US Army Corps
of Engineers®

Sacramento District
Engineering Division

Delta Islands and Levees Ecosystem Restoration Feasibility Study

Contra Costa County, California

Appendix C: Engineering Appendix

September 2018

This page intentionally left blank.

Table of Contents

Table of Contents continued

Table of Contents continued

List of Tables

List of Figures

List of Figures continued

List of Plates

List of Attachments

This page intentionally left blank.

C-1. General

C-1.1. Format and Organization. This document and the associated plates and attachments comprises the Engineering Appendix to the Delta Islands and Levees Ecosystem Restoration Final Feasibility Report/Environmental Impact Statement. This document has been formatted following ER 1110-2-1150 Appendix C - CONTENT OF ENGINEERING APPENDIX TO FEASIBILITY REPORT. Several sections of ER 1110-2-1150 Appendix C are not applicable to this Ecosystem Restoration Study and are thus not addressed, though the headings are still listed; many other sections demand only brief explanation, non-applicable sub-sections are omitted without comment. The sections most relevant to this Study are C-2 Hydrology and Hydraulics, C-4 Geotechnical, C-6 Civil Design, C-8. Electrical and Mechanical Requirements, C-10 Construction Procedures and Water Control Plan, and C-19 Cost Engineering; plates and attachments are contained following a references section at the end of this Appendix.

C-1.2. Study Area.

C-1.2.1 The Delta. The Delta (Figure C-1-1) is part of the largest estuary on the West Coast of the United States; is home to hundreds of species of fish, birds, mammals and reptiles; and is considered an ecosystem of national significance. Agricultural land irrigated by Delta water contributes billions of dollars in production for the Nation. Two deep water ports in the Delta serve as important marine terminals for dry bulk cargo vessels transporting agricultural products through the Delta’s deep draft navigation channels to world markets. Delta levees protect thousands of acres of orchards, farms, and vineyards as well as critical infrastructure including state and interstate highways, major rail lines, natural gas fields, gas and fuel pipelines, water conveyance infrastructure, drinking water pipelines, and numerous towns, businesses and homes.

The Delta is a web of channels and reclaimed islands at the confluence of the Sacramento, San Joaquin, Cosumnes, Mokelumne, and Calaveras Rivers. Forty percent of California’s land area is contained within the watersheds of these rivers. The Delta covers about 738,000 acres and is interlaced with hundreds of miles of waterways. Much of the land is below sea level and protected by a network of 1,100 miles of levees which have been constructed over the past 150 years to manage the flow of water through the Delta. The land behind the levees is predominantly agricultural (corn, wheat, vineyards, cattle) and waterways provide recreational outlets for nearby urban areas and essential habitat for fish and wildlife, including federally listed species under the Endangered Species Act. The Delta is also the largest single source of California’s water supply, providing 25 million Californians with drinking water and irrigating millions of acres of farmland in the Central Valley. In addition, more than 500,000 people live within the Delta and rely upon it for water, recreation, and livelihood. The majority of that population is in the greater Sacramento and

Stockton areas and is the focus of other USACE Flood Risk Management studies, though there are communities within the Delta. Several Delta towns, known as "legacy communities," are listed in the national registry of historic places.

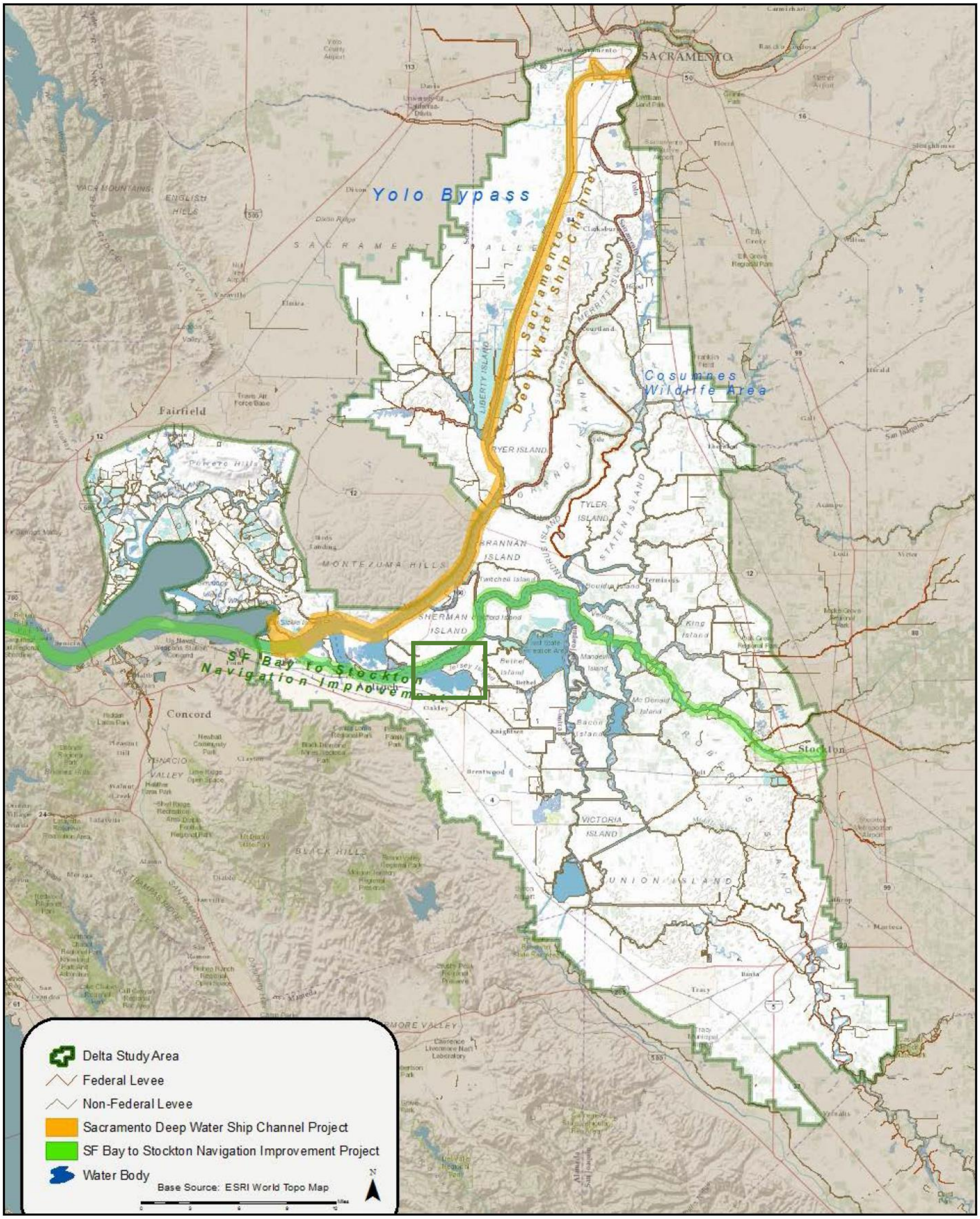

Figure C-1-1. Study Area and Selected Plan Area

Historically, the Delta was defined by tidal wetlands, primarily comprised of peat soils. The Swamp and Overflow Land Act of 1850 transferred ownership of all federally owned swamp and overflow land, including Delta marshes, from the Federal Government to private parties agreeing to drain the land and turn it to productive, presumably agricultural, use. This Act began the reclamation of wetlands in the Delta through the construction of levees and drainage channels, typically by the new land owners. The majority of levees in the Delta are still privately owned and maintained. Nearly three fourths of the Delta is now in agriculture.

C-1.2.2 Restoration Site ("Big Break"). Figure C-1-2 shows the restoration area, the eastern portion of a submerged Delta island referred to as Big Break and the neighboring Dutch Slough. A description of how this site was selected can be found in Chapter 3 of the main report.

Figure C-1-2. Big Break and Dutch Slough

Dredging along Dutch Slough between 1904 and 1910 connected Dutch Slough, Sandmound Slough, Taylor Slough and Piper Slough. The building of levees along the southern shore of Dutch Slough is largely undocumented in the available literature, but inferences can be made. Levees were built along the mouth of Marsh Creek, which forms the eastern boundary of the Big Break Regional Shoreline, as early as 1859, but the unleveed land south of Jersey Island was flooded by Marsh Creek in 1876 (Thompson 1957). The1910 Jersey Island USGS 7.5' topographic map shows levees along the southern shore of Dutch Slough. Therefore, it can be surmised that they were constructed between 1876 and 1910, and probably between 1904 and 1910 when Dutch Slough was being dredged. A clamshell dredge was likely used as they had come into widespread use during that time.

Agriculture was originally pursued at Big Break, though little is known about crops grown; however, asparagus is reported to have been grown there (East Bay Regional Park District 2014). According to a letter report prepared by Ward Hill for the East Bay Regional Park District, the property known as Big Break flooded in 1921 (Little Break). The levees broke again in 1928, flooding a 2.5 square mile area, which was never reclaimed, effectively ending any agricultural pursuits.

Howard Lauritzen acquired a 40 acre parcel of remaining uplands and the flooded area near Oakley in the 1930s through a trade with Pittsburg Steel. During the 1930s and 1940s, Lauritzen used this area to dismantle Navy pontoons and target barges as part of a scrap metal business. As many as 30 to 40 hulls are still present within the open water of the park area and along the San Joaquin River shoreline (Hill 2000).

C-1.3. Project Purpose. The goal the Selected Plan is to

1. create emergent marsh habitat through placement of coarse-grained dredged material and aquatic plantings on placed dredged material mounds,

2. create riparian habitat on the remnant levee north of the eastern portion of Big Break by eradication of invasive species and plantings,

3. construct 1. and 2. such that there is connectivity between riparian and emergent marsh habitats, enhancing the function of both habitat types,

4. construct 1. such that low tide access/egress for fish is maintained.

A maximum area of approximately 340 acres of open water habitat would be restored to intertidal marsh habitat, with approximately 90 acres planted with aquatic vegetation, and the remaining 250 acres would be shallow water habitat for aquatic fauna species; 33 of the approximately 50 acre remnant levee along the northern edge of Big Break would be restored.

C-2. Hydrology and Hydraulics.

The study area is within the Sacramento-San Joaquin Delta watershed. The contributing drainage area to the Sacramento-San Joaquin Delta encompasses approximately 40,000 square miles. The main contributors of the drainage area are the Sacramento River (25,200 square miles), San Joaquin River (13,500 square miles), and the Mokelumne River (1,200 square miles). Runoff within the study area is highly influenced by upstream reservoir regulation.

Maximum stages within the Delta result from runoff from storms of different origins which do not have the same annual exceedance frequency at all locations, and from tides of varying magnitudes which seldom reach their maximum stages concurrently with the peak flows. In some years the annual maximum stage at all locations occurs during the same storm event. However, in other years, the peak stages in the northern part of the Delta occur during a different time period than those in the southern part of the Delta and vice versa. The differences are caused by the geographical distribution of the contributing drainage basin, antecedent conditions such as snowpack and soil moisture, and the fluctuation of the storm tracks over California. If the flood runoff is from the Sacramento River basin, the stages will be higher in the northern part of the

Delta. If the main flood runoff is from the San Joaquin River, then the stages will be higher in the southern part of the Delta.

C-2.1 Big Break Site Conditions

C-2.1.1. Tide conditions and Datums.

C-2.1.1.1. Definitions. Table C-2-1 lists tidal and continental datum terms, their abbreviations (to be used hereafter in this Appendix), and their definitions.

Table C-2-1. Datum Abbreviations and Definitions.

Datum	**Abbreviation**	**Definition (**https://tidesandcurrents.noaa.gov/datum_options.html#MTL**)**
National Geodetic Vertical Datum of 1929	NGVD 29	see website
North American Datum of 1983	NAD83	see website
North American Vertical Datum of 1988	NAVD88	see website
Mean Lower Low Water	MLLW	The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.
Mean Tide Level/ Local Mean Water Level	MTL/LMWL	The arithmetic mean of mean high water and mean low water.
Mean Higher High Water	MHHW	The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

ER 1110-2-8160(4)(d) Ecosystem Restoration and Regulatory Permitting Actions states that "Ecosystem restoration projects, Civil Works compensatory mitigation projects, or regulatory permitting activities that are referenced to tidal or non-tidal datums shall be defined to a current NSRS [National Spatial Reference System], MLLW, or MHW [Mean High Water] datum, as appropriate to local, state, and federal requirements." Due to the availability of National Oceanographic and Atmospheric Administration (NOAA) bathymetry charts for the Big Break area that are relative to MLLW, MLLW was chosen for the project datum.

C-2.1.1.2. Big Break Parameter Characterization. Attachment HH-A contains the analysis for the determination of tidal and NAVD88 datums for Big Break. Table C-2-2 shows the MLLW, MHHW, and Local Mean Sea Level (LMSL) datums at three locations relative to the NAVD88 geodetic datum; these water levels were obtained using the NOAA vertical datum software and reflect the average over the 1983 to 2001 tidal epoch. The water level used for design, for construction initiating in 2022, is estimated to be 0.02 foot higher than the 1992 midpoint epoch elevation based on historical sea level rise rates (some previous water level analyses predated current sea level rise guidance). This difference is far below the scale of other project uncertainties and is concluded to be negligible.

Table C-2-2. Water Levels (Feet) Relative to NAVD 88 Vertical Datum, Epoch 1983-2001

Parameter	San Francisco Gauge (FT-88)	Port Chicago Gauge (FT-88)	Big Break (FT-88)
MHHW	+5.90	+6.01	+5.92
LMSL	+3.18	+3.66	+4.03
MLLW	+0.06	+1.08	+2.00
NAVD 88 Datum	+0 .00	+0.00	+0.00

As described in ER 1100-2-8162 the year 1992 is assumed to reflect the midpoint of the 1983 to 2001 epoch.

C-2.1.2. Bathymetry. Bathymetry for Big Break was determined from NOAA Chart 18660 (3rd E., Sep. 2005. Last Correction: 10/23/2017/ Cleared through: LNM 0718 (2/13/2018), NM: 0818 (2/24/2018)); the feasibility level design analyses herein were performed between the timeframe of the last correction and cleared through dates. Figure C-2-1 shows the area surrounding Big Break from Chart 18660.

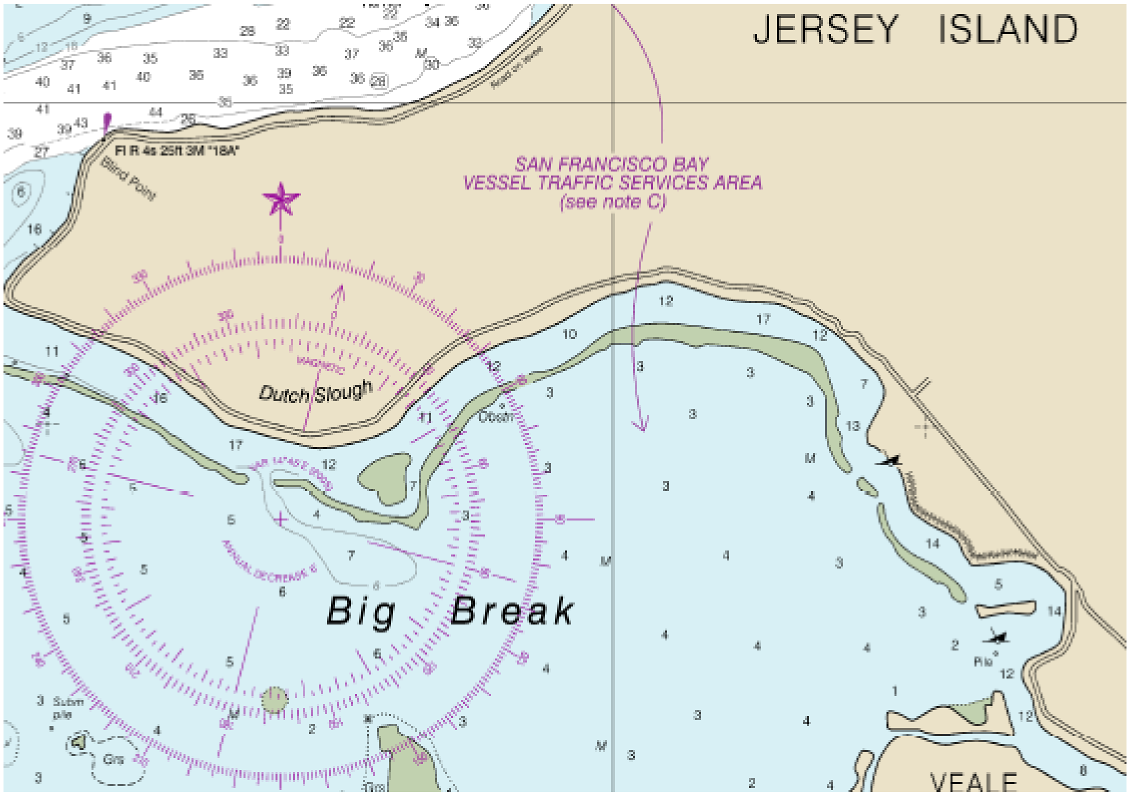

Figure C-2-1. Big Break bathymetry from NOAA Chart 18660

Figure C-2-1 shows that bathymetry for Big Break area in and around the Selected Plan footprint to be 3 to 4 ft of water relative to MLLW; thus the elevation of the sediment bed in Big Break can be portrayed as -3 to -4 ft MLLW or -1 to -2 ft NAVD88 (based on Table C-2-2).

C-2.1.3. Parameter Design Assumptions for Big Break. Table C-2-3 shows a matrix of datums and the sediment bed elevations at Big Break relative to one another based on Table C-2-2 to two significant digits; the data in Table C-2-2 are at a level of precision beyond many of the other information or parameters available for Feasibility Level Design, 0.1 ft measurements in feet were deemed appropriate for design calculations.

Table C-2-3. Datums and Big Break Bed Elevations

Design Parameter	Elevation Above Reference Datum (Feet)			
	MHHW* (Ft)	LMSL* (Ft)	MLLW* (Ft)	NAVD88 (Ft)
MHHW*	0	+2.0	+4.0	+6.0
LMSL*	-2.0	0.0	+2.0	+4.0
MLLW*	-4.0	-2.0	0.0	+2.0
NAVD88	-6.0	-4.0	-2.0	+0.0
Average Existing Bed Elevation at Big Break Restoration Site	-7.0	-5.0	-3.0	-1.0

*References to tidal parameters and tidal datums based on 1983-2001 tidal epoch

The parameter values (and precisions) in Table C-2-3 are used hereafter in this Appendix.

C-2.1.4. Water Velocity Data at Big Break. Depth averaged hydrodynamic data from June 2009 was supplied by the California Department of Water Resources (DWR) so that a screening assessment of placed dredged material stability could be performed. The June 2009 time frame appears representative for screening purposes of typical conditions at Big Break based on a 720 day evaluation of Dutch Slough gauge velocity data. Heat plots for maximum depth averaged velocities for the restoration area are shown in Figures C-2-2 (flood tide) and C-2-3 (ebb tide).

Geotechnical properties of dredged material are discussed in Section C-4 Geotechnical, and the stability screening analysis utilizing data in Figures C-2-2 and 3 is shown in C-6 Civil Design.

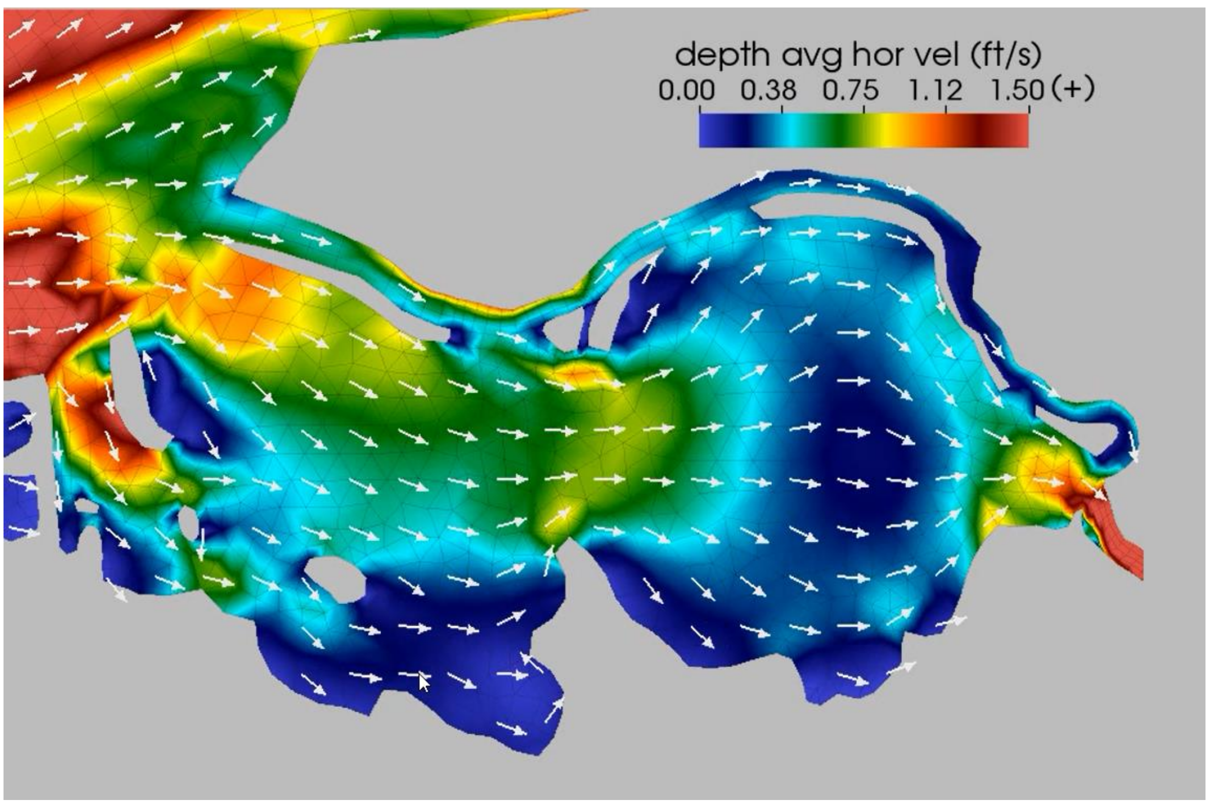

Figure C-2-2. Depth averaged velocities on a flood tide at Big Break

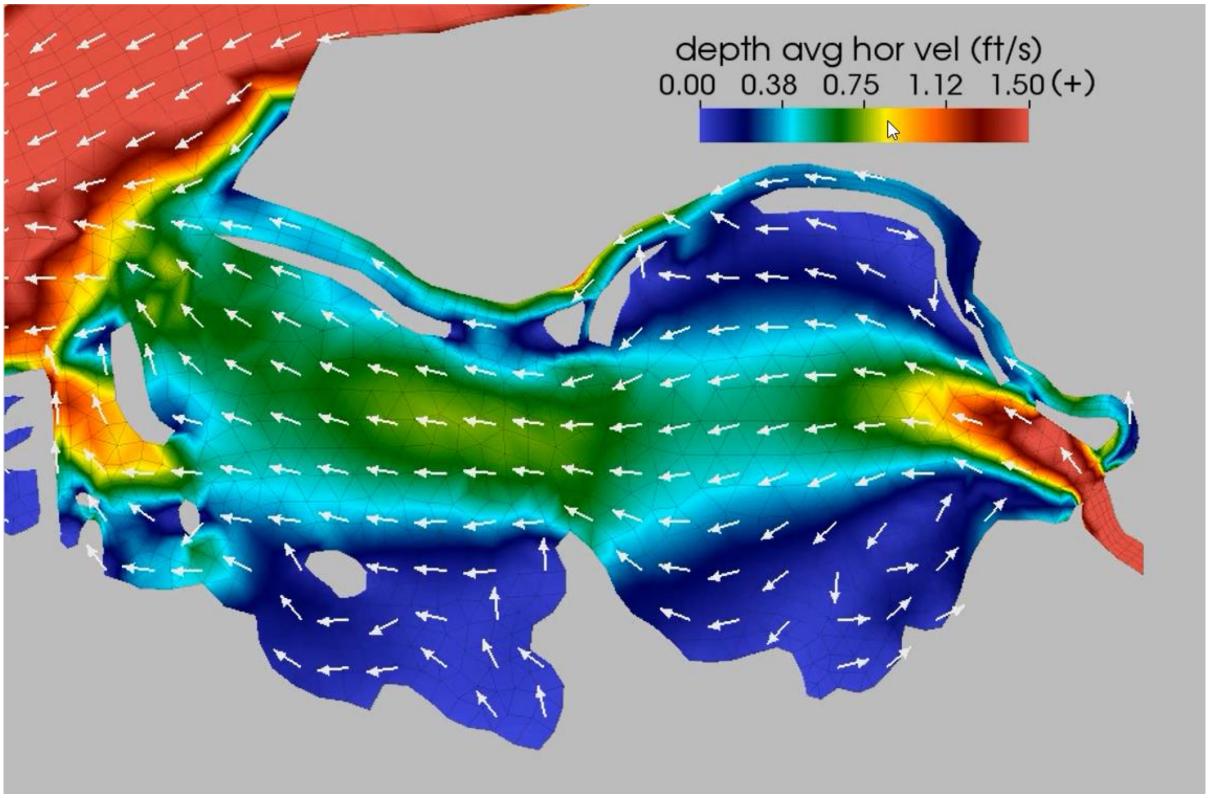

Figure C-2-3. Depth averaged velocities on an ebb tide at Big Break

C-2.1.5. Wind Velocity Data

DWR supplied a past wind analysis (Philip Williams & Associates 2007) for the Delta that included a wind rose for Antioch California, about 5 miles from the restoration site. Figure C-2-4 shows the full year, hourly wind rose diagram for 1 JAN. 1997 - 30 DEC. 2005.

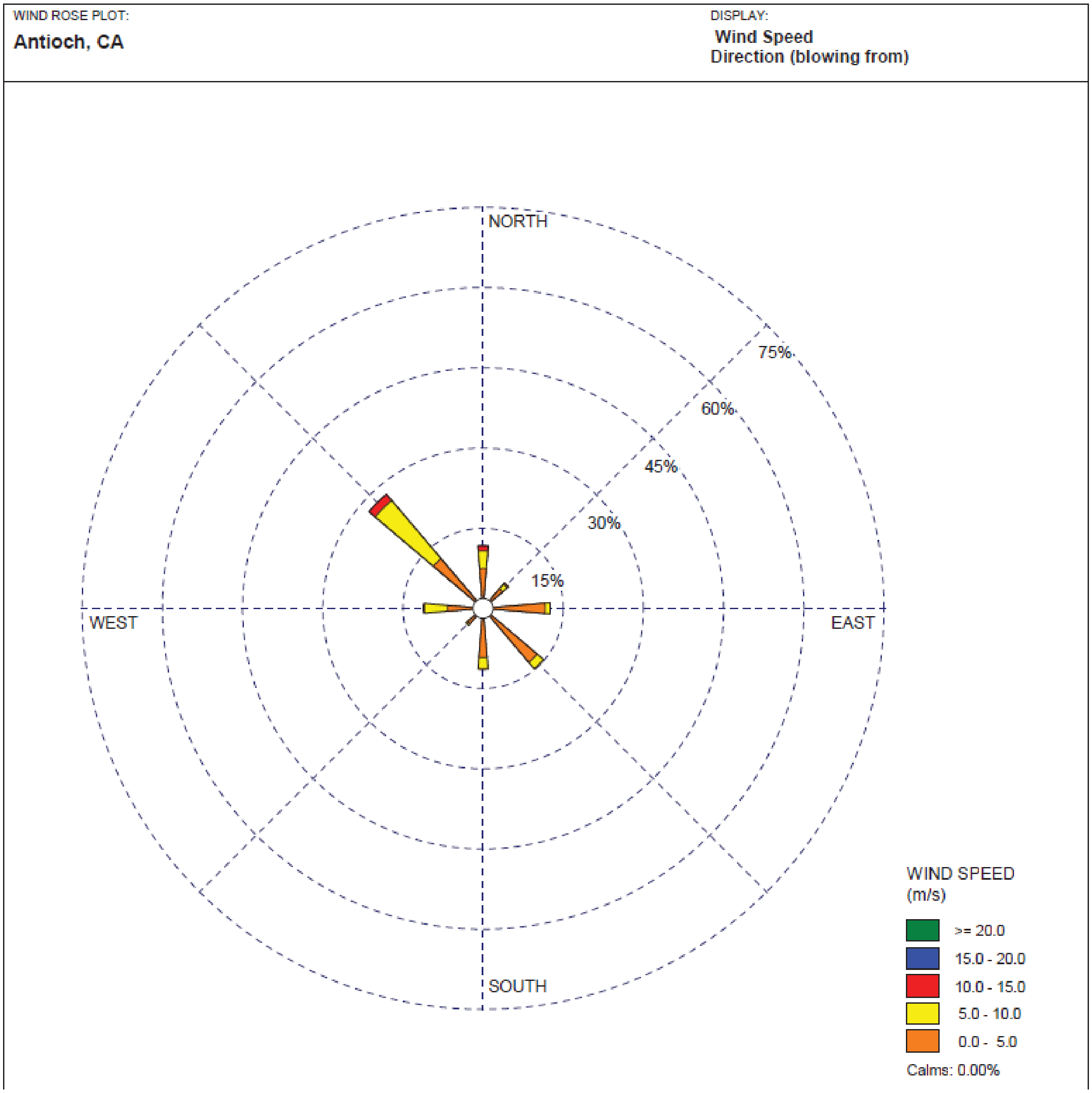

Figure C-2-4. Annualized wind rose for Antioch, CA

Analysis of Figure C-2-4 shows that the prevailing wind direction and direction of highest winds is the northwest. If applied to the restoration site at Big Break (see Figure C-6-2 for the final proposed footprint, northwesterly winds have virtually no fetch in the restoration area due to Jersey Island and the remnant Big Break levee. Due to this lack of fetch, wind driven water velocities are concluded to be negligible for feasibility level design and tidal velocities will be used in mound stability screening assessments. Wind induced waves and water velocities will be considered during final design in the Preconstruction Engineering and Design phase.

C-2.2 Sea Level Rise. Attachment HH-A is a technical memorandum documenting a sea level rise assessment. ER 1100-2-8162 was adhered to for low, medium, and high rates of sea level change. The computed relative sea level change (SLC) at the project site based on ER 1100-2-8162 and San Francisco gauge data are computed as 0.66 feet, 2.08 feet, and 6.59 feet as low, medium, and high, respectively for the year 2122; although the San Francisco gauge is 50 miles from the project site and subsidence is a concern in the Delta at large, subsidence of the long-inundated Big Break area is concluded to contribute negligibly to this analysis when scaled with other project uncertainties. Subsidence in the delta is highly variable and depends soil conditions and exposure. The highest rates of subsidence occur within the interior of dry islands. That majority of the subsidence is due to the oxidation of peat soils and does not reflect inundated areas like Big Break island. A search of readily available information did not find any source of estimates for ground subsidence of submerged channels or islands that are not subject to the oxidation. However, considering that the underlying soils within Big Break Island are inundated, it is probably negligible and the regional rate is a reasonable approximation for the ecosystem restoration site. Use of the current estimates are considered to have extremely low study risk. The PDT thus recommended the study proceed to PED without expending additional time and study funds to evaluate this assumption in further detail. Based on this, water levels at Big Break Island for year 2122 (100 year life cycle for the project) are shown in Table C-2-4."

Table C-2-4. Adjusted Water Levels (Feet) in Year 2122 for Big Break Island

Parameter	Low SLC	Medium SLC	High SLC
MHHW	+6.78	+8.2	+12.71
LMSL	+4.89	+6.31	+10.82
MLLW	+2.86	+4.28	+8.79
NAVD 88 Datum	+0.00	+0.00	+0.00

The emergent marsh habitat constructed in the Selected Plan is anticipated to be sustainable and resilient to sea level rise. Emergent marsh habitat accrues sediment through lowering flow velocities; as sea level and thus Delta water levels slowly rise, vegetation should adjust to the new water levels and continue to recruit sediments over time, raising the marsh level, and so on. This provides the project with a continuum of adaptive capacity so that there's no threshold that affects performance. C-4 Geotechnical details 1 foot of sand mound placement to account for miscellaneous losses of sand mound area/volume, including sea level rise. If 1. unforeseen changes in SLR rates beyond current policy-determined high rate estimates and/or 2. accretion rates occurred such that accretion did not outpace or match relative changes in water surface elevation, then the zone currently attributed to Marsh Wren habitat would slowly transition to shallow water habitat for other species.

C-2.3 Climate Change Impacts on Inland Hydrology. Attachment HH-B is a technical memorandum containing a policy compliant Inland Hydrology analysis. Inland hydrology is not concluded to affect ecosystem restoration feasibility level designs.

C-2.4 Water Quality. Section C-9 Hazardous and Toxic Chemicals discusses water quality issues associated with contaminants in dredged material or placement site sediments, Section C-10 Construction Procedures and Water Control Plan discusses water quality issues connected with resuspended dredged material or placement site sediments. Thus, only water quality with respect to salinity will be discussed in this section.

The Selected Plan involves the transplant of sandy material (see Section C-4 Geotechnical) in the Stockton Deepwater Ship Channel from north of the western peninsula of Jersey Island to the Big Break area south of that peninsula. Both sites in the freshwater are part of the Delta. Dredged material placement at Big Break should have no effect on salinity (or hydraulics or hydrology) of the Delta at large.

C-2.5 Water Surface Elevation Effects of Proposed Project.

Plates CV-1 (flood tide) and CV-2 (ebb tide), which are attached at the end of this Memorandum, show the depth averaged velocity data from Figures C-2-2 and C-3-3 overlain on the proposed restoration footprint (see Section C-6 Civil Design). Most of the proposed project will have no hydraulic impact on stage and velocity because it's not active flow conveyance area due to the position of old remnant levees.

A portion of the project would be placed within the flow conveyance area where existing velocities are less than 1 foot per second. Within this region the proposed berms and vegetation will slow down the water resulting in a minimal increase in the velocity elsewhere because the obstructed flow will seek a path of least resistance (the remaining flow conveyance area) or take a different flow path through the upstream sloughs to the San Joaquin River.

Impacts on the overall conveyance area of delta outflows is extremely small and impacts to stage and flow are probably not measurable. Based on hydrodynamic modeling performed for the Sacramento-San Joaquin Feasibility Study (USACE 2002), flood stages at the site are impacted by backwater from ocean tides combined with the total net outflow of floodwaters from the Sacramento and San Joaquin River systems.

According to the model results, the peak net outflow of the Delta System for a 1% ACE event is approximately 920,000 cfs. Of this total net outflow, the existing condition peak outflow from Dutch Slough for the 1% ACE event is only 14,000cfs. As described above, the proposed project would only impact a small portion of the total conveyance are of Dutch slough so the potential impact is even smaller than the flow comparison indicates.

The impacts to flow conveyance area would be less for larger floods because water depths are greater and the proposed sand mounds will become less of a percentage of the total conveyance area.

Analysis of available gauge and flow data and hydrodynamic modeling results suggests that it is highly unlikely the proposed Ecosystem Restoration (see C-4 Geotechnical and C-6 Civil Design for material and design specifics) to have a measurable increase in stage in the Big Break area. Following the SMART Planning process and the tenants of Risk-Based Decision Making, the risk of adverse impacts to the floodplain and the omission of detailed hydrodynamic modeling of the with-project condition is deemed to be low by the Project Delivery Team (PDT); this risk has been added to the Project's Risk Register. Should more detailed study in Preconstruction Engineering and Design suggest a necessity for detailed hydrodynamic modeling, that modeling can be accomplished in that phase of the project.

C-3. Surveying, Mapping, and Other Geospatial Data Requirements

Bathymetry data for this project was obtained from NOAA charts as described in C-2.1.2. Tidal Datum information was obtained from several sources as detailed in Attachment HH-A Sea Level Rise Technical Memorandum. Civil Design and Cost Engineering siting and other distance calculations were made using Google Earth Pro v. 7.1.5.1557.

C-4. Geotechnical

C-4.1 Regional Setting

C-4.1.1 Geology. The Delta and Suisun Marsh lie within California's Central Valley, which is approximately 465 miles long and 40 to 60 miles wide. The valley is bounded by the Sierra Nevada on the east and the Coast Ranges on the west. Paleogeographic reconstructions of this region indicate that Miocene sedimentation was similar to a modern fore-arc basin (a sea floor depression between a subduction zone and an associated volcanic arc), shedding arkosic (granular quartz and feldspar or mica), and volcanoclastic sediments westward from the continent. In the mid-Pliocene Epoch, a shift in plate tectonics triggered uplift of the Coast Ranges, which gradually closed the southern marine outlet to the basin. By the late Pliocene, sub-aerial conditions prevailed throughout the valley, resulting from marine regression (i.e., when the oceans were regressing seaward over land) and sedimentation from the west. During Pleistocene Epoch, the valley separated from the Pacific Ocean and developed internal drainage, the modern outlet being the Carquinez Strait, through which the Sacramento and San Joaquin Rivers flow to the San Francisco Bay (Lettis and Unruh 1991).

The historical Delta evolved at the inland margin of the San Francisco Bay Estuary as two overlapping geomorphic units. The Sacramento River Delta comprises about 30% of the total area and was influenced by the interaction of rising sea level and river floods that created channels, natural levees, and marsh plains. During large river flood events, silts and sands were deposited adjacent to the river channel, forming natural levees above the marsh plain. In contrast, the larger San Joaquin River Delta—located in the central and southern portions of the Delta and having relatively small flood flows and low sediment supply—formed as an extensive, unleveed freshwater tidal marsh dominated by tidal flows and organic soil (peat and muck) accretion (Atwater and Belknap 1980). Because the San Joaquin River Delta had less well defined levees, sediments were deposited more uniformly across the floodplain during high water, creating an extensive tule marsh with many small branching tributary channels. As a result of the differential amounts of inorganic sediment supply, the peats and mucks of the San Joaquin River Delta grade northward into peaty mud and then into mud as it approaches the natural levees and flood basins of the Sacramento River Delta (Atwater and Belknap 1980).

Soils formed in the Sacramento–San Joaquin Delta (Delta) as the result of geologic processes over approximately the past 7,000 years. These processes produced landward accumulation of sediment behind the bedrock barrier at the Carquinez Strait, forming marshlands comprising approximately 100 islands that were surrounded by hundreds of miles of channels (Weir 1950). Generally, mineral soils formed near the channels during flood conditions and organic soils formed on marsh island interiors as plant residues accumulated faster than they could decompose. Prior to the mid-1800s, the Delta was a vast marsh and floodplain, under which peat soils developed to a thickness of up to 30 feet in many areas (Weir 1950), with a thickness of approximately 55 feet in the vicinity of Sherman Island. The tidal portion of the Delta consisted of backwater areas, tidal sloughs, and a network of channels that supported highly productive freshwater tidal marsh and other wetland habitats (CALFED Bay-Delta Program 2000).

C-4.1.2 Seismicity. The California Coast Ranges physiographic province lies along the complex boundary between two tectonic plates: the North American Plate and the Pacific Plate. The geologic and tectonic conditions in the Delta and Suisun Marsh have been, and continue to be, controlled primarily by the interaction of these two massive blocks of the Earth’s crust. Under the current tectonic regime, the Pacific Plate moves northwestward relative to the North American Plate at a rate of about 1.57 inches (40 millimeters) per year (Working Group on California Earthquake Probabilities 2003). Although relative motion between these two plates is predominantly lateral (strike-slip), an increase in convergent motion along the plate boundary within the past few million years has resulted in the formation of mountain ranges and structural valleys of the Coast Ranges province.

The San Andreas Fault system dominates the seismicity of the region, and it comprises several major faults including the San Andreas, Hayward–Rodgers Creek, Calaveras, Concord–Green Valley, and Greenville faults. In addition to these major faults, many other named and unnamed regional faults accommodate relative motion between the plates and relieve compression stresses that also act along the plate boundary.

The Delta and Suisun Marsh are in the eastern portion of the greater San Francisco Bay region, one of the most seismically active areas in the United States. Since 1800, several earthquakes with magnitudes greater than 6.5 have occurred in the immediate San Francisco Bay Area, including the 1868 magnitude 6.8 earthquake on the Hayward Fault, the 1906 magnitude 7.9 San Francisco earthquake on the San Andreas Fault, and the more recent 1989 magnitude 6.9 Loma Prieta earthquake that occurred in the Santa Cruz Mountains.

C-4.2 Big Break Site Description.

The flooded Delta Island referred to as Big Break is shown in Figure C-4-1.

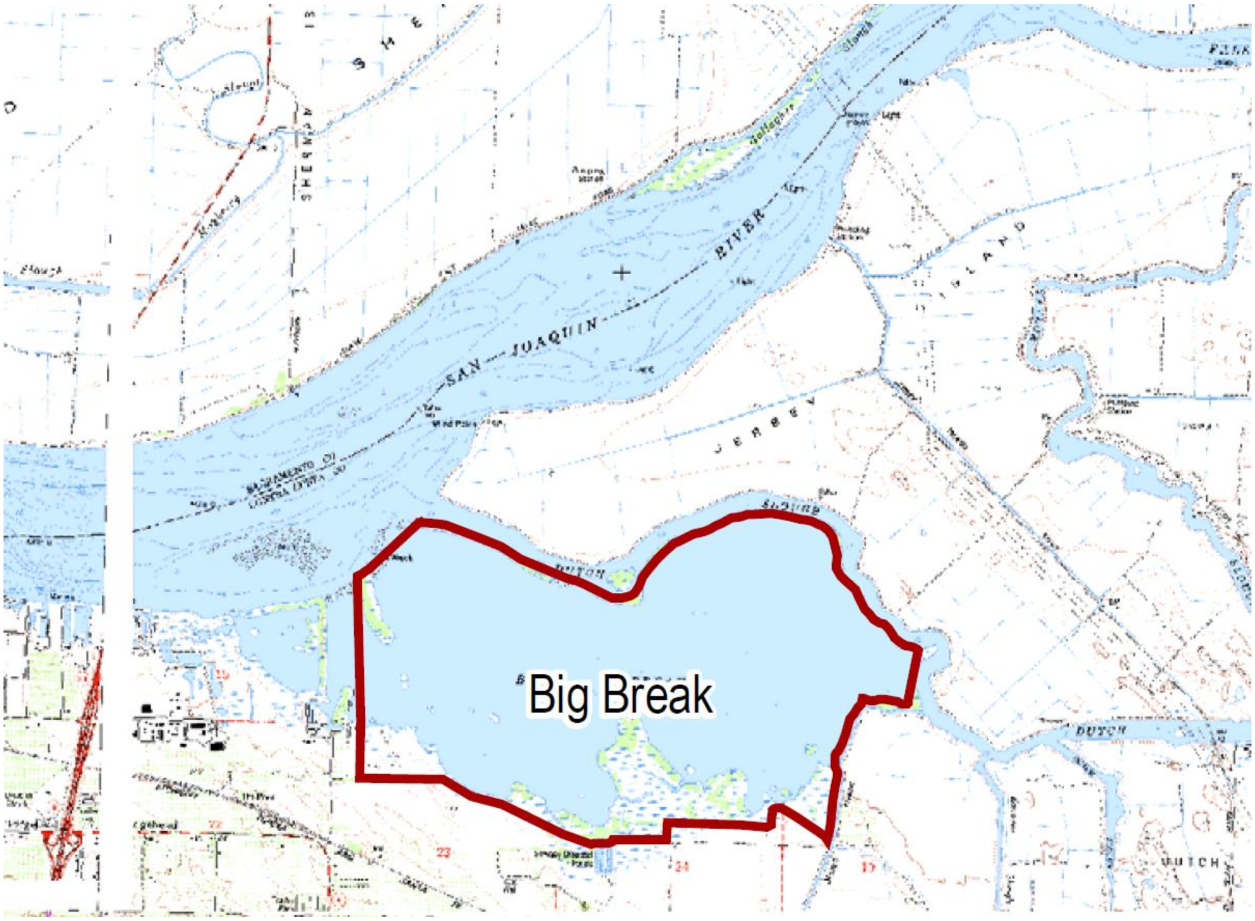

Figure C-4-1. Outline of the breached Delta Island now known as Big Break

EDAW et al. (2005) is a thorough baseline report prepared for the California Department of Water Resources (DWR) for submittal to the California Bay Delta Authority. This baseline report detailed the potential for ecosystem restoration at Franks Track, Big Break, and Lower Sherman Lake.

For the remnant levees selected for riparian planting in this Study, EDAW et al. (2005) states the following (making reference to American Association of State Highway and Transportation Officials soil classification):

> "The levees and larger islands are classified as "Fc," Cluvaquents, very poorly drained, loamy, mineral soils in sloughs and river channels. The tidal slough and low areas of the Lauritzen Site are "Pd," Piper sand. These soils formed in windblown material that had encroached into the northwestern part of the Delta. They are very poorly drained and are saturated within 20 to 40 inches all year and within 20 inches for as much as 4 months per year. These soils

are used primarily for dryland or irrigated pasture. In the early 1900s, before the levee failed, asparagus was farmed at Big Break."

Direct sediment data for the dredged material placement area is not known; however, data is available for soils in the area and land use for agricultural purposes is available, EDAW et al. (2005) states:

> "Known soils in Big Break consist of fluvaquents; Rindge muck, partially drained, 0–2% slopes; marcuse clay, strongly alkali; and delhi sand, 2–9% slopes...The soils of Big Break are those of the Delta Plain, which was once a freshwater marsh. These soils formed in the accumulated remains of tules, reeds, and other aquatic plants with thin layers of silty mineral matter. The organic content increases with depth. The surface of these soils lie at or below sea level to about 15 feet above sea level. Most wetland soils at Big Break are classified as "Rd," Rindge Muck. Rindge soils are deep, black, organic material and have been primarily used for irrigated pasture, field corn, and asparagus."

For feasibility level design purposes, sediment at Big Break is assumed to be similar in character to muck-type with low strength and high compressibility. Design assumptions for settlement of placed sandy dredged material are detailed in Section C-4.3.4. Thorough physical and chemical characterization of Big Break sediments planned for dredged material placement are to be performed during Preconstruction Engineering and Design to inform final designs, plans, and specifications.

C-4.3 Dredging Material for Ecosystem Restoration

4.3.1. Background. The Selected Plan is to use approximately 100,000 cubic yards (cy) per year of dredged material (subject to natural variation in availability) from the Stockton Deepwater Ship Channel. The dredged material used for Ecosystem Restoration would most likely otherwise be placed in the Scour Pond, McCormack Pit, and Bradford Island dredged material placement sites as part of an ongoing Operations and Maintenance Project/Authority. The Selected Plan will use 10 years of ~100,000 cy placements at Big Break to construct emergent marsh habitat. Figure C-4-2 shows the Big Break Area, the aforementioned dredged material placement sites, and the station markers on the Stockton Deepwater Ship Channel.

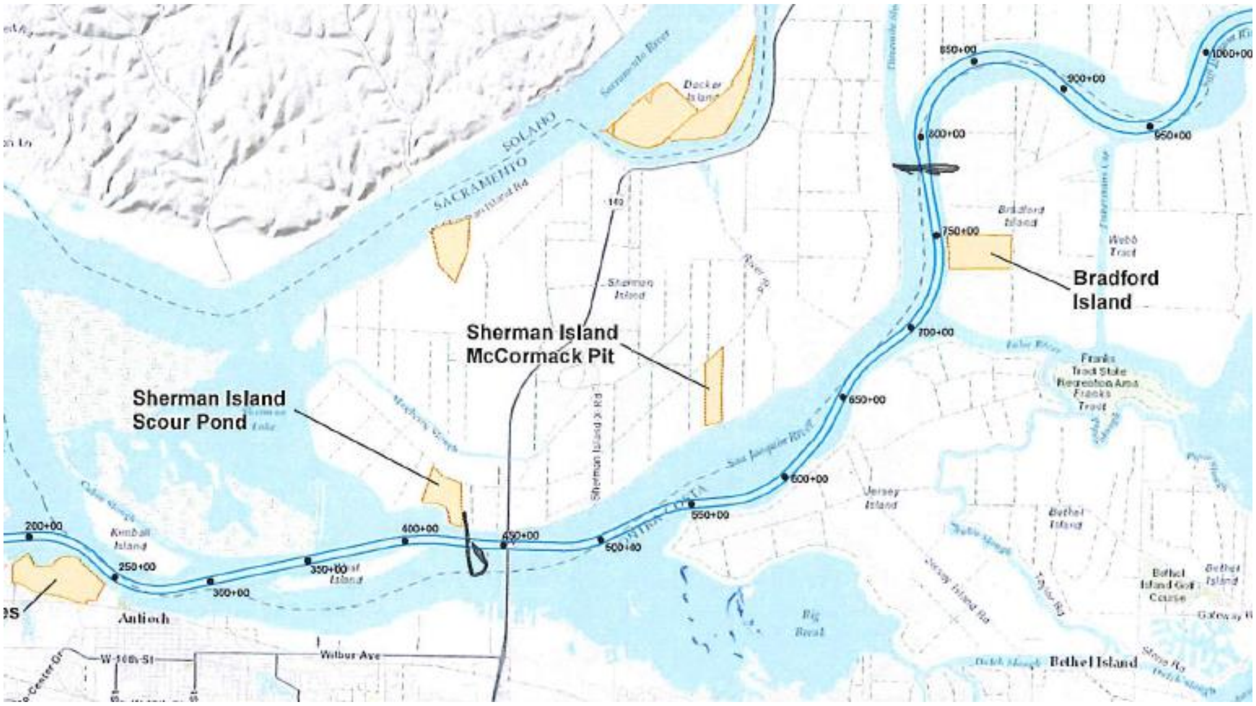

Figure C-4-2. Dredged Material Placement Sites near Big Break and Stockton Deepwater Ship Channel Station IDs

C-4.3.2. Physical Characterization of Dredged Material. Because dredged material is to be diverted from regular placement sites used for the Operations and Maintenance project for the Stockton Deepwater Ship Channel, physical characterization data and estimated dredging volumes are available dating back as far as 1994. Pre-dredging physical and chemical characterization are performed prior to dredging and placement each year.

Table C-4-1 shows station intervals for pre-dredging estimated volumes and associated grain size distribution data for nearby Big Break from 2009 to 2016. With the exception of 2011 (no data for reaches that are high volume in other years), all years in Table C-4-1 indicate over 100,000 cy of over 90% sandy material available in each year. The high clay measurement in 2011 is at the downstream edge of that reach; this is an example of material that may not be utilized for use in Ecosystem Restoration placement in any one year if encountered, depending on the controls and other engineering considerations that are identified following year-to-year pre-dredging characterizations.

Similar to any physically unsuitable materials, were pre-dredging characterization to identify reaches where sediment is not chemically suitable for open water placement, those sediments would not be utilized for Ecosystem Restoration at Big Break. Such sediments would be handled according to the standard procedures of the maintenance dredging project.

Table C-4-1. Estimated dredging volumes and grain size distributions for 2009-2016 in the Big Break Area

	Dredging Estimate			Grain Size Distribution Samping				
Year	Channel Station		Total Estimated CY	Channel Station		Sand	Silt	Clay
2016	818.00	856.00	143,220	680.00	840.00	94.1%	5.9%	0.0%
	805.00	812.00	3,597			75.8%	24.2%	0.0%
	700.00	720.00	10,095					
	613.00	627.00	2,849	550.00	660.00	98.2%	1.8%	0.0%
	578.00	600.00	9,132			99.2%	0.8%	0.0%
	454.00	490.00	6,173	380.00	520.00	98.5%	1.5%	0.0%
	395.00	416.00	6,374			99.5%	0.5%	0.0%
2012	No Data			710.00	860.00	90.0%	10.1%	0.0%
						96.9%	5.4%	0.0%
	580.00	640.00	26,470	570.00	630.00	96.0%	3.8%	0.2%
						78.9%	20.9%	0.2%
	440.00	500.00	37,090	440.00	490.00	95.8%	4.0%	0.2%
						96.7%	3.1%	0.2%
	395.00	405.00	5,120	390.00	430.00	97.3%	2.5%	0.2%
						98.1%	1.7%	0.2%
	285.00	325.00	37,250	280.00	330.00	97.5%	2.3%	0.2%
						95.7%	4.1%	0.2%
2011	No Data			815.00	860.00	95.1%	4.7%	0.0%
						95.6%	3.2%	0.0%
				700.00	730.00	66.6%	26.7%	4.2%
						89.8%	7.8%	0.1%
	610.00	620.00	7,467	605.00	640.00	96.6%	3.2%	0.2%
						96.8%	3.1%	0.2%
	573.00	595.00	13,800	570.00	590.00	95.1%	3.7%	0.2%
						95.8%	4.0%	0.2%
	440.00	490.00	6,732	440.00	490.00	96.2%	2.5%	0.2%
						97.0%	2.8%	0.2%
	397.00	425.00	6,276	390.00	430.00	97.3%	2.5%	0.2%
						14.0%	47.7%	22.6%
2010	No Data			883.00	920.00	83.8%	13.1%	2.1%
	815	860	142,994	No Data				
	795	815	20,516	795.00	815.00	91.9%	5.9%	1.6%
	730	740	8,532	730.00	740.00	98.1%	1.7%	0.0%
	590	598	11,273	572.00	615.00	73.9%	22.1%	2.9%
	470	488	18,900	465.00	468.00	95.6%	3.6%	0.0%
	440	446	10,359	443.00	445.00	94.1%	5.1%	0.0%
	395	425	17,244	395.00	425.00	92.7%	6.6%	0.3%
	286	326	14,528	286.00	326.00	94.0%	4.8%	0.5%
2009	815	860	126,107	815.00	860.00	93.3%	6.7%	0.0%
						96.1%	3.9%	0.0%
	615	645	29,694	No Data				
	465	470	4,602					

C-4.3.3. Design for Restoration Using Dredged Material.

Initial Designs. Initial iterations of this Feasibility Study investigated reclamation of dredged material previously placed upland and/or dredged material for sites upstream of Station 860+00; dredged material from either of these sources was anticipated to be finer-grained than materials in Table C-4-1. The fine grained nature of these potential restoration materials led to initial restoration placement designs that were necessarily large, continuous swaths so that fine material could be confined and settle out without excessive losses. Initial volumetric estimates were based on 100,000 cy per year of available dredged material based in part on the NOI data in Table C-4-1.

Grain Size and Volumetric Assumptions for Feasibility Level Design. Analysis of past dredging data, including those contained in Table C-4-1, suggested that dredged material from approximately reach 300+00 to 860+00; sediments in these reaches are almost entirely sand. Based on some silt content in the sediments and the natural sorting that would be expected from riverine sediment transport, the dredged material used for ecosystem restoration is assumed for design purposes to be very fine sand with coarse silt. The coarse grained nature of these sediments that have settled freely in water is similar enough to the nature of hydraulically placed dredged material that it is assumed for design purposes that the volume of in-site dredged material is equal to the volume of material placed at Big Break (i.e. no shrinkage, compression, or bulking).

NOI dredging volumes are generally greater than the volume actually dredged in order to be conservative from a permitting perspective. NOI volumes were thus chosen as a probable maximum volume of available dredged material per year and used in design, constructability, cost, and real estate analyses herein (see sections C-6 Civil Design, C-8 Electrical and Mechanical Requirements, Construction Procedures and Water Control Plan, and C-19 Cost Engineering). Table C-4-2 contains pay quantities (volumes) for dredging from approximately stations 300+00 to 860+00 ranging from 0 cy in 2012 and 2014 to 135,646 cy in 2016 and averaging to 64,970 cy over the 10 year period shown (including zero values); these pay quantities and the probable maximum volume of available dredged material in Table C-4-1 bound a range of volumes that could be expected in any year, with averaged pay quantities representing the most probable volumes. Adjustments for variable dredged material volumes in future years or other adaptations to restoration construction would be handled during the Preconstruction Engineering and Design phase each year. While this Ecosystem Restoration Project is proposed for 10 years of dredged material placement, dredging and placement each of those 10 years is treated herein as an individual phase of construction with an associated PED phase preceding construction in that calendar/fiscal year. Procurement strategies relating to construction years and O&M dredging contracts are discussed in Section C-19 Cost Engineering.

Table C-4-3 lists these key design assumptions.

Table C-4-2. Pay quantities for Stockton Deepwater Ship Channel from Approximately Reaches 300+00 to 860+00

Year	Station		DMPS	Total Dredged Material (cy)	Yearly Total
2017	287.00	327.00	Antioch	11,031	24,117
	577.00	600.00	McCormack	9,463	
	592.00	594.00	McCormack	3,623	
2016	700.00	720.00	Bradford	6,800	135,646
	805.00	812.00	Bradford	2,845	
	818.00	856.00	Bradford	126,001	
2015	289.00	329.00	Antioch	11,948	89,491
	397.00	415.00	Scour	19,091	
	575.00	610.00	Scour	12,308	
	610.00	644.00	McCormack	14,064	
	704.00	740.00	Bradford	32,080	
2014					0
2013	295.00	326.00	Antioch Dunes	40,310	61,489
	395.00	405.00	Scour	9,010	
	589.00	597.00	McCormack	12,169	
2012	Contract Protest				0
2011	292.00	323.00	Scour	40,421	87,482
	397.00	425.00	Scour	7,529	
	573.00	595.00	McCormack	23,975	
	610.00	620.00	McCormack	15,557	
2010	286.00	326.00	Scour	20,555	82,448
	440.00	446.00	Scour	10,313	
	470.00	488.00	Scour	17,970	
	590.00	598.00	McCormack	13,092	
	730.00	740.00	Bradford	3,881	
	795.00	815.00	Bradford	16,637	
2009	465.00	470.00	Scour	4,454	40,188
	615.00	645.00	McCormack	35,734	
2008	290.00	327.00	Scour	51,384	128,535
	442.00	502.00	Scour	28,006	
	579.00	599.00	McCormack	30,188	
	710.00	726.00	Bradford	18,957	

Table C-4-3. Dredged material assumptions for placement design

Dredged Material Grain Size Distribution	Very fine sand with little coarse silt, ~75 micron for repose/stability purposes
Volume of Available Dredged Material	Assumed 100,000 cy/yr for 10 years
Dredged Material Placement Volumes	1 to 1 with volumes of in-situ dredged material (zero bulking/shrinkage)

C-4.3.4. Dredged Material Placement Design. Dredged material with the grain size properties assumed in Table C-4-3 is far more easily used to construct landforms (whether above or below water) of various designs due to the near immediate settling of the particles and the angle of repose of mineral coarse-grained sediment. In order to maximize the surface area of emergent marsh habitat created by dredged material, mounds of sand that stabilize at a natural, gradual angle of repose during hydraulic placement were decided upon for design, as mounds are the most efficient geometry in terms of surface area to volume and require no confinement to construct. A raised outflow manifold with baffle plate will be utilized to reduce the horizontal spreading of dredged material during placement so that mounds are constructed as symmetrically (and thus efficiently) as practicable.

The Engineer Research and Development Center's (ERDC) Environmental Laboratory (EL) has performed support to dredged material management and sediment remediation operations that involve the aquatic placement of sand for engineered subaqueous structures (dredged material placement, capping). ERDC-EL was consulted for design assumptions for the nature of very fine sand mounds hydraulically placed with a baffle plate. Very fine sand is assumed to settle to a 1 on 20 slope below the local mean water line (LMWL, which is assumed to be 2 feet higher than MLLW, see Section C-2.1.1 for datums) and to a 1 on 10 slope above the LMWL (Schroeder, pers. comm).

As stated in Section C-4.2, there is some anecdotal information about the sediment characteristics at Big Break but no engineering properties of the sediment are known. Knowledge of the "losses" of placed dredged material for restoration purposes to the compression of underlying sediments is essential to designing dredged material mounds (as a greater volume of sand is necessary to construct a mound of a given height above the sediment bed) and determining the overall restoration footprint for 1,000,000 cy of dredged material specified in the Selected Plan.
ERDC-EL was consulted for reasonable feasibility level design assumptions for the settlement of the assumed highly organic and compressible existing sediments at Big Break under the load of sand mounds. Angle of repose and sediment bed compression assumptions were based on tidal parameters in Section C-2 Hydraulics and Hydrology:

1. Below Mean Low Low Water: dredged material placed at this depth is assumed to take on the "submerged" angle of repose of 1 on 20. Because this comprises very thin layers at the skirt of the sand mound and it is constantly buoyant due to inundation, no compression of underlying sediments is attributed to sand placed below MLLW.

2. Between Mean Low Low Water and Local Mean Water Level: dredged material placed at this depth is assumed to take on the "submerged" angle of repose of 1 on 20 since this elevation range is inundated most of the time. The increased dredged material height and lack of continuous inundation led to an estimate of 1 ft of bed sediment compression beneath sand placed in this elevation range.

3. Between Local Mean Water Level and Mean High High Water Level: dredged material placed at this depth is assumed to take on a semi-submerged angle of repose of 1 on 10 since this elevation range is not inundated most of the time. The increased dredged material height and short period of inundation led to an estimate of 2 ft of bed sediment compression beneath sand placed in this elevation range. This 2 ft of settlement would be in addition to the 1 ft of settlement caused by the underlying sand layer between Mean Low Low Water and Local Mean Water Level.

4. Above Mean High High Water: dredged material placed at this depth is assumed to take on a semi-submerged angle of repose of 1 on 10 due to hydraulic placement with a baffle plate. Dredged material placed at or above this elevation is not expected to be inundated under normal tidal action. The relatively small volume of dredged material placed above this elevation with respect to the volumes beneath led to no increased assumptions in the settlement of underlying bed sediments beyond the 3 ft resulting from Bullets 2. and 3. of this list.

Table C-4-4 lists these settlement assumptions and angle of repose assumptions (Paul Schroeder, pers. comm.).

In addition to losses of placed dredged material by the compression of underlying existing sediments at Big Break, other potential sand mound losses that could occur include:

- Wave wash erosion during storms,
- Unpredicted consolidation in excess of assumed amounts, and,
- Decreased mound area due to sea level rise.

Table C-4-4. Assumed Incrementally Induced Bed Consolidation Based on Placement Increments

Placement Increment (Depth Range)		Angle of Repose of Placement Mound within Depth Increment	Incremental Bed Consolidation from Loading in this Depth Increment	Sand Mound Losses (feet)
above MHHW		1 on 10	0	1
LMWL	MHHW	1 on 10	2	0
MLLW	LMWL	1 on 20	1	0
bottom	MLLW	1 on 20	0	0

Table C-4-4 also indicates 1 foot of additional mound height to account for losses due to some combination of these factors based on judgement.

The bed level within the proposed Big Break restoration footprint varies from -3 to -4 feet MLLW; tides within Big Break range from 0 feet MLLW to +4 feet MLLW (See Section C-2.1.1). Based on input from the Sacramento District Landscape Architecture Section (see attachment CV-A, discussed in more detail in C-6 Civil Design) and lessons learned at a similar nearby restoration site (England et al.1990), the proposed sand mounds would be constructed with a target final elevation (i.e. after settling and other losses) of +3 feet MLLW. Thus, at high tide sand mounds will be approximately 1 foot below the water surface level and at low tide the top of the vegetated sand mounds would be exposed.

Figures C-4-3 and C-4-4 display the initial placement (black line) and final geometry (red line, used for plantable area sizing calculations) of a sand mound placed on existing bed elevations of MLLW -3 feet and -4 feet, respectively based upon the assumptions listed in Table C-4-4. It is estimated that the sand mounds would require on the order of 6 months for the majority of settlement to occur following construction (Schroeder pers. comm.). Following the settlement period, aquatic vegetation would be installed (see C-6 Civil Design and Attachment CV-A).

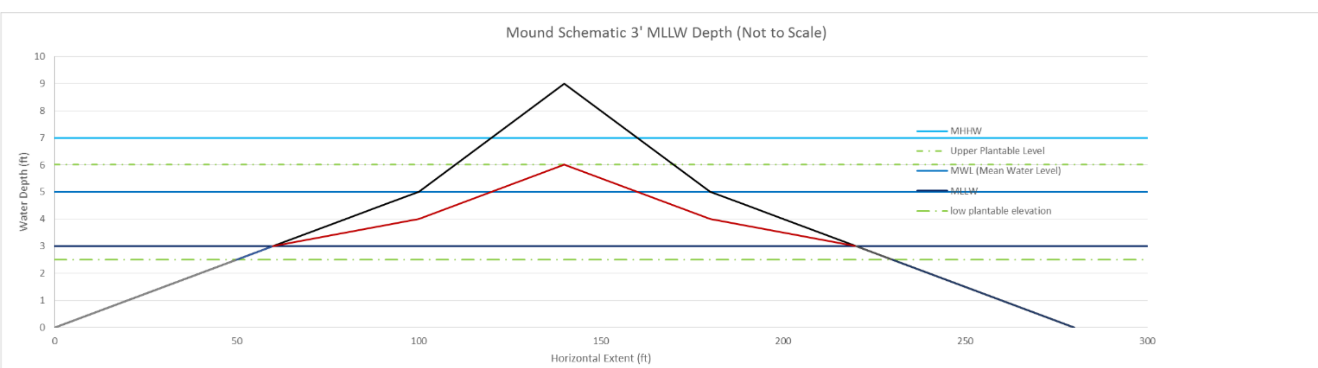

Figure C-4-3. Initial and Final Assumed Sand Mound Geometry for existing bed elevation MLLW -3 feet

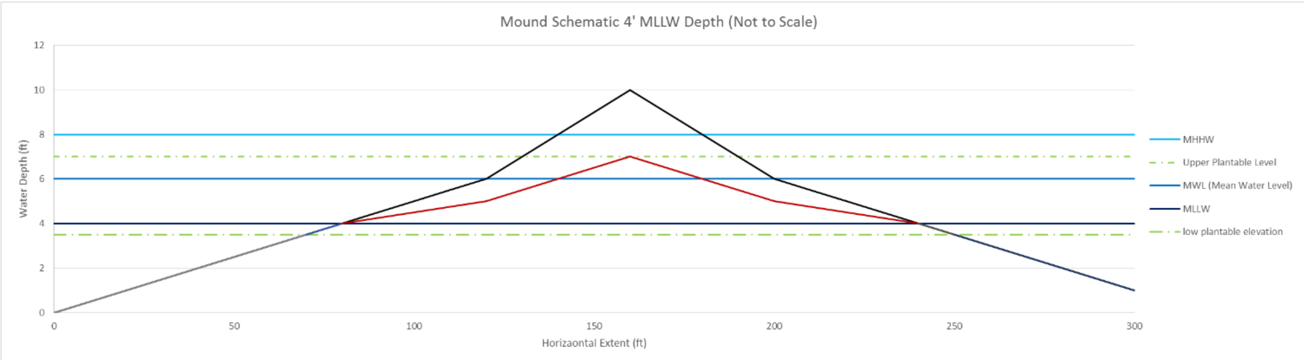

Figure C-4-4. Initial and Final Assumed Sand Mound Geometry for existing bed elevation MLLW -4 feet

Details regarding the stability of the sand mounds outlined in this section under the assumed controlling tidal current regime discussed in Section C-2 Hydrology and Hydraulics and the siting of sand mounds are presented in Section C-6 Civil Design.

C-4.3.5. Sand Mound Volume Calculations. As stated in Table C-4-4, dredged material placed at Big Break is assumes to be equal to the in-situ volume of material dredged from the Stockton Deepwater Ship Channel. Placement volume calculations for the initial geometries (prior to settling or other losses) indicated by Figures C-4-3 and C-4-4 can be made by straightforward geometric formulas for truncated cones:

$$V = \frac{1}{3}\pi(r_1^2 + r_1 r_2 + r_2^2)h$$

where V is the volume, r_1 is the lower radius (the larger radius for mounded material) of a truncated cone, r_2 is the upper radius of a truncated cone (the smaller radius for mounded material), and h is the height of a truncated cone. Sand mound volumes were calculated following Table C-4-4 using a 1 on 20 slope from the existing bed to LMWL (a truncated cone) and a 1 on 10 slope above the LMWL (a normal cone, thus $r_2 = 0$).

A lateral area of interest for a truncated cone can be calculated similarly,

$$LA = \pi(r_1 + r_2)\sqrt{(r_1 - r_2)^2 + h^2}$$

where LA is the lateral area. Lateral area is of interest in estimating the plantable area of sand mounds after settlement and in the calculation of ecosystem benefits; these areas are discussed in Section C-6 Civil Design.

Table C-4-5 shows the parameters for sand mounds placed at bed elevations of -3 ft and -4 ft (MLLW) and associated areas and volumes.

Table C-4-5. Parameters for sand mound surface area and volume calculations

Parameter		Existing Bed Elevation	
Slope		-3 ft MLLW	-4 ft MLLW
1 on 10	h	4 ft	4 ft
	r_2	0 ft	0 ft
	r_1	40 ft	40 ft
	V	250 cy	250 cy
	LA	5,050 sq ft	5,050 sq ft
1 on 20	h	5 ft	6 ft
	r_2	40 ft	40 ft
	r_1	140 ft	160 ft
	V	5,200 cy	7,820 cy
	LA	56,620 sq ft	75,500 sq ft
	Total Mound Volume	5,450 cy*	8,070 cy*
	Total Lateral Area	1.4 acres**	1.4 acres**
	Mound Footprint	1.4 acres**	1.8 acres**

*27 cu ft per cy
**43,560 sq ft per acre

Although these calculations are based on idealized geometries, they are assumed to be adequately accurate for feasibility level design purposes.

C-5. Environmental Engineering

As this is a proposed ecosystem restoration project, several aspects of environmental engineering are incorporated into each aspect of the project, including:

- Use of environmentally renewable materials,
- Design of positive environmental attributes into the project,
- Inclusion of environmentally beneficial operations and management for the project,
- Consideration of indirect environmental costs and benefits,
- Integration of environmental sensitivity into all aspects of the project;

Details of the items on this list are contained in C-6 Civil Design and Appendix D - Environmental.

Any issues or concerns noted in the Environmental Review Guide for Operations (ERGO) will be addressed through the Environmental Assessment in the main report, all applicable clean air, water, and other permits, and through the California Environmental Quality Act.

C-6. Civil Design

C-6.1 Ecosystem Restoration Footprint

C-6.1.1 Initial Restoration Footprint. As noted in Section C-4.3.3, the initial project siting was based on placement designs for dredged material with a significant fine-grained fraction that were necessarily large, continuous swaths so that fine material could be confined and settle out without excessive losses. Figure C-6-1 shows the initial area designed for dredged material placement (in light blue) at Big Break.

Figure C-6-1. TSP placement area for dredged material with significant fine-grained fraction

C-6.1.2 Feasibility Level Design and Footprint Expansion. Further investigation of the dredged material properties in the Stockton Deepwater Ship Channel north of Big Break revealed that fine sand and coarse silt sediments were abundant in the dredging reaches near Big Break, leading to the updated feasibility level designs for mounds of dredged material shown in Figures C-4-3 and C-4-4. The high surface area to volume ratio of sand mounds allowed for significantly more ecosystem restoration benefit area to be designed for each assumed 100,000 cy dredging material placement season for all seasons. The placement scheme that was settled upon involved the placement of 17 sand mounds at existing bed elevations of -3 ft MLLW with 280 ft diameter bases (see Table C-4-4); while sand mounds placed in -4 ft MLLW have a greater base diameter, fewer mounds are placed per 100,000 cy, thus 17 mounds with 280 ft diameter bases is adequately representative and used for sizing.

A placement scheme was developed based on the hydrodynamic and wind data presented in C-2 Hydrology and Hydraulics, the sand mound volume data in C-4 Geotechnical, and the initial design placement footprint in Figure C-6-1 to satisfy the following goals:

- Placement of sand mounds without toe overlap between mounds so that channelization between the mounds is maintained to promote adequate circulation to prevent water quality degradation due to poor circulation (informed by lessons learned from Donlon Island (England et al. 1990)),

- Adequate channelization for a kayak trail through the restoration area (to be sited in Preconstruction Engineering and Design in coordination with the East Bay Regional Park District),

- Placement beginning on the western edge first due to lower currents so that subsequent years of placement would have these established edge mounds as breakwaters,

- Placement beginning at the remnant levee and moving southward so that there is no wind fetch between the remnant levee and newly placed mounds to promote stability and thus vegetative establishment,

Following this placement progression, 1,000,000 cy is represented in Figure C-6-2.

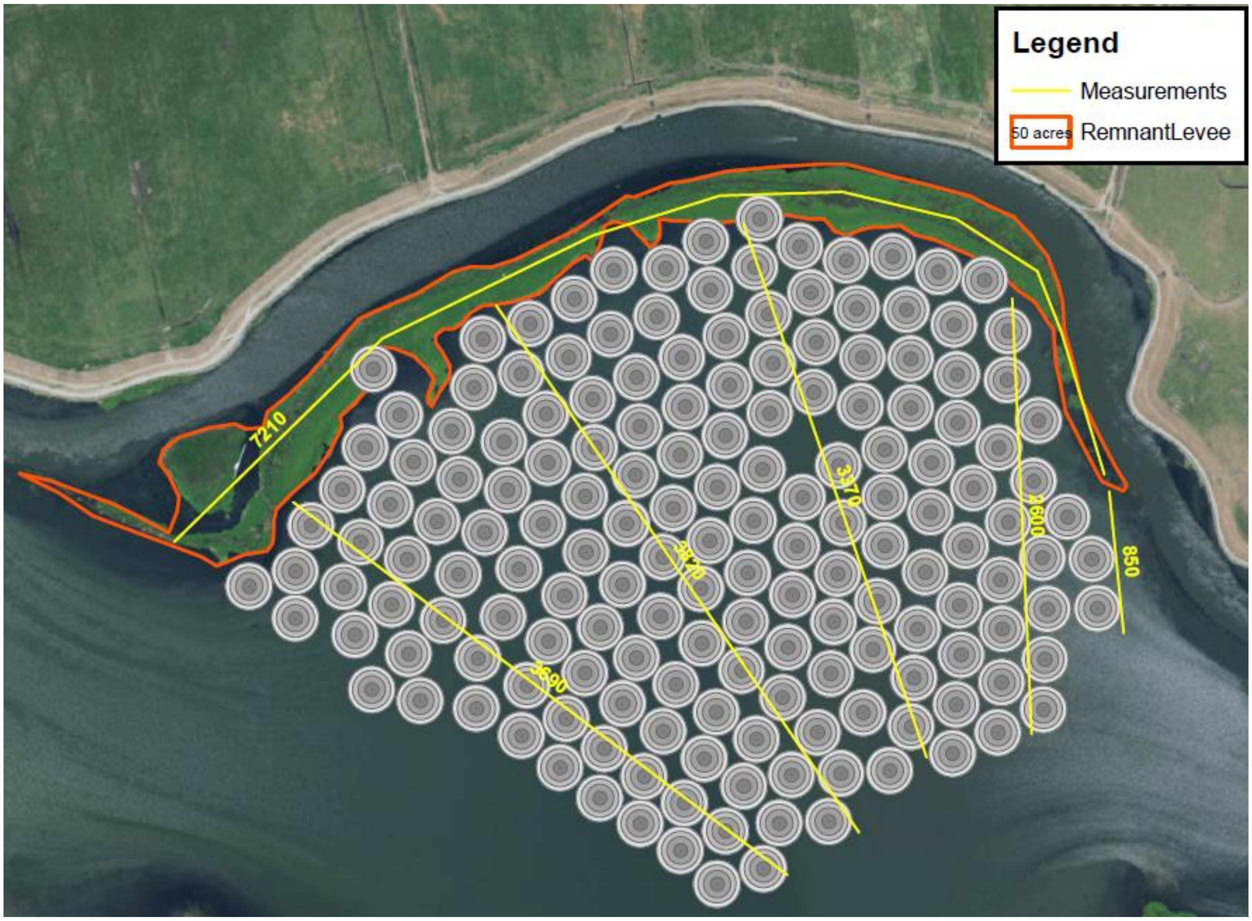

Figure C-6-2. 1 million cubic yards of sand mound placement at Big Break with reference dimensions in feet

Based on the sand mound placement in Figure C-6-2, the total aquatic Ecosystem Restoration footprint is approximately 340 acres.

C-6.2 Sand Mound Stability Analyses.

This section evaluates the stability of sand mounds with respect to water-induced erosion due to tidal forcing. Section C-2.1.5 contains the conclusion that that tidal induced erosion is controlling over wind-driven water velocities for stability concerns, thus stability with respect to water velocities only is evaluated in this section. Assumptions and design for stability with respect to consolidation of the Big Break sediment bed beneath sand mounds are discussed in Section C-4.3.4.

The stability calculations herein do not include considerations for extreme events (seismic activity, medium or low probability higher flow events), 1 ft of sand mound losses are assumed from multiple sources as noted in Table C-4-3. The primary reasoning for this is approach is that 1. there is no life safety component to this Ecosystem Restoration project and that 2. USACE 2002 indicates only a 0.2 ft to 1 ft stage increase above mean tide for 10% and 1% ACE events, respectively, and 3. the Big Break area is a sheltered embayment similar to the Donlon Island restoration site, and that nearby similar Donlon Island restoration site, constructed in the early 1990s, has remained stable through multiple flood seasons including the 1997 flood that is the largest on record. Should disruption of constructed sand mounds or riparian or aquatic plantings occur during the construction or establishment period of the project, features would be replaced through adaptive management and adaptive construction (see Attachment CE-A). Following the establishment period for the project, any changes of the site due to extreme events are considered a natural evolution of the emergent marsh/riparian habitat.

C-6.2.1. Screening Analysis of Sand Stability. An analysis of sand mound stability at the Big Break restoration area can be contextualized by a straightforward assessment of the critical shear stress for incipient motion for coarse-grained material representative of the expected dredged material characteristics. The Soulsby-Whitehouse approximation calculates critical shear stress for coarse-grained sediments on level beds. Although intended for bed sediments, the 1 on 20 final slope of placed sand mounds (see Table C-4-3) is assumed to be reasonably close to a level bed so that the Soulsby-Whitehouse approximation will yield results meaningful to screening analyses; any inaccuracies in the application to a 1 on 20 sloping bed are assumed to be overcome by the application of conservative parameter values in calculations.

A conservative d50 of 75 microns was chosen for critical shear stress evaluation using the Soulsby-Whitehouse approximation; although d50 data is not readily available for past dredging events, grain size distribution data in Table C-4-1 suggest a d50 greater than 75 microns, the fine sand/silt cutoff. 75 microns will thus give a low end estimate of the critical shear stress. Temperature was assumed to be 15 degrees C for the critical shear stress calculation (this is conservative when 10 degrees C is used for shear stresses calculated from hydrodynamic results in Section C-6.2.3 below). No salinity was assumed.

Table C-6-1 lists the parameters and critical shear stress results from calculations using the Soulsby-Whitehouse approximation.

Table C-6-1. Parameters and result of Soulsby-Whitehouse approximation

ERDC-CHL MATLAB Function taucr		
Parameter	**Value**	**Units**
d50	0.075	millimeters
Temperature	15	deg Celsius
Salinity	0	parts per thousand
Particle Density	2650	kg/m^3
Calculated Critical Shear Stress	0.12	Pascals

C-6.2.2. Water Velocities Near Sand Mounds. Plates CV-1 and CV-2 show overlays Figure C-6-2 on the depth averaged velocity results from hydrodynamic modeling in Figures C-2-2 and C-2-3; Plate CV-1 shows velocities on a flood tide, Plate CV-2 shows water velocities on an ebb tide. Plates CV-1 and 2 are an overlay of the proposed sand mound placements upon existing condition hydrodynamic modeling, not hydrodynamic modeling of the restoration footprint with sand mounds present. The intention for feasibility level design is an initial evaluation of stability to inform the need for controls so that real estate requirements and a Class III cost estimate for authorization can be generated; any more detailed modeling or design optimization will be performed during Preconstruction Engineering and Design.

Analysis of Plate CV-1 shows that maximum water velocities on a flood tide between 0.75 and 1.00 feet per second near proposed sand mound locations at the western edge of the placement area. Analysis of plate CV-2 shows that maximum water velocities on an ebb tide range from 0.80 to about 1.10 feet per second near proposed sand mound locations on the eastern edge of the placement area.

C-6.2.3. Induced Shear Stresses. The depth averaged maximum water velocities noted in Section C-6.2.2 can be converted to shear stresses so that shear stress results can be compared to the critical shear stress for sand mounds to inform design decisions. The shear stress equation used contains a parameter z for a representative depth above the sediment bed for the input velocity, U. In order to generate conservative (i.e. high) induced shear stress estimates, a 1 meter (~3 foot) depth of water was assumed based on -3 ft MLLW existing bed elevation. Using the 1 meter depth of water assumption, a representative z value of 0.3 meters (~1 ft) was chosen.

Table C-6-2 shows the parameters used for shear stress calculations and the shear stress results for three different depth averaged velocities.

Table C-6-2. Parameters and results of bed shear stress calculations

ERDC-CHL MATLAB Function taub		
Parameter	**Value**	**Units**
d50	0.1	millimeters
Temperature	10	deg Celsius
Salinity	0	parts per thousand
Particle Density	2,650	kg/m^3
Water Velocity	1.00	ft/s
Calculated Bed Shear Stress	0.14	Pascals
Water Velocity	1.50	ft/s
Calculated Bed Shear Stress	0.31	Pascals
Water Velocity	1.75	ft/s
Calculated Bed Shear Stress	0.42	Pascals

Following the rationale for conservative critical shear stress assumptions in Section C-6.2.1, conservative assumptions in Table C-6-2 include:

- Using 10 deg C: when coupled with use of 15 deg C used in critical shear stress calculations, the lower temperature will induce greater shear due to denser water,

- Use of 100 mm for d50: while a larger representative particle size would give an unconservative (i.e. higher) critical shear stress value, the larger particle size represents increased roughness and thus an increased induced shear stress based on depth average velocities.

C-6.2.3. Sediment Stability Conclusions. Table C-6-2 shows that a 1 ft/s depth averaged velocity is near the critical shear stress for a 75 micron particle, and velocities above 1 ft/s would very likely cause sand movement. While exceedance of the critical shear stress for sand does not imply large scale erosion per se, the possibility of movement in a screening level analysis was deemed sufficient to warrant velocity reducing controls to endure sand stability until vegetation can be established on sand mounds so that long term stability is probable.

C-6.3 Hay Bale Placement for Enhanced Sediment Stability.

Initial restoration designs included the use of hay bales for the confinement of dredged material with a significant fine-grained fraction. While the confinement coarse-grained dredged material of similar character to Table C-4-1 is not anticipated to be necessary, hay bales can be utilized as velocity dissipation measures to reduce the water velocities impacting mounds of dredged material prior to vegetative establishment. Hay bales are assumed to persist underwater for about 2 years prior to disintegration (Koger, pers. comm.), providing more than the expected time for vegetation to establish on dredged material mounds; this vegetation is assumed to provide erosion resistance for the sand mounds indefinitely.

Higher depth averaged water velocities would be expected for lower water levels at Big Break during flood and ebb tides. 3 ft high hay bales should act as velocity dissipation measures during the highest velocity periods at Big Break if placed on the eastern and western edges of the restoration area.

Based on the dimensions in Figure C-6-2, a hay bale placement consisting of 1,800 linear feet along the western edge of the restoration area was designed for the first year of construction. A second 1,800 linear foot placement was designed for the second year of construction, thus providing a breakwater for the entire western edge of the placement area and allowing establishment of vegetation for mounds placed in years 1 and 2; these mounds will then serve as breakwaters for mounds placed to the east in subsequent years.

Similar logic is applied to hay bale placement on the eastern edge of the restoration area for years 9 and 10. Velocities are predicted to be higher at the eastern edge of the placement area based on Plate CV-2; however, there is a greater amount of remnant levee protecting mounds on the eastern portion of the restoration area. Two placements of 1,800 linear feet were designed for years 9 and 10 for cost estimating purposes. Due to the shorter distance to protect, the line of bales could be doubled up, extended to the southwest, or used in some other configuration. Bale design will be refined once more detailed velocity and bathymetry data are collected in Preconstruction Engineering and Design. Excess hay bales could be utilized to form parts of the kayak trail through the restoration area, if available.

C-6.4. Riparian and Aquatic Planting Designs.

Attachment CV-A is a technical memorandum prepared by the Sacramento District's Landscape Architecture group detailing the riparian planting design on the remnant levees and the aquatic planting designs for placed mounds of dredged material. Some brief details of those plantings are presented in this section. Section C-10 Construction Methods and Water Control Plan discusses the construction methods for the designs in Attachment CV-A.

C-6.4.1 Riparian Planting. Terrestrial riparian species will be planted on the approximately 33 acres of the two remnant levee islands at 235 plants per acre and protected and maintained for 3 years so that the roots will have achieved purchase. Ground water is relatively close to the ground level, so survival is expected to be high and will easily achieve a goal of 141 plants per acre, or 60% of all installed plants. The ultimate goal is to promote root growth and enable the plants to achieve self-sufficiency after 3 years.

The second goal for remnant levee restoration is the removal of invasive vegetation. This vegetation will be eradicated and managed to ensure it does not return for the duration of the 3-year establishment period. Eradication of invasives is necessary to ensure the desirable planted grass and terrestrial vegetation establishes without competition, effectively giving the desirable vegetation a head start and making the return undesirable vegetation difficult. Native grass will be seeded to provide both habitat and soil stabilization.

C-6.4.2 Aquatic Planting.

Based on data from Donlon Island, the ideal plantable area is from -2.5 to 1 ft LMWL. Figures C-4-3 and 4 show the plantable areas on sand mounds for pre- and post-settlement profiles. This profile leads to a plantable area of about 0.5 acres per mound using the plantable area and lateral area formula in Section C-4.3.5. Aquatic planting was calculated based on 17 mounds per year, thus 9 acres of aquatic planting would be performed per year once mounds of dredged material have settled.

Bulrush and cattails are two desirable prominent aquatic species that are expected to colonize the mounds. However, since cattail is a dominate colonizer and bulrush is slow to colonize, bulrush will be planted to give it a head start. Other aquatic species to be planted are rushes, sedges and spike-rushes. Ten percent of the target plantable area will be planted with bulrush spaced at 3 feet on center. Bullrush will be installed in the mid elevation of the aquatic planting elevation zone following the majority of mound settlement (e.g. at MLLW +1.25') and from there it will spread to lower and higher elevations over time.

C-6.5 Project Footprint

Dredged material must be pumped from the maintenance dredging locations to the restoration area via pipeline. Considerations for siting pipeline include

- Minimizing pipeline length
- Minimizing the potential for navigation impairment
- Ease of maintenance, assembly, disassembly, and maintenance/repair.

Analysis of Figure C-2-1 led to the decision to create a key-in structure at the northern side of the Jersey Island peninsula, directly south of about station 585+00. Floating pipe from the dredging operation would attach to the ecosystem restoration project pipeline at this key point. The ecosystem restoration pipeline would run southward from the key-in structure, up and over the northern levee, across Jersey Island, and up and over the southern levee. Once across the southern levee, floating pipe would be used for dredged material placement in the Big Break restoration area using a floating barge with a placement manifold and baffle plate. Figure C-6-3 shows the proposed pipe key in location and layout across Jersey Island and into Big Break.

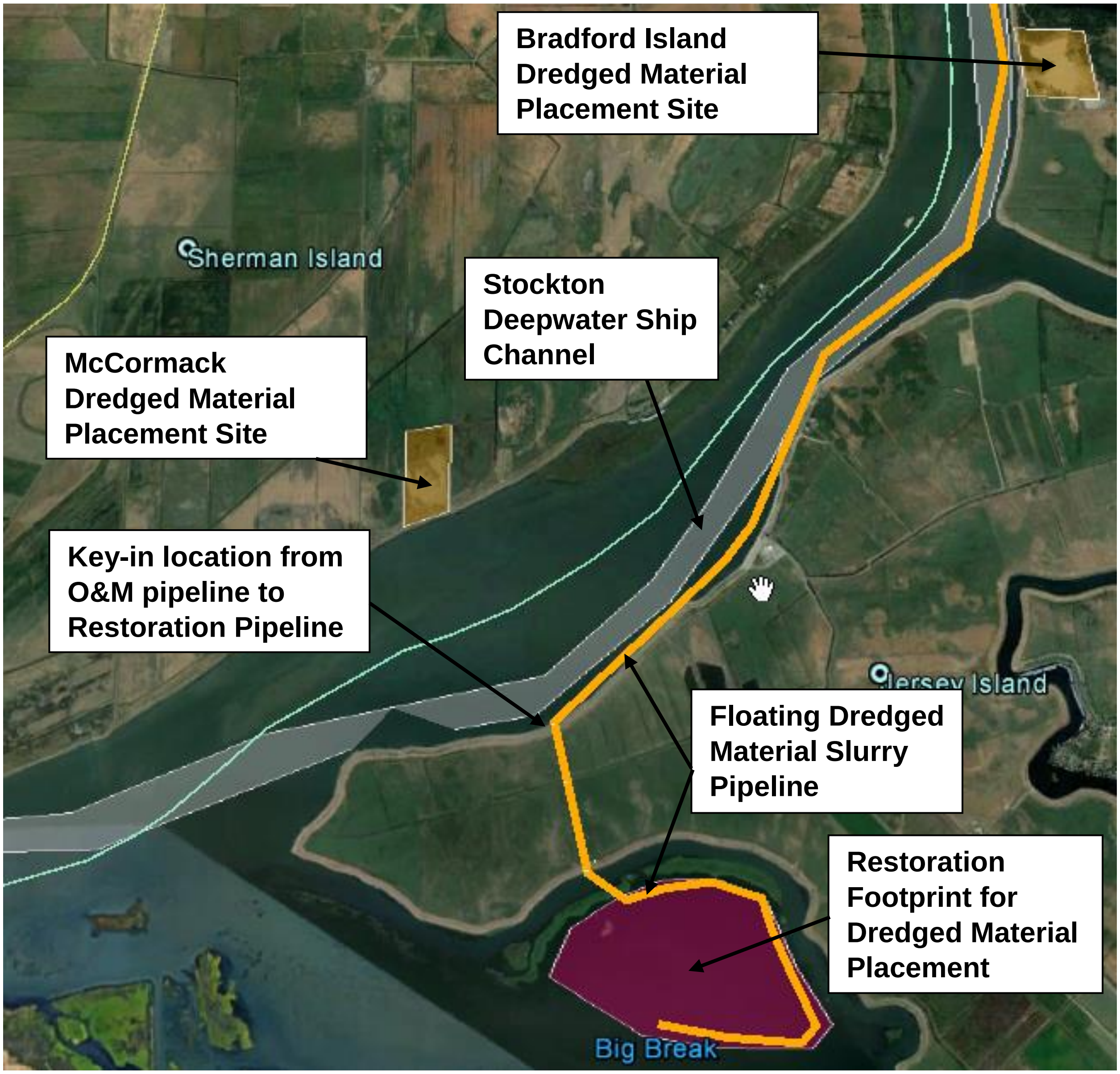

Figure C-6-3. Pipeline layout for dredged material placement at Big Break

C-6.6. Access Road, Haul Road, Staging Area. Siting of the pipeline informed choices of access and haul roads and staging area. Jersey Island Road is a county road to the east of the placement area on Jersey Island and several farm roads are available that could lead to possible staging areas north and east of the restoration area. Since some ground/road improvements will be necessary to place pipeline across Jersey Island, fully creating/improving an access/haul road across the island adjacent to the pipeline path for use for the life of the construction operation would have cost efficiency and minimize the project footprint (thus minimizing easements on Jersey Island). The northern levee road is 25' wide and gravel and could be used to link Jersey Island Road to this haul/access road. A construction staging area at the terminus of this road near the south levee is a logical site that takes advantage of the improved road used for pipeline placement. Figure C-6-4 shows the proposed route to the project site using Jersey Island Road, the northern levee road, the haul/access road, and the staging area.

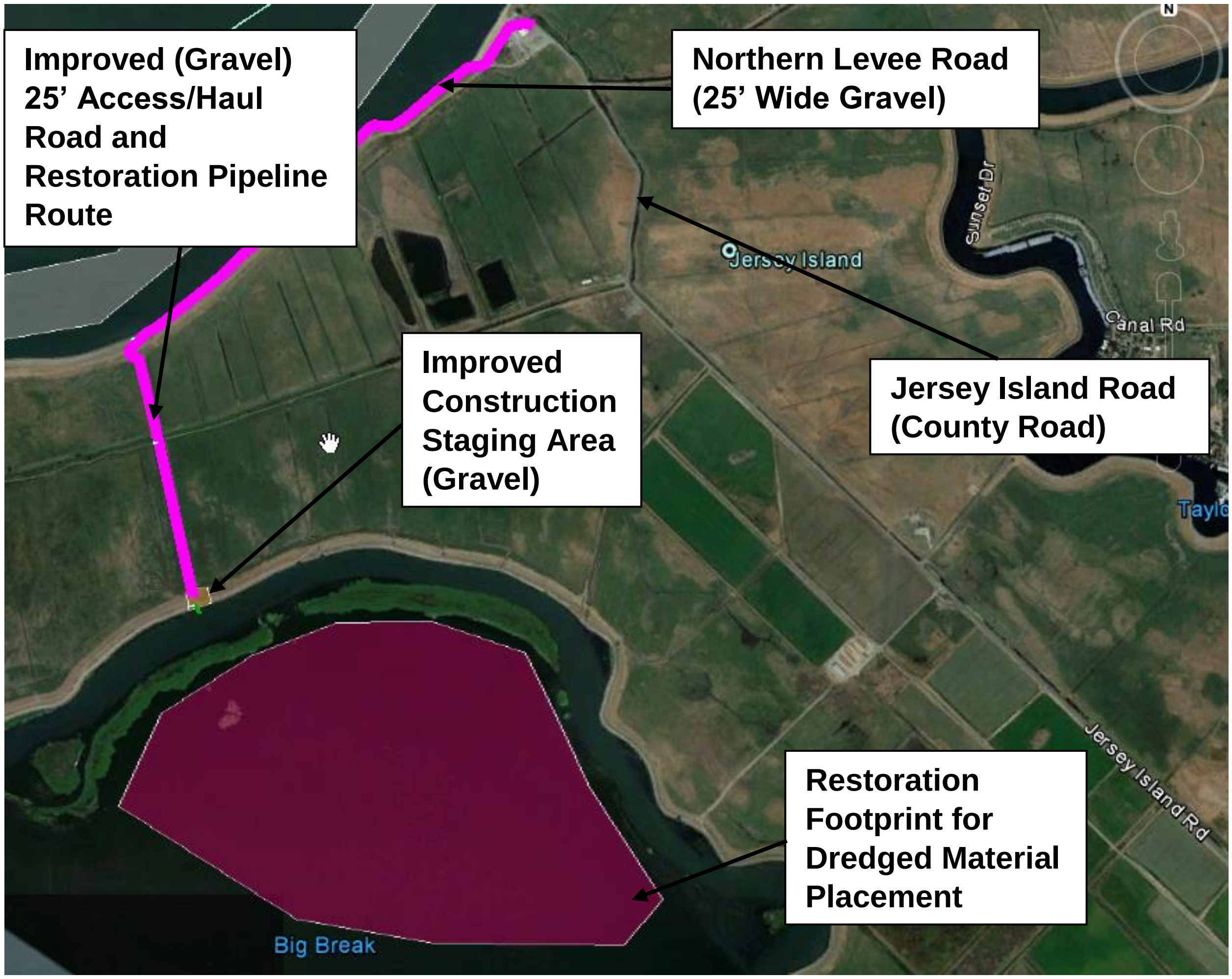

Figure C-6-4. Access and Haul Road routes, Overland Pipeline Route, and Staging Area Locations

C-6.7. Real Estate. Figure C-6-5 shows a parcel map for the restoration project footprint and adjacent areas. Analysis of Figures C-6-2 and C-6-5 shows that the expanded restoration footprint remains on the same parcels as the initial design footprint. Access along north levee road, the north-south haul/access road, and the pipeline overland route would require easements from Ironhouse Sanitary District for approximately one month per year for the assumed 10 years of placement, and floating pipeline crossing Dutch Slough will require an easement from California State Lands Commission for approximately 3 weeks per year for the assumed 10 years (see C-8 Electrical and Mechanical Requirements for placement duration calculations).

DELTA ISLAND - TRACT ACQUISITION REGISTER - December 04, 2017								
APN	OWNER	ADDRESS (Mail)	PARCEL AREA	T.W.A.E. Haul	T.W.A.E. Staging	T.W.A.E. Constr	P.E.	APN Sub Totals
			ACRES	ACRES	ACRES	ACRES	ACRES	ACRES
027-020-009-0	IRONHOUSE SANITARY DISTRICT	460 WALNUT MEADOWS DR, OAKLEY, CA, 94561-3139	46.00	0.104				0.104
027-020-010-8	IRONHOUSE SANITARY DISTRICT	PO BOX 1105, OAKLEY, CA, 94561-1105	38.00	0.115				0.115
027-020-011-6	IRONHOUSE SANITARY DISTRICT	PO BOX 1105, OAKLEY, CA, 94561-1105	41.00	0.415				0.415
027-020-027-2	IRONHOUSE SANITARY DISTRICT	PO BOX 1105, OAKLEY, CA, 94561-1105	89.24	0.423				0.423
027-050-001-0	IRONHOUSE SANITARY DISTRICT	PO BOX 1105, OAKLEY, CA, 94561-1105	398.95				0.719	0.719
027-050-002-8	IRONHOUSE SANITARY DISTRICT	PO BOX 1105, OAKLEY, CA, 94561-1105	627.39	3.231			1.178	4.409
037-191-004-3	EAST BAY REGIONAL PARK, DIST	2950 PERALTA OAKS CT., OAKLAND, CA 94661	454.00			53.162		53.162
037-191-029-0	EAST BAY REGIONAL PARK, DIST	2950 PERALTA OAKS CT., OAKLAND, CA 94661	306.36			31.564		31.564
E. Cypress Rd.	Contra Costa County		n/a	2.450				2.450
Jersey Island Rd.	Contra Costa County		n/a	7.700				7.700
			2001.94	14.437	0.000	84.726	1.897	101.060
						99.163		
	LEGEND							
FEE=	PROPERTY DIRECTLY ACQUIRED							
T.W.A.E.=	TEMPORARY WORK AREA EASEMENT (includes Hauling & Staging Area)							
P.E.=	PIPELINE EASEMENT							

Figure C-6-5. Real Estate parcel map with owner information (TSP design area shaded)

Dredged material placement at Big Break would require an easement for restoration in perpetuity or a similar non-fee simple acquisition mechanism; the Real Estate Plan contains further acquisition details. Section C-9 Hazardous and Toxic Materials details the pre-acquisition sampling and characterization that will take place prior to acquisition.

C-6.8. Relocations. No facility/utility relocations are required as a result of this Ecosystem Restoration project.

One east-west farm road and two levee roads will be obstructed by dredge pipeline during placement operations; culvert-style pipe crossings capable of supporting heavy farm equipment will be placed over the pipe to facilitate access to the western portion of Jersey Island during placement if needed. The cost of these crossings has been accounted for in the project cost estimate.

Floating dredge pipe will cross slough between the remnant levee islands and the south shore of Jersey Island during placement operations; Taylor Slough (between Bethel and Jersey Islands) offers an alternate navigation route from the San Joaquin River to Franks Tract for pleasure craft drawing more than 3 ft. of water during placement operations.

C-7. Structural Requirements.

There are no structural features of this Ecosystem Restoration project.

C-8. Electrical and Mechanical Requirements.

There are no permanent electrical or mechanical requirements for this Ecosystem Restoration project. This section discusses the mechanical and electrical requirements for construction.

C-8.1 Electrical Requirements.

C-8.1.1 Site Preparation and Improvements. No external electrical requirements are anticipated for staging site preparation, haul road improvements, or overland pipeline siting. All power requirements should be self-contained within the equipment for these tasks (equipment is detailed in Section C-10 Construction Procedures and Water Control Plan).

C-8.1.2 Dredging and Placement of Dredged Material. There are no land based electrical requirements for dredging and dredged material placement operations; all electrical needs for these operations are fulfilled by integrated diesel generators (i.e. the dredge plant and booster pumps).

C-8.1.3 Riparian Planting on Remnant Levee Islands. No shore-based power will be required for riparian planting or associated work on the remnant levee islands at the north of the restoration area; however, irrigation pumps will require power intermittently to operate automatically over extended periods during the 3 year establishment period for riparian plantings. The details of the electrical design for the pumps will be left to

Contractors competing for a service contract to execute irrigation through the establishment period, though it is highly likely that battery based systems (perhaps with solar components) will be specified due to boat-limited access to the islands and the automatic nature of the irrigation needs.

C-8.1.4 Aquatic Planting on Mounded Dredged Material.

There are no electrical requirements for aquatic planting operations, these operations will take place by small boat and plantings will be performed by hand.

C-8.2 Mechanical Requirements.

This section discusses the mechanical requirements for the non-standard construction methods (i.e. other than typical loader, grader, blade construction equipment) associated with this Ecosystem Restoration project. A more detailed discussion on construction methods is contained in Section C-10 Construction Procedures and Water Control Plan.

Mechanical requirements for the cutterhead dredge plant are covered by the O&M dredging project. Pipeline and booster pump requirements above what would be needed for O&M placement are the responsibility of the restoration project, as is end-of-pipe dredged material placement mechanical requirements. The Cost Engineering Dredge Estimating Program (CEDEP) spreadsheet tool was provided by the USACE Cost Engineering Directory of Expertise (Cost DX) and used to determine the number of booster pumps necessary to transport sandy dredged material to the restoration site based on siting information derived in C-6 Civil Design.

C-8.2.1 Dredge Pipeline. The maximum pipeline estimate for CEDEP input was based on the dredged material availability data in Table C-4-1 and the Stockton Deepwater Ship Channel station information in Figure C-2-2. A distance of 28,000 ft from station 860+00 to the proposed key-in site for the land based pipeline near station 580+00 data was added to an overland pipe length of 3,100 ft to get a rough estimate of 31,100 ft for CEDEP input.

C-8.2.2 Booster Pumps. The CEDEP main tab predicted the need for 3 booster pumps for this length of pipe with a maximum pumping capacity over 44,000 ft before a 4th booster would be needed. Pipe length is not anticipated to be in excess of 44,000 ft in any foreseeable scenario, thus 3 booster pumps were assumed for mechanical requirements and cost engineering considerations.

C-8.2.3 Mechanical Support Equipment Requirements. Booster pumps require a barge with spuds, a fuel barge, and a tender boat for operation through the dredging operation. Pipeline placement is facilitated by tug and barge and loaders for transfer to Jersey Island for overland pipeline placement. This equipment is all standard parts of a dredging contractor's inventory and will be included in the dredging placement contract. The dredged material placement equipment will be on site only for the mobilization, dredging operation (from approximately station 400+00 to 860+00 only) and demobilization; this equipment will not be present during approximately 11 months of the year.

C-9. Hazardous and Toxic Materials.

C-9.1. Big Break Dredge Material Placement Site

C-9.1.1 Past Land Use. EDAW et al. (2005) is a thorough baseline report prepared for the California Department of Water Resources (DWR) for submittal to the California Bay Delta Authority that includes past land use information and soil information surrounding Big Break. EDAW et al. (2005) states that the flooded island that is now Big Break was likely used for dryland or irrigated pasture purposes and asparagus cultivation prior to flooding in 1928. This land use information would not suggest legacy contaminants associated with past activities:

- the island was flooded prior to the wide use of environmentally persistent chlorinated pesticides (e.g. DDT),

- any gasoline, diesel, or oil tanks that were inundated by the 1928 flooding of the island would be expected to have released or leached these materials over the 90+ years between flooding and proposed project implementation.

C-9.1.2 Records Search. The potential presence of hazardous or toxic materials from a reported site, spill, or release from a permitted facility was investigated using the California State Resources Control Board's GeoTracker (website). Figure C-9-1 shows the results of a GeoTracker search for the Selected Plan restoration area. One Leaking Underground Storage Tank (LUST) cleanup site was found at the nearby Big Break Marina. That cleanup was initiated in 1992 and closed in 1997 with a No Further Action Closure letter as shown in Figure C-9-2.

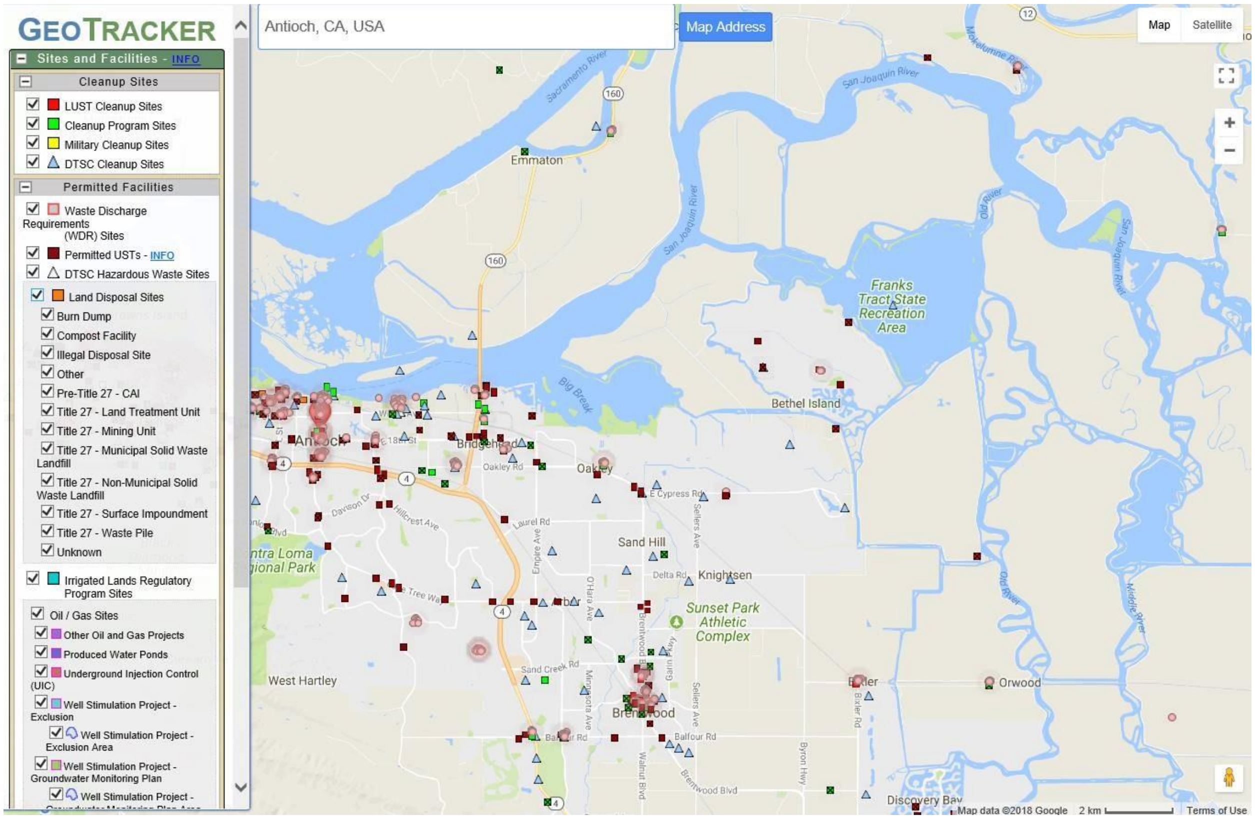

Figure C-9-1. Geotracker search results for Big Break and surrounding areas

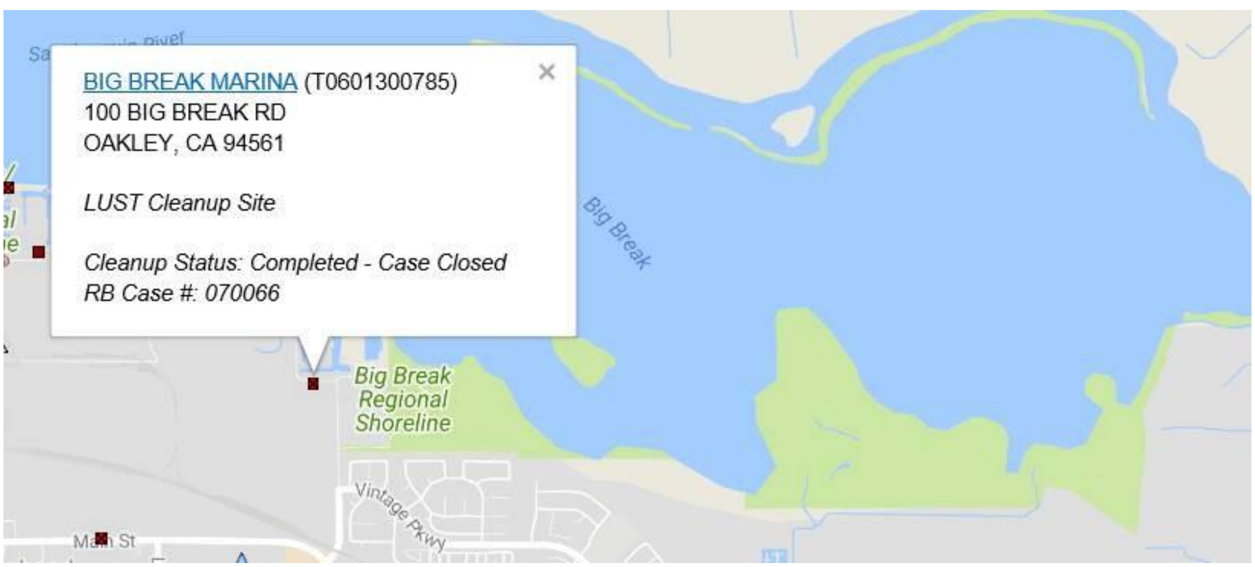

Figure C-9-2. Geotracker details for closed Big Break Marina cleanup

No other releases or sites that could potentially impact the restoration project area are known to California Department of Toxic Substances Control or the California State Resources Control Board.

C-9.1.3 Pre-Acquisition Sediment Sampling.

The sediments in the area of Big Break proposed for dredged material placement will be thoroughly chemically characterized prior to real estate acquisition in Preconstruction Engineering and Design. This characterization is the most direct and exhaustive means of ensuring land with excessive hazardous and toxic materials is not acquired by the Government's non-Federal Sponsor(s).

C-9.2. Water Quality/Contaminant Transport

There are Total Maximum Daily Load (TMDL) Basin Plan Amendments for organic enrichment and dissolved oxygen for portions of the San Joaquin Deep Water Ship Channel based on the current 303d Clean Water Act list for the Delta; however, the Selected Plan location is outside of impaired areas. There is also a TMDL for methyl mercury in the Delta, which includes wetland and open water sources in the restoration project area. Total mercury loads and potential methyl mercury loads are required to comply with the TMDL allocations. A TMDL consistency evaluation will be conducted prior to dredge material placement at Big Break.

C-9.2.1. Mercury at Big Break. EDAW et al. (2005) states "At the Big Break site, methyl mercury concentrations were noticeably lower than most of the surrounding central and western Delta sites…Methyl mercury potential was also low relative to other sites in the central and western Delta ..."

C-9.2.2 Dredged Material Characterization. Material to potentially be dredged is physically and chemically characterized prior to each dredging event. Should contaminant concentrations be detected that are unsuitable for open water placement, those materials would not be piped to Big Break and would instead be placed upland following the standard procedures of the O&M dredging project.

C-9.2.3 Water Quality Conclusions. Mercury and other heavy metal contamination is generally associated with fine silts and clay-sized particles; these particle sizes are not significantly present in past dredged material as show in Table C-4-1. Data from EDAW et al. (2005) does not suggest high mercury concentration in bed sediments at Big Break. This information coupled with the rejection of any material to be dredged that is unsuitable for open water placement suggests that mercury and methyl mercury production are likely not water quality concerns for this restoration project. Nonetheless, any contaminant releases from placed dredged material or resuspended bed sediments will be addressed and controlled as part of the Clean Water Act Section 401 Certification for in water work.

C-10 Construction Procedures and Water Control Plan.

C-10.1. Ecosystem Restoration Construction.

This section briefly describes the construction procedures for each phase of the Selected Plan. Complete details for each operation are contained in the MII Cost Estimate files and the CEDEP spreadsheet tool, see Section C-19 Cost Engineering.

C-10.1.1 Access/Haul Road and Staging Area Improvement.

Construction of the north-south access/haul road across Jersey Island and the staging area at the terminus of that road near the southern levee is expected to follow standard procedures for road improvements and staging area construction. Required equipment for this task is assumed to be

- 14.6' loader/backhoe
- self-propelled 12 ton, single drum vibratory roller
- 4,000 gal water truck
- 12' blade articulated grader
- 8 gravel trucks running 8 hrs/day
- support crew of 6

Multiple gravel sources were sited 30 miles from the staging area.

C-10.1.2 Hay Bale Acquisition, Staging, Placement. A Hay Bale source was assumed to be sited at 30 miles from project site. 1,800 linear feet (LF) of bales are assumed to be placed prior to construction in years 1, 2, 9, and 10. Bales for one season's placement (1,800 LF of 3' x 3' x 5' bales) are assumed to be deliverable by 4 semi-trucks in one day. Bales will be offloaded and staged at the Jersey Island staging area near the southern levee road (see Figure C-6-4). Bales will be lifted over levee to floating 7.5 x 14 ft barges by 60 ton, 141 ft. truck-mounted boom crane. The boom crane is assumed to have an oiler truck and crew with work truck for support. Floating barges moved by two shallow draft pushboats (300 HP inboard with pushknees and a pilot house) will ferry hay bales (estimated 8 to a barge) to a loader with bale attachment mounted on two 7.5 x 14 ft barges (calculated to draw between 1.5 and 2 ft) with spud accessories. One pushboat will bring a barge loaded with bales while the other returns to the staging area with an empty barge and re-loads. A 1,800 LF bale placement operation is estimated to be executable in one week. Any anchoring needs for the hay bales will be determined following detailed site characterization during Preconstruction Engineering and Design.

C-10.1.3 Dredged Material Placement. Dredging within reaches of interest on the Stockton Deepwater Ship Channel can occur anytime between September and end of November based on current fish windows. Exact placement dates are unknown from year to year, bale placement and other staging will be scheduled each year once dredging schedules are available. Note that C-20 Schedule for Design and Construction assumes the latest possible schedule (with dredged material placement concluding at the end of November) to illustrate the latest possible dates each season for the various construction activities (this would lead to minimal, and thus conservative, schedule float for finish-start activities).

The Notice of Intent (NOI) to Dredge documents (also used to compile Table C-4-1) consistently state that cutterhead dredging operations along the Stockton Deepwater Ship Channel average between 300 and 600 cy/hr production and operate 24 hours per day with approximately 18 hours of 450 cy/hr effective production per day. CEDEP requires an average pipeline length for production and other cost estimating purposes.

Based on the ~30,000 ft maximum pipeline estimate (see Section C-8.2.1), an average pipeline length of 15,000 ft was input into CEDEP. CEDEP calculated an effective production of 455 cy/hr for this average pipeline length, virtually identical to the NOI average of 450 cy/hr. This estimate was thus carried in CEDEP to determine fuel usages, equipment usages, and eventually dredging and placement costs.

The CEDEP spreadsheet tool estimated a 10 person crew, one tender tug (150 + 25 HP) and one fuel barge would be necessary for pipeline mobilization, transport to site, and pipeline offloading based on a Bay Area point of origin and 31,100 ft pipeline length. This pipe mobilization is estimated to take one 12 hour day plus transit time. Demobilization of the pipeline and booster pumps will follow the same process as mobilization.

Pipe assembly is estimated to take approximately a week prior to the dredging operation and a week after for disassembly. Based on production rates, sediment type, average pipeline length, roughly 15 days of dredging is estimated, putting the total estimated dredging operation at 25 days (output as 0.82 months in CEDEP). The CEDEP tool estimated 3 booster pumps to be necessary to move dredged material, along with a tender boat and fuel barge for booster pump support (detailed in C-8 Electrical and Mechanical Requirements).

The end of pipe placement of dredged material is assumed to take place from a floating barge (assumed two connected 7.5 x 14 ft barges) with spud attachments, with raised outflow pipe (able to place up to +6 ft MLLW, see figures C-4-3 and 4) and baffle plate to decrease outflow energy and facilitate low momentum sand mound placement. The placement barge will need to be repositioned approximately 300-350 ft once a sand mound is completed based on sand mound geometry assumptions. Production calculations put this repositioning at a rate of about once per day, varying based on production and bed elevation. A shallow draft inboard pushboat with pilot house will be used to reposition the placement barge in a timely fashion so that the dredging operation is not interrupted and excessive dredged material is not lost during movement.

This placement method is planned for 10 seasons. Actual placement volumes and durations will vary year to year based on the availability of dredged material, with the actual number of season based on completion of the restoration acreage. Pre-dredging bathymetry surveys will allow for preconstruction engineering and design each season to optimize design and placement for the material available.

C-10.1.4 Riparian Planting. Riparian planting on the remnant levee islands is assumed to take place in the first construction year following cessation of dredged material placement activities (see C-20 Schedule for Design and Construction). Riparian planting and associated site preparation, mowing and spraying, and invasive species eradication is to take place over 33 acres of the two islands. Construction procedures are anticipated to follow those for routine landscape architecture work and involve tractor mounted flails/mowers, tractors for discing and seeding, man-portable hedging equipment and manual labor; the notable exception to standard procedures is that equipment and crews will have to be barge delivered to the remnant levee islands. A maximum of 2 tractors will be staged on the site (transported in by barge, with likely landing zone siting on the remnant slough on the north side of the islands). The total duration for riparian planting is estimated at approximately 8 calendar months. The estimated establishment period following construction is 3 years. Attachment CV-A is a technical memorandum that includes riparian plant design. Specific tasks are listed below with brief descriptions in sequential order:

- Establishment of staging, implementation of SWPPP and erosion and sediment control BMPs, establishment of BMPs for heavy equipment offloading, fueling, operation, and general site prep.

- Eradication of exotic/invasive species on the remnant levee islands. Approximately a five week operation involving a tractor and flail, 8-person power hedging crew.

- Soil prep and grass seeding next operation, involves use of tractor (ideally same one used for eradication operations once sufficiently cleaned/treated) for discing and later seeing, estimated to be a 5 week operation.

- Irrigation installation, including pump and battery installation on the two islands, 6 crew is estimated to accomplish this in 17 days.

- Installation of woody plants involves a 3-person crew that will collect and transport seeds to the site over 27 days. An 8-person crew will install cages and plants on the two islands for 51 days.

- Mowing and Spraying operations will be conducted 4 times per year (with the exception of 3 times in the first year of construction) for the 3 year establishment period. A tractor and spraying crews must be barged to islands for each event, assumed to use shallow draft pushboats with a pilot house. Each spraying and mowing event is estimated to take 17 days to complete.

C-10.1.5 Aquatic Planting. Aquatic planting on placed mounds of sandy dredged material entails planting approximately 4,300 plants over 9 acres per year for 10 years. This effort is estimated to use

- a 6-person crew for staging and seed acquisition over 2 days using a small workboat
- a 4-person crew for plantings using 2 workboats over 12 days.

Plantings will either be installed directly from workboats or by an individual in waders. A dedicated safety team member will be present during aquatic planting operations.

C-10.2 Water Control Plan

C-10.2.1 Jersey Island Work. For the first year of construction, overland pipeline placement, access/haul road improvement, and staging area construction activities will all employ BMPs and sediment and erosion controls as part of a Stormwater Pollution Prevention Plan. The entirety of ground disturbing activities on Jersey Island are on land surrounded by levees, thus runoff to a waterbody is not anticipated to be a significant concern.

Activities on Jersey Island for construction years 2 through 10 will not consist of new ground disturbing activities, though pipeline assembly over the access/haul road, road and staging area maintenance, and staging of a boom crane and hay bale transport trucks will be necessary in some years. The Construction General permit obtained in year 1 will likely be kept through the entirety of construction with BMPs employed and maintained as needed.

C-10.2.2 Hay Bale and Dredged Material Placement. Hay bale placement and dredged material placement are both in water work activities from a permitting perspective. Site specific requirements for these activities will be addressed through the Clean Water Act Section 401 Certification process. The sediment bed at the Big Break restoration site will be physically and chemically characterized in Preconstruction Engineering and Design. Dredged material is physically and chemically characterized every year prior to dredging as part of the O&M dredging project.

In addition to serving as breakwaters to allow vegetation establishment on sand mounds, hay bales can also act as controls during dredged material placement. Silt curtains have also been budgeted in the project cost estimate as a contingency control in case finer-grained material is unexpectedly encountered and proposed for placement for restoration. Note that settling/turbidity controls would not generally be expected for a low energy, shallow water placement of material with the grain size characteristics in Table C-4-1.

C-10.2.3 Remnant Levee Riparian Planting. Riparian planting on the remnant levee islands does not involve in-water work. A Stormwater Pollution Prevention Plan will be necessary for riparian planting activities, including

- Best Management Practices (BMPs) to prevent irrigation water and herbicide runoff from the island into Big Break,
- BMPs associated with heavy equipment maintenance and fueling,
- BMPs associated with construction crews near a receiving water,
- BMPs associated with sediment disturbance (staging area, discing) and mowing near a receiving water.

These BMPs will be identified by the planting contractor(s) as part of the National Pollution Discharge Elimination System (NPDES) Construction General permitting process. BMPs will likely be maintained through the 3 year establishment period for riparian plantings as needed/required by the Construction General permit.

C-10.2.4 Aquatic Plantings. Aquatic plantings on mounds of sandy dredged material do not involve excavation or placement of soil/sediment and would thus not be expected to require water controls. It is possible that because this activity is part of the overall Ecosystem Restoration project, coverage under the overall project 401 permit may occur. Regardless, best management practices will be employed to minimize disruption of the environment during aquatic placement activities.

C-11. Initial Reservoir Filling and Surveillance Plan

Initial Reservoir Filling and Surveillance Plan Flood Emergency Plans for Areas Downstream of Corps Dams is not a relevant aspect of this ecosystem restoration study.

C-12. Flood Emergency Plans for Areas Downstream of Corps Dams

Flood Emergency Plans for Areas Downstream of Corps Dams is not a relevant aspect of this ecosystem restoration study.

C-13. Environmental Objective and Requirements.

This information is provided in the main body of the report. Mitigation is not authorized for Ecosystem Restoration projects.

C-14. Reservoir Clearing

Reservoir clearing is not a relevant aspect of this Ecosystem Restoration study.

C-15. Operation and Maintenance

Operation and maintenance requirements for Ecosystem Restoration projects are to be minimal by design. This Ecosystem Restoration project is expected to have a minimal $5k per year Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) cost based on judgment. This cost will be borne 100% by the non-Federal Sponsor for 10 years following termination of monitoring and adaptive management; because there is no structural component to this Ecosystem Restoration project, OMRR&R responsibilities end after this 10 year period.

C-16. Access Roads

Please see C-6 Civil Design Section C-6.6 for a discussion of access roads.

C-17. Corrosion Mitigation

There are no permanent project features that would require corrosion mitigation. Coatings and/or cathodic protection will be included in the design for temporary project features (e.g. irrigation systems) as required for materials which are installed in water or soil.

C-18. Project Security

This Ecosystem Restoration project is not anticipated to require a security plan.

C-19. Cost Estimates

C-19.1. Approach. In developing the feasibility level cost estimates for the Selected Plan, the Cost Engineering team utilized a construction methodology incorporating the estimating software MII 4.3 (MCASES Version 4.5.51209) and generated costs at a Class 3 level. Project costs were based on the CEDEP spreadsheet tool and generation of crews and equipment necessary for the construction or the Selected Plan within MII; Section C-6 Civil Design and Section C-10 Construction Procedures and Water Control Plan discuss the bulk of these project aspects that are integrated into MII.

C-19.2. Cost Uncertainties. There are inherent uncertainties in the quantities at the feasibility level of design as the result of lacking detailed design, plans or specifications. These discrepancies are reflected in the contingency acquired through the Abbreviated Cost Risk Analysis (ACRA).

An initial Abbreviated Cost Risk Analysis (ACRA) was performed for the project since Class 4 estimates were well below $40 million. The risk analysis process involved dividing project costs into typical risk elements and placing them into a Risk Register, then identifying the risks/concerns relative to those risk elements, and then justifying the likelihood of the risk occurring and the impact if the risk occurs. A Risk Matrix utilizing weighted likelihood/impacts is used to establish the cost contingency for each risk element (work feature) for use in alternatives comparisons. Risk analysis results are intended to provide project leadership with contingency information in order to support decision making and risk management as the project progresses from planning through implementation. To fully recognize its benefits; cost and schedule risk analysis should be considered as an ongoing process conducted concurrent to; and iteratively with; other important project processes such as scope and execution plan development, resource planning, procurement planning, budgeting and scheduling.

An abbreviated cost risk analysis was held 29 October 2014 with the project manager and PDT members that was led by SPK Cost Engineering. The meeting primarily focused on risk factor identification through discussions based on risks prevalent to dredging placement operations and ecosystem restoration projects. The meeting encompassed risk factor assessment and quantification which resulted in revisions to the estimate. Project risks were identified and documented leading to the development of a risk register spreadsheet. Following the analysis the draft risk register was forwarded to the PDT for review.

The qualitative impacts of each risk element on costs and schedule were analyzed using a combination of professional judgment, empirical data and analytical aptitude. Risks not immediately agreed upon by the PDT were discussed at length and agreed upon in the form of inputs into the probability density functions. Quantification involved multiple project team disciplines and responsibilities. The resulting product model reflects the risk register parameters as developed by the team.

Contingency is an amount added to an estimate and/or schedule allowing for items, conditions or events for which the occurrence or impact is uncertain. It is probable these uncertainties will result in the additional costs being incurred or additional time being required. Based on ACRA results, the contingency for the Tentatively Selected Plan was calculated to be 17%.

Subsequent to the 29 October 2014 ACRA meeting and contingency calculation, the project was put on hold. The project resumed at the beginning of FY18. The nature of the Selected Plan did not change following the project pause, though the restoration footprint was expanded and dredging placement methodologies changed slightly. An ACRA update meeting was held on 19 April 2018 to verify that the previously identified risks, project impacts, and calculated contingency remained applicable to the project after feasibility level design. . Following this meeting, some risk category documentation was updated, with additional emphasis given to dredged material availability/uncertainty and impacts to the pumping operation. A second update meeting was held 09 May 2018 to further address dredged material availability concerns. The result of these updated ACRA meetings was an increased overall contingency value of 27.4% for use in Class 3 (10-60% quality of project definition) cost estimates.

C-19.3. Total Project Schedule. Section C-19.8 describes the project schedule assumptions in detail; PED for the first year of construction is assumed, with optimal funding, to occur in FY 20 with construction commencing FY 21. Construction is assumed to take 10 years with a 5 year monitoring period thereafter. These assumptions are reflected in the total project cost summary (TPCS).

C-19.4. Review. The feasibility level cost estimates and Abbreviated Cost-Schedule Risk Analysis underwent District Quality Control by the Engineering Support Branch Chief at the Sacramento District, and a District Quality Control certificate was signed by the Cost Engineering Section Chief, Technical Lead, and Engineering Support Branch Chief. Following DQC, cost engineering and other project documentation was provided to the Cost Dx in Dr. Checks as part of the Agency Technical Review Process. Comment responses were deemed adequate; a Cost Certification was signed by the Cost Dx 07 June 2018. The Cost Certification is included as a cover sheet to the TPCS sheets as part of Attachment CE-B (see Section C-19.6).

C-19.5. Key Assumptions

a. CEDEP estimates are based on pipeline and production assumptions detailed in Section C-8 Electrical and Mechanical Requirements.

b. Haul and Distances – Gravel and hay bale sourcing were sited to be 30 miles from the project staging area. Worker commute distances were assumed to be 1 hour (~30 miles) one way for some tasks, and 30 minutes (~15 miles) one way for others. MII files and the Air Quality analysis in the main report detail these assumptions. The uncertainty in these estimated distances could affect costs.

c. Real Estate – Real Estate Costs reflect the fair market value of the parcels shown in Section C-6.7 and the Real Estate Plan. There is uncertainty in the value of subaqueous land, conservative assumptions were made using dry land comparables by the SPK Real Estate Division.

d. Quantity Uncertainty – Dredged material volumes suitable for restoration placement will vary from year to year. Some years may have more dredged material available and placement beyond 100,000 cy may be possible should funding/authorization allow. In other years, 100,000 cy of dredged material may not be available, increasing costs due to an increased number of mobilizations and associated permitting and monitoring activities.

e. Project Schedule – 1 years of initial PED is assumed, beginning in FY20 following (optimal) authorization in FY19. Limited PED would be performed prior to the following FY's construction for construction years 2 thought 10 (see C-20 Schedule for Design and Construction for details).

f. The dredged material placement for ecosystem restoration involves the pumping of sandy material into a shallow open water area. This activity is most accurately estimated by use of the 17 Account (Beach Replenishment), even though it could be classified as a 06 Account activity. No beach nourishment is to be performed and no authority other than Ecosystem Restoration is to be used on this project.

g. Planning, Engineering & Design Costs – A Planning, Engineering, and Design (30 Account) percentage of 10% was used in lieu of the usual 27.5% assumption. This reduced percentage is based on the fact that this project is ecological, thus reduced costs for engineering and design are expected relative to conventional construction projects. The 30 Account estimate accounts for approximately 8 Full Time Equivalent staff members for each year of design/procurement activities which is consistent with the anticipated team composition.

h. Construction Management – A Construction Management (31 Account) percentage of 10% was used in lieu of the usual 14.5% assumption. This reduced percentage is based on the fact that this project is ecological in nature, thus reduced costs are expected relative to conventional construction projects. The 31 Account estimate accounts for approximately 10 Full Time Equivalent staff members for each year of construction activities which is consistent with the anticipated team composition.

i. Permitting, Monitoring, and Sampling/Characterization up front (i.e. Year 1) costs
    a. up front cost of $125k + $53k for chemical and physical characterization of the placement site sediments,
    b. $64k for a water quality baseline/background data at Big Break restoration area and nearby anticipated compliance points (~300 ft from project boundaries),
    c. $100k for Cultural Resources unexpected discovery contingency.

j. Permitting, Monitoring, and Sampling/Characterization Cost annual cost assumptions
    a. $60k/yr for 10 years for permitting the placement operation,
    b. $64k/yr for 10 years for water quality monitoring during construction (401 compliance),
    c. $62k/yr for 10 years for silt screens (for 401 compliance)
    d. $50k/yr for 10 years for survey biologist for Dredged Material Placement Site (i.e. Big Break),
    e. $85k/yr for 15 years for monitoring and adaptive management WQ monitoring

C-19.6. Monitoring and Adaptive Management Costs. Monitoring and adaptive management costs were adapted from existing tasks within MII when possible, and otherwise estimated externally from MII using straightforward labor, crew, and equipment assumptions and then imported into MII as lump sum items. Attachment CE-A is a table detailing the monitoring and adaptive management tasks for each restoration physical action, the costs, and the assumed year(s) of implementation (in the case of adaptive management). These costs are entered individually inside TPCS spreadsheet cells with cell comments identifying them.

C-19.7. Total Project Cost Summary. Total Project Cost Summary (TPCS) sheets for the 10 years of restoration construction and the subsequent 5 years of monitoring and adaptive management are contained in Attachment CE-B; a TPCS sheet was generated for each of these years, thus there are 15 annual TPCS sheets and one rollup sheet for the entire project. One midpoint for Real Estate acquisition was input for Construction Year 1. Midpoints for the 06 Fish and Wildlife Facilities, 17 Beach Replenishment, 18 Cultural Resources, 30 Planning Engineering and Design cost accounts and the Construction Midpoint were entered for each construction year. Table C-19-1 summarizes the first and fully funded costs for each year of construction, monitoring, and adaptive management and the total project cost.

Table C-19-1. Summary of costs

Construciton Year	Costs in $1,000s	
	First Cost	Fully Funded Cost
1	$4,619	$5,070
2	$2,019	$2,168
3	$1,777	$2,002
4	$1,789	$2,067
5	$1,769	$2,087
6	$1,808	$2,186
7	$1,776	$2,201
8	$1,779	$2,260
9	$1,897	$2,472
10	$2,014	$2,762
11	$148	$203
12	$218	$306
13	$148	$214
14	$239	$355
15	$148	$226
Total Project Cost	**$22,266**	**$26,579**

As noted in Section C-15 Operation and Maintenance, a minimal OMRR&R annual cost is estimated to be $5,000 per year for 10 years, with no OMRR&R cost thereafter.

C-20. Schedule for Design and Construction

Section C-10 Constructability and Water Control Plan details project construction elements and C-19.8 details assumptions regarding PED timing and cost account and construction midpoints. The construction schedule for 10 years of ecosystem restoration and 5 years of subsequent monitoring and adaptive management is shown in Attachment CE-C.

C-21. Special Studies

As stated in C-4 Geotechnical and C-9 Hazardous and Toxic substances, thorough physical and chemical characterization of dredged material and bed sediment at the restoration site are planned. Baseline water quality, water stage and velocity data will be gathered in the first year of Preconstruction Engineering and Design and monitoring will continue through the 15th year of the project (see Attachment CE-A). No special studies beyond this work are anticipated to be necessary for this Ecosystem Restoration project.

C-22. Plates, Figures, and Drawings

Figures have been embedded in line with text in this Appendix. Plates for Civil Design (CV-1 and CV-2) follow the References section of this Appendix. Attachments for Hydraulics and Hydrology (HH-A and HH-B) Civil Design (CV-A), and Cost Engineering (CE-A through CE-C) follow plates at the end of this Appendix.

C-23. Data Management.

In accordance with South Pacific Division policy, this project utilized ProjectWise software for both engineering data management and data management for other disciplines. During the feasibility study, electronic data was compiled and maintained in project folders for each discipline involved on the server. This data is backed up regularly by USACE's data manager (ACE-IT). Project information will be available for the next phase of the project.

C-24. Use of Metric System Measurements.

In accordance with SMART Planning Principles, British Units were predominantly used on this project due to the substantial existing body of available work on the watershed that utilized British Units. Surveys and existing GIS and modeling work have been performed using British Units, conversion of these to metric units would be prohibitively time consuming and costly. It is anticipated that future chemical and sediment characterization work will utilize SI units (e.g. mg/L, mg/kg, kg/m^3).

References

Atwater, B. F., and D. F. Belknap 1980. Tidal–Wetland Deposits of the Sacramento–San Joaquin Delta, California. In M. E. Field, A. H. Bouma, I. P. Colburn, R. G. Douglas, and J. C. Ingle, (eds.), Quaternary Depositional Environments of the Pacific Coast: [papers] Pacific Coast Paleogeography, Symposium 4, April 9, 1980. Los Angeles, CA: Pacific Section, Society of Economic Paleontologists and Mineralogists.

CALFED Bay-Delta Program. 2000. Multi-Species Conservation Strategy. Programmatic EIS/EIR Technical Appendix. CALFED Bay-Delta Program, Sacramento, California. July 2000.

East Bay Regional Park District. 2014. http://www.ebparks.org/parks/big_break

EDAW, Swanson Hydrology + Geomorphology, Hansen Environmental, Inc. 2005 Flooded Islands feasibility study baseline report prepared for: California Department of Water Resources for submittal to: California Bay-Delta Authority, February 2005
England, A., Sogge, M., Naley, M. 1990. Design and Biological Monitoring of Wetland and Riparian Habitats Created with Dredged-Materials. Final Report.

Hill, W. 2000. Letter Report: Historic Architecture Evaluation, Big Break Regional Shoreline, Lauritzen Parcel, Oakley, California.

Lettis, W. R., and J. R. Unruh. 1991. Quaternary Geology of the Great Valley, California. In R. B. Morrison (ed.), Quaternary Non-Glacial Geology of the Western United States: Decade of 7 North American Geology. Volume K-2, Geological Society of America, 164–176.

Philip Williams & Associates 2007. Delta Risk Management Strategy Wind Wave Analysis January 31, 2007 FINAL DRAFT

Thompson, J. 1957. The Settlement Geography of the Sacramento-San Joaquin Delta California. Ph.D. Dissertation, Department of Geography, Stanford University, California.1980. From Waterways to Roadways in the Sacramento Delta. California History 59 (Summer):144-169. 2006. Early Reclamation and Abandonment of the Central Sacramento-San Joaquin Delta. Sacramento History Journal 6:41-72.

Weir, W. 1950. “Subsidence of Peat Lands of the Sacramento–San Joaquin Delta, California.” *Hilgardia* 20(3):37–55.

Working Group on California Earthquake Probabilities 2003. http://www.wgcep.org/

Engineering Plates

Engineering Attachments