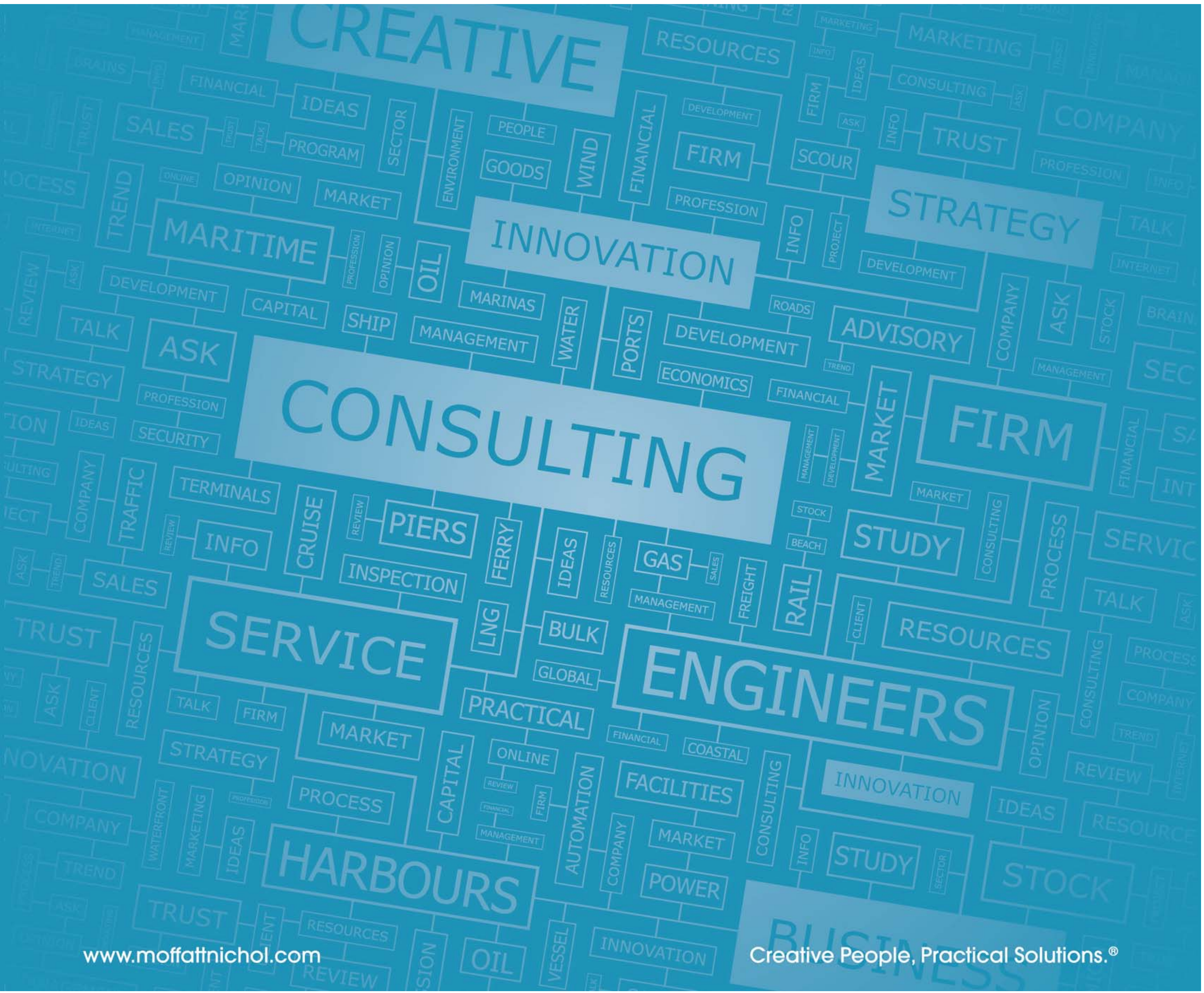
moffatt & nichol

Franks Tract Engineering Feasibility Assessment

PREPARED FOR THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

NOVEMBER 15, 2017



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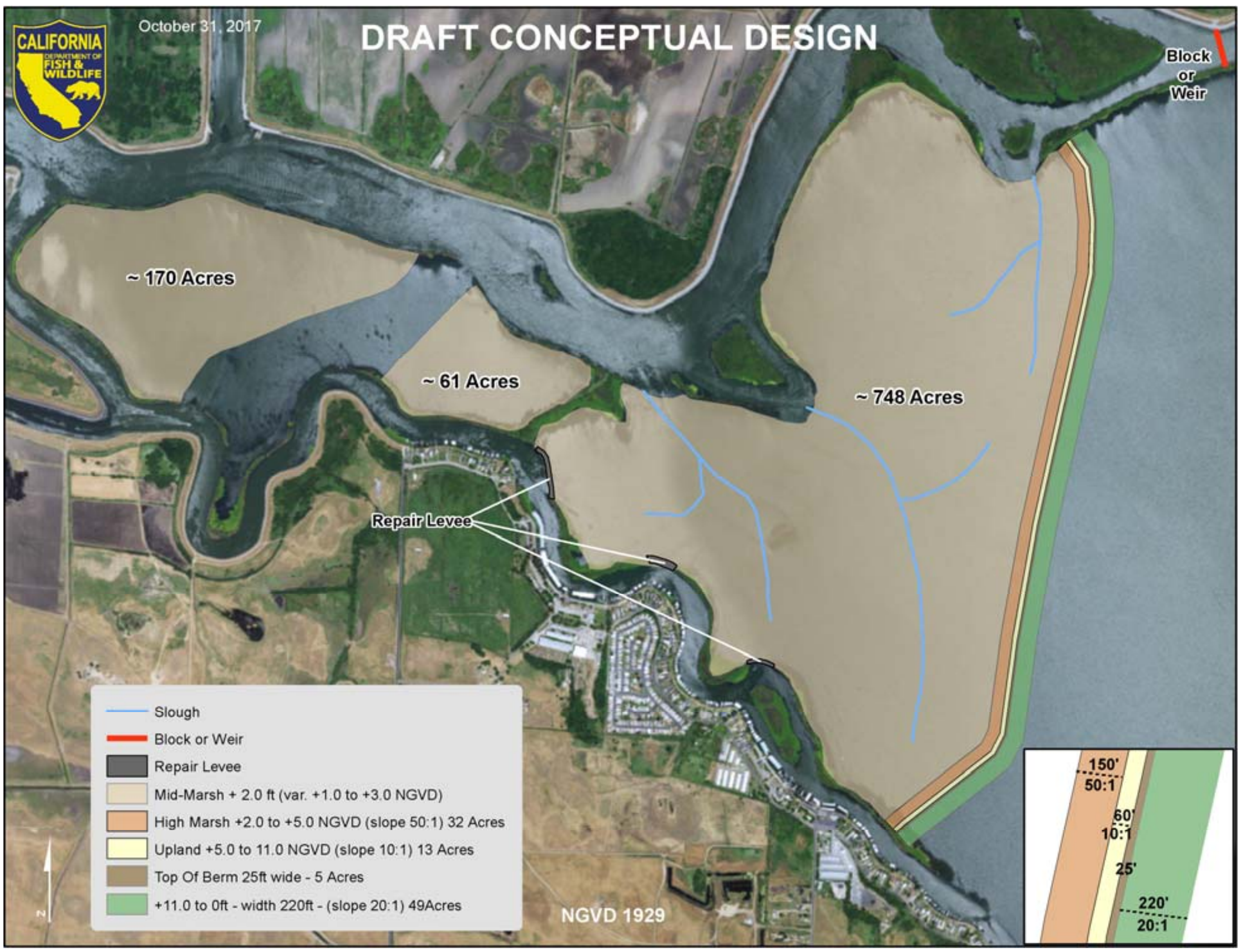
Executive Summary

Moffatt & Nichol (M&N) was retained by the Metropolitan Water District of Southern California (MWD) to provide an engineering feasibility assessment for restoration of Franks Tract State Recreation Area (SRA) in collaboration with the California Department of Fish and Wildlife (CDFW), and the California Department of Water Resources (DWR). The draft conceptual restoration alternative proposed by CDFW is shown in the figure below.

In the context of the Delta Smelt Resiliency Strategy Program, the focus of the conceptual design is to improve water quality, reduce invasive aquatic vegetation, reduce predation on Delta Smelt, increase turbidity, and improve food webs. This work is performed to pursue the best scientific research to protect and restore fish, wildlife, and the Delta's ecosystem while ensuring water supply reliability.



Water quality is improved through construction of a berm across Franks Tract and False River, which works to reduce salinity intrusion into the Delta.

Improvement of food webs and turbidity is achieved by raising bed elevations to approximately +2 feet NGVD using approximately 20 million cubic yards of imported fill material to produce 979 acres of mid-marsh land form with natural channel features within Little Franks Tract and the western portion of Franks Tract. The conceptual design will also incorporate 32 acres of high marsh at elevations from +2 to +5 NGVD along the berm.

The present report evaluates options for construction, including constructability and engineering constraints, sources of fill material, schedule for construction, and unit rates, leading to a rough order of magnitude construction cost estimate. The schedule for the construction depends on the source(s) selected for the fill material but is estimated to take from 4 to 6 years as a minimum.

Table 1: Summary of unit costs and ROM costs

Source	Unit Cost (cy)	ROM Cost Estimate
Decker Island	$34.03	$650,530,365
Reusable Tunnel Material	$31.85	$608,535,650
Stockton DWSC Dredge Material	$19.72	$376,786,250
Franks Tract Dredge Material	$16.45	$314,381,817

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List of Abbreviations

AACE	American Association of Cost Estimators
CCF	Clifton Court Forebay
CDFW	California Department of Fish and Wildlife
cfs	Cubic feet per second
DEM	Digital Elevation Model
DI	Decker Island
DWR	Department of Water Resources
DWSC	Deep Water Ship Channel
EM	Engineer Manual
FIPS	Federal Information Processing Standard
fps	Feet per second
FWHB	Floating Waterfowl Hunting Blind
IF	Intermediate Forebay
LiDAR	Light Detection and Ranging
M&N	Moffatt & Nichol
MTO	Material Take-Off
MWD	Metropolitan Water District
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Unit
PSU	Practical Salinity Unit
ROM	Rough Order of Magnitude
RP	Return Period
RTM	Reusable Tunnel Material
SAV	Submerged Aquatic Vegetation
SPCS	State Plane Coordinate System
SRA	State Recreation Area
USCS	Unified Soil Classification System
USDA	Unites States Department of Agriculture
USED	United States Engineering Datum
USGS	United States Geological Survey

1. Introduction

Moffatt & Nichol (M&N) was retained by the Metropolitan Water District of Southern California (MWD) to participate in a feasibility assessment for restoration of Franks Tract State Recreation Area (SRA) in collaboration with the California Department of Fish and Wildlife (CDFW), and the California Department of Water Resources (DWR).

1.1. Report Purpose and Scope

The objective of this report is to develop an engineering feasibility assessment for restoration of Franks Tract per the concept developed by CDFW. The work is conducted under the overall Delta Smelt Resiliency Strategy Program with the intent to reduce invasive aquatic vegetation, reduce predation on Delta Smelt, increase turbidity, and improve food webs.

This report presents basic construction cost estimates and schedules for the conceptual restoration alternative, and includes the following:

- A project basis, which captures aspects related to construction, including the site bathymetry, topography, and subsurface soil conditions; water levels, tidal hydraulics, wind statistics, and wave exposure.
- Identify potential sources of fill materials for placement in Franks Tract, as well as providing available quantities, quality and suitability of the fill material for the intended use.
- Constructability, including methods for transporting and placing fill materials.
- Engineering constraints, including logistics, permitting, and other technical constraints.
- Rough Order of Magnitude (ROM) cost estimates, and schedules for the alternative, including unit rates and quantities for materials, equipment and labor.

This work is performed for the Metropolitan Water District of Southern California (MWD) under the performance measure to pursue the best scientific research to protect and restore fish, wildlife, and the Delta's ecosystem while ensuring water supply reliability.

1.2. Project Background

Franks Tract consists of approximately 4,600 acres of flooded lands, bordered by Webb Tract to the north, Mandeville Island to the east, and Bethel Island and Holland Tract to the south. The western extent of the area along West False River consists of Little Franks Tract. The State Recreation Area (SRA) is 3,523 acres and was established in 1959. Figure 1-1 provides an overview of the area. Note: approximate extent of submerged aquatic vegetation overlain in dark green.

Franks Tract was originally marshland in the Delta, reclaimed between 1902 and 1906. The land was used for farming of potatoes, beans, asparagus, sugar beets, onions, seed crops, small grains, and corn. In February 1937, portions of the levee surrounding Franks Tract gave way and the farmland became inundated. The land was subsequently reclaimed by October that same year, but in February of 1938 the False River levee broke and Franks Tract was flooded and never reclaimed. Little Franks Tract prevailed during the 1937 and 1938 floods, but flooded in January 1982 and was also not reclaimed.

1.3. Franks Tract Conceptual Restoration Alternative

Figure 1-2 depicts the conceptual restoration alternative for the Franks Tract SRA provided by CDFW.

The intent of the restoration alternative is to limit salinity intrusion to improve water quality in the Delta, and to facilitate development of marsh within Little Franks Tract and the western portion of Franks Tract.

Salinity intrusion is inhibited by incorporation of a berm across Franks Tract (Figure 1-2) and by closing off False River on the northern side of Franks Tract. Marsh enhancement is achieved by raising bed elevations to approximately +2 feet NGVD to produce mid-marsh within 170-acre and 61-acre areas of Little Franks Tract and over a 748-acre area in the western portion of Franks Tract bounded by the berm across the tract (Figure 1-2). Mid-marsh elevations are intended to range from around +1 to +3 feet NGVD (+2 feet NGVD on average) and incorporate natural channel features. High marsh, having an elevation range from +2 to +5 NGVD is incorporated along the berm.

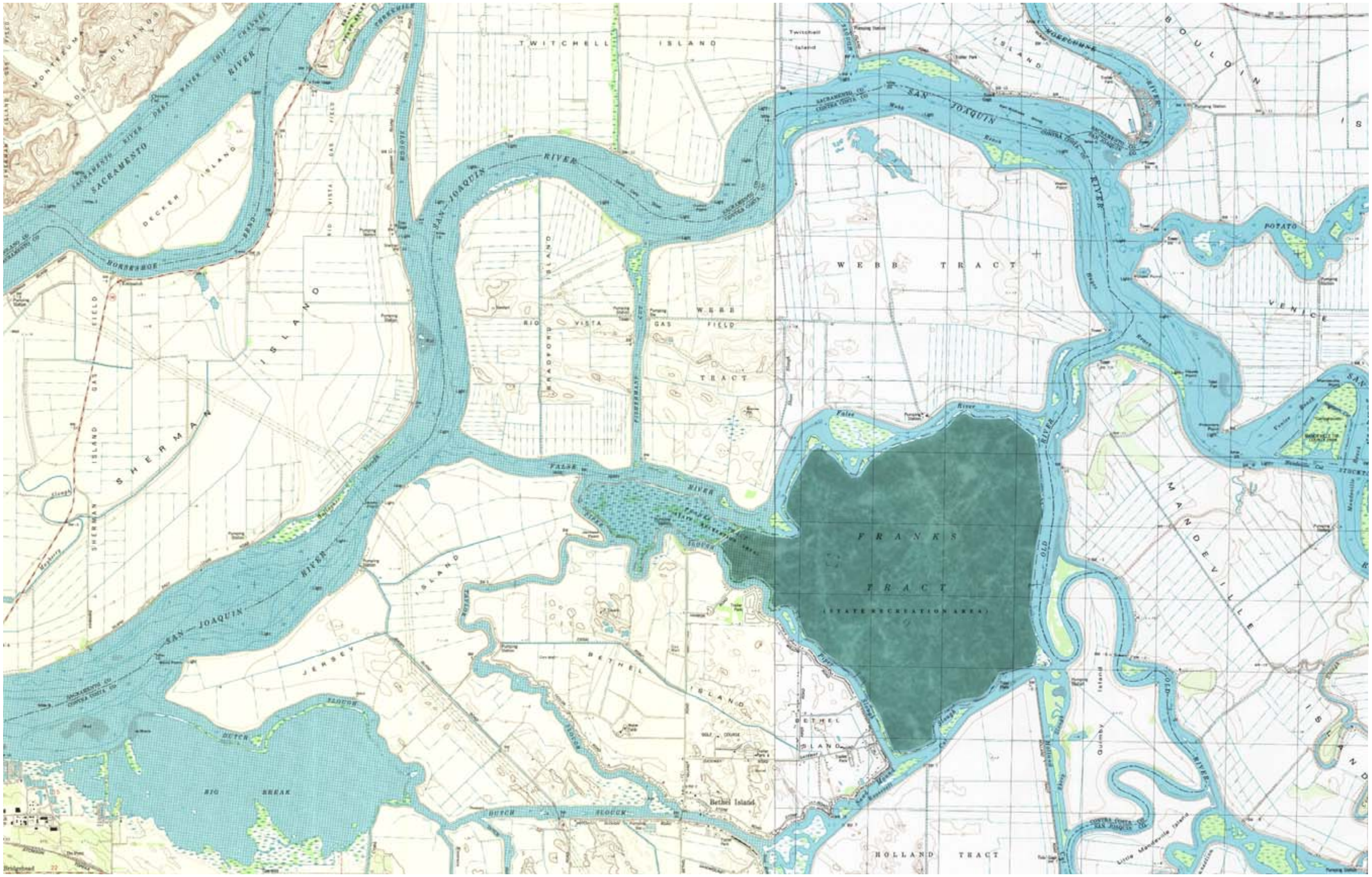


Figure 1-1: Franks Tract SRA, Jersey Island and Bouldin Island quad maps, scale 1:24,000, *USGS (1978, 1997)*

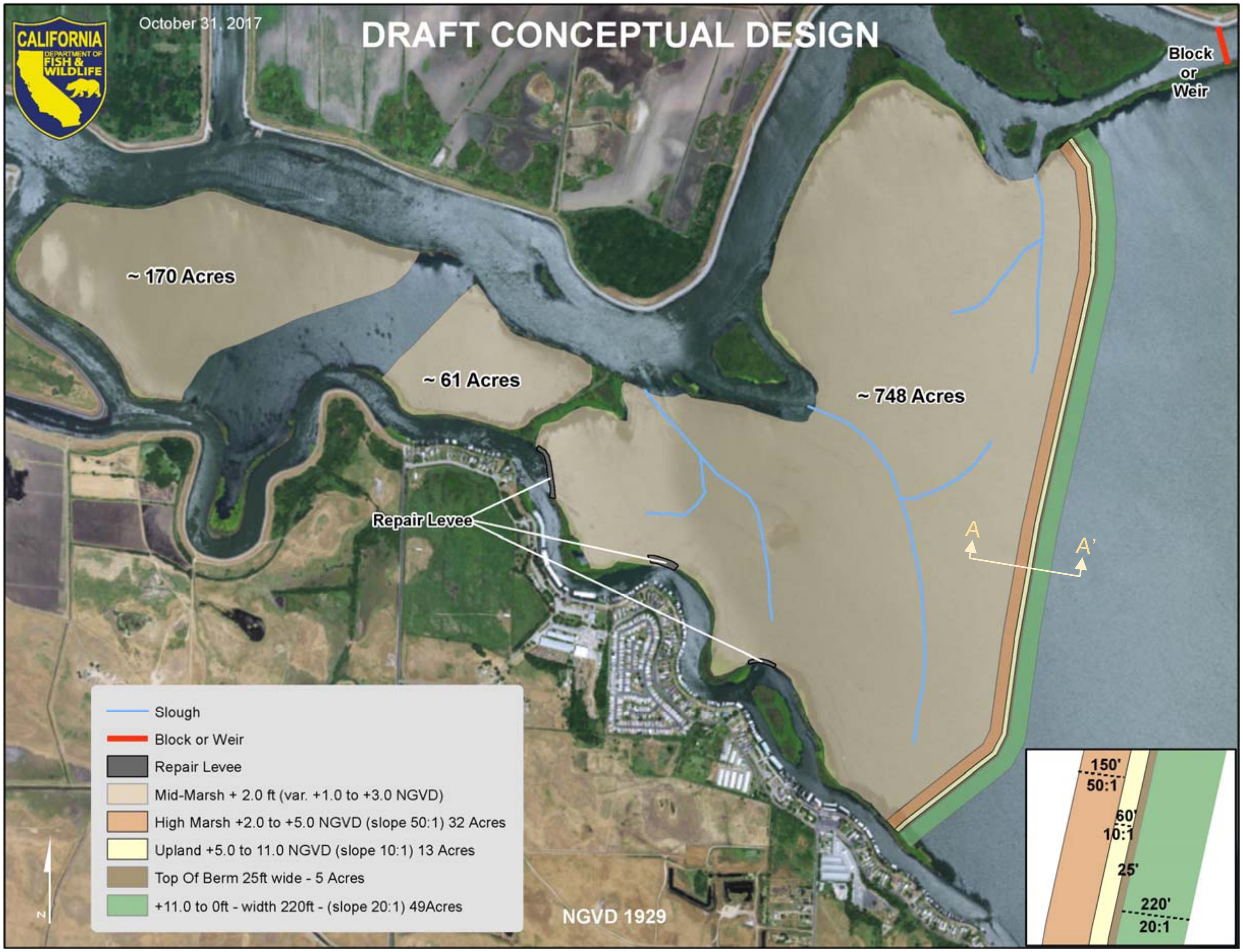


Figure 1-2: Franks Tract SRA Restoration Alternative, *CDFW (2017).* See Figure 1-3 for cross-section A-A'.

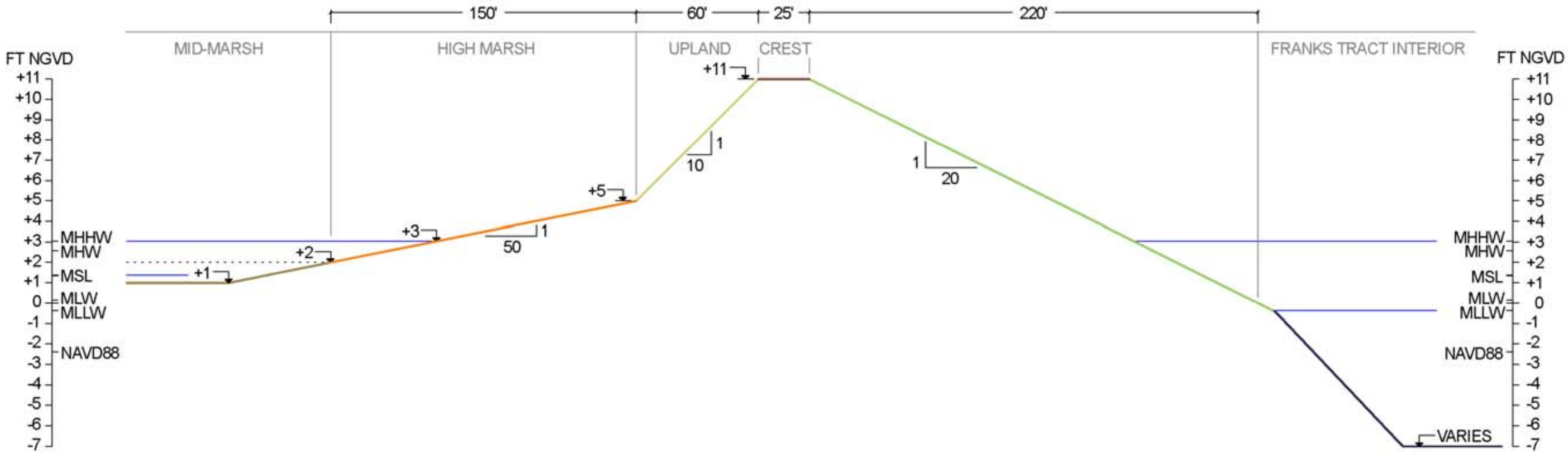


Figure 1-3: Representative cross-section showing planned marsh zonation within the restoration area

2. Project Basis

2.1. Datum Information

Elevation data used in this study is referenced to Mean Lower Low Water (MLLW) unless noted otherwise. Where elevations are referenced to other vertical datums, Figure 2-1 provides the relations between vertical reference systems developed based on information from *NOAA (2016)*.

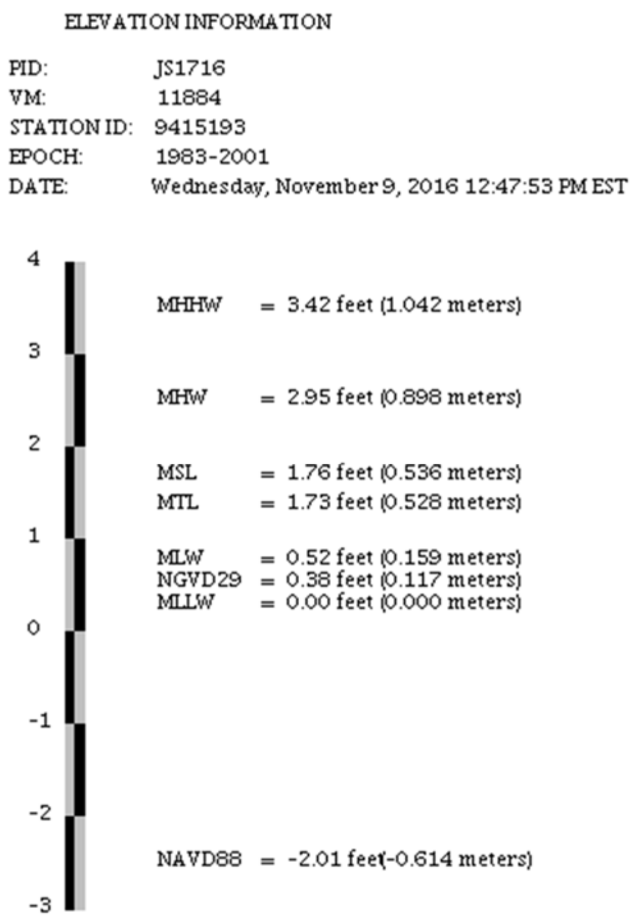


Figure 2-1: Vertical datum information for Three Mile Slough

2.2. Digital Elevation Data

Digital elevation data utilized for the study consists of bare-earth LiDAR data, *DWR (2012)*. The planar reference for the data is Universal Transverse Mercator (UTM) Zone 10 in meters, with vertical elevation reference to the North American Vertical Datum of 1983 (NAD83) in meters.

The corresponding project-specific planar reference is the California State Plane Coordinate System (SPCS), Zone III (FIPS 0403) in feet, with vertical datum reference to NAVD88 in feet.

Figure 2-2 shows the elevation range of the LiDAR data. Dark blue colors indicate the deeper portions of channels and waterways. Light blue indicates the shallower water depths within Franks Tract and along riverbanks. Shades of green through yellow indicate the elevation range land below sea level. Geography that is generally above the tide range is indicated with yellow colors. The pronounced orange lines are representative of the crest of levees, generally around +12.0 feet NAVD88.

Figure 2-2: Franks Tract color-coded terrain map, contours at three-foot intervals

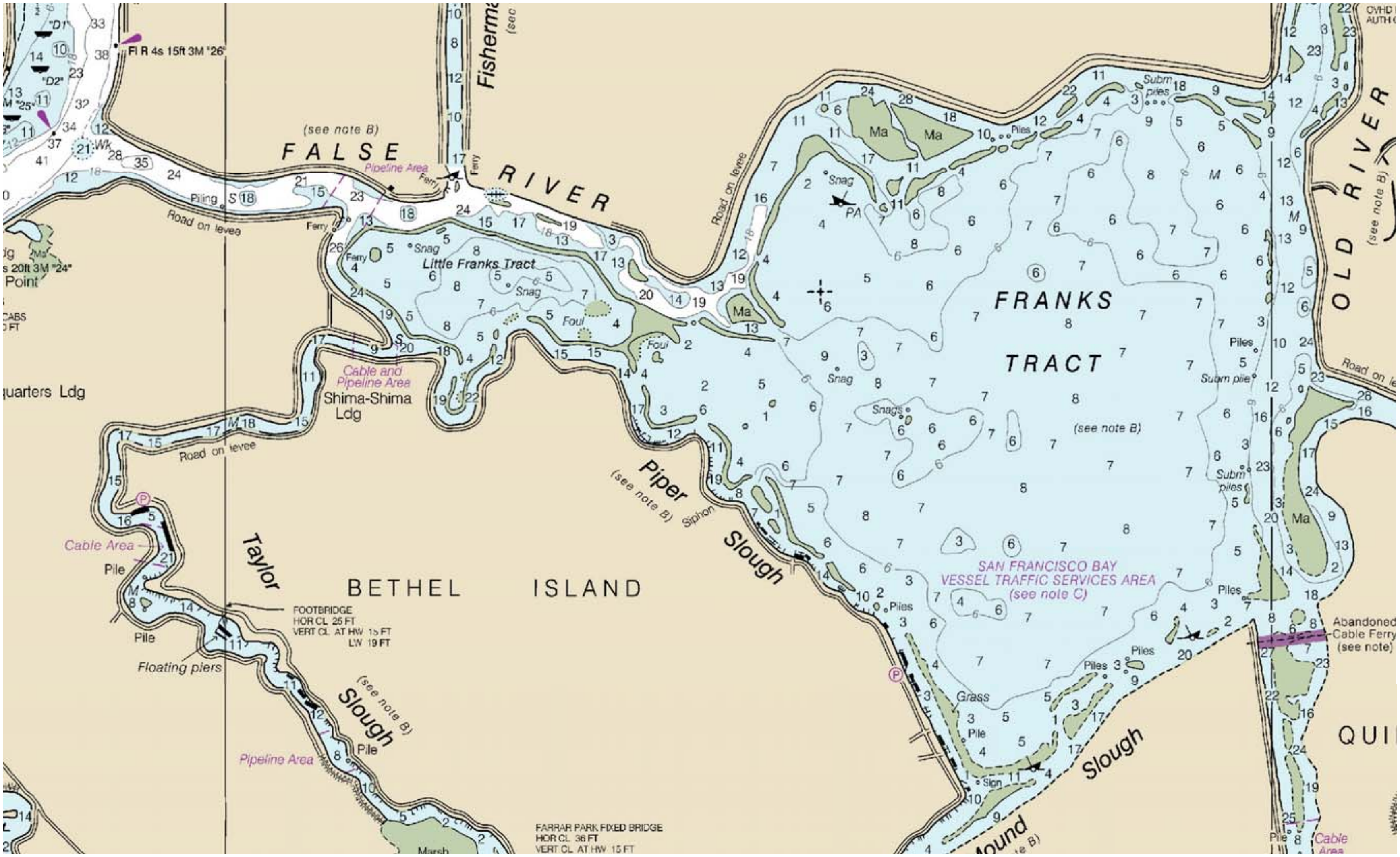


Figure 2-3: Franks Tract bathymetry, excerpt from Nautical Chart No. 18661, *NOAA (2016).* Water depths in feet relative to Mean Lower Low Water.

2.3. Bathymetry

An overview of the bathymetry within Franks Tract is provided in Figure 2-3, reproduced from NOAA Navigation Chart No. 18661 - Sacramento and San Joaquin Rivers, Old River, Middle River and San Joaquin River extension; and Sherman Island. The area encompassing Franks Tract includes includes Bradford Island and Webb Tract to the north, Mandeville Island and Quimby Island to the east, and Holland Tract and Bethel Island to the south, and southwest. The western extent of Franks Tract continues into Little Franks Tract, bordered by Jersey Island to the west.

Waterways surrounding Franks Tract include West False River continuing into False River along the north side, Old River to the east, Sand Mound Slough to the south and Piper Slough running along Bethel Island. Access to Franks Tract is from the waterside only.

2.3.1. West False River

West False River has water depths in the range from 21 to 28 feet at Mean Lower Low Water, with shoal areas limiting water depths to 15-18 feet. The general seabed composition is labeled as sand *(S)*. A known wreck *(Wk)* exists at the Sacramento River entrance to West False River. An area where pipelines cross West False River exists at the commencement of Little Franks Tract. A wreck, portions of which are visible at low tide is located at the entrance to Fishermans Cut. A second wreck with remnants visible at low tide is located at the northern bank of West False River near the entrance to Fishermans Cut.

2.3.2. Little Franks Tract

Little Franks Tract consists of submerged land, with remnant levees along most of the perimeter. Water depths within Little Franks Tract reach around 8 feet MLLW in the center of the area, gradually decreasing to 4-5 feet near the remnant levees. Access to the area is from the waterside only through a few openings where the levees have breached. The area within is prone to snags and foul areas and is generally not safe for navigation.

2.3.3. Franks Tract

Franks Tract consists of a greater area of submerged land, with remnants of earlier levees along its perimeter. The most apparent levee remnants exist along the north and west sides. These are noticeable in areas bordering marsh *(Ma)*. Levee remnants along the southern part of Franks Tract have eroded down to the level where they become submerged on high tides. These are noticeable in the area denoted with submerged aquatic vegetation *(Grass)* in shallow water, unsurveyed areas that grows to the surface but does not emerge. Remnants of levee structures along the eastern extent of Franks Tract are barely discernible as these have eroded substantially due to the prevailing wave exposure being from westerly directions.

Water depths are generally 6 to 7 feet relative to Mean Lower Low Water, in the central portion increasing to 8 feet, and in isolated areas decreasing to 1-3 feet.

Known locations of wrecks exist in Sand Mound Slough where it borders the southern portion of Franks Tract. A wreck and snags exists within Franks Tract near the remnant levees to the northwest, position is approximate *(PA)*. Piles and submerged piles exist at many locations along the circumference of Franks Tract. Some of these may be remnants of earlier attempts at levee repair.

The general area is subject to numerous uncharted piles, snags, pumps, piles, and wrecks, some submerged, and uncharted shoals.

A portion of Piper Slough bordering Franks Tract to the southwest contains numerous docks and slips accessed from Bethel Island.

2.4. Water Levels

Water level variations in Franks Tract SRA are governed by outflow from the Delta and tidal exchange with San Francisco Bay. The tidal prism contained within Franks Tract is around 15,600 acre-ft. The tidal exchange via West False River is about double that, at 31,800 acre-ft. Table 2-1 summarizes vertical datum information for West False River based on water level information from *NOAA (2016)*, combined with *FEMA (2016)* data, and flood stage information for Rio Vista from *CDEC (2016)* and *NWS (2016)*.

Table 2-1: Vertical Datum Information for West False River

Datum	Elevation (feet)	Remarks
LCE	+10.00	Levee Crest Elevation
HOWL	+9.50*	Highest Observed Water Level. Peak Stage of Record
BFE	+7.40	FEMA Base Flood Elevation, 1% Annual Chance Water Level
HAT	+4.33	Highest Astronomical Tide
MHHW	+3.42	Mean Higher High Water
MHW	+2.95	Mean High Water
MSL	+1.76	Mean Sea Level
MTL	+1.73	Mean Tide Level
DTL	+1.71	Diurnal Tide Level
MLW	+0.52	Mean Low Water
NGVD29	+0.38	National Geodetic Vertical Datum of 1929
MLLW	0.00	Mean Lower Low Water
LAT	-0.97	Lowest Astronomical Tide
USED	-1.66	United States Engineering Datum
NAVD88	-2.01	North American Vertical Datum of 1988

** Flood stage information for Rio Vista.*

2.5. Tidal Hydraulics

The United States Geological Survey (USGS) and the California Department of Water Resources (DWR) maintain gauges near the Franks Tract SRA to monitor current flow velocities and water levels. Data recorded at the gauges at Old River near Franks Tract (OSJ), and False River (FAL), circled in Figure 2-4, was used to analyze the correlation between river stage, current velocity, and discharge.

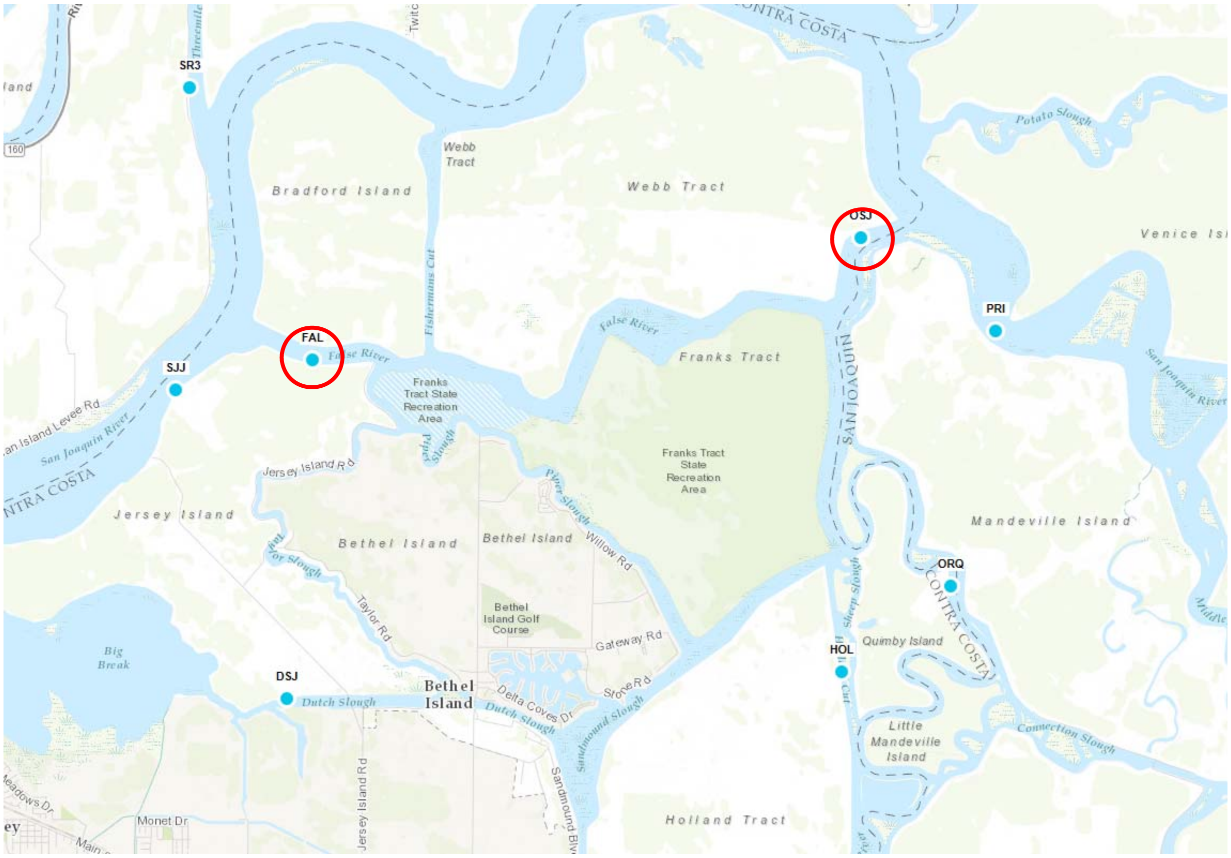


Figure 2-4: Location of Old River (OSJ) and False River (FAL) gauges

Figure 2-5 shows the highest recorded velocities during each tidal cycle at OSJ and FAL gauges from 2010 to 2015. The discharge corresponding to the peak tidal velocities at both gauges is also summarized in Figure 2-5. Upstream of Franks Tract at the OSJ gauge, the maximum recorded velocities range between 0.4 to 1.0 fps with discharges between 12,000 to 18,000 cfs. At the FAL gauge downstream of Franks Tract, peak velocities range from 2.0 to 2.6 fps, corresponding to discharges of about 40,000 to 60,000 cfs. The time series exhibit small spring-neap variation but otherwise vary little over time because they are tidally dominated. Most of the channels around Franks Tract are unaffected by net flow except in very exceptional years.

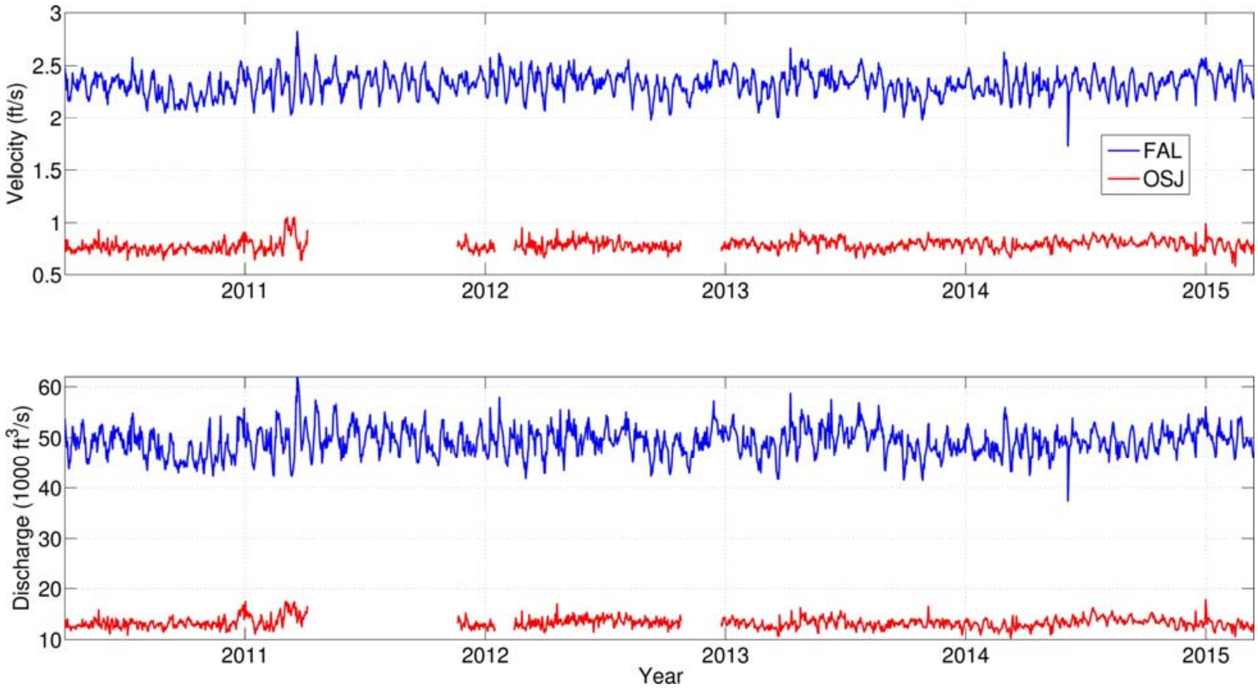


Figure 2-5: Peak velocity (top) and discharge (bottom) over tide cycles at FAL and OSJ gauges

The relationship between discharge and stage is determined by tides. The USGS observes water levels and velocity, and estimates discharge from the relationship Q=VA, where Q is the discharge or tidal flow, V is the channel averaged velocity and A is area which depends on stage. The relative timing of flow and stage is shown in Figure 2-6 for False River. Peak flood tide flow precedes high tide by several hours and construction crews are more likely to encounter the combination of strong flood and high water or low tide with ebb. This tendency is modest, a point which is highlighted in the plot of Figure 2-7, which traces using lines the mutual evolution of discharge and stage over a four week period in June.

The foregoing description of flow and velocity pertains to historical conditions. Modeling results from *DWR (2017)* the project will have an appreciable effect on some local tidal and net flows, including at the FAL and OSJ stations (Figure 2-8). The new regime will prevail from approximately the time of closure of the main berm. To the extent that these changes affect access and constructability, it would most likely be on Old River where velocities would be expected to increase to 3 feet/s.

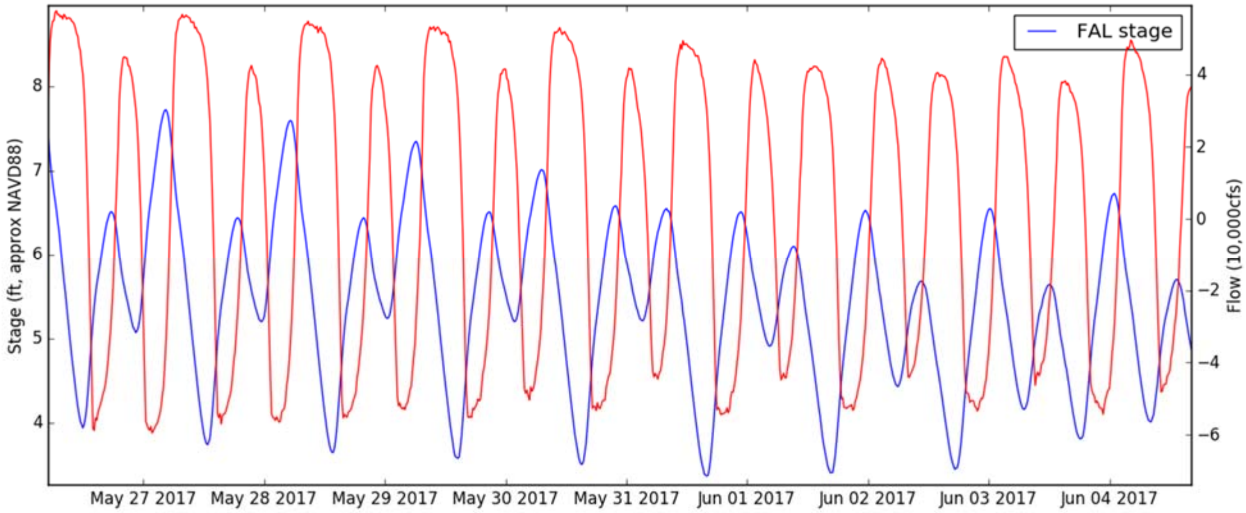


Figure 2-6: False River (FAL) variation of flow and stage

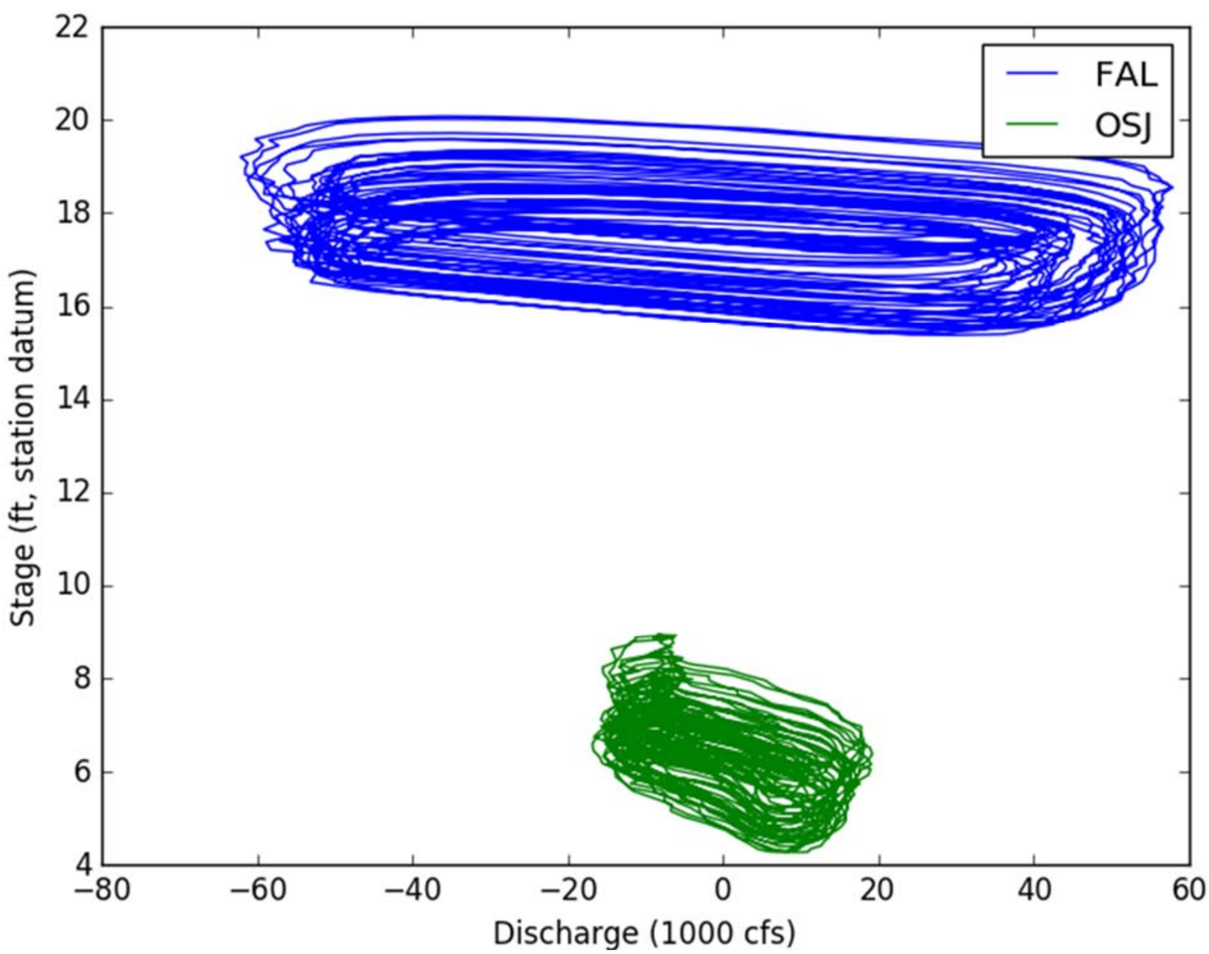


Figure 2-7: False River (FAL) and Old River (OSJ) example stage-discharge relationship

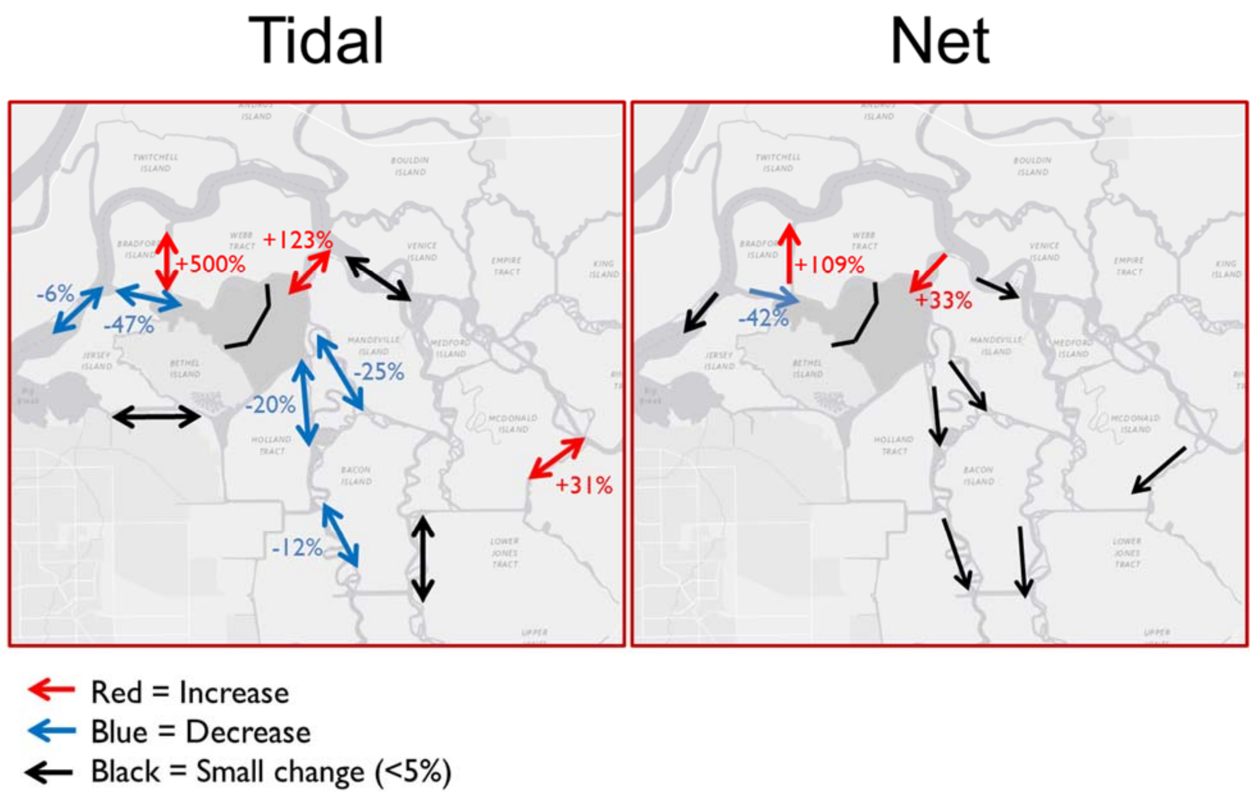


Figure 2-8: Effect of project on local tidal and net flows

2.6. Wind Statistics

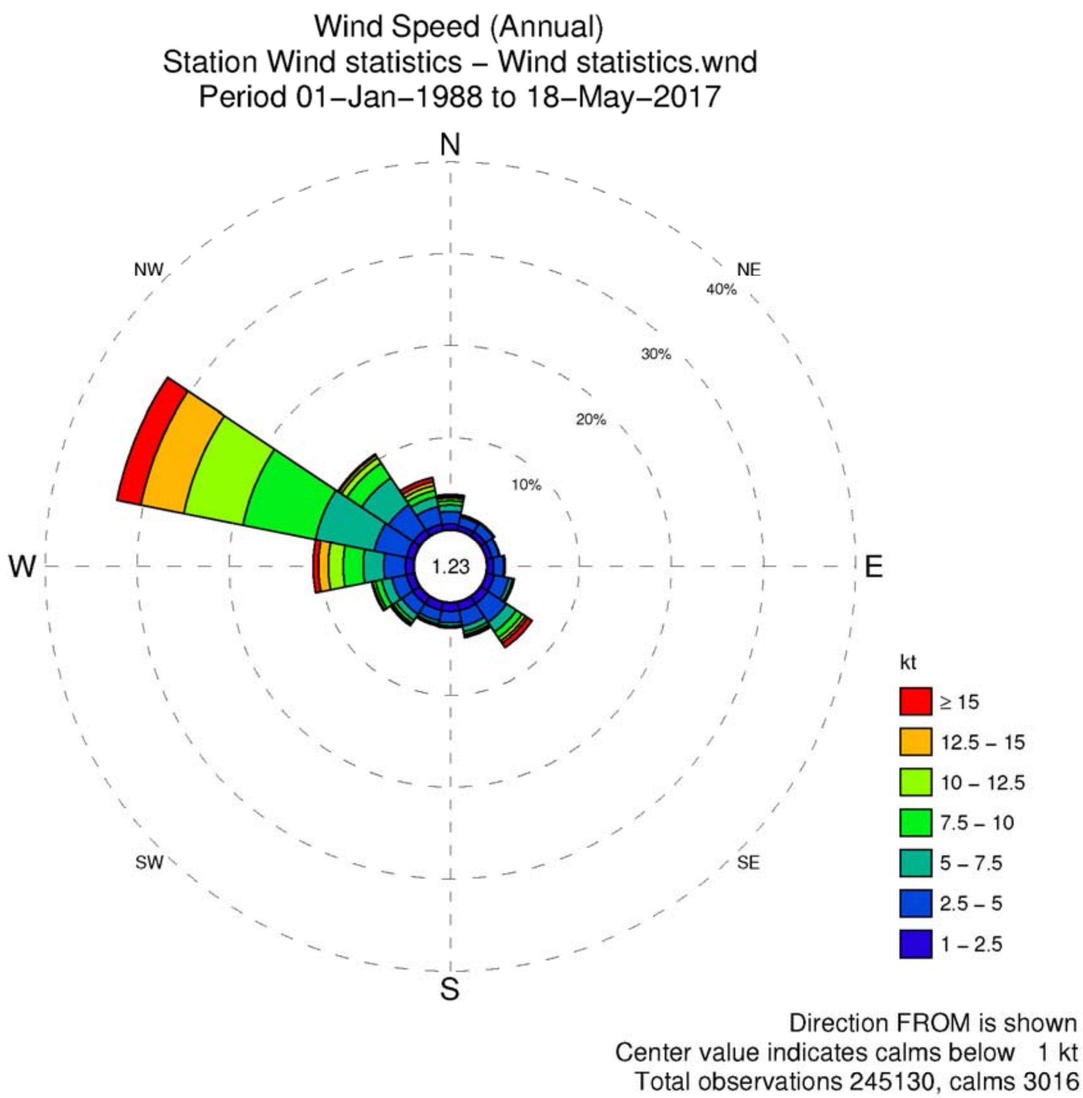
Wind data was acquired from the BAAQMD station on Bethel Island, which captured data for the years from 1987 through to 2017. The sensor recorded wind speed, wind direction, temperature, relative humidity, solar insolation. Table 2-2 summarizes data for the wind station.

Table 2-2: BAAQMD wind station at Bethel Island

Data	Remarks
Station	Bethel Island
Site ID	2901
Dates of operation	6/23/1987 to 5/18/2017
Latitude/Longitude	121.6420°W 38.0063°N
Elevation	1.5 m
Wind height	10.0 m

Figure 2-9 shows a wind rose and summarizes wind statistics by wind speed in knots and percentage of occurrence by direction. It can be seen that the predominant winds are from the sector W to NW, which accounts for 52.6% of the time. Winds from these directions are prevalent in the months of February through November. Although winds exceeding 15 knots may occur from these directions, the highest wind speeds occur from southerly and south-southeasterly directions. Winds from these directions occur primarily in the months from November (some years as early as October) through March (at times extending into April).

Figure 2-10 provides a breakdown of wind speeds by month, where it can be seen that wind speeds are within 5 knots for 40-60% of the time in the months of Jan-Feb-Mar, and Oct-Nov-Dec. Prevailing wind speeds are generally higher over the summer months, where winds are within 10 knots for 60-80% of the time over the months from April through September. Figure 2-10 emphasizes the prevailing wind speeds. Extremes of higher wind exposures (infrequent) are discernible by the red bars at the top of the figure, seen for the months of Nov-Mar.



Percentage of Occurrence

Wind Speed, kt	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
Total	3.85	1.74	1.77	1.48	1.96	3.08	6.67	3.94	2.75	2.66	3.81	4.73	10.78	32.96	10.72	5.87	98.77
≥ 15	0.19						0.58						0.59	2.66	0.15	0.47	4.83
12.5 – 15	0.21						0.29					0.10	1.06	4.76	0.33	0.43	7.43
10 – 12.5	0.30						0.43	0.16			0.21	0.30	1.60	6.56	0.70	0.52	10.98
7.5 – 10	0.47					0.11	0.75	0.33	0.16	0.15	0.40	0.67	2.16	8.04	1.93	0.71	15.97
5 – 7.5	0.69	0.19	0.12		0.13	0.40	1.27	0.62	0.33	0.35	0.76	1.13	2.21	6.51	3.51	1.11	19.39
2.5 – 5	1.36	0.99	1.06	0.82	1.10	1.63	2.43	1.73	1.27	1.16	1.42	1.63	2.30	3.59	3.28	1.94	27.71
1 – 2.5	0.63	0.50	0.56	0.58	0.70	0.85	0.92	0.92	0.92	0.90	0.91	0.86	0.86	0.83	0.82	0.69	12.45

Figure 2-9: Wind statistics at Bethel Island

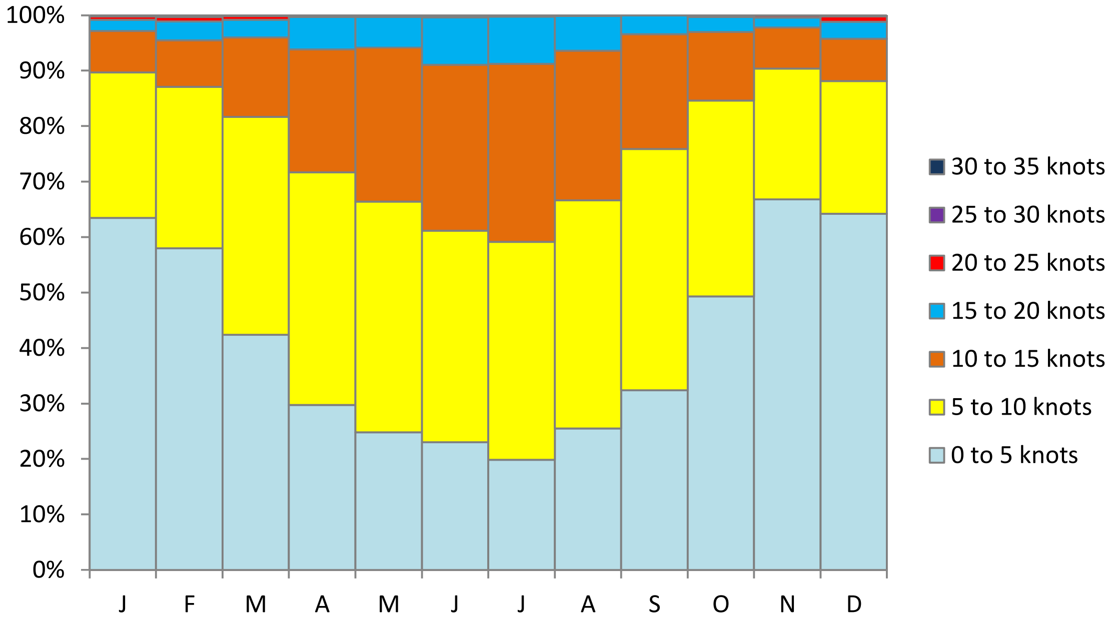


Figure 2-10: Distribution of wind speeds by month

Projected extreme wind speeds are summarized in Table 2-3, which provides a breakdown of wind speeds by recurrence interval and by direction corresponding to the cardinal and secondary intercardinal compass headings. Winds indicated are from the respective directions. It can be seen that the highest wind speeds occur from south-easterly directions.

Table 2-3: Wind speeds by direction and recurrence interval (RP)

Wind Speed (knots) by Direction																	
RP	**N**	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**All**
1	21.2	12.6	8.2	7.8	8.7	15.6	29.4	20.2	13.6	14.6	16.5	16.9	22.4	22.2	19.2	23.1	29.2
5	23.1	17.1	10.3	9.9	11.1	20.4	33.2	23.5	16.9	17.1	18.5	20.2	25.1	23.9	21.4	26.2	33.0
10	24.3	18.7	11.3	11.1	12.1	21.6	34.8	25.5	17.9	18.3	19.6	21.4	26.0	24.7	22.5	27.4	34.6
25	25.5	20.8	12.6	12.2	13.6	23.3	37.1	28.2	19.4	19.2	20.8	23.3	27.0	25.7	23.9	29.2	36.9
50	26.4	22.7	13.6	13.2	14.4	24.3	38.9	29.7	21.0	20.4	21.8	24.3	28.2	26.6	25.1	30.5	38.7
100	27.2	24.3	14.6	14.2	15.6	25.3	42.0	31.5	22.2	21.4	22.9	25.7	29.2	27.2	25.7	31.5	41.8

2.7. Wave Statistics

Figure 2-11 summarizes significant wave heights within Franks Tract for the annual average omnidirectional winds. The significant wave height is a statistical average of the one third highest of waves occurring during a wind event. As a rule of thumb, the maximum wave heights can be taken as approximately $H_{max} = 1.8 \times H_S$. The wave data has been compiled based on wind speeds with a recurrence interval of one year over the compass directions indicated in Table 2-3. The data depicts the highest significant wave height that can occur irrespective of wind direction at a given location.

It can be seen that the eastern side of Franks Tract may see a moderate wave exposure with significant wave heights up to around 1.3 feet. The northwest corner may see slightly higher significant wave heights up to around 1.8 feet. The calmest portion of Franks Tract is formed by a wide band extending from approximately the north-northeast corner down to the southwest side of Franks Tract. Significant wave heights within this area are limited to around 1.1 feet. This is due to the absence of strong winds from south-southwesterly and north-easterly directions, despite the large overwater fetch distance across the tract. Significant wave heights within Little Franks Tract and in the adjacent channels and sloughs are limited to 1.0 foot or less.

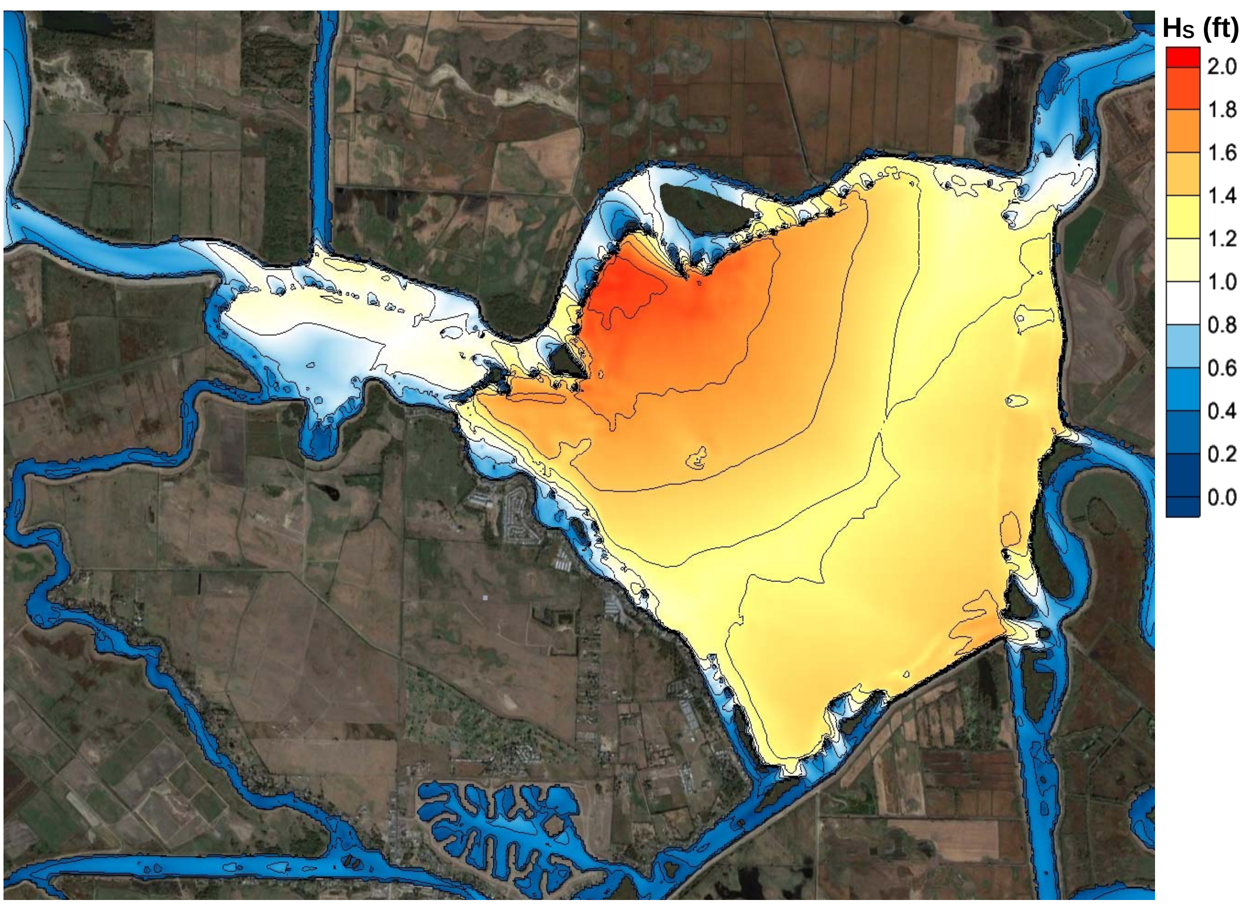


Figure 2-11: Significant wave height variation for annual average omnidirectional winds

Figure 2-13 summarizes the peak wave periods corresponding to the significant wave heights shown in Figure 2-11. It can be seen that the wave period of waves within Franks Tract at most will reach 2.8 seconds for the annual average wave conditions. The peak wave period of waves in adjoining channels and sloughs is limited to 2.0 seconds or less.

Due to the absence of strong winds from south-southwesterly and north-easterly directions, peak wave periods across Franks Tract do not exceed 2.2 seconds within the band described previously.

While wave heights within Little Franks Tract are limited (Figure 2-11), it can be noted that there can be an amount of spillover of longer wave periods developed by wind blowing across Franks Tract towards Little Franks Tract.

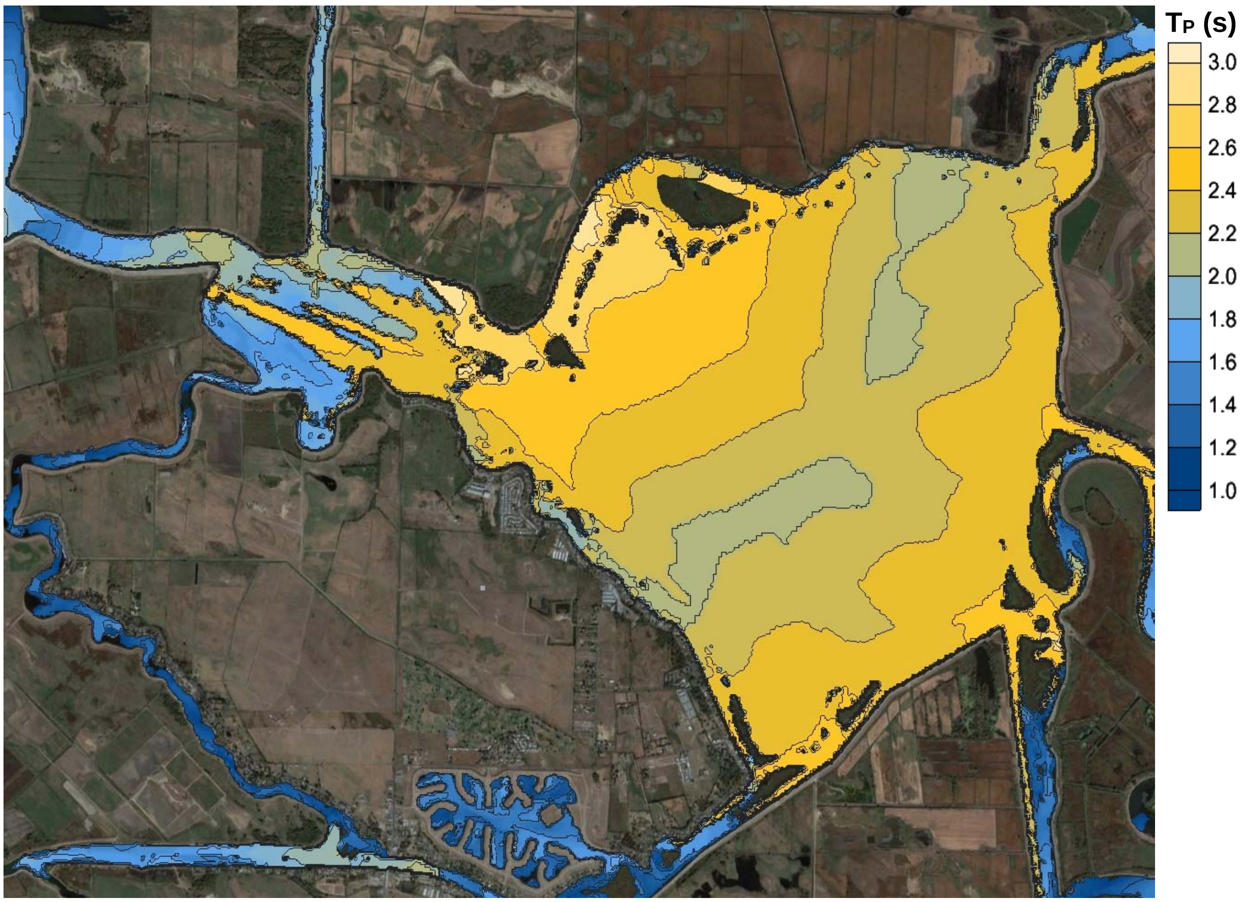


Figure 2-12: Peak wave period variation for annual average omnidirectional winds

2.8. Subsurface Conditions

Locations of borings acquired in relation to earlier work at Franks Tract, *HLA (1990)*, are summarized in Figure 2-13. These borings were sufficiently deep to establish the thickness of peat within Franks Tract and the character of underlying strata.

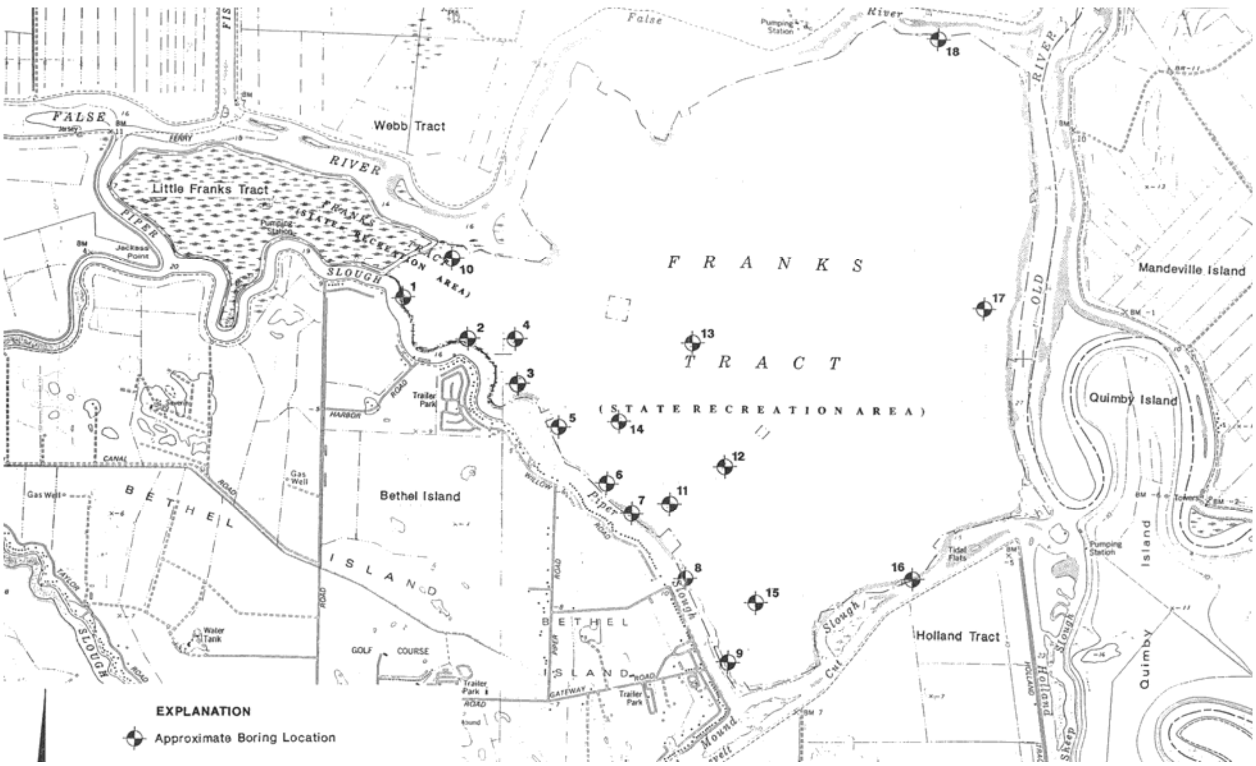


Figure 2-13: Approximate boring locations within Franks Tract, *HLA (1990)*

Figure 2-15 provides an overview of the boring logs acquired within Franks Tract *(HLA, 1990)*, using the abbreviated Unified Soil Classification System (USCS) legend shown in Figure 2-14. Approximate water depths are indicated by the light blue extent at the top of the columns. The boring logs generally show peat deposits with thicknesses in the range from 5 to 18 feet, in a few instances overlain by silt. Borings B-3, B-4, B-10 through B-13, and B-15 do not contain peat deposits, and consist primarily of clean, poorly graded sands, and silty sands. Gravels are not present in any of the borings.

Classification		ID	Description
Gravels	Clean	GW	Well graded gravels
		GP	Poorly graded gravels
	With Fines	GM	Silty gravels
		GC	Clayey gravels
Sands	Clean	SW	Well graded sands
		SP	Poorly graded sands
	With Fines	SM	Silty sands
		SC	Clayey sands
Silts and Clays LL 50% or less		ML	Inorganic silts
		CL	inorganic clays
		OL	Organic silts or clays
Silts and Clays LL greater than 50%		MH	Inorganic silts
		CH	inorganic clays
		OH	Organic silts or clays
Highly Organic Soils		Pt	Peat

Figure 2-14: Unified Soil Classification System (abbreviated)

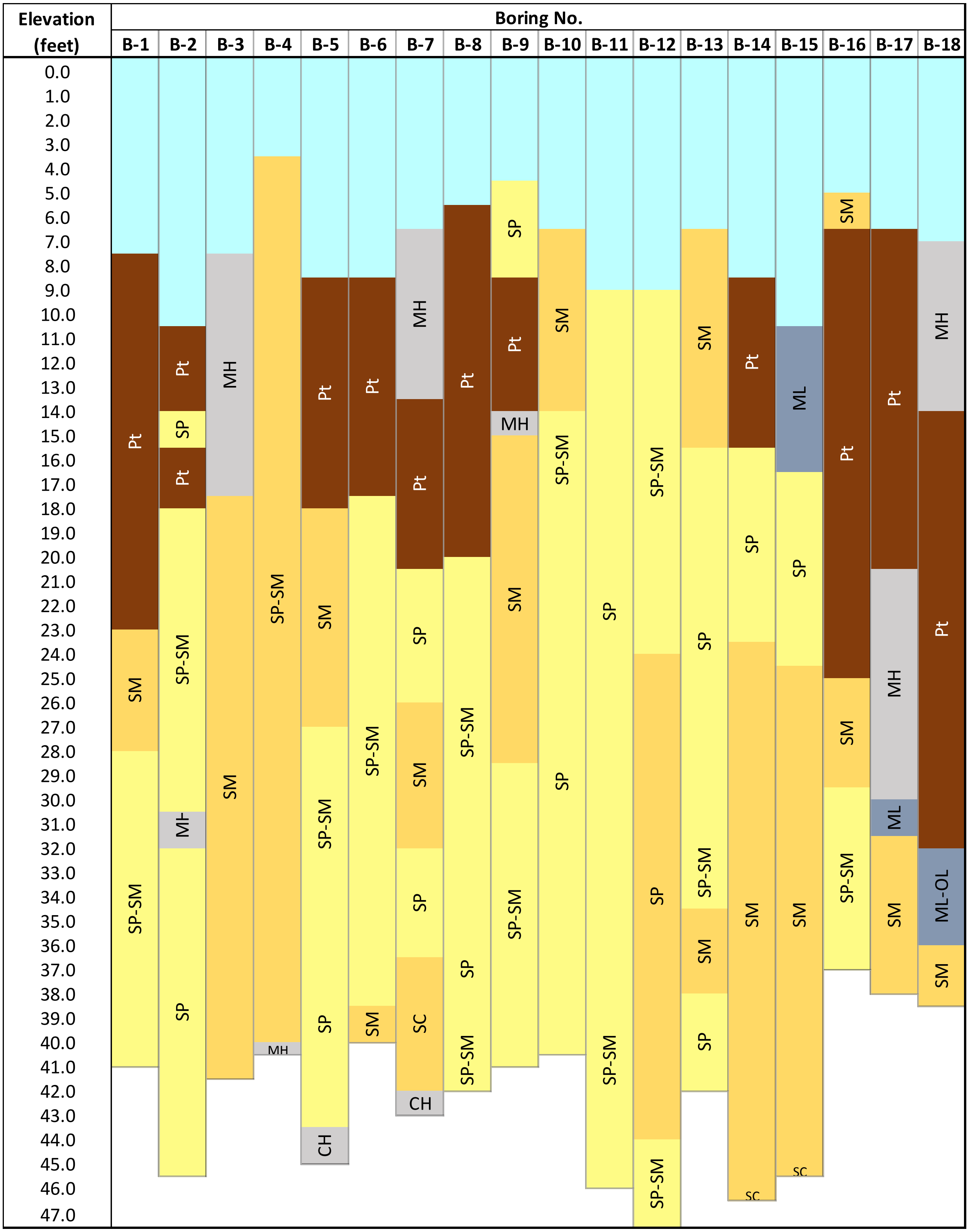


Figure 2-15: Summary of boring logs from *HLA (1990)*

Figure 2-16 provides an indication of the average peat layer thicknesses across Franks Tract. The data has been compiled based on information from the borings taken within Franks Tract (Figure 2-13) from *HLA (1990)*, combined with information from borings taken on adjoining islands and tracts summarized in *USGS (1982)*, Jersey Island and Bouldin Island quadrangle sheets. It can be noted that the deepest peat deposits exist around the northeast extent of Franks Tract, with layer thicknesses of around 25 feet deep. Going east to west, the thickness of the peat deposits decreases gradually to around 10 feet deep in the center of Franks Tract, down to less than 5 feet at the transition to Little Franks Tract. The thickness of peat deposits within Little Franks Tract ranges from 5 to 10 feet. The areas surrounding Franks Tract generally have peat deposits of similar thickness, but with localizes areas where the depth of peat increases or decreases substantially. It can also be seen that peat deposits on the west side of the San Joaquin River are as much as 55 feet deep.

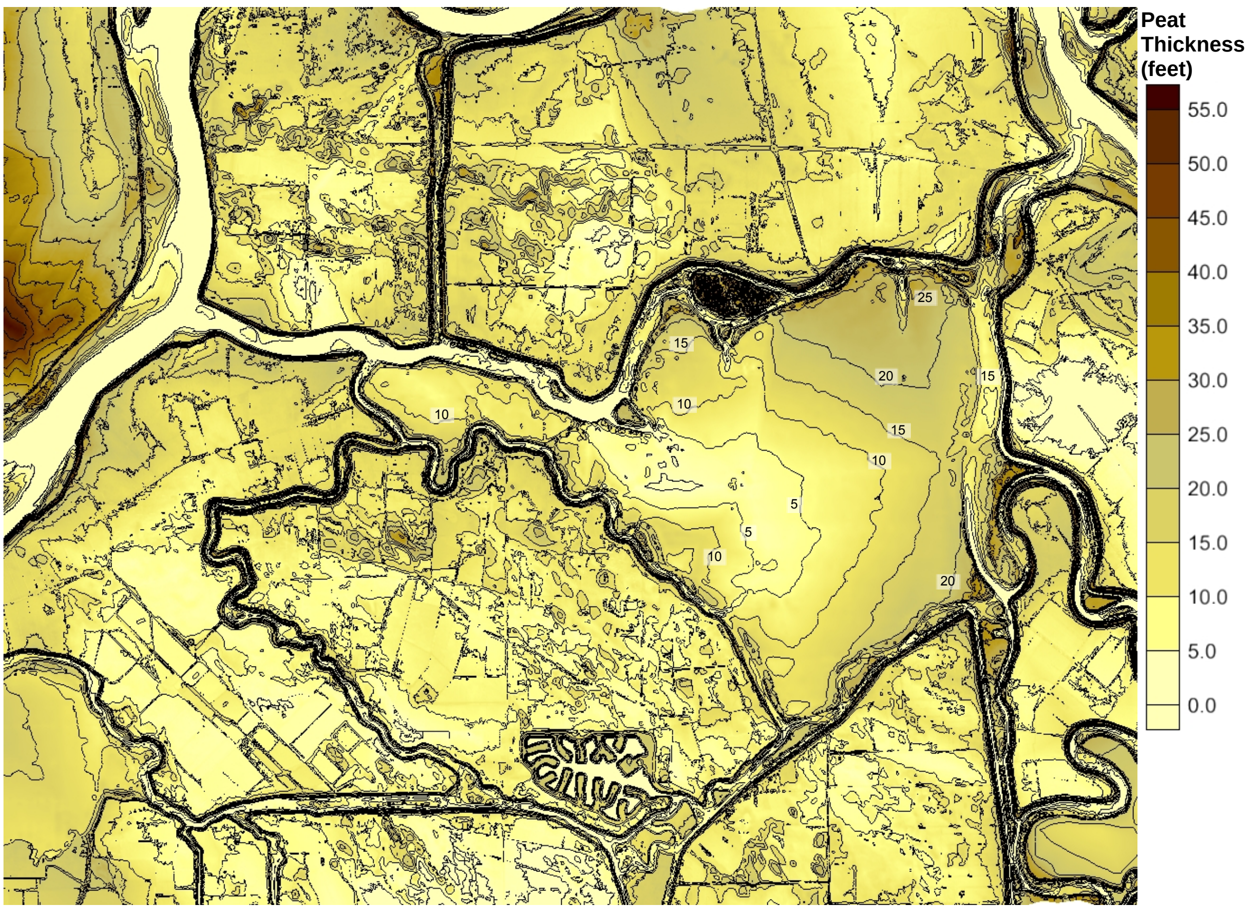


Figure 2-16: Franks Tract SRA, contours in feet of average peat layer thickness

2.9. Consolidation

Figure 2-17 summarizes peat consolidation data developed in *HTE (1999)*. The table on the left hand side provides the peat base elevation in the vertical relative to Mean Sea Level (MSL). Because mudline elevations within Franks Tract generally range from -5 to -8 feet, the blue portion of the following columns indicates the water depth. Values below indicate the thickness of fill (in feet) required to raise the bed elevation up to mean sea level. The amount of fill needed is indicated with color ranging from green (small) to orange (high).

Peat Base Elevation (feet MSL)	Thickness of Fill (feet) Mudline Elevation (ft MSL)			
	-5	-6	-7	-8
0				
-1				
-2				
-3				
-4				
-5	5.0			
-6	5.2	6.0		
-7	5.4	6.2	7.0	
-8	5.6	6.4	7.2	8.0
-9	5.8	6.6	7.4	8.3
-10	6.0	6.8	7.7	8.6
-11	6.2	7.1	8.0	8.8
-12	6.4	7.3	8.2	9.1
-13	6.6	7.6	8.5	9.5
-14	6.9	7.9	8.8	9.8
-15	7.2	8.2	9.1	10.1
-16	7.5	8.5	9.5	10.5
-17	7.8	8.8	9.8	10.9
-18	8.2	9.2	10.2	11.2
-19	8.5	9.6	10.6	11.7
-20	9.0	10.0	11.1	12.1
-21	9.4	10.4	11.5	12.5
-22	9.8	10.9	11.9	13.0
-23	10.4	11.4	12.4	13.5
-24	10.9	11.9	12.9	13.9
-25	11.5	12.5	13.5	14.5
-26	12.1	13.1	14.0	15.0
-27	12.8	13.7	14.6	15.5
-28	13.5	14.4	15.2	16.1
-29	14.3	15.1	15.9	16.7
-30	15.1	15.8	16.6	17.3

Peat Base Elevation (feet MSL)	Consolidation (feet) Mudline Elevation (ft MSL)			
	-5	-6	-7	-8
0				
-1				
-2				
-3				
-4				
-5	0.0			
-6	0.2	0.0		
-7	0.4	0.2	0.0	
-8	0.6	0.4	0.2	0.0
-9	0.8	0.6	0.4	0.3
-10	1.0	0.8	0.7	0.6
-11	1.2	1.1	1.0	0.8
-12	1.4	1.3	1.2	1.1
-13	1.6	1.6	1.5	1.5
-14	1.9	1.9	1.8	1.8
-15	2.2	2.2	2.1	2.1
-16	2.5	2.5	2.5	2.5
-17	2.8	2.8	2.8	2.9
-18	3.2	3.2	3.2	3.2
-19	3.5	3.6	3.6	3.7
-20	4.0	4.0	4.1	4.1
-21	4.4	4.4	4.5	4.5
-22	4.8	4.9	4.9	5.0
-23	5.4	5.4	5.4	5.5
-24	5.9	5.9	5.9	5.9
-25	6.5	6.5	6.5	6.5
-26	7.1	7.1	7.0	7.0
-27	7.8	7.7	7.6	7.5
-28	8.5	8.4	8.2	8.1
-29	9.3	9.1	8.9	8.7
-30	10.1	9.8	9.6	9.3

Figure 2-17: Estimated thickness of fill and corresponding consolidation, *HTE (1999)*

The table can be utilized as follows. At a mudline elevation of -5 feet, if the peat baseline elevation is also at -5 feet, 5.0 feet of fill will be required to bring the mudline elevation up to mean sea level. In this example there is no consolidation because there is essentially no peat layer. If, on the other hand, the peat baseline elevation is at -30 feet and the mudline elevation is at -5 feet, i.e. a peat deposit 25 feet thick, the amount of fill needed to bring the mudline elevation up to MSL is 15.1 feet of fill. So, in addition to the 5-ft water depth, the 25-ft peat layer consolidates by 10.1 feet. This is what is shown in the table on the right hand side of the figure, where the amount of consolidation can be read directly off the chart. The ranges of consolidation covered are indicated with light tan representative of little or no consolidation, increasing progressively to darker tan color indicating higher amounts of consolidation.

2.10. Sand Dune Deposits

Significant areas with remnant eolian deposits in the form of sand dunes are present on Bradford Island and Webb Tract, and a few are also present within Franks Tract. Figure 2-18 provides a mapping of areas estimated to contain sand dune material. Areas of potential deposits have been identified based on the shape of the terrain (hills) relative to adjoining (level) ground, and based on color patterns in aerial photography where the sand deposits appear as lighter patches on the ground. In Figure 2-18, areas of sand deposits have been mapped with a color indicating their height above level ground. The tallest deposits reach heights of approximately 30 feet (orange colors), with deposits in the 20-foot height range in yellow, and shallower deposits shown in light blue to dark blue. The color contours indicate only the height of surficial deposits, i.e. above grade. Potential quantities below grade have not been mapped.

Under consideration as a potential source of fill material, estimates of the potential sand dune deposits have been summarized in Table 2-4. The first row of the table indicates the surficial deposits. These have been estimated based on LiDAR survey data, and therefore represent a good estimate of the minimum quantities available. The following rows of the table provide estimates based on fixed excavation depths, assuming a linear increase in volume based on the acreages listed in the table. It has been assumed that excavation would not go substantially past five feet of depth due to groundwater intrusion.

Table 2-4: Estimates of sand dune deposits on Bradford Island and Webb Tract

Excavation Depth (ft)	Sand Dune Deposits (acre-ft)	
	Bradford Island	Webb Tract
Surficial	2,286	3,107
1	2,747	3,910
2	3,208	4,713
3	3,669	5,516
4	4,131	6,320
5	4,592	7,123
Acreage	461.0 acres	803.0 acres

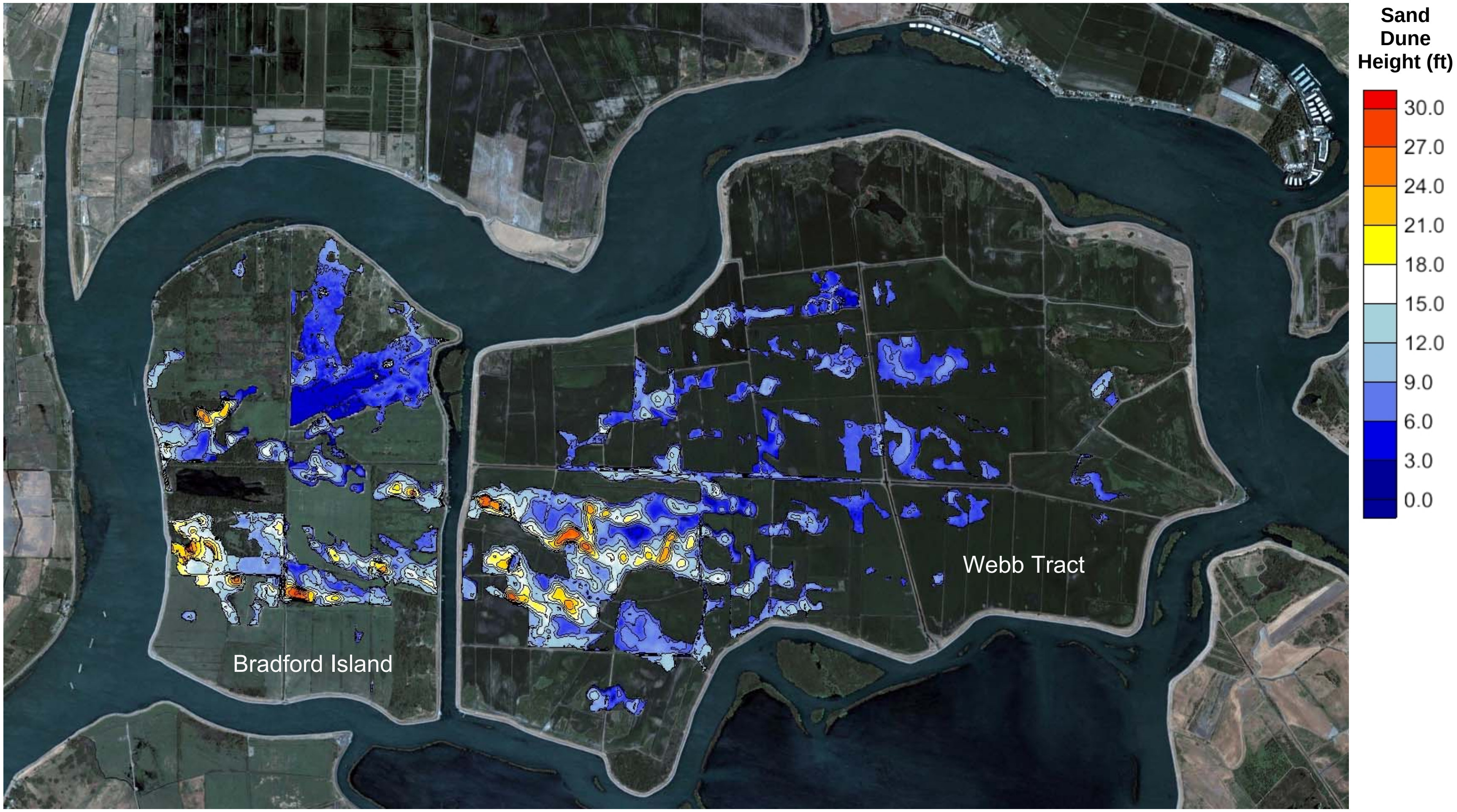


Figure 2-18: Sand dune deposits on Bradford Island and Webb Tract

3. Sources of Fill Material

This section lists the potential sources of fill material, available qualities and quantities, and provides evaluations of suitability of materials for restoration work.

3.1. Potential Sources

Potential sources of fill material considered for the restoration project are summarized in Table 3-1. The available quantities and the material source distances from Franks Tract are also listed in this table.

Table 3-1: Sources of fill material

Source Material	Location	Volume (CY)	Area (Acres)	Distance (miles)
DI Aggregate [a]	Decker Island	51,900,000	400.0	8.6
Sand dune deposits [b]	Bradford Island	5,660,000	460.0	0.8
Sand dune deposits [b]	Webb Tract	8,780,000	800.0	0.8
RTM and dredged material [c]	Intake 2 Disposal Site	1,020,000	45.6	40.2
RTM [c]	IF Disposal Site	9,060,000	404.7	21.2
RTM [c]	Bouldin Island Disposal Site	8,340,000	1,208.8	2.6
RTM [c]	CCF Disposal Site	5,370,000	899.6	15.2
Dredged material [c]	CCF	7,000,000	2,208.0	16.2
DWSC Eastern Reach [d]	Stockton Ship Channel	15,000,000	1,860.0	10.0
Franks Tract [e]	Eastern part of Franks Tract	18,000,000	2,250.0	1.0
	Total	**70,730,000**	**8,426.7**	

Legend:

RTM Reusable Tunnel Material
IF Intermediate Forebay
CCF Clifton Court Forebay
DI Decker Island
DWSC Deep Water Ship Channel

Reference:

[a] HWF (2017)
[b] Table 2-4.
[c] URS (2014)
[d] AQEA (2014)
[e] Figure 1-2.

Table 3-2 lists additional potential sources of fill material considered previously *(NHC, 2003)*.

Table 3-2: Additional sources of fill material, *NHC (2003)*

Material Source	Estimated Availability		Estimated Average Cost		
	Total (CY)	Annual (CY/year)	Unit $/CY	Total ($)	Annual ($ per year)
Local sources					
Delta dredge spoil	50,000	590,000[a]	5-8	230,000,000	110,000
River sediment inflow		3,500,000[b]			

Material Source	Estimated Availability		Estimated Average Cost		
	Total (CY)	Annual (CY/year)	Unit $/CY	Total ($)	Annual ($ per year)
Excess channel material	200,000,000		13-18	3,000,000,000	
Future dredging projects	8,000,000[c]		6-7	50,000,000	
Montezuma Hills	10,000,000,000[d]		6-8	5,000,000,000[e]	
Distant Sources					
Bay dredge spoil		5,020,000[f]	10-41		75,000,000
Yolo Bypass	84,000,000[g]	N/A	6-8	560,000,000	
Water reservoirs	200,000,000[h]	4,500,000[h]	10-32	4,300,000,000	95,000,000
Organic waste		200,000,000[i]			
Municipal solid waste		11,300,000[j]	14.5[k]	-10,000,000,000[l]	-160,000,000[m]
Biomass accretion			~0.6 inches		

[a] Annually dredged material from Sacramento and Stockton DWSCs.
[b] 94% suspended load and 6% bed load.
[c] Mokelumne River and South Delta.
[d] Total volume of Montezuma Hills.
[e] Cost of 700,000,000 yd^3 material needed for western Delta Islands.
[f] Dredged in 1998.
[g] Depth of excavation 1 ft.
[h] 10 reservoirs within 120 mile radius with largest sediment deposits.
[i] Generated statewide.
[j] Disposed of in landfills in the vicinity of the Delta.
[k] Averaged landfill tipping fee for compacted material.
[l] Total fee for disposal of 700,000,000 yd^3 of waste.
[m] Annual fee for disposal of 11,300,000 yd^3 of waste.

3.2. Suitability of Materials for Restoration

3.2.1. Classification of Source Materials

3.2.1.1. Dredge Material

Dredged material, e.g. from Decker Island and other dredged material sources can be characterized as material with diameters ranging from fine sand down to coarse silt. This type of material is suitable for hydraulic conveyance and placement.

3.2.1.2. Sand Dune Deposits

Material in existing sand dune deposits can generally be characterized as fine-grained, uniformly graded sand, at times poorly graded (SP) and with a silt content (SM), refer to Figure 2-14 for USCS soil classification categories. These types of material are generally suitable for hydraulic conveyance, but may effect high levels of turbidity during placement.

3.2.1.3. Reusable Tunnel Material

Reusable Tunnel Material (RTM) generally falls in the category of sandy lean clay (sCL) in the baseline condition. Conditioners may be added to the RTM to facilitate tunnel boring excavation, and in that case the resulting material composition may classify as clayey sand (SC), sandy lean clay (sCL), lean clay with sand (CLs), or sandy silt (sML), depending on the type of conditioner product added. The fines content for the material in the baseline condition ranges from 67% to 69% fines, and with conditioner added ranges from 45% to 71% fines.

In terms of concentrations of inorganic constituents, preliminary testing of the RTM provides the indication that the material would meet regulatory threshold limits for placement as a waste material. In terms of human health safety, the material would typically be acceptable for unrestricted land use, and could also meet standards for application as an ecological resource to support vegetation and soil microflora and microfauna.

While the RTM material may be suitable for placement at Franks Tract in some form, placement by clam shell operation will translate into very low production rates, while hydraulic conveyance and material placement may result in substantial amounts of wastage and will produce significant levels of turbidity. Turbidity can to some extent be controlled via deployment of silt curtains or large settling basins, but turbidity concentrations can remain high depending on ambient flow conditions and wind-wave action.

Figure 3-1 summarizes the characteristics of the fill material types described above in terms of the sand, silt, and clay fraction of the materials. It can be seen that dredge material types (red), generally fall in the category of medium to fine sand with no silt/clay content and classify as *sand*. In the case where the dredge material contains a limited fraction of coarse silt, it may classify as *silty sand*. Likewise, existing sand dune deposits are likely to generally classify as *sand*. The Reusable Tunnel Material (blue) contains larger fractions of silt and clay, and broadly classifies as *sandy clayey silt*, *silty sand*, and *sandy silt*.

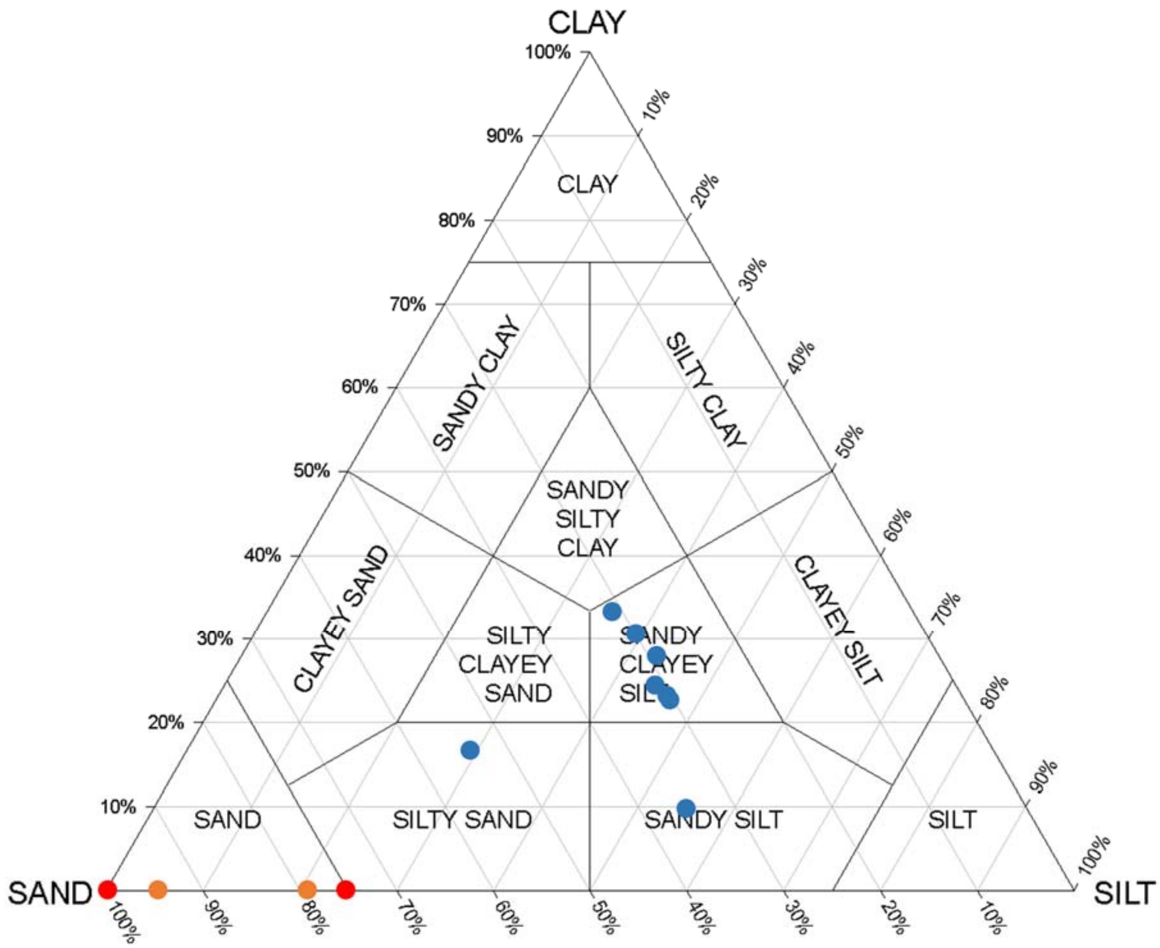


Figure 3-1: Fill material categorization by sand, silt, and clay content

3.2.2. Hydraulically Placed Fill Material Slopes

Figure 3-2 provides a schematic of material slopes resulting from placement of fill material via hydraulic conveyance. Three general regions exist, defined by a mild slope above water (β_1), a flatter slope within the tidal zone (β_2), and a steeper slope below water (β_3) as described in the following.

3.2.2.1. Above Water Slope

In the case of fill material discharged above water, the driving force is the flow of water, which due to gravity will flow downhill. Retarding forces relate to the sediment diameter (larger grain sizes will settle more swiftly, while small-diameter material will remain suspended more readily, and the concentration of fill material volume versus the amount of water applied to convey the fill material. In terms of practical construction, the concentration at which fill material can be fluidized and pumped via pipeline is relatively constant around 20% fill material to water volume. And the primary parameters governing the resulting slope are therefore sediment grain size and discharge volume.

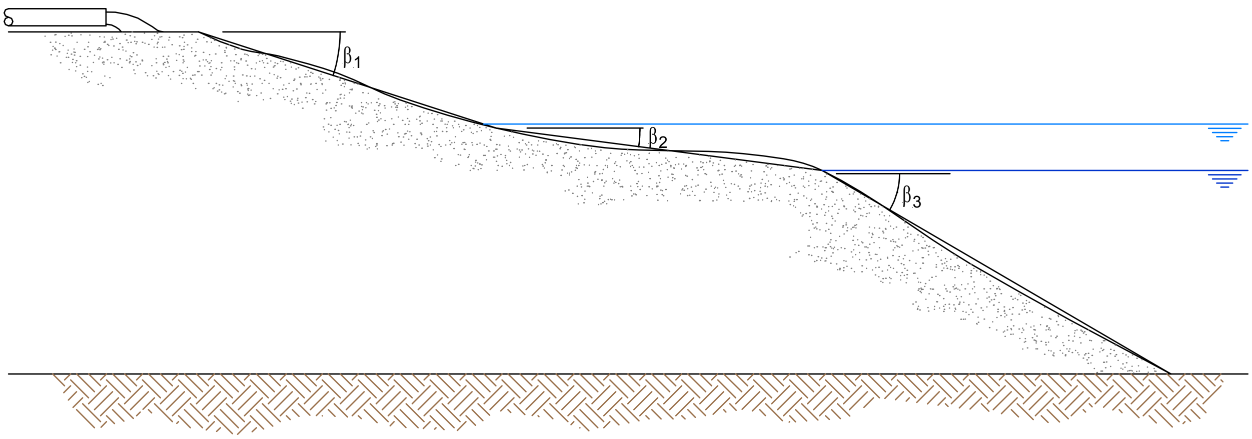


Figure 3-2: Above water and below water slopes of hydraulically placed fill

3.2.2.2. Slope in the Tidal Zone

The formation of the equilibrium fill slope in the tidal zone is more complex as more forces and dynamics affect placement of the fill material. There is still the driving force of the flow of water from the discharge, but it is diffused upon entry at and below the waterline. The action of tides usually has the effect of causing the placed material to slump, which flattens the slope. Similarly, wave action will tend to pull fill material out from the beach, again working to produce a flatter profile.

3.2.2.3. Underwater Slope

Below water, the entry of the discharge water is diffused, and likewise, wave action diminishes with depth. The fill material will therefore settle out more rapidly, which typically produces a steeper slope. For sand, which in general terms possesses an angle of repose of around 28-32º, the below water slope could ideally be as steep as the angle of repose (maximum angle sustained by intergranular friction). However, because the flow of fill material behaves as a density current, and deposited material is subject to flow slides, the actual slope angle of deposited fill material will be significantly flatter than the angle of repose of the material.

Figure 3-3 summarizes equilibrium slope data gained from experiments and field placement of hydraulically conveyed fill materials. It can be seen that the slope above water (light blue) is generally slightly steeper than the slope in the tidal zone (dark blue squares), while the underwater slope (yellow) is somewhat steeper. The data covers the range from fine sand, across medium sand, to coarse sand (Appendix A - Wentworth scale). For a common grain size of 250 µm, the slope above water could therefore be around 3-4º, the slope at the waterline as flat as 2º, and the slope below water around 6º. The equilibrium slope will to some extent also depend on the amount of discharge.

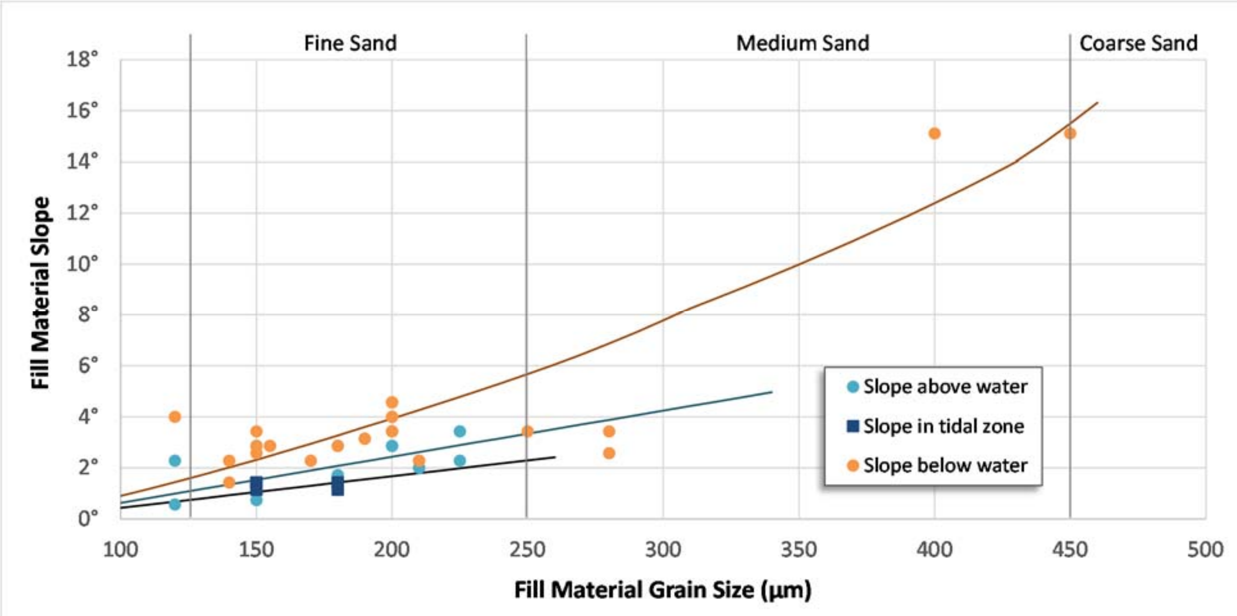


Figure 3-3: Above and below water fill material slopes as a function of material grain size

The data also illustrates that significantly steeper placement slopes cannot be achieved unless the material is coarse, i.e. coarse sand or larger such as gravel size material. It should be mentioned that steeper slopes could be achieved by other material placement methods such as by clamshell. However, it is estimated that the production rates would be so low that the potential benefit of the smaller material volume for construction would not be justified. Lastly, the data summarized in Figure 3-3 demonstrates that fill materials with diameters smaller than fine sand are generally not suitable for hydraulic placement because the slopes at which the material will settle out are near-horizontal. In the extreme case, infill with material containing large amounts of silt would produce very turbid waters that would need containment with e.g. silt curtains or leveed settling ponds, and the material would settle out over a prolonged period of time essentially with a horizontal surface extent. Another limitation on the steepness of underwater slopes is the potential for slope failure, especially when placed loosely on weak peat deposits.

4. Constructability

4.1. Sediment Delivery to the Construction Site

Sediment delivery is a key factor for the cost estimation of Franks Tract SRA restoration project. A common method to deliver construction material which was widely used in previous wetland restoration projects (e.g. Hamilton Wetland Restoration) is to pump sediment through a slurry pipeline system. Accordingly, a review of available approaches to set up the pipeline system is provided in this section. A discussion of other possible sediment delivery methods is also provided.

4.1.1. Slurry Pipeline System

Slurry pipeline system is an effective way to deliver sediment to the construction site. The floating pipeline contains slurry about 15-35 percent sediment by weight mixed with water. Under controlled conditions, with uniform sand without rocks, cobbles, and other debris, transport rates up to 50% sand by weight are possible. There are two typical slurry pipe types; 1) Steel Pipes with Floats (Figure 4-1) that can be customized to specific demands, using steel pipes in combination with dredger hoses and ring floats; 2) Floating Hoses which can tolerate higher pressures and transport more sediment in a certain timeline compared to the steel pipes with floats (Figure 4-2). Floating Hoses cost more and are usually used in the vicinity of the pumps or boosters to control high pressure slurry flow.

The slurry pipeline system access to the construction site is limited by considerations required to ensure navigation channels are not blocked during construction. One possible approach to use slurry pipeline system could be to unload the source material barges offshore in the vicinity of Franks Tract SRA (e.g. Little Franks Tract), and use a hydraulic semisubmersible pump to deliver material to the construction site. These pumps can provide discharges ranging from 150 to 30,000 GPM depending on their horse power and distance from the project site. Table 4-1 provides a list of these pumps and their specifications from different providers.

The production rate of semisubmersible hydraulic pumps is constrained by the distance and sediment grain size. Finer sediment grain size can result in higher production rates, while the discharge level significantly decreases when the distance to the outlet is large. Figure 4-3 shows production curves for DOP pumps with different horse powers for two types of fine (D_{50}=0.11 mm) and coarse (D_{50}=0.37 mm) sediment. As shown in the figure, the production rate is at least decreased by 50% for every type pump for distances larger than 3,000 feet, meaning that booster stations would be required to conduct slurry pumping. Figure 4-4 demonstrates a typical booster station used to improve sediment discharge production rate. Booster stations can provide discharges of 4,000 to 50,000 GPM, but their usage would increase the cost of the project. In some cases, a booster station can improve production rate up to 150% (Figure 4-5).

Figure 4-1: Slurry Pipeline System using steel pipes with floats

Figure 4-2: Slurry Pipeline System using floating hoses

Table 4-1: Semisubmersible hydraulic pumps

Provider	Pump	Rate (GPM)	Rate (m^3/hr)	Concentration (%)
Hevvy Pumps	Toyo DXL Series	158 to 560	36 to 120	2%
Hevvy Pumps	Toyo DL Series	30 to 2,100	6 to 475	20%
Hevvy Pumps	Toyo DP Series	132 to 3,200	30 to 720	30-50%
DAMEN	DOP 150-450	2,600 to 17,600	600 to 4,000	30-35%
BIG Dredging	HDD SDP 450	19,800	4,500	31%
BIG Dredging	DOP 450 L	17,600	4,000	30%
SCHURCO Slurry	Severe Duty Series (H,S,Z)	3,000 to 22,000	700 to 5,000	20%
SCHURCO Slurry	Heavy Duty Series (L,U)	6,000 to 30,000	1,350 to 6,800	20%
Drag Flow North America	HY 24-400	130 to 6,600	30 to 1,500	35%

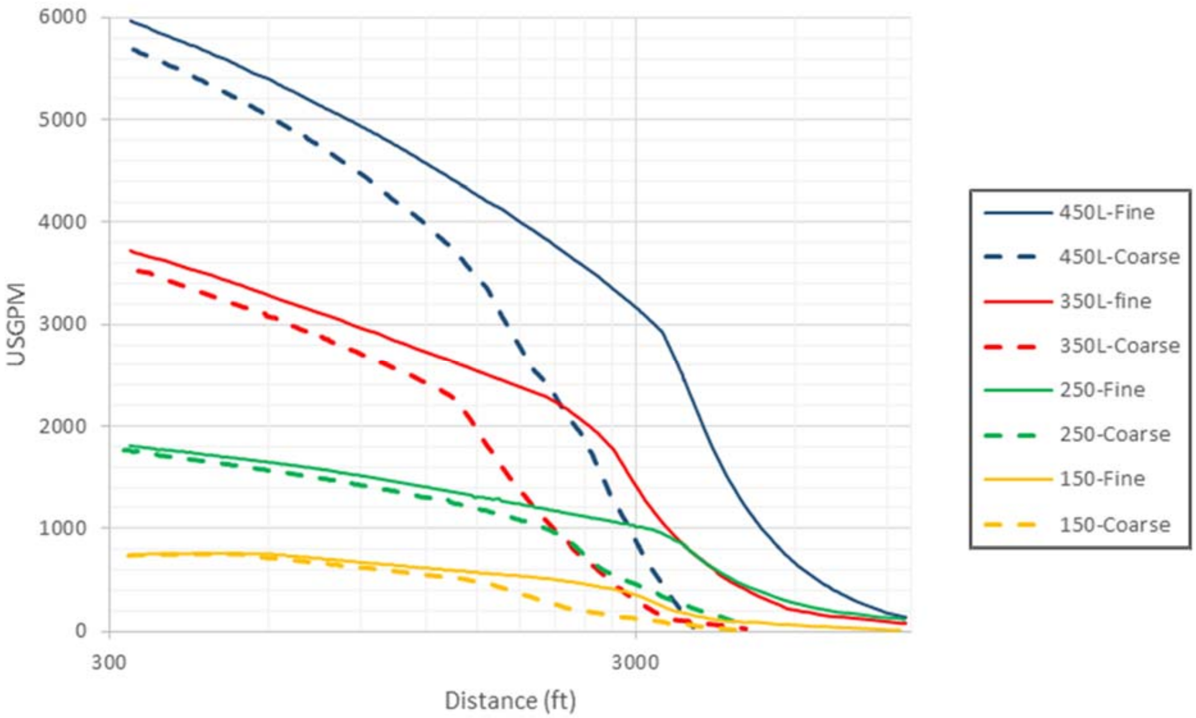


Figure 4-3: DOP pump production rates for fine and coarse sediments

Figure 4-4: A typical booster station, used to improve sediment discharge production rate

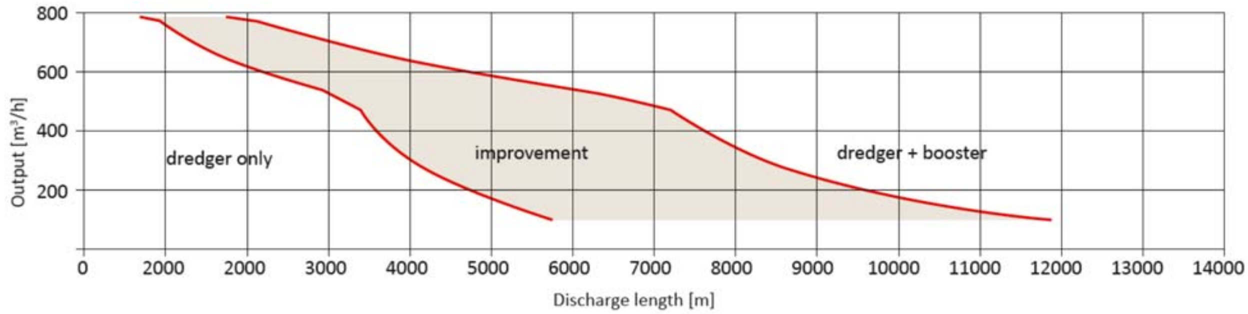


Figure 4-5: Booster effect on production rate *(IHC MERWEDE)*

Beside the combination of semisubmersible pumps and boosters, there are other possible approaches to pump sediment to the project site. A hydraulic off-loader can be positioned where material is unloaded by barges to pump sediment to the construction area. This alternative was previously used in Hamilton Wetland restoration project to place approximately 6.2 MCY of material at the project site (Figure 4-6).

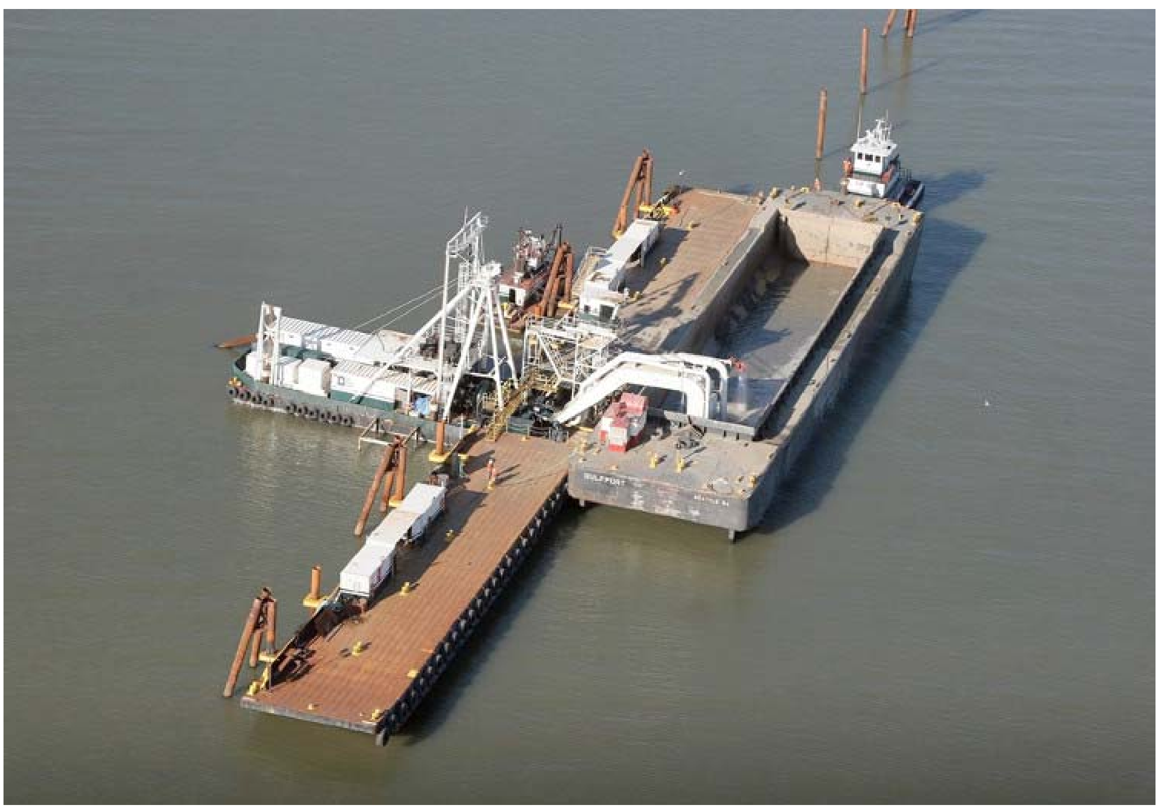


Figure 4-6: Manson/Dutra JV Liberty off-loader used for Hamilton Wetlands restoration project

Another option would be to use dredgers to pumping sediment. Dredgers usually have powerful hydraulic pumps. For example, a typical Cutter Suction dredger (Figure 4-7) can provide up to 50,000 USPG discharge, and do not need a booster stations for distances less than 5,000 ft. Cutter Suction dredgers use a rotating cutter device to agitate and stir up material on the bottom surface where it sucks up the slurry and transfers the mixture through the pipeline. To use this sediment delivery method, one possible way could be to unload source material in one of the breached channels along the Franks Tract levees, while the dredger pumps the sediment to the construction location.

Figure 4-7: Typical Cutter Suction dredge

4.1.2. Other Delivery Methods

1) Truck Haul

Using truck hauls is one of the conventional methods to deliver sediment to construction sites. Truck hauls usually have a capacity in range of 12-18 cy. Working 5 hours per day, three trucks could move 1,500 cy of sand for final placement and grading. Figure 4-8 shows an example of these vehicles. Considering that Franks Tract SRA is not accessible by land, using truck hauls for construction is probably not a feasible option.

2) Pneumatic Sediment Conveying System

Pneumatic (air) conveyance systems are commonly used in industrial settings for transfer of bulk materials such as grain, cement, fly ash, and other dry bulk products, typically over short distances. The material to be conveyed is fed into the inlet hopper section of the pump, and an auger imparts an initial mechanical velocity towards an acceleration cone. Figure 4-9 demonstrates the use of this system in the field.

3) Conveyor Belt System

Conveyor belts have been used for beach nourishment projects on both the East and West Coasts of the US. The system requires a minimum corridor width of 4 feet, and can be supplied at the entry point using a space with a minimum width of 12 feet. Maximum production rate is reported to be 600 tons per hour, roughly equivalent to 440 cubic yards per hour (336 cubic meters per hour) depending on sand density. Figure 4-10 shows an example of the conveyor belt system in Palm Beach, Florida.

Figure 4-8: Truck haul

Figure 4-9: Pneumatic sediment conveying system

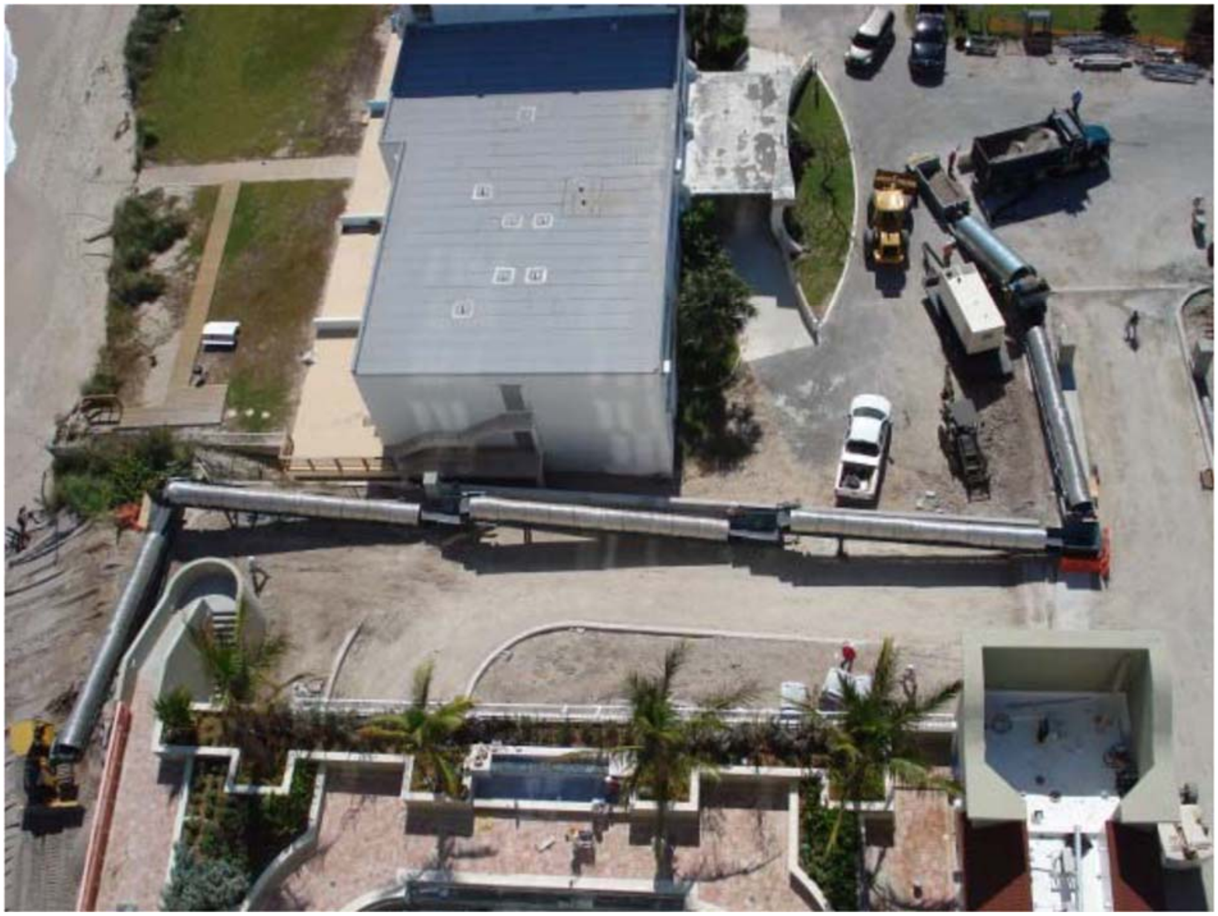


Figure 4-10: Conveyor belt system

5. Engineering Constraints

Construction activities associated with restoration work at Franks Tract can be categorized into following activities:

1) Dredging\excavation of material (material sourcing)
2) Screening of the material (optional)
3) Transport of materials to the site
4) Placement of materials on site
5) Grading and finishing to design profiles and elevations

Each of these construction activities may be subject to several constraints. Some of these relate to sourcing of materials, while other constraints relate to the environment, general construction, and the physical setting of the project as described in the following.

5.1. Material Sourcing Constraints

Availability of materials and the reliability of the supply can influence the construction process. If there is a need to specify particular material properties to achieve a specific level of stability and durability of in-place materials, specification of the material (suitability) can impact material availability. Also, if construction has to draw upon several sources of material, variation between material sources may cause differences in quality from the various sources; though all must meet specification, differentiation could allow more effective placement if properly managed. As discussed in Section 3, several sources can potentially be used for the project and materials can be delivered to the project site by several methods. The loss of material during transport can increase the project cost, and extend the duration of construction.

Figure 5-1 depicts the location of potential material sources and options for transport to Franks Tract as a marine-based operation. The distances between source locations and the project site range from around 1 to 40 miles.

Figure 5-2 summarizes locations of material sources and routes for delivery of materials to Franks Tract by land. The distances between source locations and the project site through ground transportation range between 1-73 miles. Table 5-1 summarizes the waterway and land access distances between potential source locations and Franks Tract.

Ground transportation generally has longer transit distances than marine-based delivery. And aside from traffic related issues, ground transportation is generally subject to fewer limitations compared to water-side delivery, which can be subject to a wider range of exposures such as winds, waves, currents, and water depth limitations. However, due to the significant number of truckloads needed, and associated impacts, marine-based delivery of materials will be the most feasible choice for transport of materials to Franks Tract.

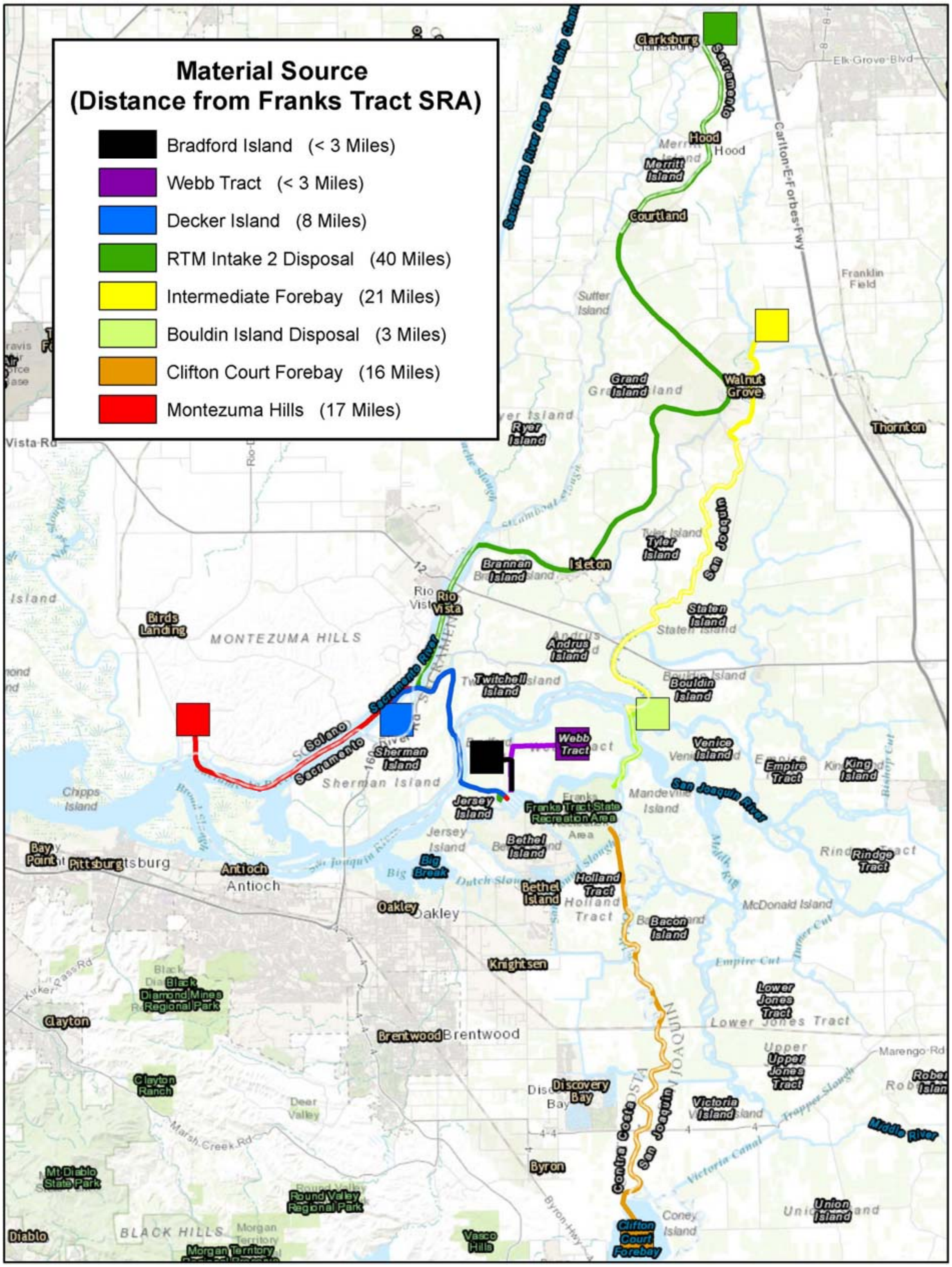


Figure 5-1: Potential material sources and transit paths for marine-based delivery

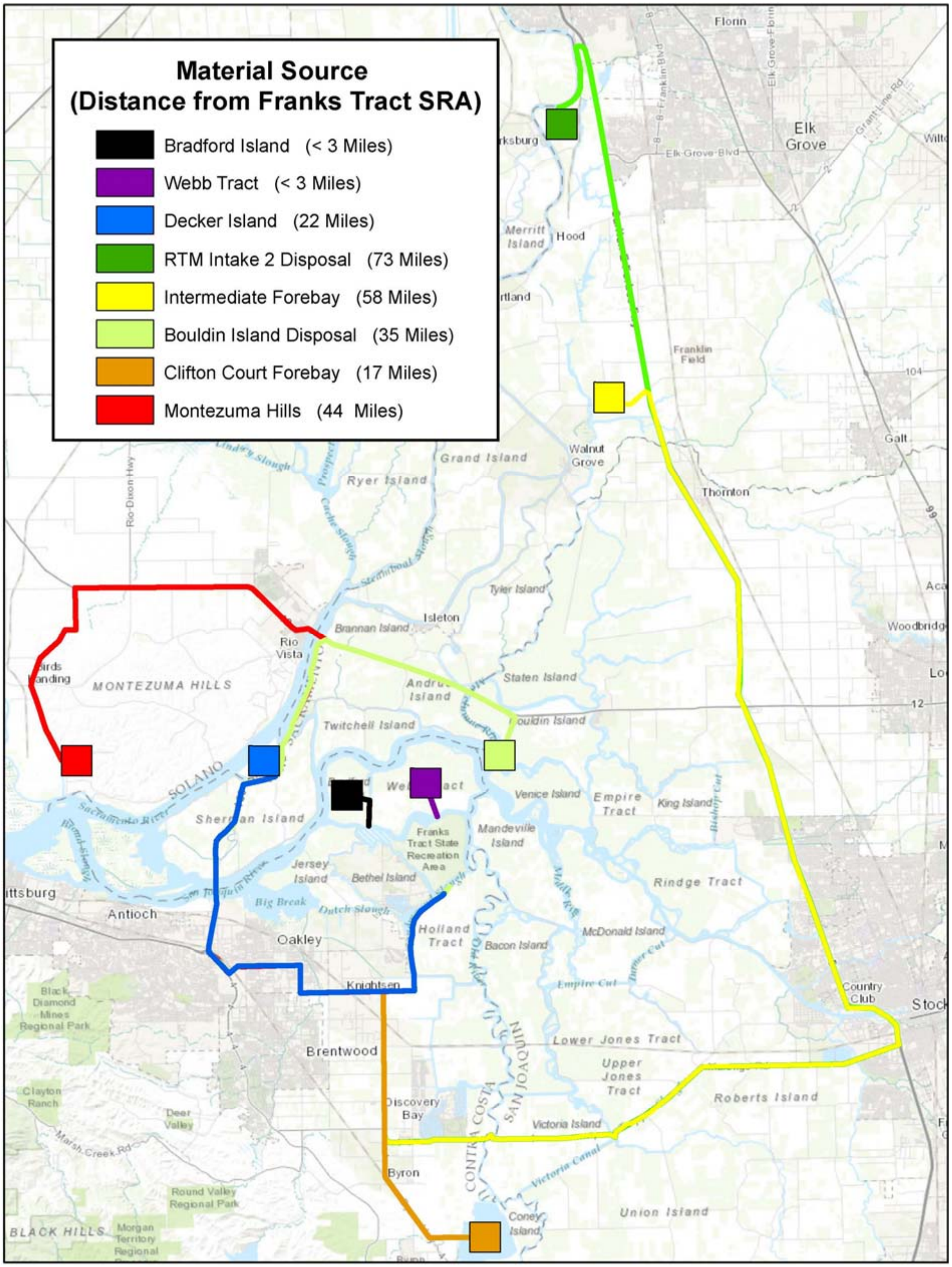


Figure 5-2: Potential material sources and transit paths for land-based delivery

Table 5-1: Transit distances for delivery of materials to Franks Tract via water and ground transportation

Material Source Location	Waterside Transportation (miles)	Ground Transportation (miles)		
		Highways	Local Roads	Total
Bradford Island	1.3	0.0	< 3.0	< 3.0
Webb Tract	3.0	0.0	< 3.0	< 3.0
Decker Island	8.0	0.0	22.2	22.2
Intake 2 Disposal	40.4	39.1	34.1	73.2
Intermediate Forebay	20.5	26.4	32.1	58.5
Bouldin Island Disposal Site	3.1	0.0	34.7	34.7
Clifton Court Forebay	16.1	0.0	16.5	16.5
Montezuma Hills	16.8	0.0	44.2	44.2

5.2. Environmental Constraints

5.2.1. Water Depth Limitations

Marine transportation can be constrained by water depth limitations. A functional and operable vessel needs to have water depths sufficient for its draft range from empty to loaded (carrying cargo). In addition the vessel needs room underneath (underkeel clearance) in order to maneuver and to accommodate fluctuations in water level and/or draft. Reduced clearance under the keel can occur for several reasons including if the vessel is over-loaded, if it's sailing against a pronounced current (squat), if it's subject to wave action, or if the cargo on board is not balanced, causing the vessel to float at an angle (trim).

Hopper barges (Figure 5-3) usually require 11 to 12 feet of water depth to be fully operable. In shallower waters, deck barges can be used to transport materials. Deck barges can operate at a smaller draft than hopper barges, but at the sacrifice of considerably reduced cargo capacity compared to hopper barges. Deck barges also carry an increased risk of materials being lost over the side of the vessel. This is oftentimes compensated for by use of coaming, which are the raised side walls seen on the hopper barge (left) in Figure 5-3. Hopper barges can also operate at reduced draft by carrying less cargo (partially laden). However, less cargo carried per vessel will necessitate more trips, and/or more vessel in order to meet delivery of a total quantity of cargo within a given time frame.

Also evident in Figure 5-3 are tugboats accompanying the barges. Barges are typically not self-propelled and are therefore incapable of moving around on their own. Tugs are therefore utilized to push and maneuver barges. In addition, a complement of other marine equipment is usually mobilized for marine construction projects.

Figure 5-3: Hopper Barge (Left), Deck Barge (Right)

Table 5-2 lists vessel types and their common draft ranges as compared to water depths in and around Franks Tract. A skiff is a small shallow-bottomed open boat with an outboard motor, typically used to get from one location to another on the water, or for access to marine equipment on the water, e.g. staff going to and from work. A work boat is a larger boat, typically a utility vessel used for a wide range of services. These typically have more deck space and/or a covered portion and are used to ferry workers around, or transport equipment and goods. A pontoon is a large rectangular box, typically pieced together to form a larger, primarily stationary, floating platform (examples trade names are Flexifloat and Poseidon modular barges). Pontoons are similar to deck barges, but have a larger area to displacement ratio, and therefore typically achieve smaller drafts than deck barges. Pusher tugs are smaller versions of tugs, but typically with a flat front enabling them to push directly against the sides of barges. A harbor tug is a larger version of tugboat, typically with more engine power. The capacity of larger tugs is measured in bollard pull, i.e. how much force they can apply to maneuver non self-propelled vessels and marine equipment around. A simple mechanical dredge consists of a conventional excavator mounted on a deck barge. A suction dredge is a specialized vessel with built-in equipment and pumps to evacuate (dredge) sediments from the seabed and discharge these via a dedicated pump. A derrick barge is a vessel specialized in lifting heavy loads. These come in a wide range of sizes, the larger of which are typically termed crane barges.

The table illustrates that the marine equipment able to work within Franks Tract is limited to small-draft vessels ranging from skiffs and work boats to pusher tugs (solid portion of blue bars). Vessels with deeper draft such as deck barges, harbor tugs, and mechanical dredges may have some capacity to enter and work within Franks Tract, but limited to the areas that have sufficient water depth (variable depths indicated by hatched blue colors). Other vessels would not be able to work within Franks Tract without pre-dredging to the needed draft range (indicated by the brown hatch in the table).

As a main route to the Franks Tract area, the San Joaquin River has sufficient depths for navigation to accommodate all of the common types of marine equipment (dark solid blue bar to 33 foot depth). However, upon entry to Franks Tract via the Old River or False River, water depths would be limited to around 7 to 11 feet and might require general deepening or deepening in isolated areas to clear water depths for navigation. In the table, *West False River* denotes the portion of the river approaching Franks Tract from the San Joaquin past Little Franks Tract. *False River* denotes the remaining portion along the north side of Franks Tract where water depths are shallower.

Table 5-2: Typical draft ranges of marine equipment

Vessel Type	Draft Range (feet)	Franks Tract	False River	West False River	San Joaquin River	Old River
Skiff	½					
Work boat	1					
Pontoon	3					
Pusher tug	4					
Deck barge	5					
Harbor tug	6					
Mechanical dredge	7					
	8					
	9					
	10					
Suction dredge	11					
Hopper barge	12					
Derrick barge	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	33					

The table highlights that the necessary water depth clearances, if not present, can be achieved via dredging. However, the indication is also that substantial dredging would be needed to fully accommodate loaded hopper barges and derrick barges.

Construction methodologies seeking to minimizing dredging and make the most use of existing marine equipment would therefore aim to bring fill materials in to the channels bordering Franks Tract, and from there convey the material into the interior of Franks Tract for placement.

5.2.2. Water Level Variations

Water level variations can also affect marine construction. The primary water level variations at Franks Tract are due to tides, and at times of substantial outflow from the Delta due to increases in river stage associated with the discharge.

Low water levels can have the effect of reducing navigable water depths, preventing access, promoting erosion at the toe or base of structures, cause reshaping of slopes, or slope failure, and increase structure foundation loads. High water levels have the potential to promote erosion near the crest of structures, or can cause breaching due to overflow.

5.2.3. Wind Climate

Wind can influence construction in several ways. The main concern are high and persistent winds, which have the potential to affect construction equipment and the construction site itself. Wind can affect construction equipment by exerting pressures that can affect mobility.

When using landside equipment, e.g. material transport using trucks, wind effects are commonly dealt with by covering the truck load, traveling at reduced speeds, and ceasing transportation during high wind events (downtime).

Marine transportation is more sensitive to wind pressures, which can affect vessel transits and work on the water. The main concern for a vessel is to remain stable and on position, or on course, with sufficient water depths for navigation. Table 5-5 summarizes typical operational wind limits for marine construction.

Sustained winds blowing over an open body of water will also produce waves, which are discussed in the following section.

5.2.4. Currents

Currents play an active role at Franks Tract and in adjoining waterways. The two components that contribute to currents at the site are tidal currents and outflow from the Delta.

As it relates to marine construction, currents can impact construction by affecting the ability of vessels to remain on position, affect the ability of vessels to navigate safely, affect the ability to place materials within tolerance, erode partially completed works, transport and disperse materials, and apply loading on temporary works.

DWR conducted numerical modeling of the project area and adjoining Delta. Figure 5-4 shows an example snapshot of flood flow on a spring tide, i.e. a tide occurring when there is the greatest difference between high and low water. It can be noted that flow velocities in West False River, Fishermans Cut, and the dendritic channels within the project areas can reach 0.5 to 0.8 feet per second (areas shaded in aquamarine to green).

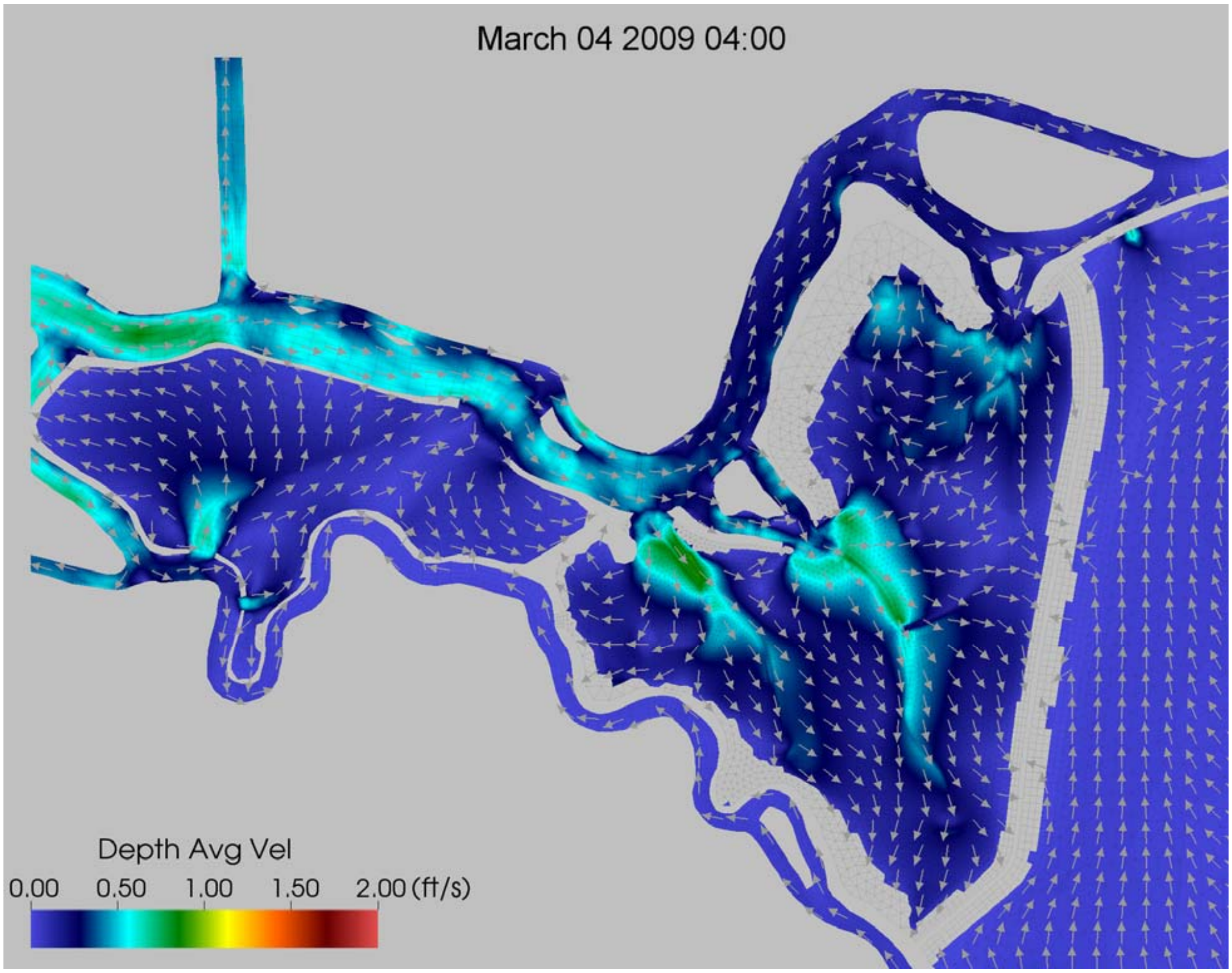


Figure 5-4: Snapshot of flood flow on spring tide

Figure 5-5 shows an example snapshot of ebb flow on a spring tide. Ebb flow velocities are somewhat higher than flood flow velocities (Figure 5-4), reaching up to 2 feet per second in Fishermans Cut (areas shaded orange to red), and around 1.3 feet per second in West False River (yellow to orange). Ebb flow velocities within the project area are of the same order of magnitude as the flood flow velocities (Figure 5-4), reaching velocities of around 0.5 to 0.8 feet per second (aquamarine to green).

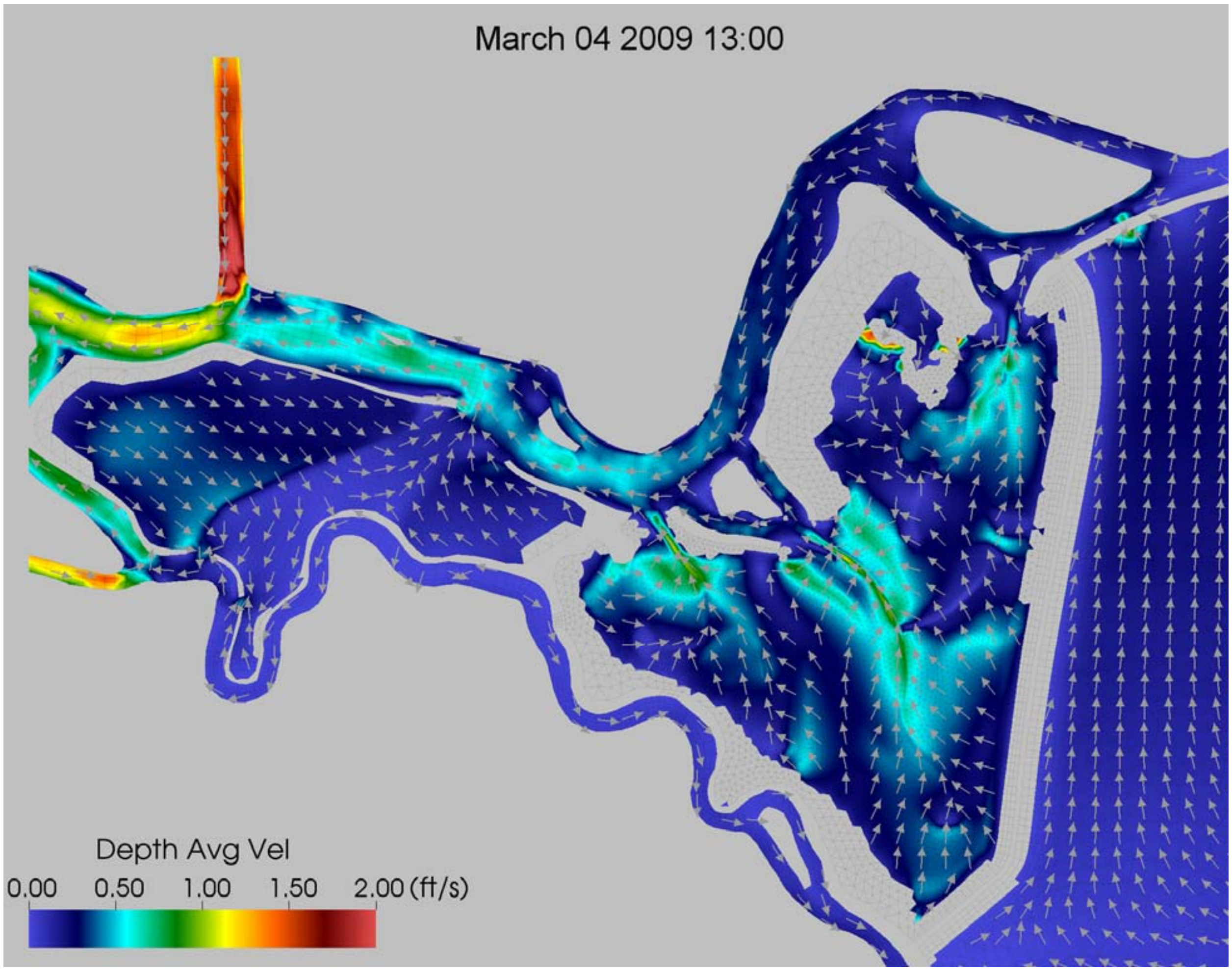


Figure 5-5: Snapshot of ebb flow on spring tide

Figure 5-6 captures the maximum depth-averaged velocities occurring within the project area and its vicinity over the period simulated. From Feb. 11, 2009 to Feb 23. Flow velocities within the project area are on the order of 0.5 to 0.8 feet per second (aquamarine to green), chiefly limited to the dendritic channel network. Outside of the channels, flow velocities are generally 0.3 feet per second or lower.

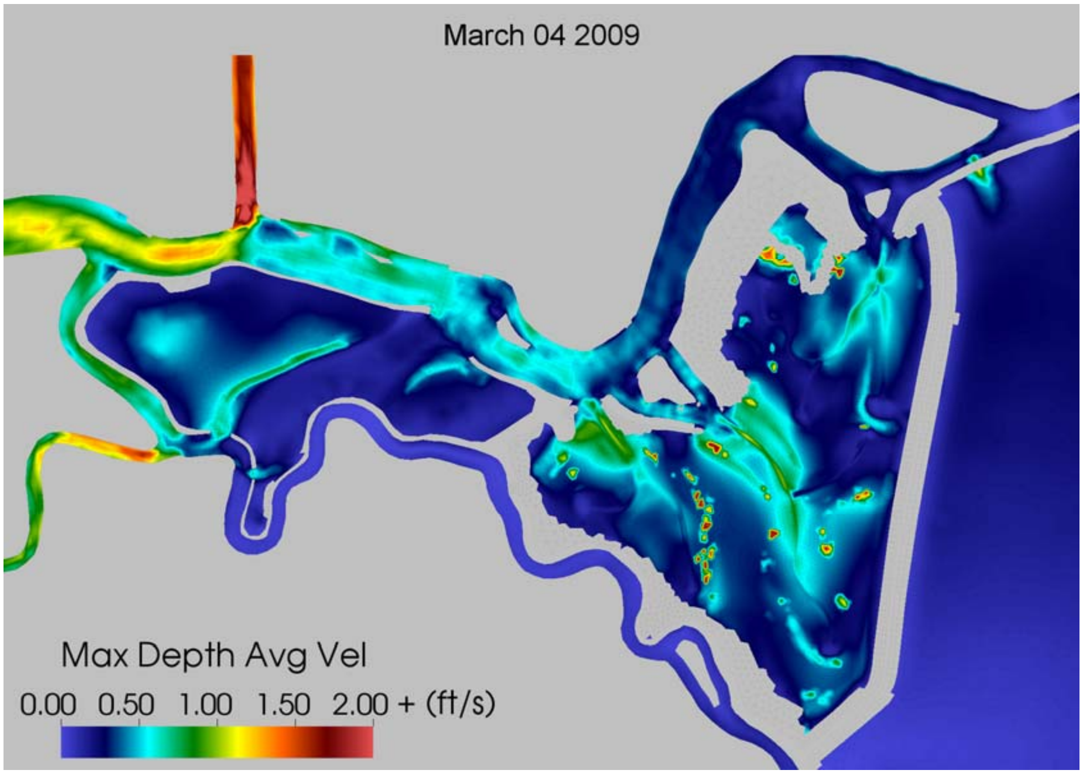


Figure 5-6: Maximum depth-averaged velocities within project area and vicinity

Table 5-3 summarizes maximum permissible flow velocities for channels of small slope with water depths less than 3 feet in varying types of substrate. It can be seen that irrespective of the material selected for construction, the dendritic channel network can be expected to remain stable. Over the period following infilling within the project area to achieve the desired grade and establishment of marsh vegetation, some redistribution of sediment may take place.

Table 5-3: Maximum permissible velocities *(USDA, 2007)*

Channel Material	Permissible Velocity (feet/sec)		
	Clear water, no detritus	Water transporting colloidal silts	Water transporting noncolloidal silts, sand, gravel, or rock fragments
Fine sand (noncolloidal)	1.5	2.5	1.5
Sandy loam (noncolloidal)	1.75	2.5	2.0
Silt loam (noncolloidal)	2.0	3.0	2.0
Alluvial silt (noncolloidal)	2.0	3.5	2.0
Ordinary firm loam	2.5	3.5	2.25
Stiff clay (very colloidal)	3.75	5.0	3.0
Alluvial silt (colloidal)	3.75	5.0	3.0
Fine gravel	2.5	5.0	3.75
Coarse gravel (noncolloidal)	4.0	6.0	6.5
Cobbles and shingles	5.0	5.5	6.5

Flow velocities along the berm within Franks Tract are also within 0.3 feet per second, and thus materials placed can be expected to remain stable to currents following construction.

During the period of construction, placement of material for the berm is likely to commence starting from the northern side of Franks Tract and the southern side of Franks Tract and close in the middle (Figure 5-7). Over the period of construction the opening will progressively become smaller. This will act as a constriction of the tidal flow and increase flow velocities through the opening (tidal flow denoted by yellow arrows).

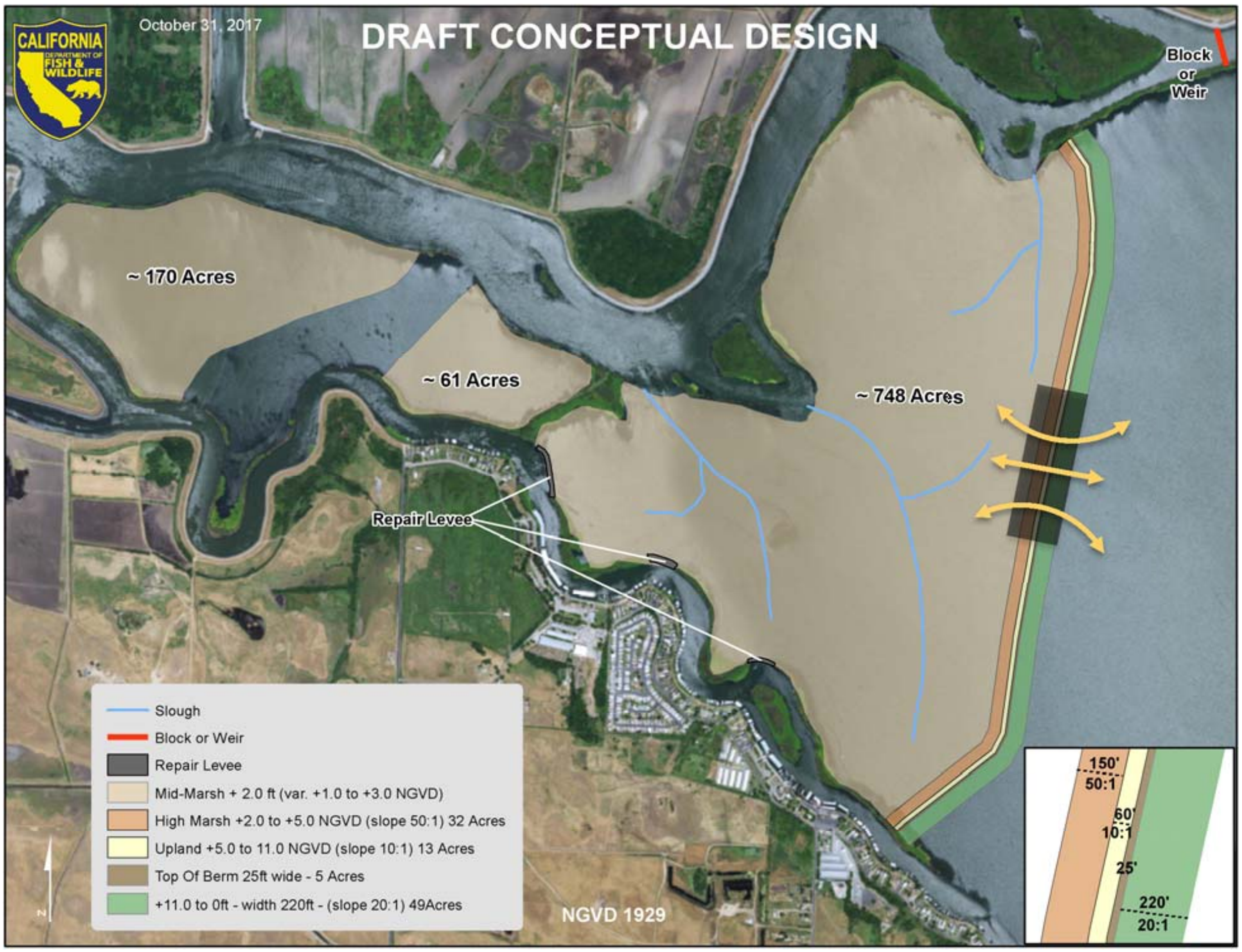


Figure 5-7: Berm construction, closing at the center

DWR conducted simulations to determine maximum tidal flow velocities for gaps in the berm ranging from 100 to 1,000 feet wide. Figure 5-8 shows examples of flow jet formation through the gap on peak tides.

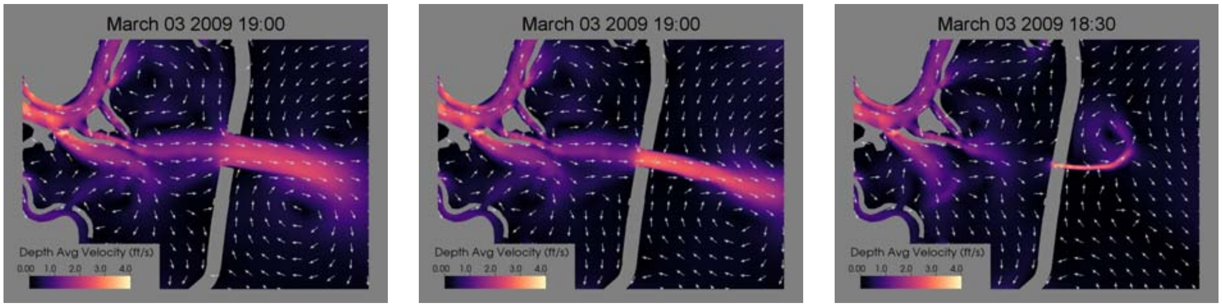


Figure 5-8: Flow velocities for gaps 1000' wide (left), 500' wide (center), and 100' wide (right), *DWR (2017)*

Table 5-4 summarizes peak flow velocities through a gap in the berm as a function of the opening width. Going from a 1,000-foot wide g9ap and narrower it can be seen that flow velocities progressively increase from around 2.5 feet per second to 4.0 feet per second. As the gap closes, within 100 feet or so, flow resistance will increase to the point where velocities rapidly decrease toward zero as the gap is closed. It should be noted that this effect will only take place if placed material remain immobile. Comparing with the permissible channel flow velocities summarized in Table 5-3, it can be seen that material placed to close the gap could consist of gravel, cobble and shingle (or larger) in order to remain stable.

Table 5-4: Maximum tidal flow velocities as a function of gap width

Gap (feet)	Max. Tidal Flow Velocity (fps)
1,000	2.5
500	2.9
100	4.0

5.2.5. Wave Climate

Wave exposure has the potential to significantly affect construction in the marine environment. Wave action can impact material transport by preventing vessels from leaving port, requiring vessels to seek shelter, delaying transits, preventing them from unloading, affecting the ability of vessels to navigate safely, and affecting the ability to place materials within tolerance. Table 5-5 summarizes limits to marine construction due to wave action.

Table 5-5: Operational constraints related to winds and wave action

Construction Activities	Limiting Wind Speed (knots)	Limiting Wave Height (feet)
Feasible condition for broad range of marine construction activities.	4 knots	< 2 feet
Limit for sand filling activities, loading and unloading of barges, and use of floating cranes.	15 knots	2 feet
Limit for dredging activities, and transportation of materials by barge.	28 knots	3 feet
Marine construction halted. Vessels seek shelter in ports or at safe anchorage.	> 28 knots	> 3 feet

Wave action additionally has the potential to damage temporary works, damage uncompleted works where permanent protection is not yet in place, cause erosion, transport, and dispersal of placed material, and increase turbidity levels.

There are several processes that occur in shallow water areas that affect wave action, which include refraction, shoaling, diffraction, reflection, interaction with currents, and wave breaking, all of which probably occur at Franks Tract at some level.

5.2.6. Sediment Transport

Section 5.2.4 investigated currents within the project area and found that flow velocities can increase considerably through constricted openings. Wave action is another factor that can mobilize and transport sediments and placed fill material.

Based on the wind statistics summarized in Figure 2-9, an analysis of the longshore sediment transport potential due to wind-generated waves was conducted. The analysis follows *CEM (2002)*, using the following relations:

$$S = \begin{cases} 0.0012 \cdot \pi \cdot H_S^2 \cdot C_1 \cdot \sin 2\alpha_b \,, & \dfrac{H_S}{\Delta d_{50}} > 50 \\ 0.0012 \dfrac{H_S\sqrt{\cos\alpha_b}}{d_{50}} \left(\dfrac{H_S\sqrt{\cos\alpha_b}}{d_{50}} - 11 \right) \cdot \sin\alpha_b \cdot g \cdot d_{50}^2 \cdot T_p \,, & 10 < \dfrac{H_S}{\Delta d_{50}} < 50 \end{cases}$$

Where S is the longshore sediment transport rate, H_S is the significant wave height, T_p is the peak wave period, g the gravitational acceleration, α_b the angle of wave incidence, and d_{50} the mean sediment grain size.

The first equation expresses that if the wave action is sufficiently large in proportion to the submerged weight of sediment grains, the amount of material transported is only dependent on the significant wave height, the wave angle of incidence, and the deep-water wave celerity, C_1, which is given by:

$$C_1 = g\frac{T_p}{2\pi}$$

The second equation expresses that the longshore transport rate will decrease if the submerged weight of the individual sediment grains becomes large enough to impede mobilization due to wave action. This equation also incorporates a threshold that acts as a cutoff in the case that the sediment grains are so large that wave action won't mobilize the material, i.e. the material is stable.

The angle of wave incidence, α_b, is determined from Snell's Law using the relation:

$$\sin \alpha_b = \sqrt{g \frac{H_b}{\kappa}} \sin \frac{\alpha_1}{C_1}$$

Where α_1 is the deep-water angle of incidence, $\kappa \simeq 0.78$ is the breaker index, and H_b the breaking wave height determined by:

$$H_b = H_1^{\frac{4}{5}} \left[\frac{C_{g1} \cos \alpha_1}{\sqrt{\frac{g}{\kappa}} \cos \alpha_b} \right]^{\frac{2}{5}}$$

Where H_1 is the deep-water wave height, and C_{g1} is the wave group celerity.

Using the above approach, based on the wind statistics tabulated in Figure 2-9 and wave statistics per Section 2.7, the sediment transport potential was evaluated for three locations along the berm shown in Figure 5-9, namely the southern (S), central (C), and the northern (N) portion of the berm.

The results are captured in Figure 5-10, which depicts the longshore sediment transport rate in cubic feet per year as a function of the orientation of the berm. Because wave incidence perpendicular to the berm or shoreline produces no net longshore transport, the shoreline orientation is measured relative to the shore-normal so that negative transport rates indicate material transport along shore towards the north, and positive transport rates indicate transport south along the berm. The figure explores alignments of the berm shore-normal ranging from 70°N to 180°N in order to determine the longshore transport potential as a function of the shoreline orientation. The actual shore-normal directions are indicated by the vertical blue lines, dark blue for the northerly (N) portion of the berm, medium blue for the central (C) portion of the berm, and light blue for the southern (S) portion of the berm.

It can be seen that only the southern portion of the berm has an orientation that is close to the point of zero net transport. Conversely, the central berm segment has an orientation that would results in transport of shoreline material of to 8,000 ft^3 per year. The northern portion of the berm could be subject to sediment transport rates as high as 12,000 ft^3 per year.

The reason for these results is that the shoreline along the berm facing the interior of Franks Tract is dominated by south-easterly winds, which are predominant in the winter months.

These results demonstrate that unprotected fill materials placed for construction consisting of sand and fines would be highly sensitive to wave action.

berm

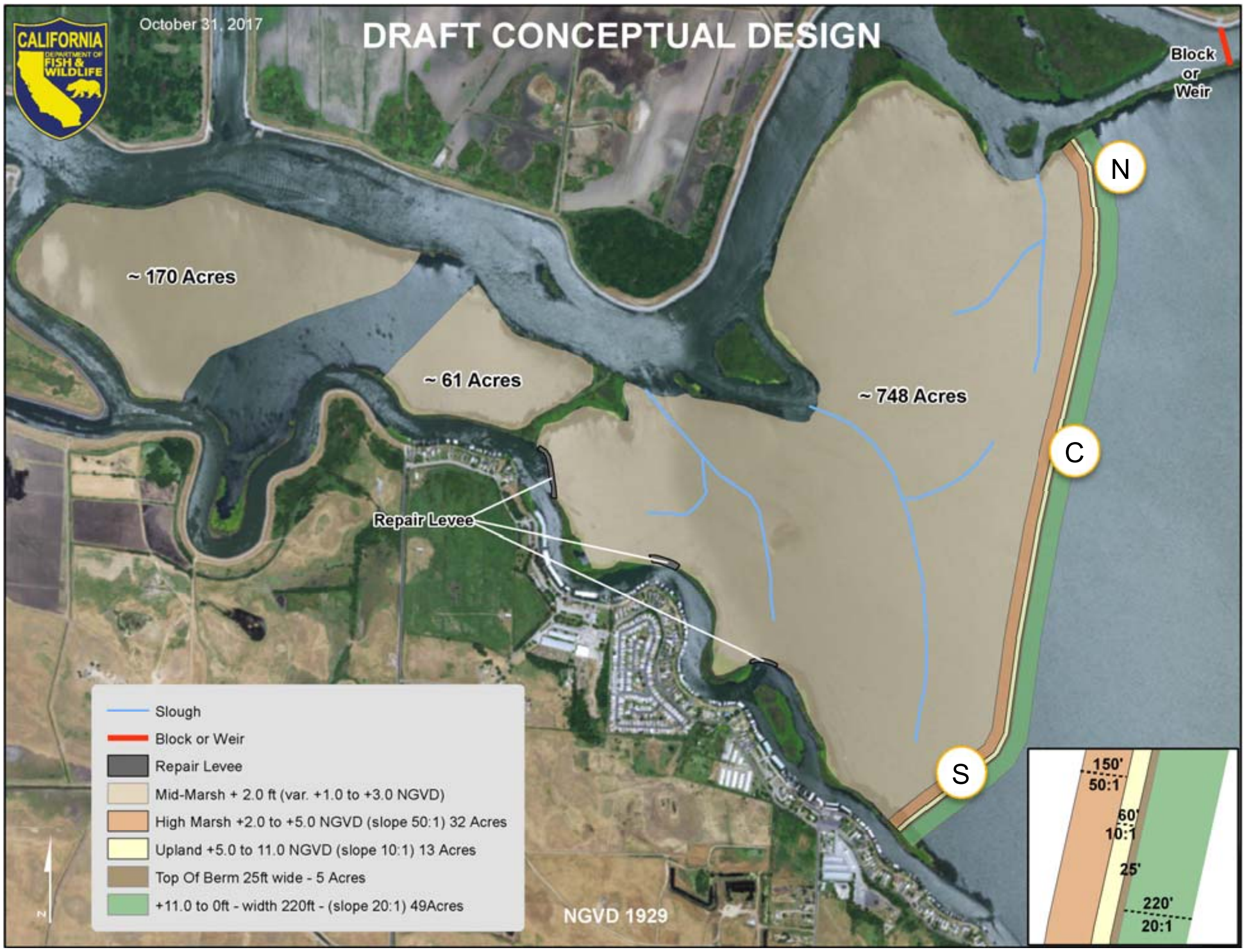


Figure 5-9: Analysis of longshore sediment transport potential along berm

Further analysis of the potential longshore sediment transport rates was conducted in order to determine the size of material that will remain stable following placement. It was determined that material with a mean diameter of 1 inch or greater will remain stable to wave action.

It would subsequently be possible to protect the side slopes of the berm with material consisting of 1-inch gravel, or quarry spalls.

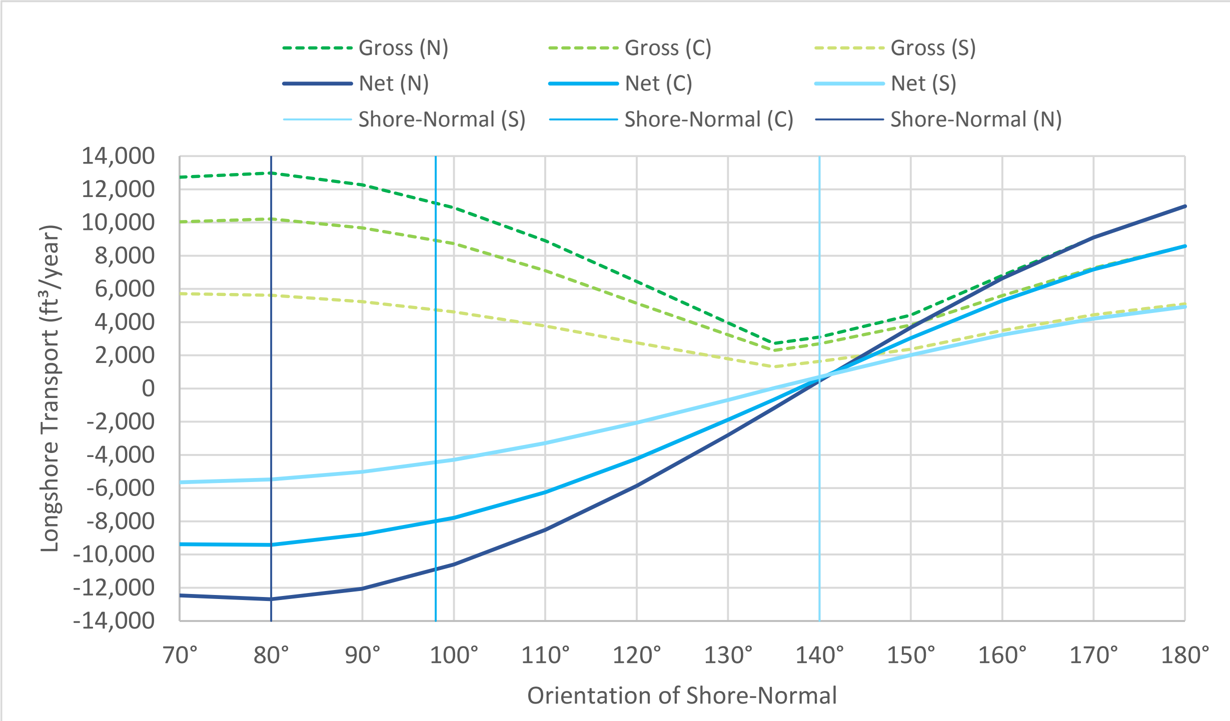


Figure 5-10: Longshore sediment transport potential along berm

5.2.7. Fish Migration Windows

Several species of fish exist in Upper San Francisco Estuary, including adult and juvenile Chinook salmon, Sacramento Splittail, Largemouth Bass, Striped Bass, Delta Smelt, and Longfin Smelt. Many of these fish use rivers and sloughs in the delta for spawning during different times of the year. Construction activities may be affected by fish migratory patterns and halted at times of the year, especially during the spawning season when fish migrate upstream to lay their eggs. The spring-run migration of adults upstream typically occurs over a time from March through June. Spawning takes place August through October. Juvenile fish are found in-river all months of the year.

The main pathway of anadromous fish runs is via the Sacramento River, where four runs occur, namely a spring run, fall run, late fall run, and winter run.

Appendix B provides a visual identification table of genus and species present in the vicinity of Franks Tract.

5.2.8. Vegetation

Several types of invasive submerged aquatic (SAV) and floating aquatic (FAV) vegetation are present in Franks and Little Franks tracts. These include Curly-leaf pondweed *(Potamogeton crispus)* and Brazilian waterweed *(Egeria densa)* and water hyacinth *(Eichhornia crassipes)*. Figure 5-11 from *Ustin (2016)* shows the September 2015 binned Normalized Difference Vegetation Index (NDVI). Higher values indicate higher densities of vegetation. Figure 5-11 shows the extent of invasive SAV at Franks

Tract, consisting primarily of Curly-leaf pondweed *(Potamogeton crispus)* and Brazilian waterweed *(Egeria densa)* which are prevalent nearly everywhere within Franks Tract.

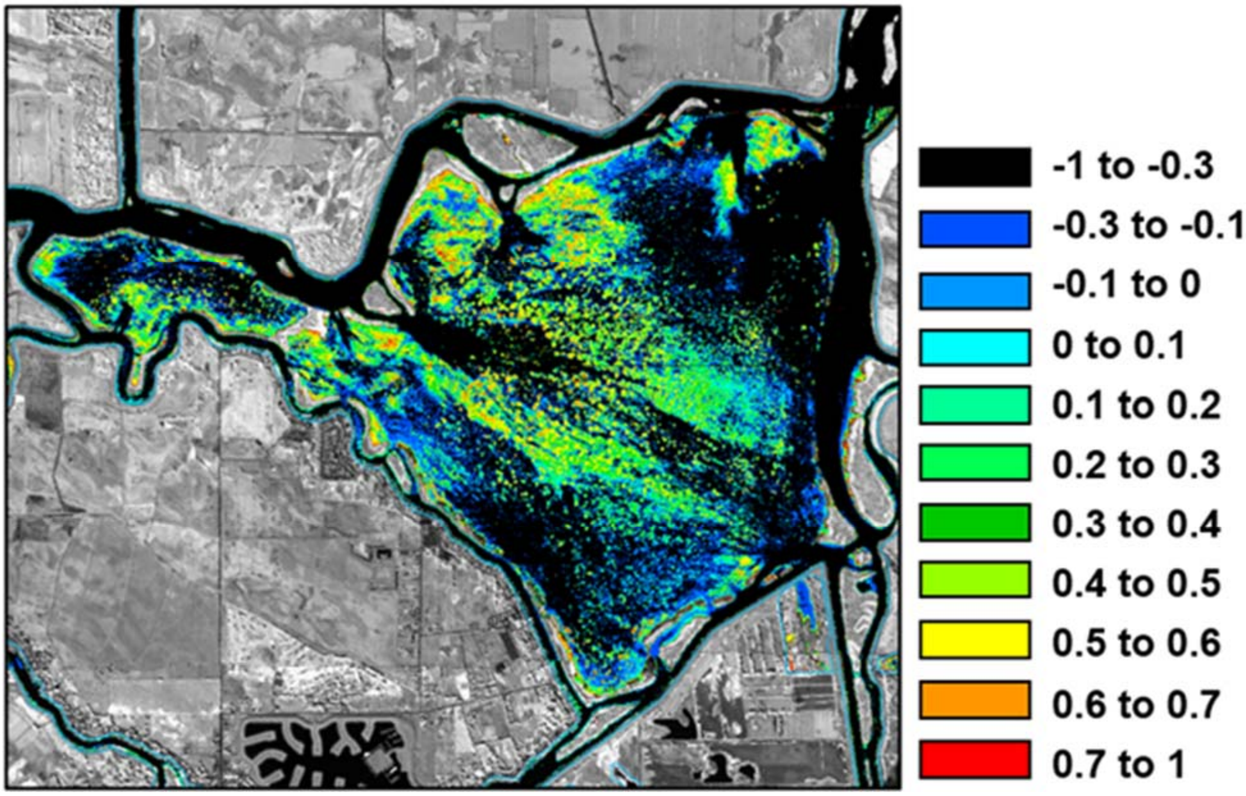


Figure 5-11: September 2015 Normalized Difference Vegetation Index *(Ustin, 2016).*

Figure 5-12 depicts the life cycle of these invasive plant species. Their growing cycle is from early spring through to late summer where they reach their peak, followed by a period of senescence over the winter months.

These invasive species are found extensively in tidal freshwater subtidal areas of the Delta, particularly areas with low water velocity, i.e. flooded islands. The main concern of SAV to construction at Franks Tract is impact to marine plant operation, which could affect navigation, and foul the propellers of tug boats and other vessels used for construction.

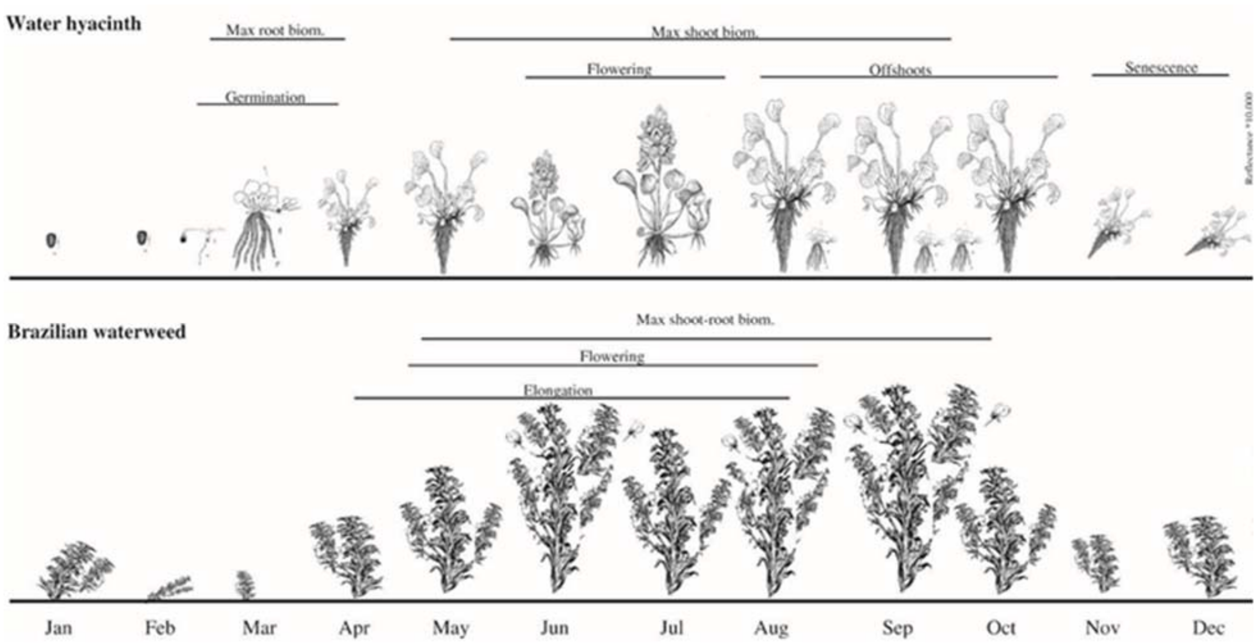


Figure 5-12: Life cycle of invasive SAV in the California Delta Ecosystem *(Hestir et al., 2008)*

5.3. Site-Specific Constraints

5.3.1. Access Availability

Considering the physical setting of Franks Tract, construction activities may be impacted by access limitations. The interior of the project area is only accessible by water, and thus precludes land-based access unless dedicated access is provided as part of construction. Although accessible from the waterside, some areas such as Little Franks Tract are access constrained due to hazards for navigation.

The NOAA nautical chart (Figure 2-3) marks several locations within Franks Tract with wrecks, snags, and piles which can cause various navigational issues and impact construction activities.

5.3.2. Existing Structures

Existing structures can influence construction in various aspects. Remnants of the levees around Franks Tract and Little Franks Tract can cause access issues during construction. On the other hand, these levees can be used as stations for construction activities, although there are some uncertainties about the condition of these structures.

Bethel Island on the southern edge of Franks Tract is home to many residents with a developed shoreline, which includes a marina and other facilities. During construction activities, necessary measures must be considered to minimize potential impacts to these existing structures.

5.3.3. Ground Conditions

Ground conditions will affect construction activities at Franks Tract involving any type of work requiring a foundation as the seabed of the site consists of peat (see section 2.8). Surcharging the bottom peat can effect a number of potential impacts including: settlement of in-place works; creep, i.e. lowering of design elevations over time; and failure or fracturing of the peat, which may cause peat mats to resurface.

Given that the remnants of levee structures around the perimeter of Franks Tract are former structures placed on a peat foundation, it should be evaluated whether these levee segments have a potential to work as retaining structures for placed materials, or whether they are too weak to take up foundation loads.

5.4. General Operational Constraints

In addition to site-specific constraints, there are several general restrictions for any construction activity. These constraints include but are not limited to:

5.4.1. Public Safety

Because material placement activities are usually carried out using a spread of construction equipment to transport and place materials, there is a risk to public safety. Construction should therefore be planned so as to minimize risks to the public. Also, knowing that Franks Tract SRA is an attractive location for fishing, jet skiing, any other recreational activities, public access must be limited to the project site during construction to ensure safety during construction.

5.4.2. Restrictions on Working Hours

Construction activities may require the use of large plant, economically suitable for 24-hour operation. However, potential impacts to the surrounding environment and nearby populated areas, may impose restrictions on working hours in order to limit noise levels, lighting during nighttime operations, and other similar issues. These limitations must be considered in cost estimation of the project.

5.4.3. Timing of Works

The contractor must consider the possibility of adverse weather conditions, fish spawning windows, and other times that construction activities can be limited or impossible. In General, it is recommended to time marine-based filling operations between spring to late fall. However, site-specific engineering constraints define the best timing for construction.

6. ROM Cost Estimates

The following sections provide cost estimates for restoration of Franks Tract based on sourcing of materials from 1) Decker Island, 2) Reusable Tunnel Material; and 3) Dredge material from deepening of the Port of Stockton Deepwater Channel. These sourcing alternatives are considered the most likely out of the sources listed in Table 3-1 and Table 3-2. The remaining source locations have been omitted because they are infeasible in terms of unit costs, material quantity is insufficient, materials are located too far from the project site, or are no longer available.

6.1. Quantities

Gross fill quantities for the primary project areas shown in Figure 1-2 are summarized in Table 6-1. The quantities account for the neat material placement volumes, including compensation for consolidation of the underlying peat.

Table 6-1: Gross quantities for project fill areas

Area	170 AC	61 AC	748 AC	Embankment	Total
Fill (cy)	2,394,000	696,000	10,706,000	2,058,000	15,854,000
Consolidation (cy)	505,000	158,000	2,119,000	478,000	3,260,000
Total (cy)	2,899,000	854,000	12,825,000	2,536,000	19,114,000

6.2. ROM Estimate Tools, Rates, Procedures and Assumptions

The HCSS cost estimating system was utilized to develop costs. The estimates are Rough Order of Magnitude (ROM) construction costs, corresponding to AACE Class 5 estimates, without costs for design and engineering.

6.2.1. Labor Rates and Working Schedule

West coast union labor rates were used as the basis for the labor cost. These rates are fully burdened. The estimate utilizes a 7 × 24 hour per week work week schedule with standard overtimes applied to the labor. The estimate utilizes a workmen’s comp rate that is over water work. The estimate used a 24-hour calendar for all operations.

6.2.2. Equipment Rates

Standard equipment rates for US work were used as a basis for the equipment costs, both rent and operations cost. The equipment rates are based on the 2016 Blue Book rates and local contractor equipment rates for marine equipment. The cost for diesel fuel used in the estimate was $3.00 per gallon.

6.2.3. Materials, Supplies, Subcontractors

6.2.3.1. Permanent Materials

The main fill material is the primary permanent material for the project. The rate used is based on past work.

6.2.3.2. Construction Supplies

Normal rates for construction supplies are based on west coast costs.

6.2.3.3. Subcontractors

No subcontractors are included in this ROM estimate.

6.2.4. Estimating Procedure

The estimate was performed by setting up bid items for all major items of work. Material Take-Offs (MTO's) were added to each of these items of work. This was further subdivided into individual work activities where crews of labor and equipment were added to perform the work along with an estimated production rate for the crew. Permanent materials, supplies, and subcontractors were also added to the activity. The production rates used for the crews are based on history, experience and estimates from similar projects.

6.2.5. Project Management Duration

A project schedule was developed that provides an approximate construction period of 6 years or 72 months. Therefore, the management and supervision was estimated at 72 months and is included in the detailed cost estimate.

6.3. General Approach and Costs for Executing the On-Site Work

6.3.1. Mobilization and Demobilization

6.3.1.1. Floating Equipment

It was assumed that local marine contractors will be utilized for dredging, rock bedding, and scour protection rock. The estimate allows three days to mobilize a marine contractor.

6.3.2. Material Sources

The sources used for the ROM estimate are listed in Table 3-1 except the sand dune deposits at Bradford Island and Webb Tract. These sources are not considered viable.

6.4. Decker Island

6.4.1. Description

Decker Island is a readily available source of materials for the project. Up until recently, DI Aggregates mined and sold materials for other levee projects in the Delta. A recent example of this is the Tyler Island Emergency Levee Repair project where material from Decker Island was mined, loaded on barges, transported and placed on Tyler to repair a levee slope failure. The primary material on Decker Island is dredge materials from past dredging projects although it is known that there are deep deposits of good coarse sand. The current status of Decker Island is that DI Aggregates has discontinued the mining operation, demobilized the mining equipment and conveyors and that the Island is for sale. However, the source remains available and for a project the size of Franks Tract, the mining operation could be remobilized, plant and loading operations set up. The activities necessary for a Decker Island operation as a source material for Franks Tract would be:

6.4.1.1. Remobilize the mining operation and load out conveyors

Upon award of the contract, Decker Island could be remobilized by transporting the plants, conveyors, trucks, loaders, generators and other support equipment. For a job this size, it would also be necessary to increase the plant and loading capacity. The current configuration of one conveyor and plant produces approximately 4,000 tons of aggregate per day. This could be increased up to 16,000 tons (10,000 cubic yards) per day with increased plant. Mine, process and load barges with source materials. Once the plant is remobilized, mining and loadout operations could once again produce fill materials.

6.4.1.2. Transport barges to Franks Tract

Barges will be loaded at Decker Island and then transported to offload at Franks Tract. For a project of this size, 4,000 ton hopper barges will be utilized to haul materials.

6.4.1.3. Dredge access for constructing berm

The first work activity will be to construct the berm. This will be accomplished by dredging a channel, approximately 75 foot wide to a bottom depth of 15 foot to allow the derrick and material barges to access the channel. The dredged material, which will be mostly peat, would be side cast and stockpiled within the fill material. The access channel will be excavated from the north to the south along the total length of the barrier. This will require approximately 3.15 million cubic yards of peat to be excavated.

6.4.1.4. Offload by crane barge

Once a channel is open on the east side of the barrier, crews can begin placing material on the barrier itself with a second derrick spread. Material will be transported from Decker Island and will be offloaded by a derrick/crane barge onto the barrier working from north to south.

6.4.1.5. Place fill material with LGP dozers & LGP hauling units

Once the barrier has been constructed, both derricks will move to locations where material can be offloaded from barges and spread by dozers, or as an alternative the material can be liquefied and pumped off to various locations.

6.4.2. Decker Island ROM Cost

ROM costs for material sourcing at Decker Island is summarized in Table 6-2.

Table 6-2: Decker Island ROM Costs

Item	Description	Quantity	Unit	Unit Price	Amount
1000	Mobilization	1	LS	$3,037,415	$3,037,415
2000	Procure Fill Mat'l and loadout @ Decker	19,114,000	CY	$19.66	$375,781,240
3000	Transport Material to Frank's Tract	19,115,000	CY	$7.24	$138,385,360
4000	Dredge Channel to Build Barrier	3,150,000	CY	$3.09	$9,733,500
5000	Offload Material by Derrick/Crane Barges	6,305,000	CY	$3.09	$19,482,450
6000	Offload Material with Pump and Pipe	12,614,000	CY	$2.66	$33,663,240
7000	Doze & Level Material	19,114,000	CY	$3.69	$70,530,660
	Total	19,114,000	CY	$34.03	$650,503,365

6.4.3. Decker Island ROM Cost Assumptions

The ROM cost estimate is based on the following assumptions:

1. Operation will be continuous from start to finish with no annual shutdowns due to environmental windows.
2. Operation will work on a 24 hour per day seven days per week.
3. The estimated price of procuring material and loading out from Decker Island is $11.00 per ton plus tax ($17.60 per cubic yard).
4. Dredging will be allowed within Franks Tract. No dredging permits will be required.
5. No costs are included for containment of sediments as they are placed.
6. No escalation is included in the above estimate.
7. No downtime for weather and environmental work windows is included.
8. No factor has been included for material losses due to bulking, erosion or other factors.

6.4.4. Projected Schedule

The above costs are based on loading and hauling 16,000 tons (4 barges) per day to Franks Tract and offloading. This is equivalent to 10,000 cy. Allowing for three months of preparation, setup and mobilization, the project will take 1,914 days to place the material. Including an allowance for holidays and weather, it is estimated that approximately six years will be needed to perform with work, without an allowance for environmental work windows.

6.5. Reusable Tunnel Material

6.5.1. Description

The California Department of Water Resources (DWR) Delta Habitat Conservation and Conveyance Program (DHCCP) is considering water conveyance through the Delta in a series of pipelines/tunnels. The pipelines/tunnels would transmit water from multiple on-bank intakes located between the towns of Freeport and Courtland to an intermediate forebay. The material that will be excavated from the tunnels will be stockpiled in four locations identified in Table 3.1. The total material volume that would be available for Franks Tract would be 23,790,000 cubic yards. One advantage of the tunnel material is the assumption that the material will be available at no cost at the tunnel material stockpile. The one disadvantage is the uncertainty of the schedule of the tunnel work.

6.5.2. Work plan

The tunnel materials would be deposited near rivers and channels that could be used to transport the material to Franks Tract. From the tunnel stockpile, the material would be loaded and hauled to the side of the channel where it will be offloaded. From there it will be conveyed onto barges. The barges would then be transported to Franks Tract where they are offloaded in the same manner as the materials from Decker Island. The plan would be to have loading operations simultaneously at three RTM locations. Each shift could load one barge. On a two- shift operation 2 barges at each location would be loaded and transported for a total of 24,000 tons (15,000 cy) per day. The activities necessary to sustain this operation are:

6.5.2.1. RTM tunnel materials stockpile

From the stockpile, load and haul material to a location where the materials can be stockpiled, then loaded into a conveyor that will put the material onto a barge. It is assumed that this material will not need to be processed and that it is suitable for conveyor.

6.5.2.2. Transport barges to Franks Tract

Loaded barges will be transported to offload at Franks Tract. For a project of this size, hopper barges will be utilized to haul materials.

6.5.2.3. Dredge access for constructing berm

The first work activity will be to construct the berm. This will be accomplished by dredging a channel, approximately 75-foot wide to a bottom depth of 15 foot to allow the derrick and material barges to access the channel. The dredged material, which will be mostly peat, would be side cast and stockpiled within the fill material. The access channel will be excavated from the north to the south along the total length of the barrier. This will require approximately 3.15 million cubic yards of peat to be excavated.

6.5.2.4. Offload by derrick/crane barge

Once a channel is open on the east side of the barrier, crews can begin placing material on the barrier itself with a second derrick spread. Material will be transported from Decker Island and will be offloaded by a derrick/crane barge onto the barrier working from north to south.

6.5.2.5. Place fill material with LGP dozers & LGP hauling units

Once the barrier has been constructed, both derricks will move to locations where material can be offloaded from barges and spread by dozers, or as an alternative the material can be liquefied and pumped off to various locations.

6.5.3. Reusable Tunnel Material ROM Cost

ROM costs for material sourcing based on reusable tunnel material is summarized in Table 6-3.

Table 6-3: Reusable Tunnel Material ROM Costs

Item	Description	Quantity	Unit	Unit Price	Amount
1000	Mobilization	1	LS	$3,120,000	$3,120,000
2000	Load & Haul Material from RTM sites	19,114,000	CY	$11.20	$214,076,800
3000	Transport Material to Frank's Tract	19,115,000	CY	$13.50	$258,039,000
4000	Dredge Channel to Build Barrier	3,150,000	CY	$3.09	$9,733,500
5000	Offload Material by Derrick/Crane Barges	6,305,000	CY	$3.09	$19,482,450
6000	Offload Material with Pump and Pipe	12,614,000	CY	$2.66	$33,553,240
7000	Doze & Level Material	19,114,000	CY	$3.69	$70,530,660
	Total	19,114,000	CY	$31.84	$608,535,650

6.5.4. Reusable Tunnel Material ROM Cost Assumptions

The ROM cost estimate is based on the following assumptions:

1. Operation will be continuous from start to finish with no annual shutdowns due to environmental windows.
2. Operation will work on a 24 hour per day seven days per week.
3. The RTM tunnel material will be available for no cost.
4. Sufficient tunnel material will be available at the time the Franks Tract work begins.
5. Dredging will be allowed within Franks Tract. No dredging permits will be required.
6. No costs are included for containment of sediments as they are placed.
7. No escalation is included in the above estimate.
8. No downtime for weather and environmental work windows is included.
9. No factor has been included for material losses due to bulking, erosion or other factors.

6.5.5. Projected Schedule

The above costs are based on loading and hauling 24,000 tons (6 barges) per day to Franks Tract and offloading. This is equivalent to 15,000 cy. Allowing for three months of preparation, setup and mobilization, the project will take 1,275 days to place the material. With an allowance for holidays and weather, it is estimated that approximately four years will be needed to perform with work, without an allowance for environmental work windows.

6.6. Dredging at Clifton Court Forebay and Stockton Ship Channel

6.6.1. Description

Two sources of fill material for Franks Tract is dredging at the Clifton Court Forebay and dredging the eastern section of the Stockton Ship Channel. The Clifton Court Forebay has 7,000,000 cubic yards of material available and the eastern reach of the Stockton ship channel has 15,000,000 cubic yards of material. Combined, they provide 22,000,000 cubic yards of material. The advantage of these two sources is that they are readily available and would be economical dredge and haul to Franks Tract. The major disadvantages are timing, schedule and permits.

6.6.1.1. Work Plan

Two dredges and scows would be mobilized to perform the dredging at each site. These would be 26 cubic yard clamshell dredges equipped with environmental buckets. Dredging would proceed and fill scows that would then be transported to Franks Tract and offloaded. Anticipated production would be approximately 4,000 tons (2,500 cy) per ten hour shift. Each dredge would have four scows in the rotation. Once being filled, one being transported to Franks Tract, one being unloaded, and one being returned to the dredge. On a two shift operation two barges at each location would be loaded and transported for a total of 16,000 tons (10,000 cy) per day. The activities necessary to sustain this operation are:

6.6.1.2. Transport barges to Franks Tract

Loaded barges will be transported to offload at Franks Tract. For a project of this size, 4,000 ton hopper barges will be utilized to haul materials.

6.6.1.3. Dredge access for constructing berm

The first work activity will be to construct the berm. This will be accomplished by dredging a channel, approximately 75 foot wide to a bottom depth of 15 foot to allow the derrick and material barges to access the channel. The dredged material, which will be mostly peat, would be side cast and stockpiled within the fill material. The access channel will be excavated from the east to the west along the total length of the barrier. This will require approximately 3.15 million cubic yards of peat to be excavated.

6.6.1.4. Offload by derrick/crane barge

Once a channel is open on the east side of the barrier, crews can begin placing material on the barrier itself with a second derrick spread. Material will be offloaded by a derrick/crane barge onto the barrier working from north to south.

6.6.1.5. Place fill material with LGP dozers & LGP hauling units

Once the barrier has been constructed, both derricks will move to locations where material can be offloaded from barges and spread by dozers, or as an alternative the material can be liquefied and pumped off to various locations.

6.6.2. Dredge Material ROM Cost

ROM costs for material sourcing based on dredge material is summarized in Table 6-4.

Table 6-4: Dredge Material ROM Costs

Item	Description	Quantity	Unit	Unit Price	Amount
1000	Mobilization	1	LS	$2,650,000	$2,650,000
2000	Load & Haul Material from Dredge Sites	19,114,000	CY	$7.30	$139,532,200
3000	Transport Material to Frank's Tract	19,115,000	CY	$5.30	$101,304,200
4000	Dredge Channel to Build Barrier	3,150,000	CY	$3.09	$9,733,500
5000	Offload Material by Derrick/Crane Barges	6,305,000	CY	$3.09	$19,482,450
6000	Offload Material with Pump and Pipe	12,614,000	CY	$2.66	$33,553,240
7000	Doze & Level Material	19,114,000	CY	$3.69	$70,530,660
	Total	19,114,000	CY	$19.71	$376,786,250

6.6.3. Dredge Material ROM Cost Assumptions

The ROM cost estimate is based on the following assumptions:

1. Operation will be continuous from start to finish with no annual shutdowns due to environmental windows.
2. Operation will work on a 24 hour per day seven days per week.
3. Dredging permits can be obtained.
4. Dredging will be allowed within Franks Tract. No dredging permits will be required.
5. No costs are included for containment of sediments as they are placed.
6. No escalation is included in the above estimate.
7. No factor has been included for material losses due to bulking, erosion or other factors.
8. No downtime for weather is included or environmental work window is included.
9. Dredging will occur simultaneously or back to back at both locations.

6.6.4. Projected Schedule

The above costs are based on loading and hauling 16,000 tons (4 barges) per day to Franks Tract and offloading. This is equivalent to 10,000 cy. Allowing for three months of preparation, setup and mobilization, the project will take 1,914 days to place the material. With an allowance for holidays and weather, it is estimated that approximately six years will be needed to perform with work, without an allowance for environmental work windows.

6.7. Dredging at Franks Tract with Decker Island Material for the Containment Berm and Offload Island

6.7.1. Description General Work Plan

The general work plan will be to obtain the majority of fill materials by dredging material from the south side of the containment berm. These materials will be dredged, hauled to an area where they can be offloaded, offloaded and pushed into the fill area. This area will be an island built adjacent to the eastern side of the containment berm of approximately five acres in size and will fill to an elevation of +6 or +7. This elevation will keep this area above the water line and stable enough to operate LGP dozers, excavators and LGP trucks in moving material from the offload area to a location where it can be dumped and dozed into the fill area.

6.7.1.1. Daily Operations

Daily operations will consist of dredging on the south side of the berm and hauling dredged material by hopper barge to the constructed unload island where it will be offloaded by a derrick barge. From there the dredged material will be pushed ahead into the marsh or once the distance requires, loaded into LGP trucks and hauled and dumped over the side. From there is will be dozed into the marsh.

6.7.1.2. Construction of the Berm and Island

The initial work will be to construct the containment berm using materials from Decker Island. The Decker Island materials will be dry and will allow the containment berm to be built without disappearing into the peat, mud, and water. Building the containment berm out of dredged materials will not produce a berm that can contain materials. Similarly, constructing the island where dredge materials can be delivered and offloaded will require materials with a dry consistency. This will provide a platform where the materials can be offloaded and handled.

6.7.1.3. Detailed Work Plan

One dredge dredging, one dredge offloading scows and three scows would be mobilized to perform the dredging at each site. These would be 26 cubic yard clamshell dredges equipped with environmental buckets. Dredging would proceed and fill scows that would then be transported to Franks Tract and offloaded. Anticipated production would be approximately 4,000 tons (2,500 cy) per ten hour shift. The dredge would have three scows in the rotation. After being filled one being transported to the offload area at Franks Tract, one being unloaded, and one being returned to the dredge. On a two shift operation two barges at each location would be loaded and transported for a total of 16,000 tons (10,000 cy) per day. The activities necessary to sustain this operation are:

6.7.1.4. Transport barges to Franks Tract

Loaded barges will be transported to offload at Franks Tract. For a project of this size, 4,000 ton hopper barges will be utilized to haul materials.

6.7.1.5. Dredge access for constructing berm

The first work activity will be to construct the berm. This will be accomplished by dredging a channel, approximately 200 foot wide to a bottom depth of 18 foot to allow the derrick and material barges to access the channel. The dredged material, which will be mostly peat, would be side cast and stockpiled within the fill material. The access channel will be excavated from the east to the west along the total length of the barrier. This will require approximately 3.15 million cubic yards of peat to be excavated.

6.7.1.6. Offload by derrick/crane barge

Once a channel is open on the east side of the barrier, crews can begin placing material on the barrier itself with a second derrick spread. Material will be offloaded by a derrick/crane barge onto the barrier working from north to south.

6.7.1.7. Place fill material with LGP dozers & LGP hauling units

Once the barrier has been constructed, both derricks will move to locations where material can be offloaded from barges and spread by dozers, or as an alternative the material can be liquefied and pumped off to various locations.

6.7.2. Dredging Franks Tract Material ROM Cost

ROM costs for material sourcing based on dredge material is summarized in Table 6 4.

Table 6-5: Dredge Material ROM Costs

Item	Description	Quantity	Unit	Unit Price	Amount
1000	Mobilization	1	LS	$3,037,415	$3,037,415
2000	Procure Material and loadout @ Decker	1,200,000	CY	$19.66	$23,592,000
3000	Transport Material DI to Frank's Tract	1,200,000	CY	$7.24	$8,688,000
4000	Dredge Channel for access to Build Barrier and Dredge fill for Placement north of containment barrier	19,114,000	CY	$3.09	$59,062,260
5000	Offload Material by Derrick/Crane Barges	19.114,000	CY	$3.09	$59,062260
6000	Haul Material from Franks Tract	19,114,000	CY	$2.66	$50,843,240
7000	Doze, Haul & Level Material	19,114,000	CY	$5.76	$110,096,640
	Total	19,114,000	CY	$16.45	$314,381,817

6.7.3. Dredge Material ROM Cost Assumptions

The ROM cost estimate is based on the following assumptions:

1. Operation will be continuous from start to finish with no annual shutdowns due to environmental windows.
2. Operation will work on a 24 hour per day seven days per week.
3. Dredging permits can be obtained.
4. Dredging will be allowed within Franks Tract. No dredging permits will be required.
5. No costs are included for containment of sediments as they are placed.
6. No escalation is included in the above estimate.
7. No factor has been included for material losses due to bulking, erosion or other factors.
8. No downtime for weather is included or environmental work window is included.

6.7.4. Projected Schedule

The above costs are based on loading and hauling 10,000 cy (3 barges) per day to Franks Tract and offloading. This is equivalent to 10,000 cy. Allowing for three months of preparation, setup and mobilization, the project will take 1,914 days to place the material. With an allowance for holidays and weather, it is estimated that approximately six years will be needed to perform with work, without an allowance for environmental work windows.

6.8. ROM Cost Summary and Conclusions

The ROM cost estimate has presented three scenarios for providing and placing fill for Franks Tract. Following is a summary table that presents each scenario and outlines the advantages and disadvantages of each.

Table 6-6: Summary of units costs and ROM costs

Source	Unit Cost (cy)	ROM Cost Estimate
Decker Island	$34.03	$650,530,365
Reusable Tunnel Material	$31.85	$608,535,650
Stockton DWSC Dredge Material	$19.72	$376,786,250
Franks Tract Dredge Material	$16.45	$314,381,817

Dredging of the south side of Franks Tract and using materials from DI present the lowest cost alternative. This is primarily due to obtaining the material at no cost for the material and nearby resulting in a lower cost haul. However, the majority of the material being dredged is peat and when handled could lose water, integrity and mass. In that case, a lot of peat would be handled and not provide consistent fill material. More dredging would be required to move the peat and then get dredge materials to complete the fill on the north side of the containment berm. This has not been considered in the above cost. The other disadvantage to this scenario is that pumping this dredged material (peat) is not feasible and crews of loaders, trucks, backhoes, and dozers will be needed to get the dredged material into final position. The assumption is that after a while, the material consolidates enough to operate LGP equipment.

The dredge materials from the Clifton Court Forebay and the Stockton Ship Channel present the second lowest cost alternative. This is primarily due to obtaining the material at no cost for the material. This option would be a win-win for getting the dredging performed and for getting fill for Franks Tract at the same time. The primary disadvantage will be obtaining dredging permits and observing environmental windows during the dredging cycle. This will significantly lengthen the performance period for filling Franks Tract and will result in several mobilizations and demobilizations for the dredges.

The materials from the proposed tunnel project is the third best option in terms of total cost. For this option it is assumed that the tunnel materials will be available at no cost other than loading and hauling it. As with the dredge materials this option would also be a win-win for both the tunnels and the Franks Tract fill. The disadvantage for this option is the probability of the tunnel project proceeding at some time in the future. At present, this source material is not the best candidate.

The highest cost option is the Decker Island fill source. This is primarily due to the cost of obtaining fill material from the source. The big advantage to Decker is that the material is readily available and the plant that was previously dismantled and moved from the island could be remobilized and put back into operation. The biggest disadvantage to Decker is the purchase cost of the material. However, with a project of this size, the price could be reduced with guarantees of the amount of volume that will be sold.

7. References

AQEA (2014). *Multi-Purpose Planning Evaluation for Phase II of the San Francisco Bay to Stockton Navigation Improvement Study.* Prepared for: Port of Stockton, 2201 West Washington Street, Stockton, CA 95203. Prepared by: Anchor QEA, LLC, 130 Battery Street, Suite 400, San Francisco, CA 94111. Project Partners: WSPA, California Contra Costa County. April, 2014.

CEM (2002). *Coastal Engineering Manual.* Engineer Manual: EM 1110-2-1100. U.S. Army Corps of Engineers, 30 April 2002.

CDEC (2016). *California Data Exchange Center*. Department of Water Resources, 1416 9th Street, Sacramento, CA 95814. http://cdec.water.ca.gov/index.html

CNRA (2016). *California Waterfix, Reliable Clean Water.* Bay Delta Conservation Plan. Alternative 4A. California Natural Resources Agency, 1416 9th Street, #1311. Sacramento, CA 95814.

DWR (2012). *A Continuous Surface Elevation Map for Modeling (Chapter 6).* In *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 23rd Annual Progress Report to the State Water Resources Control Board.* Wang, R. & Ateljevich, E., California Department of Water Resources, Bay-Delta Office, Delta Modeling Section (2012).

DWR (2017). *Hydrodynamic Modeling in Support of Franks Tract Restoration Feasibility Study, Delta Resilience Strategy.* Eli Ateljevich PE, PhD, Kijin Nam PE, PhD, Bay-Delta Office, Delta Modeling Section, Department of Water Resources (2017).

FEMA (2016). *FEMA Flood Map Service Center.* https://msc.fema.gov/portal. Official website of the Department of Homeland Security.

Hestir et al. (2008). *Identification of Invasive Vegetation Using Hyperspectral Remote Sensing in the California Delta Ecosystem.* Hestir, Erin & Khanna, Shruti & E. Andrew, Margaret & Santos, Maria & H. Viers, Joshua & Greenberg, Jonathan & S. Rajapakse, Sepalika & Ustin, Susan. (2008). Remote Sensing of Environment. 112. 4034-4047. 10.1016/j.rse.2008.01.022.

HLA (1990). *Geotechnical Investigation. Franks Tract State Recreation Area, Contra Costa County, California.* Prepared by Harding Lawson Associates, 1355 Willow Way, Suite 109. Concord, California 94520. Prepared for Moffatt & Nichol Engineers, 3000 Citrus Circle, Suite 230. Walnut Creek, California 94598. December 1990.

HTE (1999). *Restoration Islands.* Geotechnical Engineering Services. Franks Tract State Recreation Area, Contra Costa County, California. Prepared by Hultgren-Tillis Engineers. Project No. 336.01. December 20, 1999.

HWF (2017). *Appraisal Report of Milpitas Main Street Investment, LLC Surface & Open Pit Mining Operation, Decker Island, Solano County, California.* Prepared for: Bender Rosenthal, Inc. and Department of Water Resources. Prepared by: Harold W. Bertholf, Inc., Appraisers, Engineers, 1601 Executive Court, Suite 1, Sacramento, CA 95864-2607. February 14, 2017.

NHC (2003). *Sources and availability of fill material for subsidence reversal in the Sacramento-San Joaquin Delta.* Northwest Hydraulic Consultants. 22 April, 2003.

NOAA (2009). *Sacramento and San Joaquin Rivers.* Navigation Chart 18661. Mercator Projection, Scale 1:40,000 at Lat. 38° 25'. North American Datum of 1983 (World Geodetic System 1984). Soundings in feet at Mean Lower Low Water, Height in feet above Mean High Water. 30th Edition, Mar. 2009.

NOAA (2016). *Tides & Currents.* Center for Operational Oceanographic Products and Services (CO-OPS), 1305 East-West Highway, Silver Spring, MD 20910-3281. https://tidesandcurrents.noaa.gov/

NWS (2016). *National Weather Service.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration. National Weather Service, 1325 East West Highway, Silver Spring, MD 20910.

UCD (2016). *2015 Estimate of SAV & FAV based on preliminary data AVIRIS-NG imagery.* Dr. Shruti Khanna, Center for Spatial Technologies and Remote Sensing, Department of Land, Air and Water Resources (CSTARS). University of California, Davis.

URS (2014). *Reusable Tunnel Material Testing Report.* Delta Habitat Conservation and Conveyance Program. Standard Agreement 4600008104, Task Order WGI 14. Prepared for: State of California Department of Water Resources, Division of Engineering, 1416 9th Street, Room 510, Sacramento, CA 95814. Prepared by: URS, 2870 Gateway Oaks Drive, Suite 150, Sacramento, CA 95833. In association with: California Department of Water Resources, Delta Habitat Conservation & Conveyance Program. March, 2014.

USDA (2007). *National Engineering Handbook, Part 654 - Stream Restoration Design.* Chapter 8: Threshold Channel Design. United States Department of Agriculture. Natural Resources Conservation Service. Issued August 2007.

USGS (1978). *Jersey Island, California.* 7.5 Minute Series (Topographic). SW/4 Rio Vista 15' Quadrangle. N3800-W12137.5/7.5. AMS 1660 II SW – Series V895. United States Department of the Interior, Geological Survey. Scale 1:24,000. Contour interval 10 feet.

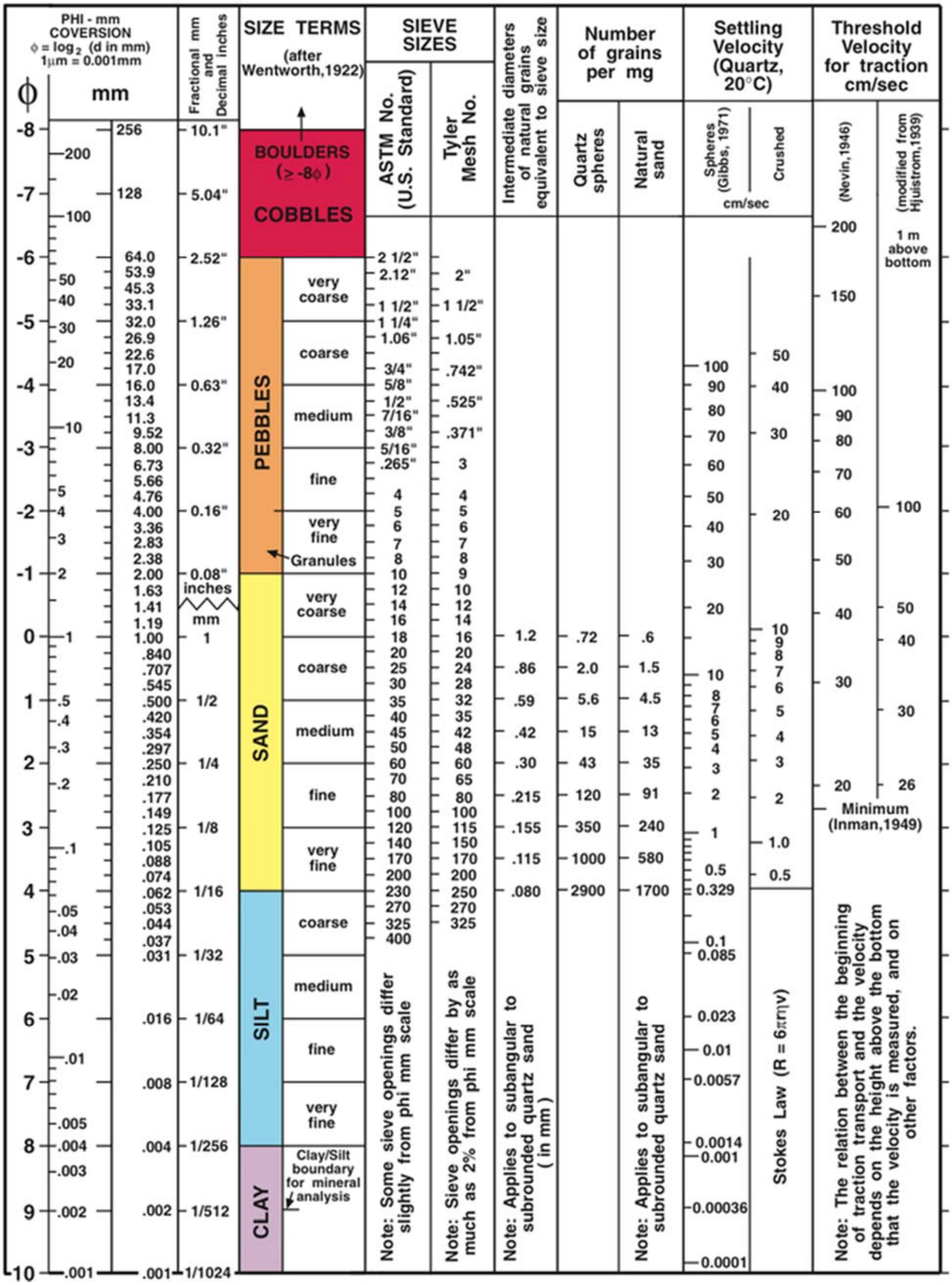
USGS (1982). *Geologic maps of the Sacramento-San Joaquin Delta, California.* Atwater, B.F., USGS Numbered Series. Miscellaneous Field Studies Map MF-1401. Pamphlet: 15 p.; 21 Sheets. Scale 1:24,000. U.S. Government Printing Office, Washington, D.C.

USGS (1997). *Bouldin Island, California.* 7.5 Minute Series (Topographic). NIMA 1660 SE-Series V895. U.S. Department of the Interior, U.S. Geological Survey. Scale 1:24,000. Contour interval 5 feet.

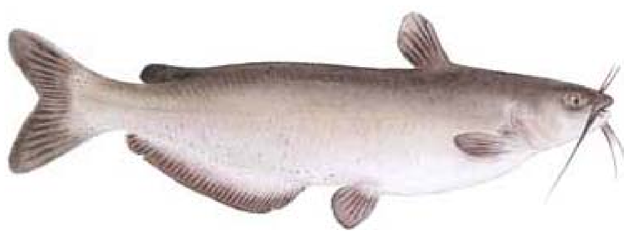
Ustin et al. (2016). *Impact of drought on Submerged Aquatic Vegetation (SAV) and Floating Aquatic Vegetation (FAV) using AVIRIS-NG airborne imagery.* Ustin, S,. Khanna S, Bellvert J, Boyer JD, Shapiro K. 2016. California Department of Fish and Wildlife (2016).

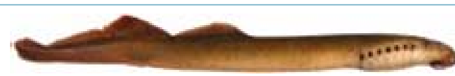
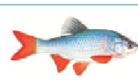
Appendix A – Wentworth Scale

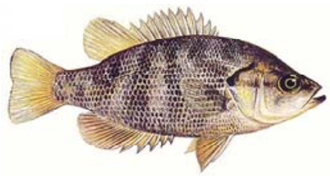
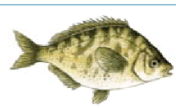
Grade and class terms for clastic sediments.


PHI - mm COVERSION
ϕ = log2 (d in mm)
1μm = 0.001mm
ϕ
mm
Fractional mm and Decimal inches
SIZE TERMS
(after Wentworth,1922)
SIEVE SIZES
ASTM No. (U.S. Standard)
Tyler Mesh No.
Intermediate diameters of natural grains equivalent to sieve size
Number of grains per mg
Quartz spheres
Natural sand
Settling Velocity (Quartz, 20°C)
Spheres (Gibbs, 1971)
Crushed
cm/sec
Threshold Velocity for traction cm/sec
(Nevin,1946)
(modified from Hjuistrom,1939)
1 m above bottom
BOULDERS (≥-8ϕ)
COBBLES
PEBBLES
very coarse
coarse
medium
fine
very fine
Granules
SAND
very coarse
coarse
medium
fine
very fine
SILT
coarse
medium
fine
very fine
CLAY
Clay/Silt boundary for mineral analysis
Minimum (Inman,1949)
Note: Some sieve openings differ slightly from phi mm scale
Note: Sieve openings differ by as much as 2% from phi mm scale
Note: Applies to subangular to subrounded quartz sand (in mm)
Note: Applies to subangular to subrounded quartz sand
Stokes Law (R = 6πrηv)
Note: The relation between the beginning of traction transport and the velocity depends on the height above the bottom that the velocity is measured, and on other factors.

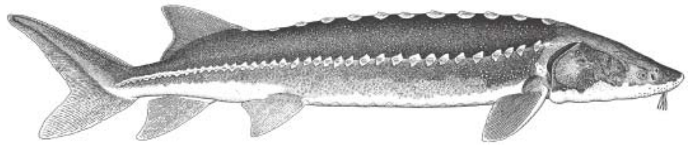
Appendix B – Species of Fish in Vicinity of Franks Tract

Common Name ***Genus and Species***	**Identification**
American Shad *Alosa sapidissima*	
Bigscale Logperch *Percina macrolepida*	
Black Bullhead *Ameiurus melas*	
Black Crappie *Pomoxis nigromaculatus*	
Bluegill *Lepomis macrochirus*	
Brown Bullhead *Ameiurus nebulosus*	
Channel Catfish *Ictalurus punctatus*	
Rainbow Trout *Oncorhynchus mykiss irideus*	

Common Name ***Genus and Species***	**Identification**
Common Carp *Cyprinus carpio*	
Delta Smelt *Hypomesus pacificus*	
Golden Shiner *Notemigonus crysoleucas*	
Goldfish *Carassius auratus*	
Green Sunfish *Lepomis cyanellus*	
Hardhead *Mylopharodon conocephalus*	
Threespine Stickleback *Gasterosteus aculeatus microcephalus*	
Largemouth Black Bass *Micropterus salmoides*	
Longfin Smelt *Spirinchus thaleichthys*	
Mississippi Silverside *Menidia Audens*	
Pacific Lamprey *Entosphenus tridentata*	
Prickly Sculpin *Cottus asper*	
Red Shiner *Cyprinella lutrensis*	
Redear Sunfish *Lepomis microlophus*	

Common Name ***Genus and Species***	**Identification**
River Lamprey *Lampetra ayresii*	
Sacramento Blackfish *Orthodon microlepidotus*	
Sacramento Hitch *Lavinia exilicauda exilicauda*	
Sacramento Perch *Archoplites interruptus*	
Sacramento Pikeminnow *Ptychocheilus grandis*	
Sacramento Splittail *Pogonichthys macrolepidotus*	
Sacramento Sucker *Catostomus occidentalis occidentalis*	
Sacramento Tule Perch *Hysterocarpus traskii traskii*	
Smallmouth Bass *Micropterus dolomieu*	
Green Sturgeon *Acipenser medirostris*	

Common Name ***Genus and Species***	**Identification**
Spotted Bass *Micropterus punctulatus*	
Staghorn Sculpin *Leptocottus armatus*	
Starry Flounder *Platichthys stellatus*	
Striped Bass *Morone saxatilis*	
Threadfin Shad *Dorosoma petenense*	
Wakasagi Smelt *Hypomesus nipponensis*	
Warmouth *Lepomis gulosus*	
Mosquitofish *Gambusia affinis*	
White Catfish *Ameiurus catus*	
White Crappie *Pomoxis annularis*	

Common Name ***Genus and Species***	**Identification**
White Sturgeon *Acipenser transmontanus*	
Yellowfin Goby *Acanthogobius flavimanus*	

Source: www.fishbase.org

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