Task 3.3 and 3.4 Memo

October 31, 2025

To	Hank Seemann, Humboldt County	**Project No.**	12632378
From	Mazen Idriss, EIT, Kristen Orth-Gordinier, Jeremy Svehla, PE, Conor Shea, PE, PhD (GHD) Jeff Anderson, PE (NHE)		
Project Name	Humboldt Bay Living Shoreline Planning Project		
Subject	Dredge and Upland Sediment Source Evaluation		

1. Introduction

The County of Humboldt (County) was awarded a State Coastal Conservancy (SCC) Grant (SCC Grant Agreement #23-069) to undertake technical analyses, design, CEQA and permit applications for the Humboldt Bay Living Shoreline Project (Project). The Project seeks to restore approximately 17 acres of salt marsh along Eureka Arcata Highway 101 and Humboldt Bay Trail Corridor (Figure 1). The Project will enhance the region's ability to reduce flood risks associated with sea level rise (SLR) and take advantage of local sediment sources to reestablish the salt marsh at the Project site.

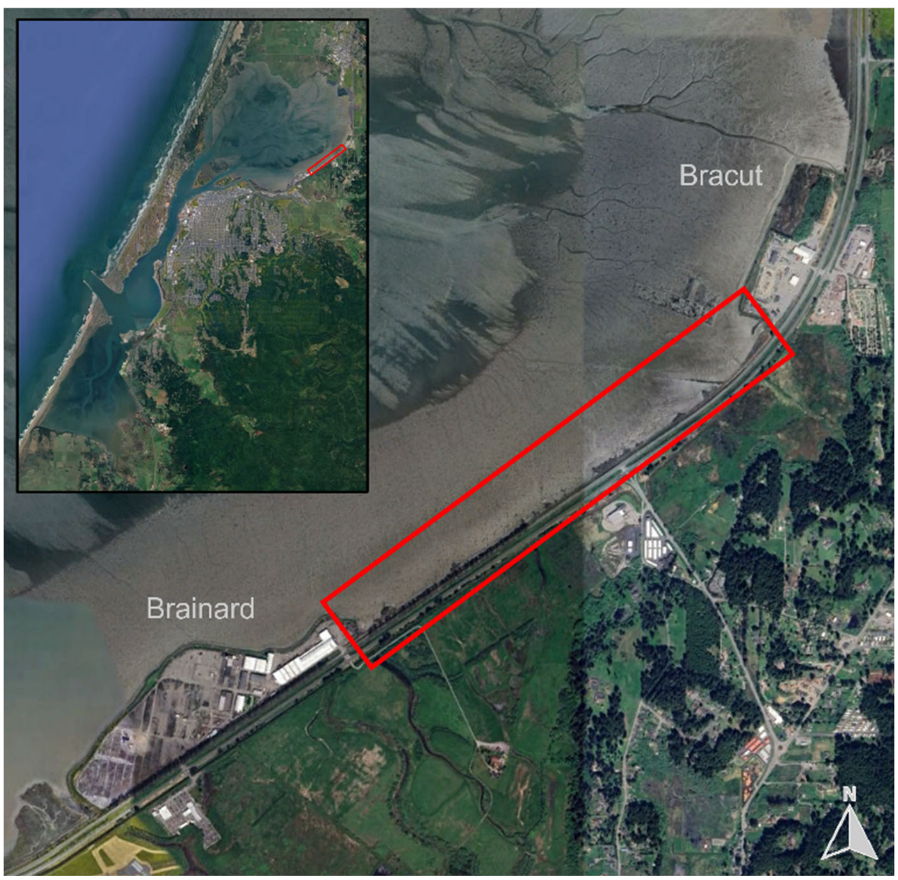

Figure 1. Project location on Humboldt Bay.

1.1 Purpose of this Memorandum

The purpose of this memorandum is to describe potential sediment sources and the range of transport methods to inform project planning. The Project requires approximately 125,000 cubic yards (yd^3) of fine-grained sediment to restore the salt marsh and could serve as a beneficial sediment reuse site. This memo summarizes the characteristics of Project site sediment and then outlines potential options for sediment sources and explores methods for delivery of the sediments to the Project site.

2. Project Site Sediment Characteristics

The Project site has lost approximately 90% of its historical salt marsh (1870-2021) due to anthropogenic alterations to the shoreline (GHD, 2021) (Figure 2). The fringing salt marsh that remains is comprised of highly organic silty clay or clayey peat and the fronting tidal flats are comprised of clayey silts. Sediment sampling was previously completed throughout the Project site to inform Project planning and is described below.

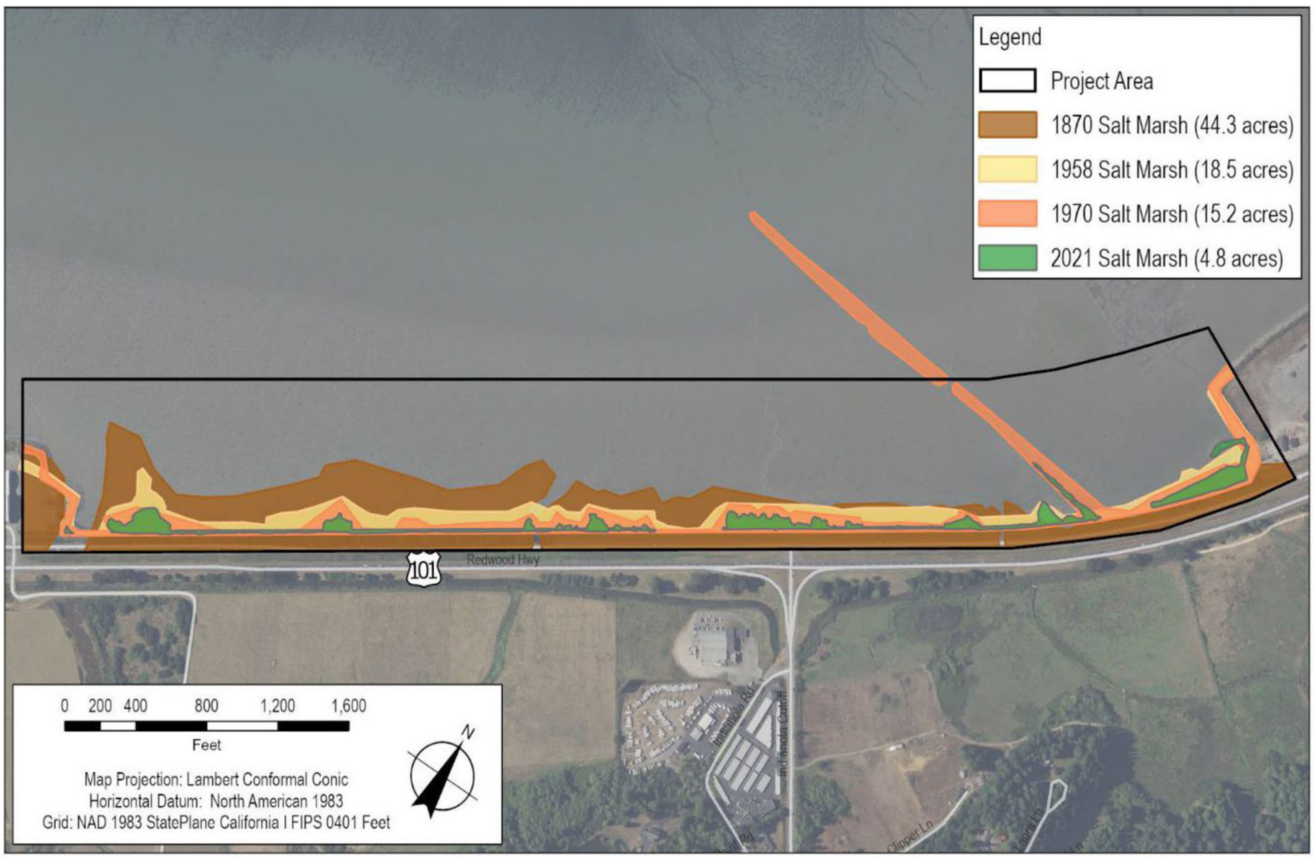

Figure 2. Reduction in salt marsh throughout Project site since 1870.

2.1 Grain Size Distribution

Sediment sampling to characterize grain size distribution and support SEDFlume analyses was previously completed for the Project site and described below (GHD, 2021) (SHN, 2021) (Figure 3).

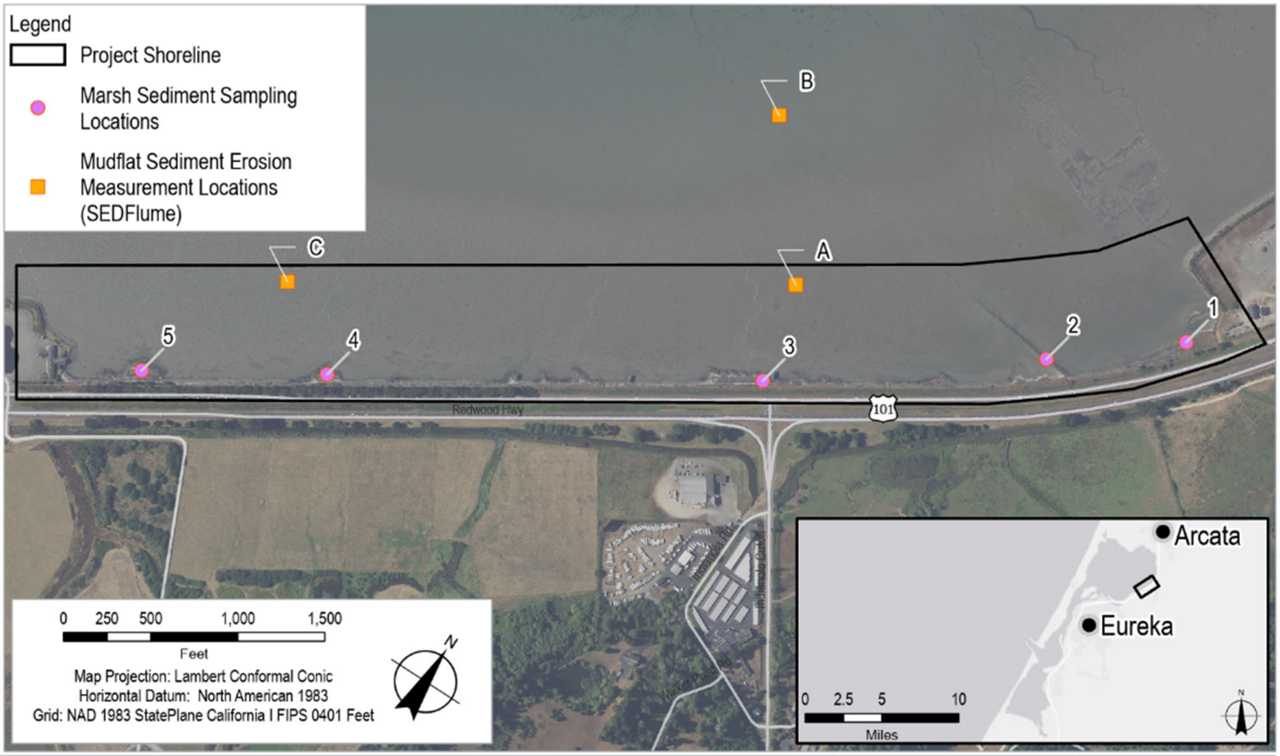

Figure 3. Location of sediment sampling throughout the Project site (SHN, 2021).

In core A, the sediment grain size was predominantly silt and ranged from clay to coarse silt. The sediment size decreased slightly with depth and both bulk density and critical shear stress increased with depth. In core B, sediment grain size was predominantly silt and ranged from clay to very fine sand. The sediment size increased slightly with depth as did the bulk density and critical shear stresses. In core C, sediment grain size was predominantly silt and ranged from clay to coarse silt. The sediment size and bulk density slightly decreased with depth however the critical shear stresses increased. The increase in shear stress with depth observed in all cores indicates that the surface sediment has higher erosion rates (are more erodible) relative to the deeper sediments. Relative to one another, the critical shear stresses were similar between cores A and B, however core C critical shear stresses were higher, indicating lower erosion potential compared to cores A and B. In core B, a layer of organic debris and shell fragments was detected at 18cm below ground surface. This could have been a historic mudflat surface with 18cm of deposition. However, this sample was collected at the location of a remnant dike which may have directly or indirectly disturbed the mudflat in this vicinity altering the erosion and depositional patterns.

Hand auger borings were completed by SHN at five locations along the study area shoreline on the remaining salt marsh. The sample locations are shown in Figure 3 numbered sequentially from north to south (1 through 5). Due to the soft, wet condition of the marsh soil, samples were only retained in the auger to full (6') depth in two of the borings (1 and 3). Notably, these two borings were logged as containing distinct organic horizons (noted as concentrations of plant fragments). In the absence of significant plant fragments, it appears the muds were too soft to be retrievable from deeper than about 2 to 4 feet. In two cases, the hand auger could literally be pushed to the full 6-foot depth under body weight, which is indicative of very soft, saturated muds.

The two borings that reached the 6-foot target depth (1, 3) both encountered distinct horizons characterized by concentrations of buried roots and organics. We infer that these horizons represent formerly exposed marsh surfaces that have been subsequently buried.

Based on the long, linear morphology of the northwest-trending "peninsula" at site 2 (extending nearly 1,000 feet into the bay), we infer this feature is a remnant of a historic man-made structure that is composed of fill soils. We note that the silty fill soils at the site were too soft and contained insufficient organics to be retained in the auger.

Soils in borings 4 and 5 were also too soft to retrieve from deeper than 4 and 2 feet, respectively. Logs for these borings note an absence of buried root/organic horizons, which appears to have contributed to their "soupy" texture. The absence of buried organic strata at these sites may suggest these are younger marsh soils, due to either natural or anthropogenic infilling. Borings 4 and 5 also appear to be located along a historic dredge channel track (GHD, 2021). The associated unconsolidated, saturated muds could also be the result of relatively rapid accretion/infilling of the deeper dredged channel and the inability of the accreted muds to naturally consolidate in the subtidal environment.

2.2 Incremental Sampling Methodology (ISM)

Placement of sediment at the Project site will require comparative analyses of constituents between the in-situ sediments and the candidate imported sediments following the Incremental Sampling Methodology (ISM) methods described below:

1. Analyze sediments for total concentration levels of Cam 17 metals, PAHs, PCBs, Pesticides, Dioxins/Furans, TPH and values for pH, TOC, and texture.
2. Conduct modified Deionized Water Waste Extraction Test (Di-WET) test on soluble and mobile constituents that are elevated above the receiving site and analyze for soluble concentrations.

If all levels of fill constituents are similar to or below those of the receiving Project site, the fill material will meet suitability requirements. If imported fill constituent levels exceed receiving site levels for specific chemicals, exposure toxicology would need to be further assessed to ensure imported fill material is suitable for these beneficial uses and is compatible with species associated with the re-established aquatic habitats.

Supplemental Toxicological Testing and Analysis include:

1. Compare elevated import fill results with NOAA Screening Quick Reference Tables (SQuiRT) for preliminary screening for potential risks levels.
2. If imported fill constituent levels exceed receiving site values, conduct sediment exposure toxicology assessment with 10-day acute bioassay using appropriate sensitive organism representative of three life history stages (filter-feeding, burrowing, and deposit feeding) of appropriate benthic aquatic species, using imported fill sediment. (US Army Corps Inland Testing Manual Protocol).

ISM testing was conducted at the Project site by SHN, and the results are consistent with regional background levels for other parts of the Humboldt Bay shoreline (SHN, 2024b). Testing of sediment collected from the Project site shows that concentrations present are consistent within all three composite samples collected based on the following observations:

- No detectable concentrations of petroleum hydrocarbons, PCBs, pesticides, or herbicides,
- Concentrations of metals are consistent with regional background levels for this area, and
- Dioxin Toxic Equivalent (TEQ) and some SVOCs are present at very low levels.

As candidate sediment sources are identified the comparison of ISM testing results can be made to determine compatibility and if additional analyses are needed.

3. Sediment Sources for Salt Marsh Restoration

The Project will require approximately 125,000 yd^3 of fine-grained sediment to restore the salt marsh to the extent described in the preliminary studies (GHD 2021). Restoring the salt marsh can be completed through direct placement or indirect placement of sediment. The two approaches are summarized below and further described in subsequent sections of this memo as they relate to various sediment sources. The direct placement approach would include placement of dry sediment on the mudflat using conventional earthwork equipment or placement of wet sediment from offsite dredging sources using pump methods. Placement of wet sediments would require construction of barrier berms comprised of dry sediments/coarse gravels around the placement perimeter to contain the wet sediment in-place. Although the dry sediment placement would not require berms for placement, some type of protection such as a shingle (coarse gravel) beach would be required to prevent wind-wave erosion of the fill edge.

The indirect sediment placement approach would include strategic placement of sediment offshore of the Project site and relying on natural processes (wind, wave, and tidal currents) to transport the sediment into the Project site and promote sediment accretion overtime. This approach has not been applied in Humboldt Bay and therefore the accretion rates and timeframe needed to elevate the existing mudflat to salt marsh at the Project site is not known. As part of this Project, Northern Hydrology & Engineering (NHE) is conducting hydrodynamic and sediment transport (HST) modeling to better understand potential sedimentation rates from natural processes at the Project site. Results of the HST modeling can be used to provide insight into the applicability/feasibility of the indirect sediment placement approach to build salt marsh.

Multiple sites throughout the Humboldt Bay region could provide a source of sediment for the Project. Given the multiple candidate sites, a combination of both direct and indirect placement approaches should be considered during this planning phase, as a single sediment source has not been defined nor the timing of availability. Implementation of the Project will ultimately be influenced by the availability of suitable quantity and quality of sediment and as such a phased implementation approach will likely be needed to accommodate the variable timing to receive sediments. As sediment sources are identified, grain size and ISM will be needed to confirm reuse compatibility with the onsite sediments described above. Several potential sediment sources have been identified and described below as *wet dredged sediments*, *dry dredged sediments*, or *upland sediments*. Wet dredged sediments are sediment sources that have not been dewatered. These types of sediments are sourced from hydraulic dredging operations and would be placed using hydraulically pumped methods. Dry dredged sediments were once wet dredged sediments but have since been dewatered and can be handled and transported similar to upland sediments. Upland sediments are imported from non-bay sources. These three categories of sediments each have different handling and delivery methods which are further described below and will require further analyses prior to implementation.

3.1 Wet Dredged Sediment Sources

Wet dredged sediments are sources of sediments within Humboldt Bay that would be dredged using hydraulic suction hopper or clamshell excavation dredging methods and would be delivered directly to the Project site via scows equipped with discharge pipes and pumps. Potential wet sediment sources within Humboldt Bay are described below and the compatibility of these sediment sources with Project site reuse is discussed where data is available. The handling and delivery methods for these sediment sources are described in subsequent sections.

3.1.1 Humboldt Bay Harbor District's Offshore Wind Terminal Improvement Project

The Humboldt Bay Harbor, Recreation, and Conservation District (HBHRCD) is currently in the preliminary design and permitting process for the development of the Redwood Marine Multipurpose Terminal Replacement Project (RMT2) near the town of Samoa. The RMT2 project is expected to dredge 5 million yd^3 of sediment over the course of five years (SHN, 2024a). While some of the dredged material will be used for

RMT2 construction, additional sediments will be available for potential beneficial reuse or will be disposed of at the Humboldt Open Ocean Disposal Site (HOODS), a permanent ocean disposal site established in 1995. The Dredge Characterization Sampling and Analysis Plan Considerations Technical Memorandum (SHN, 2024a) developed for the HBHRDC RMT2 project noted that an option for disposal and potential beneficial reuse being considered for this project includes the placement onto salt marshes to maintain the elevation required to support salt marsh ecosystems as sea level rises.

Sediment Characteristics and Compatibility for Project Reuse

A Sediment Sampling and Analysis Plan (SAP) is in development for the RMT2 project by SHN. The results of a geotechnical investigation by SHN are shown in Figure 4 (SHN, 2024c).

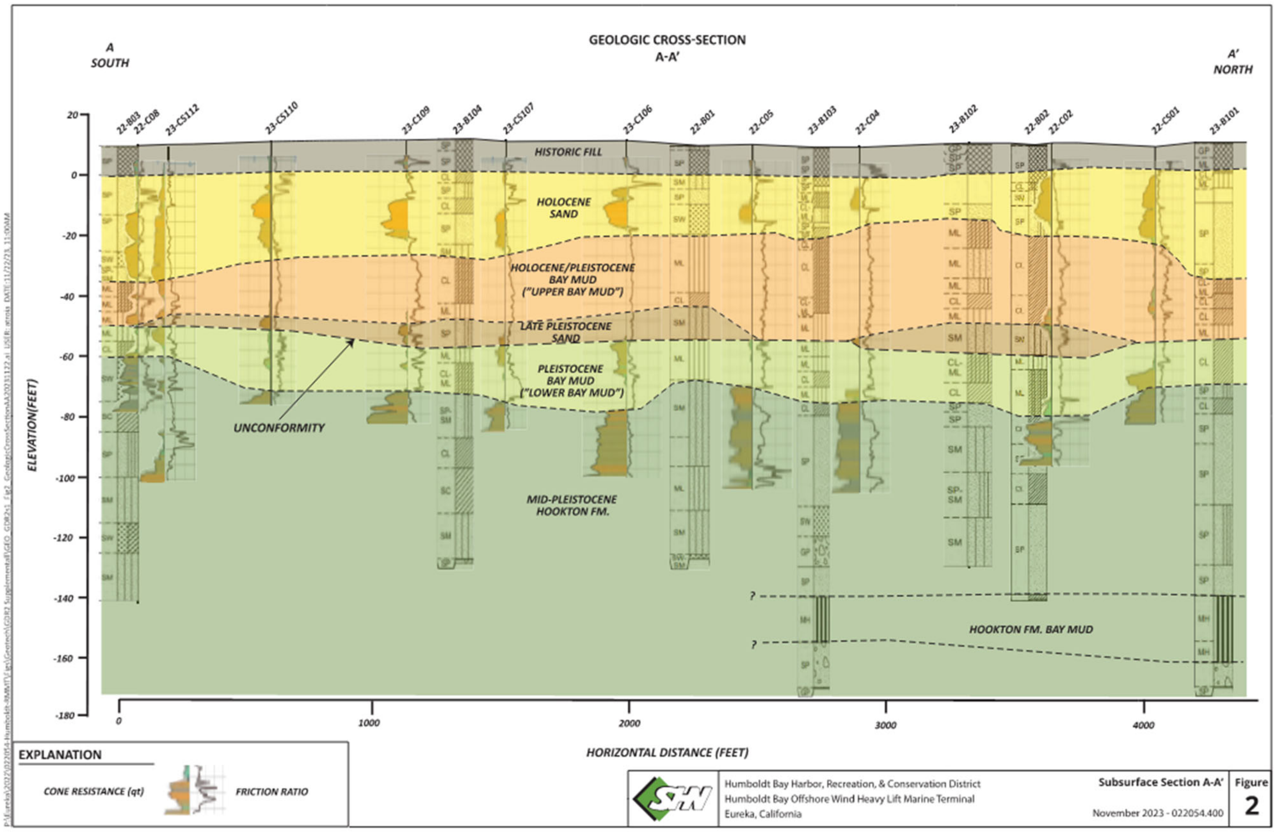

Figure 4. A 2023 field investigation revealed an updated interpretation of the subsurface conditions. Dredging is projected to occur up to an elevation of -40ft (SHN, 2024c).

RMT2 planning is underway, and dredging could begin within the near future. The planned dredging operation, which extends to depths of up to 40 feet, will yield a wide range of sediment with varying grain sizes. Not all dredged sediment is suitable for marsh restoration. Sand, a major component of the dredged material, is too coarse for marsh creation. However, "Upper Bay Muds", which are abundant at depths shallower than 40 feet, will also form a significant portion of the dredged material and are well-suited for marsh creation. The SAP, scheduled to be completed in the near future, will include the sampling results needed to confirm ISM compatibility with the Project site. Methods for dredging these sediments have not yet been defined but could include clamshell excavation and/or hopper suction dredging.

3.1.2 Routine Maintenance Dredging Sources

Maintenance dredging is conducted by HBHRCD, the City of Eureka, and private entities on an irregular basis throughout various locations within Humboldt Bay. The timing and volume of maintenance dredging can vary considerably, and sediment would need to be evaluated to inform compatibility with the Project site. The various sources are described below.

3.1.2.1 Woodley Island Marina

The Woodley Island Marina, the largest marina on Humboldt Bay, serves commercial, recreational, research, and safety vessels. The marina includes 237 boat moorage slips and is dredged by HBHRCD every 3-7 years generating approximately 60,000 yd^3 per dredge cycle. Dredged sediment is currently disposed of at HOODS, however some of the dredged sediments have recently been placed and dried on HBHRCD Samoa property to assess reuse potential. The Woodley Island dredging has been completed using clamshell excavation, where the sediment is placed on a containment barge and transported to HOODS or the HBHRCD Samoa property. Suction dredging has not been recently applied due to potential impacts to longfin smelt requiring additional regulatory approvals beyond those needed for clamshell excavation.

Compatibility for Project Reuse

Previous characterization of Woodley Island Marina sediments which were predominantly silts and fine sands would indicate future compatibility with the Project site and suitability for marsh creation.

3.1.2.2 Eureka Public Marina

The City of Eureka owns and manages the Eureka Public Marina. The marina includes 150 boat moorage slips. Less than 60,000 yd^3 are dredged from the boat basin every few years. Information from the City of Eureka is not available regarding where this disposed sediment is placed, but it is likely sent to HOODS.

Compatibility for Project Reuse

Similar to Woodley Island Marina, previous characterization of Eureka Public Marina sediments would indicate future compatibility with the Project site.

3.1.2.3 USACE Navigation Channel Dredging

The USACE oversees routine maintenance dredging of the federal navigation channels where approximately 1 million yd^3 is removed annually by the hopper suction dredge vessel, Yaquina (USACE, 2024).

Compatibility for Project Reuse

All sediment from navigation channel maintenance dredging is currently transported to HOODS, however near shore placement for beneficial reuse along the open coast shoreline fronting Samoa dunes is currently being planned. The Yaquina has a deep draft and is not equipped to pump dredge spoils to the Project site. Additionally, much of the sediment dredged from the federal navigation channel is sand and fine sand, which is not suitable for marsh creation.

3.1.2.4 Private Waterfront Facilities

Periodic dredging opportunities with other private waterfront properties, such as Chevron, Green Diamond, or Shneider, could be considered. However, the amount of dredged sediment is small and infrequent, making it challenging to align its availability with the Project’s requirements.

3.2 Dry Dredged Sediment Sources

Removing water from and drying wet dredge sediment simplifies transport and placement of sediment but requires additional material handling, storage, and time. Wet dredge sediment may be dried through passive or active means. Passive methods involve pumping wet sediment into drying basins or constructed drying beds. Water is removed from the dredge sediment by gravity drainage or through evaporation. Evaporative drying can be encouraged by working the sediment with heavy equipment. Active drying methods are more expensive but can reduce drying times. Active drying methods include the use of centrifugal pumps, filter presses, and geotextile tubes to extract water from the sediment.

Dry dredged sediment sources within the vicinity of the Project site are described below. The compatibility of the sediment source with the Project site is discussed where data is available.

3.2.1 Samoa Lagoons Dewatering Site

The Samoa Lagoons Dewatering Site managed by HBHRCD have been used historically for placement, dewatering, and storage of Humboldt Bay dredged sediment. The site is composed of two dewatering basins, an upper primary disposal basin, and a lower secondary decant basin. The basin currently has approximately 45,000 yd^3 for dredged sediment which is likely sourced from the Woodley Island Marina (Rob Holmlund, pers. comm., 26 July 2024).

Compatibility for Project Reuse

Given the sediment source was from former dredging of HBHRCD marina facilities, grain size characteristics are likely compatible for Project reuse, however an SAP has not been completed to assess contaminant levels relative to the Project site ISM.

3.2.2 Project-based Dewatering Site

It may be feasible to construct a dewatering site near to or adjacent to the Project site. Candidate sites include the former mill site to the south, the Brainard mill site to the north, or low-lying pastures near the Project site. The feasibility of constructing project-based sites is dependent on the feasibility of pumping or trucking dredge sediment to the facility, costs for constructing the dewatering facility, trucking costs for wet and dry dredge sediment, and ability to obtain environmental permits.

3.3 Upland Sediment Sources

Upland sediment sources within the vicinity of the Project site that potentially possess suitable soil characteristics are described below. Other upland sediment sources such as the College of the Redwoods Facilities Improvement Project may become available in the future. Caution must be taken to verify that borrow from upland sediment sources is composed of fine grain sediment with minimal sand and free of contaminants.

3.3.1 Local Restoration Projects

Local restoration projects, especially larger wetland/estuary type projects, could be a source of sediment for the Project site. These types of restoration projects typically restore or enhance wetland and estuary features by widening and deepening existing channels, or excavating a new network of tidal channels, which generate large volumes of fine-grained sediments. While much of the excavated sediments could be reused on site to elevate subsided tidal wetlands, construct tidal hummocks, or construct set-back berms if needed, transporting the sediments to the Project site could be an alternative beneficial reuse. Two local projects, the Elk River Restoration Project and the Jacoby Creek Restoration Project, are currently in the planning and/or design phase. Both projects, or other similar projects, could be a viable source of fine-grained sediments at the Project site. Implementation funding and timing is currently undefined for both projects, and sediment sampling would need to be completed to confirm compatibility with the Project site ISM.

3.3.2 Local Construction Projects

Local construction projects are a potential source of sediment. The potential for use of waste sediment from local projects is limited by several factors. Borrow sediment from local projects must be tested for contaminants. The borrow sediment must be rejected if contaminant levels are greater than in-situ conditions in the bay. Contractors that are potential sediment donors might be hesitant to commit sediment due to the uncertainty that their sediment is acceptable. Further, sediment quality testing costs are high. Borrow sediment volumes need to be large (i.e., greater than 20,000 CY) to produce economically competitive unit costs ($/CY) in comparison with other disposal methods available to a contractor.

Another limitation is that sediment from construction sites may possess coarse grain sizes (sand and gravel) which are unsuitable for marsh placement because coarse sediment allows rapid water drainage from marsh sediment and inhibits vegetation establishment. Local construction projects could provide a source of coarse sediment for protective berms and beaches.

Beneficial sediment reuse guidelines in San Francisco Bay distinguish between “surface material” and “foundation material” SFRWQCB (2019). Surface material has acceptable contaminant levels and is suitable for the establishment of salt marsh vegetation. Foundation material which may possess unsuitable contaminant quality may be placed in marshes at least three feet below the surface and at least 200 feet from tidal channels. The depth of three feet is assumed to be below the limits of biotic uptake. Pearce et al. (2021) suggested that coarse sediment could be used as foundation material in marsh fills at depths greater than three feet below the surface and below MHHW.

4. Transport, Placement and Handling Methods

The sediment source(s) described above will ultimately dictate the methods of transport, handling, and placement at the Project site. A single sediment source has not yet been identified to meet the Project needs and therefore the Project design should be advanced to accommodate sediments from multiple sources (wet dredged, dry dredged and upland sediments). Placement methods are categorized as either direct or indirect placement for the purpose of describing the range of potential placement methods for various sources. Considerations associated with each placement method are discussed below and summarized in Table 1. Figures 5 and 6 depict possible transport routes that could be taken for wet and dry dredged sediments. Figure 5 focuses on indirect placement strategies whereas Figure 6 shows direct placement strategies.

Table 1. Transport and placement methods for various sediment sources.

Sediment Source Type	Potential Source Location	Placement Method	Transport Method	Handling Considerations
Wet Dredged Sediments	Woodley Island Marina, Eureka Public Marina, RMT2 Dredged Sediment	Direct (Figure 6)	Slurry pumped from dredge site to Project site through pipeline (may require multiple booster pumps)	Receiving sediments would need to be dewatered at site
		Indirect (Figure 5)	Dredge sediment placed in shallow draft barge/scow equipped with hydraulic pumps.	Requires anchoring of barge/scow in deep channel off-shore from Project site and pumping sediment as slurry across mudflats.
Dry Dredged Sediment	Samoa Lagoon	Direct (Figure 6)	Truck / Haul	None
Upland Sediment	Elk River Restoration	Direct (Figure 6)	Truck / Haul	Wet upland sediment may require time to drain on site before site grading occurs.
	Jacoby Creek Restoration			
	Construction Borrow			

Figure 5 (left) and 6 (right). Possible routes for transporting sediment to the Project site are shown on the right. Indirect placement strategies are shown on the left.

4.1 Direct Placement

Direct placement methods involve transporting sediment from its source and direct placement at the Project site. Sediment sources for direct placement will be described below as dry dredged sediment or upland sediment, and wet dredged sediment.

4.1.1 Direct Placement of Dry Dredged or Upland Sediments

4.1.1.1 Introduction

Direct placement of dry dredged or upland sediments would employ haul trucks to transport sediment and with conventional earthwork equipment to place sediment at the Project site in accordance with the Project Geotechnical Memorandum (SHN 2024c). As depicted in Figure 6, dry dredged or upland sediment may be hauled from the Samoa Lagoon, the Elk River Restoration Project site, the Jacoby Creek Restoration Project site, or another site yet to be identified. Dry dredged sediments or upland sediments could also be trucked to the site and stockpiled (at Bracut or Brainard, for example) prior to placement.

Dredge sediment developed by direct excavation is suitable for truck hauling. During a recent dredging project at the Woodley Island Marina, sediment was excavated by a clamshell dredge, placed in a transport barge, loaded from the barge into truck by an excavator, and then transported to a disposal site (Adam Wagshal, personal communication).

4.1.1.2 Example Direct Placement of Dry Sediments

An example of direct placement of dry sediment to create a salt marsh on an existing mudflat was recently completed in San Francisco Bay as part of the South Bay Salt Pond Restoration Project near the City of Mountain View (Figures 7 and 8). This example project included the placement of dry sediments placed using conventional earthwork equipment to create a salt marsh ecotone. Similar methods were employed by the U.S. Fish and Wildlife Service (USFWS) to construct the White Slough marsh in southern Humboldt Bay.

Figures 7 and 8. Direct placement of dry sediment to create a salt marsh ecotone as part of the South Bay Salt Pond Project.

4.1.1.3 Work Sequence

The Natural Shoreline Infrastructure in Humboldt Bay for Intertidal Coastal Marsh Restoration and Transportation Corridor Protection Report (NSI) prepared by GHD (2021) proposed breaking up the Project site into nine work zones with the notion that the Project could be implemented over several years as sediment becomes available (Appendix Exhibit A-1). Each zone could be completed independently of other zones. One or more zones could be constructed over a single construction season.

The sequence of work placing dry sediment is illustrated in Appendix Exhibit A-2. The first phase of work is to construct haul routes for access to and around the work zone. The first haul route would be constructed of dry sediment placed at the base of the rock slope protection on the bayside of the Humboldt Bay Bike trail and would have a surface elevation of 9.0 feet NAVD 1988. The second haul route would be constructed at the outer edge of the proposed marshplain. The outer haul route can be set with a crest at 9.0 feet to prevent flooding of the Project site at high tides until placement of fill is completed. Both routes can be constructed by trucking dry sediment to the site, dumping the sediment directly onto the mudflat, and then using a dozer to push sediment out to form the haul route. The outer haul route would also include a section at the west end that ties back to the inner haul route. When complete, there would be a circular route around the marsh area that allows for efficient movement of delivery trucks around the Project site. Repetitive truck traffic would compact the soil on the haul routes. As the haul routes are being constructed, the shingle beach will simultaneously be constructed by placing a gravel/sand mix on the bayside of the outer haul route to the 9.0-foot elevation. This shingle beach will protect the haul route from wave erosion.

The second phase of work consists of delivering dry sediment to the marsh area. Sediment dumped on the side of the haul route would be pushed out by dozers to provide a minimum of four feet of fill material. The loose mud on the existing mudflat would be squeezed out by placement of dry sediment but captured within the marsh area.

The third phase of work would consist of channel excavation and final grading of the marsh plain. The marsh plain should be graded to provide positive drainage towards the tidal channel network. The final grading may generate excess sediment that can be placed at an adjacent work zone or used to achieve the final marsh plain elevation as some subsidence is anticipated of the fills placed in the second phase. The outer haul route would be lowered to allow overtopping of the marsh edge from the bayside. As the haul route is being lowered, the upper portions of the shingle beach will be incorporated into the remaining lower portions of the shingle beach. The marsh plain surface should be mechanically decompacted. The final step would be to breach the outer edge of the marsh to allow tidal flooding of the channel network.

The inner haul route should be maintained to allow access to work zones further west. When all work zones are completed, the haul route should be lowered and graded, and the surface decompacted and planted.

4.1.1.4 Planting

The marshplain should become vegetated naturally by seed delivery from adjacent marshes. Full vegetation should be established within five years. Vegetation establishment can be accelerated by adding nutrients to the soil. Fertilizing might also be considered for soils obtained from source areas where nutrients are poor or lacking sufficient organic content. The marsh ecotone, a transition zone from the rail prism to the marsh plain will be actively planted.

Site monitoring will be required during the time that vegetation is establishing. Active management measures may be required to prevent the introduction of invasive species.

4.1.1.5 Schedule

Given the source of fill to construct the project is currently undefined, construction of individual work zones using placed dry sediment is anticipated to occur over multiple years. There will be settlement of the soft bay muds after placement of dry sediment. Constructing the site over multiple years will allow time for the initial soil placement to settle and for additional soil to be placed to bring the site up to final design grades.

Completing the entire Project is anticipated to require several years. The NSI Report (GHD 2021) estimated that the Project in-situ fill volume required was 125,000 CY. Allowing for compaction and settlement, this might require as much as 180,000 CY of imported dry sediment or about 20,000 CY per work zone. The U.S. Fish and Wildlife Service White Slough Wetland Restoration Project (White Slough) in south Humboldt Bay was able to import and place about 240,000 CY over four construction years. The White Slough project employed a single operator on the project site to spread and grade fill, and a single excavator operator at borrow sites. This suggests that if suitable dry sediment is available that three work zones could be initially filled in a single construction year. Allowing a year for initial settlement, all nine work zones could be completed in four years. The schedule could be accelerated if sediment is readily available, if more operators are used, and if sufficient trucking is available.

Delivery rates are dependent on the number and type of trucks used and the amount of travel time between borrow sites and the Project site. Using 20 CY capacity trucks, loading times are typically ten minutes at the borrow site and ten minutes at the delivery site for unloading. Trucks are only loaded to 80% of capacity. Delivery of 180,000 CY at the site using 20 CY trucks would require 11,250 trips.

4.1.1.6 Feasibility Assessment

Direct placement of dry sediments is a feasible project approach in terms of constructability. The construction methods required to transport and placed dry sediment to restore salt marshes are well understood. They have been successfully employed around Humboldt Bay to restore salt marshes. Constructing a salt marsh at the Project site will employ similar methods but will also require some additional treatments to stabilize the outer edge of the constructed salt marsh.

A potential impediment to project implementation is sourcing sediment. The USFWS White Slough project struggled to find suitable supplies of dry sediment. Ultimately, the White Slough project imported 240,000 cubic yards of sediment from four local sources. The process of identifying suitable borrow locations, evaluating environmental quality of soils, and developing and permitting site excavation does require significant time and labor investment. The County will need to take a proactive approach to identify suitable sediment sources and volumes to implement direct placement methods.

The White Slough project provides a good example of potential implementation costs for this Project. Overall construction costs for permitting, sediment sourcing, sediment excavation and loading, sediment trucking, and placement of sediment at White Slough were $15.00 a cubic yard (Conor Shea, coauthor). The White Slough unit cost does not include costs for two items: (1) engineering design costs for White Slough were covered by USFWS staff time; and (2) costs for excavation and trucking of soils from the Martin Slough project were covered by the Martin Slough project.

Projecting potential costs for the Project is difficult because much of the cost is dependent on the trucking distance between borrow areas and the Project site. Sourcing from restoration projects at Jacoby Creek or Elk River would produce low unit costs for sediment. Trucking from areas further away such as the Eel River Valley would produce higher unit costs. We estimate that approximate costs for sourcing, trucking, and placement of dry sediment from upland sources would range between $25.00 to $35.00 a cubic yard. Total costs for sediment sourcing, trucking, and placement of dry sediment would be between $3,125,000 and $4,375,000. The NSI Report (GHD 2021) estimated costs for soil to range between $3,250,000 and $6,500,000. (This estimate does not include other project costs which the NSI Report (GHD, 2021) estimated to range between ($13,450,000 and $17,600,000). Trucking of excavated dredge sediments would have similar costs.

4.1.2 Direct Placement of Wet Dredged Sediments

4.1.2.1 Transport

Wet dredged sediment can be generated by suction dredging which creates a slurry or by direct excavation. Wet dredge sediment can be transported by pipeline, or by shallow draft barges and vessels.

Transport by pipeline is most compatible with suction dredging. The feasibility of pumping wet dredged sediment to the Project site is largely driven by the distance from the dredge location to the Project site. It is possible to pump over long distances through use of large power pumps, booster pumps, and large diameter pipelines, but over very long distances, the additional power and equipment required make other methods financially better choices. Woodley Island, Eureka Public Marina, and RMT2 dredge spoils, as depicted in Figure 6, are considered wet sediment sources where hydraulically pumping the sediment is considered feasible.

Transporting excavated dredge sediment by pipeline would require mixing with water to create a pumpable slurry. This creates additional handling steps that makes it an inefficient choice compared to transport by truck.

Barges of shallow draft scows can be used to transport dredge sediment generated by suction dredging or by direct excavation. Barge transport would require several handling operations. The tidal range and shallow mudflats fronting the Project site precludes direct placement from a vessel or barge at the Project site. The drafts associated with scows or barges are too deep to reach the Project site, even during high tides. Transport by barge would require loading at the dredging location and then towing of the loaded barge or scow into the main North Bay channel to an anchoring location near the Project site where depths allow. Locations with suitable depths are a minimum of 10,000 feet from the Project site. From the anchor location, the barge / scow would pump the sediment through a temporarily placed pipeline to the Project site. To allow pumping, the dredge sediment must be mixed with water to create a pumpable slurry. The allowable solids content of the slurry is about 15% for sand and 20% for silts. Sediments that are dredged using excavation methods have a relatively low water content and will require significant water addition and mixing work compared to sediments dredged using suction methods. The sediment slurry would be pumped from the scow with an on-board pump and into a 10–12-inch diameter High Density Polyethylene (HDPE) pipe and discharged at the Project site. The pipe will float when empty or filled with water, so to prevent the pipe from hindering navigation between uses it can be configured with buoys to reveal its location, or a series of weights that clamp on to the pipe which keep the pipe placed on the bottom. This could allow the pipe to remain in place for multiple dredging cycles and until the Project site has received the desired amount of sediment. It might not be possible to leave the pipeline in place over the winter season due to strong waves and currents.

Trucking wet dredge sediments developed by suction dredging does not appear practical due to the high water content (>70%). It would be more efficient to dewater suction dredging derived sediment prior to transport.

4.1.2.2 Placement and Containment

Processing and placement of the pumped wet dredged sediment at the Project site requires heavy equipment and construction operations. A containment cell must be constructed to hold the wet dredged sediment and to allow for dewatering and sediment consolidation. During pumping, the location of the pipe outlet must be shifted around to effectively fill the containment cells.

The containment cell would be formed by the construction of an earthen berm with an outer shingle beach along the outer edge of the proposed marsh plain, similar to the dry sediment option described above. The crest of the berm would be a minimum of 9.0 feet NAVD 1988 in elevation to prevent overtopping by extreme tides. The berm would need to be wide and stable enough to support heavy equipment for moving the pumping pipeline outlet. Wet dredged sediment would be pumped from the transport vessels as a slurry that will flow into place. The berm would contain the slurry. Decanting would occur by evaporation or by outflow through overflow weirs in the berm at lower tides. Silts and clays will require longer settling periods. Heavy equipment will not be able to access the area within the containment cell to redistribute saturated sediments until the sediment has substantially consolidated. Multiple placement operations over multiple years may be required to achieve final design grades. Final site grading, channel excavation, lowering of the containment berm, and incorporating the removed upper shingle beach into the lower shingle beach would occur after the containment cell is filled with dewatered sediment, and the placed sediment has consolidated

4.1.2.3 Work Sequence

The work sequence for placing wet dredged sediment is similar to placing dry sediment. The Project is broken up into nine work zones. Each work zone may be constructed individually or in combination with adjacent work zones over multiple years. The Project will require a staging area adjacent to the shoreline.

The work sequence for placing wet dredged sediment is illustrated in Appendix Exhibit A-3. The first phase of work for placing wet dredged sediment is to construct berms forming the containment cells, and as previously described for the dry sediment placement. The berms will also be used as haul routes to access the work zone. The first haul route would be constructed of dry sediment placed at the base of the rock slope protection on the bayside of the Humboldt Bay Bike trail and would have a surface elevation of 9.0 feet NAVD 1988. The outer containment berm would be constructed fine-grained sediment placed along the outer edge of the proposed marshplain. The crest of the berm would be set at or above elevation 9.0 feet NAVD 1988. The fine-grained sediment for the berm will need to be imported. A series of shallow overflow weirs will be constructed into the berm for decanting of the wet dredged material. The shingle beach will simultaneously be constructed on the outer edge of the berm to an elevation of 9 ft. The outer berm would also include a section at the west end that ties back to the inner haul route. When complete, there would be a circular route around the marsh area.

The second phase of work is to fill the containment cell with wet dredged sediment up to elevation 8.5 feet NAVD 1988. After initial placement, the sediment would require settlement time to dewater and consolidate. Additional placement sequences may be required depending on the amount of fluid in the dredged sediment.

The final phase of work consists of several components. Tidal channels would be excavated into the marsh plain. Cut material from the channel would be placed and spread on the marsh plain. Final grading would create positive drainage to the tidal channel network. The outer containment berm would be lowered, and the upper portions of the shingle beach will be integrated into the lower shingle beach to form erosion protection on the outer edge of the marsh and to allow overtopping of the marsh edge from the bayside. The marsh plain surface should be mechanically decompacted. The final step would be to breach the outer edge of the marsh to allow tidal flooding of the channel network.

4.1.2.4 Planting

The process of natural revegetation and monitoring would be the same for wet dredged sediment as for dry placed sediment. The marsh ecotone, a transition zone from the rail prism to the marsh plain will be actively planted.

4.1.2.5 Schedule

Construction of containment berms and haul routes for an individual work zone can be completed within several weeks. The time requirements for placing dredge sediment are subject to the rate of dredge material delivery, the amount of water in delivered sediment, and the settlement time for the sediment/water mixture. Depending on sediment size, sediment delivery rates pumping from a barge run between 500 and 1,100 CY/day using a single barge-mounted pump (The Dutra Group, personal communication). It would require between 115 and 250 working days to deliver 125,000 CY of sediment to the Project site. This would require at least two construction seasons to deliver sediment to the site. Additional construction seasons might be required to allow for consolidation, to cut tidal channels, and to perform final site grading and planting.

4.1.2.6 Feasibility Assessment

There are significant communitywide benefits that would be generated by use of wet dredged sediment to construct the Project. Sediment for the Project will be difficult to source while disposal of sediment from current dredging projects remains problematic. Beneficial reuse of dredged sediment at the Project site resolves both sourcing and disposal issues and promotes environmental sustainability.

4.1.2.6.1 Pumping Wet Dredge Sediment

There are several logistical considerations that limit the feasibility of direct placement of pumping wet dredged sediment directly from the dredge site to the Project site. Environmental protection measures currently limit available dredging methods to direct excavation. Suction dredging has not been permitted in Humboldt Bay because of potential entrainment of longfin smelt and salmonid species. Use of a pipeline to directly transport dredge sediment to the Project site would be a complex undertaking. In-water placement would require crossing navigation channels and mudflats which would be difficult to permit. Placement of a pipeline along roadways would require road crossings that are not practical. Excavated sediment would require mixing with water to create a slurry that could be pumped, but it would be more efficient to transport excavated dredged sediment using trucking.

4.1.2.6.2 Transport of Wet Dredge Sediment by Barge

Transport of dredge sediment by barge to a channel near the Project site and then pumping to the Project site is feasible. The proposed construction methods and equipment are in use by dredging contractors in the United States and internationally.

Several local logistical issues might impede implementation of barge transport methods. Dredging methods would likely be limited to direct excavation because of environmental regulations. Excavated sediment must be mixed with water to create a pumpable slurry. Water extraction from bay waters would require fish screens and may pose environmental permitting hurdles that limit operational efficiency. Construction equipment (barges, barge mounted cranes, and pumps) used to perform these operations are not generally available in the Humboldt Bay area and would need to be mobilized from larger Pacific Coast ports.

We discussed potential dredging operations with a dredging contractor that recently conducted dredging in Humboldt Bay. Our discussions indicate that approximate costs for excavation dredging, placement in barges, transport within the bay, and pumping to fill containment cells would range between $15.00 to $20.00 a cubic yard. Mobilization costs to transport equipment to Humboldt Bay is anticipated to be $1,000,000. Equipment would need to be mobilized at least twice. (Alternatively, the Project might have to cover storage costs and costs for idling the equipment over the winter). This raises the unit costs to $27.00 to $32.00 a cubic yard. Total costs for sediment sourcing and placement of wet sediment would be between $4,860,000 and $5,760,000. This estimate does not include other project costs which the NSI Report (GHD, 2021) estimated to range between $13,450,000 and $17,600,000.

4.1.3 Indirect Placement

4.1.3.1 Approach

Indirect placement involves placement of sediment in an off-shore location and allowing natural waves and other transport processes to deliver the sediment to the shoreline and build the marshplain. Indirect placement relies on natural processes to transport sediment to its desired location. One approach for the Project site is to construct a low berm at the outer perimeter of the proposed salt marsh. The berm would have with a breach cut to allow tidal flow exchange. The berm would lesson wave action within the enclosed area, creating calm water conditions that would allow fine sediment to settle and accumulate. Assessing wind-wave and current resuspension from the original dredged placement location, and deposition potential at a Project site for indirect placement are critical to ensuring the marsh development at the Project site. The shallow water fronting the Project site coupled with the exposure to wind waves make this option potentially viable but would require additional studies. As mentioned earlier, NHE is conducting a HST modelling study to understand potential sediment accretion rates from natural processes for existing conditions, and to assess the feasibility of only constructing the outer berm and allowing the marsh to build from mudflat elevations by increased sediment accretion rates due to the outer berm reducing wave energy within the Project site. If the indirect placement approach were to be explored further, the developed HST model could be used to better understand how this approach may increase sedimentation rates at the Project site, either to build the marsh from mudflat elevations ,or better allow existing marshes to accrete sediment and keep pace with increased rates of sea-level rise into the future.

Wet dredged sediment sources from RMT2, Woodley Island Marina, or Eureka Public Marina could be utilized and transported through a hydraulic pumped pipeline or with low draft scows (Figure 5). In either case, sediment would be placed offshore of the Project site and allow natural processes to disperse the sediment along the Project site, or to other tidal wetlands in the area, over time. This method has not been applied on Humboldt Bay; however, it is being piloted in San Francisco Bay by the USACE as described below.

4.1.3.2 Example Indirect Placement of Wet Dredged Sediments

An indirect placement of sediment was carried out in San Francisco Bay by the USACE. As part of the Shallow Water Placement Pilot Project, the USACE is seeking to replenish Whale’s Tail, a shallow water marsh ecosystem suffering from drowning and erosion (Beagle & Lacy, 2024).

The USACE strategy involved a modeling phase that identified the most optimal locations for sediment placement offshore. Target cells for dumping sediment were located roughly two miles offshore of the target marsh. 90,000 yd^3 of sediment was loaded into several shallow-draft scows (Figure 9). The scows were emptied throughout the established cells in 169 loads spanning nearly a month.

Months of monitoring proceeded the sediment placement cycle. Oceanographic data was collected in the region including waves, currents, salinity, and suspended-sediment concentrations. Impacts of the project on benthic communities were assessed, a tracer study was conducted, and bathymetric surveys helped assess the progress of the project. USACE expressed concerns with compaction of the placed sediment. Compaction was not considered in their modeling and is hypothesized to slow the sediment transport process.

This USACE pilot project has demonstrated that indirect placement can be a viable method to avoid the logistical challenges associated with direct placement, but the use of this approach on Humboldt Bay would require additional studies and analyses to better understand the efficacy and regulatory constraints and necessary approvals.

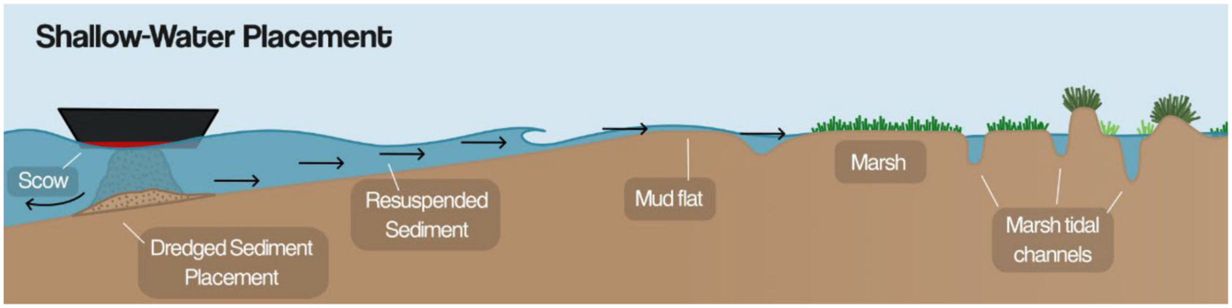

Figure 9. Indirect placement using shallow draft scow used by the USACE in the San Francisco Bay.

5. Conclusions

Identifying sufficient amounts of suitable salt marsh sediment is one of the major challenges to Project implementation. Construction activities around Humboldt Bay are limited in scope and do not regularly generate sufficient volumes of sediment. The best opportunities lie with restoration projects that might generate surpluses of floodplain sediments. Other opportunities lie with on-going maintenance dredging and large-scale dredging that might occur with port development.

There are two practicable methods for sourcing and delivery of sediment to the Project site: (1) trucking from upland areas or local restoration projects; (2) barge transport of excavated dredge sediments with placement by pumping from the barge to the Project site. Both methods have well-established construction procedures. Unit costs for sediment sourcing and placement are similar. The choice of methods will likely depend on where sediment is available.

We recommend the County take a proactive approach to identifying potential sediment sources. The County should coordinate with regional partners that include the Humboldt Bay Harbor and Recreation District, City of Eureka, City of Arcata, the Humboldt Bay National Wildlife Refuge, the local U.S. Army Corps of Engineers, and others to implement a regional strategy that matches up potential sources of sediment with beneficial reuse sites. The strategy should focus on identifying potential restoration and dredging projects which generate excess sediment.

Given a specific source of sediment and timing of availability is currently undefined, the Project design should be advanced to serve the region as a beneficial reuse site capable of receiving wet, dry, and upland sediments using a range of transport and placement methods described above. This strategy would facilitate a phased approach that would accommodate receiving sediments over time similar to the White Slough Restoration Project on the Humboldt Bay National Wildlife Refuge. This approach would also allow a range of sediment sources and placement methods to be applied as part of an initial demonstration phase to test the efficacy in salt marsh creation and to inform implementation of future phases.

6. References

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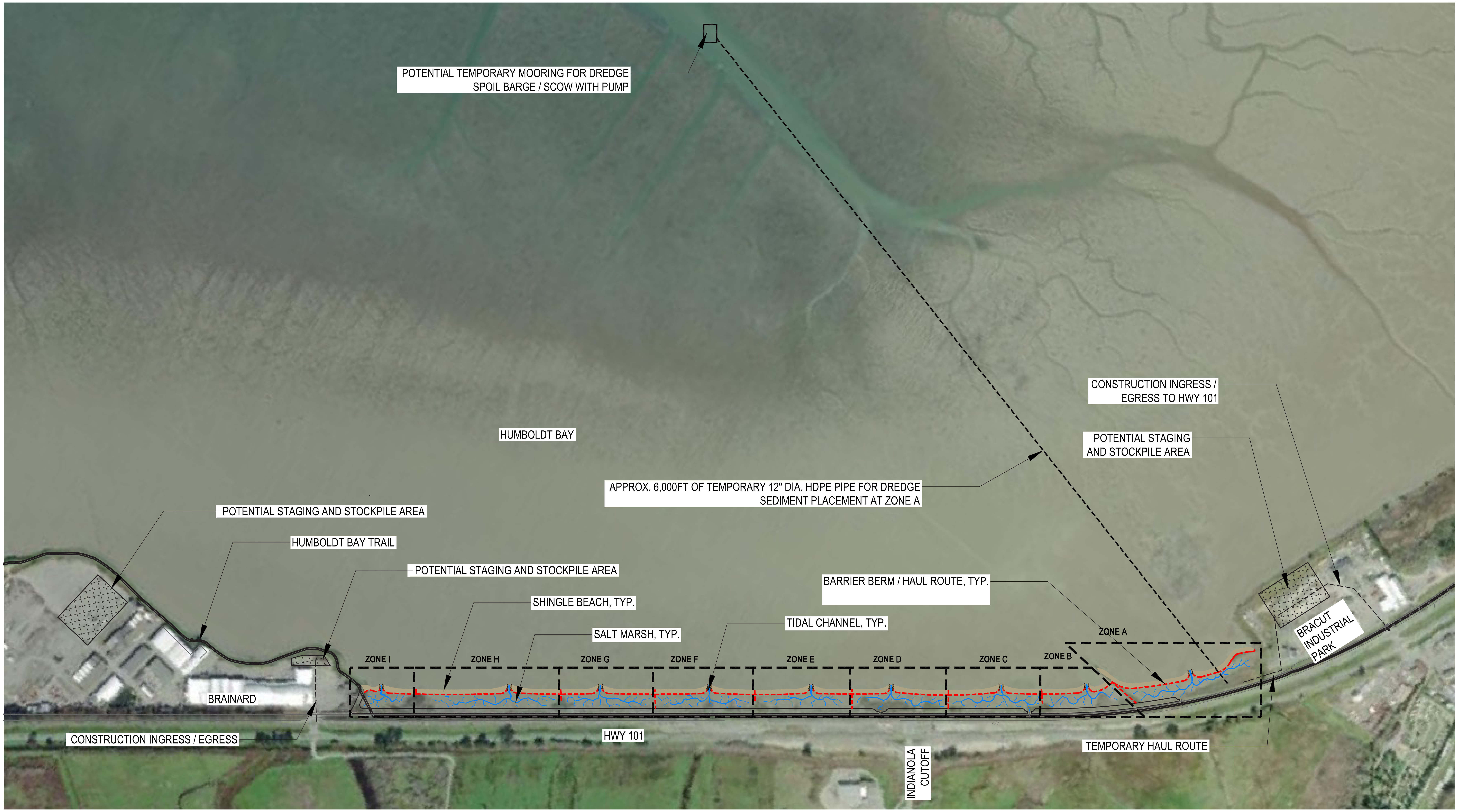
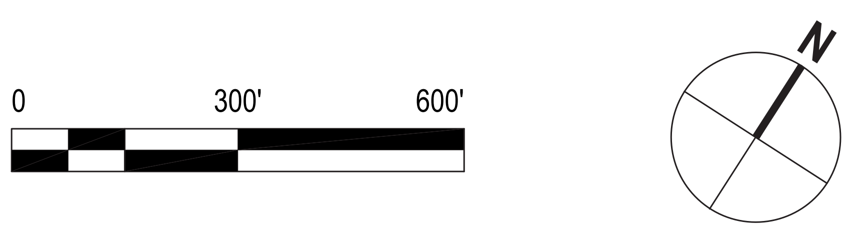
APPENDIX A: WORK SEQUENCE EXHIBITS

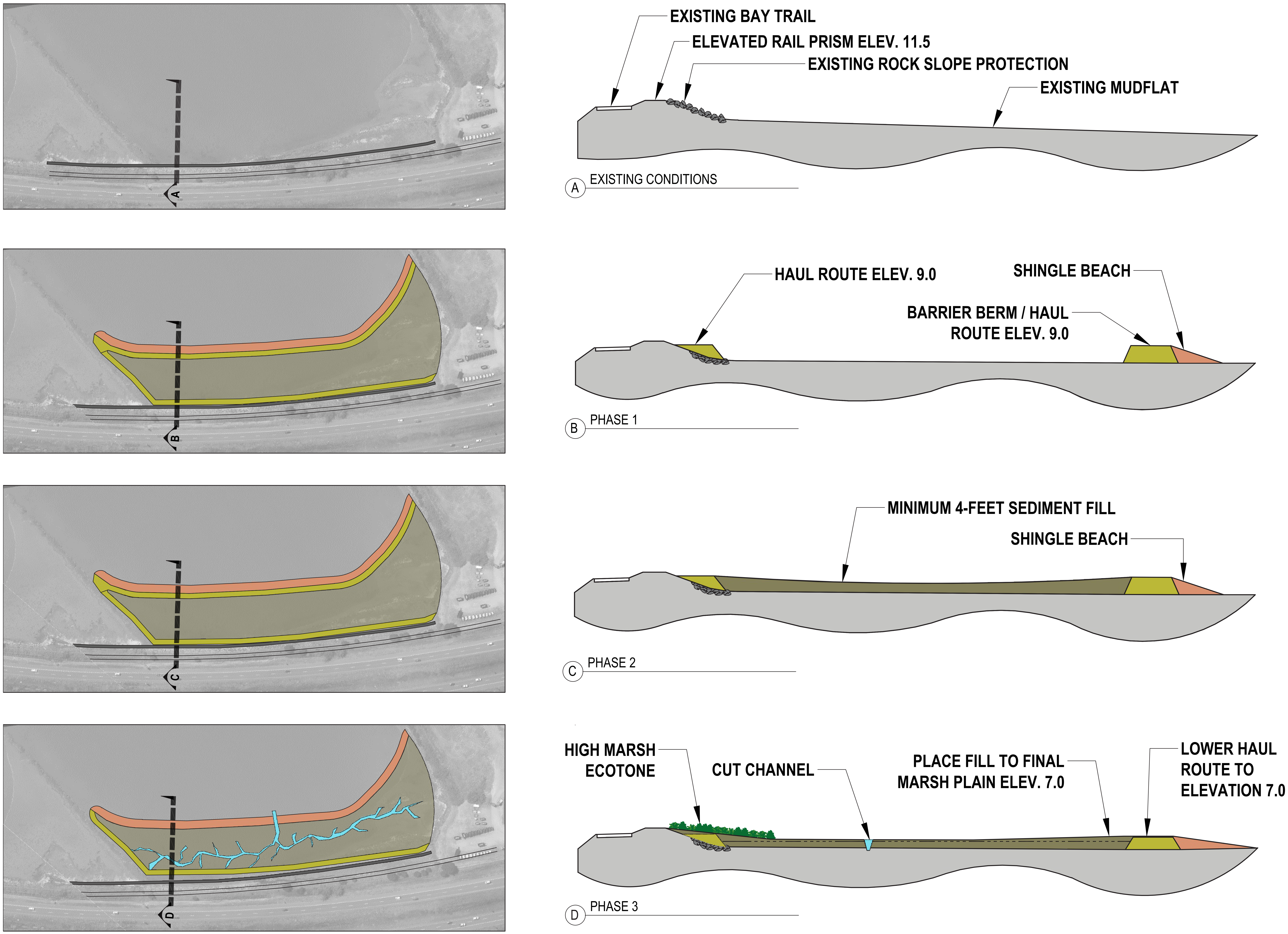




NOTES:

1. CONSTRUCTION PHASING (SHOWN AS ZONES) WILL BE SUBJECT TO AVAILABILITY OF SALT MARSH FILL. ACTUAL PHASING MAY VARY FROM THAT SHOWN.
2. BARRIER BERMS PLACED TO MAINTAIN THE SALT MARSH FILL AREA DE-WATERED DURING CONSTRUCTION AND FOR MATERIAL HAUL ROUTES.
3. BARRIER BERMS PLACED MAY REMAIN IN PLACE FOLLOWING CONSTRUCTION.
4. SEQUENCE OF WORK MAY BE FROM ZONE A TO I OR ZONE I TO A.

GHD	HCDPW HUMBOLDT BAY LIVING SHORELINE PROJECT	FIGURE A-1: CONSTRUCTION STAGING AND SEQUENCING PLAN	Project No. 12632378 Date: October 2025



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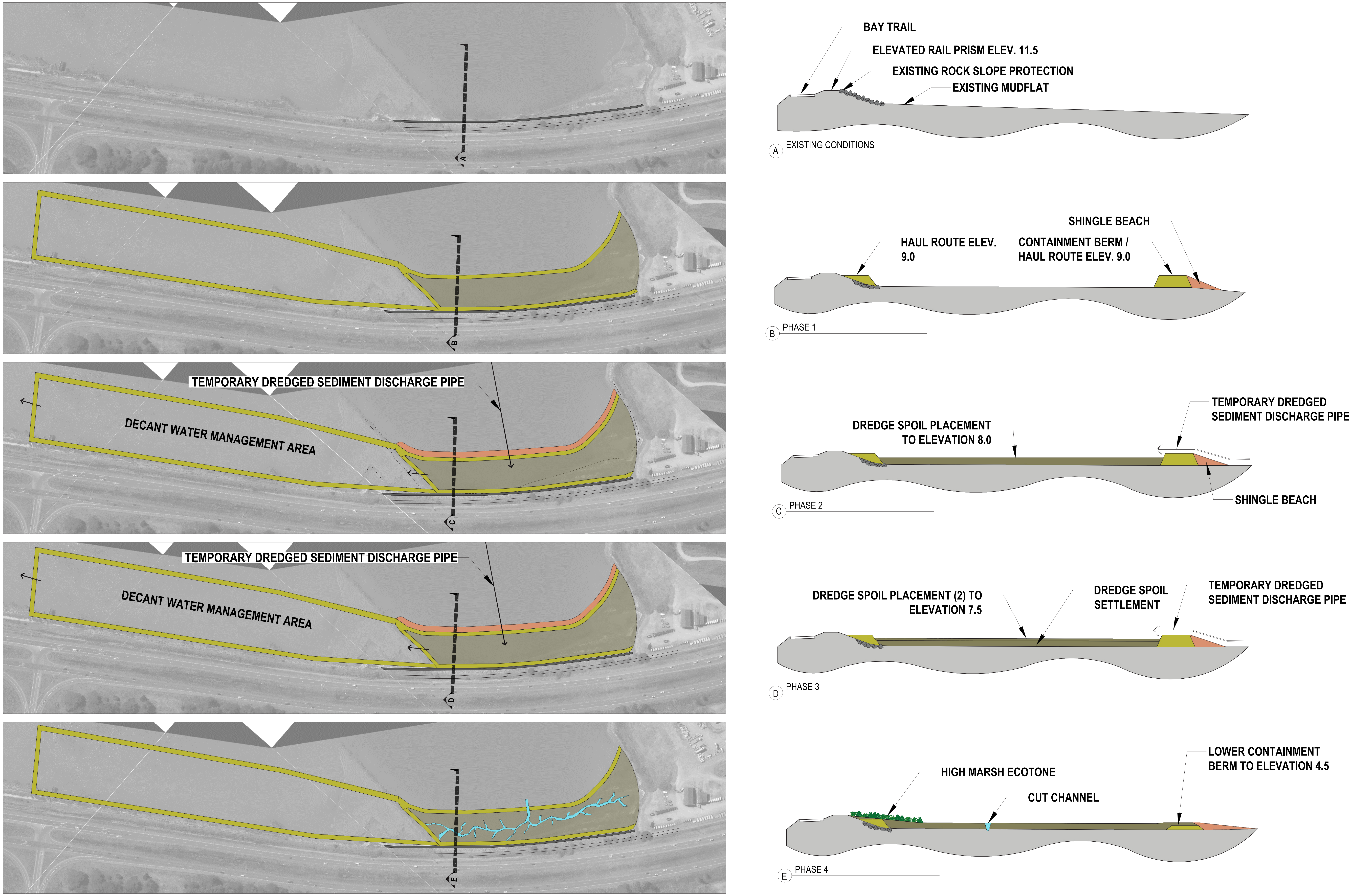
HUMBOLDT BAY LIVING SHORELINE PROJECT

FIGURE A-2: DRY SEDIMENT PLACEMENT - ZONE A

Project No. 12632378
Date: October 2025



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HUMBOLDT BAY LIVING SHORELINE PROJECT

FIGURE A-3: WET DREDGED SEDIMENT PLACEMENT - ZONE A

Project No. 12632378
Date: October 2025