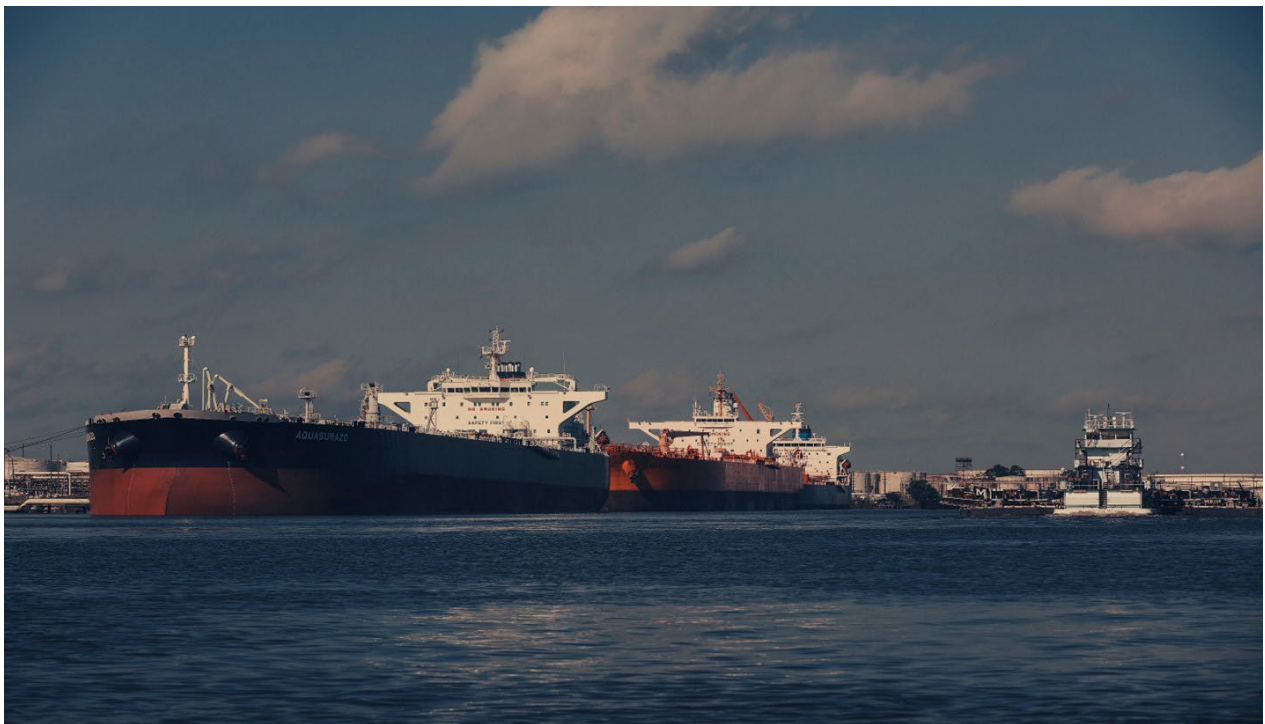


Sabine Neches Navigation Improvement Project Integrated Section 203 Feasibility Report and Environmental Assessment

Appendix A Engineering



*Prepared by HDR Engineering, Inc.
TBPELS Firm Registration No. F-754*

February 2026

FEASIBILITY STUDY

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DATE: 11/19/2025

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Acronyms and Abbreviations

AB4	Anchorage Basin No. 4
AdH	Adaptive Hydraulics
ADV	Acoustic Doppler Velocimeters
AIS	Automatic Identification System
AM	Advance Maintenance
AOD	Allowable Overdepth
BHE	Bessie Heights East
BU	Beneficial Use
CU	Consolidated-Undrained
CY	Cubic Yard
DHI	Danish Hydraulics Institute
DMMP	Dredged Material Management Plan
DO	Dissolved Oxygen
DTM	Digital Terrain Model
DWT	Deadweight Tonnage
EC	Existing Conditions
ERDC	Engineer and Research Development Center
FEIS	Final Environmental Impact Statement
FM	Flexible Mesh
ft	Feet
Fugro	Fugro USA Land, Inc.
FWOP	Future Without Project
FWP	Future With Project
FWPFB	Future With Project Full Build
GIWW	Gulf Intracoastal Waterway
HD	Hydrodynamic
HDR	HDR Engineering, Inc.
HTRW	Hazardous, Toxic, and Radioactive Waste
kn	Knot
LOA	Length Overall
MLLW	Mean Lower Low Water
MLT	Mean Low Tide
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1930
NRC	Neches River Channel
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations & Maintenance
ORC	Old River Cove
PA	Placement Area

PED	Preconstruction Engineering and Design
RCE	Rose City East
RMSE	Root Mean Square Error
RSLC	Relative Sea Level Change
RTK	Real-Time Kinematic
SNC	Sabine-Neches Canal
SNND	Sabine-Neches Navigation District
SNWW	Sabine-Neches Waterway
SPT	Standard Penetration Tests
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TCOON	Texas Coastal Ocean Observation Network
TPWD	Texas Parks and Wildlife Department
TSP	Tentatively Selected Plan
TSPCS	Texas State Plane Coordinate System
UC	Unconfined Compression
USACE	U.S. Army Corps of Engineers Galveston District
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
UU	Unconsolidated-Undrained
VDatum	Vertical Datum Transformation

ATTACHMENTS

Note – All attachments to this report are included as separate PDFs.

- Attachment 1 – Ship Simulation Report
- Attachment 2 – Engineering Drawings
- Attachment 3 – Tidal Circulation Modeling Report
- Attachment 4 – Storm Surge Modeling Report
- Attachment 5 – Vessel Effects Modeling Report
- Attachment 6 – Water Quality Modeling Report
- Attachment 7 – HTRW Report
- Attachment 8 – Cost Report

1 Introduction

The Sabine-Neches Waterway (SNWW) provides a valuable avenue for waterborne commerce to transit between the Gulf of America and the inland ports. The Sabine-Neches Navigation District (SNND) is conducting a study of potential channel improvements to the SNWW to be used for preparing a Section 203 Integrated Feasibility Report and appropriate environmental analyses. A separate United States Army Corps of Engineers (USACE) channel improvement project (“deepening”) is currently under construction to reconfigure and deepen portions of the existing channel and allow expanded vessel sizes. In 2011, a final environmental impact statement (FEIS) and feasibility report were completed to present an evaluation of potential impacts of the deepening project. The purpose of this new evaluation is to examine measures to widen various reaches of the navigation channel to increase vessel traffic efficiency and navigation safety along the SNWW (“widening”).

The federal channel along the waterway is currently being deepened from -40 ft MLLW to -48 ft MLLW; however, the ongoing deepening project does not widen the channel and current navigation restrictions due to channel width will remain in effect after the channel is deepened. The channel is currently 400 ft wide in the Sabine-Neches Canal (SNC) and the Neches River Channel (NRC) reaches. The navigation restrictions required for a 400-ft-wide channel (daylight only transits and no meeting for thousands of vessels) combined with the increasing number of vessels transiting the waterway is the cause of substantial congestion and vessel delays. The purpose of this study is to investigate navigation improvements to reduce delays and maximize the navigational opportunities along the waterway.

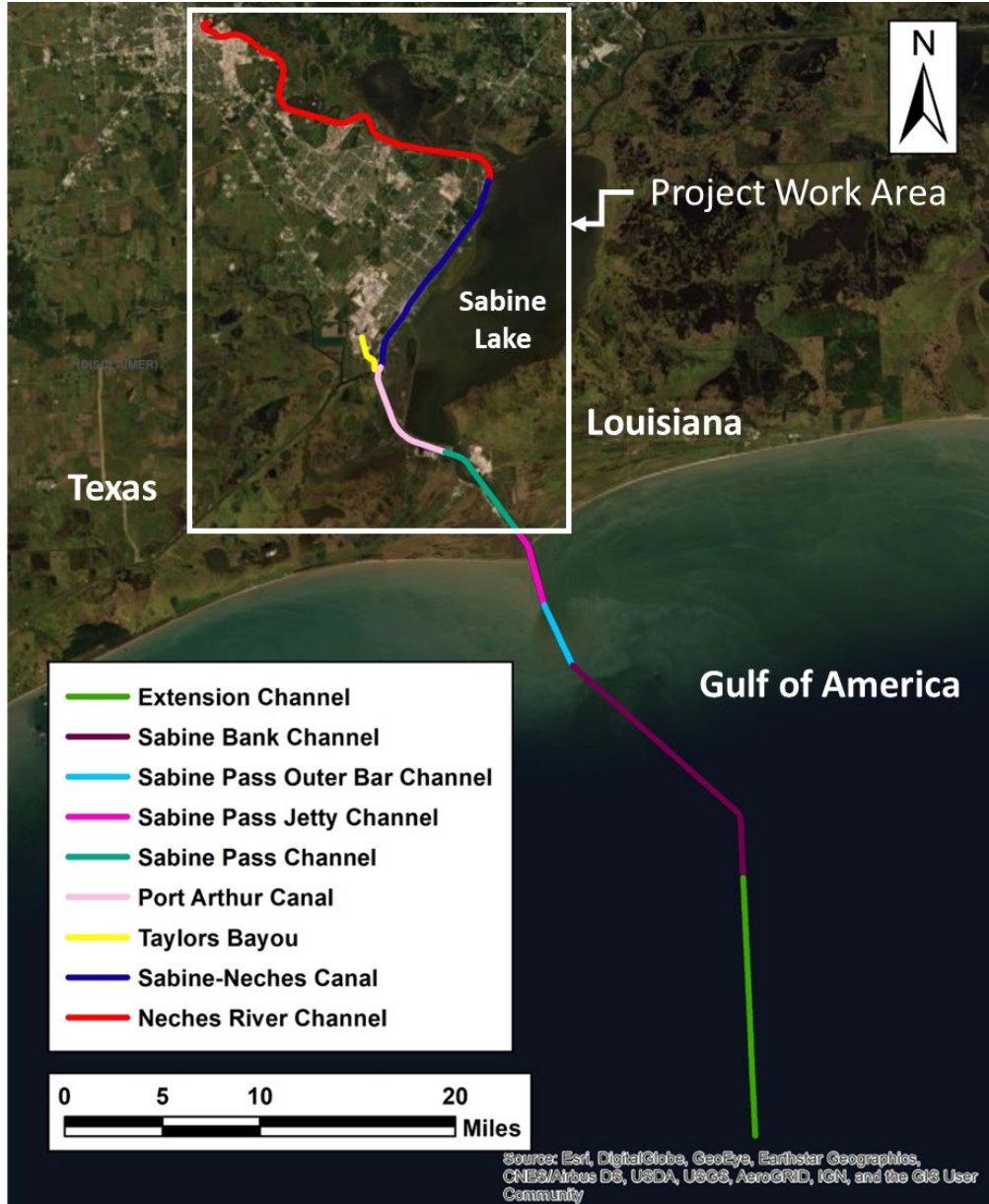
Vessel maneuvering simulations were performed to evaluate preliminary alternatives for the widening project. Improvement concepts were considered along both the main channel and anchorage basins. The concepts were developed to a level suitable for preliminary screening, including conceptual-level analyses of potential costs; dredged material placement area identification and capacity; and real estate and environmental impacts.

Data developed for feasibility analysis, design, and construction of the deepening project have been applied to the widening project to the extent practicable. Evaluations included gathering, compiling, and assessing readily available bathymetric, geophysical, and topographic survey data; aerial photography; and navigation charts that serve as the basis for evaluating channel alignment and geometry. This information was also applied to help identify and avoid potential interferences and conflicts with existing improvements adjacent to the channel including docks, bulkheads, shoreline protection, roads, buildings, dredged material placement areas, and other existing infrastructure. Additional field data gathered for this study included drawdown and return current data for calibration and validation of the vessel effects modeling and water quality field measurements of salinity, temperature, pH, and dissolved oxygen (DO).

2 Civil Design Investigation

2.1 Project Background

The channel widening study area is generally located within the SNWW on the west side of Sabine Lake in Texas as shown in Figure 2-1. The SNWW is authorized to 48 ft deep and is 63.8 miles long, extending from the Gulf of America to the Beaumont Maneuvering Basin.



**Figure 2-1
Project Location Map**

The SNWW will be deepened to an authorized depth of 48 ft (inshore channel reaches) and 50 ft (offshore channel reaches) as part of the channel improvement (deepening) project (USACE 2011). The deepening project will extend the offshore channel reaches an additional 13 miles offshore. Within the context of this report the deepened channel without widening will be referred to as the “future without project” (FWOP) condition, and the proposed channel widening improvements will be referred to as the “future with project” (FWP) condition (Table 2-1). No additional channel deepening is being considered for the FWP condition.

**Table 2-1
Channel Condition Terminology**

Future Without Project (FWOP)	=	authorized channel deepening
Future With Project (FWP)	=	proposed channel widening improvements

Each channel reach of the SNWW is listed below, and the FWOP channel dimensions are listed in Table 2-2. Neither the SNC Section B, also known as the channel to Orange, Texas, nor the NRC upstream of the Beaumont Maneuvering Basin, was included in this study.

2.1.1 Extension Channel

The Extension Channel is in the process of being constructed as part of the FWOP to an authorized depth of 50 ft. This will lengthen the overall channel by 13.2 miles offshore from Station -117+072 to -186+800.1

2.1.2 Sabine Bank Channel

Sabine Bank Channel is approximately 14.8 miles and connects the Sabine Extension Channel to the Sabine Pass Outer Bar between Stations -117+072 and -39+430. It will be constructed to an authorized depth of 50 ft as part of the FWOP.

2.1.3 Sabine Pass Outer Bar

Sabine Pass Outer Bar is 3.1 miles long, extending from Station -39+430 to -23+000. It will be constructed to an authorized depth of 50 ft as part of the FWOP.

2.1.4 Sabine Pass Jetty Channel

Sabine Pass Jetty Channel extends the entire length of the jetties, 4.3 miles from Station -23+000 to 0+000. The channel width gradually tapers the entire length, from 500 ft at the inshore end to 800 ft at the offshore end. The Sabine Pass Jetty Channel will be dredged to an authorized depth of 48 ft (remainder of SNWW inshore of the Sabine Pass Jetty Channel will be deepened to an authorized depth of 48 ft).

2.1.5 Sabine Pass Channel

Sabine Pass Channel begins just north of the jetty and extends 5.6 miles upstream to Mesquite Point on Pleasure Island from Station 0+000 to 29+625.

¹ The offshore station of the FWOP will be updated during E&D based on the location of the natural 50 ft depth contour.

2.1.6 Port Arthur Canal

Port Arthur Canal begins near Mesquite Point on Pleasure Island and extends 6.2 miles upstream to the junction area with Taylor Bayou from Station 29+625 to 62+235. The Junction Area serves as a turning basin and has an irregular shape. The Taylor Bayou channels join the Port Arthur Canal at the junction area. The Gulf Intracoastal Waterway (GIWW) (west access) merges with the SNWW within the junction area.

2.1.7 Taylor Bayou

Taylor Bayou consists of several sub-reaches: Entrance Channel, East Turning Basin, West Turning Basin, Connecting Channel, and Taylor Bayou Turning Basin. The Entrance Channel is also referred to as Port Arthur Entrance Channel, and the East and West Turning Basins are also referred to as Port Arthur East and West Turning Basins. Throughout this report, they will be referenced as being within the Taylor Bayou area. There is no downstream-current in this reach because the original Taylor Bayou was plugged and diverted. The West Turning Basin bottlenecks into the Connecting Channel, which terminates into the Taylor Bayou Turning Basin.

2.1.8 Sabine-Neches Canal (SNC)

Sabine-Neches Canal runs between Port Arthur area and Pleasure Island and is 11.2 miles long from Station 62+235 to 121+517. The GIWW merges with the SNWW within this reach.

2.1.9 Neches River Channel (NRC)

The Neches River Channel begins just south of the confluence of the Neches and Sabine Rivers and extends 18.6 miles north to Beaumont, Texas from Station 00+00 to 1037+32. The GIWW (east access) follows the Sabine River and leaves the SNWW at Station 30+00.

**Table 2-2
FWOP Channel Dimensions**

Reach Description	Stations		FWOP Channel Bottom Width ^[2]	Authorized Project Depth ^[3]	Channel Dimensions, ft			
	From	To			O&M Template		New Work Template	
					Advance Maintenance Depth	Allowable Overdepth	Contract Required Depth ^[4]	Contract Allowable Overdepth (total depth)
Extension Channel	-186+800	-117+072	700	50	52	54	53	54
Sabine Bank Channel	-117+072	-81+400	700	50	53	55	54	55
	-81+400	-74+400	700	50	52	54	53	54
	-74+400	-39+430	700-1101	50	54	56	55	56
Sabine Pass Outer Bar Channel	-39+430	-23+000	800	50	54	56	55	56
Sabine Pass Jetty Channel	-23+000	-21+413	800	50	54	56	55	56
Sabine Pass Channel	0+000	10+000	500	48	50	52	51	52
	10+000	29+625	500-1154	48	53	55	54	55
Port Arthur Canal	29+625	57+500	500	48	51	52	52	53
	57+500	62+235	500-1660	48	55	56	56	57
Sabine-Neches Canal	62+235	66+235	1035-435	48	52	53	53	54
	66+235	121+517	435-400	48	51	52	52	53
	0+00	75+00	500	48	52	54	53	54
	75+00	155+00	500-400	48	52	53	53	54
	155+00	345+00	400	48	51	52	52	53
Neches River Channel	345+00	510+00	400-600	48	52	53	53	54
	510+00	645+00	423-400	48	51	52	52	53
	645+00	680+00	400	48	52	53	53	54
	680+00	730+00	400	48	51	52	52	53
	730+00	980+00	400-1170	48	52	53	53	54
Taylor Bayou								
Entrance Channel	0+00	25+27	853-435	48	55	56	56	57
East Turning Basin	0+00	18+47	596-370	48	53	54	54	55
West Turning Basin	25+27	41+30	590-265	48	55	56	56	57
Connecting Channel	41+30	71+50	210-1245	48	51	52	52	53
Taylor Bayou Turning Basin	71+50	105+50	1245-50	48	51	52	52	53

Notes:

- 1) Dimensions in this table represent the FWOP conditions associated with the authorized channel deepening currently under construction.
- 2) Where a range of bottom widths are shown, this range represents the minimum and maximum bottom widths within the designated reach.
- 3) Values listed under "Authorized Project Depth" do not include advance maintenance or allowable overdepth.
- 4) For the FWOP new work template, advance maintenance was increased by 1 ft as compared to the O&M template to account for "hard" material that may be encountered while performing new work dredging (in accordance with ER 1130-2-520).

2.2 Site Selection and Project Development

This section describes the widening features considered during project development including the initial widening concepts, preliminary and final alternatives, and the Tentatively Selected Plan (TSP). For details on plan formulation, refer to Section 4 of the main report.

2.2.1 Initial Widening Concepts

Figure 2-2 presents an overall site plan of the widening concepts, with the channel segments that were initially considered for widening designated by color. Note that channel widening for the offshore channels was not evaluated in this analysis because the FWOP channel is sufficiently wide (700 ft minimum width) for vessel meeting. These channel segments and the associated widening features are summarized in Table 2-3 and described in more detail below. Figure 2-3 through Figure 2-8 provide cross-sections of the widening measures considered for these channel segments.

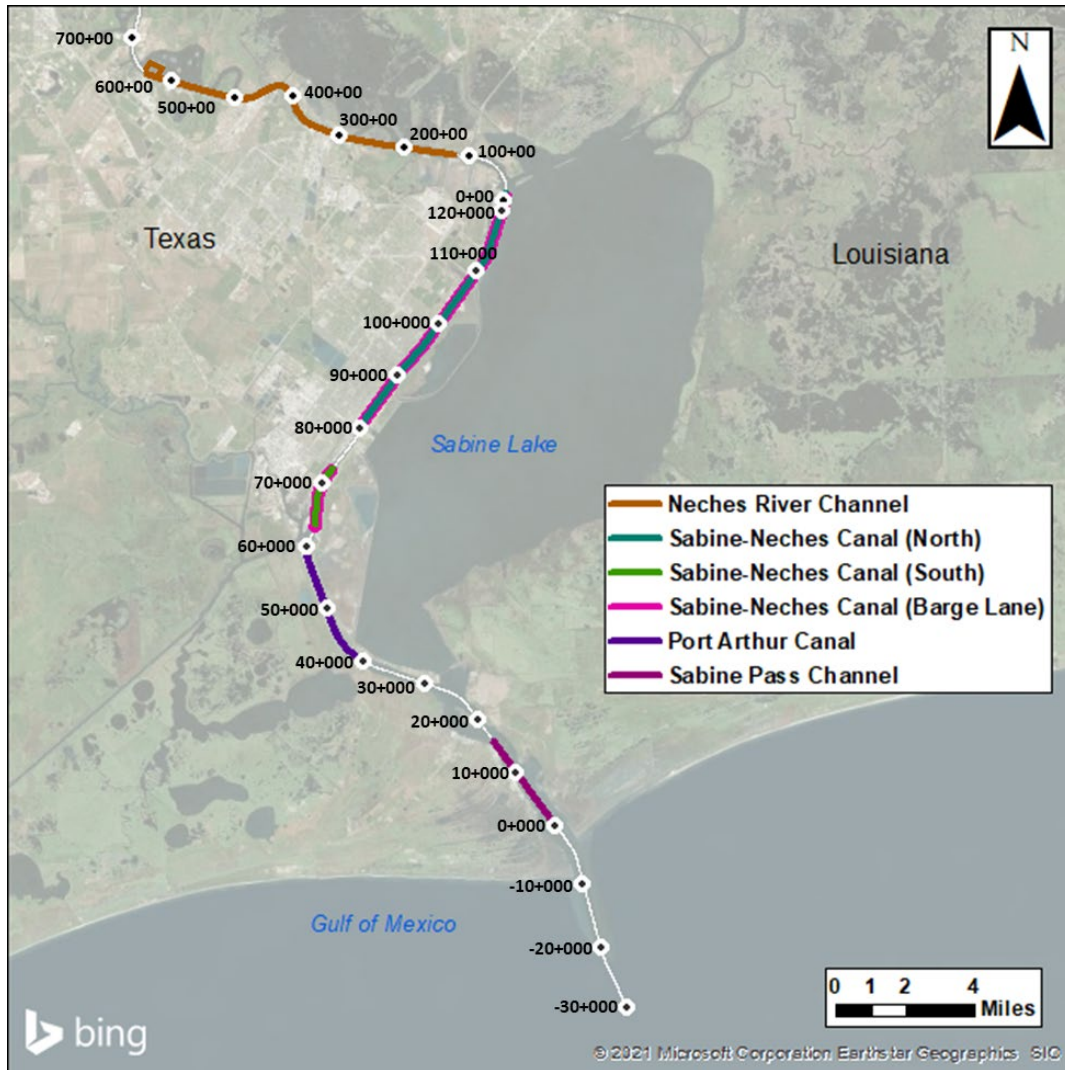


Figure 2-2
Channel Segments Considered for Widening during Initial Plan Formulation

Sabine Pass Channel

Two channel widening concepts were considered for the Sabine Pass Channel (Station 0+150 to 15+990) where the FWOP channel bottom width is 500 ft. Widening concepts were considered for 100 ft (600 ft total width) and 200 ft (700 ft total width) increases. Both concepts would widen the channel symmetrically on each side of the channel. Refer to Figure 2-3 for the typical channel cross-sections considered along the Sabine Pass Channel. The Sabine Pass Channel widening was not selected as part of the TSP.

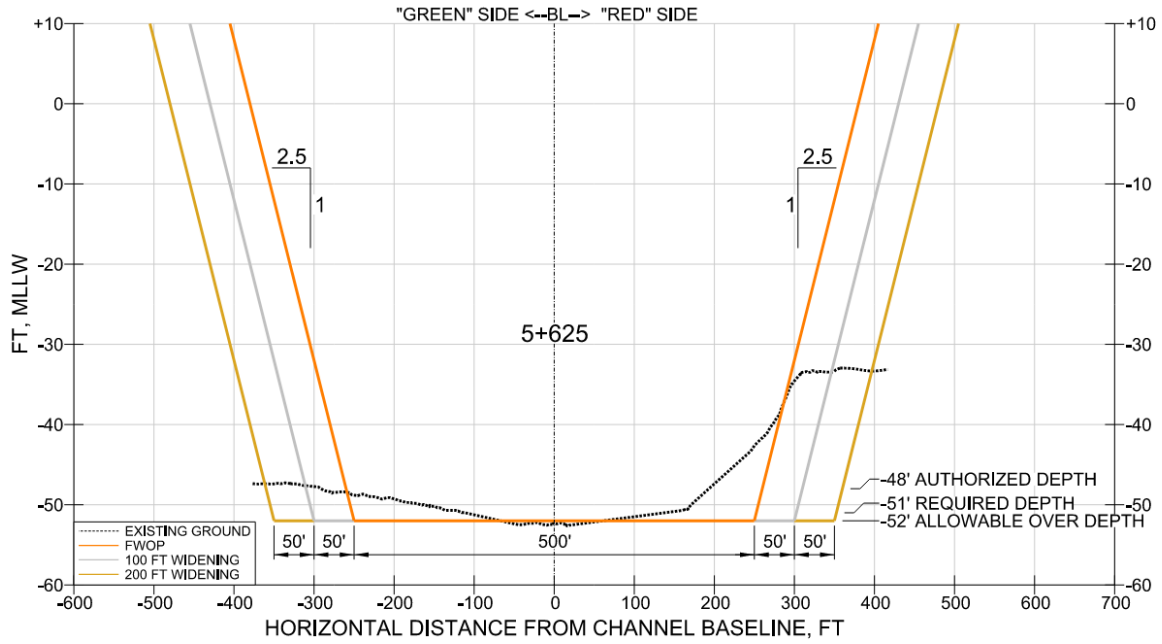


Figure 2-3
Typical Cross-Section: Sabine Pass Channel

Port Arthur Canal

Two channel widening concepts were considered for the Port Arthur Canal (Station 43+900 to 59+740) where the FWOP channel width is 500 ft. Widening concepts were considered for 100 ft (600 ft total width) and 200 ft (700 ft total width) increases. Both concepts would widen the channel symmetrically on each side of the channel. Refer to Figure 2-4 for the typical channel cross-sections considered along the Port Arthur Canal. The Port Arthur Canal widening was not selected as part of the TSP.

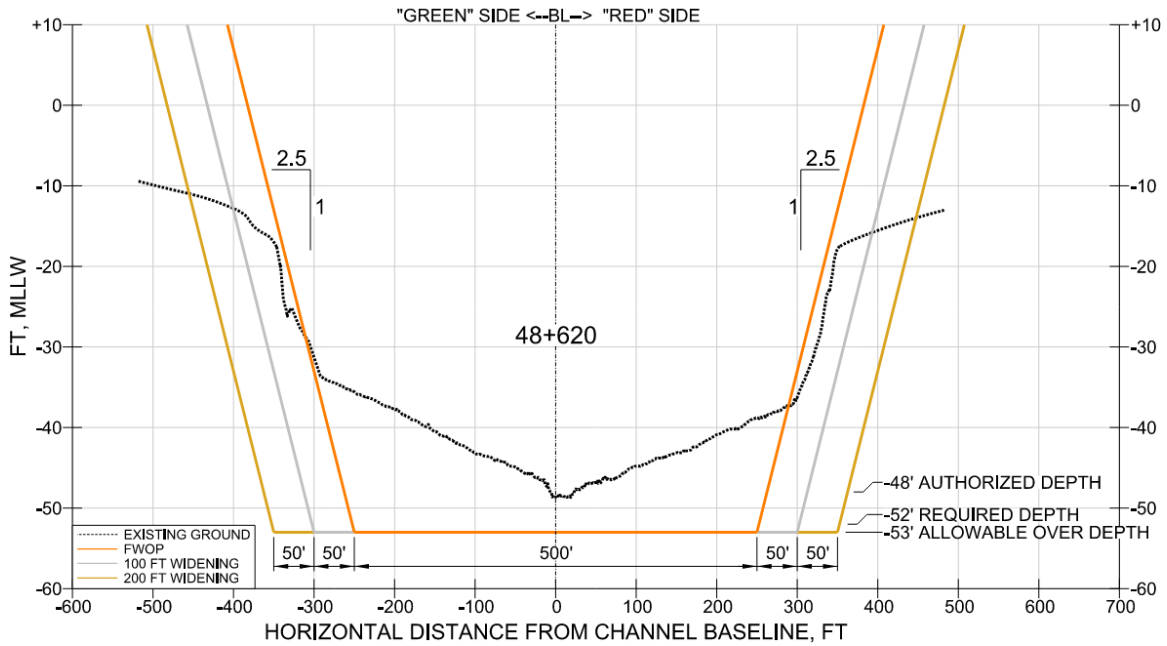


Figure 2-4
Typical Cross-Section: Port Arthur Canal

Sabine-Neches Canal (SNC) (South)

Three channel widening concepts were considered for the downstream (“south”) portion of the SNC (Station 63+500 to 72+700). Within this section of channel, the FWOP width transitions from 500 ft to 400 ft. Widening concepts were considered to increase the width by 100 ft, 200 ft, and 300 ft. Widening concepts were applied to the red (left descending) side of the channel to avoid impacts to existing infrastructure on the green (right descending) side of the channel. Refer to Figure 2-5 for the channel cross-sections considered along the SNC (South). The channel template depths and side-slopes were updated to 2H:1V for the TSP based on updated geotechnical analysis, refer to Table 2-2 for the updated channel depths.

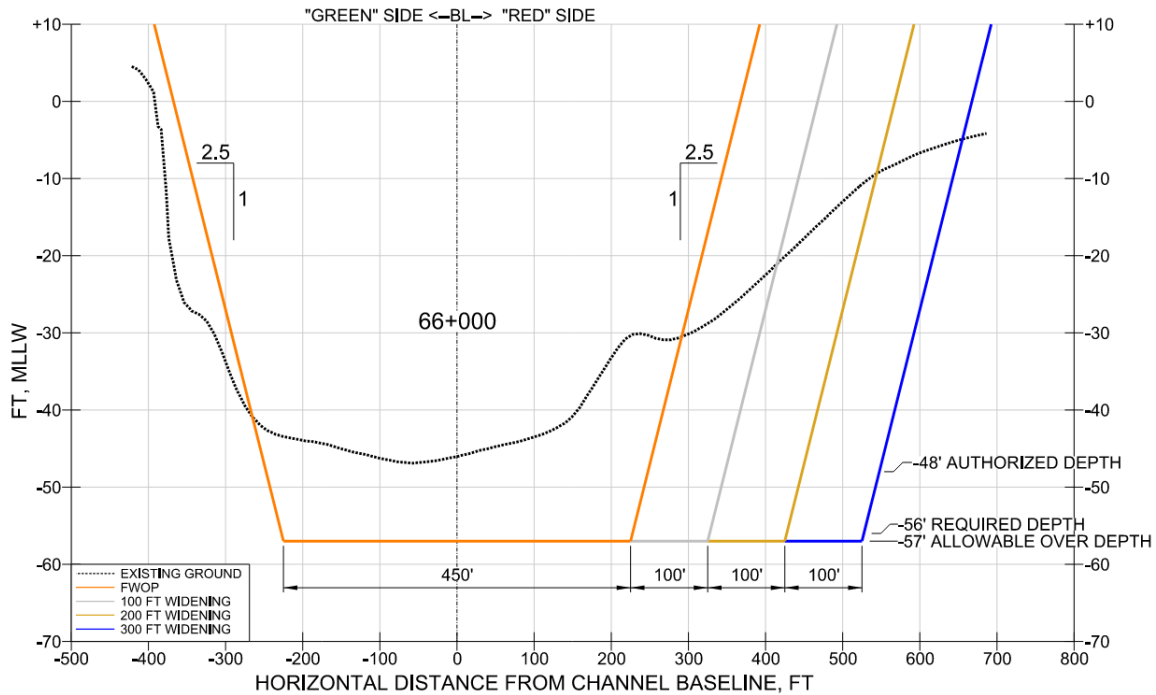


Figure 2-5
Typical Cross-Section: Sabine-Neches Canal (South)

Sabine-Neches Canal (SNC) (North)

Three channel widening concepts were considered for the upstream (“north”) portion of the SNC (Station 81+742 to Neches River Channel Station 40+00) where the FWOP width is 400 ft. Widening concepts were considered for 100 ft (500 ft total width), 200 ft (600 ft total width), and 300 ft (700 ft total width) increases. Widening concepts were applied to the red (left descending) side of the channel to avoid impacts to existing infrastructure on the green (right descending) side of the channel. Refer to Figure 2-6 for the channel cross-sections considered along the SNC (North). The channel template depths and side-slopes were updated to 2H:1V for the TSP based on updated geotechnical analysis, refer to Table 2-2 for the updated channel depths.

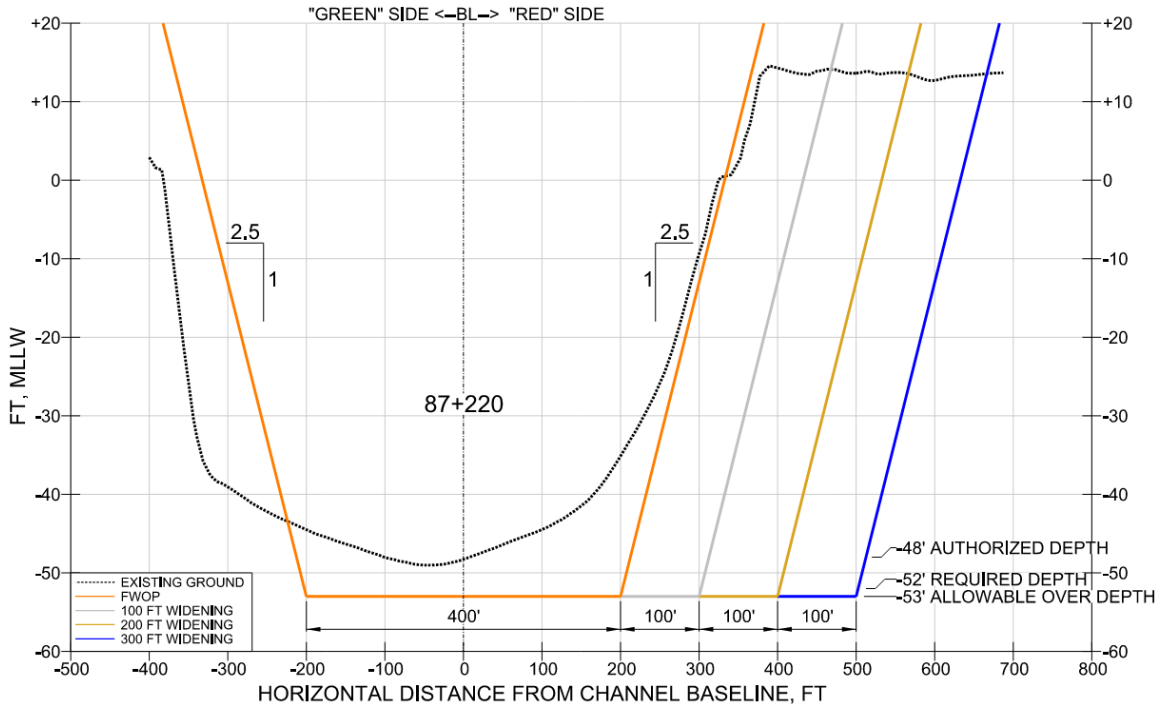


Figure 2-6
Typical Cross-Section: Sabine Neches Canal (North)

Sabine-Neches Canal (SNC) Barge Lane Concept

Three channel widening concepts were considered for a proposed barge lane along the red (left descending) side of the SNC (Station 63+700 to NRC Station 40+00). No widening was proposed between Stations 72+500 and 81+742. The SNC barge lane concept would be an alternative to the SNC (North) and SNC (South) widening concepts but the barge lane would have a shallower depth of only 20 ft. The FWOP channel width is 400 ft, with 100 ft, 150 ft, or 200 ft barge lane concepts considered along the red (east) side of the channel. Refer to Figure 2-7 for the channel cross-sections considered along the SNC for dedicated barge lanes.

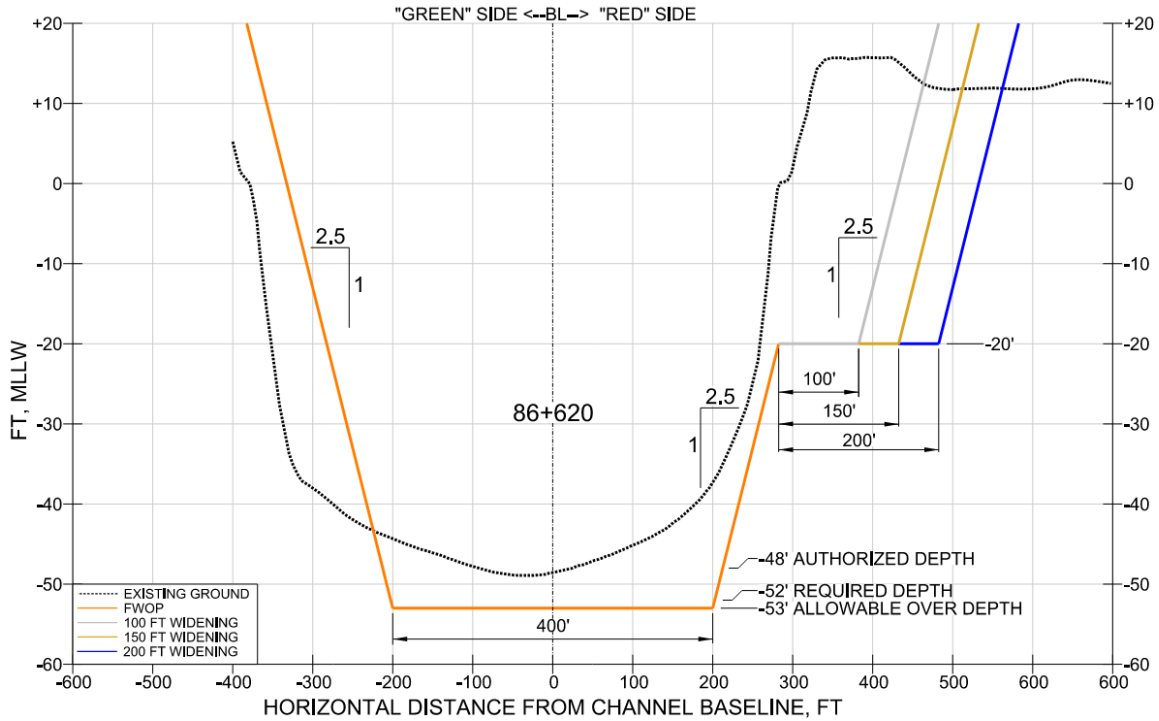


Figure 2-7
Typical Cross-Section: Sabine-Neches Canal (Barge Lane)

Neches River Channel (NRC)

Two channel widening concepts were considered for the Neches River Channel (Station 122+40 to 640+00) where the FWOP width is 400 ft. Widening concepts were considered for 100 ft (500 ft total width) and 200 ft (600 ft total width) increases. Widening concepts were applied to the red (left descending) side of the channel to avoid impacts to existing infrastructure on the green (right descending) side of the channel. Refer to Figure 2-8 for the typical channel cross-sections considered along the NRC. The channel template depths and side-slopes were updated to 2H:1V for the TSP based on updated geotechnical analysis, refer to Table 2-2 for the updated channel depths.

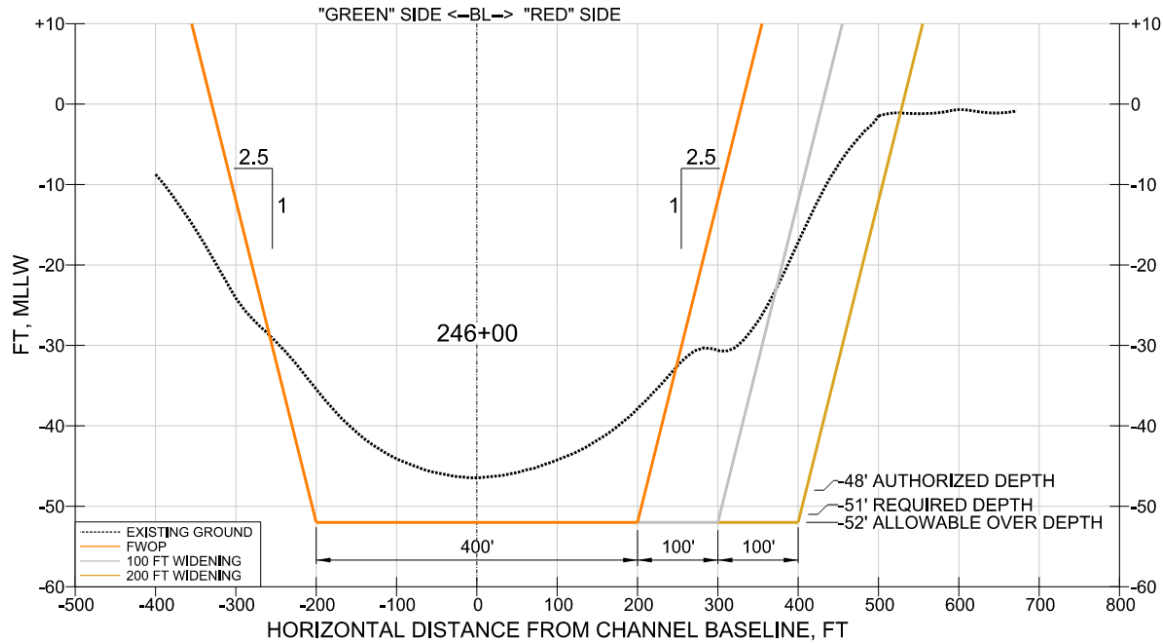


Figure 2-8
Typical Cross-Section: Neches River Channel

Anchorage Basin No. 4

A widening concept was considered for Anchorage Basin No. 4 (AB4), which is adjacent to the Neches River Channel near Station 640+00 (Figure 2-9). The FWOP basin area is approximately 18 acres and was initially proposed to be increased to a total of approximately 97 acres. This increased width could accommodate anchorage of up to five vessels at once. This concept was carried into the initial set of alternatives for modeling but was dropped from the final alternatives based on economic analyses.

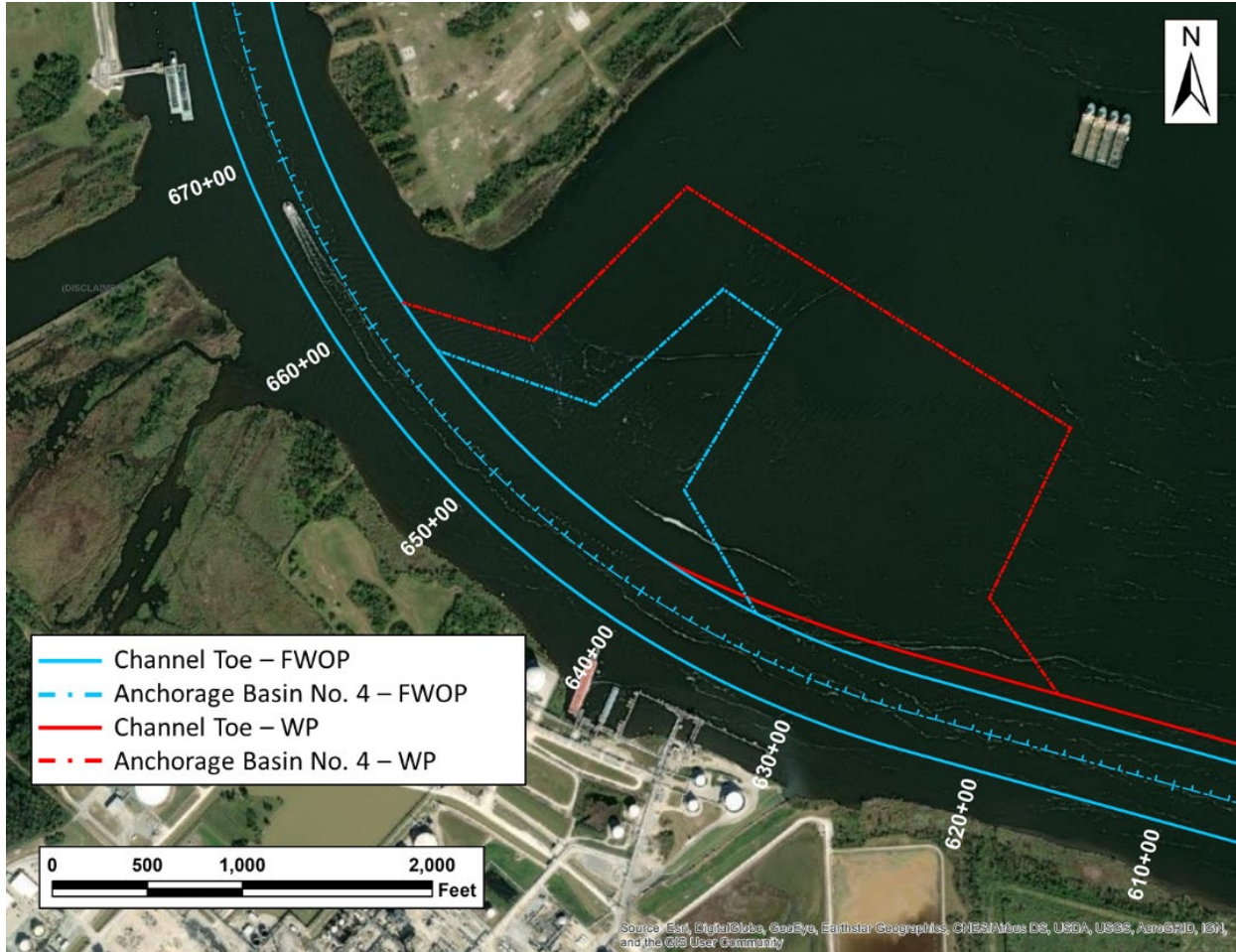


Figure 2-9
Anchorage Basin No. 4 Expansion Concept

Table 2-3
Channel Widening Concepts

Widening Options	Proposed Channel Width (ft) ^[1]	Station (Start)	Station (End)	Length (ft)	Widening Concept: Additional Channel Width (ft)
Sabine Pass Channel	600	0+150	15+990	15,840	100
	700				200
Port Arthur Canal	600	43+900	59+740	15,840	100
	700				200
SNC (South)	500	63+500	72+700	9,200	100
	600				200
	700				300
SNC (North)	500	81+742	40+00 ^[2]	41,507	100
	600				200
	700				300
SNC (Barge Lane)	500	63+700	40+00 ^[2,3]	50,217	100
	550				150
	600				200
NRC	500	122+40	640+00	51,760	100
	600				200
AB4	97 acres	623+00	653+50	--	79 acres

Notes:

1. The proposed channel width represents the maximum channel width outside of channel transition areas (e.g., FWOP channel width increases around curves in channel).
2. The Sabine Neches Canal (SNC) ends at Station 121+517. At that point, stationing restarts at zero for the Neches River Channel (NRC). NRC segment 0+00 to 40+00 is grouped with SNC (North) segment since that portion of the NRC segment is connected to SNC (North) and not the NRC widening segment.
3. The SNC (Barge Lane) segment does not include channel widening between Stations 72+500 and 81+742.

2.2.2 Alternatives Evaluated

Selected widening concepts for the various channel features were developed into three preliminary alternatives (Table 2-4 and Figure 2-10). The channel alignment in all reaches of the widened channel follows the FWOP alignment. The FWOP condition includes the previously-authorized deepening project that will take place prior to or concurrently with the proposed widening project.

Alternative 1

In Alternative 1, the SNC South, SNC North, and NRC selected reaches would be widened by 100 ft on the red side of the channel for a total width of 500 ft. Alternative 1 (Figure 2-11) is the Tentatively Selected Plan (TSP) based on economic analyses.

Alternative 2

In Alternative 2, the SNC South, SNC North, and NRC selected reaches would be widened by 200 ft on the red side channel for a total width of 600 ft.

Alternative 3

In Alternative 3, the Sabine Pass Channel and Port Arthur Canal selected reaches would be widened by 200 ft, with 100 ft of widening on each side of the channel for a total width of 700 ft. The SNC South, SNC North, and NRC selected reaches would be widened by 100 ft on the red side channel for a total width of 500 ft. Alternative 3 was evaluated as a preliminary alternative but later dropped as a final alternative based on economic analyses.

**Table 2-4
Preliminary Channel Widening Alternatives**

Widening Section	Station (Start)	Station (End)	FWOP Condition, ft	FWP Condition, ft		
				Alt. 1 (TSP) ¹	Alt. 2	Alt. 3
Sabine Pass Channel	0+150	15+990	500	N/A	N/A	700
Port Arthur Canal	43+900	59+740	500	N/A	N/A	700
SNC (South)	63+500	72+700	400	500	600	500
SNC (North)	81+742 0+00 ²	121+517 40+00 ²	400	500	600	500
NRC	122+40	640+00	400	500	600	500

Notes:

1. Alternative 1 is the Tentatively Selected Plan (TSP).
2. The Sabine Neches Canal (SNC) ends at Station 121+517. At that point, stationing restarts at zero for the Neches River Channel (NRC). NRC segment 0+00 to 40+00 is grouped with SNC (North) segment since that portion of the NRC segment is connected to SNC (North) and not the NRC widening segment.

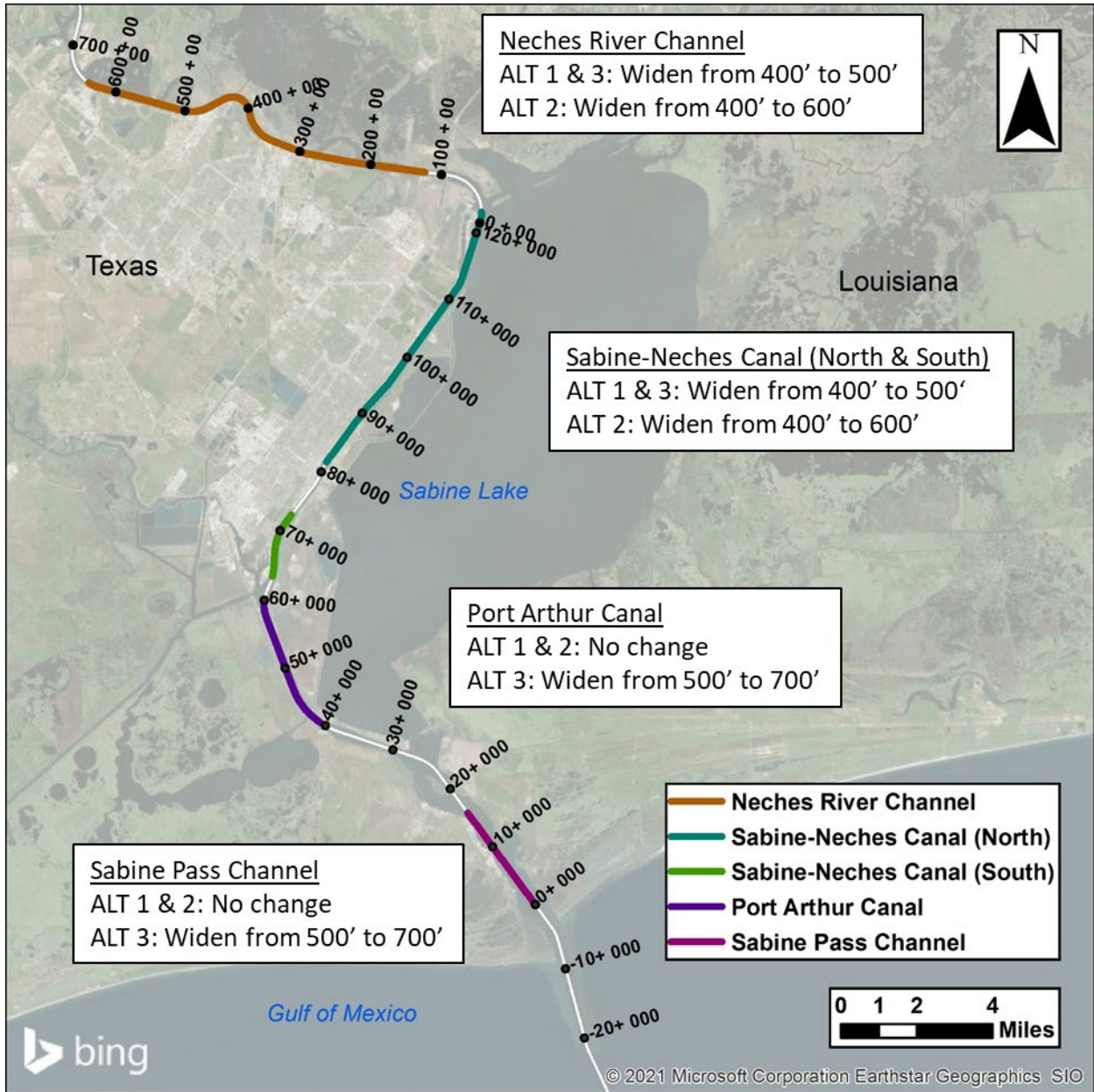


Figure 2-10
Widening Reaches Considered in the Preliminary Alternatives

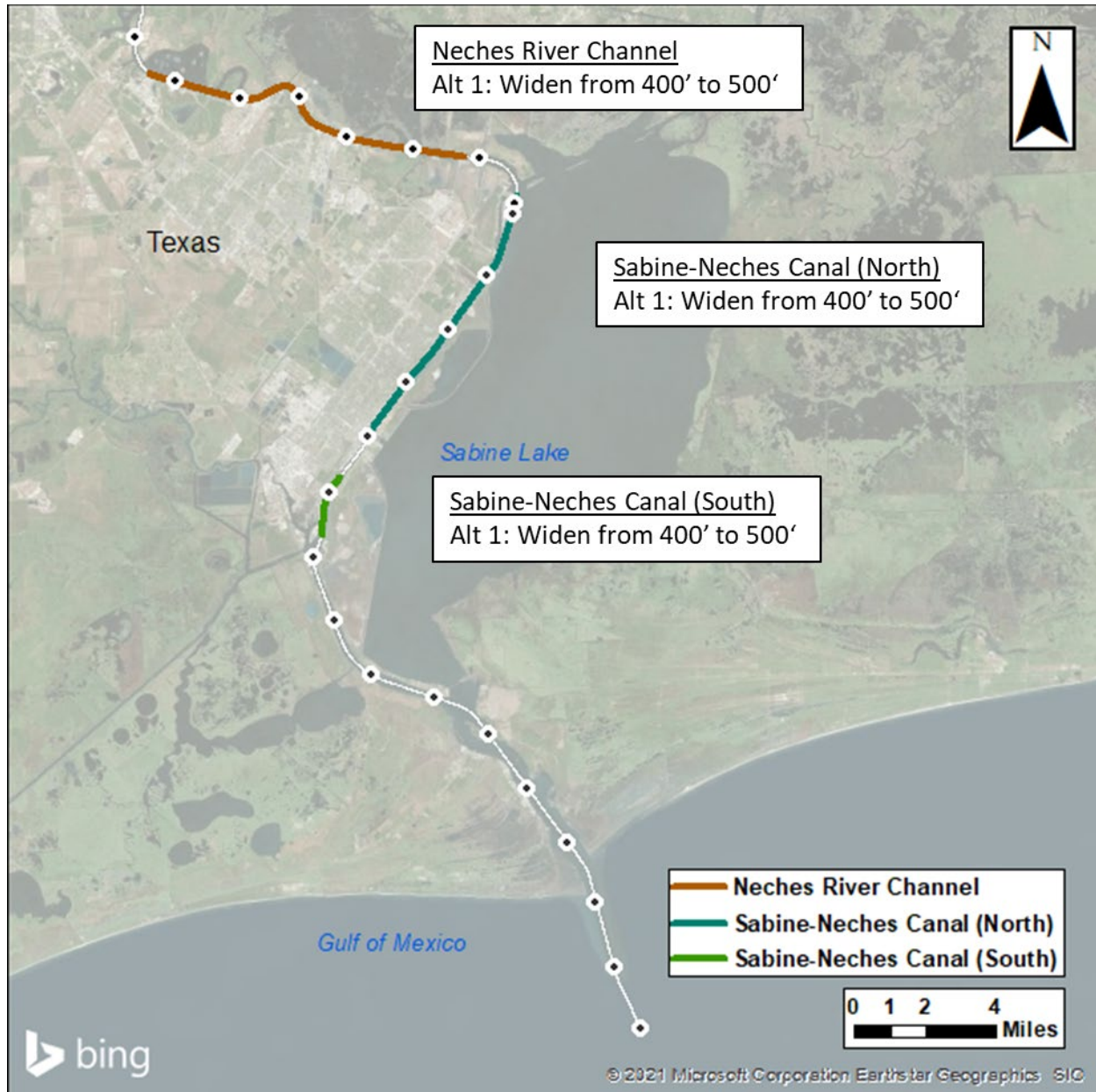


Figure 2-11
Channel Segments Selected for Widening in the TSP (Alternative 1)

2.3 Ship Simulations

Ship simulation modeling was performed at the Marine Pilots Institute and the San Jacinto Maritime College. Desktop simulations performed at the SNND offices were also used to verify vessel operating procedures under alternative widening conditions. Full bridge simulations of the TSP included ship and tow interactions with members of the Sabine Pilots Association operating the ship and multiple tow operators from the Gulf Intracoastal Canal Association operating the tow. The ship simulation modeling verified channel width requirements for vessel meeting and elimination of the daylight restriction (see Attachment 1).

2.4 Real Estate

The top of the channel template for the widening project (TSP) will intersect dry land approximately 20,800 linear feet along the east bank of the channel in several locations in the SNC and the NRC (Figure 2-12). In the SNC (North) segments near Pleasure Island and PA 11, shoreline protection (riprap) remaining after the construction of the deepening project (FWOP) will need to be removed as part of the widening project as discussed in Section 6.1. Refer to the Real Estate Appendix (Appendix C) for further details on real estate requirements for the TSP.

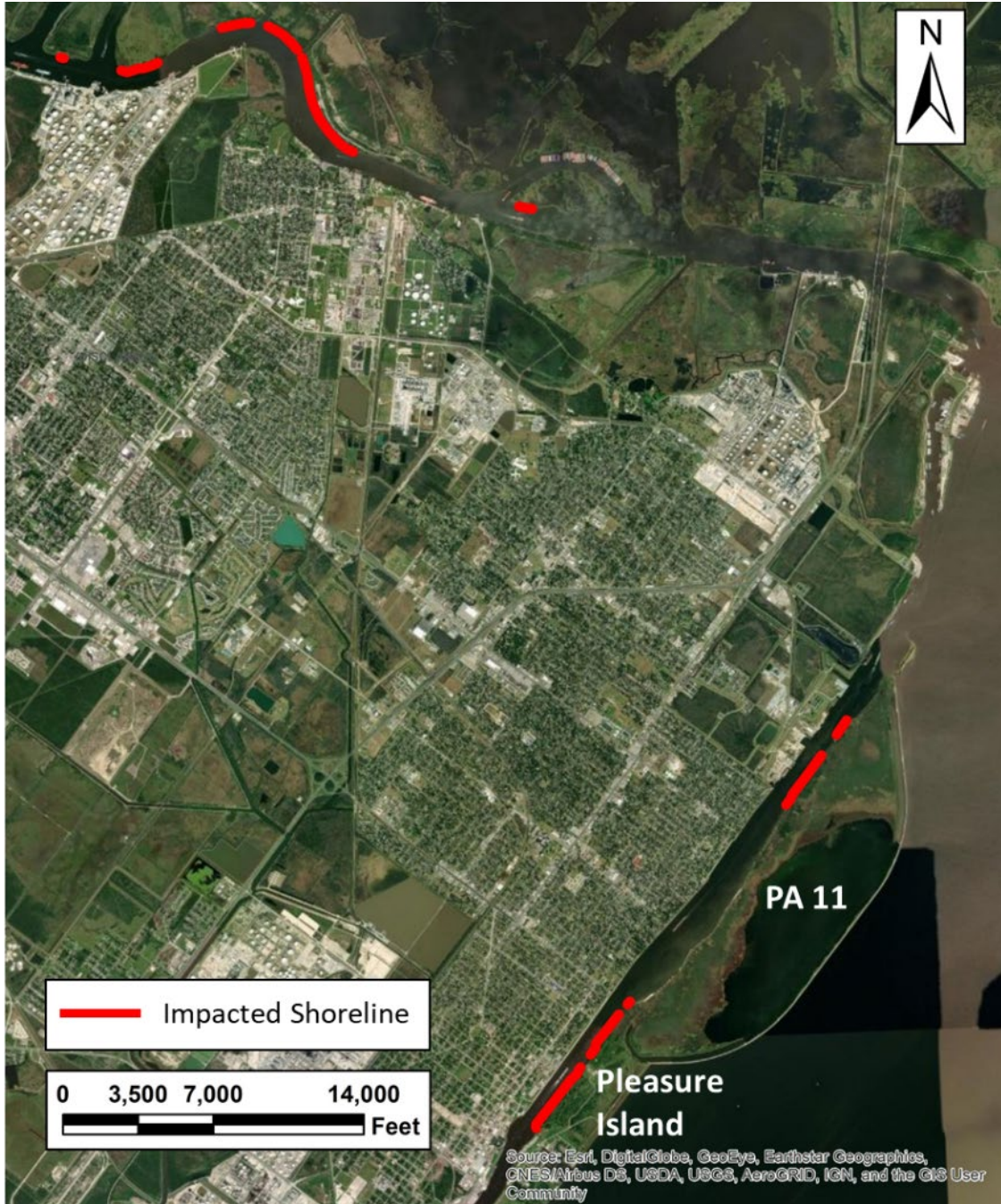


Figure 2-12
Impacted Shoreline

2.5 Relocation of Facilities

Known pipeline and utility crossings within the vicinity of the work required for the TSP are shown on the Drawings (Attachment 2). The pipelines in conflict with the TSP will be relocated as part of the ongoing channel deepening (i.e., they will have been moved as part of the FWOP and will no longer need relocation under the widening TSP). During Preconstruction Engineering and Design (PED), pipeline depths should be verified, and a detailed hazard survey (magnetometer,

side-scan sonar, or similar) should be performed over areas where work will be performed to help locate any additional buried/surficial obstructions, uncharted pipeline crossings, and/or other anomalies.

An electricity transmission tower just west of NRC Station 193+00 will require relocation as part of the TSP (see Figure 2-13). This tower is currently owned and operated by Entergy Corporation. SNND has requested as-built drawings of the transmission tower from Entergy for the channel deepening project PED analysis. The channel toe of the TSP is approximately 24 ft from the base of the transmission tower based on Google Earth aerial imagery (see Figure 2-13).

No bridges, docks, or wharfs will require relocation.

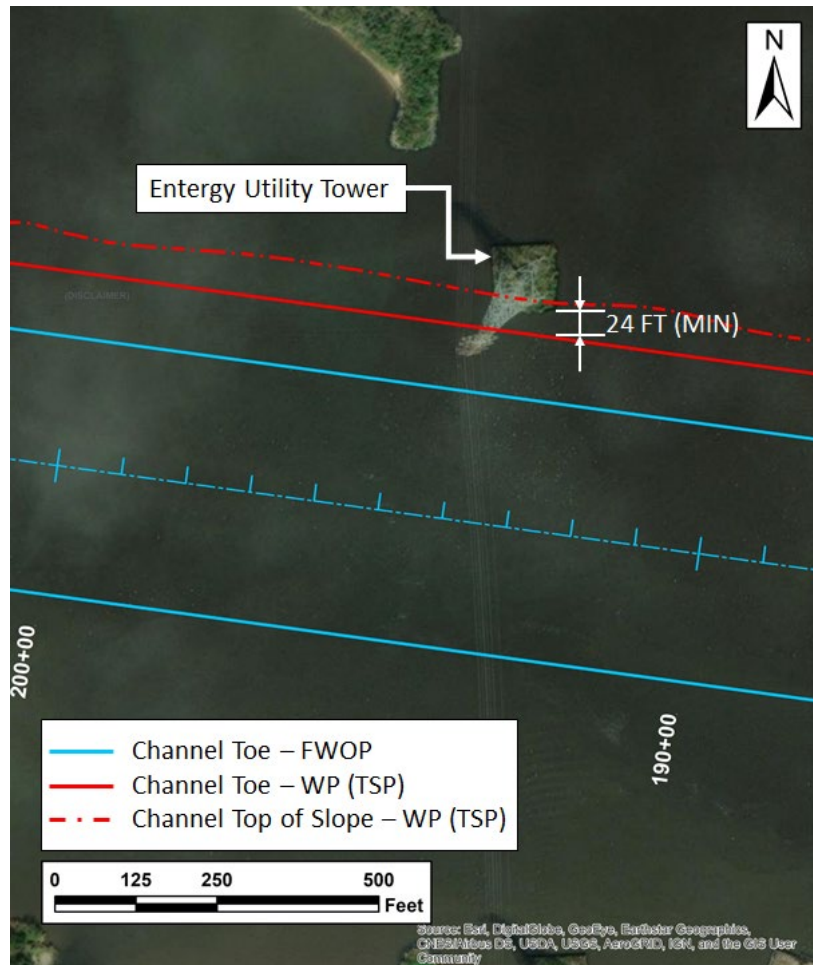


Figure 2-13
Energy Transmission Tower

2.6 Aids to Navigation

Information on aids to navigation (ATONs) in the channel was obtained from the National Oceanic and Atmospheric Administration (NOAA) nautical charts 11342 (57th ed.), published in August 2019 and last corrected in July 2021, and 11343 (39th ed.), published in December 2013 and last corrected in April 2021. According to these charts, 15 ATONs within the channel widening project

area will require relocation. The ATON relocations will be performed by the U.S. Coast Guard. Refer to the Drawings in Attachment 2 for current ATON locations.

2.7 Dredging

2.7.1 New Work Dredging

The term “new work” refers to the material outside of the FWOP channel template that is required to be removed to increase the channel width to the FWP dimensions. The new work material quantities were calculated using a digital terrain model (dtm) file generated by the MicroStation CADD Bentley InRoads software program. A dtm file consists of an overall surface of x-, y-, z-coordinate data points which compose a three-dimensional (3D) representation of the existing channel conditions. Refer to Section 3.1 for additional information on the survey data used to create the surface.

The templates were modeled as described above, with the new work channel dredging volumes computed for each component to be widened. The channel depths are summarized in Table 2-5, with all FWP depths matching the adjacent section of channel from the FWOP conditions. Refer to the FWOP Design Documentation Reports for additional information (HDR 2024, 2025a) on the channel dredging templates. The dredging volumes for the FWP channel widening sections are provided in Table 2-6.

2.7.2 Advance Maintenance

Advance Maintenance (AM) consists of dredging deeper than the authorized channel depth to offset the accumulation of sediment from shoaling. In critical and fast-shoaling areas it is required to avoid frequent re-dredging and to ensure the reliability and least overall cost for operating and maintaining the authorized depth. The AM depths for the channel widening sections will match the FWOP condition and are presented in Table 2-5.

USACE reevaluated the advance maintenance depths from the FWOP engineering appendix for the deepening project (USACE 2021) while this widening study was being prepared. The advance maintenance depths for both the deepening and widening projects may be updated during engineering and design (E&D) based on coordination with USACE on their final recommendations.

2.7.3 Allowable Overdepth

A certain amount of additional depth outside the required template is permitted to be dredged to allow for inaccuracies in the dredging process. This additional dredging allowance is referred to as a dredging tolerance or allowable overdepth (AOD). The AOD for channel widening sections will match the FWOP conditions and are shown in Table 2-5.

2.7.4 Non-Pay Dredging

Non-pay dredging is dredging outside the paid allowable overdepth that may occur due to such factors as unanticipated variations in substrate, incidental removal of submerged obstructions, or wind or wave conditions. No known conditions exist that would require the dredging contractor to perform extensive non-pay dredging to cut the proposed channel template. Thus, the new work volumes do not include any estimate of non-pay dredging.

Table 2-5
FWOP Channel Depths in the Widening TSP Reaches

Reach	Station (Start)	Station (End)	Authorized Project Depth ^[2] , ft	AM (O&M), ft	AOD (O&M), ft	O&M Template, ft		New Work Template, ft	
						Required Depth ^[3]	AOD (Total Depth)	Required Depth ^[4]	AOD (Total Depth)
SNC (South)	63+500	66+235	48	4	1	52	53	53	54
	66+235	72+700	48	3	1	51	52	52	53
SNC (North)	80+660	121+517	48	3	1	51	52	52	53
	0+00 ^[5]	40+00 ^[5]	48	4	2	52	54	53	54
NRC	122+40	155+00	48	4	1	52	53	53	54
	155+00	345+00	48	3	1	51	52	52	53
	345+00	510+00	48	4	1	52	53	53	54
	510+00	640+00	48	3	1	51	52	52	53

Notes:

- 1) Refer to Table 2-6 for channel slopes and bottom widths.
- 2) Values listed under "Authorized Project Depth" do not include Advance Maintenance or Allowable Overdepth.
- 3) Values listed under "Required Project Depth" include Advance Maintenance, but not Allowable Overdepth.
- 4) For the new work template, advance maintenance was increased by 1 ft as compared to the O&M template to account for "hard" material that may be encountered while performing new work dredging (in accordance with ER 1130-2-520).
- 5) The Sabine Neches Canal (SNC) ends at Station 121+517. At that point, stationing restarts at zero for the Neches River Channel (NRC). NRC segment 0+00 to 40+00 is grouped with SNC (North) segment since that portion of the NRC segment is connected to SNC (North) and not the NRC widening segment.

**Table 2-6
Channel Widths, Side Slopes, and Cut Volumes (TSP)**

Reach	Station (Start)	Station (End)	FWOP Bottom Width, ft	FWP (TSP) Bottom Width, ft	Estimated New Work Cut Volume, CY with 2.5H:1V Side Slopes	Estimated New Work Cut Volume, CY with 2H:1V Side Slopes ^[3]
SNC (South)	63+500	72+700	400	500	867,000	812,000
SNC (North)	80+660	121+517	400	500	5,677,000	5,472,000
	0+00 ^[2]	40+00 ^[2]	400	500		
NRC	122+40	640+00	400	500	5,102,000	4,954,000
TOTAL:					11,646,000	11,238,000

Notes:

- 1) New work dredge volumes were measured based on the AOD (total depths) presented in Table 2-5. These dredge volumes do not include a material bulking and/or shrinkage factor.
- 2) The Sabine Neches Canal (SNC) ends at Station 121+517. At that point, stationing restarts at zero for the Neches River Channel (NRC). NRC segment 0+00 to 40+00 is grouped with SNC (North) segment since that portion of the NRC segment is connected to SNC (North) and not the NRC widening segment.
- 3) The dredge template was updated to match the channel deepening design contracts (HDR 2025a) using a 2H:1V dredge side-slope, and new advanced maintenance depths (HDR 2025a).

2.7.5 Non-Federal Dredging

No non-Federal dredging is proposed for the TSP.

2.7.6 Maintenance Dredging

Refer to Section 5.3.2 for the discussion on maintenance dredging.

3 Surveying, Datums, and Survey Control

3.1 Surveying

The primary data set for the model elevation data is the NOAA Continuously Updated Digital Elevation Model (CUDEM). This data set is a merged product of topography and bathymetry and is developed by NOAA to support different NOAA objectives such as inundation modeling (CIRES 2014). Elevation data in the CUDEM originated from various sources and is provided with 3 meters (approximately 10 ft) resolution horizontally. This data set was compared to USACE hydrographic surveys of the SNWW to verify consistency.

The CUDEM data set was selected because the hydrodynamic models (see Section 7) required a regional dataset outside of the main project area. The CUDEM data provided a combined dataset that covered the entirety of the model domains. For consistency the CUDEM data was also applied to develop dredging volumes and as a basis for the channel cross-sections shown on the Drawings in Attachment 2. Additionally, multiple sources of bathymetric and topographic survey data were compiled for the SNWW and surrounding areas including the upland PAs and BU sites (Table 3-1).

**Table 3-1
Available Survey Data**

Survey	Publication Date	General Description
Access 3D Solutions	2019	Bathymetry data along jetties, Taylor Bayou, Port Arthur Canal Junction, and along Pleasure Island. LiDAR data along shoreline of Taylor Bayou, PA 8 and PA 11, and RTK transects along PA 8 western perimeter dike.
Burrow Global	2018	Bathymetry data, side-scan sonar, and magnetometer surveys along FWOP channel. Pipeline identification survey.
Fugro	2019	Bathymetry data of Taylor Bayou, magnetometer, and side-scan sonar data along FWOP channel, and sediment boring samples along FWOP channel.
NOAA CUDEM	2021	Merged bathymetric and topographic survey data of project area.
	2019	Bathymetry data along FWOP channel.
USACE	2021	Bathymetry data along FWOP channel.
	Historical	Historical sediment boring samples along FWOP channel.
Tolunay-Wong Engineering	2023	Sediment boring samples along channel.
	2025	Sediment boring samples along channel.

Additional bathymetric surveys are regularly performed by USACE in support of ongoing operations and maintenance activities. Bathymetric survey data for the length of the SNWW were obtained from the Galveston District (2021). Additional bathymetric surveys were performed in 2019 by Access 3D Solutions in parts of the Port Arthur Canal and along the shoreline of Pleasure Island, which lies alongside the Sabine-Neches Canal. Access 3D Solutions also performed a topographic survey along the shoreline of Pleasure Island.

Hazard surveys, including magnetometer and side-scan sonar surveys, were performed by Burrow Global (2018) and Fugro (2019) for the length of SNWW. These surveys were performed in accordance with EM 1110-2-1003 (USACE 2013). All data were collected using real-time kinematic (RTK) corrections with bases set at local control points and tied into local U.S. Geological Survey (USGS) and USACE benchmarks.

3.2 Additional Surveys

Updated surveys will be required during E&D for the project area, including bathymetric, topographic, magnetometer, and side scan sonar surveys. A site planned for beneficial use of dredged material (i.e., the “BU” site) will also require updated aerial photography.

3.3 Datums and Survey Control

3.3.1 Horizontal

The North American Datum of 1983 (NAD 83), Texas State Plane Coordinate System, South Central Zone, is the horizontal datum for this project.

3.3.2 Vertical

The vertical datum for available background data for this project is a compilation of USACE Mean Low Tide (MLT), National Geodetic Vertical Datum of 1929 (NGVD29), and the newer North American Vertical Datum of 1988 (NAVD88). After application of the appropriate datum conversions, channel cross-sections, volumes and depths are referenced to Mean Lower Low Water (MLLW). Land surveys performed for the placement areas were referenced to NAVD88. The correlation between vertical datums is described in more detail in Section 3.3.4.

3.3.3 Tidal Datum

In accordance with Army regulations and HQ guidance on tidal datums as provided in ER 1110-2-8160, “Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums,” and EM 1110-2-6056, “Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums,” MLLW has been applied as the navigation project datum for this project. Application of MLLW as the project datum provides consistency throughout the ports of the U.S., enhances the continuity of NOAA, and U.S. Coast Guard (USCG) navigation charts, and helps avoid misconceptions within the shipping and dredging industries regarding channel depths.

3.3.4 Survey Control and Datum Conversions

The survey control monuments in the project area were investigated based on both the availability of a datum conversion between NAVD88 and MLLW and their relative proximity to the channel reaches (Figure 3-1). Multiple sources of datum conversion information were considered, including tide stations and published information on existing survey control monuments, to select the datum conversion. Available information was gathered and compiled from NOAA tide stations, historical TCOON tide stations, and NOAA’s VDatum (NOAA 2013) conversion tool.

The VDatum conversion tool was selected for converting vertical datums for this project because it provides a consistent and reproducible conversion that helps eliminate discontinuities from one area to the next. Where datum conversions were required, VDatum was applied for conversion of elevation data in both the Drawings (Attachment 2) and the hydrodynamic models (Attachments 3 through 6).

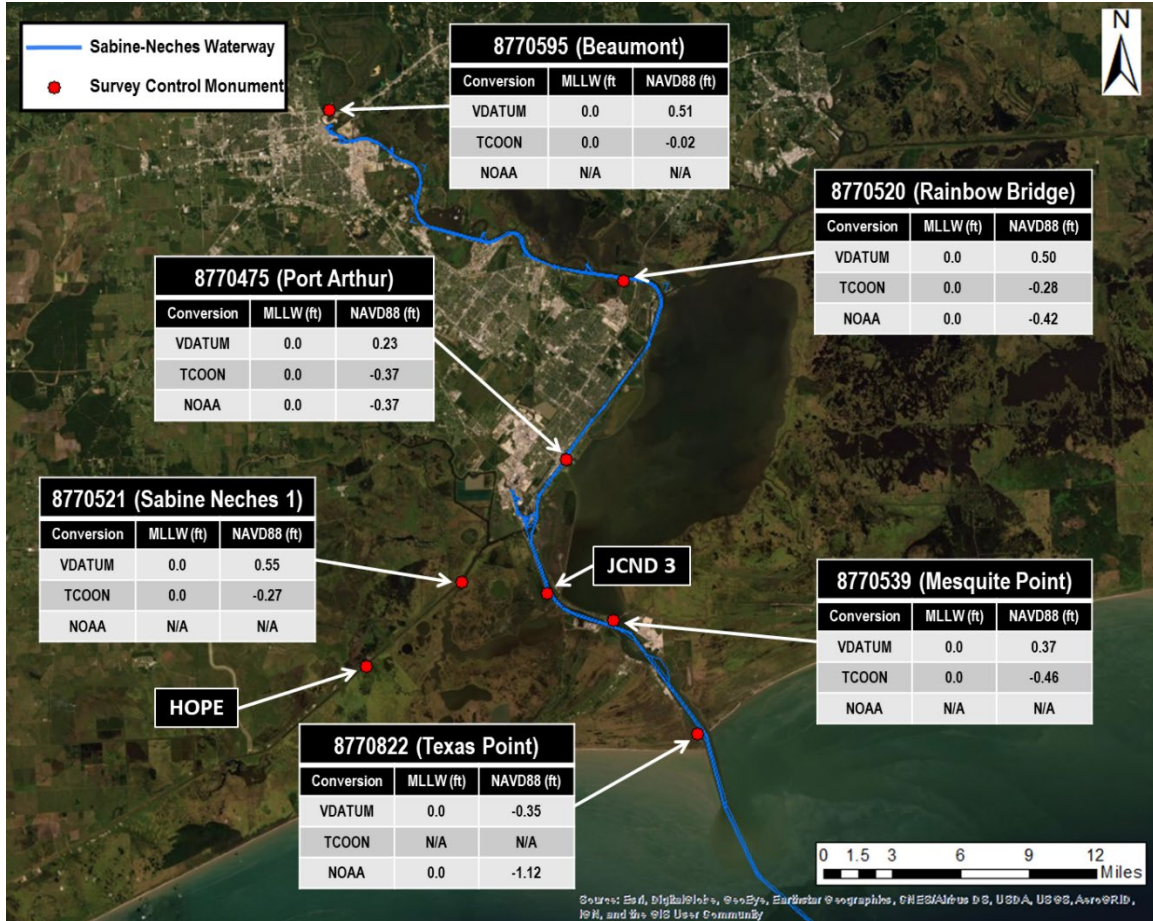


Figure 3-1

Survey Control Monuments and Vertical Datum Relationships as of March 2021

4 Geotechnical Investigations

This section has been prepared to provide sufficient information to support the development of the project plan including verification of channel design, placement area selection and use, dredged material distribution, and cost estimates. This preliminary investigation for this feasibility study uses available geotechnical investigation information, establishment of suitable design parameters and geotechnical assumptions, and production of quantities for a 50-year dredged material disposal plan have been performed with the purpose of providing sufficient detail to substantiate the TSP and the baseline cost estimate. The designs of the BU and PA sites are outside the scope of the feasibility study herein.

4.1 Regional Geology

The overall SNWW extends from the Port of Beaumont on the Neches River through the Sabine-Neches Canal and Sabine Pass and into the Gulf of America (Figure 2-1). As summarized in USACE (2011), the project is in the Coastal Plain physiographic province of Texas. This region contains marine sediments, mainly younger Holocene deposits overlying older Pleistocene deposits. More recent riverine overwash deposits overlie the Holocene sediments in floodplains in the Neches and Sabine Rivers. The subdivision of the Coastal Plain in which the project lies is

called the Coastal Prairie. This area is characterized by low-lying flat land and has evolved to its present conditions by erosion, deposition, compaction, and subsidence, all of which are still active. Gradual faulting continues as Pleistocene and older Gulf basin sediments continue to compact.

4.2 Site Geology

The site geology is characterized by modern marine deposits overlaying recent Holocene deposits that in turn overlay Beaumont and Lissie Formations of the Pleistocene Series (USACE 2011). The modern deposits are generally consolidated clays, silts, and fine sands that were deposited through natural overwash and sedimentation processes or through man-made depositional processes. The recent deposits of the Holocene consist of silts, clays, silty sands, clayey sands, and clayey silts that exhibit the characteristics of normally to lightly overconsolidated materials. These deposits are generally encountered to depths of 30 to 40 ft.

Beaumont Clay is the predominant Pleistocene formation whose eroded surface forms the upper limit of stiff to very stiff clay material. It is red, yellow and brown calcareous stiff clay that weathers into black or gray soil at the surface. Lenses of fine grained, poorly graded sand and silt, and calcareous nodules are sometimes encountered in this formation. The clay fraction is composed of montmorillonite (generally with calcium as the exchangeable cation), kaolinite, illite and finely ground quartz, in that order of prevalence. The high percentage of montmorillonite accounts for the high shrink-swell potential of the material. Previous desiccation of the clays results in significant over consolidation to great depths. In addition to preconsolidating the soil, the desiccation process, along with occasional rewetting, has resulted in a network of fissures and slickensides that are now closed but which represent potential planes of weakness within the stratum. The thicknesses of these clays range from 25 to 400 ft. The Lissie formation underlies the Beaumont and consists primarily of sands and silty sands.

4.3 Field Exploration

As summarized in USACE reports (2008, 2010a), most of the subsurface data for the FWOP Feasibility Report was compiled from historical data, and from analyses for placement areas as part of periodic dike raising projects. The historical subsurface data were supplemented with soil borings obtained in 2019 (Fugro 2019), 2023 (TWE 2023) and 2025 (TWE 2025). Site subsurface data are presented as boring logs in the Drawings (Attachment 2).

4.4 Soil Borings and Laboratory Testing

Soil borings, performed during the feasibility study and preconstruction engineering and design of the FWOP were drilled to explore the subsurface conditions along the channel (USACE 2008, 2010a, Fugro 2019, TWE 2023, and TWE 2025). The soil borings located within the TSP footprint are summarized in Table 4-1.

**Table 4-1
Soil Boring Details**

Boring ID ¹	Northing (ft)	Easting (ft)	Top of Boring Elevation (ft)	Drill Depth (ft)	Termination Elevation (ft)
Neches River Channel (NRC): Sta. 122+40 to 640+00					
NRC-17	13,952,004	3,544,111	-14	56	-70
73-85	13,950,746	3,548,481	1	53	-52
NRC-20	13,950,403	3,549,983	-16	60	-76
NRC-21-A	13,949,611	3,552,815	-37	34	-71
3ST-162	13,949,428	3,558,806	-19	31	-50
D-6	13,948,884	3,556,783	3	100	-97
NRC-23-A	13,950,296	3,560,261	-24	46	-70
W-6	13,951,077	3,561,693	5	100	-95
W-5	13,950,620	3,564,023	5	100	-95
NRC-25	13,949,004	3,564,899	-24	46	-70
W-4	13,948,237	3,565,202	5	100	-95
NRC-27-AA	13,945,621	3,566,357	-18	52	-70
D-4	13,945,391	3,566,814	-3	100	-103
3ST-151	13,945,017	3,567,050	-34	18	-52
73-84/3ST-147	13,943,835	3,570,152	1	53	-52
NRC-29-A	13,943,423	3,571,059	-22	48	-70
W-3	13,943,622	3,571,178	3	100	-97
NRC-30-A	13,942,944	3,573,289	-20	50	-70
W-2	13,942,555	3,575,230	2	100	-98
NRC-32	13,941,936	3,577,521	-28	42	-70
3ST-137	13,941,661	3,579,585	-33	20	-53
73-83/3ST-133	13,941,238	3,583,397	2	55	-53
NRC-34	13,940,807	3,585,428	-22	48	-70
Sabine Neches Canal (North): SNC Sta. 81+742 to NRC 40+00					
3ST-117	13,933,987	3,597,002	-44	8	-52
SNC-01-A	13,932,390	3,596,813	-11	60	-71
3ST-113	13,929,835	3,595,872	-41	12	-53
SNC-03	13,928,803	3,595,573	-19	42	-61
73-82/3ST-111	13,927,624	3,595,568	2	54	-52
SNC-05	13,924,962	3,594,361	-9	62	-71
73-81	13,923,086	3,593,389	2	54	-52
SNC-07	13,921,541	3,592,128	-19	52	-71
SNC-09	13,918,348	3,589,858	-5	66	-71
73-80	13,917,730	3,589,310	15	67	-52
SNC-11	13,915,068	3,587,422	-14	56	-70
73-79/3ST-95	13,914,322	3,587,024	-9	68	-77
SNC-13	13,911,779	3,585,075	-9	62	-71
3ST-224	13,908,843	3,582,575	-3	50	-53
SNC-16	13,907,220	3,581,221	-14	58	-72
SNC-18-A	13,904,207	3,578,892	-24	48	-72
D-2	13,902,785	3,578,317	8	100	-92
W-1	13,902,189	3,577,736	6	100	-94
73-76/3ST-79	13,901,258	3,576,904	16	68	-52
D-1	13,900,648	3,576,371	10	100	-90
SNC-20	13,900,901	3,576,393	-46	24	-70
SNC-21-A	13,900,034	3,575,771	-41	30	-71

Sabine Neches Canal (South): Sta. 63+500 to 72+700						
POI-13	13,891,866	3,570,517	-9	62	-71	
SNC-24-A	13,890,014	3,569,206	-9	62	-71	
73-74	13,890,005	3,569,537	19	70	-51	
SNC-25	13,888,364	3,568,517	-27	45	-72	
73-73	13,884,557	3,568,448	6	58	-52	
Anchorage Basin No. 4: NRC Sta. 623+00 to 653+50²						
NRC-15-A	13,953,804	3,541,569	-17	54	-71	
B-4-1	13,953,324	3,541,915	-22	80	-102	
B-4-2	13,954,042	3,542,337	-21	80	-101	

Notes:

1. The boring locations are shown on the Drawings (Attachment 2). Borings were performed during the feasibility and E&D phases of the deepening project. Fugro collected the borings with IDs that start with "NRC", "SNC", "POI", and "B" (Fugro 2019); those elevations are in ft MLLW. TWE collected the borings with IDs that start with "W" or "D" (TWE 2023 and TWE 2025); elevations are not reported on those boring logs. USACE collected the historical borings with IDs that start with numbers; those elevations are in ft MLT (USACE 2008, 2010a).
2. Two borings were collected within the AB4 expansion area since it was included in the preliminary alternatives, but AB4 expansion was dropped from the final alternatives.

In general, soil samples were taken continuously to obtain 3-inch diameter undisturbed samples of cohesive materials and disturbed split-spoon samples of cohesionless soils. Consistencies of cohesive soils were estimated in the field using a pocket penetrometer or a Torvane. Where cohesionless soils were encountered, standard penetration tests (SPT) were performed to estimate the in situ relative density. Laboratory testing was conducted on representative samples collected from the borings. Tests on cohesive soils consisted of determining moisture content, unit dry weight, grain size analyses, liquid limit and plastic limit. Grain size analyses were performed on samples of cohesionless soils. The results of these tests were used to classify the various material layers. Undrained shear strengths of cohesive soils were determined in the laboratory by performing miniature vane shear tests, unconfined compression tests (UC), and unconsolidated-undrained (UU) triaxial compression tests. Drained shear strengths of select cohesive soils were determined in the laboratory by performing 3-stage consolidated-undrained (CU) triaxial compression tests.

Detailed descriptions of the soils encountered including results of the field and laboratory testing are presented on boring logs in the geotechnical reports (Fugro 2019, TWE 2023, and TWE 2025), and on the Drawings (Attachment 2). Laboratory tests results are also presented in tables in the geotechnical report. A summary of the laboratory testing performed on the recent borings (Fugro 2019, TWE 2023, and TWE 2025 in Table 4-1) is presented in Table 4-2. Historical borings in the SNWW are available from USACE. Additional historical geotechnical information is available online at the Texas Coastal Sediment Geodatabase (TxSED) website:

<https://experience.arcgis.com/experience/487184e05fd347489cc8258a17401a4a>.

**Table 4-2
Summary of Recent Laboratory Testing within TSP**

Test Description	Test Quantity	Test Method
Water (Moisture) Content of Soil	462	ASTM D2216
Amount of Material in Soils Finer than No. 200 Sieve	221	ASTM D1140
Liquid Limit, Plastic Limit and Plasticity Index of Soils	234	ASTM D4318
Density (Unit Weight) of Soil Specimens	91	ASTM D7263
Unconfined Compression on Cohesive Soils	46	ASTM D2166
Unconsolidated-Undrained Triaxial Compression on Cohesive Soils	76	ASTM D2850
Consolidated-Undrained Triaxial Compression Test	7	ASTM D4767
Consolidated-Drained Direct Shear Test	3	ASTM D3080

It should be noted that more laboratory testing was performed along the reaches of the NRC and SNC of the TSP, but not within the footprint of the proposed widening. Those laboratory tests are not included in the quantities listed in Table 4-2 but were taken into consideration during the selection of subsurface parameters.

4.5 Subsurface Soil Characterization

The recent boring logs (Fugro 2019, TWE 2023, and TWE 2025) were reviewed to summarize the new work material along the SNC and the NRC within the proposed TSP. The boring logs provided the classification and strength/density data based on field and laboratory testing. Table 4-3 is provided to reference the categorization density/strength ranges that were used in the development of the subsurface soil characterization herein.

**Table 4-3
Density and Strength of Soil (Terzahi and Peck, 1948)**

Relative Density of Sand		Strength of Clay		
Relative Density of Sand (blows/ft)	Relative Density	Penetration Resistance N (blows/ft)	Unconfined Compressive Strength (tons/ft²)	Consistency
0-4	Very Loose	<2	<0.25	Very Soft
4-10	Loose	2-4	0.25-0.50	Soft
10-20	Medium	4-8	0.50-1.00	Medium
30-50	Dense	8-15	1.00-2.00	Stiff
>50	Very Dense	15-30	2.00-4.00	Very Stiff
		>30	>4.00	Hard

Based on a review of the recent soil borings and historical soil borings, new work material along the NRC (122+40 to 640+00) is primarily comprised of very soft to soft clays with intermittent very loose to medium dense sands and clayey sands. Table 4-4 provides a summary of the percentage of the general soil types contained in the soil borings and Table 4-5 provides a summary of the strength/density percentages of the soil within the TSP of the Neches River Channel.

**Table 4-4
Subsurface Sediment Types: NRC (122+40 to 640+00)**

Soil Type	% of Total
Clay/Sandy Clay	65%
Silty Sand/Clayey Sand	20%
Sand	15%

**Table 4-5
Subsurface Sediment Strength/Density: NRC (122+40 to 640+00)**

Soil Type	Strength/Density	% of Total
Cohesive Clays Sandy Clays	Very Soft to Soft	51%
	Medium	5%
	Stiff	8%
	Very Stiff	1%
	Hard	0%
Granular Sands Silty Sands Clayey Sands	Very Loose	3%
	Loose	16%
	Medium Dense	16%
	Dense	0%
	Very Dense	0%

The new work material along the SNC North (81+742 to NRC 40+00) is primarily comprised of firm to stiff clays. Table 4-6 provides a summary of the percentage of the general soil types contained in the soil borings and Table 4-7 provides a summary of the strength/density percentages of the soil within the TSP of SNC North.

Table 4-6
Subsurface Sediment Types: SNC North (80+660 to NRC 40+00)

Soil Type	% of Total
Clay/Sandy Clay	97%
Silty Sand/Clayey Sand	2.5%
Sand	0.5%

Table 4-7
Subsurface Sediment Strength/Density: SNC North (80+660 to NRC 40+00)

Soil Type	Strength/Density	% of Total
Cohesive Clays Sandy Clays	Very Soft to Soft	19%
	Medium	36%
	Stiff	36%
	Very Stiff	6%
	Hard	0%
Granular Sands Silty Sands Clayey Sands	Very Loose	2%
	Loose	1%
	Medium Dense	0%
	Dense	0%
	Very Dense	0%

The new work material along the SNC South (63+500 to 72+700) is primarily comprised of firm to stiff clays and loose to medium dense sands. Table 4-8 provides a summary of the percentage of the general soil types contained in the soil borings and Table 4-9 provides a summary of the strength/density percentages of the soil within the dredge template of SNC South.

Table 4-8
Subsurface Sediment Types: SNC South (63+500 to 72+700)

Soil Type	% of Total
Clay/Sandy Clay	82%
Silty Sand/Clayey Sand	18%
Sand	0%

Table 4-9
Subsurface Sediment Strength/Density: SNC South (63+500 to 72+700)

Soil Type	Strength/Density	% of Total
Cohesive Clays Sandy Clays	Very Soft to Soft	4%
	Medium	59%
	Stiff	18%
	Very Stiff	1%
	Hard	0%
Granular Sands Silty Sands Clayey Sands	Very Loose	10%
	Loose	8%
	Medium Dense	0%
	Dense	0%
	Very Dense	0%

Subsurface profiles along the channel segments are presented in the geotechnical report (Fugro 2019) on Plates 3d through 3k along with general subsurface conditions encountered in the borings along each segment.

4.6 Channel Slope Stability

Channel stability analysis was performed for the Sabine-Neches Canal and Neches River Channel at 12 representative stations within the proposed widening areas to help verify the stability of the proposed FWOP deepened channel (HDR 2025b). This analysis did not include the stability of existing improvements along the bank, such as shoreline protection, bulkheads, docks, piers, etc. A review of the geometry and soil conditions along the TSP was conducted to identify critical sections to consider for slope stability analyses. The 12 representative cross-sections were selected at the locations of the deepest dredge cuts (and considering the subsurface conditions at these locations) in that channel reach, making them more susceptible to slope failures. It was assumed that if the dredge cuts at these locations are stable, the remainder of the reach should be stable as well.

Within the TSP, slope stability analyses were performed using Slope/W by Geostudio 2022.1. Spencer's method was used that applies two-dimensional limit equilibrium analysis to determine the factor of safety for the slope. The computed factor of safety is the ratio of the forces resisting movement to the forces driving movement. The assumptions used in our analysis are summarized below:

- No Surcharge.
- Water level is at El. 0 ft MLLW.
- Rapid drawdown analyses were not required/applicable.
- Slopes maintain their geometry as our analyses did not consider the effects of scour or erosion.
- Slope stability analyses were limited to static forces. We did not evaluate the effects of dynamic forces from waves, currents, passing vessels, and other hydrodynamic forces. The

dynamic effects of “extreme” events such as tropical storm or hurricane events were not considered.

- Stability analyses of structures, docks, wharfs, and bulkheads were not included in the analyses.

The recommended minimum factors of safety for the proposed dredged slopes are in accordance with those outlined in *EM 1110-2-1913: Design and Construction of Levees*. A summary of the recommended minimum factors of safety for the given condition is summarized in Table 4-10. Rapid drawdown was not considered in the slope stability analyses due to the channel slopes being submerged.

**Table 4-10
Recommended Minimum Factors of Safety for Global Stability**

Condition	Minimum Required Factor of Safety
End of Construction (short-term)	1.3
Steady State (long-term)	1.4
Rapid Drawdown	Not Applicable

To assess multiple configurations for slope stability along the TSP, thirteen (13) critical stations were selected as shown in Table 4-11.

**Table 4-11
Critical Cross-Sections along TSP**

Reach Name	Station	Contract Full Depth (Includes Allowable Over-Depth), feet MLLW
SNC South	63+536	-54
	71+413	-53
SNC North	83+000	-53
	87+000	-53
	102+100	-53
	111+617	-53
	12+00	-54
	200+00	-53
NRC	340+72	-53
	355+00	-54
	403+60	-54
	488+00	-54
	591+00	-53

The undrained and drained parameters are selected for each soil stratum based on the laboratory and field test data collected during the recent field exploration and laboratory testing (Fugro 2019, TWE 2023, and TWE 2025), previous geotechnical studies performed in the region, and our experience with similar projects and subsurface conditions.

The stratigraphy used in the analyses, along with the short-term and long-term parameters selected for each stratum, are summarized in Table 4-12 through Table 4-24. It should be noted that the stratigraphy in each table was primarily based on the boring(s) identified in the table caption, however, other nearby borings were also considered if applicable.

Table 4-12 Soil Properties Used at SNC Sta. 63+536 (Boring POI-15, SNC-27A)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft)	-50	110	250	0	75	18
Clay (stiff)	-70	125	1,500	0	150	18

Table 4-13 Soil Properties Used at SNC Sta. 71+413 (Boring SNC-24A, POI-12/13)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (firm)	-18	125	750	0	80	25
Clay (firm)	-50	110	750	0	80	18
Clay (stiff)	-70	115	1,250	0	125	18

Table 4-14 Soil Properties Used at SNC Sta. 83+000 (Borings SNC-20 and D-1)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (stiff)	-2	110	1,200	0	200	20
Clay (stiff)	-13	120	1,500	0	390	13
Silty Sand (loose)	-23	110	0	28	0	28
Clay (firm to stiff)	-33	120	1,000	0	200	20
Clay (firm)	-78	110	900	0	200	21.5
Sand (very dense)	-80	115	0	38	0	38

Table 4-15 Soil Properties Used at SNC Sta. 87+000 (Boring SNC-18A and D-2)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (stiff)	-9	125	1,100	0	200	20
Clay (stiff)	-20	120	1,100	0	200	20
Silty Sand (loose)	-25	115	0	30	0	30
Clay (stiff)	-75	120	1,100	0	200	20
Clay (soft)	-83	110	450	0	50	18
Silty Sand (very loose)	-88	115	0	25	0	25
Clay (firm)	-105	120	800	0	150	18

Table 4-16 Soil Properties Used at SNC Sta. 102+100 (Boring SNC-11)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (soft to firm)	-14	110	500	0	50	18
Clay (firm)	-26	120	700	0	150	18
Clay (firm to stiff)	-36	115	1,000	0	200	20
Clay (firm)	-43	110	600	0	150	18
Clayey Sand (medium dense)	-64	110	0	34	0	34

Table 4-17 Soil Properties Used at SNC Sta. 111+617 (Boring SNC-06A)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (stiff)	-32	110	1,250	0	150	18
Clay (firm to stiff)	-40	115	1,000	0	100	18
Clayey Sand (loose)	-44	115	0	30	0	30
Clay (stiff)	-57	115	1,500	0	150	18
Clay (firm)	-70	115	750+	0	100	18

Table 4-18 Soil Properties Used at NRC Sta. 12+00 (Boring SNC-01A)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft)	-34	100	150	0	50	18
Clay (firm)	-40	115	750	0	75	18
Clay (Stiff)	-45	115	1,500	0	150	18
Sand with Clay (medium dense)	-56	115	0	31	0	31
Clay (stiff)	-67	115	1,500	0	150	18
Sand (medium dense)	-72	115	0	32	0	32

Table 4-19 Soil Properties Used at NRC Sta. 200+00 (Boring NRC-33A)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft)	-50	110	125	0	50	18
Sand (loose to medium dense)	-58	115	0	32	0	32
Clay (stiff)	-70	120	1,500	0	150	18

Table 4-20 Soil Properties Used at NRC Sta. 340+72 (Boring NRC-27AA)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft)	-30	110	100	0	50	18
Sand (loose)	-36	110	0	29	0	29
Sand (medium dense)	-58	115	0	32	0	32
Clay (firm)	-70	110	500	0	50	18

Table 4-21 Soil Properties Used at NRC Sta. 355+00 (Boring NRC-27AA and D-4)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft to soft)	-36	110	200	0	100	18
Sand (medium dense)	-54	115	0	32	0	32
Clay (firm)	-75	110	750	0	200	18

Table 4-22 Soil Properties Used at NRC Sta. 403+60 (Boring D-5)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft to soft)	-35	100	250	0	50	18
Sand (loose to medium dense)	-55	115	0	32	0	32
Sand (very dense)	-70	120	0	36	0	36

Table 4-23 Soil Properties Used at NRC Sta. 488+00 (Boring D-6)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft to soft)	-20	100	200	0	100	18
Sand (very loose)	-25	110	0	25	0	25
Clay (soft)	-60	110	400	0	200	20
Sand (dense)	-70	115	0	34	0	34

Table 4-24 Soil Properties Used at NRC Sta. 591+00 (Boring NRC-18)

Stratum/ Material	Bottom Elevation (feet)	Total Unit Weight (pcf)	Undrained (short-term)		Drained (long-term)	
			Cohesion, c (psf)	Friction Angle, ϕ (°)	Effective Cohesion, c' (psf)	Effective Friction Angle, ϕ' (°)
Clay (very soft)	-28	100	100	0	50	18
Clay (firm)	-38	120	750	0	75	18
Sand (medium dense)	-44	115	0	32	0	32
Clay (firm)	-52	115	800	0	75	18
Sand (medium dense)	-64	115	0	32	0	32
Clay (soft to firm)	-70	125	500	0	50	25

The thirteen (13) cross-sections were developed from the proposed channel dimensions and were selected based on geometric configuration and subsurface conditions that varied at the sections analyzed. The factors of safety are summarized in Table 4-25.

Table 4-25 Calculated Factors of Safety from Stability Analyses

Reach	Station	Dredge Cut Slope Inclination	Condition	Minimum Required Factor of Safety	Minimum Factor of Safety Calculated in <i>Slope/W</i>
Sabine Neches Canal	63+536	2H:1V	Short-Term	1.3	1.3
			Long-Term	1.4	1.5
Sabine Neches Canal	71+413	2H:1V	Short-Term	1.3	4.0
			Long-Term	1.4	1.4
Sabine Neches Canal	83+000	2H:1V	Short-Term	1.3	1.5
			Long-Term	1.4	1.4
Sabine Neches Canal	87+000	2H:1V	Short-Term	1.3	1.3
			Long-Term	1.4	1.5
Sabine Neches Canal	102+100	2H:1V	Short-Term	1.3	2.0
			Long-Term	1.4	1.4
Sabine Neches Canal	111+617	2H:1V	Short-Term	1.3	2.9
			Long-Term	1.4	1.5
Neches River Channel	12+00	2H:1V	Short-Term	1.3	2.6
			Long-Term	1.4	1.5
Neches River Channel	200+00	2H:1V	Short-Term	1.3	1.4
			Long-Term	1.4	1.4
Neches River Channel	340+72	2H:1V	Short-Term	1.3	1.4
			Long-Term	1.4	1.4
Neches River Channel	355+00	2H:1V	Short-Term	1.3	1.6
			Long-Term	1.4	1.4
Neches River Channel	403+60	2H:1V	Short-Term	1.3	1.4
			Long-Term	1.4	1.4
Neches River Channel	488+00	2H:1V	Short-Term	1.3	1.3
			Long-Term	1.4	1.7
Neches River Channel	591+00	2H:1V	Short-Term	1.3	1.9
			Long-Term	1.4	1.4

The slope stability for this project analysis implemented the FWOP depths, which match the FWP depths for the TSP, and the channel side slopes of 2H:1V. Results from the channel stability analysis show that channel side slopes of 2H:1V are adequate to meet the minimum factor of safety for the proposed FWOP deepening and FWP widening along the entire Sabine-Neches Canal and Neches River Channel alignments. Further details on the slope stability analyses are provided in HDR 2025b.

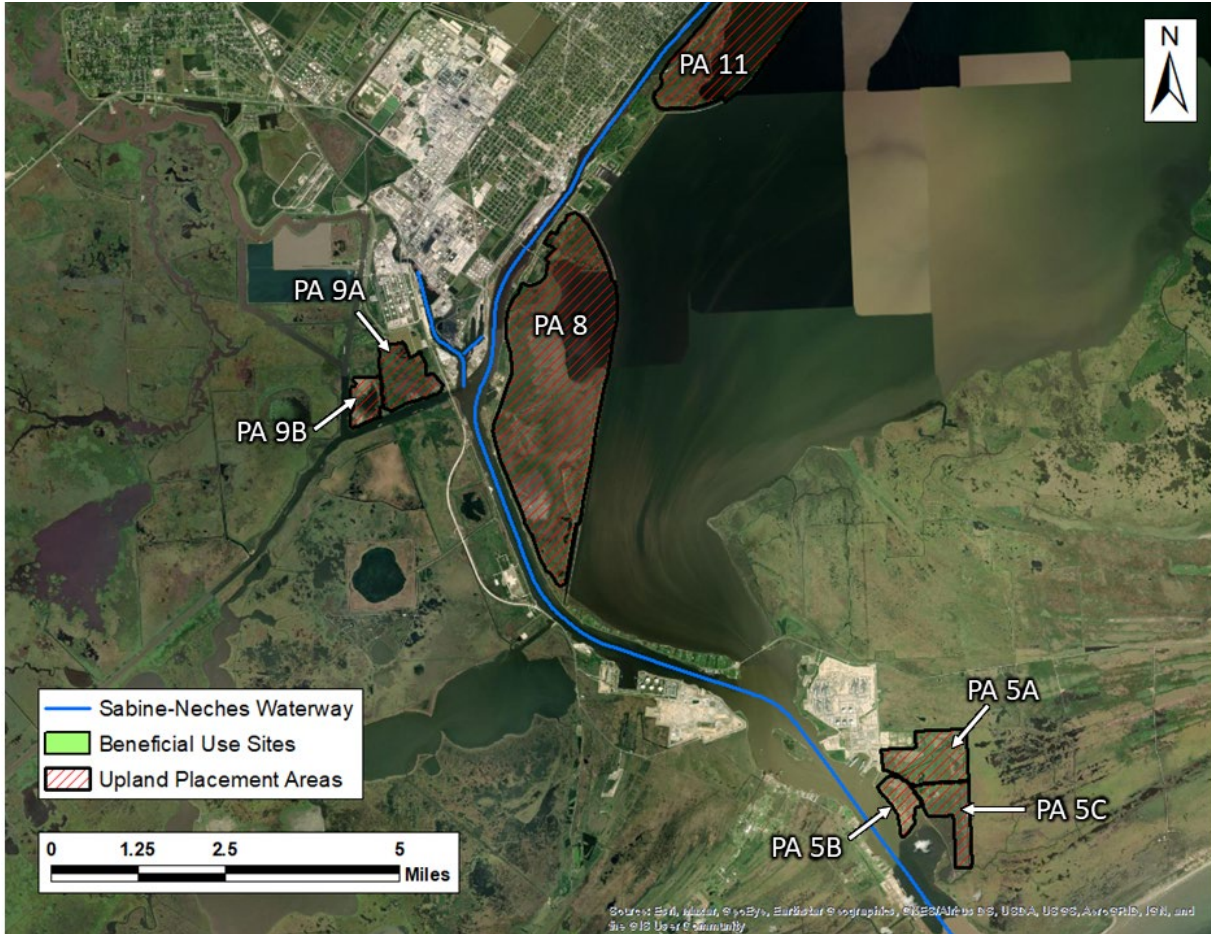


Figure 5-2
Upland Placement Areas and Beneficial Use Sites (SNC)

5.1 Upland Placement Areas

The upland PAs are confined with earthen containment dikes, and dredging effluent is discharged from the PAs via controlled spillways to outfall canals and drainage ditches. The upland PAs are operated and maintained by SNND, except for PA 8 and PA 11, which are federally operated and maintained placement areas. Table 5-1 provides the approximate dimensions of the upland PAs, including footprint, existing containment dike heights, and future containment dike heights that are planned to be constructed over the next 50 years.

Table 5-1: Upland Placement Area Dimensions

Placement Area ^[1, 2]	Footprint (Acres)	Existing Containment Dike Height (FT)	Future Containment Dike Height (FT) ^[3]
5A	489	17	26
5B	175	18	26
5C	333	17	26
8	3,598	19	27
9A	324	22.5	36
9B	172	15	41
11	2,033	10	23
12	366	23	28
13	151	20	31
14	245	14	29
16	284	10.5	22
17	267	16	20
18	354	19	20
21	168	5	21
22	134	7	21
23	512	13	18
24	389	14	30
25	657	10	12
26	173	9.5	34
27	270	5	38

Notes:

- 1) This table includes all upland placement areas along the Sabine-Neches Waterway.
- 2) Information in this table was provided by SNND, except for PA 8 and PA 11 which was based on information provided by USACE.
- 3) Future PA perimeter dike elevations were retrieved from the FWOP engineering appendix (USACE 2010a).

5.2 Beneficial Use Sites

The FWOP channel improvement project includes three planned beneficial use (BU) sites, Bessie Heights East (BHE), Old River Cove (ORC), and Rose City East (RCE), as shown in Figure 5-1. These BU sites will provide ecosystem enhancements through wetlands creation. The three BU sites will be designed during E&D of the FWOP (which is currently ongoing). Because the BU sites are not yet designed, the size and planned use for the BU sites is based on the assumptions in the FWOP engineering appendix (USACE 2008, 2010a, and TCB 2003). The FWOP engineering appendix (USACE 2008, 2010a) and feasibility study (USACE 2011) assumed that the three BU sites would be built-out using new work and maintenance material from the channel deepening as follows:

- **Bessie Heights East** — New work material from the channel deepening would be used for construction of containment berms for placement of marsh fill for the first 30 years of the 50-year O&M dredging.
- **Old River Cove** — New work deepening material would be used to complete the entire BU site (no future O&M dredge material placement was planned).
- **Rose City East** — The first phase this BU site would be constructed with new work material from the deepening project, and the second phase would be completed with the first cycle of maintenance material.

If construction of the widening occurs at the same time as the deepening, material may be placed in the BU sites to supplement material from the main channel. Refer to Section 5.3.4 (Beneficial Use) for more discussion on how the BU sites could be used for the widening TSP.

5.3 Dredged Material Placement Plan

5.3.1 New Work Material

Table 5-2 summarizes the widening TSP new work dredging volumes and placement options by channel segment. Multiple placement areas are provided for each reach to provide flexibility in the placement plan which would be refined during E&D.

**Table 5-2
New Work Dredging Volumes
and Preliminary Placement Areas for the Widening TSP**

Widening Section	Station (From)	Station (To)	Placement Area(s)	Cut Volume (CY) ^[1]	Bulked Volume (CY) ^[2]
SNC (South)	63+500	72+700	8, 11	812,000	894,000
SNC (North)	80+660	110+000	8, 11	3,542,000	3,896,000
SNC (North)	110+000	121+517 ^[3]	11, 12, 13	1,432,000	1,575,000
SNC (North)	0+00 ^[3]	40+00	12, 13, 14	498,000	547,000
NRC	122+40	208+00	13, 14, 16	819,000	901,000
NRC	208+00	256+00	14, 16, 17	460,000	505,000
NRC	256+00	353+00	16, 17, 18	928,000	1,021,000
NRC	353+00	462+00	17, 18, 22	1,043,000	1,147,000
NRC	462+00	480+00	18, 22, 23	173,000	190,000
NRC	480+00	640+00	22, 23	1,531,000	1,684,000
Total:				11,238,000	12,360,000

Notes:

- 1) New work dredging volumes include advance maintenance and allowable overdepth.
- 2) New work dredging volumes were increased by 10% to account for material bulking.
- 3) Channel stationing restarts at 00+00 for the start of the Neches River Channel. The Sabine-Neches Canal ends at station 121+517.

Bulking Factor

The new work dredging volumes were increased using a bulking factor. The amount of bulking varies with the type of sediments and the method of dredging (mechanical or hydraulic). Other factors that affect bulking include size of dredge, horsepower, pipeline (pumping) distance, and residence time in the pipeline. For the TSP, dredging will be conducted hydraulically with cutterhead-suction (pipeline) dredges. The long-term bulking factor for new work dredged material was assumed to be 1.1. This long-term bulking factor considers short-term bulking and long-term consolidation.

Dike Raises

Prior to placing any new work material into the placement areas, available capacity will be reviewed and when necessary, dike heights will be increased to accommodate the dredged material. The cost estimate for the widening TSP assumes dike raises will be needed at the SNND-owned and operated PAs to accommodate new work material. No dike raises will be required at the federal PAs (PA 8 and PA 11) for approximately 8 to 12 years following the new work placement of material dredged from the FWOP and TSP work.

5.3.2 Maintenance Material

Maintenance dredging volumes for the widening TSP were quantified over a 50-year period of analysis. Table 5-3 includes the expected maintenance volume per dredging cycle, the number of years between cycles, the total number of dredging cycles over 50 years, and the total 50-yr maintenance volumes with and without shrinkage by channel segment.

**Table 5-3
50-Year Shoaling Analysis for the Widening TSP**

Reach	Station (From)	Station (To)	O&M per Cycle ^[1] , CY	Years per Cycle	Total # of Cycles over 50 years	Total 50-Yr O&M, CY	Total 50-Yr O&M (Shrinkage Included) ^[2] , CY
SNC	63+500	66+250	125,000	3	16	2,000,000	1,400,000
SNC	66+250	72+700	105,000	4	12	1,260,000	882,000
SNC	81+742	110+000	461,000	4	12	5,532,000	3,872,000
SNC	110+000	121+517	188,000	4	12	2,256,000	1,579,000
NRC	0+00	40+00	83,000	3	16	1,328,000	930,000
NRC	122+40	155+00	68,000	3	16	1,088,000	762,000
NRC	155+00	345+00	344,000	3	4	5,504,000	3,853,000
NRC	345+00	475+00	314,000	4	12	3,768,000	2,638,000
NRC	475+00	505+00	109,000	6	8	872,000	610,000
NRC	505+00	640+00	180,000	6	8	1,440,000	1,008,000
Total:						25,048,000	17,534,000

Notes:

- 1) Shoaling quantities were calculated based on the shoaling rates in the SNWW Channel Improvement Project Dredged Material Management Study shoaling analysis report (USACE 2021).
- 2) Long term placement of O&M material includes a shrinkage factor of 0.7.

Shoaling Rates

Changes to channel depth or width can lead to changes in shoaling rates in varying scales both in the near-term during system acclimation and in the long-term (USACE 2021). Shoaling rates assumed in the FWOP engineering appendix were based on a desktop study performed by ERDC (USACE 2010a). USACE reevaluated the shoaling rates for the deepening project in April 2021 (USACE 2021). Although channel widening was not included in the study, the portions of the channel where widening are proposed were reviewed to assess changes in shoaling rates between the USACE 2010 and 2021 shoaling studies. In all the channel segments with proposed widening, shoaling rates slightly decreased from the USACE 2010 to 2021 shoaling studies for the channel deepening. In some of the other segments of the channel where no widening is proposed, shoaling increased.

This widening study also assesses the potential for changes to the shoaling rates due to the widening project. The rate of deposition of sediment for a given area in a channel depends on

particle settling velocity, probability of particle resuspension, and concentration of particles near the bed (USACE 2006). Particle density and diameter influence the settling velocity (Krone 1962) and current velocity at the channel bottom influences the probability of resuspension (USACE 2006). In the channel, sediment particles form flocs, which have a lower density and a greater diameter than the individual particles. Flocculation is a complex process driven in large part by salinity and current velocity.

Sediment characteristics are not expected to change due to the widening project. Therefore, any changes to the shoaling rates would be due to any potential changes to salinity or current velocity. Numerical modeling was performed to investigate potential changes in velocity and salinity using 2D and 3D hydrodynamic numerical models as described in Section 0 and in further detail in Attachments 3 and 6. The modeling results suggested changes in both current velocity and salinity were negligible and less than model confidence levels. Therefore, because the channel widening project is generally not expected to alter salinity or current velocity in the SNWW, floc size, settling velocity and resuspension, and consequently shoaling per area will be unchanged from the FWOP channel condition. Shoaling in the channel will increase proportionally to the increase in cross-sectional area that occurs because of the widening project. This analysis is consistent with the approach previously taken to estimate changes in shoaling from the FWOP (USACE 2008).

Dredging Cycles

The dredging cycle of a channel is defined by the average number of years between the O&M dredging operations for a historical period. The updated USACE shoaling analysis methodology assumes a dredge cycle consistent with what was recommended in the deepening feasibility study but notes that further analysis could be done to evaluate the economics of the dredge cycle (USACE 2021). For the purposes of this study, it was assumed the dredging frequencies would remain the same for the FWOP and FWP conditions.

Shrinkage Factor

Long-term storage capacity requirements for the deepening E&D and the widening feasibility are based on a shrinkage factor. Items that affect the shrinkage include the soil composition, pan evaporation rate, consolidation, desiccation, climatological conditions, drainage efficiency or dewatering measures implemented, and dredging schedule of maintenance material placed at the sites. Determination of a precise shrinkage factor for a placement area can be a complex task that includes modeling the consolidation and desiccation shrinkage based on laboratory test data, climatological data, drainage characteristics, and operational characteristics. The FWOP engineering appendix (USACE 2008) applied a shrinkage factor between 0.55 and 0.75 for SNWW maintenance dredging. A shrinkage factor of 0.65 was applied for a similar project at the Freeport Ship Channel (USACE 2012). For this feasibility study, the development of the long-term storage capacity and containment dike height requirements was based on a shrinkage factor of 0.7 for maintenance material.

5.3.3 50-yr Placement Capacity Analysis

New work and maintenance dredging volumes from the proposed widening TSP improvements were determined to fit within the overall 50-yr DMMP that was developed as part of the FWOP design. The 50-yr DMMP is a living document and modifications to the plan are under development as part of the deepening construction contract E&D. As shown in Table 5-4, the SNWW PAs and BU sites have sufficient capacity to hold all new work and 50-year maintenance

material for the deepening and widening dredging assuming the future dike heights presented in the feasibility study for the FWOP conditions (USACE 2011).

**Table 5-4
50-Year Placement Capacity Summary**

Project Element	Volume, CY
FWOP New Work Placement Capacity (After Deepening)	41,523,000 ^[1]
New Work Dredging Volume (Widening)	12,360,000 ^[2,3]
Remaining Capacity After Widening New Work Placement:	29,163,000
50-Year O&M Placement Capacity after New Work Placement (Deepening and Widening)	199,711,000 ^[6]
50-yr O&M Dredging Volume (Deepening)	172,101,000 ^[4]
50-yr O&M Dredging Volume (Widening)	17,534,000 ^[4,5]
Remaining Capacity After 50 Years:	10,076,000

Notes:

- 1) FWOP placement capacity includes dikes raises at existing PAs as well as construction of BU sites, which will be constructed as part of the channel deepening work. FWOP placement capacity was estimated for the deepening project design documentation reports (DDR).
- 2) New work dredging volumes were increased by 10% to account for material bulking.
- 3) Refer to Table 5-2 for new work volumes by widening section.
- 4) Long term placement of O&M material includes a shrinkage factor of 0.7.
- 5) Refer to Table 5-3 for O&M volumes by widening section.
- 6) The 50-yr PA capacity assumes dike raises will be constructed to the future heights in the FWOP engineering appendix (USACE 2010a) as shown in Table 5-1.

5.3.4 Beneficial Use

Since the FWOP condition assumes the BU sites will be built-out using new work and maintenance material from the channel deepening, it was assumed for the preliminary widening placement plan that no new work material from the TSP would go to the BU sites; however, the capacity of the BU sites will be verified and updated to current conditions using data gathered as part of the ongoing FWOP E&D (e.g., existing water depths and soil borings). Based on ongoing preliminary design of the deepening project, additional capacity may be available at the BHE and ORC BU sites as compared to what was identified in the FWOP engineering appendix. This capacity is expected to increase due to erosive conditions within the marsh, relative sea level rise, and sediment consolidation. If additional capacity at the BU sites is identified during E&D, the additional material could come from the widening TSP. The long-term capacity of the BU sites will need to be adaptively managed based on future conditions.

Creation of the wetlands at these BU sites may be accelerated by placing dredged material from the TSP to supplement placement of dredged material from the FWOP work if capacity is available. Because dredging the TSP may occur concurrently with dredging for the FWOP work, placement of the additional dredged material from the TSP construction would accelerate the time frame for ecological benefits to be achieved from beneficial placement at the BU sites.

In summary, the conceptual placement plan developed during this study for the widening TSP is based on all dredged material going to upland PAs, but during the widening E&D a plan should be developed to place material at the BU sites if the opportunity presents itself, with the benefit being that the ecosystem benefit goals of the FWOP could be reached sooner.

6 Shoreline Protection and Dike Relocation

Quantities in this section were developed based on a 2.5H:1V channel side slope for the TSP. The channel side slopes were updated to 2H:1V based on updated geotechnical analysis following the development of this section (HDR 2025a). These quantities are considered conservative for the development of the cost estimate and will be updated for steeper side slopes during the design phase.

6.1 Riprap/Debris Removal

Rock and other material along the Sabine-Neches Canal between Sta 81+800 and 105+800 requires removal during construction. Materials consist of engineered riprap mixed with rubble/concrete debris that is believed to have been dumped along this reach when Pleasure Island was created. The exact source or volume of rubble/concrete debris within the area affected by the widening is unknown.

Table 6-1 summarizes the approximate length of material to be removed as part of the FWOP and TSP by reach. Approximately 4,470 ft of existing, non-continuous riprap and debris will be removed as part of the FWOP. An additional 5,300 ft will be removed for the channel widening project (TSP). Assuming 10 CY per linear ft, the total volume of material to be removed as part of the widening TSP is estimated to be approximately 53,000 CY.

**Table 6-1
Existing Shoreline Protection to be Removed⁽¹⁾**

Location Description	FWOP Length ^[2], ft	FWP (TSP) Length, ft	Total Length ^[3], ft
Pleasure Island Golf Course (South): Station 81+000 to 85+300	2,485	1,070	3,555
Pleasure Island Golf Course (North): Channel Sta. 86+000 to 88+300	1,880	465	2,345
Near but not adjacent to PA 11: Channel Sta. 88+900 to 89+100	0	170	170
Adjacent to PA 11 dike (South): Channel Sta. 100+800 to 103+600	0	2,850	2,850
Adjacent to PA 11 dike (North): Channel Sta. 104+800 to 105+700	105	745	850
Total, ft:	4,470	5,300	9,770

Notes:

- 1) The exact volume of rubble/concrete debris is unknown but can be approximated by multiplying lengths in the table by 10 assuming 10 CY per linear ft.
- 2) The FWOP dredging would impact approximately 4,470 ft of existing riprap. These same areas would also be impacted by the FWP (TSP), but it was assumed that these areas will only be removed/replaced once.
- 3) The total length of existing riprap to be removed/relocated between both the FWOP and FWP (TSP) dredging.

6.2 Revetment Replacement

A portion of the existing riprap (approximately 3,300 LF) stabilizes the containment dike for a federal dredged material placement area, PA 11. The PA 11 containment dike will be relocated, and the revetment will be reconstructed after the channel widening as part of the TSP work.

Revetment will be constructed with rock riprap placed on geotextile fabric. Design dimensions were assumed to be as follows resulting in an estimated volume of 33,000 CY of riprap:

- 2.5:1 slope
- Crest at elevation +5 ft MLLW.
- Toe at elevation -10 ft MLLW.
- Revetment Layer Thickness = 5 ft.

6.3 Containment Dike Relocation

A portion of the existing PA 11 containment dike (approximately 3,300 LF) will be relocated after the channel widening as part of the TSP work. Design dimensions were assumed to be as follows, resulting in an estimated volume of 4,440 CY of containment dike reconstruction:

- Containment dike will be shifted 50 ft to the east.
- Length of containment dike relocation will match the length of shoreline protection reconstruction.
- Containment dike cross-section will match USACE Placement Area No. 11 FY21 Dike Improvement plans (Solicitation W912HY21B0017).
- Containment dike Crest Elevation at +10 ft MLLW.

- Containment dike Crest Width of 10 ft.
- Containment dike Side Slopes 3H:1V.
- Material compaction factor of 1.2.

Prior to dike relocation, the ultimate capacity of PA 11, based on a dike height of 23 ft, is estimated to be over 41 MCY. Containment dike relocation will reduce the remaining PA capacity by 80,000 CY, which is less than 0.2% of the ultimate capacity.

6.4 Construction Access for Riprap/Debris Removal and Revetment Construction

Rock riprap will be delivered to construction sites via barge. Depending on location, removal of riprap/debris and reconstruction of revetment will be constructed using bucket excavators working either from a barge or the bank. Potential landside 12-ft to 25-ft wide construction access routes are shown in Figure 6-1.



Figure 6-1
Land-based Construction Access Routes

7 Hydrodynamic Modeling

Numerical modeling was used to assess hydrodynamic changes to the SNWW system resulting from the project alternatives and TSP and to infer potential changes to bank erosion, shoaling, and water quality. The overall hydrodynamic modeling effort included four numerical models (Table 7-1), including two-dimensional (2D) modeling of hydrodynamics associated with daily tides, storm surge events, and hydrodynamic modeling of passing vessels in the SNWW, and 3D modeling of hydrodynamics to assess water quality changes. The effects of relative sea level change and the effects of wind in combination with the astronomical tide on the hydrodynamics in the channel and bay system were included in the investigations. The modeling effort and supporting work are described in detail in Attachments 3 through 6 to this engineering appendix and summarized in the following sections.

**Table 7-1
Hydrodynamic Models**

Model	Purpose	Findings and Conclusions
Tidal Circulation (Attachment 3)	Evaluate potential effects of the proposed channel widening on the movement of water in and out of the SNWW to assess shoaling and navigation impacts.	Small changes in current speeds due to the widening would not affect navigation or shoaling rates associated with the deepened channel. Additional shoaling in the widened areas would increase proportionally to the increase in cross-sectional area from the channel widening.
Storm Surge (Attachment 4)	Assess potential changes to storm surge inundation resulting from the channel widening project.	Changes to peak surge elevations due to the channel widening are de minimis, and the project is not expected to have an impact on the surge elevations or durations around the SNWW.
Vessel Effects (Attachment 5)	Evaluate potential effects of proposed channel widening on vessel drawdown, return currents, and bank erosion.	The proposed widening is not expected to increase drawdown, return currents, or bank erosion. The number and type of vessels calling on the SNWW are not expected to change due to the channel widening.
Water Quality (Attachment 6)	Evaluate potential changes to current speed, water elevation, salinity, temperature, and dissolved oxygen (DO) due to the proposed channel widening.	The proposed widening is expected to have negligible effects on current speeds, tidal amplitude and phase, salinity, temperature, and DO. The channel widening is limited to certain reaches of the channel and not expected to materially change the volume exchange of the SNWW and surrounding water bodies.

Modeling performed for previous related feasibility studies were reviewed as a foundation for this study. Available existing data was used for the modeling efforts with additional collected data where noted. The modeling team used the best available published survey data at the time model development was initiated. Elevation data were published by NOAA, a trusted federal entity for coastal elevation data and modeling across the industry. Modelers performed a search for additional available datasets and did not discover more recent data at the time modeling was initiated in 2020. Since completion of the modeling for this report, bathymetric datasets have been collected as part of the Sabine to Galveston Study, which will be available for any future studies. The differences in the modeled bathymetry dataset and newer bathymetry datasets will not have much effect on project alternative evaluations, since the primary intention of the model is the

comparison of with and without project conditions, which is successfully performed by maintaining a constant elevation dataset between model runs and only changing the channel geometry to determine the incremental difference between with and without project conditions. Further, elevation data in the channel were modified to match the with and without project dredging templates such that existing elevation data in these areas are irrelevant.

The modeling effort underwent an independent external peer review by Dynamic Solutions, LLC. Dynamic Solutions, LLC maintains a staff of largely senior-level engineers, scientists, and modelers who are experts in multi-dimensional hydrodynamic, sediment transport, water quality, and ecosystem modeling applications and applied research. Reviews of the four models were conducted to ensure the modeling is technically sound; represents the system being modeled; is applied correctly; uses appropriate data for calibration and validation; and provides the basis for the conclusions being drawn from the results. The review tasks included early coordination on model selection and setup, model calibration and validation, review of modeling reports and coordination with project modelers to assess the applicability and completeness of the modeling efforts, and ultimately peer review of the completed work. The review confirmed acceptability of the modeling approach (e.g., modeling software, boundary conditions, model grids, calibration, etc.), calibration and validation, results, and the appropriateness of conclusions.

7.1 Modeled Channel Configurations

For each of the 2D modeling efforts (i.e., tidal circulation, storm surge, and vessel effects), six different channel configurations were modeled as described below. Given the timing of the 3D hydrodynamic modeling, the modeled channel configurations were reduced to existing conditions, FWOP, and the final alternatives (Alternatives 1 and 2) for evaluation of water quality impacts.

- (1) Existing Conditions (EC): Channel conditions in place during the time of the data record used for model calibration (2018-2020 timeframe) prior to the start of the deepening project construction.
- (2) Future Without Project (FWOP): Completed deepening project to an authorized depth of 48 ft below MLLW without the proposed widening measures.
- (3) Future with Project Full Build (FWPFB): Largest combination of proposed widening measures before screening of widening concepts and development of alternatives.
- (4) Alternative 1 (ALT1 or TSP): Widening to 500 ft (+100 ft) reaches of the Sabine-Neches Canal and the Neches River Channel. Authorized depth remains 48 ft below MLLW. Same as Alternative 1 described in Section 2.2.2, except that it also included the AB4 expansion.
- (5) Alternative 2 (ALT2): Widening to 600 ft (+200 ft) reaches of the Sabine-Neches Canal and the Neches River Channel. Authorized depth remains 48 ft below MLLW. Alternative 2 includes widening in the same locations as Alternative 1 but increases the width by 100 ft. Same as Alternative 2 described in Section 2.2.2, except that it also included the AB4 expansion.
- (6) Alternative 3 (ALT3): Widening to 500 ft (+100 ft) reaches of the Sabine-Neches Canal and the Neches River Channel and widening to 700 ft (+200) the Sabine Pass Channel and the Port Arthur Canal. Alternative 3 is the same as Alternative 1 in the Sabine-

Neches Canal and Neches River Channel but also includes widening of the southern reaches. Same as Alternative 3 described in Section 2.2.2, except that it also included the AB4 expansion.

Table 7-2 summarizes the modeled channel configurations and indicates which were modeled with relative sea level change (RSLC) for comparison to the without RSLC model runs. Results for channel configurations modeled with and without RSLC were extrapolated to alternatives where configurations were not run with RSLC. Refer to Section 7.3, Relative Sea Level Change, for details on the RSLC scenario.

**Table 7-2
Modeled Configurations and RSLC Comparisons**

Model	EC	FWOP	FWPFB	ALT1	ALT2	ALT3
Tidal Circulation (Attachment 3)	1	1, 2	1, 2	1	1	1
Storm Surge (Attachment 4)	1	1, 2	1, 2			
Vessel Effects (Attachment 5)	1	1, 2	1, 2	1, 2	1, 2	1, 2
Water Quality (Attachment 6)	1	1, 2		1, 2	1, 2	

Notes:

1) Modeled without RSLC

2) Modeled with RSLC

7.2 Water Levels, Wind, and Currents

Water level, flow discharge, and current velocity data were available from NOAA and USGS online datasets and were used for calibration and validation in the modeling studies. Additional data on wind speed and direction and bathymetric and topographic elevations were available from NOAA. Historical and synthetic wind speed, hurricane track, and water level data for the storm surge modeling study were available from the Coastal Hazards System published by USACE. Refer to the modeling reports in Attachments 3 through 6 for further details.

7.3 Relative Sea Level Change

Analysis of RSLC was incorporated into the SNWW hydrodynamic modeling in accordance with USACE guidance document ER 1100-2-8162 “Incorporating Sea Level Change in Civil Works Programs.” ER 1100-2-8162 provides methods for determining the range of possible future rates of global, regional, and local RSLC that planning studies are required to consider. The RSLC rates represent eustatic sea level change and vertical land motion, and are classified as “low,” “intermediate,” or “high” scenarios, as follows:

- The low rate is based on linear trends developed from historical observed data from tide stations.
- The intermediate rate is determined based on the modified NRC Curve I (NRC 1987).

- The high rate is determined based on the modified NRC Curve III (NRC 1987).

RSLC scenarios for this study are based on data from the NOAA 8770570 Sabine Pass North, TX gauge near the entrance the Gulf of America to the SNWW (Figure 7-1).

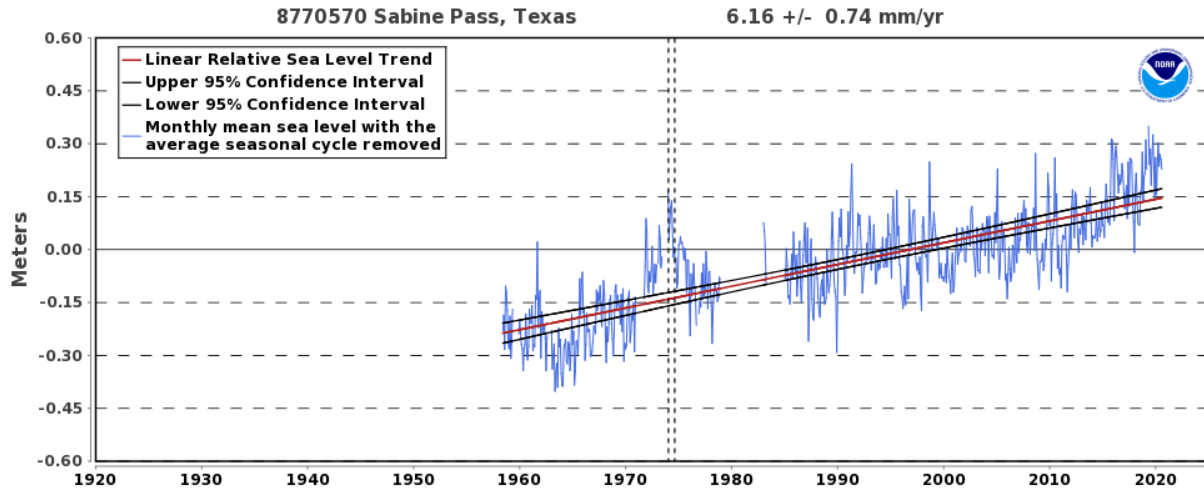


Figure 7-1
Relative Sea Level Trend at NOAA Station 8770570 from 1958 to 2020

(Source: [Sea Level Trends - NOAA Tides & Currents](#))

Scenarios for three RSLC rate scenarios (low, intermediate, and high) and two timeframes (50 and 100 years after project baseline of 2028) were generated using USACE’s online sea-level calculator (Figure 7-2). The low RSLC rate, based on the observed data at NOAA 8770570, is approximately 6 mm/yr², which results in approximately 0.5 m (1.6 ft) RSLC by 2078 (Table 7-3). The intermediate and high RSLC scenarios show accelerating RSLC and result in approximately 0.7 m (2.2 ft) and 1.3 m (4.3 ft), respectively, by 2078.

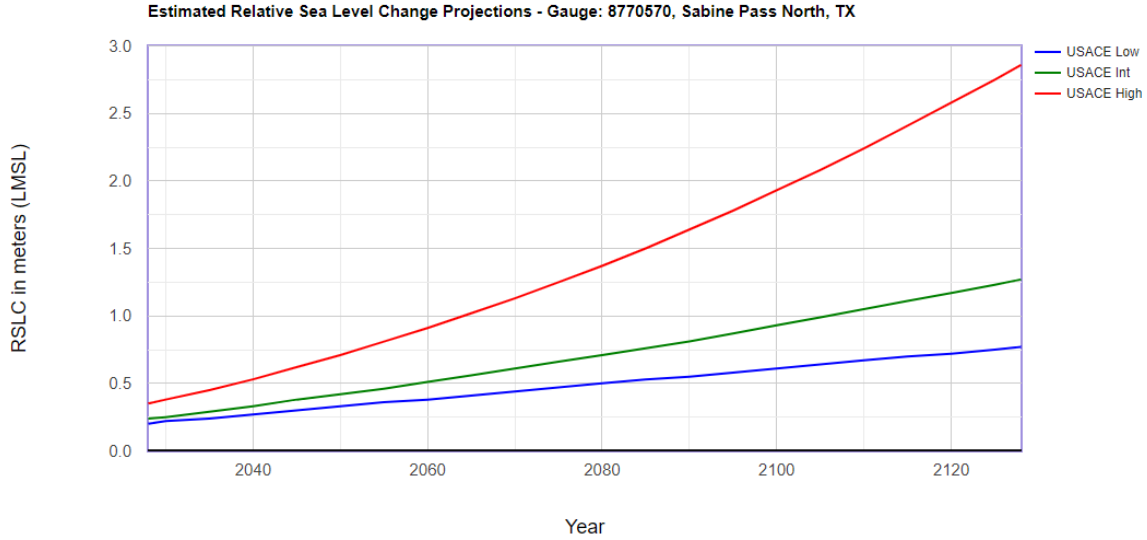
Table 7-3
RSLC Values Based on USACE Online Sea-Level Calculator (NOAA 8770570)

Scenario	50 Years (2078) ^{1,2}	100 Years (2128) ¹
Low	0.5 m (1.6 ft)	0.8 m (2.5 ft)
Intermediate	0.7 m (2.2 ft)	1.3 m (4.2 ft)
High	1.3 m (4.3 ft)	2.9 m (9.4 ft)

¹All values are expressed in feet relative to LMSL (NAVD88 was not available for NOAA 8770570 gauge).

² Values for 2078 are the average of 2075 and 2080 values shown in Figure 7-2.

² The relative sea level trend applied in the SNWW hydrodynamic modeling was 5.66 mm/yr with a 95% confidence limit of ± 1.07 mm/yr derived based on observations from 1958 to 2006. A more recent relative sea level trend is 6.16 mm/yr with a 95% confidence interval of ± 0.74 mm/yr based on observations from 1958 to 2020.



8770570, Sabine Pass North, TX
 NOAA's 2006 Published Rate: 0.00566 meters/yr
 All values are expressed in meters relative to LMSL
 Gauge Status: Compliant

Year	USACE Low	USACE Int	USACE High
2028	0.20	0.24	0.35
2030	0.22	0.25	0.38
2035	0.24	0.29	0.45
2040	0.27	0.33	0.53
2045	0.30	0.38	0.62
2050	0.33	0.42	0.71
2055	0.36	0.46	0.81
2060	0.38	0.51	0.91
2065	0.41	0.56	1.02
2070	0.44	0.61	1.13
2075	0.47	0.66	1.25
2080	0.50	0.71	1.37
2085	0.53	0.76	1.50
2090	0.55	0.81	1.64
2095	0.58	0.87	1.78
2100	0.61	0.93	1.93
2105	0.64	0.99	2.08
2110	0.67	1.05	2.24
2115	0.70	1.11	2.41
2120	0.72	1.17	2.58
2125	0.75	1.23	2.75
2128	0.77	1.27	2.86

Figure 7-2
USACE RSLC Scenarios from 2028 to 2128
 (Source: [Sea-Level Change Curve Calculator \(army.mil\)](http://sea-level-change-calculator.army.mil))

The ER 1100-2-8162 guidance suggests a single scenario can be used to identify the preferred alternative under that scenario. The preferred alternative's performance can then be evaluated under all RSLC scenarios to determine its overall performance. This approach is appropriate when project performance is not highly sensitive to RSLC. RSLC values between 1.0 m and 1.43 m NAVD88 were applied within each of the hydrodynamic models. Since the approximate 2020 mean sea level is equivalent to 0.43 m NAVD88, adding 1.43 m NAVD88 to the modeling meshes is equivalent to adding 1.0 m of sea level rise, which falls between the intermediate and high RSLC scenarios for 50 years. Refer to the modeling reports in Attachments 3 through 6 for further details on RSLC modeling. Note: The RSLR timeframes presented in the modeling reports are slightly different than in this appendix, because this appendix has been updated to reflect an updated economic baseline year of 2028.

The results of the hydrodynamic modeling showed that the inclusion of RSLC resulted in smaller incremental differences between FWOP and the channel widening alternatives. The channel widening project is not highly sensitive to RSLC, so RSLC is not an important factor in formulation of the TSP (unlike a storm surge reduction levee design project where RSLC would be factored into the levee elevation and level of risk reduction). A potential impact that RSLC would have on the TSP is that the revetment protecting PA 11 may need to be raised in the future. Further RSLC considerations on the PA 11 dike relocation should be evaluated during PED.

7.4 Tidal Circulation Modeling

This section provides a brief overview of the tidal circulation modeling performed to evaluate potential effects of the proposed channel widening on the movement of water in and out of the SNWW to assess shoaling and navigation impacts. Refer to the Tidal Circulation Modeling Report in Attachment 3 for details.

7.4.1 Model Software

Tidal circulation modeling was performed using the MIKE 21 Flow Model HD FM (hydrodynamic modeling using flexible mesh) designed to resolve the navigation channel and important hydraulic features. MIKE 21 Flow Model HD FM is a state-of-the-art commercial software distributed by Danish Hydraulics Institute (DHI) that simulates hydrodynamics based on oceanic tidal boundary conditions and meteorological forcing (wind and pressure). The flexible mesh module allows for higher resolution model gridding at locations requiring more resolution of the hydrodynamics (e.g., near the project site and key features such as jetties and channel openings). Notably, this model is on the FEMA list of “Hydraulic Numerical Models Meeting the Minimum Requirement of National Flood Insurance Program,” and use of MIKE 21 Flow Model HD FM for this type of project is consistent with industry standards. This model is 2D in the sense that it simulates hydrodynamics using vertically depth averaged equations.

7.4.2 Modeling Overview

The techniques applied for this work were developed after a review of the previous hydrodynamic modeling of daily tides that was completed for the SNWW deepening project, and of similar work for Houston Ship Channel (HSC).

The model mesh extends approximately 50 km (31 mi) landward from the SNND jetties, approximately 53 km (33 mi) to the east and 43 km (27 mi) to the west of the main shipping

channel. The model was forced at the entrance to the Gulf of America using water level, as well as two additional upstream water level boundaries and one upstream discharge boundary based on available NOAA and USGS gauges (Figure 7-3). Model runs simulated a 2-week period and model calibration was performed using NOAA gauges located within the model domain. Additional model runs were performed to qualitatively assess changes due to RSLC and wind.

A series of MIKE 21 Flow Model HD FM model scenarios were developed to investigate the influence of widening portions of the SNWW channel on hydrodynamics associated with typical tidal activity. In total, ten combinations of channel configurations, model forcing, and boundary conditions were modeled. The analysis focused on two key parameters: (1) peak current speed along the entire length of the channel and (2) time series of velocity along the channel, which enabled comparisons of trends in the data and the isolation of flood and ebb velocities.

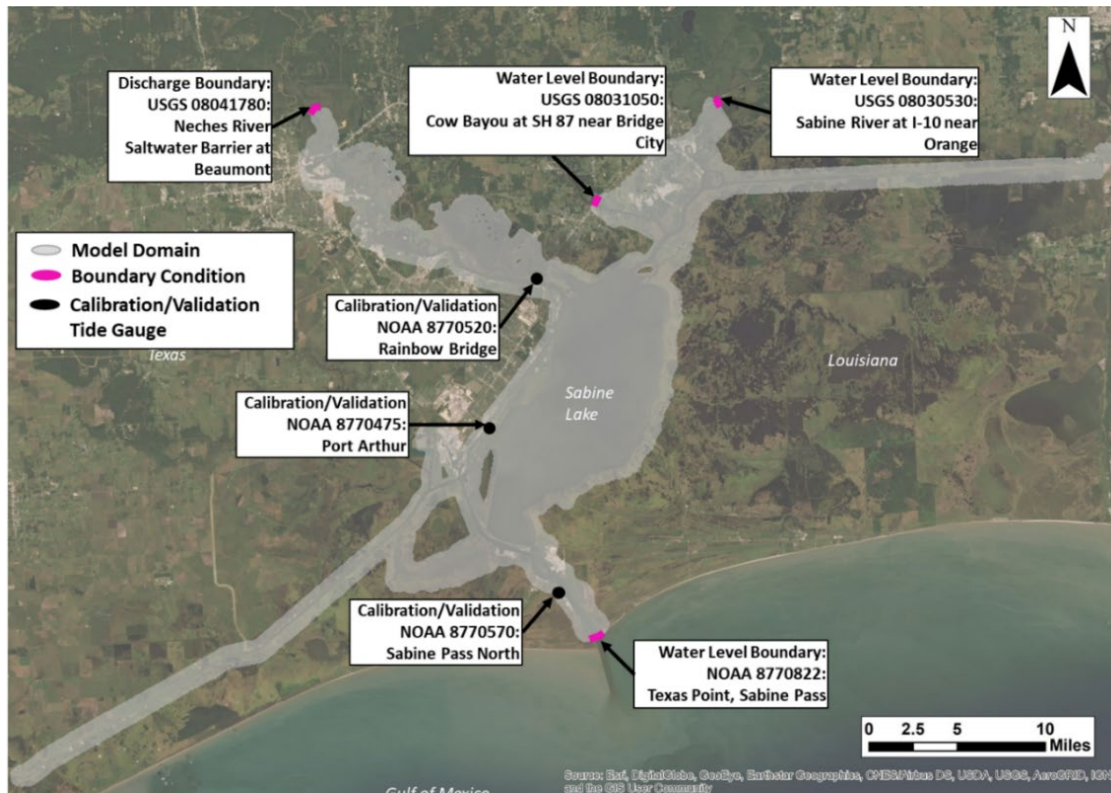


Figure 7-3
Model Boundary Conditions and Calibration Locations

7.4.3 Model Results and Conclusions

Model results for the EC, FWOP, and FWPFB conditions are compared based on peak absolute current velocity and peak flood and ebb current velocity and direction. Results for the alternatives are similar to the results seen for the FWPFB. The results from the modeling can be summarized as:

- The FWPFB model generally shows a small decrease in the maximum current speeds within the widened segments of the channel and a small increase in current speeds for areas that are not widened. This result is consistent for both flood and ebb tides.

- The inclusion of RSLC increased peak and average current speeds throughout the domains, but the relationship between the FWOP and FWPFB remained the same.
- Inclusion of a moderate wind in the model domain had little effect on the small differences between the FWOP and FWPFB model comparisons. Model runs with more extreme winds were not performed. Although faster winds may increase current velocities, the comparisons between FWOP and the widened channels is not expected to change.
- Unvalidated model tidal velocity results indicate that base-to-plan changes will be small, less than the model uncertainty bounds of 0.3 m/s.

In summary, small changes in current speeds due to the widening would not affect navigation or shoaling rates associated with the deepened channel. Additional shoaling in the widened areas would increase proportionally to the increase in cross-sectional area that occurs from the channel widening.

7.5 Storm Surge Modeling

This section provides a brief overview of the storm surge modeling performed to assess potential changes to storm surge inundation resulting from the channel widening project. Refer to the Storm Surge Modeling Report in Attachment 4 of this engineering appendix for details.

7.5.1 Model Software

Storm surge modeling was performed using the MIKE 21 Flow Model HD FM to simulate the hurricane-generated storm surge inundation within the existing channel, surrounding inundation plain, and future project alternatives. Features of the MIKE21 Flow Model HD FM were previously described in Section 7.4.1.

7.5.2 Modeling Overview

Model calibration/validation was based on comparisons of similar storm surge modeling developed by USACE as part of the Sabine to Galveston (S2G) modeling study (USACE, 2015). The MIKE Flow Model HD FM model domain extends approximately 20 km offshore to 5 km north of Orange, and east and west (lateral boundaries) approximately 23 km and 34 km from the SNWW entrance, respectively (Figure 7-4). The model domain also includes one of two major flood defenses either existing or planned within the Sabine Region (Figure 7-5). The Port Arthur flood defense system helps protect the town of Port Arthur, TX from hurricane surge via an earthen levee that surrounds the town on three sides. The Port Arthur features were modeled in MIKE 21 Flow Model HD FM as an “infinitely tall” wall, consistent with the approach used during the S2G study (USACE, 2015). The S2G study also includes a proposed Orange, TX flood defense feature. This feature is, however, still under design and was consequently not included as a “Project Feature” in this study.

Model forcing used synthetic storms downloaded from the USACE Coastal Hazard System (USACE, 2015) which, for this project, used a subset of storms from FEMA’s flood insurance mapping (FEMA, 2011). Boundary conditions in the model applied output from the same FEMA FIS modeling which had incorporated a larger regional area. One synthetic storm was applied as model calibration and two synthetic storm surge events were modeled to assess changes in water

level within the SNWW and near the proposed flood defense feature meant to reduce risk to the town of Orange, Texas. The same storms were modeled incorporating RSLC.

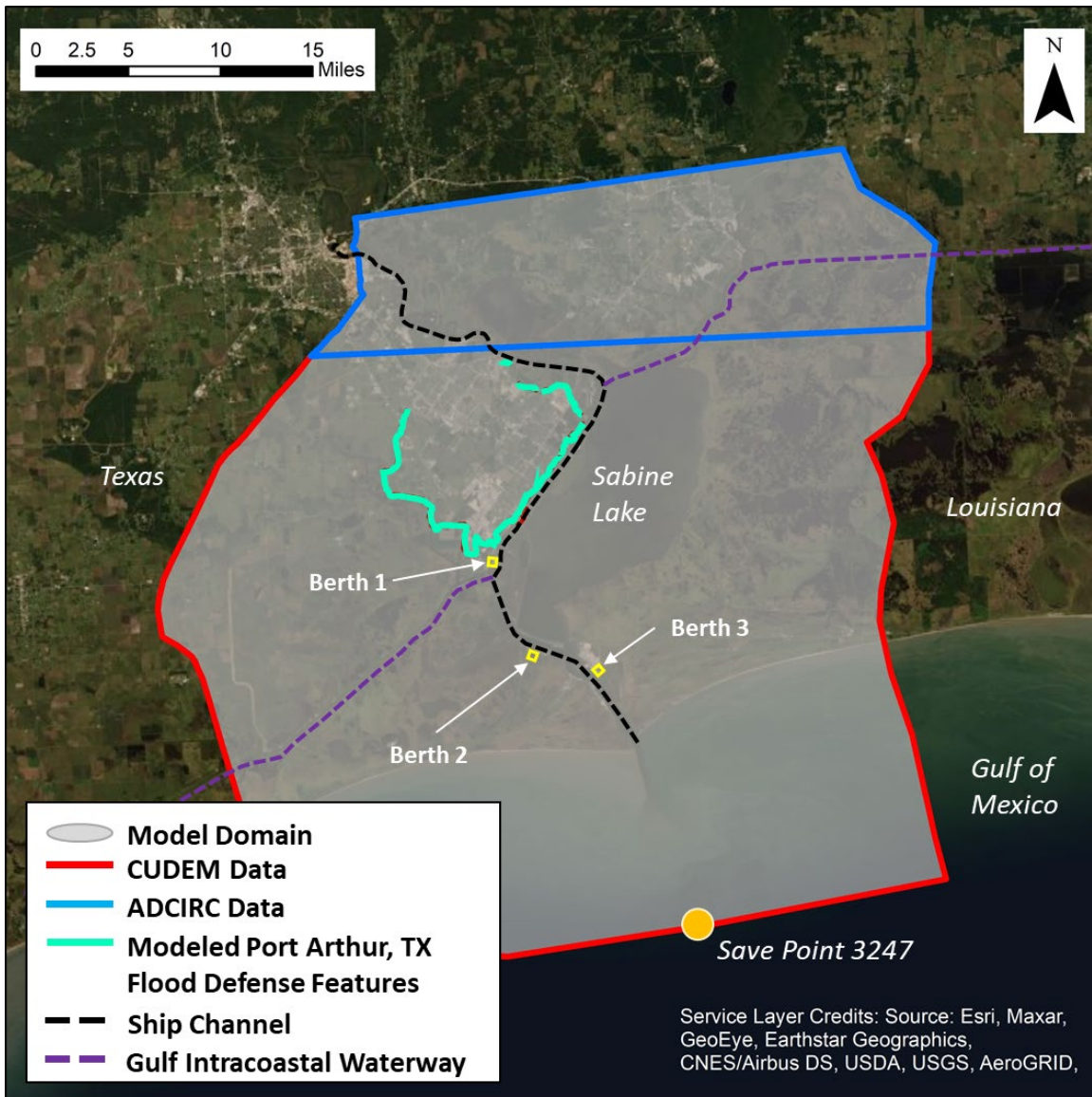


Figure 7-4
Storm Surge Model Domain and Elevation Source Data Summary

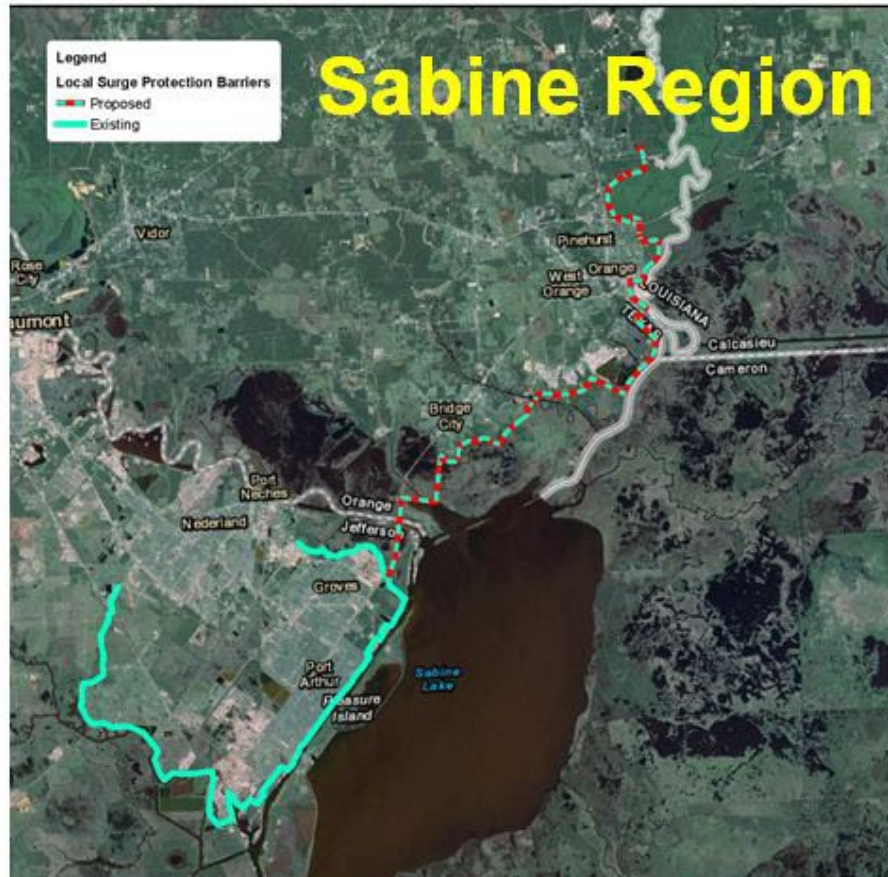


Figure 7-5

Port Arthur, TX And Proposed Orange, TX Flood Defense Features: USACE (2015)

7.5.3 Model Results and Conclusions

The following results were observed from the storm surge modeling:

- Model calibration resulted in a mean error of 10 cm.
- Comparisons of peak water level along the channel alignment and at the Orange flood defense structure showed a maximum increase of 7 cm between the FWOP and FWPFB conditions, and a maximum increase of 3 cm between the FWOP and Alternative 1 (TSP) conditions.
- Evaluation of model time series showed no change in inundation duration.
- The inclusion of relative sea level change resulted in smaller differences between FWOP and the channel widening alternatives.

Based on the results of the modeling, the changes to peak surge elevations due to the channel widening are de minimis and the Project is not expected to have an impact on the surge elevations or durations around the SNWW.

7.6 Vessel Effects Modeling

This section provides a brief overview of the vessel effects modeling performed to evaluate potential effects of proposed channel widening on vessel drawdown, return currents, and bank erosion. Refer to the Vessel Effects Modeling Report in Attachment 5 of this engineering appendix for details.

7.6.1 Model Software

AdH was applied for simulating vessel hydrodynamics in the SNWW. AdH is a water circulation modeling software developed by the Coastal and Hydraulics Laboratory (CHL) of the USACE that can incorporate moving vessels. AdH uses hydraulic flow dynamics to solve two-dimensional shallow water flows, including hydraulic processes caused by the movement of single or multiple vessels (Berger, Tate, Brown, and Savant 2010). The model simulates a transiting vessel by applying a moving pressure field that displaces the equivalent volume of water as the modeled vessel. Vessel parameters can be specified including size, speed, and heading. The model is used to calculate time-dependent hydrodynamic parameters (water surface elevations and velocities) within the domain. An additional benefit of the model is the adaptive mesh capability, which further refines the mesh based on hydraulic criteria during the model run. This feature enhances model resolution when and where it is important without excessively increasing computational demand.

The other numerical modeling performed for the SNND proposed channel widening (documented in separate reports) was performed in MIKE21. The numerical modeling team at HDR is proficient in the use of MIKE21 for hydrodynamic modeling of tides and storm surge. However, while application of MIKE21 for vessel effects modeling is now being marketed by model developers, the application is new and the HDR has previously invested time into working with AdH to model vessel wakes. HDR has applied the AdH model to simulate vessel drawdown and return current in the Houston Ship Channel, SNWW, Corpus Christi Ship Channel, and additional locations, including several calibration exercises.

7.6.2 Vessel Hydraulics Data Field Investigation

A 2-day field investigation was performed to measure the effects of transiting vessels on water levels and velocity in the SNWW. The purpose of the field investigation was to gather drawdown and return current data for calibration and validation of the numerical modeling. Acoustic Doppler Velocimeters (ADV) were deployed to measure water levels and currents at several locations adjacent to the channel in approximately 2.5 m (8 ft) water depth. During the field deployment, a total of four transiting vessels were observed from which the field team was able to collect six different vessel wake events. The datasets consist of three outbound vessels at a single location on August 19, 2020 and an inbound vessel at three separate locations on August 20, 2020. Vessel parameters such as direction, length overall (LOA), breadth, draft, and speed were gathered from MarineTraffic.com, a webservice that provides access to the automatic identification system (AIS) real-time ship tracking. Of the six events from the four vessels, two datasets from the largest vessels were chosen for calibration and validation. Refer to the Vessel Effects Modeling Report in Attachment 5 of this engineering appendix for further details.

7.6.3 Model Overview

Model meshes were developed to cover the entire project length as well as surrounding areas including Sabine Lake and adjacent marsh inlets where water may flow in and out during vessel

transit events. Six transiting vessel model scenarios were developed; each consisted of one of the six channel configurations (i.e., EC, FWOP, FWPFB, ALT1, ALT2, ALT3) combined with a vessel size, draft, and speed (Table 7-4). All six scenarios focused on the Suezmax vessel class, approximately 135,000 DWT in size, which is the largest vessel class expected to use the deepened SNWW channel. The modeled vessel drafts, selected for safe underkeel clearance, were 36 ft for the existing channel condition and 44 ft for future channel conditions. A constant vessel speed of 8 kts was applied for all modeled scenarios.

**Table 7-4
AdH Model Vessel Input Parameters Simulated with Each Channel Configuration**

Simulated Condition	Description	Length (ft)	Beam (ft)	Draft (ft)	Speed (kts)	% Limit Speed
EC (2019)	Existing Conditions (channel conditions in place in the 2018 to 2020 timeframe)	900	164	36	8	90
FWOP	Future Without Project (channel deepening project completed)	900	164	44	8	89
FWPFB						
ALT1	Future With Project (channel widening scenarios)	900	164	44	8	74
ALT2						
ALT3						

The analysis of the model scenarios is broken down into paired comparisons summarized as follows and illustrated in Figure 7-6 for a typical channel cross-section:

- Comparison A: Increasing the depth of the channel and the draft of the vessel (EC to FWOP) with the same 8 kts vessel speed. This vessel speed is approximately 90 percent of the limit speed for EC and FWOP.
- Comparison B: Increasing the width of the channel (FWOP to FWP) using the same vessel speed and draft. The wider channel increases the limit speed such that 8 kts is 74 percent. Comparison B is used to describe comparisons between FWOP and each of the FWP scenarios, i.e., FWPFB (Comparison “B”) and ALT1, ALT2, and ALT3 (Comparisons “B1 to B3”). While it is physically possible for vessels to transit faster based on the limit speed, communications with the SNND Pilots indicated that vessel speeds will not increase for safety and to limit impacts on adjacent features.

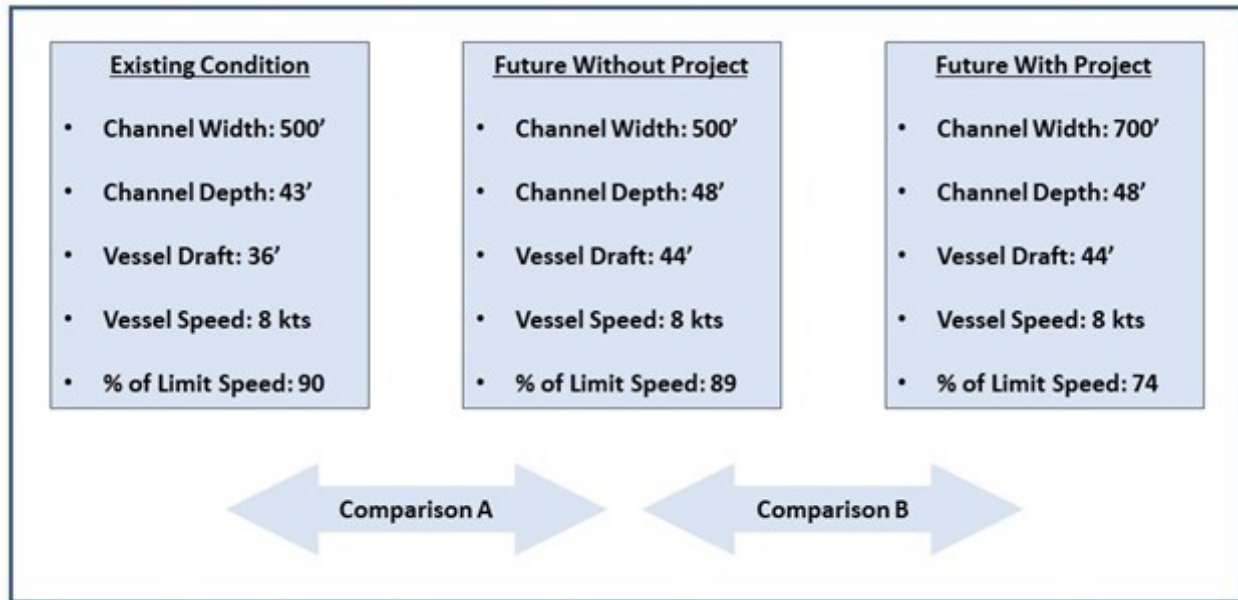


Figure 7-6
Scenarios Modeled Including Vessel Size, Draft, and Speed
for Each Channel Configuration

7.6.4 Model Results and Conclusions

A series of AdH model scenarios were developed to investigate the influence of widening portions of the SNWW channel on vessel generated hydrodynamics. Model results for the EC, FWOP, FWPFB, ALT1, ALT2, and ALT3 conditions are compared based on peak vessel-generated hydrodynamics. Several additional simulations were also compared for future with-project conditions and predicted RSLC. The results generally follow the expectations from theory, such as:

- Increasing both the channel cross-sectional area and the vessel draft while holding the speed fixed as a constant percentage of the theoretical limiting speed leads to a small increase in predicted changes to drawdown and return currents (Comparison A).
- Increasing the size of the cross-sectional area of channel while keeping the vessel speed and draft fixed leads to a reduction in predicted changes to drawdown and return currents (Comparison B).
- Because the number and type of vessels calling on the SNWW are not expected to change due to the channel widening, and the vessel hydrodynamics are expected to remain the same or minimally decrease, the bank erosion is not expected to increase as a result of the channel widening.

In general, a deeper and wider channel will reduce vessel effects for the same vessel size, draft, and speed as explained by the physics of the Schijf equations (Jansen and Schijf 1953). This finding is consistent with the finding of the deepening project feasibility study (USACE, 2008) where increased channel area was projected to reduce erosion effects for a single vessel event. For the proposed widening project, additional vessel traffic is not expected and therefore changes to bank erosion can be inferred based on the qualitative change for a given passing vessel event.

These results suggest that the widened channel will tend to reduce the vessel effects relative to FWOP for Suezmax class vessels with the same speed and draft. These findings are consistent with those from the deepening project feasibility study (USACE, 2008).

7.7 Water Quality Modeling

This section provides a brief overview of the water quality modeling performed to evaluate potential changes to current speed, water elevation, salinity, temperature, and infer changes to dissolved oxygen (DO) due to the proposed channel widening. Refer to the Water Quality Modeling Report in Attachment 6 of this engineering appendix for details.

7.7.1 Model Software

A 3D hydrodynamic model (MIKE3 FM) of the SNWW was developed to provide tidal transport from both freshwater inflows as well as tidal influences at the Gulf of America and Intracoastal Waterway boundaries in addition to density driven circulation. The MIKE3 FM hydrodynamic model solves systems of equations to assess current speed, water elevation, salinity, and temperature in three dimensions (horizontal, lateral, vertical) as a function of external model inputs. The hydrodynamic model uses model inputs and external forcings (e.g., freshwater inflow, Gulf of America tidal water elevations, meteorology) to calculate water elevation, salinity, and temperature throughout the model domain. In addition, the model includes wetting and drying of areas depending on bottom elevation and water level.

The MIKE3 FM hydrodynamic model is commercial software distributed by DHI. Except for calculating in three dimensions, the MIKE3 FM hydrodynamic model follows similar governing hydrodynamic equations (i.e., fluid motion and density driven circulation) to the DHI MIKE2D software (MIKE21), which is included on FEMA's list of "Hydraulic Numerical Models Meeting the Minimum Requirement of National Flood Insurance Program." In addition, personal communication with USACE (Earl Hayter, ERDC 2020) indicated that MIKE3 FM is also an approved model for evaluating tidal circulation in estuarine and coastal systems.

7.7.2 Model Overview

The modeling was completed to investigate the effects of proposed channel modifications on current speeds, water elevation, salinity, and temperature in the SNWW where channel modifications are proposed and other surrounding areas. While salinity and temperature are quantitatively modeled, direct quantitative modeling of DO concentrations was not completed. Rather, the potential changes to DO levels are inferred from changes in current speed, salinity, and temperature due to the widening alternatives as calculated with the hydrodynamic model along with review of available DO concentration data in the SNWW and surrounding areas.

Model meshes were developed to cover the entire project length as well as surrounding areas including the Sabine and Neches Rivers, Sabine Lake, marsh areas and near shore Gulf of America. The 3D hydrodynamic model was calibrated with data from July through September 2018 that included water elevation, current speed, temperature, and salinity at various stations around the modeling study area. This time period was selected as it represents a period of low freshwater inflow when salinity intrusion would be the greatest, water temperatures are the highest, and DO levels are the lowest as compared to other times of the year. Potential changes were evaluated at 13 locations throughout the study area (Figure 7-7) including in the channel, Sabine Lake, and various bayous during the low flow period of July through September 2018.



Figure 7-7
Model Evaluation Target Locations

7.7.3 Model Results and Conclusions

The water quality modeling report focused on modeling of tidal hydrodynamics and effects on current speed, water elevation, temperature, salinity, and potential changes to DO concentrations. The following bullets summarize the findings of the modeling effort and ALT1 tentatively selected plan results as compared to the FWOP baseline. Since the ALT2 condition affects a slightly wider channel condition than ALT1 (i.e., 100 ft wider), the calculated differences due to ALT2 are slightly greater than that for ALT1, the tentatively selected plan, but are still negligible.

- The 3D hydrodynamic model was calibrated to available current speed, water elevation, temperature, and salinity data at various locations throughout the SNWW. Average RMSEs were considered acceptable and were 7 cm for water elevation, 21 cm/s for current speed, 5 PSU for salinity and 1.4°C for temperature. The relative RMSEs were 7% for water elevation, 24% for current speed, 20% for salinity and 24% for temperature. Model uncertainty for comparison of plans (e.g., baseline to ALT1) was defined for this project as approximately one half of the model average RMSEs (i.e., 4 cm for water elevation, 11 cm/s for current speed, 3 PSU for salinity and 0.7°C for temperature). The calibrated hydrodynamic model was used to calculate current speed, water elevation, temperature, and

salinity changes for ALT1 and ALT2 conditions that were then compared to the FWOP baseline.

- Average water elevation changes between the FWOP and ALT1 conditions over the 13 evaluated locations are negligible (less than 0.1 cm \pm 4 cm).
- At the navigation channel and Neches River target locations, average surface and bottom temperature increases due to ALT1 were 0.01°C with a maximum increase in the surface of 0.11°C and in the bottom of 0.06°C. These maximum temperature changes occurred in the Neches River. At all other target locations, average surface temperature increased by 0.01°C (maximum increase of 0.03°C) and bottom temperature increased by 0.03°C (maximum increase of 0.04°C) due to ALT1 with the maximum temperature changes occurring at the mouth of Willow Bayou. All calculated temperature changes due to ALT1 as compared to the FWOP baseline are negligible (less than 0.11°C \pm 0.7°C).
- At the navigation channel and Neches River target locations, average surface salinity increased by 0.03 PSU due to ALT1 with a maximum increase 0.34 PSU. There was no change in average bottom salinity at these target locations due to ALT1 with a maximum salinity increase of 0.08 PSU. These maximum salinity changes occurred at the mouth of the Neches River. At all other target locations, average surface salinity decreased by 0.01 PSU (maximum increase of 0.12 PSU) and average bottom salinity decreased by 0.02 PSU (maximum increase of 0.08 PSU) with the maximum changes occurring at the mouth of the Sabine River. Calculated salinity changes due to ALT1 as compared to the FWOP baseline are negligible (less than 0.34 PSU \pm 3 PSU).
- At the navigation channel and Neches River target locations, average current speed decreased by 0.23 cm/s due to ALT1 with a maximum decrease of 3.77 cm/s, which occurred at the north end of Pleasure Island. At all other locations, the average current speed decreased by 0.02 cm/s due to ALT1 with a maximum decrease of 0.15 cm/s, which occurred at the south Sabine Lake location. Calculated current speed changes due to ALT1 as compared to the FWOP baseline are negligible (less than 3.77 cm/s \pm 11 cm/s).
- Model simulations of the FWOP and ALT1 cases were conducted with and without RSLC. Results showed that changes to current speed, elevation, salinity, and temperature between the FWOP and ALT1 conditions with RSLC were about the same magnitude as the non-RSLC cases.
- Evaluation of potential DO changes due to the proposed widening were inferred from the calculated changes to temperature, salinity, and current speed for ALT1. The potential effects on DO concentrations were evaluated based on changes to DO saturation as a result of temperature and salinity changes; temperature change effects on oxygen consumption and atmospheric reaeration oxygen supply rates; and current speed effects on residence time. The DO evaluations used calculated bottom changes since the bottom of the water column is where DO levels are typically the lowest.
- At all target locations, the calculated change in DO saturation concentration for ALT1 ranges from - 0.01 to 0.01 mg/L. This calculated change in DO saturation concentration is

negligible. Since the change in DO saturation concentration is negligible (i.e., zero average change), ALT1 is not expected to change DO levels in the SNWW study area.

- Another potential effect on DO concentrations is an increase in oxygen consumption rates (e.g., BOD oxidation, sediment oxygen demand) and atmospheric oxygen reaeration supply due to slightly warmer temperatures. The maximum temperature increase of 0.06°C for ALT1, which is considered negligible, was used to calculate a change in the BOD oxidation rate, sediment oxygen demand rate and the atmospheric oxygen reaeration rate. These rates increased by less than 0.5% are negligible. The increase in the atmospheric oxygen reaeration rate will partially offset the increase in the BOD and sediment oxygen demand rates. The potential temperature change effects on DO consumption and supply rates due to ALT1 as compared to the FWOP baseline are not expected to change existing DO levels in the SNWW study area.
- Decreases in current speeds can increase residence time and provide more time for oxygen consumption (BOD oxidation and sediment oxygen demand) to decrease DO levels. Given negligible changes to current speeds and residence time due to ALT1 as compared to the FWOP baseline, changes to DO concentrations in the SNWW study area are not expected to occur.
- The DO evaluation for ALT1 indicates that the potential changes to DO saturation concentrations, oxygen consumption and atmospheric reaeration rates, and residence time due to the widening are negligible and not expected to change existing DO levels in the SNWW study area. In addition, the calculated temperature, salinity and current speed changes due to ALT1 are negligible. Therefore, the estimated changes to existing DO levels are also considered negligible.

8 HTRW

A Hazardous, Toxic, and Radioactive Waste (HTRW) assessment of the widening project was conducted using information from the 2011 deepening project feasibility study, the 2017 Sabine Pass to Galveston Bay, Texas Coastal Storm Risk Management and Ecosystem Restoration feasibility study (USACE, 2017), and other available information. This HTRW assessment (Attachment 7) was limited to a desktop assessment and was not a Phase I Environmental Site Assessment meeting ASTM standards.

The HTRW assessment identified known sources of contamination and incidents (i.e., spills and releases) with the potential to affect the project. This review also considered whether the release of contaminants from previously identified priority HTRW sites³ (Figure 8-1) was ongoing or had been effectively eliminated through remedial efforts.

³ The 2011 FEIS (USACE, 2011) defined “*priority HTRW sites*” as facilities that posed a potential concern based on the nature and extent of contaminants at the site, their location relative to the placement areas and the waterway, and the number of pathways in which the contaminants could reach the placement areas and the waterway, and this document continues that usage.

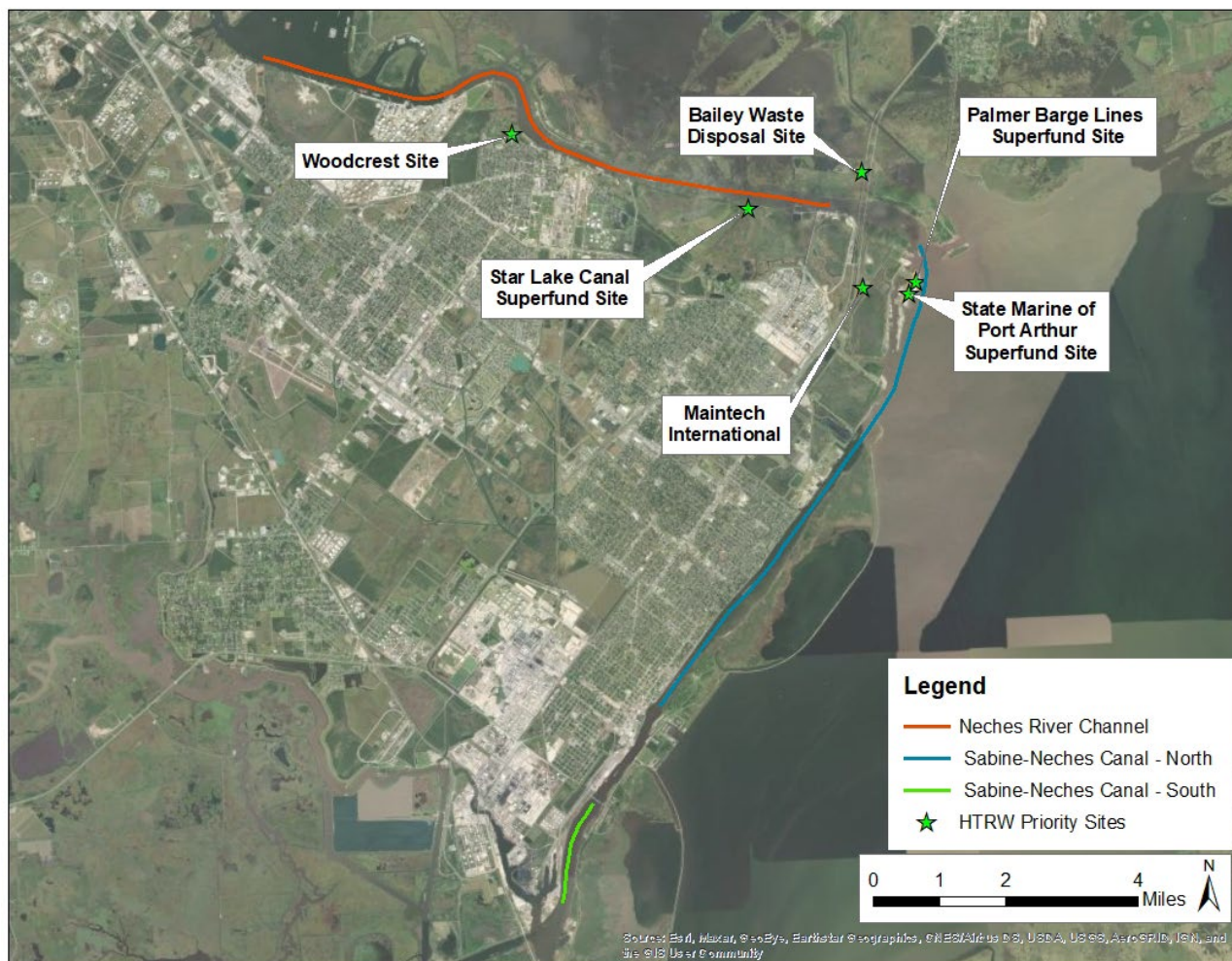


Figure 8-1
HTRW Priority Site Locations

The HTRW evaluation as described in Attachment 7 finds:

- The conditions at the Woodcrest, Bailey, and Maintech sites (Figure 8-1) are such that no additional investigations would be recommended. These sites present a lesser threat due to effective corrective actions and distance from the proposed widening improvements;
- There is no reason to believe there are new releases of contamination from the Star Lake Canal, Palmer, and the State Marine sites (Figure 8-1). Although these sites are physically separated from the areas for proposed channel widening by the existing federal navigation channel, there is a slight potential risk for encountering contaminated sediments from these sites and further evaluation during PED is recommended; and
- The review of the regulated facilities and current agency database reviews (USEPA and TCEQ) for events (i.e., spills and releases) do not identify any recognized environmental conditions that would affect project alternatives.

Analytical data characterizing the sediments to support dredged material placement and beneficial use decisions need to reflect conditions at the time of construction. Therefore, sediment sampling and analyses will be evaluated and conducted during the PED phase of planning. Should sampling

and analyses during PED identify any recognized environmental condition that required a response action, the development and execution of any federal, state, and/or locally required HTRW response action would be at 100 percent cost to SNND (USACE, 1992). If areas of contaminated sediments ineligible for placement into the confined upland placement areas are identified, they would typically be removed by a mechanical (i.e., backhoe/bucket) dredge that collects contaminated sediments for placement in a hopper or container. If this was necessary, there are appropriate vendors to provide material transportation and disposal nearby.

9 Cost Estimates

The Cost Estimate for the TSP is included in Attachment 8. Attachment 8 includes the construction and cost estimating assumptions, the MII cost estimate, the cost and schedule risk analysis, the total project cost summary, and 50-year O&M estimates.

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