Hickory Cove Marsh Restoration And Living Shoreline

Bridge City, TX

WRDA 2016 Section 1122

Beneficial Use of Dredged Material

Appendix A: Engineering

U.S. Army Corps of Engineers

Southwest Division

Galveston District

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1 INTRODUCTION

1.1 Study Overview and Purpose

The Hickory Cove Marsh Restoration and Living Shoreline Beneficial Use of Dredged Material (BUDM) pilot project is a partnership between the U.S. Army Corps of Engineers (USACE), Galveston District and the Port of Orange, Texas. The project is intended to demonstrate the beneficial use of dredged material to address ecosystem-related problems in the Hickory Cove study area and identify a plan that ultimately improves, preserves, and sustains ecosystem resources.

Texas is estimated to have lost approximately 210,590 acres of coastal wetlands from the mid-1950's to early 1990's (Ducks Unlimited, 2013). The ecosystem functions and values provided by these habitats are crucial to support critical waterfowl and coastal fish habitat, and reduce storm damage to property and infrastructure and provide recreational opportunities for the neighboring communities. Identified problems specific to Hickory Cove include marsh loss from wave action, subsidence, sea level rise, insufficient sediment supply, and increased salinity resulting in marsh habitat conversion from freshwater or intermediate marsh to saltwater marsh. The priority to protect and restore the habitat of Hickory Cove is recognized within the Chenier Plains Initiative Area, by the Gulf Coast Joint Venture Initiative Areas effort (Ducks Unlimited, 2013). The purpose of this study is to characterize the problems and identify solutions in support of BUDM and preservation of ecosystem resources at Hickory Cove, consistent with regional conservation programs.

1.2 Study Authority

This study was conducted under the authority of Section 1122 of the Water Resources Development Act (WRDA) of 2016 which requires USACE to pursue pilot demonstrations of the beneficial use of dredged material (BU). The projects studied and implemented under this authority should serve the purpose of using dredged material for the purposes of –

(1) Reducing storm damage to property and infrastructure;

(2) Promoting public safety;

(3) Protecting, restoring, and creating aquatic ecosystem habitats;

(4) Stabilizing stream systems and enhancing shorelines;

(5) Promoting recreation;

(6) Supporting risk management adaptation strategies; and

(7) Reducing the costs of dredging and dredged material placement or disposal, such as projects that use dredged material (USACE, 2018).

1.3 Study Area

The project is located within Hickory Cove Bay and is located adjacent to the Sabine River and the northern end of Sabine Lake (Figure 1). The focused study area includes 677.31 acres of marsh with the potential to be restored from open water to freshwater marsh habitat dependent on sediment availability. The land is owned and operated by the Hawk Club and adjacent to the Lower Neches Wildlife Management Area, which is owned and operated by Texas Parks and Wildlife Department (TPWD). There are two federal navigation projects in or near the study area including the Sabine River and the Gulf Intercoastal Waterway (GIWW). Sabine Lake is a lake estuary situated in the southeast corner of Texas, along the border of Texas and Louisiana.

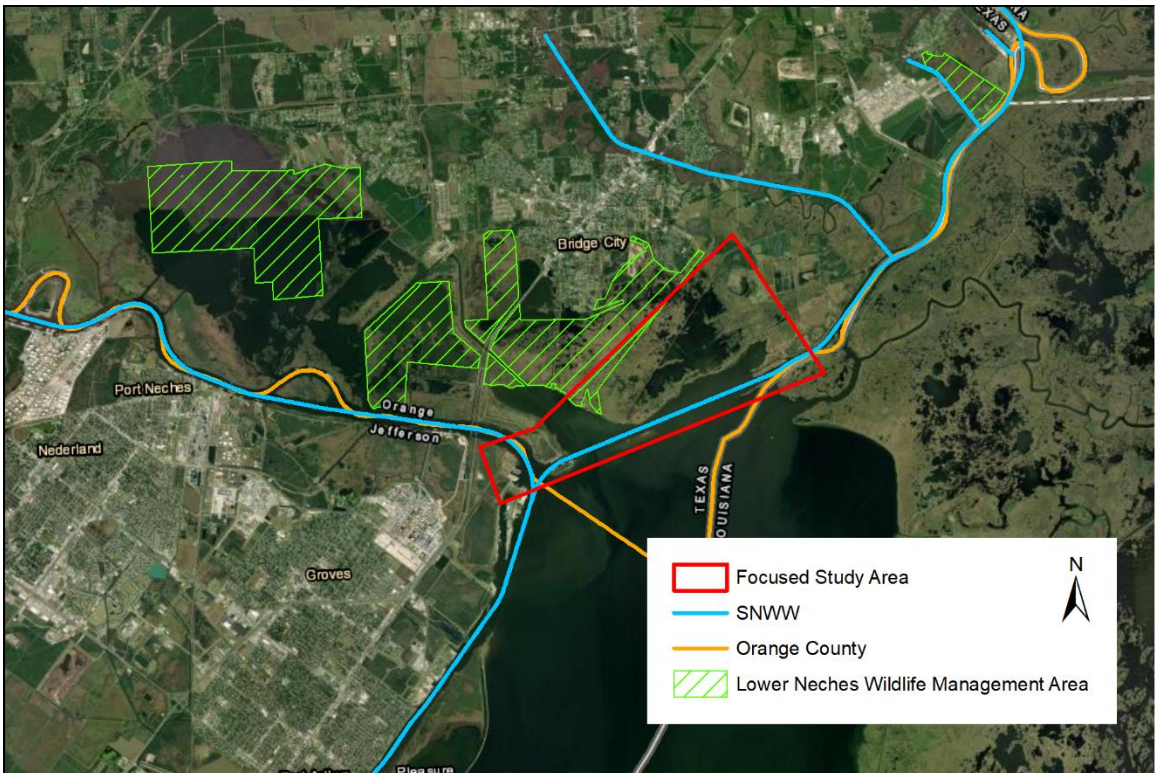


Figure 1. Hickory Cove Marsh Restoration and Living Shoreline Section 1122 Feasibility Study Area

1.4 Overview of other Ecosystem Restoration (ER) Projects

Other agencies have undertaken marsh restoration measures by beneficially using dredged material to restore habitat near the study area. Texas Parks and Wildlife Department (TPWD) cooperated with the Port of Orange and local private industry to restore habitat to support emergent wetland plants at Old River Cove in the Lower Neches Wildlife Management area adjacent to Hickory Cove as shown in Figure 2.

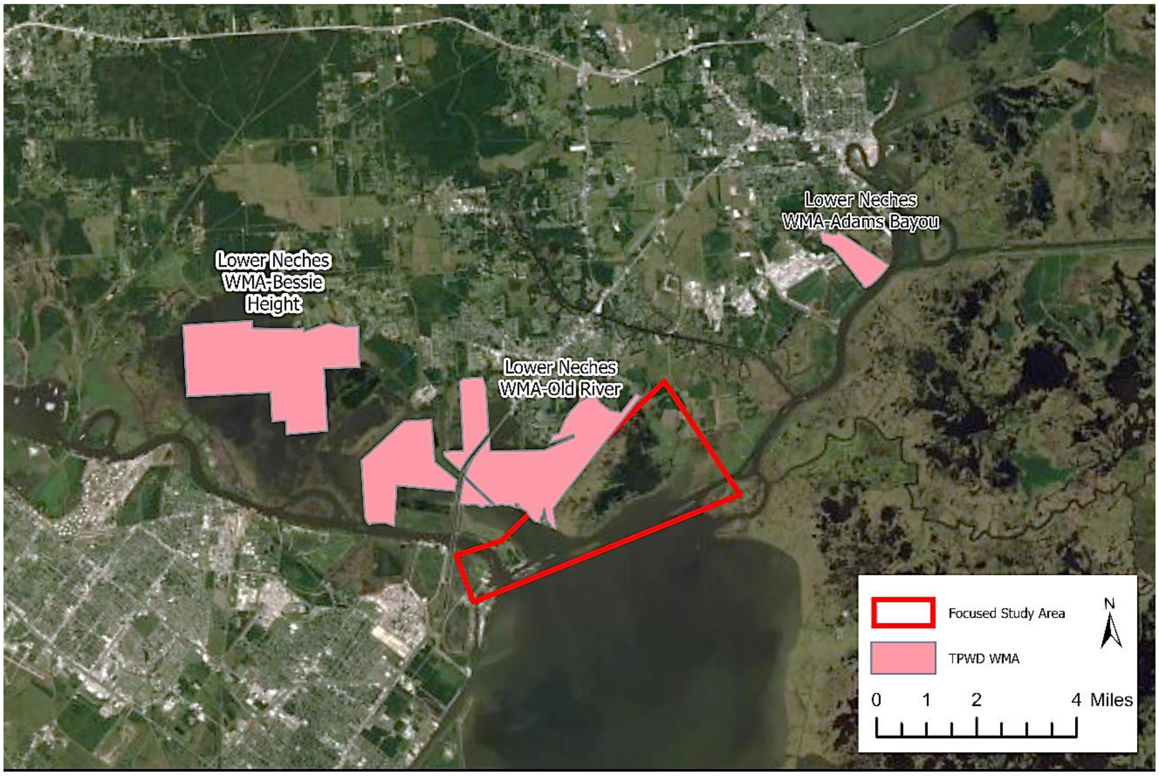


Figure 2. Wildlife Management Areas near the Study Area

2 ALTERNATIVES

2.1 Focused Alternatives Array

An initial suite of alternatives was generated to assess the viability of the pilot study proposal, based on formulation strategies informed by project goals and study area conditions. Preliminary screening identified alternatives that could beneficially use dredge material on site to assess which most completely addressed the problems and objectives identified. The alternatives considered, apart from no action, were incremental actions that built upon one another to beneficially use dredge material for effective and sustainable marsh restoration. Due to the uncertainty associated with available dredge material quantities, a range of potential volumes and areas associated with each were considered and are summarized in Table 1 and presented as subsets of each alternative described thereafter. The marsh modification area reflected in figures 3 through 6 represents the open water areas with potential to restore. Alternatives that add a breakwater and living shoreline summarized in this section are assumed to be compatible with varying quantities of material, assuming material quantity is minimally sufficient for the containment levee repairs. Unless otherwise noted, all elevations are relative to NAVD88 vertical datum.

Table 1. Range of Alternative Subsets and their Associated Marsh Restoration Area

	Alternative Subset	a	b	c	d
	Range Upper Limit (CY)	500K	900K	1.3M	1.5M
Sediment Quantities	Area (acres)	68	126	190	213
	Marsh Restoration (CY)	468,000	867,000	1,310,000	1,470,000
	Training Berm Length (LF)	5,900	13,360	16,000	16,410
	Training Berm Quantity (CY) H = 5.5 FT	27,940	63,200	75,700	77,640
	Containment Levee Restoration (CY) (earthen, in situ matl source)	28,644	28,644	28,644	28,644
	Total (CY)	**496,644**	**895,644**	**1,338,644**	**1,498,644**

The array of alternatives include:

No Action: traditional placement of dredge material into placement areas 29A/B (fig 3).

Alternative 1: This alternative focuses on restoring marsh to a target elevation for vegetation establishment utilizing dredged material. It will also restore an existing but breached privately owned containment dike (fig. 4).

Alternative 2: This alternative builds upon Alternative 1 and includes shoreline protection to ensure sustainability of the marsh. It restores the existing but breached containment dike, restores marsh habitat and constructs a 14,623 LF detached breakwater system to attenuate waves along the SNWW/GIWW (fig 5).

Alternative 3: This alternative builds upon Alternative 2 with additional shoreline protection between the containment levee and the breakwater through implementation of a living shoreline. It restores the existing but breached containment dike, marsh habitat, plants a living shoreline on the exterior side of the containment levee and constructs a 14,623 LF detached breakwater system to attenuate waves along the SNWW/GIWW (fig. 6).

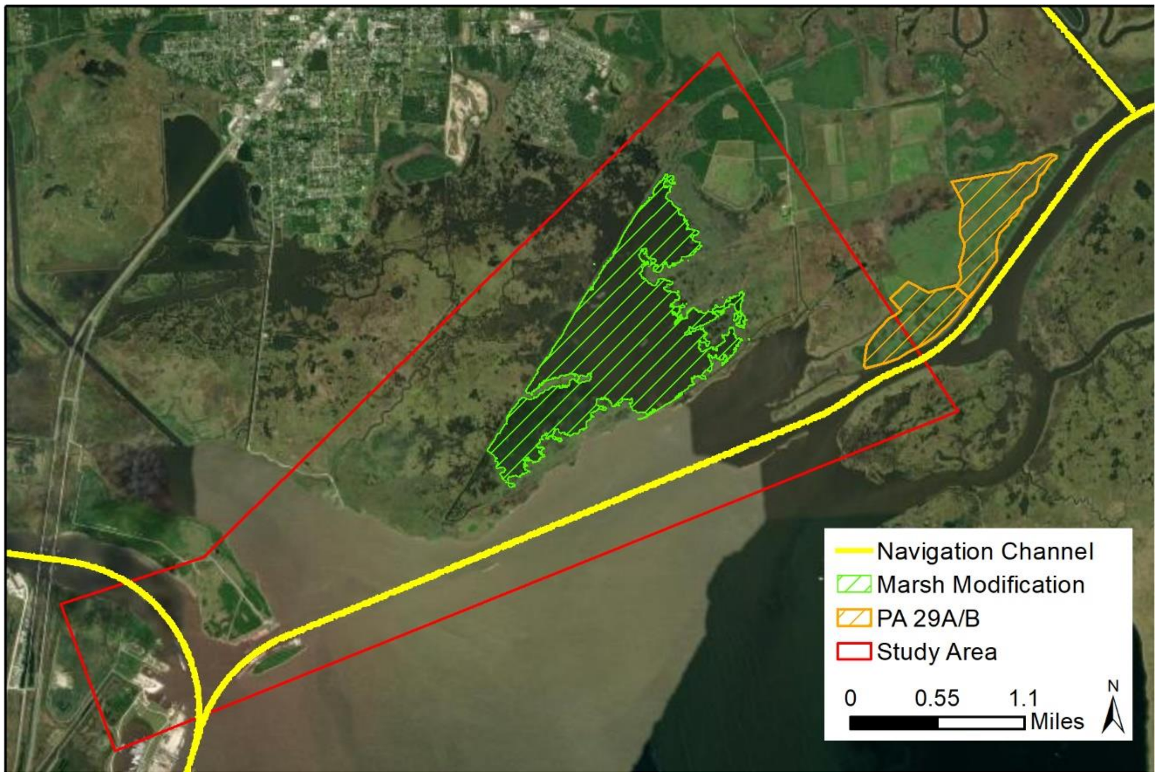


Figure 3. Hickory Cove no action plan, placement areas 29A/B

Figure 4. Hickory Cove Alternative 1

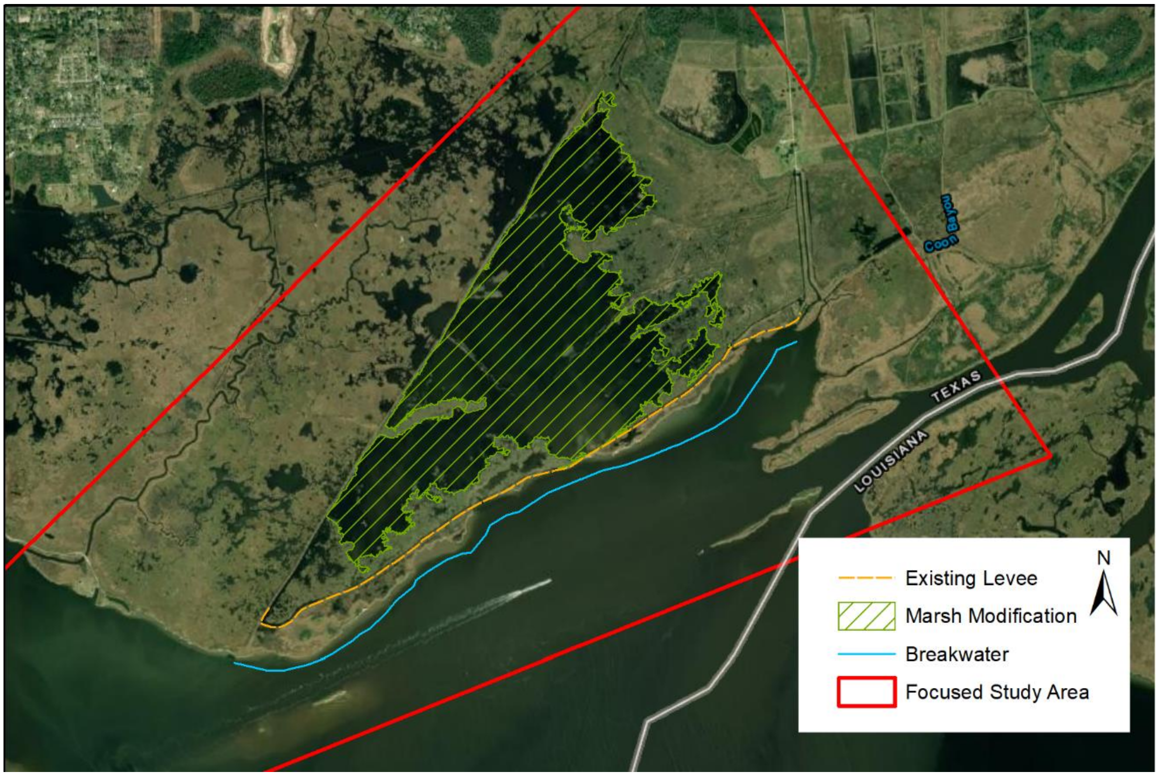


Figure 5. Hickory Cove Alternative 2

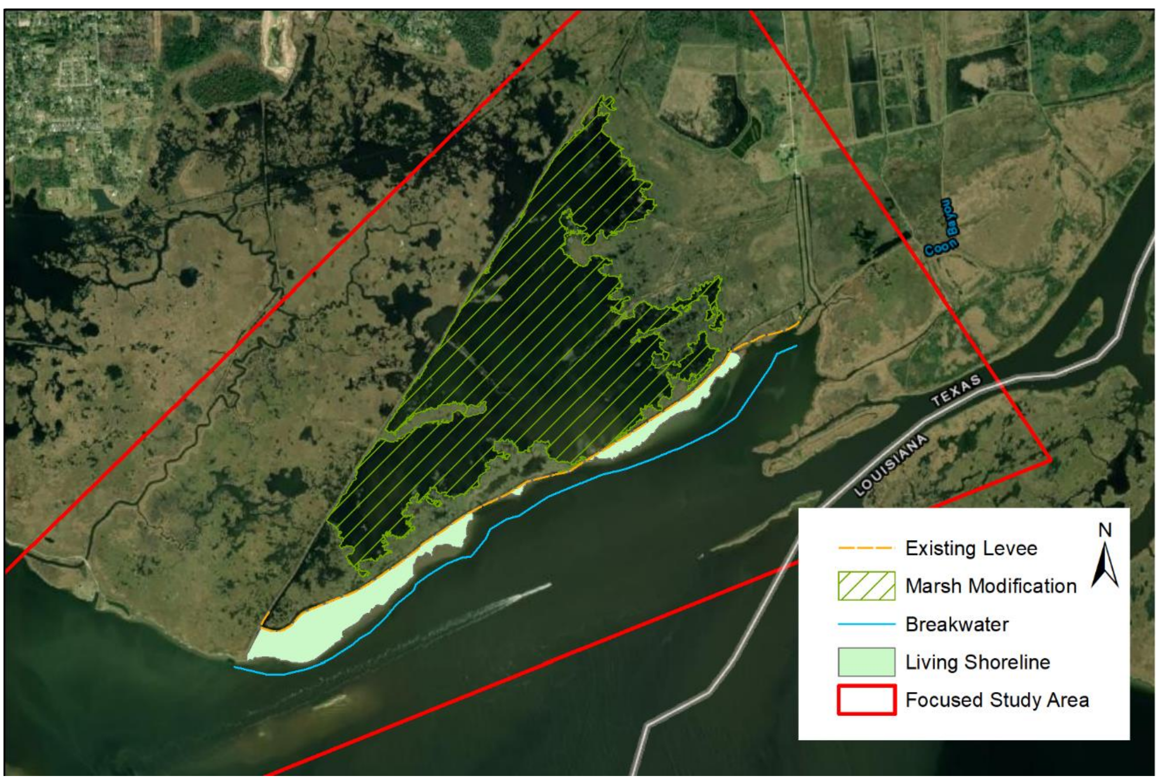


Figure 6. Hickory Cove Alternative 3

2.2 Alternatives Evaluation and Comparison

The quantities and costs for each alternative were developed using feasibility-level analysis. Available existing data, engineering assumptions and professional judgment were leveraged to develop the alternatives but should be revisited during Design and Implementation (D&I) and/or as new information becomes available. The actual acreage of marsh to be restored depends on sediment availability, the expected ranges are outlined in Section 6.2 and confirmed quantities in Section 7.

3 HYDRAULICS AND HYDROLOGY

3.1 Tidal Datum and Vertical Datum

Tidal datums are base elevations used to predict heights and depths. These datums are determined by statistical analysis of long-term water surface measurements. The U.S. National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services (CO-OPS) maintains ocean observing infrastructure that includes the permanent water level stations closest to the study area as shown in Figure 7.

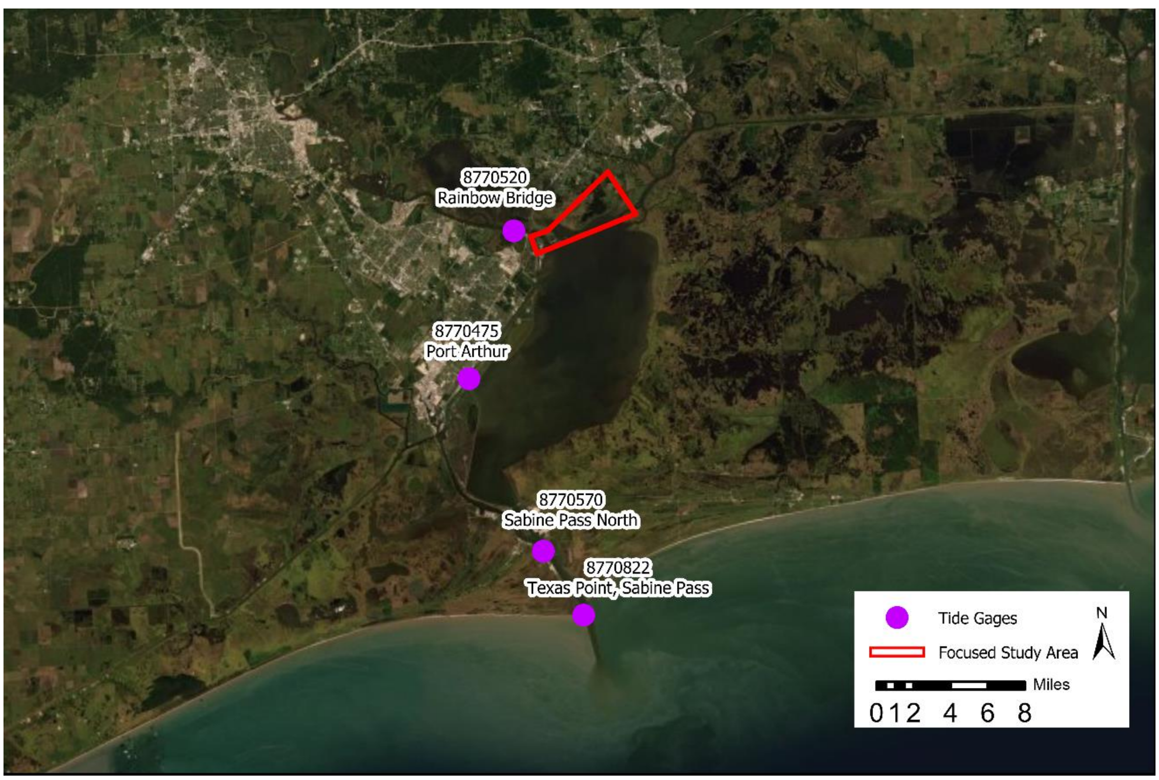


Figure 7. NOAA permanent tide gages near the study area

3.2 Hydrology

Drainage in and around the study area is driven by the Sabine River to the east of Hickory Cove and the Neches River to the west. Overland flow from the area north of the Hickory Cove (i.e. Bridge City) contributes to freshwater drainage into the study area as it exists today with a contributing drainage area of 7,120 acres. From the outlet of the Neches and Sabine rivers into Sabine Lake, Sabine Pass connects the estuary lake to the Gulf of Mexico. The USGS hydrologic units, streams and waterbodies are shown in Figure 8 and USGS stream gages in and around the study area are shown in Figure 9.

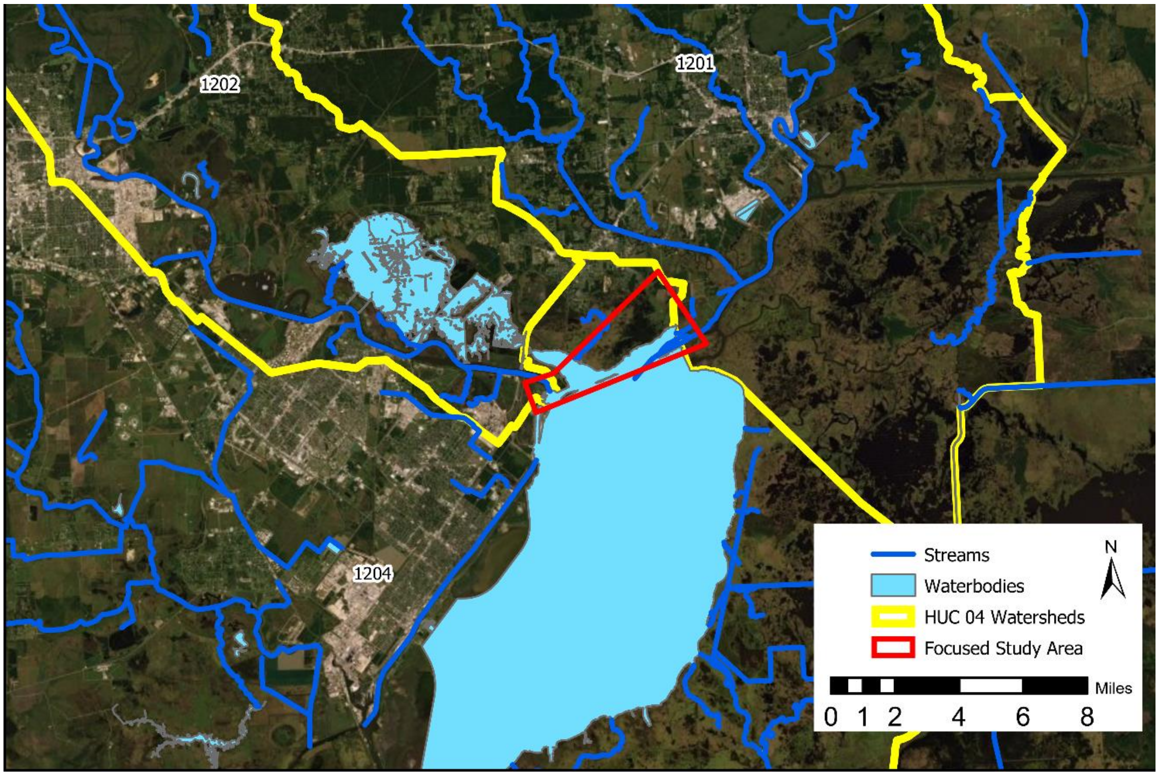


Figure 8. USGS Rivers, Streams and Waterbodies in and around the study area

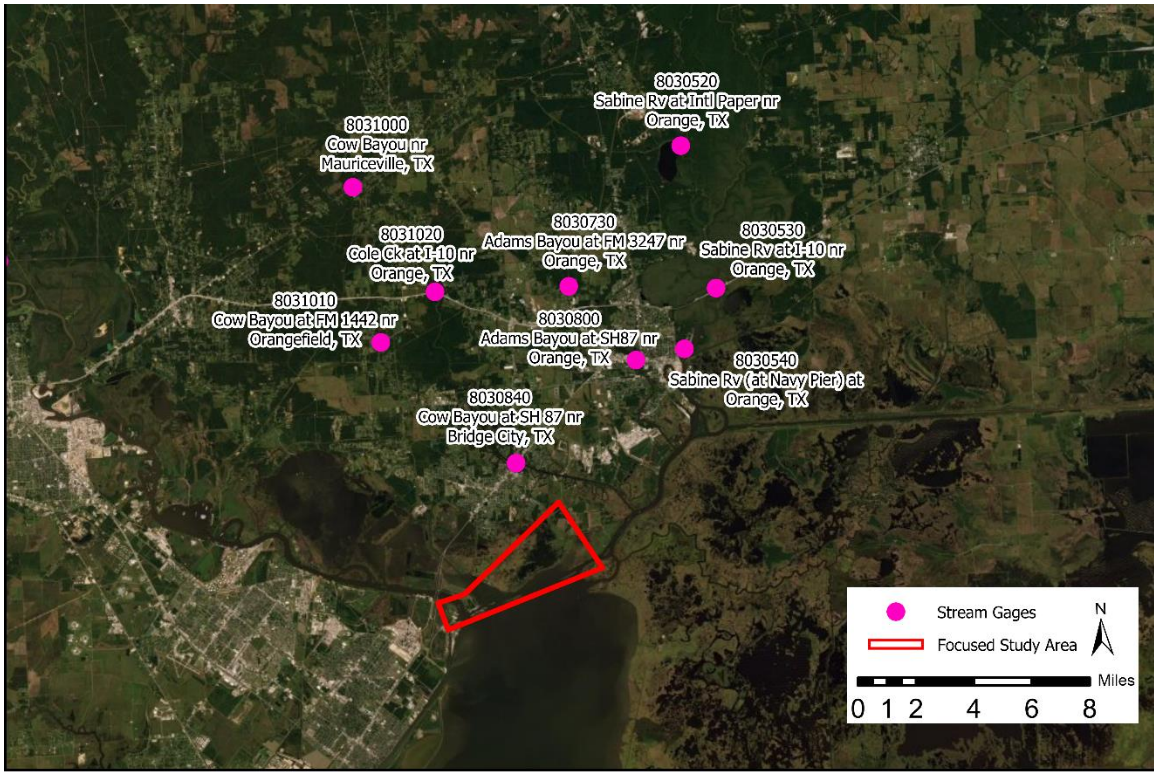


Figure 9. USGS Stream Gages near the study area

3.3 Climate Change

The western Gulf Coast is projected to experience greater sea level rise driven by climate change than the global average for almost all future global mean sea level rise (GMSL) scenarios. The impacts of future rising sea level concerns (RSLC) with respect to USACE projects is addressed using guidance from ER 1100-2-8162 (USACE, 2013) and ETL 1100-2-1 (USACE, 2014). The nearest tide gauge available for SLR analysis is 8770570 Sabine Pass North, TX shown in Figure 7. The USACE Sea Level Change Curve calculator (2019.21) was utilized to investigate expected SLR through the design life of 50 years with project construction tentatively expected to occur in 2023. The estimated RSLC curves are shown in Figure 10 and shown in Table 2. The intermediate mean sea level change is estimated at 1.72-ft NAVD88 for 2073. The high and low change to the mean sea level for the same year is 3.57-ft and 1.13-ft NAVD88 respectively. Figure 11 shows the expected inundation (MHHW) in and around the study area in Orange County from +2 feet of RSLC (NOAA/OCM, 2017c).

Table 2. USACE RSLC Results for NOAA Tide Gauges 8770570, Sabine Pass North, TX (NAVD88)

Year	Low	Int	High
2010	-0.04	-0.01	0.08
2015	0.06	0.10	0.25
2020	0.15	0.22	0.44
2025	0.24	0.34	0.65
2030	0.34	0.46	0.87
2035	0.43	0.59	1.11

2040	0.52	0.73	1.38
2045	0.61	0.86	1.66
2050	0.71	1.01	1.95
2055	0.80	1.15	2.27
2060	0.89	1.30	2.61
2065	0.99	1.46	2.96
2070	1.08	1.62	3.33
2075	1.17	1.78	3.73
2080	1.26	1.95	4.14
2085	1.36	2.13	4.56
2090	1.45	2.30	5.01
2095	1.54	2.49	5.48
2100	1.64	2.67	5.96

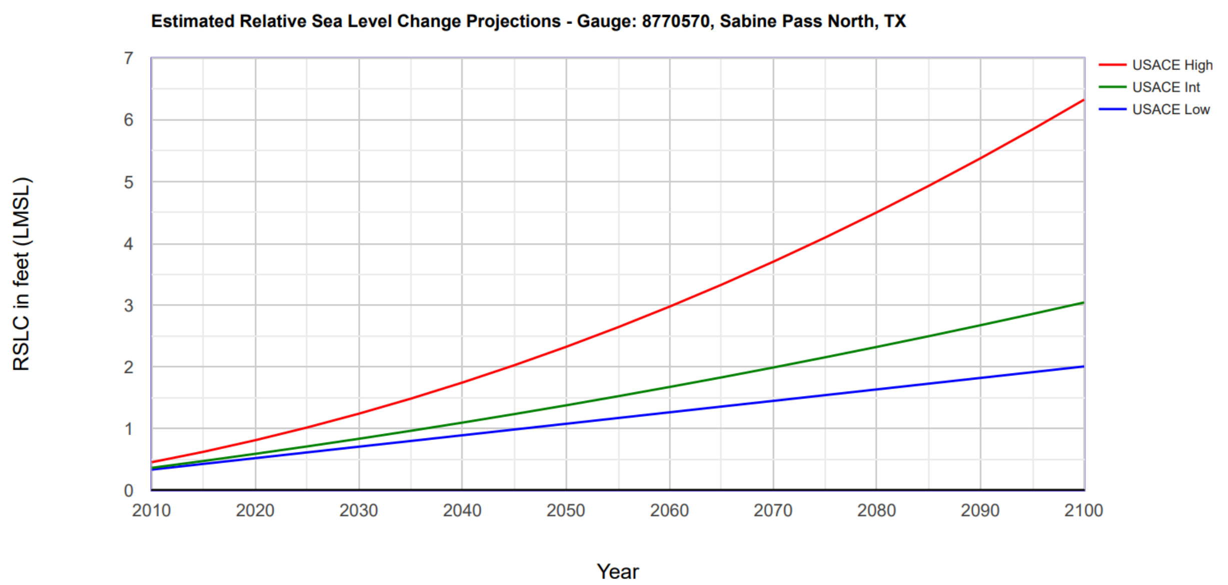


Figure 10. USACE predicted RSLC low, intermediate, and high curve

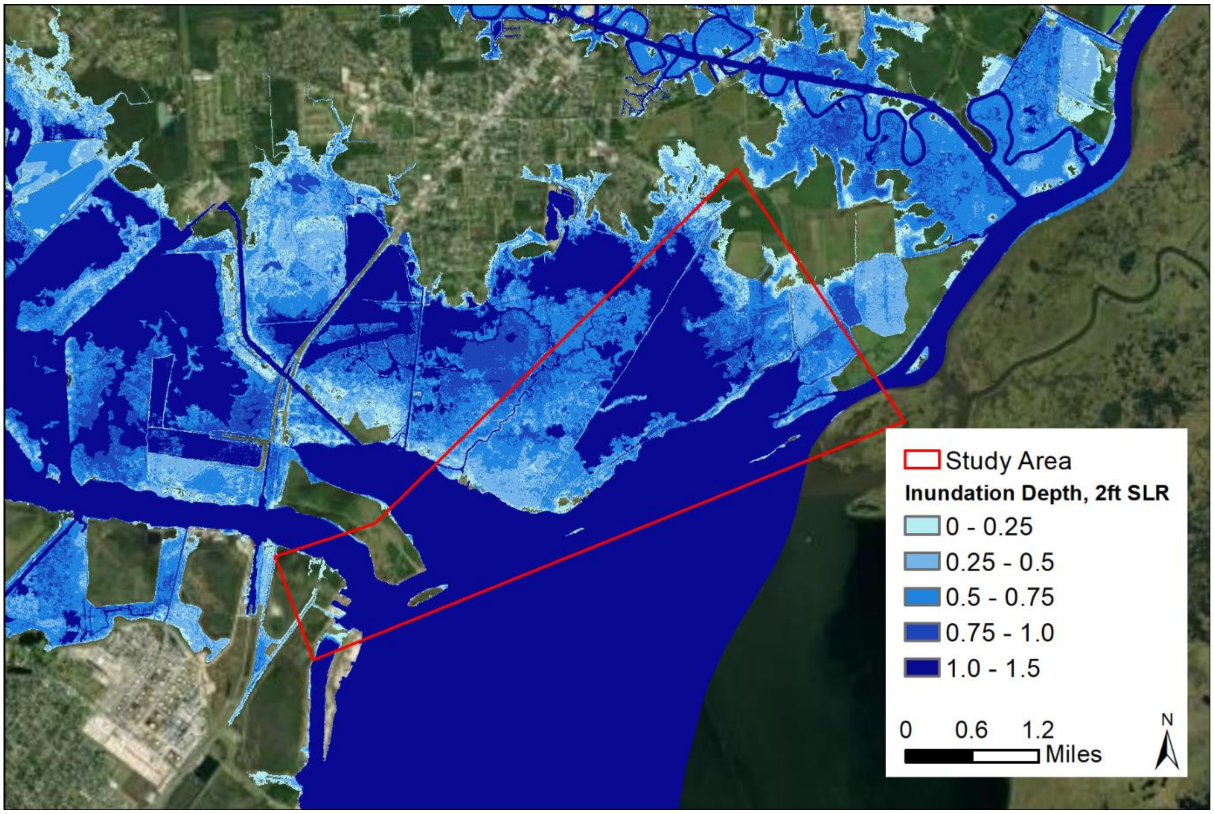


Figure 11. Overview of additional inundation (MHHW) from 2.0 ft. of RSLC in Orange County, TX based on 2010 LULC and 2019 regional LiDAR (NOAA/OCM, 2019)

3.4 Coastal Processes

3.4.1 Tides

The tides at gage 8770520 are indicative of tides nearest Hickory Cove for the purposes of this study. This assumption may be revisited in the Design and Implementation (D&I) phase if needed as the study area is located at the northern boundary of Sabine Lake and the specified tide gage is further west at the mouth of the Neches River as shown in Figure 7.

3.4.2 Currents, Circulation, Salinity

Sabine Pass is a jettied inlet for the deep-draft SNWW that connects the Gulf of Mexico to Sabine Lake at the southern tip of the lake. Freshwater is brought to the system primarily from the Sabine and Neches Rivers. Tidal action impacts the study area predominantly through Sabine Lake due to multiple breaches in the containment dike caused by erosion due to wave action. When the containment levee is intact there is minimal tidal influence on the marsh allowing for appropriate conditions for emergent freshwater marsh habitat as is currently successful in the Lower Neches Wildlife Management Area just west of Hickory Cove.

3.4.3 Storm History

Two types of meteorological events that have major impacts on the landscape are precipitation events and/or storm surge events, i.e. hurricanes. These higher energy events can cause shoreline erosion and flooding through elevated water levels and erosive waves. These phenomena impact both natural and man-made shoreward infrastructure including transportation facilities, buildings, and navigation channels.

While the damage inflicted by these tropical storms and hurricanes can be catastrophic, they are relatively infrequent. The history of coastal storms around the study area are presented in Table 3 and their respective storm tracks shown in Figure 12.

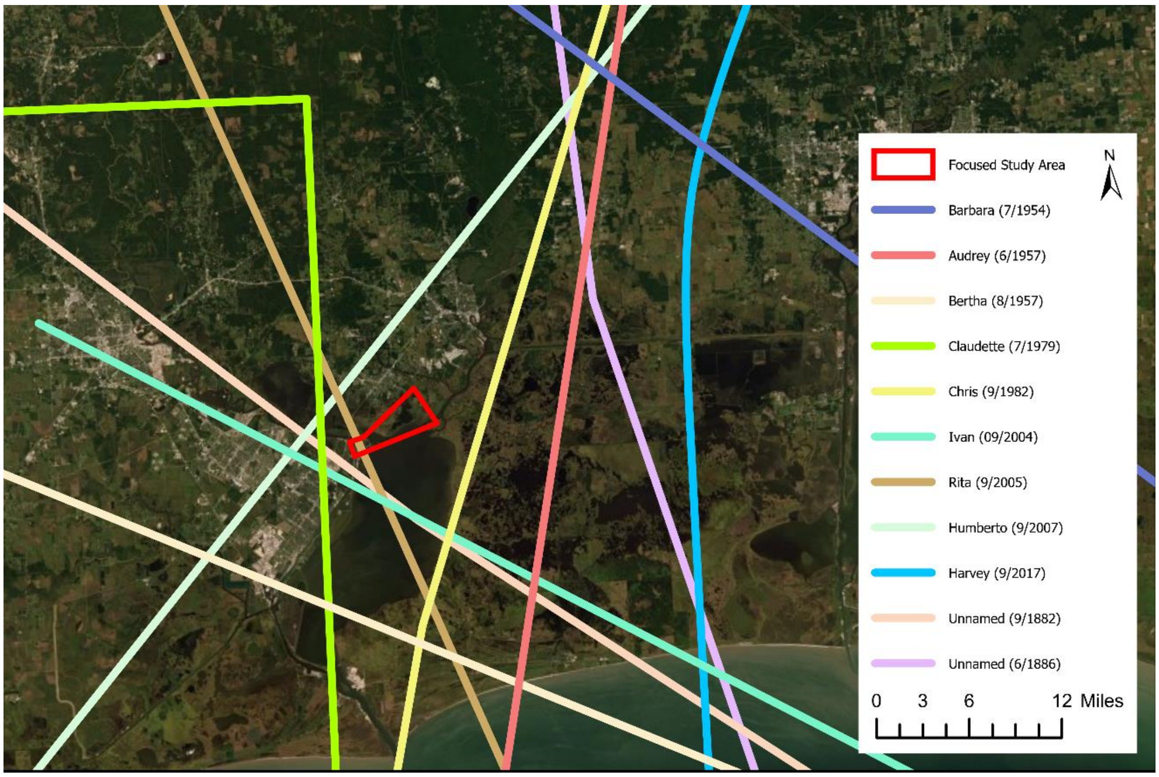


Figure 12. Select historical storm tracks in and around the study area

Table 3. Historical Storms near the Study Area

					Conditions at Landfall	
Date	**Type**	**Name**	**Latitude**	**Longitude**	**Max Wind (kts)**	**Min. Central Pressure (mb)**
August 1879	Hurricane	No Name	29.6	-94.2	90	964
June 1886	Tropical Storm	No Name	29.6	-94.2	85	-
October 1886	Hurricane	No Name	29.8	-93.5	105	-
October 1895	Tropical Storm	No Name	29.3	-94.8	35	-

September 1897	Hurricane	No Name	29.7	-93.5	75	-
September 1898	Tropical Storm	No Name	29.4	-94.7	50	-
Aug-40	Hurricane	No Name	29.7	-94.1	85	972
Sep-40	Tropical Storm	No Name	29.8	-93.4	40	-
Sep-41	Tropical Storm	No Name	29.6	-94	30	1006
Aug-42	Hurricane	No Name	29.5	-94.6	65	-
Jul-43	Hurricane	No Name	29.5	-94.6	90	967
Sep-46	Tropical Storm	No Name	29.7	-93.8	25	-
Jul-54	Tropical Storm	Barbara	29.7	-92.8	50	999
Jun-57	Hurricane	Audrey	29.8	-93.7	110	946
Aug-57	Tropical Storm	Betha	29.7	-93.9	55	998
Jul-59	Hurricane	Debra	29.1	-95.2	75	980
Sep-63	Tropical Storm	Cindy	29.8	-94.4	65	997
Sep-70	Tropical Storm	Felice	29.4	-94.1	60	997
Sep-71	Hurricane	Edith	29.5	-93.1	85	978
Aug-78	Tropical Storm	Debra	29.6	-93.6	50	1000
Jul-79	Tropical Storm	Claudett e	29.6	-93.9	45	1000
Sep-80	Tropical Storm	Danielle	29.4	-94.9	40	1004
Sep-82	Tropical Storm	Chris	29.8	-93.8	55	994
Jun-86	Hurricane	Bonnie	29.6	-94.2	75	990
Jun-89	Tropical Storm	Allison	28.7	-95.2	40	1002
Jul-89	Tropical Storm	Chantal	29.6	-94.2	75	990
Oct-89	Hurricane	Jerry	29.2	-95	75	983
3-Aug	Tropical Storm	Grace	29.4	-95.1	35	1007
4-Sep	Hurricane	Ivan	29.8	-93.6	30	1004
5-Sep	Hurricane	Rita	29.7	-93.7	100	937
7-Sep	Hurricane	Humber to	29.6	-94.3	80	985
8-Aug	Tropical Storm	Eduardo	29.6	-94.2	55	996
8-Sep	Hurricane	Ike	29.3	-94.7	95	950

3.4.4 Wave Climate

Wave characteristics available nearest the study area include Wave Information Study (WIS) hindcasts compiled by USACE ERDC-CHL and direct measurements collected as part of the National Data Buoy Center (NDBC) network (NOAA/NWS, 2017c). The available data included in the WIS hindcasts includes wave information for the Gulf of Mexico south of Sabine Lake, south of Sabine Pass, and would not be representative of wave conditions at the project site.

The USACE Wind Information Studies website was utilized to characterize wind conditions nearest the project site as shown in Figure 13. The wind rose from Station 73088 was referenced, shown in Figure 14, to determine that the dominant wind direction is from the southeast while the least frequent is from the west.

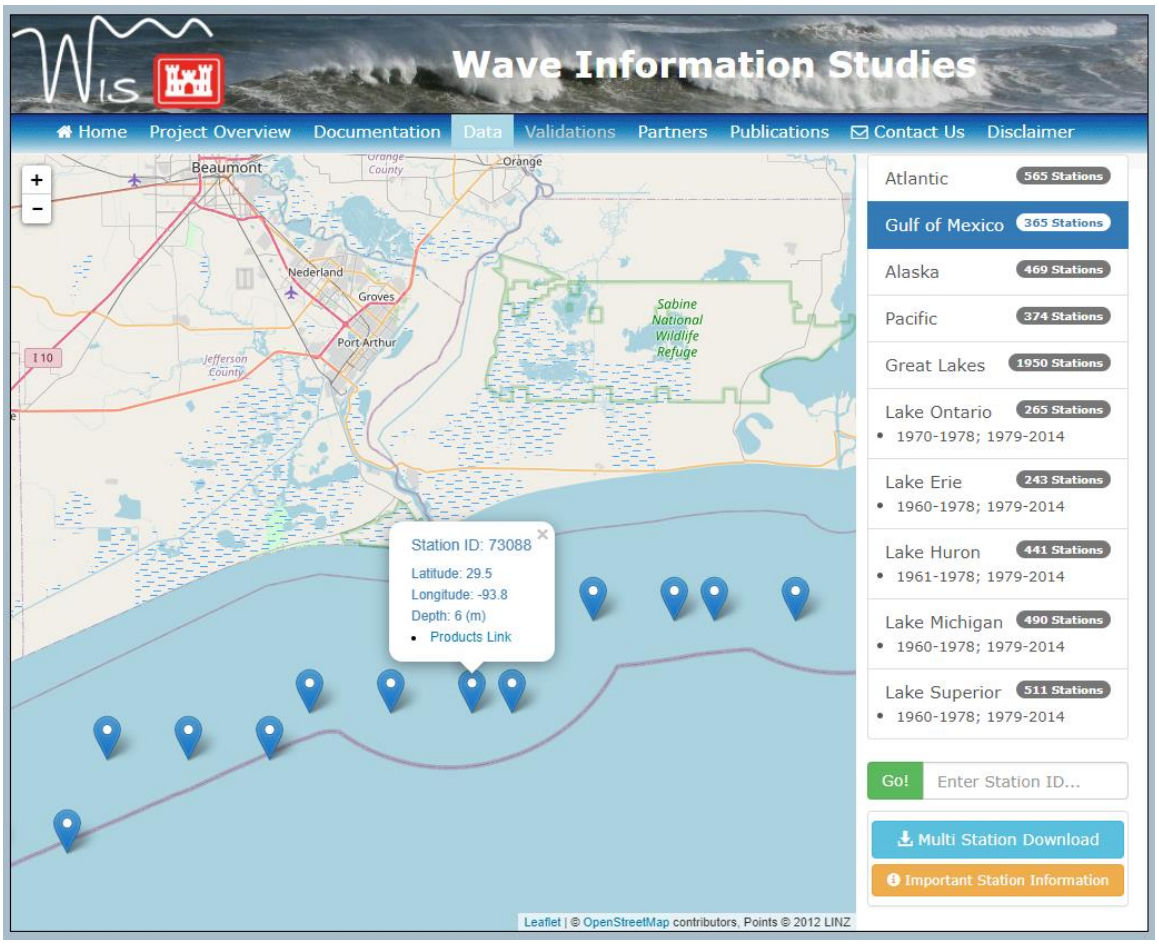


Figure 13. WIS Station 73088 Location

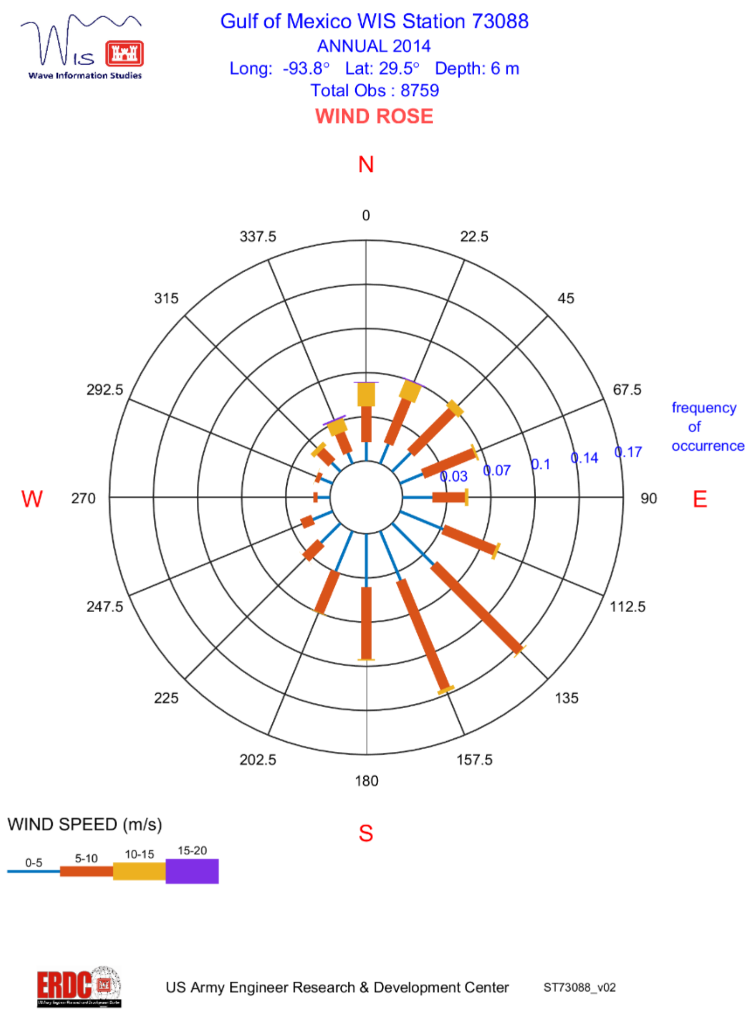
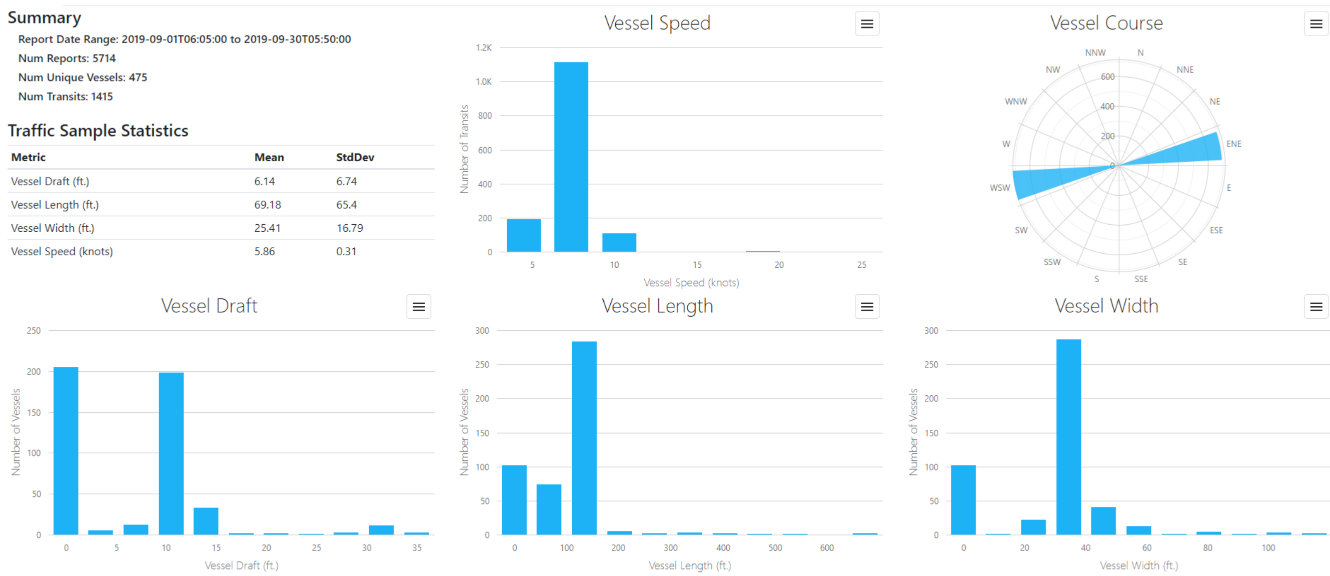


Figure 14. WIS Station 73088 Wind Rose

3.4.4.1. Ship-Induced Waves

The AISAP portal was utilized to identify vessel traffic in the study area along the SNWW/GIWW in front of Hickory Cove Bayas summarized in figure 15 (http://ais-portal.usace.army.mil/). Most of the vessel traffic consists of towing vessels. The average vessel speed is 5.86 knots with the larger vessels traveling between 3.5 and 7 knots. There were 1415 transits over this 30-day period of analysis, approximately 47 per day. The most conservative case is the Fritz vessel with a max speed of 4.2 knots, draft of 83.7-ft, length of 105-ft and width of 32.8-ft. Using the USACE developed Ship Induced Wave Analysis spreadsheet and methodology from The Rock Manual (CIRIA, 2007) the front wave height is computed as 3.77-ft and the maximum secondary wave height computed as 0.07-ft with a 2.3-s period. The maximum stern wave height was computed as 5.15-ft.



Metric	Mean	StdDev
Vessel Draft (ft.)	6.14	6.74
Vessel Length (ft.)	69.18	65.4
Vessel Width (ft.)	25.41	16.79
Vessel Speed (knots)	5.86	0.31

Figure 15. Summary Statistics for SNWW/GIWW Section adjacent to Hickory Cove Shoreline (September 2019)

3.4.4.2. Wind-Driven Waves

The wind-driven waves are computed based on the design wind speed. The ASCE 7 Hazard tool (fig. 16) (https://asce7hazardtool.online/) was utilized to determine the 10-year, 3 second gust design speed at 33-ft to be 77 mph for Exposure C Category II. Based on Figure 17, the Durst Gust-Factor conversion for 3-sec winds is 1.53. The 10-year sustained winds are 50.3 mph.

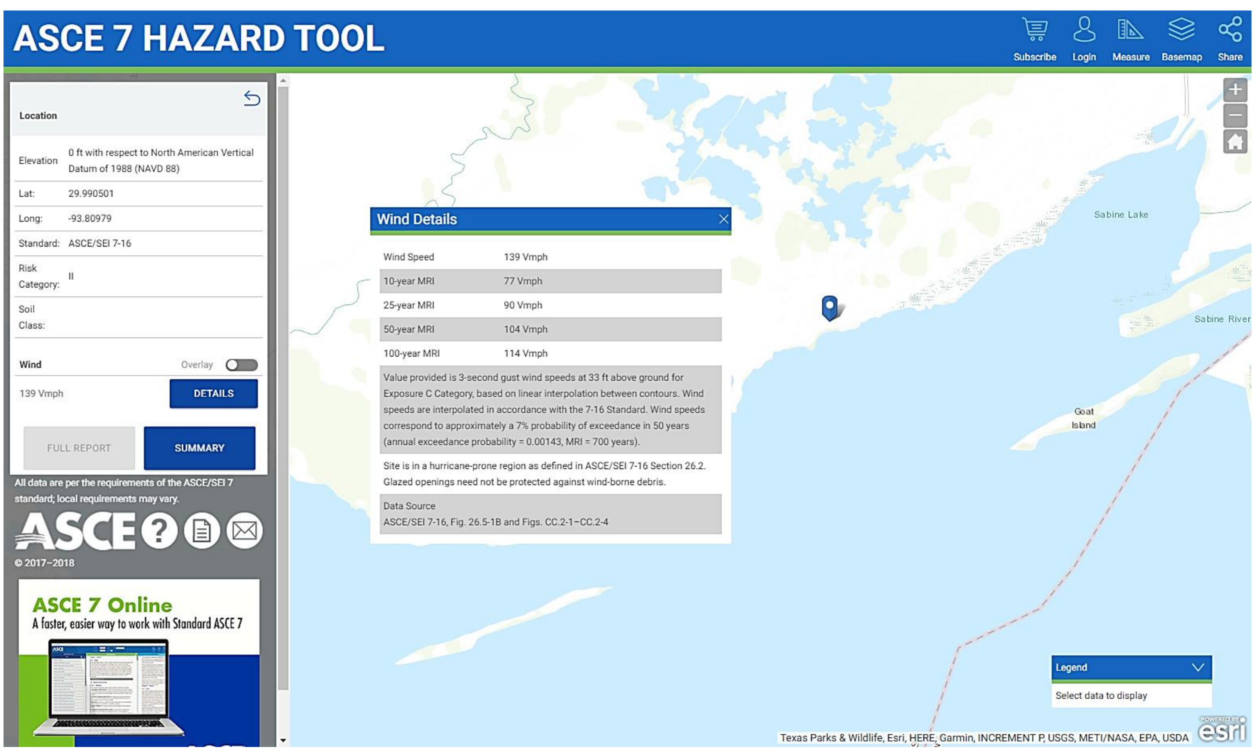


Figure 16. ASCE 7 Wind Hazard Tool

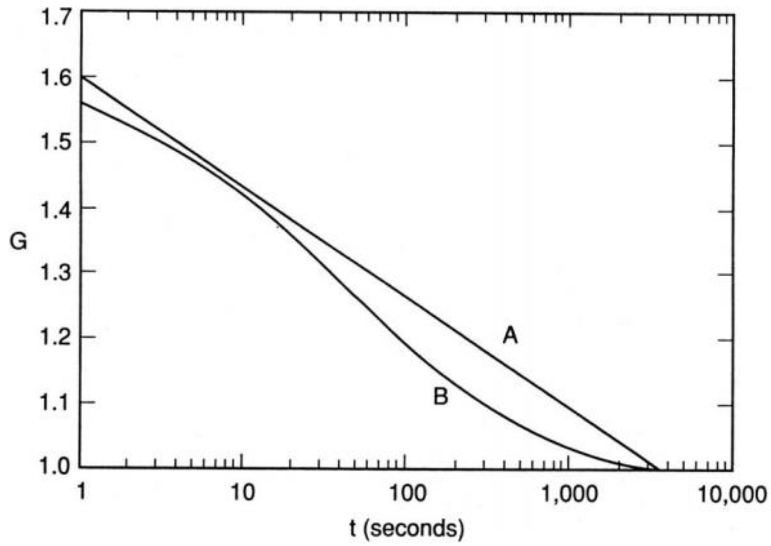


FIG. 1. Gust factors based on hourly mean wind speed ($z = 10$ m, $z_o = 0.03$ m). Curve "A" (Cook 1985) is a simplified representation of gust factors, and is used for structural design in the United Kingdom, while curve "B" (Durst 1960; ASCE 1990) is used in the United States.

Figure 17. Durst Gust-Factor Conversion (Krayer & Marshall, 1992)

The CEDAS/ACES program was used to compute fetch-generated waves for the 10-year return period. The fetch was determined by fetch lines drawn at 15-degree intervals as shown in Figure 18. The wind direction and latitude of observation is specified as 157.5-degrees and 29.5-degrees respectively based on the wind rose in Figure 14. The average fetch depth of 10.45-ft is based on the 6-ft MLLW average depth of Sabine Lake (NOAA/OCS, 2020) the intermediate predicted SLR of 2.06-ft MSL, the difference between MLLW and MSL of 0.96-ft and the stillwater depth of 4.13-ft for the 10-year storm (FEMA, 1997). This resulted in a predicted wave height of 3.08-ft NAVD88 (3.21-ft MSL) and a wave period of 3.39-sec as summarized in Figure 19.

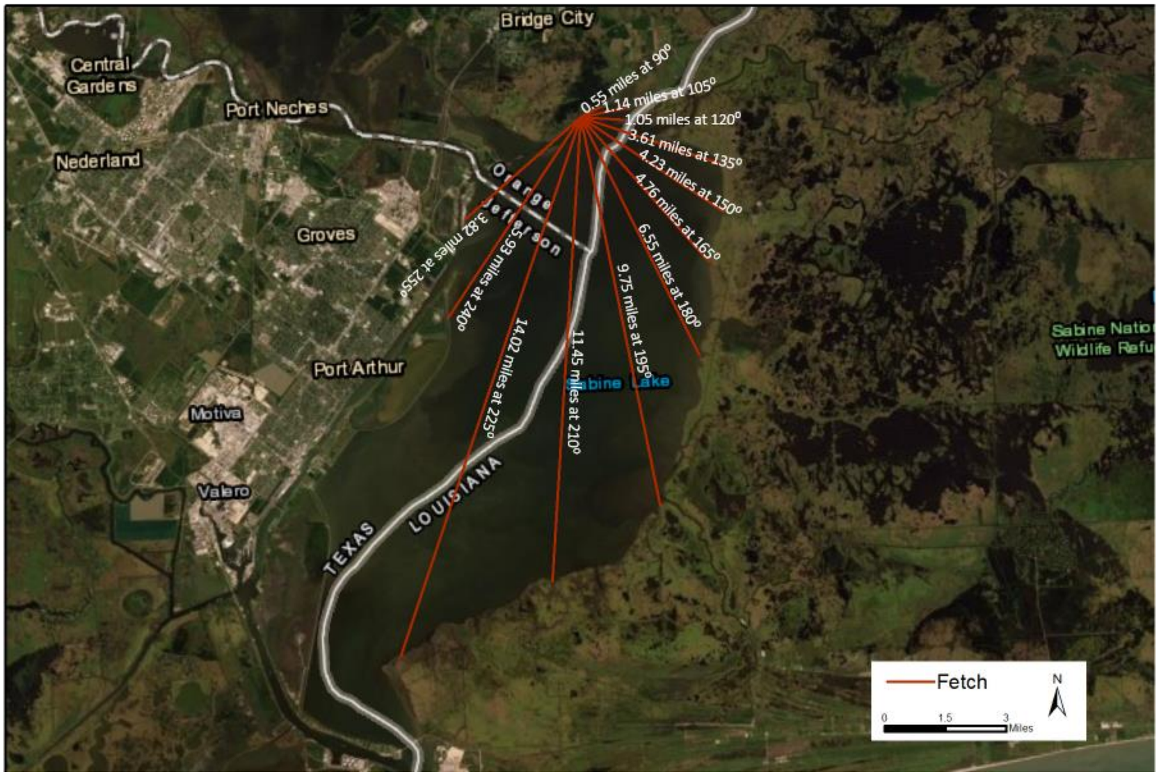


Figure 18. Fetch angles and distances across Sabine Lake

Case: 10-Year Storm

Windspeed Adjustment and Wave Growth

Breaking criteria 0.780

Item	Value	Units
El of Observed Wind (Zobs)	33.00	feet
Observed Wind Speed (Uobs)	50.30	mph
Air Sea Temp. Diff. (dT)	0.00	deg F
Dur of Observed Wind (DurO)	12.00	hours
Dur of Final Wind (DurF)	12.00	hours
Lat. of Observation (LAT)	29.50	deg
Results		
Wind Fetch Length (F)	9.22	MILES
Avg Fetch Depth (d)	10.45	feet
Wind Direction (WDIR)	157.50	deg
Eq Neutral Wind Speed (Ue)	45.27	mph
Adjusted Wind Speed (Ua)	65.70	mph
Mean Wave Direction (THETA)	193.00	deg
Wave Height (Hmo)	2.89	feet
Wave Period (Tp)	3.47	sec

Wind Obs Type	Wind Fetch Options
Shore (windward)	Shallow restricted

Restricted Fetch Geometry

#	Fetch Angle (deg)	Fetch Length (miles)
1	90.00	0.55
2	105.00	1.14
3	120.00	1.05
4	135.00	3.61
5	150.00	4.23
6	165.00	4.76
7	180.00	6.55
8	195.00	9.75
9	210.00	11.45
10	225.00	14.02
11	240.00	5.93
12	255.00	3.82

Wave Growth: Shallow

Figure 19. CEDAS/ACES output for 10-year fetch based wave growth

3.5 Shoreline Change

The shoreline of Hickory Cove Bay has eroded due to the wave climate exacerbated by navigation traffic and wind waves generated across Sabine Lake Estuary. While some isolated areas have accreted or remained generally intact, much of the shoreline has experienced significant loss. The General Marsh Model, a decision support tool developed by Ducks Unlimited (2013), identified Hickory Cove bay as a high and medium priority candidate for shoreline protection. Aerial imagery was utilized to demonstrate the shoreline change from 1989 to 2019, as shown in Figure 20. Consistent with the General Marsh Model results shown in Figure 21, the central exposed region of the shoreline has eroded significantly to the point that the containment levee surrounding the marsh has been breached in multiple locations.

Figure 20. Shoreline Change from 1989 to 2019 at Hickory Cove based on Aerial Imagery

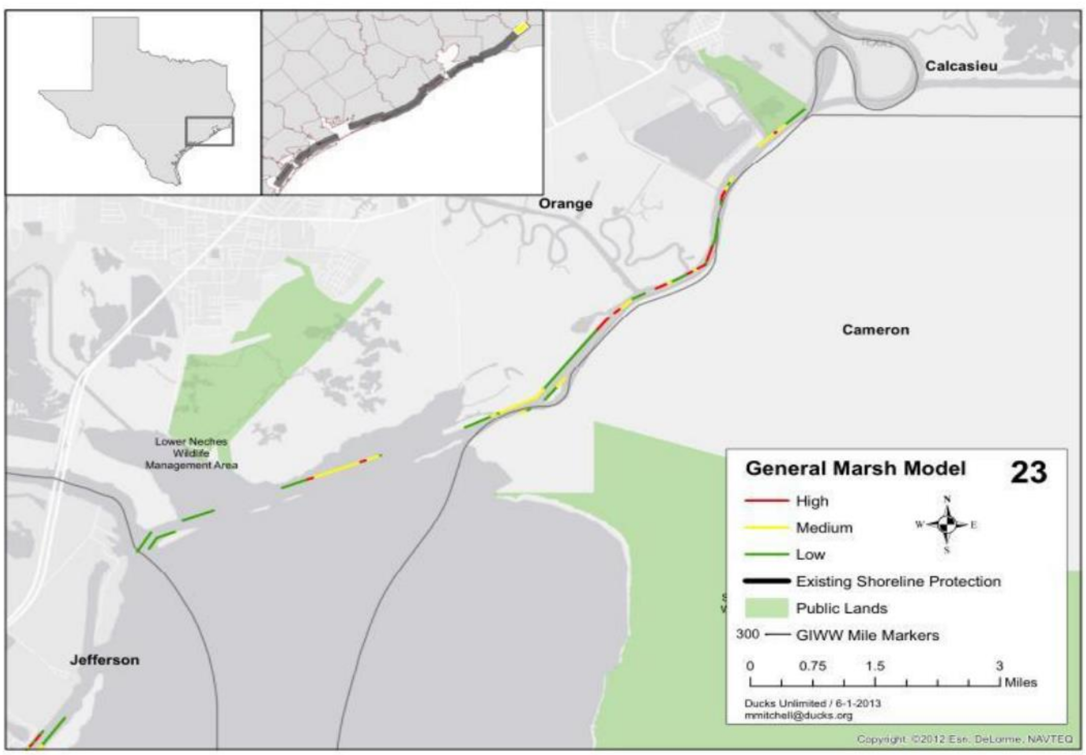


Figure 21. General Marsh Model results along GIWW for Hickory Cove (Ducks Unlimited, 2013)

4 SURVEYING, MAPPING AND OTHER GEOSPATIAL DATA

New and existing surveys were utilized to evaluate the array of alternatives. Ducks Unlimited provided survey data collected in 2018 for the containment levee and hydrographic survey data for the inundated nearshore region where the detached breakwater would be located. New hydrographic survey data was collected in November of 2019 and processed by SWG Geospatial Branch for the marsh interior as shown in Figure 23. This survey data characterized the depth of the inundated area of the marsh to be filled to the target elevations. The target elevations were informed by newly collected survey data in August of 2019 at Old River Cove restoration site, within the Lower Neches Wildlife Management Area just west of Hickory Cove, in cooperation with Texas Parks and Wildlife (TPWD). These elevations were shown to be successful at the Old River Cove site for establishing the appropriate vegetation to reestablish the freshwater marsh.

The following is an overview of the geospatial and physical data available in and around the study area:

- Aerial Imagery from 2019 (Image Landsat Copernicus), 2009 (Texas Orthoimagery Program), 1998 (USGS, GLO) and 1989 (USGS)
- LiDAR dataset for Orange County, TX
- NOAA OCM Marsh Migration Viewer provides projected change in land cover types under various SLR scenarios (NOAA/OCM, 2017a)
- Sea Level Rise and Coastal Flooding Impacts (NOAA/OCM, 2017b).
- TxSed Database, a compilation of sediment data collected by Texas General Land Office (GLO) along the Texas Coastal Zone (GLO, 2017).
- NOAA/CO-OPS water-level stations and associated datums (NOAA/CO-OPS, 2017).

Additional data and surveys will be collected during the Design and Implementation phase of the project in support of the preferred plan.

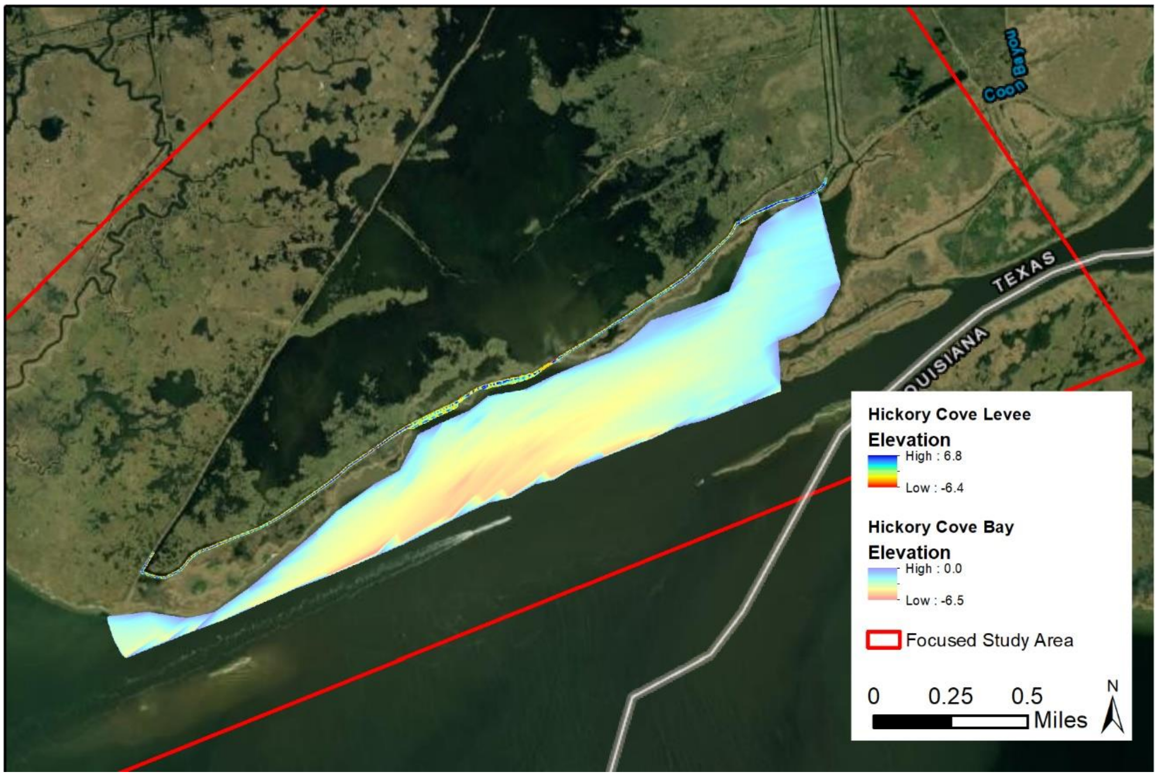


Figure 22. Hickory Cove Bay and containment levee survey (Ducks Unlimited, 2018).

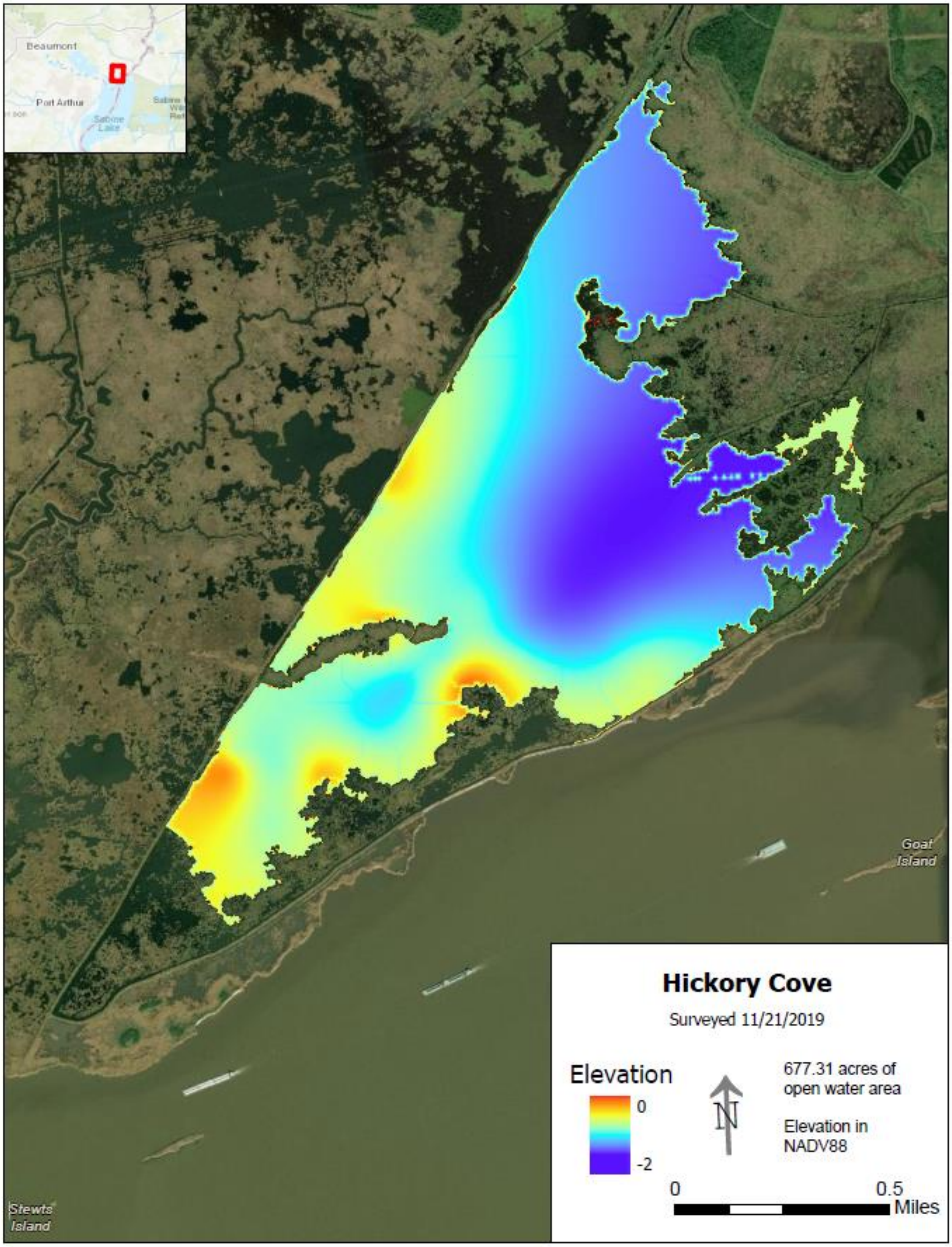


Figure 23. Hickory Cove marsh interior survey

5 GEOTECHNICAL

5.1 Geology

The study area is part of The Beaumont Formation, a spatially expansive late-Pleistocene fine-grained formation, with sediments primarily being fluvial deposits from the Mississippi River and delta system. Beaumont clay is the predominant soil. Fine -grained, poorly graded sand and silt are sometimes found in this formation.

5.2 Geotechnical Analysis and Assumptions

Geotechnical analysis has not been conducted for this study nor have soil borings or testing been done. Adequate existing soils information has not been collected in areas for construction of the breakwater. Soil investigations should be completed during the design and implementation phase to characterize the soil stratums in the area. The TxSed database provides limited information about grain size in and around the study area (fig 24-25, Table 4) (GLO, 2017). This database is maintained by Texas GLO but is obtained from many sources including TPWD, USACE and GLO among others.

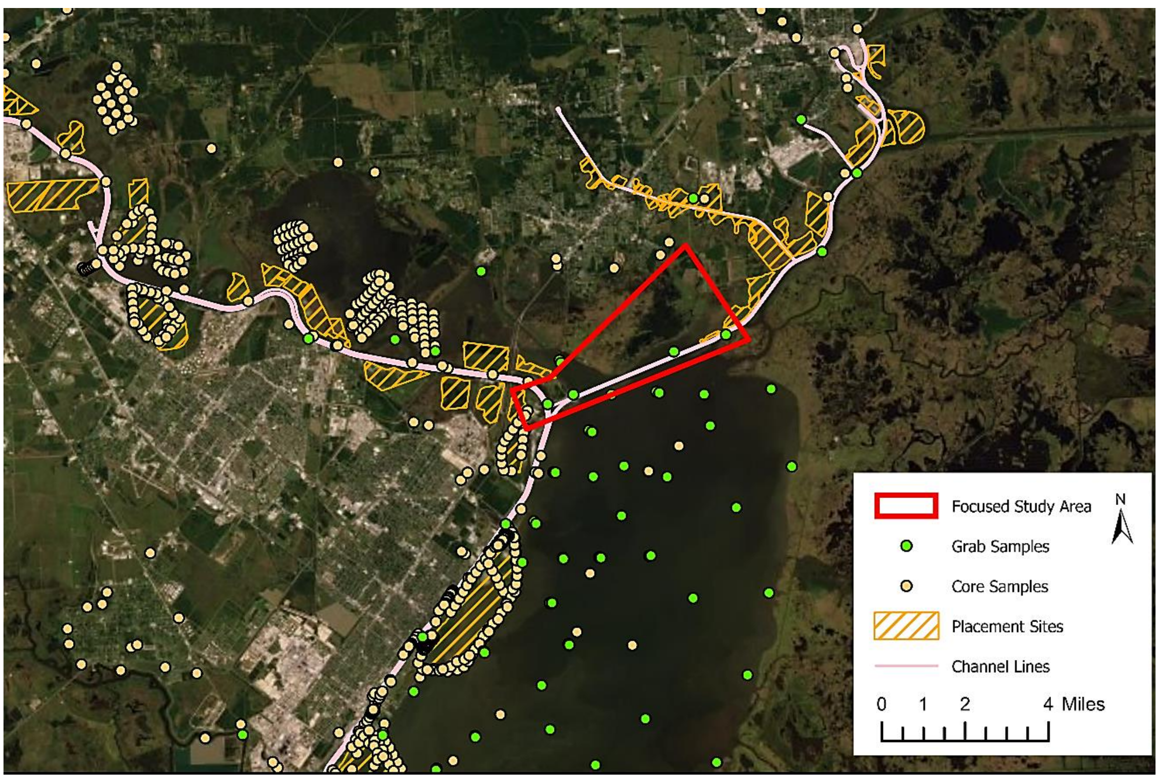


Figure 24. Sediment data available in and around study area (GLO, 2017)

Figure 25. TxSed Samples in or near the study area (GLO, 2017)

Table 4. Sediment Sample Summary of Grab Samples in Figure 25

Sample ID	Sample Date	Sand	Silt	Clay	Gravel	Phi Size	Water Body
TBEG_PSN19	January 19, 1977	45%	29%	18%	8%	5	Port Arthur - Sabine-Neches Canal
TBEG_PSN29	January 19, 1977	12%	64%	24%	0%	7	Port Arthur - Sabine-Neches Canal
TBEG_PSN35	January 19, 1977	79%	15%	5%	1%	3	Port Arthur - Sabine-Neches Canal
TBEG_SLP100	January 19, 1977	67%	25%	8%	0%	4	Sabine Lake
TBEG_SLP101	January 19, 1977	21%	60%	19%	0%	6	Sabine Lake
TBEG_SLP102	January 19, 1977	95%	4%	1%	0%	3	Sabine Lake
TBEG_SLP108	January 19, 1977	21%	68%	11%	0%	5	Sabine Lake

5.3 Feasibility Level Design – Breakwaters

Concept design for offset rock breakwaters (constructed in shallow water away from the banks) are used for estimates. A total maximum base width of 30 feet, height of 6.5 feet, crest width of 4 feet, side slopes of 2H:1V were assumed as shown below for the typical breakwater section (Figure 26). In general, placing of suitable dredged material to raise the existing grade up to the design grade of -3-foot elevation NAVD88. 1-foot thick blanket Stone (1/4 to 4 inches) above the geotextile (Tencate Mirafi 1160 N) base which is considered for the breakwater. Riprap with an average unit weight of 1.6 tons/cubic yard (cy) was considered for the study.

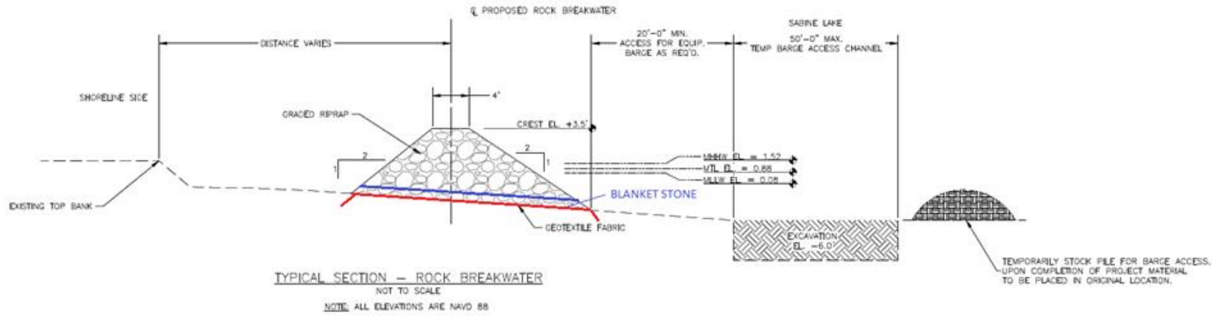


Figure 26. Typical Proposed Breakwater Section

6 FEATURE DESIGN

Discussed herein are the assumptions and design considerations associated with the array of feasibility level alternatives. Measures include marsh restoration, shoreline armoring and shoreline stabilization with a breakwater.

6.1 No Action Plan

The alternative to utilizing dredge material for marsh restoration is placing the material in a nearby placement area. Placement areas 29A and 29B were evaluated for their capacity, or what is required to bring them to capacity, to store additional dredge material. The upland site is located on a small bluff along the left ascending bank at the mouth of the middle pass of the Sabine River delta in Orange Co. Texas. The site contains two placement cells; Cell B in the northerly portion containing 175 acres and Cell A in the southerly portion containing 500 acres. There is an existing engineered outfall structure in each cell. Two exclusive areas are directly adjacent to the existing embankments and should be avoided. The exact nature of the avoidance areas is unknown. These avoidance areas occur in low laying areas along the northerly margin between the banks of Coon Bayou and the Sabine River of containment Cell 29A and an additional area along the northern perimeter in the Southerly portion of containment Cell 29A. The Sabine River navigation channel occurs along the southern border and the centerline of it serves to delineate the political boundary between the states of Texas and Louisiana. The placement areas, shown in Figure 27, will require modification to current capacity to hold additional dredge material. Current conditions and options to increase the capacity are summarized in Table 5. The quantities summarized reflect the minimum need to bring 29A/B to the elevations identified in the first column of the Dike Raise Options. Due to the uncertainty regarding available material at the time of this analysis, two dike raise options were evaluated to provide an understanding of how much of the total required material would be needed towards containment improvements alone to make the placement area, whether Hickory Cove or PA 29A/B, suitable to place additional material. Repairs to the Hickory Cove containment dike would require approximately 28,644 CY of material, a fraction of the needs described in Table 5.

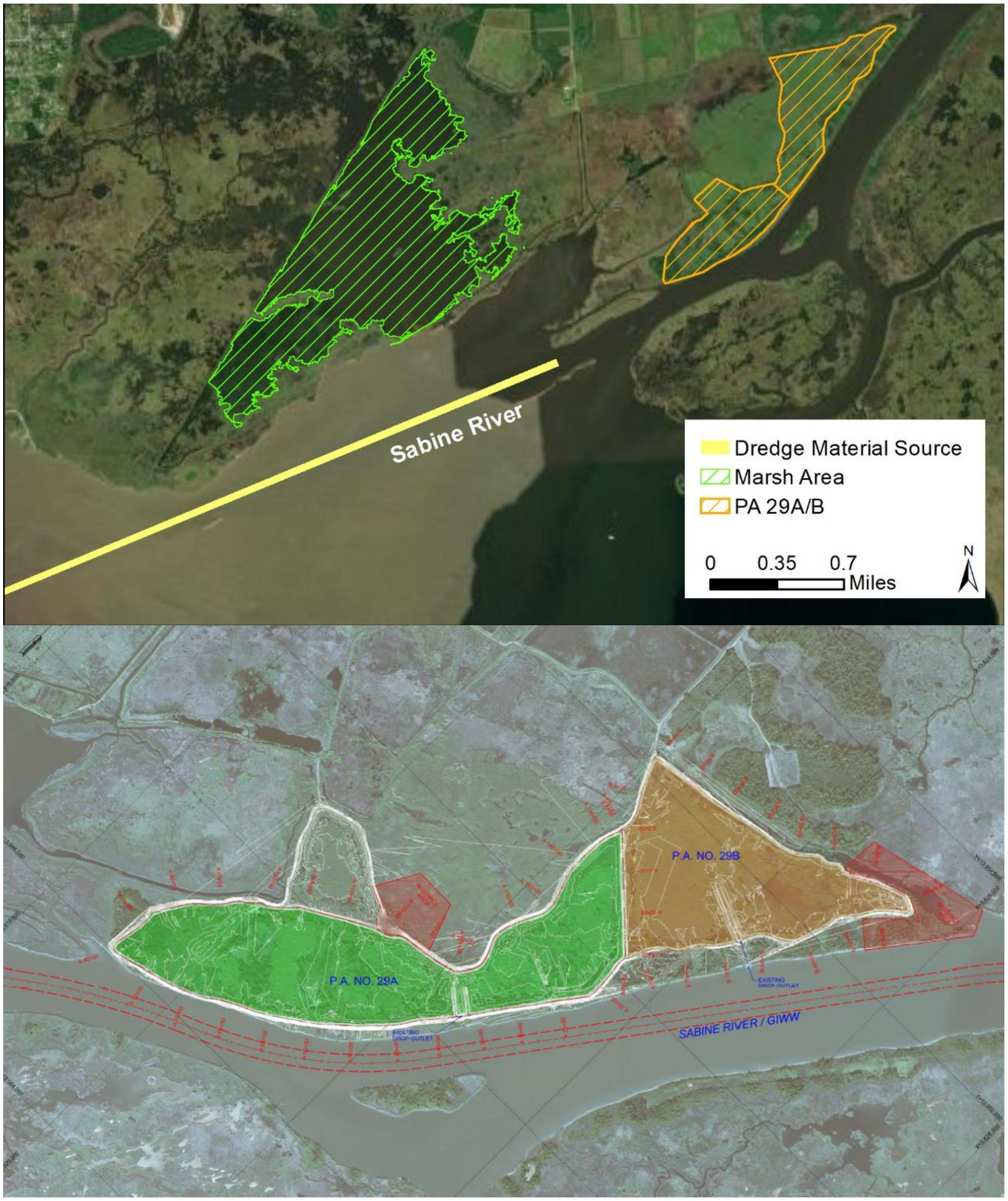


Figure 27. Placement areas 29A/B

Table 5. Geotechnical analysis summary of required PA 29A/B site design improvements

Current Conditions

- Outlet structures at both 29A and 29B need to be replaced to make site operational

	29A	29B	Total	
[1]Current Capacity (cu yds)	233,194	111,113	344,307	

Note 1: Current capacities doesn't maintain a 3 ft Freeboard throughout the PA.

Dike Raise Options

	29A	29B	Total	
[1]Raise to Both Cells to Elev. +13.0 ft (cu yds)	233,194*	522,635	755,828	
[1]Raise Both Cells to Elev. +16.0 ft (cu yds)	816,580	975,065	1.8 million	

Note 1: This elevation includes the required 3 ft Freeboard.
*Note *: This option will only increase Freeboard to 29A. It will not increase the current capacities.*

6.2 Marsh Restoration

The purpose of the Section 1122 pilot program is to demonstrate how dredged material can be beneficially used for the purposes summarized in Section 1.2 of this appendix. Coastal marsh is essential habitat for both terrestrial and aquatic species but also plays a key role in stabilizing shorelines, reducing storm damage to property and infrastructure, and mitigating the impacts of climate change (such as sea level rise) on coastal habitats and communities. Target elevations were established based on successful vegetation establishment at the Old River Cove restoration site in the adjacent Lower Neches Wildlife Management Area adjacent to Hickory Cove, managed by the Texas Parks and Wildlife Department (TPWD).

The assumptions and design considerations associated with marsh nourishment at Hickory Cove include:

- Target elevations aim to fill 60% of the marsh to 1.2 ft. and 40% of the marsh to approximately 0.5 ft. NAVD88 based on resource agency input;
- An existing containment levee will be restored with material from the marsh interior to limit tidal influence and salinity intrusion to the marsh;
- Training berms will be constructed from in-situ material during nourishment;
- Quantity calculations assumed 20% settlement
- The sediment source for marsh creation is assumed to be from the SNWW or the GIWW, either the Neches River or Sabine River segments, depending on dredge cycle timing and available quantities;

- Plantings will be provided by TPWD consistent with the adjacent Old River Cove reference site.

Available marsh nourishment quantities were provided by SWG Operations Branch based on a range of potential expected quantities determined by the dredging depth. The area of marsh to be restored with the corresponding quantity was based on hydrographic survey data and engineering assumptions. The current elevation of the marsh is shown in Figure 23. The containment levee quantities for feasibility are based on Ducks Unlimited preliminary designs as shown in Table 6. The AAHU's associated with each range listed below are described in Appendix B – Ecological Modeling, Section 3. Marsh restoration is assumed to start accruing benefits immediately but at 25% in year 1, 50% in year 2, and 100% in 3 as described in Appendix B.

Table 6. Marsh Restoration and Containment Levee Quantities

	Range Upper Limit (CY)	***500K***	***900K***	***1.3M***	***1.5M***
Sediment Quantities	**Area (acres)**	68	126	190	213
	Marsh Restoration (CY)	468,000	867,000	1,310,000	1,470,000
	Training Berm Length (LF)	5,900	13,360	16,000	16,410
	Training Berm Quantity (CY) H = 5.5 FT	27,940	63,200	75,700	77,640
	Containment Levee Restoration (CY) (earthen, in situ matl source)	28,644	28,644	28,644	28,644
	Total (CY)	**496,644**	**895,644**	**1,338,644**	**1,498,644**
Plantings	**Interior Fringe Plants**	**6,013**	**13,615**	**16,306**	**16,724**

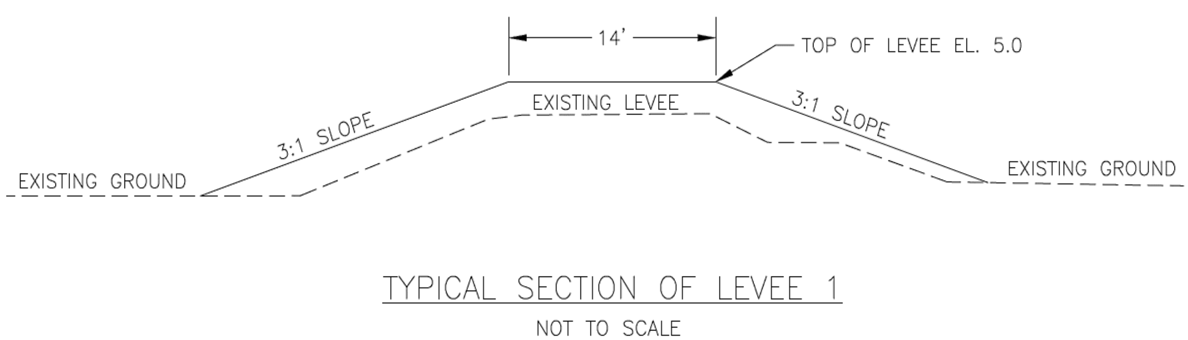


Figure 28. Typical Containment Levee Section for Hickory Cove (Ducks Unlimited, 2018a)

6.3 Breakwater

As previously stated, the purpose of the Section 1122 pilot project to be implemented at Hickory Cove is to demonstrate how dredged material can be beneficially used to restore critical marsh habitat. Marshes along the Gulf Coast are receding due to many factors including interruption of freshwater inflows, erosion due to wind waves, navigation traffic, climate change and increased salinity destabilizing sensitive vegetation that aids in shoreline stabilization. These at-risk marshes will continue to erode and recede without protection especially in areas along navigation channels and large bodies of water as identified in the General Marsh Model discussed previously in Section 3.6 (Ducks Unlimited, 2013). The containment levee is vulnerable to coastal forces and insufficient to prevent marsh degradation over time.

Hickory Cove's shoreline runs parallel to the SNWW/GIWW on the northern side of Sabine Lake and is exposed to wave action that has repeatedly degraded the containment levee on the exterior of the marsh. In addition to navigation traffic subjecting the shoreline to erosive forces, Hickory Cove's shoreline is along the northern boundary of the lake with a significant fetch leaving it vulnerable to wind-driven and ship induced wave action. Attenuating waves was considered necessary to mitigate marsh degradation exacerbated by these conditions. The preliminary design of this feature is shown in Figure 29. The assumptions and design considerations are as follows:

- Breakwater would be placed sufficiently offset from the boundaries of the SNWW navigation channel to allow for safe navigation;
- Breakwater would be placed approximately at the -3 feet contour up to a crest elevation of +3.5 feet;
- Quantities assume 1 ft. initial settlement.
- Openings would be required at access points required for fisheries access or circulation (to be determined in Design and Implementation phase);
- The base of the armoring should be on filter cloth ballasted to secure placement and prevent displacement of outboard edges;
- Armoring in the form of a breakwater placed on the natural bottom outside the dredged SNWW channel reduces ship-wake induced shoreline erosion and would facilitate construction and maintenance;
- A disadvantage to armoring in the vicinity of the channel is the danger that an empty barge tow be blown off course by strong onshore winds, damaging the armoring or empty barges;
- It would not be practical or necessary to construct the armoring to an elevation above water levels associated with tropical events. In the event of hurricane tides, the armoring would be inundated at an early stage in the approaching storm tides and would not suffer severe damage as a result of being completely inundated.

Table 7. Summary of Breakwater Quantities based on Figure 29

	Length (ft.)	Stone Tonnage	Blanket Stone Tonnage	Geotextile Area (SY)
Quantities	14,623	109,142 tons	28,592 tons	64,341

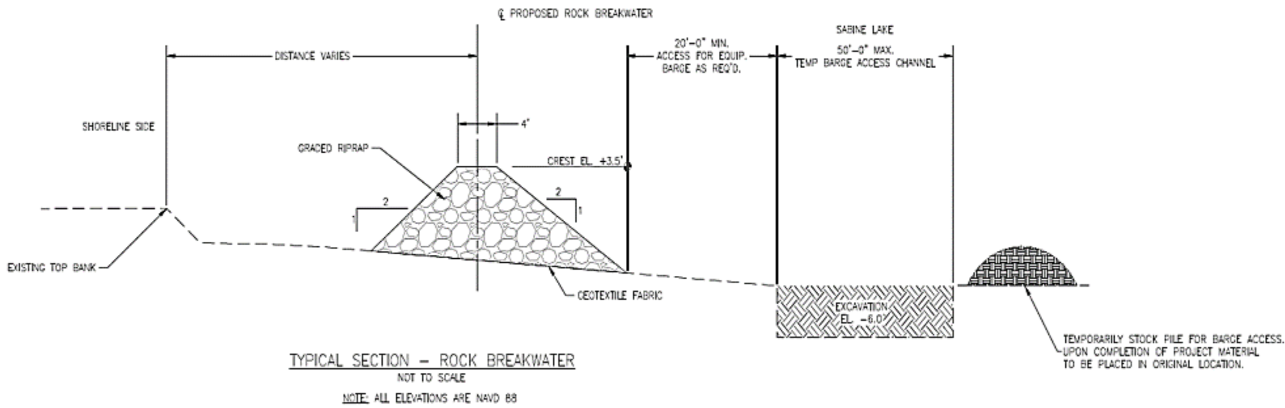


Figure 29. Typical Breakwater Section for Hickory Cove (Ducks Unlimited, 2018b)

6.4 Living Shoreline

The erosive forces along the shoreline of Hickory Cove caused habitat to erode on the exterior of the containment levee, resulting in breaches in some locations. Installing a detached breakwater between the navigation channel and the shoreline will attenuate waves and reduce risk of future breaches in the containment levee. Additional measures can be put in place to further stabilize the shoreline as well as promote sediment accretion to regain lost habitat through the implementation of a living shoreline. Unlike the interior marsh area that will be planted with freshwater marsh vegetation, the exterior of the containment levee should be planted with salinity tolerant vegetation as it will be exposed to the Sabine Lake estuary.

Shoreline stabilization measures are included in Alternative 3 with the aforementioned breakwater and living shoreline on the exterior of the containment levee for added protection and to promote sediment accretion. The number of intended plantings are summarized in Table 8.

Table 8. Summary of Living Shoreline Quantities

Shoreline Area (acres)	*Plant Spacing (inches)*	*Number of Plantings*
95.4	60	217,000

6.5 Sediment Sources

Section 1122 of WRDA requires that the Hickory Cove pilot project beneficially use dredge material to restore critical marsh habitat. The project proposal recommends the Sabine River segment shown in Figure 30 as the ideal sediment source location for this restoration effort. The non-Federal Sponsor for the Sabine River reach is the Orange County Navigation and Port District. The Sabine River is not regularly dredged and there is no current Dredge Material Management Plan in effect. Shoaling has occurred during major storm events and has raised the need for emergency maintenance dredging, the most recent being 2012.

SNWW from the Gulf of Mexico to Port Arthur and Port Beaumont is authorized to 40ft MLLW. The Sabine River reach, the portion of channel from the SNWW proposed to be dredged for the Section 1122 project, is authorized to 31ft MLLW. The non-Federal Sponsor for the 40ft MLLW portion of the SNWW is the Sabine-Neches Navigation District.

Approximately 21,000 linear feet of the Sabine River is proposed to be dredged to a depth of 26 feet MLLW. The 26-ft. dredge depth limitation, despite the authorized channel depth of 31-ft., was due to areas further up the channel being shoaled to a depth of 26-ft. The limitations on being able to utilize the full depth due to shoaling further upstream led to the determination that dredging to the authorized depth was not beneficial to the government. The 26-foot depth dredging would provide approximately 500,000 cubic yards of sediment.

Potential sediment sources near the study area, including but not limited to those in the proposal, were identified and include the sections shown in Figure 30. Available quantities are summarized as follows:

- BUDM associated with maintenance material from the SNWW (Neches River)
    - Approximately 1M cubic yards of sediment is dredged from the lower Neches River on average every 3 years with the next dredging cycle planned for FY 2021.
- BUDM associated with maintenance material from the SNWW (Sabine River)
    - Approximately 1.3M cubic yards of dredge material available from the section of Sabine River parallel to Hickory Cove's shoreline due to shoaling.

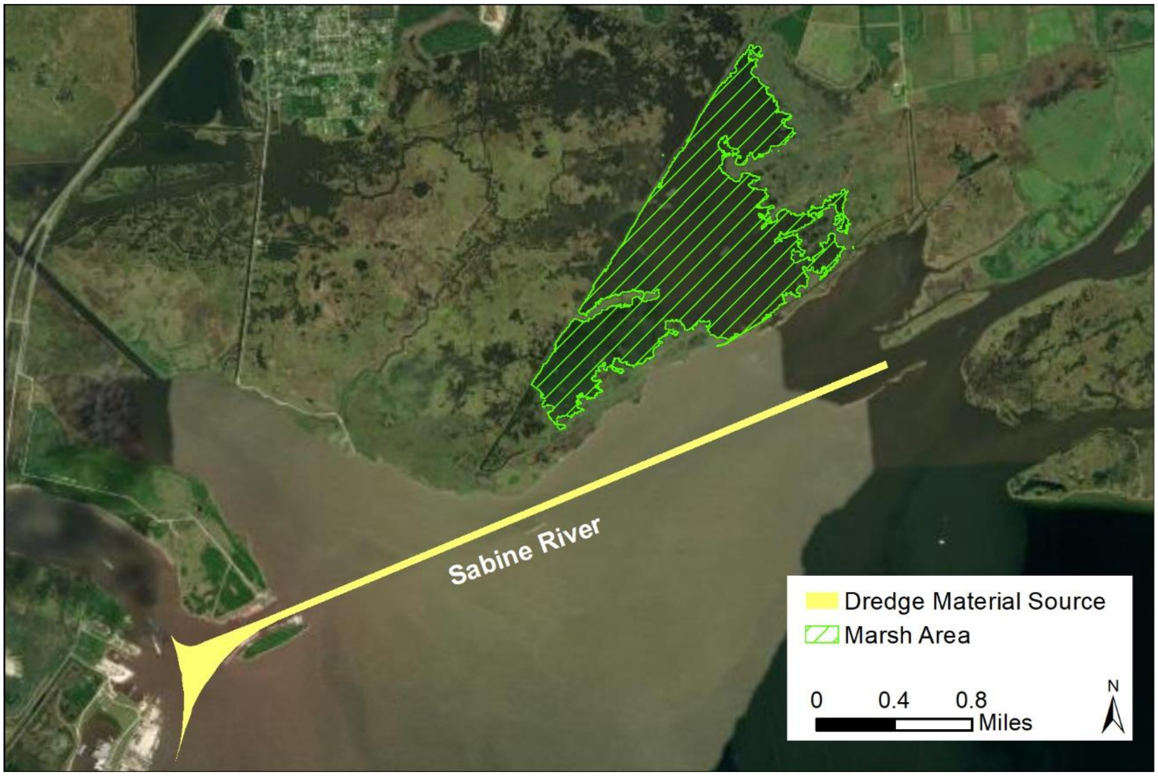


Figure 30. Potential Dredge Material Sources near Hickory Cove

7 RECOMMENDED PLAN AND D&I PATH FORWARD

7.1 Tentatively Selected Plan (TSP)

Following the TSP Milestone, the expected available sediment quantity was assumed to be 1.3 million cubic yards. The recommended plan, Alternative 3, includes containment levee repair, marsh restoration of 190 acres and the construction of a breakwater with a living shoreline. This alternative meets the intent to defend Hickory Cove marsh from erosive forces. The feasibility level designs of the breakwater, containment levee and living shoreline are consistent with the details outlined in Section 6.3 and 6.4.

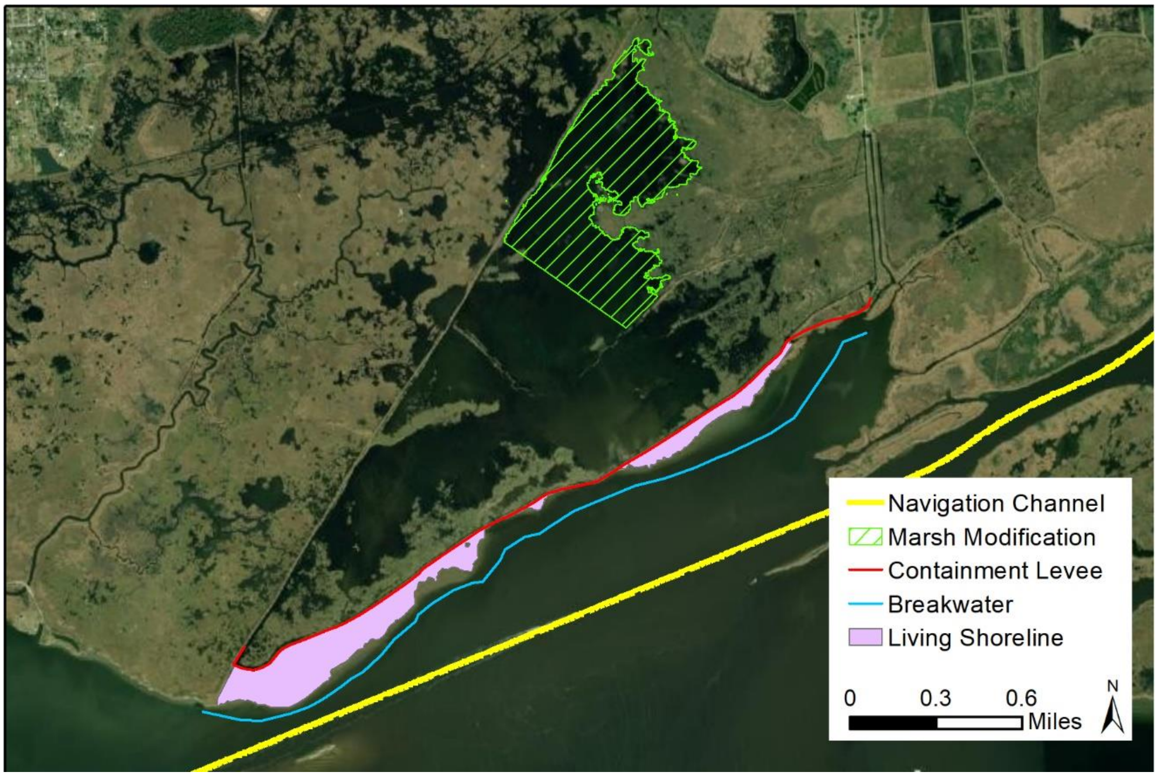


Figure 31. Hickory Cove tentatively selected plan, alternative 3.

7.2 Value Engineering (VE)

Alternative 3, the recommended plan, was further investigated with a value engineering approach. This approach aims to provide the essential function at the lowest possible cost. This alternative may be revisited as an optimized design option during the D&I phase of the project if the shoreline is considered redundant. Opportunities to reduce cost were considered in the shoreline protection component, specifically breakwater length. The containment levee is necessary as is to prevent salinity intrusion, but the breakwater protecting it extends northeast into an area of Hickory Cove Bay already protected by land at the outlet of the Sabine River. This section of land offers some protection from the navigation channel and it was proposed that a section of breakwater parallel to it could be shortened, while the marsh area, containment levee and living shoreline components remain the same. The adjusted breakwater length considered is shown in Figure 32 and updated quantities in Table 9. It was determined that the environmental benefits lost because of a shortened breakwater were too significant in comparison to any cost savings achieved, and the original breakwater length is proposed in the recommended plan.

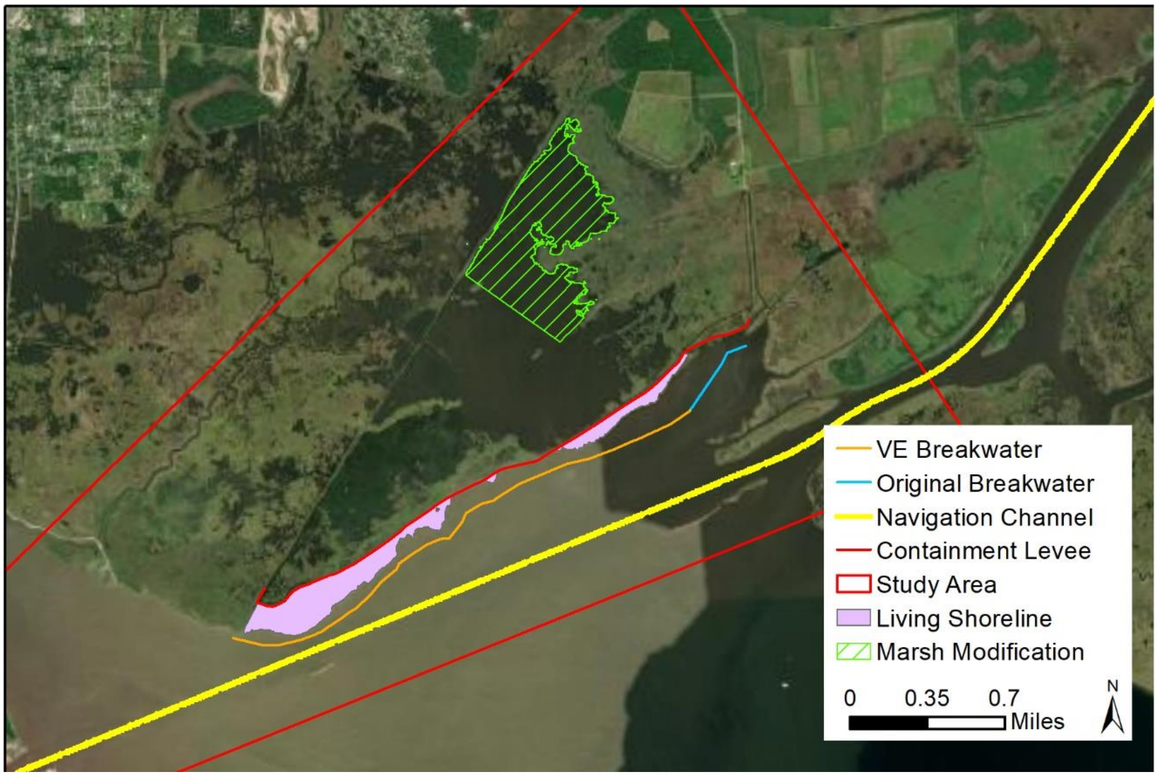


Figure 32. Hickory Cove recommended plan VE alternative

Table 9. Summary of VE Breakwater Quantities

	Length (ft.)	*Stone Tonnage*	*Blanket Stone Tonnage*	*Geotextile Area (SY)*
Quantities	12,576	82,575 tons	22,354 tons	41,920

7.3. Design and Implementation (D&I) Path Forward

There will be additional data and analysis requirements during the Design and Implementation (D&I) phase of the project that will inform project optimization. These include:

- Collection and consideration of Hickory Cove Bay hydrographic survey and containment levee survey data
- Collection of detailed geotechnical data, such as soil borings, to inform final design quantities
- Refinement of marsh cell boundaries based on availability of O&M dredge material and detailed geotechnical analysis if necessary
- Revisiting project alternatives to optimize design considerations for all aspects of the project plan, including marsh restoration strategy

The breakwater design supplied by Ducks Unlimited is typical for marsh habitat along navigation channels and/or tributary channels. While Hickory Cove lies along the Sabine River it's also along the northern boundary of Sabine Lake Estuary. These open water conditions are like that of a bay, for example, where wind waves play a significant role. While the fetch-based analysis performed in 2019, described in Section 3.4.4.2, resulted in a wave height of 3.08-ft NAVD88 for the 10-yr storm, the wind wave analysis performed since as part of the Sabine Pass to Galveston Bay, TX Pre-Construction, Engineering and Design (PED) Hurricane Coastal Storm Surge and Wave Hazard Assessment reports a wave height of 16.6-ft NAVD88 for the 10-yr storm and 26.5-ft for the 100-yr storm, 50% confidence level (Melby et. al., 2021). This updated analysis should be considered in the breakwater design moving forward. Additionally, subsidence of marsh may result in additional material required to meet desired marsh elevation. Starting marsh elevation is possible to have some error involved. Additional data sources may be available for later milestones to validate initial feasibility level assumptions.

Construction costs, described in Appendix D, include initial construction of breakwater, containment dike and marsh restoration. Marsh restoration costs include the construction of training berms and the moving of the dredging pipe to establish appropriate elevation(s) throughout the marsh. Cost of plantings include the living shoreline plants, while interior plantings along the training berms will be donated by TPWD from a neighboring successful restoration site, Old River Cove, with similar elevation targets. Once plantings are placed along the boundaries of the restoration area, it is assumed that they will establish throughout the marsh if target elevations are reached.

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