE AND THREE

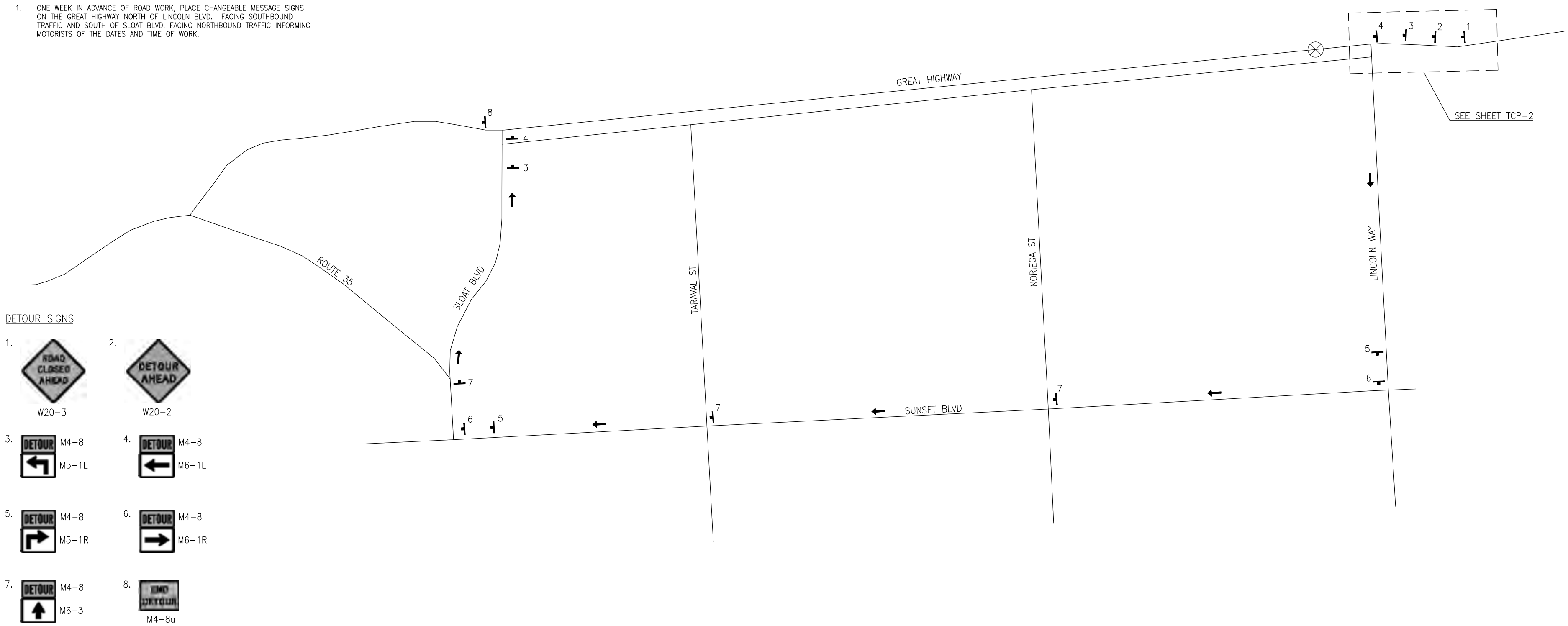
JOB ORDER NO. -
DRAWING NO. TCP-6
FILE NO. -
REV. NO.

LEGEND

- TEMPORARY SIGN ASSEMBLY
- BARRICADE (TYPE III)
- DETOUR ROUTE
- SOUTHBOUND ROAD CLOSURE

NOTES

1. ONE WEEK IN ADVANCE OF ROAD WORK, PLACE CHANGEABLE MESSAGE SIGNS ON THE GREAT HIGHWAY NORTH OF LINCOLN BLVD. FACING SOUTHBOUND TRAFFIC AND SOUTH OF SLOAT BLVD. FACING NORTHBOUND TRAFFIC INFORMING MOTORISTS OF THE DATES AND TIME OF WORK.



NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

REFERENCE INFORMATION & FILE NO. OF SURVEYS

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

DRAFT

DESIGNED	DATE
A.G.	07/12
DRAWN	DATE
A.G.	07/12
CHECKED	DATE
S.L.	07/12

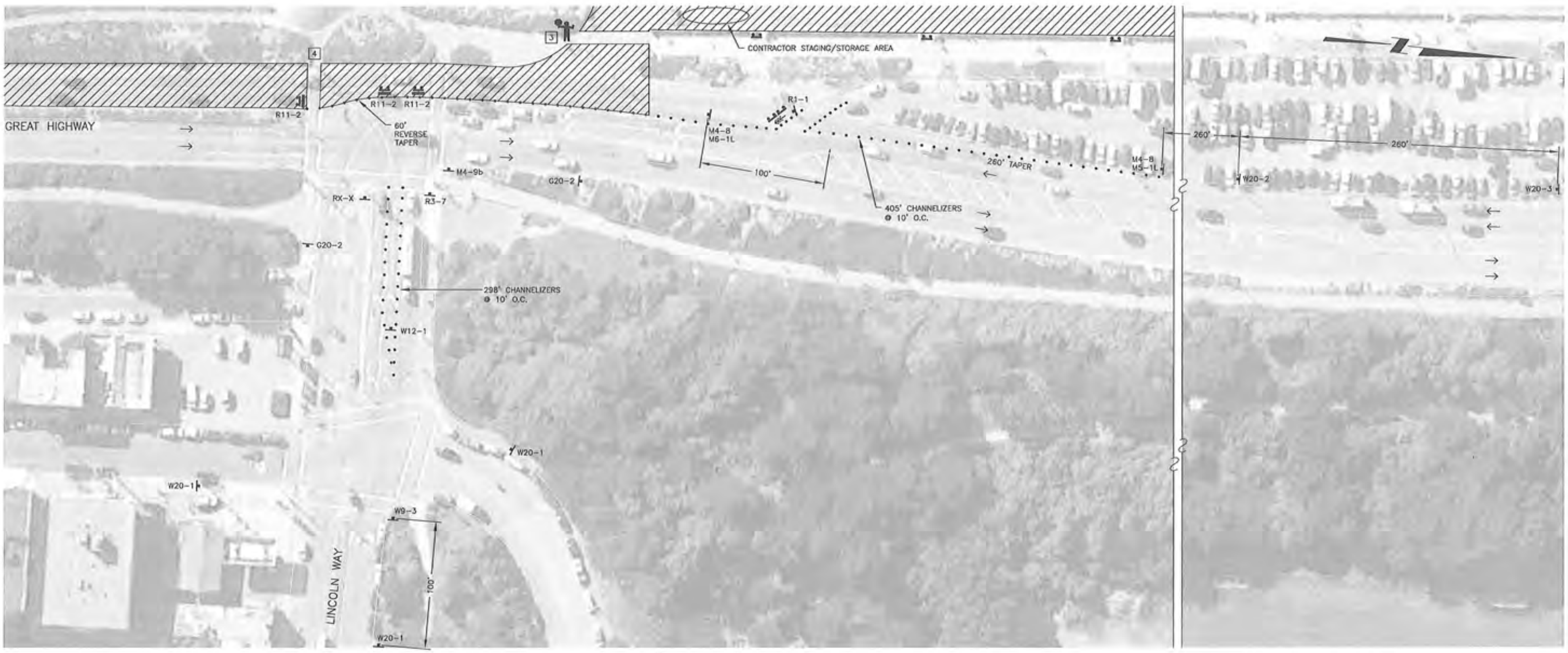
APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE: N.T.S.
SHEET OF SHEETS: 7 OF 7

OCEAN BEACH
SAND BACK PASSING

PARTIAL STREET CLOSURE DETOUR
GREAT HIGHWAY, SOUTHBOUND
PHASE TWO

JOB ORDER NO. -
DRAWING NO. TCP-7
FILE NO. -
REV. NO.



PLAN
1"=40'

NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.
2. WORK AREA/TRUCK ROUTE ON THE BEACH WILL BE DELINEATED BY ORANGE PLASTIC FENCING TO KEEP PEDESTRIANS AND EQUIPMENT SEPARATED. FENCING WILL BE REMOVED AT THE NORTH END, AS WORK IS COMPLETED.
3. PEDESTRIAN CROSSINGS OF THE WORK ZONE WILL BE ALLOWED AT STAIRWELLS 15 AND 21 AND AT THE SOUTH END OF SEA WALL PROTECTED BY FLAGGERS. CLOSE ALL OTHER STAIRWELLS WITH BARRICADES DURING WORK HOURS. STAIRWELLS WILL BE REOPENED BEGINNING ON THE NORTH END AS WORK IS COMPLETED.
4. PEDESTRIAN CROSSING OF WORK ZONE CONTROLLED BY TRAFFIC SIGNAL.
5. ONE WEEK IN ADVANCE OF SOUTHBOUND LANE CLOSURE, PLACE CHANGEABLE MESSAGE SIGNS INFORMING MOTORISTS OF THE DATES AND TIME OF WORK. SEE DWG NOS. TCP-6 AND TCP-7 FOR CMS LOCATIONS.

LEGEND AND SYMBOLS

- WORK AREA
- CHANNELIZERS
- TEMPORARY SIGN
- DIRECTION OF TRAFFIC FLOW
- BARRICADE
- BARRICADE WITH SIGN(S)
- FLASH ARROW, TYPE B
- FLAGGER

TEMPORARY TRAFFIC CONTROL SIGNS

- ROAD WORK AHEAD — W20-1
- DETOUR AHEAD — W20-2
- ROAD CLOSED AHEAD — W20-3
- CENTER LANE CLOSED AHEAD — W9-3
- W12-1
- RIGHT LANE MUST TURN RIGHT — R3-7
- ONLY — RX-X
- DETOUR — M4-8; M5-1L
- DETOUR — M4-8; M6-1L
- END ROAD WORK — G20-2
- ROAD CLOSED — R11-2
- STOP — R1-1
- DETOUR — M4-9b

1"=40' 40' 0' 40' 80'

APPROVED
8/14/12
TRAFFIC ENGINEER

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

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SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

REGISTERED PROFESSIONAL ENGINEER — EXP. 9-30-13 — CIVIL — STATE OF CALIFORNIA
8-10-12

	DATE
DESIGNED A.L.	07/12
DRAWN A.L.	07/12
CHECKED S.L.	07/12

APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE 1" = 40'
SHEET OF SHEETS 11 OF 16

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT LINCOLN WAY
PHASES 1 THRU 3

JOB ORDER NO. -
DRAWING NO. TCP-2
FILE NO. -
REV. NO.

Xrefs: Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\TITLEBLOCK\X-BOE-Std-TTLB-22x34.dwg
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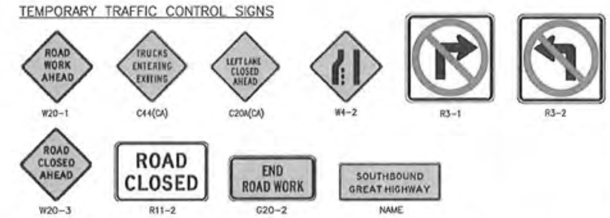
Drawing Path: Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Sheets\TCP-2.dwg, Login: Dimension Scale: 1
Plot Time: Fri, 10 Aug 2012 - 4:05pm Measurement Units are English Model Units: Inches

PLAN
1"=40'

LEGEND AND SYMBOLS

- WORK AREA
- CHANNELIZERS
- TEMPORARY SIGN
- DIRECTION OF TRAFFIC FLOW
- BARRICADE
- BARRICADE WITH SIGN(S)
- FLASH ARROW, TYPE B
- FLAGGER

TEMPORARY TRAFFIC CONTROL SIGNS



NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.
2. ONE WEEK IN ADVANCE OF SOUTHBOUND LANE CLOSURE PLACE CHANGEABLE MESSAGE SIGN INFORMING MOTORISTS OF THE DATES AND TIME OF WORK. SEE DWG NOS. TCP-6 AND TCP-7 FOR CMS LOCATIONS.

APPROVED WITH COMMENTS
8/14/12
TRAFFIC ENGINEER

1"=40' 40' 0' 40' 80'

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

REFERENCE INFORMATION & FILE NO. OF SURVEYS

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

8-10-12

DESIGNED A.L.	DATE 07/12
DRAWN A.L.	DATE 07/12
CHECKED S.L.	DATE 07/12

APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE 1" = 40'
SHEET OF SHEETS 12 OF 16

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT SLOAT BLVD
PHASE 1

JOB ORDER NO. –
DRAWING NO. TCP-3
FILE NO. –
REV. NO.

Drawing Path: Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing– 12-1023\CADD\Sheets\TCP-3.dwg, Login: dimension Scale: 1
Plot Time: Fri, 10 Aug 2012 – 4:56pm
Measurement Units are English Model Units: Inches

TEMPORARY TRAFFIC CONTROL SIGNS

NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.
2. MUNI BUS STOP TO BE RELOCATED BY SFMTA. CONTRACTOR TO COORDINATE WITH RESIDENT ENGINEER AND PROVIDE REQUIRED SIGNAGE.
3. PEDESTRIAN CROSSING CONTROLLED BY TRAFFIC SIGNAL.
4. PEDESTRIAN CROSSING CONTROLLED BY FLAGGER.
5. ONE WEEK IN ADVANCE OF SOUTHBOUND LANE CLOSURE, PLACE CHANGEABLE MESSAGE SIGNS INFORMING MOTORISTS OF THE DATES AND TIMES OF WORK. SEE DWG NOS. TCP-6 AND TCP-7 FOR CMS LOCATIONS.

LEGEND AND SYMBOLS

- WORK AREA
- TEMPORARY PARKING AND PED ACCESS
- CHANNELIZERS
- TEMPORARY SIGN
- DIRECTION OF TRAFFIC FLOW
- BARRICADE
- BARRICADE WITH SIGN(S)
- FLAGGER

1"=40' 40' 0' 40' 80'

APPROVED WITH COMMENTS
8/14/12
TRAFFIC ENGINEER

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
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SEAL OF THE CITY AND COUNTY OF SAN FRANCISCO

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

REGISTERED PROFESSIONAL ENGINEER
EXP. 9-30-13
CIVIL
STATE OF CALIFORNIA
8-10-12

DESIGNED	DATE
A.L.	07/12
DRAWN	DATE
A.L.	07/12
CHECKED	DATE
S.L.	07/12

APPROVED
SECTION MANAGER DATE
DEPUTY BUREAU MANAGER DATE
BUREAU MANAGER DATE

SCALE 1"=40'
SHEET OF SHEETS 13 OF 16

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT SLOAT BLVD
PHASE 2

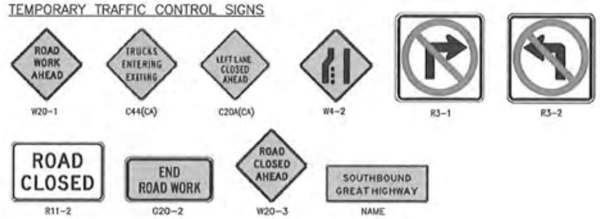
JOB ORDER NO. –
DRAWING NO. TCP-4
FILE NO. –
REV. NO.

Drawing Path: Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Sheets\TCP-4.dwg Login: Dimension Scale: 1
Plot Time: Fri, 10 Aug 2012 – 4:57pm Measurement Units are English Model Units: Inches

Exhibit 6
2-21-0912
Page 99 of 107

PLAN
1"=40'

TEMPORARY TRAFFIC CONTROL SIGNS



LEGEND AND SYMBOLS

- WORK AREA
- CHANNELIZERS
- TEMPORARY SIGN
- DIRECTION OF TRAFFIC FLOW
- BARRICADE
- BARRICADE WITH SIGN(S)
- FLASHING ARROW, TYPE B
- FLAGGER

1"=40' 40' 0' 40' 80'

NOTES

1. SETUP ADVANCE WARNING SIGNS, CHANNELIZING DEVICES, INSTALL TEMPORARY PAVEMENT MARKINGS, AND MAINTAIN MINIMUM 10'-WIDE LANE WIDTH AS SHOWN.
2. ONE WEEK IN ADVANCE OF SOUTHBOUND LANE CLOSURE PLACE CHANGEABLE MESSAGE SIGN INFORMING MOTORISTS OF THE DATES AND TIME OF WORK. SEE DWG NOS. TCP-6 AND TCP-7 FOR CMS LOCATIONS.

APPROVED WITH COMMENTS
8/14/12
TRAFFIC ENGINEER

NO.	DATE	DESCRIPTION	BY	APP.

TABLE OF REVISIONS
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REFERENCE INFORMATION & FILE NO. OF SURVEYS

BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

8-10-12

DESIGNED A.L.	DATE 07/12	APPROVED
DRAWN A.L.	DATE 07/12	SECTION MANAGER DATE
CHECKED S.L.	DATE 07/12	DEPUTY BUREAU MANAGER DATE
		BUREAU MANAGER DATE

SCALE 1" = 40'
SHEET OF SHEETS 14 OF 16

OCEAN BEACH
SAND BACK PASSING

TEMPORARY TRAFFIC CONTROL PLAN
GREAT HIGHWAY AT SLOAT
PHASE 3

JOB ORDER NO. -
DRAWING NO. TCP-5
FILE NO. -
REV. NO.

Xrefs: Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\TITLEBLOCK\X-BOE-Std-TTLB-22x34.dwg
Z:\Projects\2012\SFDPW Ocean Beach Sand Backpassing- 12-1023\CADD\Plans\Ocean beach plan.dwg
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Measurement Units are English
Plot Time: Fri, 10 Aug 2012 - 4:58pm

LEGEND

- TEMPORARY SIGN ASSEMBLY
- BARRICADE (TYPE III)
- DETOUR ROUTE
- SOUTHBOUND ROAD CLOSURE
- CMS CHANGEABLE MESSAGE SIGN

NOTES

1. ONE WEEK IN ADVANCE OF ROAD WORK, PLACE CHANGEABLE MESSAGE SIGNS INFORMING MOTORISTS OF THE DATES AND TIME OF WORK.

DETOUR SIGNS

1. ROAD CLOSED AHEAD — W20-3
2. DETOUR AHEAD — W20-2
3. DETOUR M4-8, M5-1L
4. DETOUR M4-8, M6-1L
5. DETOUR M4-8, M5-1R
6. DETOUR M4-8, M6-1R
7. DETOUR M4-8, M6-3
8. DETOUR M4-8, M5-2L
9. DETOUR M4-8, M6-2L
10. END DETOUR — M4-8a
11. SOUTHBOUND GREAT HIGHWAY — NAME

APPROVED WITH COMMENTS
8/14/12
TRAFFIC ENGINEER

NO.	DATE	DESCRIPTION	BY	APP.

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CHECK WITH TRACING TO SEE IF YOU HAVE LATEST REVISION

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BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO

REGISTERED PROFESSIONAL ENGINEER — CIVIL — STATE OF CALIFORNIA — EXP. 9-30-13
8-10-12

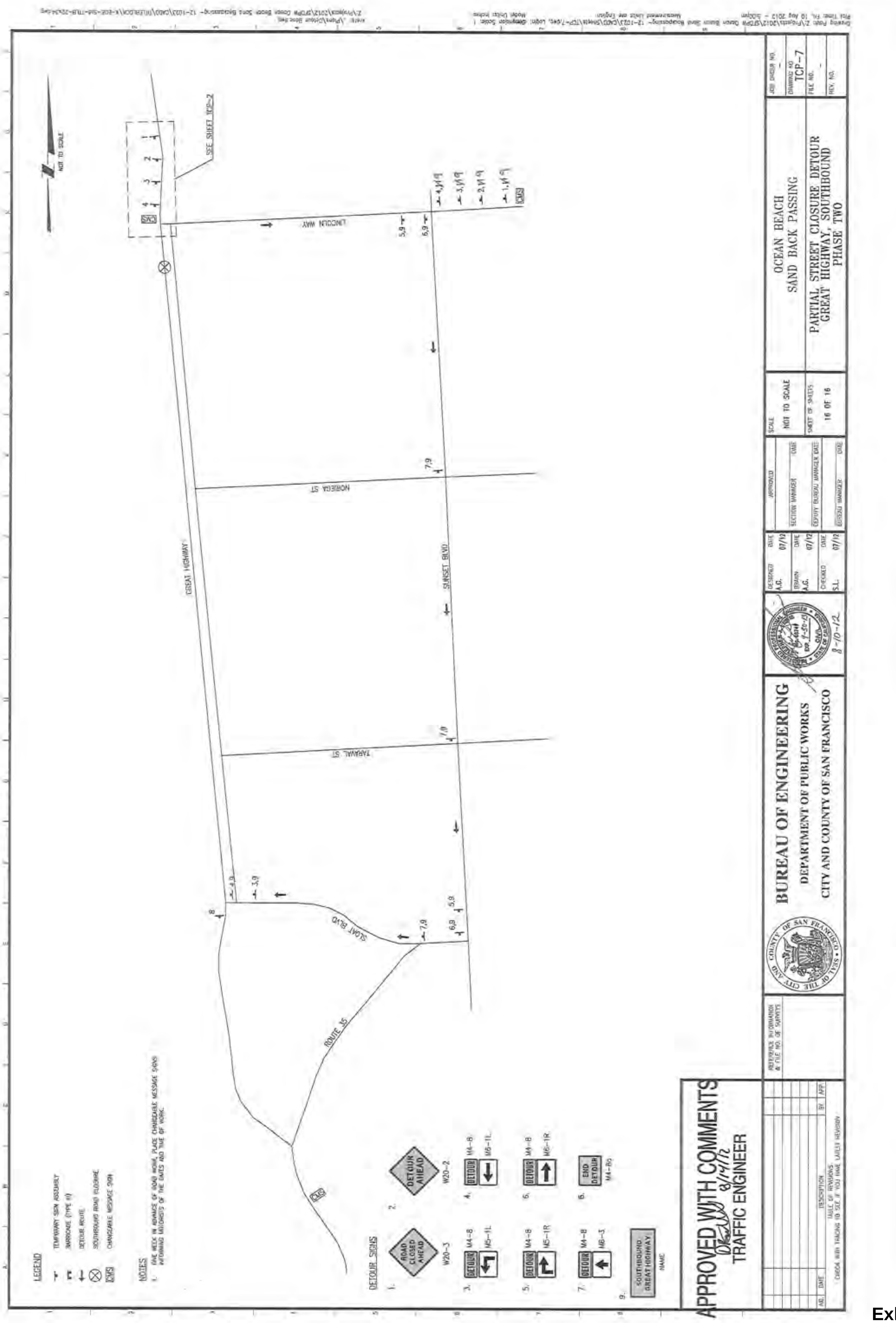
DESIGNED A.G.	DATE 07/12	APPROVED	
DRAWN A.G.	DATE 07/12	SECTION MANAGER	DATE
CHECKED S.L.	DATE 07/12	DEPUTY BUREAU MANAGER	DATE
		BUREAU MANAGER	DATE

SCALE: NOT TO SCALE
SHEET OF SHEETS: 15 OF 16

OCEAN BEACH
SAND BACK PASSING

PARTIAL STREET CLOSURE DETOUR
GREAT HIGHWAY, SOUTHBOUND
PHASE ONE AND THREE

JOB ORDER NO. -
DRAWING NO. TCP-6
FILE NO. -
REV. NO.


LEGEND
NOTES
DETOUR SIGNS
SEE SHEET TCP-2
NOT TO SCALE
LINCOLN WAY
NORIEGA ST
TARAVAL ST
GREAT HIGHWAY
SUNSET BLVD
SLOAT BLVD
ROUTE 35
ROAD CLOSED AHEAD
DETOUR AHEAD
END DETOUR
SOUTHBOUND GREAT HIGHWAY
APPROVED WITH COMMENTS
TRAFFIC ENGINEER
BUREAU OF ENGINEERING
DEPARTMENT OF PUBLIC WORKS
CITY AND COUNTY OF SAN FRANCISCO
NOT TO SCALE
16 OF 16
OCEAN BEACH
SAND BACK PASSING
PARTIAL STREET CLOSURE DETOUR
GREAT HIGHWAY, SOUTHBOUND
PHASE TWO
TCP-7


Sand Removal at North Ocean Beach


Sand Placement at South Ocean Beach


Sand Placement at South Ocean Beach


South Ocean Beach

Sand Management Plan

Ocean Beach Climate Change Adaptation Project, Long-Term Improvements

MN+AGS JV

2185 N. California Blvd., Suite 500, Walnut Creek, CA 94596