UPDATED COMPENSATORY MITIGATION APPROACH

MIDWAY TO HARBOR ISLAND PIPELINES & TERMINAL PROJECT

USACE Permit NO. SWG-2018-00789

Prepared for:
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Axis Midstream

April 2020

CONCEPTUAL PERMITTEE RESPONSIBLE MITIGATION PLAN
MUSTANG ISLAND-CROAKER HOLE SEA GRASS RESTORATION

SWG-2018-00789

FOR

MIDWAY TO HARBOR ISLAND PIPELINE & TERMINAL PROJECT

IN

NUECES COUNTY, TEXAS

PREPARED FOR:

AXIS MIDSTREAM HOLDINGS, LLC

DELTA LAND SERVICES

APRIL 22, 2020

PREPARED BY:

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1.0 Introduction

Axis Midstream Holdings, LLC (Permittee) presents this Permittee Responsible Mitigation Plan (PRMP) to compensate for the potential unavoidable temporary impacts of 7.84 acres of seagrass beds (E1AB3l, Cowardin 1979) and 0.33 acre of estuarine emergent (E2EM, Cowardin 1979) *Spartina alterniflora* living shoreline wetlands, associated with the proposed Midway to Harbor Island Pipeline and Terminal Project (Project) [SWG-2018-00789] within the U.S. Army Corps of Engineers (USACE) Galveston District (SWG). Additional, compensation mitigation for permanent Project impacts will be addressed in a separate mitigation plan.

The impacts to seagrass beds and estuarine marsh are within the Aransas Bay Subbasin (Hydrologic Unit Code; HUC; 12100405; U.S. Geological Services [USGS] 8-digit HUCs [Omernik 1995];) and the PRM area (PRMA) is located within the South Corpus Christi Bay Subbasin (HUC 12110202; Appendix A, Figure 1). Mitigation for unavoidable temporary impacts to seagrass beds will use a minimum ratio of 2:1 (mitigation acre to impact acre).

Axis Midstream Holdings, LLC (Axis; also referred to as Applicant or Permitee) is proposing to construct, own, and operate facilities and pipelines for the "Midway to Harbor Island Pipelines & Terminal" Project located in Nueces and San Patricio Counties to stage and loadout (export) crude oil. The overall project will consist of two (2) staging facilities, a ship loading terminal and the associated interconnecting pipelines.

Crude oil will originate from various sources through incoming pipelines provided by others into multiple aboveground storage tanks that will be constructed at Axis's Midway Storage Facility (MSF) located west of Gregory, TX. From the MSF, dual 36-inch diameter steel pipelines (approximately 20 miles in length) will connect to the Aransas Pass Staging Facility (APSF). Multiple aboveground storage tanks will be constructed at APSF and dual 42-inch diameter steel pipelines, a 16-inch diameter steel pipeline, a 6-inch diameter steel pipeline and a 2-inch diameter pipeline for fiber optic cable (approximately 5.5 miles in length each) are planned to connect the APSF to the Harbor Island Loading Terminal (HILT).

Delta Land Services LLC (DLS), acting as the mitigation services agent and provider (mitigation provider) for the Permittee, will be responsible for implementing and monitoring the construction and establishment of the PRMA through Year 5. Since the mitigation will occur on state-owned water bottoms/public water, no long-term steward is proposed. Implementation of this PRMP will result in the restoration[1] (i.e., re-establishment[2] and rehabilitation[3]) of 7.84 acres of seagrass beds, and the restoration (i.e., re-establishment and rehabilitation) of 5.00 acres of *Spartina alterniflora* estuarine marsh habitat. The location of the PRMA is shown on Figure 2 of Appendix A.

The Permittee proposes to construct breakwaters to help re-establish seagrass beds and marsh habitat. The proper placement of the breakwaters along the back side of Mustang Island will decrease the wave action and reduce currents protecting the island shoreline and interior marsh from further erosion and create better conditions for the growth of seagrasss and tidal marsh vegetation. The breakwaters have been analyzed, modeled and designed to identify the number, size, and location of the breakwaters to best promote sea grass re-establishment and establishment of living shoreline/marsh. A final mitigation plan will be developed once an engineering basis of design has been developed.

1.1 Mitigation Property Location

The PRMA is located approximately 8.25 miles northeast of the intersection of the Gulf Intracoastal Waterway (GIWW) and Packery Channel inlet (adjacent to Park Road 22 bridge) in Nueces County, Texas and approximately 6.4 miles southwest of the Corpus Christi Ship Channel on the Corpus Christi Bay side of Mustang Island (Appendix A, Figure 3). The approximate center of the PRMA is latitude 27.733956˚ North and longitude 97.16425278˚ West (North American Datum of 1983 [NAD83]).

The PRMA is located in the Southern Corpus Christi Bay Subbasin (HUC 12110202) within the Western Gulf Coastal Plain Level III Ecoregion (Omernik 1995). The Natioanl Wetland Inventory (2019) classifies the the PRMA as estuarine, subtidal, unconsolidated bottom (E1UBL), estuarine, subtidal, aquatic bed, rooted vascular, subtidal (E1AB3L) and estuarine, intertidal, unconsolidated shoreline, regularlly flooded (E2USN). National Wetland Inventory map of the PRMA is included as **Figure 4** in **Appendix A**.

1.2 Property Ownership

The submerged lands on which the proposed seagrass PRMA is under the ownership of the State of Texas and administered by the Texas General Land Office (GLO). A lease will be executed with the GLO for the mitigation occurring on submerged lands. The marsh wetland areas (living

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[1] Restoration is defined in 33 CFR § 332.2 as *the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource. For the purpose of tracking net gains in aquatic resource area, restoration is divided into two categories: re-establishment and rehabilitation.*

[2] Re-establishment is defined in 33 CFR § 332.2 as *the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former aquatic resource. Re-establishment results in rebuilding a former aquatic resource and results in a gain in aquatic resource area and functions*.

[3] Rehabilitated is defined in 33 CFR § 332.2 as *the manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function but does not result in a gain in aquatic resource area.*

shoreline) are either located on submerged lands or neighboring property owners. Initial discussions have begun with The Nature Conservancey, which owns the adjacent tract.

1.3 Responsible Party Qualifications

Per 33 CFR § 332.8(d)(2)(vi.), this section describes DLS's qualifications to successfully complete the proposed PRMA. Established in 2009, DLS is a land management and restoration company whose technical staff includes Certified Ecological Restoration Practitioners, Certified Foresters, Certified Wildlife Biologists, and Professional Wetland Scientists. In addition, DLS has construction specialists on staff experienced in wetland construction activities such as heavy equipment operation, vegetation establishment, herbicide application, and contractor management. The complete biography of DLS and personnel biographies are available at www.deltaland-services.com.

DLS currently operates 17 approved wetland mitigation banks (Banks) and five (5) approved amendments within four USACE Districts totaling 8,514.8 acres which include 43,044.9 linear feet of stream restoration. These Districts include CEMVK, CEMVN, CESWF, and CESWG. In addition to the Banks referenced above, DLS serves as the Responsible Party for the establishment and maintenance of 3,516.7 acres of wetlands and 8,251.0 linear feet of stream on twenty-four (32) other approved permittee responsible mitigation areas within the CEMVN, CEMVK and CESWG Districts.

1.4 Mitigation Perimeter Coordinates

Beginning at a point in the northwest corner, the PRMA perimeter is defined by the listed decimal degrees coordinates in Table 1 (NAD1983).

Table 1: Permittee Responsible Mitigation Area Perimeter Coordinates, Croaker Hole, Corpus Christ Bay/Mustang Island, Texas

Designation	Latitude	Longitude	UTM Northing*	UTM Easting*
Northeastern Corner	27.743956	-97.159258	681430.20	3070196.61
Northwestern Corner	27.744292	-97.160511	681306.13	3070232.00
Southwestern Corner	27.726492	-97.168872	680511.21	3068247.40
Southeastern Corner	27.726011	-97.167992	680598.77	3068195.40
Eastern Point	27.732544	-97.159381	681436.98	3068931.94
Eastern Point	27.735136	-97.158.687	681500.13	3069220.15

* UTM Zone 14R

1.5 Recorded Liens, Encumbrances, Easements, Servitudes or Restrictions

There are no known or apparent encumbrances on the PRMA. Additional title work will be conducted as well as, permitting and authorization through GLO and adjacent landowners, if private property is used. The PRMA is submerged lands and a GLO submerged land lease will be executed for the mitigation that occurs on submerged lands.

2.0 Goal and Objectives

At the ratio of 3.0 mitigation acre to 1.0 impact acre, the goal is to provide approximately 23.52 acres of seagrass mitigation for 7.84 acres of unavoidable seagrass impacts. Construction of the Project will occur in a manner that the bottoms in the Corpus Christi Bay will be restored to allow the impacted sea grass to naturally re-establish. In addition, 5.00 acre of *Spartina alterniflora* shoreline marsh E2EM1 marsh will be re-established for unavoidable permanent estuarine marsh impacts. Furthermore, increased shoreline stabilization is an additional benefit of the seagrass and estuarine marsh restoration project. The objectives are to restore (re-establish) the following habitats on Croaker Hole shoreline within the South Corpus Christi Bay Subbasin:

- re-establish 7.84 acres of seagrass beds;
- re-establish 5.00 acre of *Spartina alterniflora* living shoreline marsh; and
- egineering and construction of breakwaters to increase the stability of the Corpus Christi Bay/Mustang Island shoreline and reduce erosion along the shoreline and the back island wetland complex.

3.0 Aquatic Resource Type and Potential Functions

The PRMA will offset impacts to aquatic resources associated with the permitted impacts described in Section 1.0. The following are functions associated with seagrass beds (Barbier et. al. 2011):

- **Biological productivity and diversity**: re-established seagass beds will increased habitat quality.
- **Coastal protection**: re-established seagass beds and breakwaters will attenuate and /or dissipate waves.
- **Erosion control**: re-established seagass beds and breakwaters provides sediment stabilization and soil retention in vegetation root structure.
- **Improve water quality**: re-established seagass beds provide nutrient and pollution uptake and retention.
- **Maintenance of fisheries-** re-established seagass beds provide suitable reproductive habitat and nursery grounds, as well as sheltered living space.
- **Carbon sequestration-** re-established seagass beds generate biogeochemical activity, biological productivity, and sedimentation.
- **Tourism, recreation, education, and research-** re-established seagass beds provide a unique and asthetic submerged vegetated landscape and suitable habitat for diverse flora and fauna.

The following are functions associated with a estuarine emergent marsh located in the geomorphic position of the PRMAs:

- **Physical -** Temporary Storage and Detention of Surface Water (TSDS): the PRMA will provide temporary water storage during rainfall and flooding events.

- **Biological -** Maintenance of Plant and Animal Communities (MPAC): the PRMA will provide saline coastal prairie wetlands and intertidal marsh habitat for native and migratory wildlife as described in Section 4.0 below.

- **Chemical -** Removal and Sequestration of Elements and Compounds (RSEC): the PRMA will assist with the sequestration of nutrients and other pollutants washed into the Nueces Delta during rainfall events and improve downstream water quality flowing into Nueces Bay and then into Corpus Christi Bay.

4.0 Watershed and Ecological Contributions

Corpus Christ Bay in which the Project impacts and PRMA are situated, are some of the most productive estuarine ecosystems. Seagrass beds and and tidal marsh habitats are socially and economically important estuarine habitats in Texas (HRI 2018). Scientific evidence is showing many of these marine ecosystems are threatened (Costanza et al. 1997, IPCC 2001).

Once the PRMA is restored, it will become a functional portion of the Corpus Christ Bay ecosystem. The proper placement of the breakwaters along the back side of Mustang Island will decrease the wave action and reduce currents protecting the island from erosion and create better conditions for the growth of seagrass and tidal marsh vegetation. The increase in seagrass and estuarine emergent marsh habitat in the area will increase the productivity of the area by providing enhanced diversity and primary and secondary production (Heck and Orth 1980, Orth et al. 1984), greater water quality services, increased fishery nursery area, and am important carbon sink (Duarte and Chiscano 1999).

5.0 Site Selection

There are no mitigation banks or in-lieu fee programs in this region along the Texas Coast. Thus, PRM was pursued to offset Project wetland/aquatic resource impacts.The location of the Croaker Hole PRM was determined based on agency coordination over the previous two years and an understanding of an overall need for declining habitats in the region, in combination with unavoidable Project impacts. Potential mitigation sites were also identified with the input and guidence from the Seagrass Working Group, local conservation groups, academic experts, and local government leaders. Through this colaboration eight potential mitigation sites were identified. The locations of these sites are shown on Figure 6 in Appendix A. These sites include:

1. Harbor Island on site
2. Port Aransas Nature Preserve

3. Packery Channel erosion sites
4. Oil Well sites in Laguna Madre
5. Pita Island
6. Shamrock Island
7. Mustang Island State Park
8. Mustang Island-Croaker Hole

Bathemetry surveys and side scan sonar were used to assess the Croaker Hole site as well as other sites being evaluated as potential seagrass mitigation sites in the Courpus Christi Bay and Upper Laguna Madre watersheds. The Croaker Hole site has the appropriate conditions present for the reestablishment and growth of seagrasses. Appropriate conditions include the historical and current presence of seagrass beds (Fonseca et al. 1998, Short and Burdick 2005) in the area, suitable substrate (Barth 2011), and appropriate water depth, which in Texas is generally less than 2 m (Wilson and Dunton 2012). Current seagrass presence along the shoreline of the Croaker Hole area is spotty and patchy, providing room for the establishment of additional seagrasses along the shoreline and in unvegetated, subtidal areas within the back island wetland complex. Moreover, the back island wetland complex provides ample room to reestablish 5.00 acres *Spartina alterniflora* estuarine emergent marsh (living shoreline).

The metrics used to deduce which location would become the PRM site were; proximity to the project impact site, the type and area of resources that could be restored or created, probability of success, the feasibility of construction, schedule, land owner coorindation required, and potential impacts at the PRM site. The Mustang Island Croaker Hole location was determined to best fit the Project's mitigation of unavoidable impacts and provide the resouces needed in the area based on agency communication.

6.0 Site Protection

The submerged waters of Texas within the PRMA are administer by the GLO and wetland area in the back-island wetland complex is potentially privately owned. The submerged land lease will have a 20-year term and will provide the long-term protection on state lands. The marsh mitigation may occur on private lands but will be subject to the ebb and flow of the tide, which would be protected through Section 10 of the Rivers and Harbor Act.

7.0 Baseline Information

The PRMA is mostly submerged waters of Corpus Christ Bay and the western bay side shoreline of Mustang Island and the adjacent back-island wetland complex. Seagrasses (*Halodule wrightii* and *Thalassia testudinum*) are present in the area. As well, the shoreline and adjacent emergent marsh are vegetated with *Spartina alterniflora* and other obligate hydrophytes.

7.1 Land Use

7.1.1 Historical Land Use

Early land use was largely a natural tidal wetland complex and adjcent uplands as observed on the 1956 aerial photograph. Little development had occurred in the area at that time, other than some oil and gas activity within, north and south of the PRMA. The aerial photography show two barge slips for oil and gas wells dredged in to the upland shoreline along the inlet to Croaker Hole. The shore line was much less eroded and more complete except for two tidal inlets into the back island wetland complex. The 1979 aerial photography shows the area to be in the same undeveloped condition; however the northern portion of the bay shoreline had eroded to the point of being connected to the back island tidal wetland complex. Additional oil and as activity is evident during this time period. The 1985 aerial photography show the area in a similar condition, except for the increased erosion along the northern bay shoreline and in the back island tidal wetland complex. The house and pier to the south of the PRMA were built prior to 1985. This area appeard to be an oil and gas development prior to 1985. The 1995 through 2014 show the PRMA in much the same condition with additional connecttions from the bay into the wetland complex and various slight changes in shoreline condition. The February and August 2017 aerial photography show the changes along the bay shorline before and after Hurricane Harvey. The shoreline island segments appear to be smaller in size and the passes between the bay and the back island wetland complex are larger and more distinct.

7.1.2 Current Land Use

The PRMA is a natural undeveloped bay shoreline and back island tidal wetland complex. The upland island segments of the area are owned and preserved by The Nature Conservancy. The submerged areas of the PRMA are owned by the State of Texas and administered by the GLO.

7.2 Soils

The PRMA is mapped as having hydric soils. Adjacent soils are mapped and hydric and non-hydric soils. Soils within the PRMA are identified as water (Corpus Christi Bay) and tidal flats, occasionally flooded (NRCS 2019[a]; Appendix A, Figure 5). Adjacent area soil types include Coastal dunes, Mustang fine sands, 0 to 1 % slopes, occasionally flooded and frequently ponded, and Twin Palms, occasionally flooded and Yarborough frequently flooded, 0 to 3 % slopes. The dominant soil types in the PRMA are aquatic and tidal flats both of which are hydric and capable of supporting submerged aquatic and emergent wetland vegetation.

7.3 Hydrology

The primary hydrological influences on the PRMA are tidal flow and precipitation. Current rainfall data from the WETS Table website indicates an average annual rainfall of 34.4 inches (NRCS 2019[c]). Precipitation runoff in the area is negilible due to the high capacity for the sandy soils to transmitte water to the very shallow groundwater table. In addition to the tidal influence, the wetland complex recieves precipitation and brackish water from the groundwater table.

7.4 Vegetation

7.4.1 Historical Plant Community

Historic natural vegetation communities present in and adjacent to the PRMA were likely similar to those vegetation communities present today. Some variation in the plant assemblages occurred due to changes environmental and climatic conditions. One of these variations is the presence and density of black mangrove (*Avicennia germinans*). Periodic extreme winter cold fronts can reduce or eliminate the presence of black mangrove. Likewise, mild warm winters would lead to an increase in the presence and density of black mangrove. Drought conditions would lead to more brackish and salt marsh vegetative species and rainier conditions would lead to more intermediate and brackish marsh vegetation.

7.4.2 Existing Plant Community

Current vegetation communities include shoalgrass (*Halodule wrightii*) dominated seagrass meadows, low salt marsh, tidal flats, coastal grassland prairies, and coastal swales and dunes. Seagrass meadows occur in submerged subtidal areas. These meadows have lesser amounts of turtlegrass (*Thalassia testudinum*), and manatee grass (*Cymodocea filiformis*), as well as an assemblage of macroalgae. Terrestrial habitats are summarized from NatureServe (2019) ecological descriptions and field notes. Low salt marsh is dominated by smooth cordgrass (*Spartina alterniflora*) and occurs in the intertidal zone. This vegetation community type is a near monoculture with few other species present, but a mixture of sedges, rushes and herbaceous species can be scattered among the smooth cordgrass. Small patches and individual shrubs of black mangrove occurs in this zone, as well. Tidal flats are sparsely vegetated with saltwort (*Batis maritima*), glasswort (*Salicornia* spp.), salt grass (*Distichlis spicata*), shore grass (*Monanthochloe littoralis*), among others. Algal mats of blue-green and sometimes green algae are occasionally present and at times can contribute greatly to the biomass of the area. Coastal grass prairies are present in the higher elevations. Dominant vegetation in these grasslands include brown seed paspalum (*Paspalum plicatulum*), gulf dune paspalum (*Paspalum monostachyum*), shore little bluestem (*Schizachyrium littorale*), bitter panicgrass (*Panicum amarum*), switchgrass (*Panicum virgatum*) among others. A variety of sedges, rushes and herbaceous species are scattered among the dominant grasses. The highest elevation along and near the shoreline have honey mesquite (*Prosopis glandulosa*) and sweet acacia (*Vachellia farnesiana*).

8.0 Determination of Compensatory Mitigation Requirement

Mitigation for temporary seagrass impacts was determined using a ratio of 3.0 mitigation acres to 1.0 impact acre, which equates to 23.52 acres. In addition, 5.00 acres of living shoreline Spartina alterniflora marsh re-established.

9.0 Mitigation Work Plan

The timeline for PRMA construction will be determined by the approval of permit by SWG. Data collection and investigation surveys, engineering, and modeling of the breakwaters have been accomplished and are underway. Construction of the breakwaters is estimated to take approximately 6 months.

Shoreline stabilization, re-establishment and expansion of seagrass meadows, and the expansion of salt marsh are compatible with current land uses of the GLO and TNC (landowner). The USACE has also begun to place more emphasis on ecological engineering projects, using the term “building with nature.” Barth’s (2011) research has shown that coastal protection structures that not only reduce shoreline erosion but have secondary ecological benefits, in this case increased seagrass meadows and intertidal marsh. Seagrass meadows and the coastal salt marsh reference areas, specifically Shamrock Island, were selected based on existing seagrass and salt marsh vegetation communities present in the PRMA and adjacent areas (Appendix A, Figures 3).

9.1 Engineering and Construction of Breakwaters

A series of segmented breakwaters will be placed off the shoreline of the Croaker Hole area of Mustang Island. A representation of the best option alternative breakwater alignment is shown in Figure 2 in Appendix A. The breakwaters will attenuate wave energy and slow tidal currents moving in and out of the back island tidal wetland complex and along the Mustang Island/Corpus Christi Bay shoreline.

Mott MacDonald (2020) conducted the engineering analysis and modeling for alternative development and analysis and design of the breakwaters and the construction of the breakwaters. A summary of this information is provided below. Details of this analysis is provided in Mott MacDonald’s report *Mustang Island Project-Coastal Engineering Analysis* provided in **Appendix B.**

A total of eight alterative breakwater alignment scenarios were evaluated during the preliminary alternatives analysis. These alternatives are concentrated seaward of Croaker Hole complex and a smaller area to the south at a small cove. Criteria (variables) used for the alternative performance using coastal processes numerical modeling included: waves, currents, sand transport, longshore transport, and mud transport. In addition, the north end of Shamrock Island was used as a reference site. The performance of each alternative was compared to conditions at the reference site because the presence of productive seagrass meadows protected by breakwaters.

The alternatives were modeled for two month long simulations, which were based on wind and wave energy levels. The modeled months were January (high energy month) and July (low energy month. The model results were compared to determine which alternatives produced wave, current, and sediment transport, and mud transport conditions closest to those behind the Shamrock Island breakwaters in areas of seagrass meadows. These results are provided in Appendix C of the Mott MacDonald report, which is included as Appendix B.

The results of the two month modeling analysis, along with a list of pros and cons of each scenarios (also in Appendix C of the MacDonald Report) was used to determine the best two alternatives. Alternatives 2B and 5 were chosen for yearlong simulations, analysis and comparison to conditions and results at Shamrock Island. Hydrodynamic and Wind-Wave results show that wave heights are significantly reduced by the breakwaters at both sites. Current speeds behind the Alternative 2B was higher than Alternative 5 however, the current speeds at Alternative 2B are similar to those at Shamrock Island. Morphology Modeling results show that longshore transport rates are primarily north to south and are reduced under both alternatives (Mott Mac Donald 2020; Appendix B).

Geotechnical investigations have been conducted to determine soil classifications, bearing capacities, settlement analysis, slope stability analysis, and gradation tests. The geotechnical investigations required 25-foot borings at 1,000 foot intervals along the proposed breakwater alignment. This data is used in the design and placement of the breakwaters.

The break waters will be construct as segmented units from graded riprap. The break waters are expected to be approximately 6 feet tall and 400 feet long but may differ due to engineering and modeling results. The breakwaters will be constructed on a one-foot thick bedding layer and geotextile composite on existing substrate. Based on the approximate project length, breakwater dimensions, and gap spacing, a total of 10 breakwaters segments are expected for the design.

9.2 Restoration of Plant Community

After the breakwater construction, seagrasses are expected to naturally re-establish and expand on sheltered bare substrates. Shoalgrass (*Halodule wrightii*) is a pioneering species and will expeditiously colonize bare substrate. Other seagrasses are slower growing and take more time to get established and will expand into the area (Fonseca, et al. 1998).

The recolonization and expansion of seagrasses into sheltered areas shoreward of the breakwaters and potentially within the subtidal areas in the back-island wetland complex will be assessed at two years post construction. Given the area shoreward of the breakwaters and depth of water, there is an estimated 78 acres of potential expansion of seagrass meadow along the shoreline. It is expected that 23.52 or more acres of seagrasses will expand in the entirety of the PRMA. If sufficient seagrass re-establishment and expansion has not occurred after the second growing season, then the bear substrate areas along the shoreline and potentially within the back-island wetland complex will be planted with *Halodule wrightii* and *Thalassia testudinum.* Plugs will be collected from several local seagrass beds in the area of the PRMA and will be coordinated with the GLO. If planting is necessary, the PRMA will be planted in on approximately 1-meter centers equaling about 4,000 plugs or sprigs per acre. A Texas Parks and Wildlife Department (TPWD) transplanting permit will be obtained.

Restoration of the living shoreline marsh community will consist of bare intertidal shorelines and flats totaling 5.0 acres within the back-island wetland complex with *Spartina alterniflora* sprigs on 3-foot by 3-foot centers. *Spartina alterniflora* plant materials (sprigs / plugs) will be collected from the local area wetlands. The collection of plant materials will be coordinated with local landowners and a TPWD transplanting permit will be obtained.

10.0 Maintenance Plan

10.1 General

Through a contractual agreement with the Permittee, DLS is committed to restoring the intertidal emergent marsh wetlands and submerged aquatic vegetation in accordance with the provisions in this PRMP until the long-term success criteria are met. The SWG also agrees to review and provide comments on all plans, annual monitoring reports, contingency plans, and necessary permits for the PRMA.

10.2 Seagrass Meadow Management

Through the construction and establishment phases, the Permittee will monitor and follow the guidelines of this PRMP. Signage warning boaters of the shallow water depths and the presence of seagrasses will be displayed on the breakwaters and other access points into the area. This will help the development of the seagrass and minimize propeller scars. These signs will be periodically checked and replaced as needed. Exotic vegetation will not be a management concern in the seagrass meadows. None of the species listed in the invasive/exotic vegetation species listed by the Texas Invasives Database (TexasInvasives.org[4]) will persists in a subtidal estuarine environment.

10.3 Estuarine Emergent Marsh Shoreline Management

Through the construction and establishment phases, the Permittee will monitor and follow the guidelines of this PRMP. Upon the attainment of 70% hydrophytic herbaceous ground cover, long-term success will have been met and no long-term management is anticipated due to its location within an intertidal environment.

Due to the intertidal saline conditions of the bay shoreline and the back-island wetland complex, woody encroachment is not a management concern. In the event black mangrove (*Avicennia germinans*) colonizes the marsh PRM area, it will be treated as a native species and will not controlled / removed as an invasive species.

11.0 Performance Standards

The initial, interim, and long-term performance standards (success criteria) for the seagrass meadows and marsh PRMAs are provided below. The performance standards for wetland re-establishment will follow the guidelines for delineating jurisdictional wetlands standards per the 1987 Wetlands Manual (USACE 1987) and Atlantic and Gulf Coastal Plain Regional Supplement (USACE 2010). The performance standards below are preliminary and could be modified based on the engineering modeling and design.

[4] http://www.texasinvasives.org/invasives_database/

11.1 Initial Success Criteria (Year 1)

11.1.1 Hydrology

The seagrass meadows and estuarine intertidal marsh are in a natural setting along the shoreline of Corpus Christi Bay and the back-island wetland complex. Both areas are affected by daily tides. The construction of the breakwaters along the shoreline will be engineered to provide wave and current attenuation in the area to create sheltered areas shoreward of the breakwaters and will not affect the tidal influence in the area. No wetland hydrology success criteria are anticipated since the mitigation will occur within an intertidal zone.

11.1.2 Vegetation

Seagrass meadow herbaceous re-establishment and expansion will be monitored after the second growing season post construction.

Herbaceous ground cover will be monitored to determine the percent cover within estuarine emergent marsh PRMA. Percent cover will be averaged over all monitoring plots. The success criteria for Year 1 is a minimum average of 20% hydrophytic plant cover averaged over the emergent marsh restoration areas. Plant species included in the total cover will not include invasive/exotic vegetation species listed by the Texas Invasives Database. Observations of vegetation will be recorded on routine wetland determination data forms and submitted to the SWG in the monitoring reports. Seagrass performance standards will be evaluated after Year 3.

11.1.3 Soils

The both the seagrass meadows and estuarine emergent marsh shoreline PRMAs are located within Corpus Christ Bay and an estuarine wetland complex in which the soils are influenced by daily tidal inundation and the soils are hydric.

11.2 Interim Success Criteria (Year 3)

11.2.2 Vegetation

Seagrass meadows shoreward of the breakwaters and within the back-island wetland complex will be monitored to determine the amount of expansion. The expansion will be determined by comparison of aerial photography and physical verification in the field using the Braun-Blanquet 1972) survey method. If the seagrass meadows in the PRMA have not increased by 23.52 acres, then the bare substrate areas along the shoreline and potentially within the back-island wetland complex will be planted with *Halodule wrightii* and *Thalassia testudinum.* Plugs will be collected from several local seagrass beds in the area of the PRMA and will be coordinated with the GLO and TPWD.

By the end of Year 3, two years following successful attainment of the Year 1 criterion, there will be a minimum average of 40% hydrophytic plant cover averaged over all monitoring plots within estuarine emergent shoreline marsh PRMA. Plant species included in the total cover will not include invasive/exotic vegetation species listed by the Texas Invasives Database. Observations of vegetation will be recorded on routine wetland determination data forms and submitted to the SWG in the monitoring reports.

11.2.3 Soils

The both the seagrass meadows and estuarine emergent marsh shoreline PRMAs are located within Corpus Christ Bay and an estuarine wetland complex in which the soils are influenced by daily tidal inundation and the soils are hydric.

11.3 Long-term Success Criteria (Year 5)

The Year 5 monitoring of re-established and expanded seagrass meadows will be assessed based on the Braun-Blanquet (1972) survey method. It is expected that the new seagrass meadows in the PRMA will have similar density scores and cover descriptions as previously existing seagrass meadows in the general area. For long-term success criteria to be met and compensatory mitigation efforts to be considered acceptable and complete by the SWG, areal cover of seagrass meadows within the PRMA is at least 23.52 acres and have comparable density scores and cover descriptions as reference seagrass meadows.

If the success criteria for the seagrass mitigation is not met after the Year 5 monitoring the DLS will consult with the Permittee and the USACE to adapt the mitigation plan.

By the end of Year 5, or four years following successful attainment of the Year 1 criterion, herbaceous vegetation will be monitored to determine percent cover within the estuarine emergent marsh shoreline PRMA. Vegetative monitoring data must indicate that cover averages at least 70% over all plots and is dominated by hydrophytic plant species.

12.0 Monitoring and Reporting Protocols

12.1 Monitoring

The Permittee agrees to perform all monitoring work to demonstrate compliance following the performance standards established in **Section 11.0**. Following the performance standards, the Permittee will monitor the PRMA for the Year 1 (initial report), Year 3 (interim report), Year 5 (long-term report), or until achievement of the long-term performance standards. After breakwater construction, the monitoring stations will be sampled to establish baseline data for the as-built report and then for the initial, interim, and long-term reports. However, if monitoring for any given year determines that the site is not progressing as expected, monitoring will continue annually until the PRMA successfully meets or exceeds the established performance standards.

The Permittee will establish one (1) 1/100th-acre (radius = 11.7 feet) or an equivalent area linear plot, depending on the orientation and size of the planted area. Monitoring plot center will be identified and marked with GPS coordinates using Trimble® differential global positioning systems (DGPS). A map depicting the location of each plot and its coordinates will be provided to the SWG.

12.2 Reporting Protocols

12.2.1 As-built Report

An as-built report will be submitted to the SWG within 120 days following completion of all the required PRMA construction work. The as-built report will describe in detail the work performed and post construction conditions. No major deviation from the mitigation work plan described in Section 9.0 may occur without prior approval from the SWG. The as-built report will include a discussion of coordination with the SWG and a description of and reasons for any approved deviation.

12.2.2 Monitoring Reports

The Permittee will submit a report documenting monitoring efforts to the SWG by December 31 of each year in which monitoring occurs. The monitoring reports will include data sufficient for comparison to the performance standards found in Section 11.0. The Year 1, Year 3, and Year 5 monitoring reports will include pertinent information for Sections 9.0 (Mitigation Work Plan), 10.0 (Maintenance Plan), and 11.0 (Performance Standards). The Permittee will also include a discussion of all activities which took place at the PRMA. At a minimum, monitoring reports will include the following:

1) digital images taken from ground level in the monitoring stations to document overall conditions;

2) a description of the general condition of herbaceous ground cover within the living shoreline;

3) a description of the general condition of sea grass ground cover with pictures and mapping showing previously delineated sea grass and newly colonized areas;

4) a description of vegetative/sea grass communities developing in the monitoring stations; and

5) a description of wildlife usage in the monitoring stations.

13.0 Long-term Management Plan

To ensure the long-term sustainability of the PRMA, the Permittee will execute a submerged land lease with GLO.

14.0 Adaptive Management Plan

An adaptive management plan, contingency, and remedial responsibilities will be implemented in the event monitoring reveals that performance criteria have not been met. In the event of a deficiency, the Permittee shall provide a notice to the SWG within 60 days of discovery of the deficiency. The notice will include an explanation for the deficiency and will outline specific practices and measures that will guide decisions for revising the mitigation plan if needed. If the SWG determines that the PRMA is not in compliance with the terms and intent of the final mitigation plan, the SWG will provide written notice to the Permittee that includes a detailed description of the non-compliance determination. The Permittee shall submit a written adaptive management plan to the SWG for review and approval within forty-five (45) days of receiving written notice of non-compliance. The adaptive management plan shall identify the cause of the non-compliance, the necessary remedial measures, and a timeline for implementing said measures to bring the PRMA into compliance. To the extent practicable, the SWG shall approve or disapprove the adaptive management plan within forty-five (45) days of receipt, provided sufficient information and acceptable measures are contained within the plan.

15.0 Construction and Establishment Financial Assurances

The Permittee will establish short-term financial assurances for the final mitigation plan. Those assurances will provide monies to ensure monitoring and minimal adaptive management measures, such as replanting.

16.0 References

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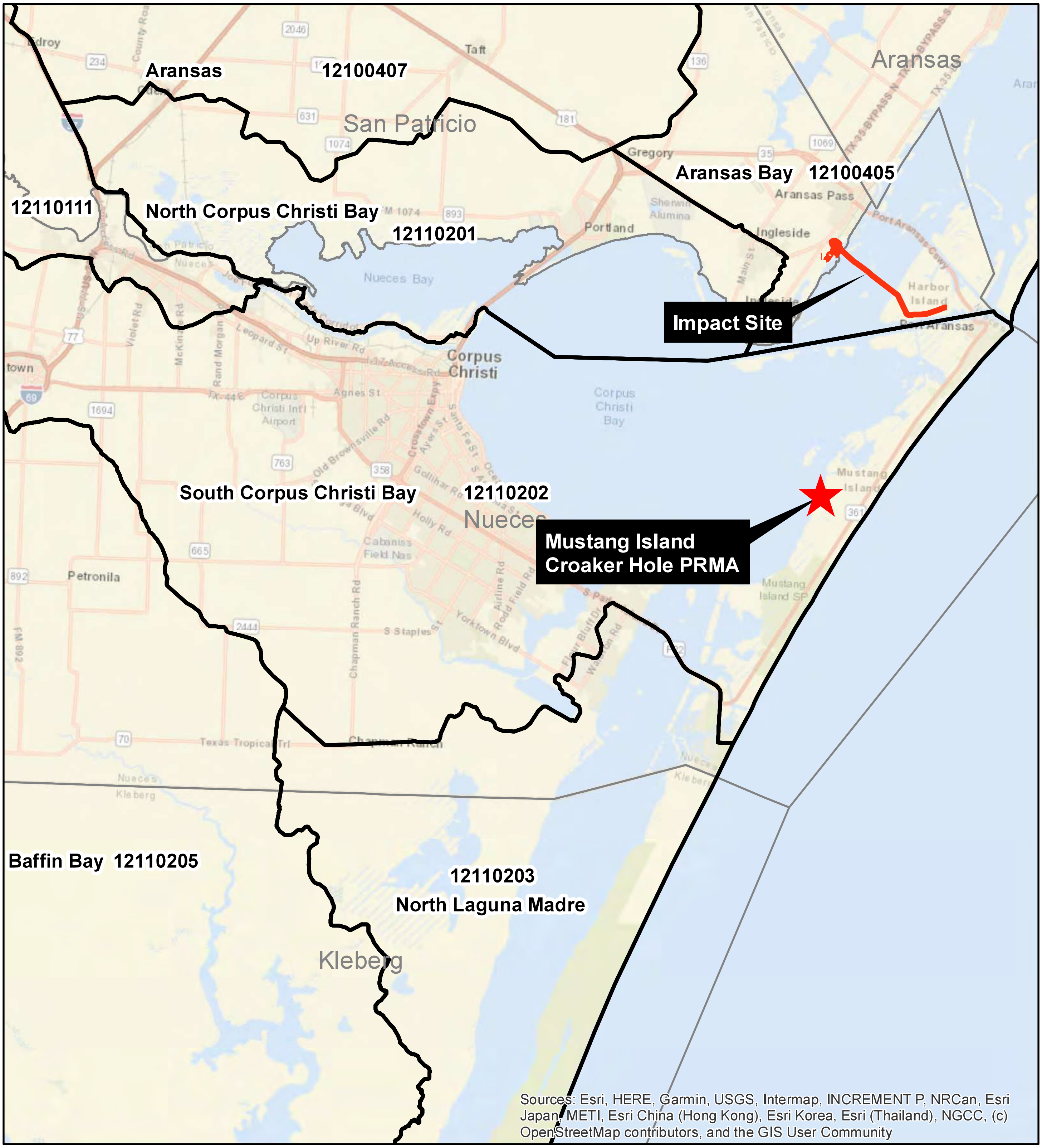
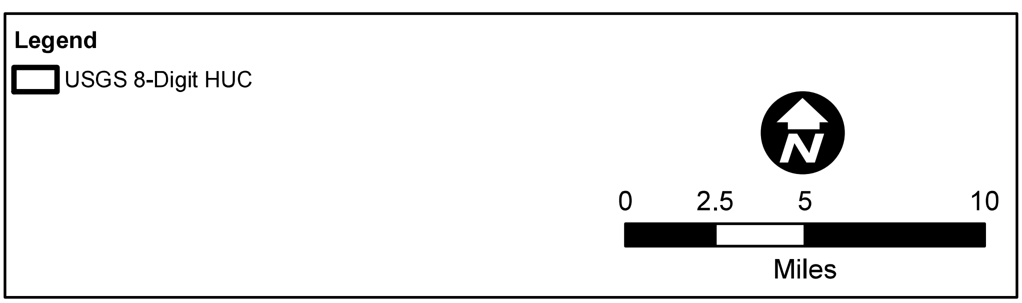
APPENDIX A. FIGURES





Axis Midstream Holdings, LLC
Midway to Harbor Island Pipelines & Terminal
SWG-2018-00789

VICINITY MAP

Nueces County, TX

Created : TSC/ARCVIEW	
Approved: AP	
Date : 4/22/2020	
Map No. : F1_Vicinity.mxd	

FIGURE 1

Legend

- Alternative 2B (3,827 LF)
- Existing Seagrass
- Area of Potential Sea Grass Re-establishment (77.7 ac)
- Spartina alterniflora Estuarine Marsh Mitigation (5.4 ac)

Note: Acreage based on the area of potential seagrass expansion in the PRMA, not the amount of seagrass mitigation (23.52 acres) required.

Axis Midstream Holdings, LLC
Midway to Harbor Island Pipelines & Terminal
SWG-2018-00789

WETLAND RESTORATION

Nueces County, TX

Created : TSC/ARCVIEW
Approved: AP
Date : 4/22/2020
Map No. : F2_WetlandRestoratio

FIGURE 2

Legend

- Alternative 2B (3,827 LF)
- Seagrass Mitigation (77.7 ac)
- Existing Seagrass
- Spartina alterniflora Estuarine Marsh Mitigation (5.4 ac)

0 1,000 2,000 4,000

Feet

Axis Midstream Holdings, LLC
Midway to Harbor Island Pipelines & Terminal
SWG-2018-00789

USGS 7.5 MINUTE QUADRANGLE MAP

Nueces County, TX

Created : TSC/ARCVIEW
Approved: AP
Date : 4/22/2020
Map No. : F3_Quad.mxd

DELTA LAND SERVICES

FIGURE 3

Legend

- Alternative 2B (3,827 LF)
- Seagrass Mitigation (77.7 ac)
- National Wetland Inventory
- Spartina alterniflora Estuarine Marsh Mitigation (5.4 ac)

0 400 800 1,600

Feet

Axis Midstream Holdings, LLC
Midway to Harbor Island Pipelines & Terminal
SWG-2018-00789

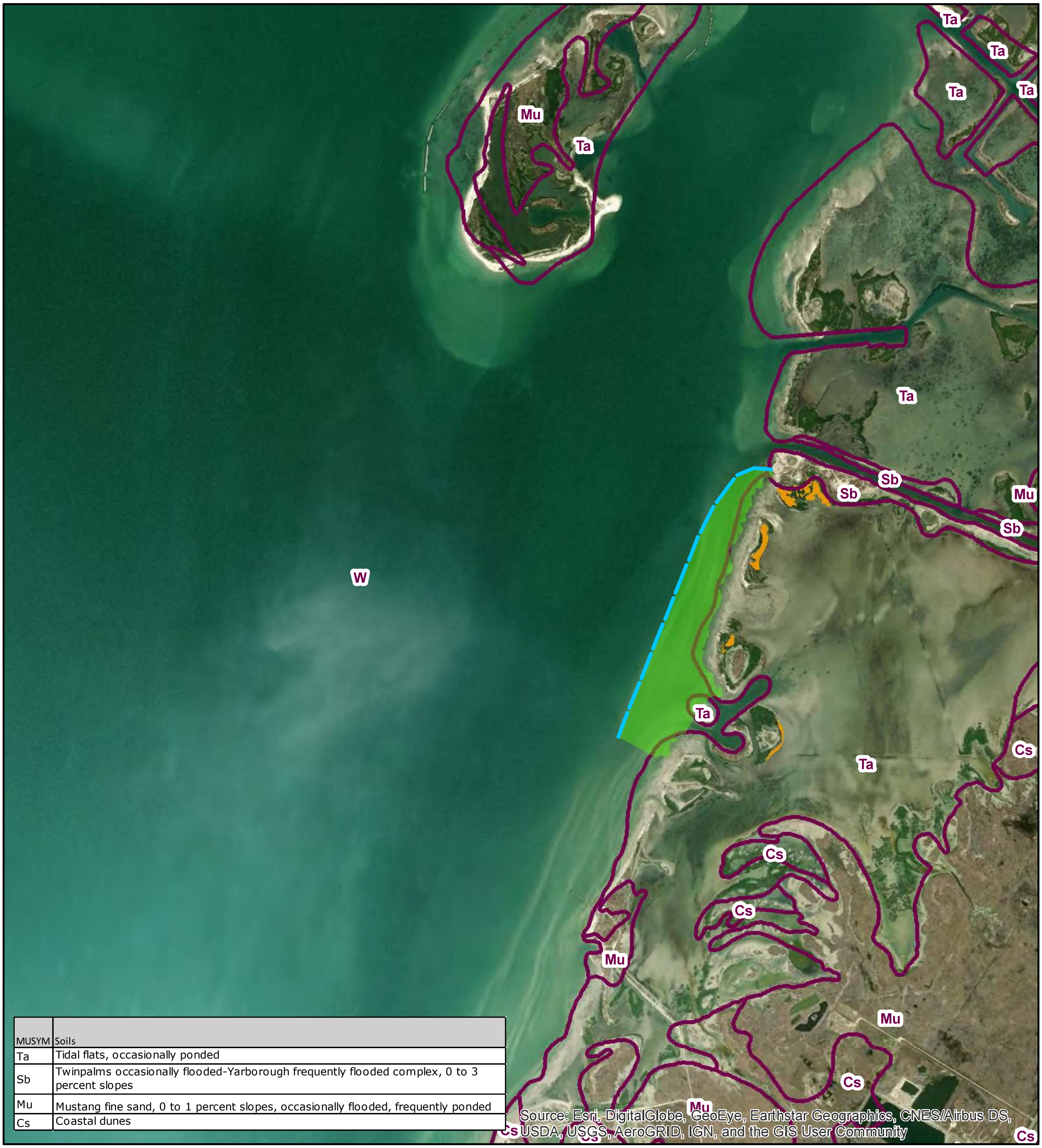
NATIONAL WETLAND INVENTORY

Nueces County, TX

Created : TSC/ARCVIEW
Approved: AP
Date : 4/22/2020
Map No. : F4_NWI.mxd

DELTA LAND SERVICES

FIGURE 4



MUSYM	Soils
Ta	Tidal flats, occasionally ponded
Sb	Twinpalms occasionally flooded-Yarborough frequently flooded complex, 0 to 3 percent slopes
Mu	Mustang fine sand, 0 to 1 percent slopes, occasionally flooded, frequently ponded
Cs	Coastal dunes

Legend

- Alternative 2B (3,827 LF)
- Seagrass Mitigation (77.7 ac)
- SSURGO Soils
- Spartina alterniflora Estuarine Marsh Mitigation (5.4 ac)

0 1,000 2,000 4,000
Feet

Axis Midstream Holdings, LLC
Midway to Harbor Island Pipelines & Terminal
SWG-2018-00789

SSURGO SOILS

Nueces County, TX

Created : TSC/ARCVIEW
Approved: AP
Date : 4/22/2020
Map No. : F5_Soils.mxd

DELTA LAND SERVICES

FIGURE 5

Legend

Mitigation Sites Analyzed for Axis Midstream Project

0 1.5 3 6

Miles

Axis Midstream Holdings, LLC
Midway to Harbor Island Pipelines & Terminal
SWG-2018-00789

ALTERNATE SITES

Nueces County, TX

Created : TSC/ARCVIEW	
Approved: AP	
Date : 4/22/2020	
Map No. : F1_Vicinity.mxd	

FIGURE 6

APPENDIX B.
COASTAL ENGINEERING ANALYSIS AND MODELING

MOTT MACDONALD

Mustang Island-Croaker Hole Mitigation Project

Coastal Engineering Analysis

April 22, 2020

Mott MacDonald
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United States of America

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Mustang Island-Croaker Hole Mitigation Project

Coastal Engineering Analysis

April 22, 2020

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
0	4/17/2020	P. McLaughlin	A. Agarwal H. Bermudez	S. Fenical	Coastal Engineering Analysis Report for Review
1	4/22/2020	P. McLaughlin	A. Agarwal	S. Fenical	Revised Coastal Engineering Analysis Report

Document reference:

Information class: Standard

Contents

1 Introduction and Methodology

1.1 Objectives

Lloyd Engineering (Lloyd) is developing a seagrass mitigation project along the bayside shoreline of Mustang Island in Corpus Christi Bay. Mott MacDonald performed a coastal engineering analysis to develop, evaluate and recommend a mitigation site location and alternative. Waves, currents and sediment transport were used as site performance criteria which were also evaluated landward of each breakwater alternative and were compared to nearby Shamrock Island, which has proven to be a productive seagrass habitat location. This comparison was made to evaluate the suitability of the alternatives for use as mitigation sites. This memo includes a concise summary of the analysis methodology and results; Appendix A describes the numerical modeling effort in detail.

1.2 Location

The mitigation site investigated lies along the southern shore of Corpus Christi Bay, near the Croaker Hole complex. Croaker hole is a shallow sandy hole that is popular for redfish fishing. The general location of the proposed mitigation site is shown in Figure 1-1. Shamrock Island, which was used as a performance comparison for all modeled alternatives, is also shown in Figure 1-1.

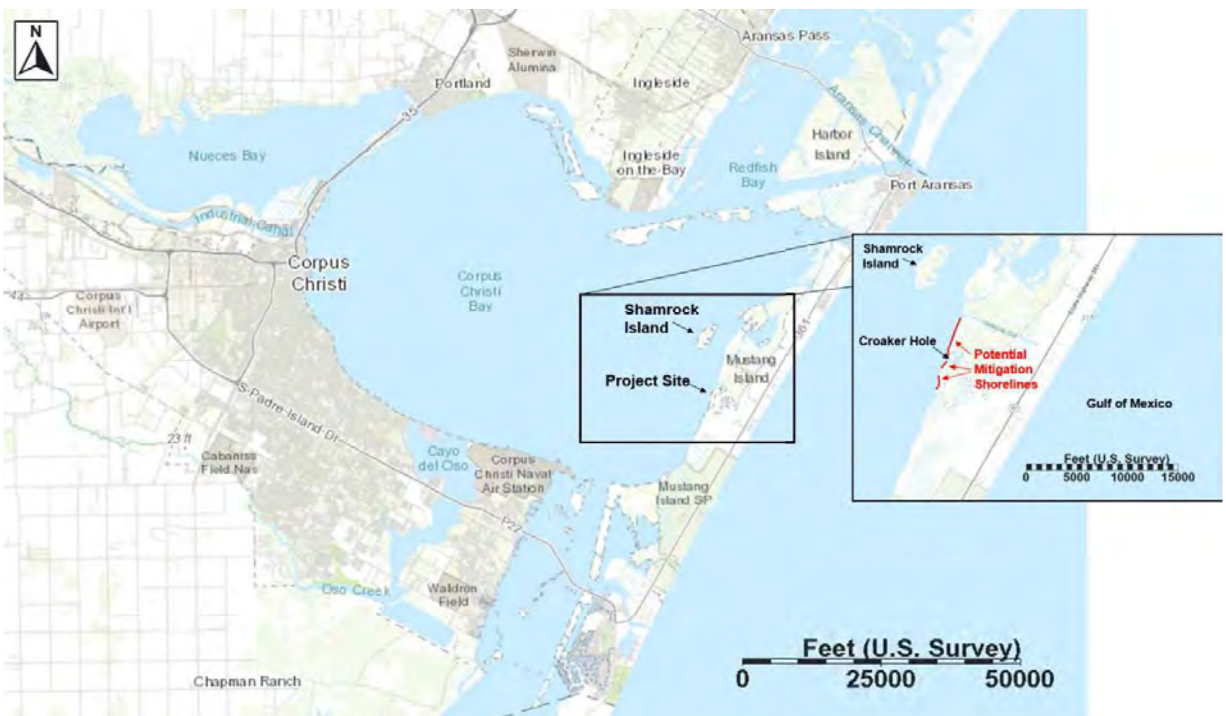

Figure 1-1. Project Location.

1.3 Methodology

Tidal and wind-driven currents, as well as wind-driven waves were simulated during previous project efforts using the MIKE modeling suite (DHI, 2019). The previous analysis evaluated potential impacts from sediment transport generated as part of pipeline installation activities across Redfish Bay (Mott MacDonald, 2019). The analysis and modeling conducted in Mott MacDonald, 2019 was used as the basis for this analysis. The hydrodynamic and wave model setup and validation performed during previous project efforts are described in Mott MacDonald, 2019. To better capture local conditions, a nested model was developed with higher resolution near the project site. The nested model included new bathymetry data provided by Lloyd (Lloyd, 2019). Appendix A (Section A.2.1) provides a full overview of the bathymetry sources used in the nested model. The nested model was driven by wave, water surface elevation, and current conditions extracted from results of the large-scale model (Mott MacDonald, 2019). Mott MacDonald (2019) performed a wind gauge analysis which determined that 2018 provided representative wind conditions, which drive current and wave generation in Corpus Christi Bay and the Laguna Madre. Therefore, local nested modeling simulations in this study to evaluate mitigation alternatives also used the 2018 modeling time frame. Figure 1-2 shows the large-scale and nested model bounds, while Figure 1-3 shows the nested model mesh and resolution.

The numerical modeling setup and results were used to evaluate alternative performance and are further discussed in Section 2.

Figure 1-2. Large scale mesh domain (light blue) (Mott MacDonald, 2019) compared to nested domain (red).

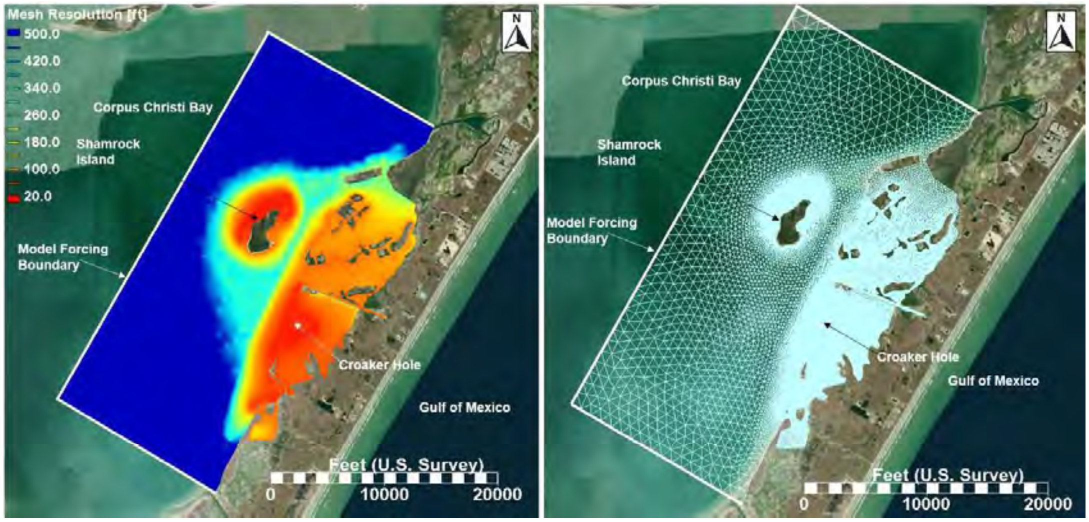

Figure 1-3. Nested model domain. Coloring scheme shows mesh resolution in feet (left) while (right) shows the actual computational mesh.

2 Alternatives Development and Evaluation

2.1 Alternatives Development Criteria

Mott MacDonald evaluated mitigation site alternative performance using coastal processes numerical modeling. The numerical model results were used as a tool to evaluate the alternative performance. A set of alternatives were developed to meet the following criteria:

1. Waves: Wind-waves were simulated using results from the larger-scale model and wind forcing conditions applied to nested domain. Wave conditions at mitigation sites should be strong enough to prevent deposition of fines, but moderate enough to preclude scour of seagrass substrate. Results were extracted in the protected area behind each alternative, and Probability of Non-Exceedance (PNE) curves developed.
2. Currents: Currents generated by tides, winds and waves were included in the simulation. Currents should be low enough to avoid scour of seagrass substrate, but high enough to allow adequate flushing and maintain appropriate water quality for seagrass growth. Results were extracted in the protected area behind each alternative, and PNE curves developed.
3. Sand Transport: Sand transport generated by currents and win-waves were also included in the simulation. The hydrodynamic and wave models were dynamically coupled to the sand transport model. Excessive sand deposition could cover seagrass beds and excessive erosion could scour seagrass substrate. Spatial plots showing sand erosion and deposition were developed for each alternative. While some deposition is expected immediately behind the breakwaters, this area should be minimized.
4. Longshore Transport: The alternatives were developed to create a low energy environment that minimizes the wave and current action behind the alternatives. However, this lower energy environment has the potential to decrease the amount of sediment reaching downdrift shorelines. Numerical model results were used to evaluate any changes to sand transport immediately downdrift of the preferred alternatives.
5. Mud Transport: Mud transport contributes to reduced light penetration in the water column as well as potential deposition on seagrass beds. While episodic high mud concentrations may be acceptable for seagrass growth, continued high concentrations or significant deposition would be detrimental to seagrass growth (TPWD, 1999 & Delta Land Services. 2019). Therefore, all proposed alternatives were assessed for suspended mud concentration and mud deposition using the results of this simulation.

For each alternative, project site model results were compared to Shamrock Island, which has productive seagrass habitats and was included in the nested model domain. This comparison was first performed for existing conditions, to gain an understanding of the coastal processes at each site. Then, the selected alternatives were built into the mesh and simulated for the same duration as existing conditions simulations i.e. full 2018 year. The results of the model simulations were compared to the Shamrock Island site to qualitatively assess each alternative's potential for seagrass growth. In addition to evaluating model results, the Project team considered other factors such as real estate implications, adjacent seagrass, feasibility, and cost. The following section provides an assessment of existing coastal site conditions using numerical model results.

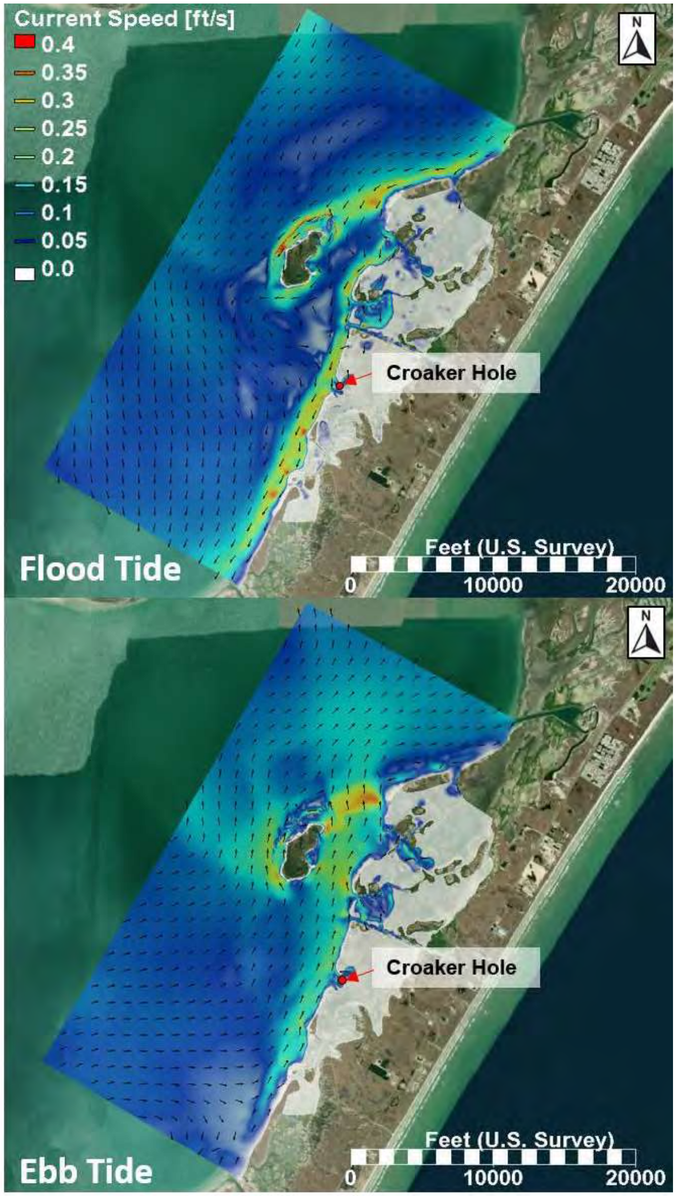

Figure 2-1. Typical flood (top) and ebb (bottom) current conditions. Croaker Hole shown by red dot.

Figure 2-1 shows the typical flood and ebb currents at the project site. A summary of key findings from the current modeling results are noted below.

Existing Conditions Current Modeling Summary:

- Flood currents are directed south, and ebb currents are directed north.
- Tide-generated currents are weaker than wave-generated currents.
- The mean current speed near Croaker Hole is roughly 0.2 ft/s, with a peak current speed of 1.8 ft/s during the 2018 simulation.

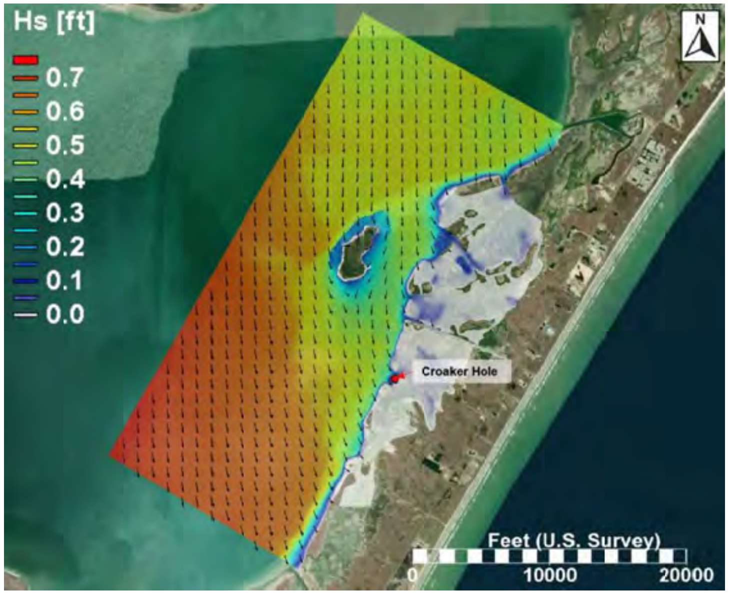

Figure 2-2. Example northerly wave conditions. Note reduced wave heights (shadow zone) behind Shamrock Island.

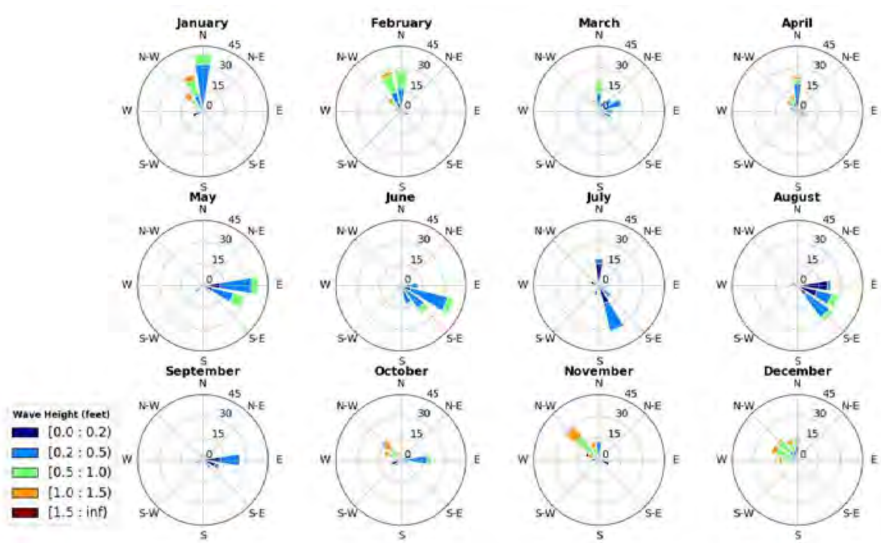

Figure 2-3. Monthly wave roses extracted near Croaker Hole.

Figure 2-2 shows an example wave condition for northerly events, for existing conditions (6.4 knots from 332 deg True North). Figure 2-3 shows monthly wave roses extracted from the model results at a location seaward of Croaker Hole.

Existing Conditions Wave Modeling Summary:

- Winter waves are largest due to stronger northerly winds and the long fetch across Corpus Christi Bay.
- Summer months are dominated by southerly to southeastern winds, which generate smaller waves at the project site.
- Shamrock Island creates a shadow zone, with smaller wave heights near Croaker Hole during northerly winds (see Figure 2-2). Wave heights continually increase towards the south.
- The mean and peak significant wave heights near croaker hole are 0.35 feet and 2.0 feet during the 2018 model simulation.

Figure 2-4. Bathymetry changes during 2018 model run.

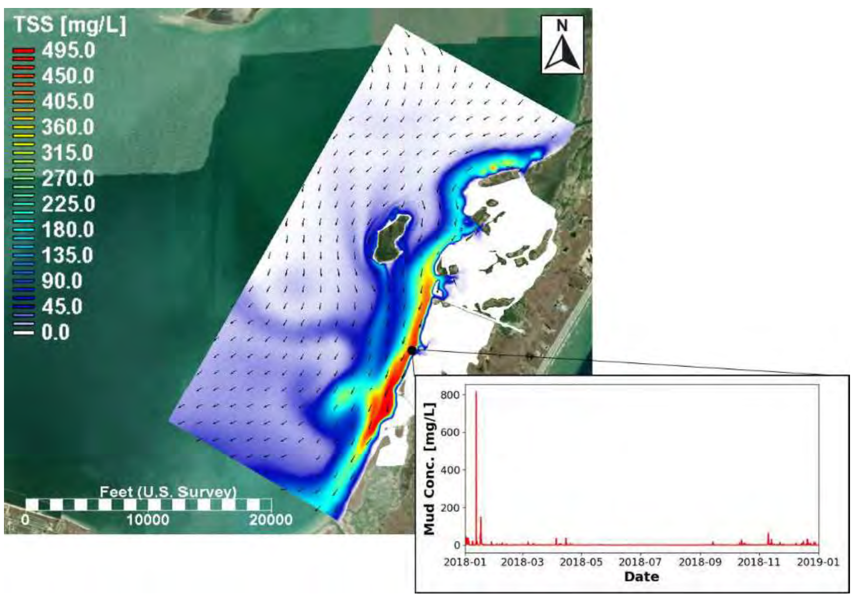

Figure 2-5. Mud concentration timeseries (inset) and spatial results for high concentration event on January 16 02:00.

Two different sediment transport simulations were performed: sand transport was simulated to evaluate mitigation site morphology, and mud transport was simulated to evaluate potential deposition at the site. Both simulations serve to evaluate changes behind the breakwater – minimal change is desired to avoid eroding or depositing on seagrass growth. However the sand morpohology model is also used to assess any change in longshore transport rate, which is ued to qualitatively assess impacts to downdrift shorelines. Both simulations included winds, waves and currents; however, the sand transport simulations were performed fully coupled for dynamic feedback between the bed elevations and hydrodynamics. Full dynamic coupling was not required in the mud transport model since only deposition at the site was of interest. Figure 2-4 shows bathymetry changes after the 2018 simulation.

Existing Conditions Sand Transport:

- Northerly cold fronts generate northerly waves causing the strongest sand transport at the site. Summer months experience low waves and sand transport due to southeast winds blowing from land. Appendix A (Section A.3.4) provides further discussion.
- Overall, the 2018 morphology simulation shows slight offshore erosion, and nearshore deposition. Results indicate shoreward sand transport caused by stronger winter wave conditions. Appendix A 0 (Section A.3.4) provides further discussion.

Figure 2-5 shows total suspended solids during the 2018 simulation at a time of higher wave activity, and a time history of concentration at the site (inset).

Existing Conditions Mud Transport:

- Results show that mud transport is episodic. Suspension and transport of fine-grained sediments primarily occurs during large wave events, with the highest concentrations occurring in winter months.
- Lower currents and smaller waves behind any proposed breakwaters may increase mud deposition relative to existing conditions. Mud deposition potential is discussed in Section 2.3.

2.2 Alternatives Overview

Eight initial alternatives were developed based on criteria in Section 2.1, analysis of nearby sites, coastal conditions, and discussions with the project team. Mott MacDonald performed screening simulations to evaluate alternatives performance for one typical winter month, and one typical summer month. The results of the month-long simulations were presented to the Project team as shown in Appendix C. Project team evaluation of the results resulted in selection of two final alternatives (shown in Figure 2-6) for year-long, detailed analysis: Alternative 2B and Alternative 5. These alternatives were selected through coordination with the Project team because:

- Numerical modeling showed the shore normal structures associated with Alt 2b and Alt 5 were critical in producing similar hydrodynamic and wave conditions to the Shamrock Island comparison site.
- Alt 2b and Alt 5 had minimal deposition of mud and sand. The majority of deposition was concentrated immediately behind the proposed structures.
- Alt 2b and Alt 5 are at different locations, allowing flexibility if permitting, real estate, or environmental issues arise with a particular site.

Appendix A0 (Section A.5)shows a full summary of all alternatives modeling, including the results for all 8 alternatives.

Figure 2-6. Final alternatives and extraction points used for comparative analysis. Ex point on Shamrock will be compared to Ex points on Alt 2b and Alt 5 to assure proposed alternatives will have similar hydrodynamic conditions conducive to sea grass growth, as is the case on Ex point Shamrock.

Alternative 2B includes nine (9) breakwaters, with lengths varying between 350 and 460 feet, spaced 100 feet apart. A 590-foot long groin is connected to land north of the Croaker Hole. The alternatives analysis modeling results showed the importance of having a shore perpendicular structure to reduce longshore currents and suspended sediment entering the project site from the north. Without the shore perpendicular structure, currents and suspended sediment concentrations were higher at the evaluated site than the comparison site at Shamrock Island. Alternative 5 includes four (4), 400-foot-long breakwaters 130 feet apart. In addition, Alternative 5 includes both southern and northern shore-connected groins, 475 and 470 feet long, respectively.

2.3 Performance Evaluation

This section discusses the statistical analyses of numerical model results for the final two alternatives and its comparison to existing conditions as well as conditions at Shamrock Island which has productive seagrass habitat. To compare the current, wave, and suspended sediment distributions that occurred during the 2018 simulation, PNE plots were developed for water surface elevations (WSE), current speed, wave height, and mud concentration that occurred during the 2018 simulation by extracting results at a single point at 2.6-foot MSL depth for each alternative, as shown in Figure 2-6.

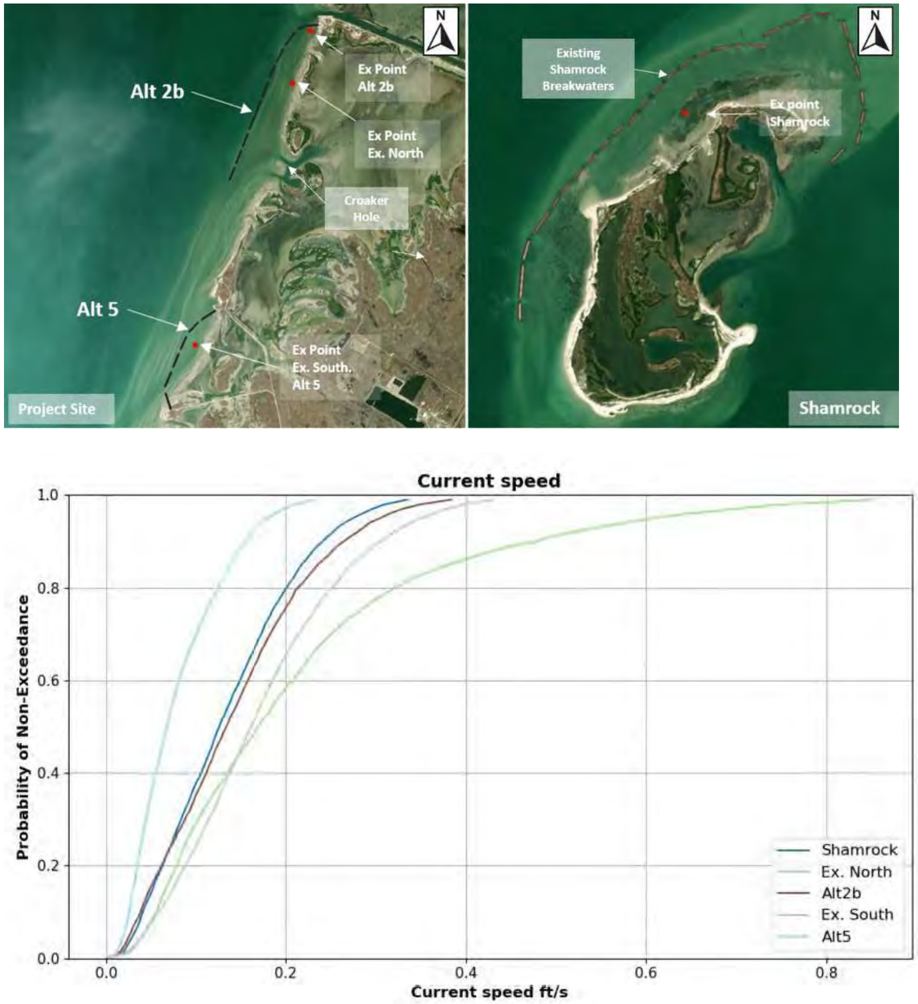

Figure 2-7. Location Graphic showing extraction points used for PNE plotting (top) and current speed PNE plot (bottom).

PNE plots were developed to describe the 2018 frequencies of predicted water surface elevations and current speeds for existing conditions, at Shamrock Island, and for each alternative. The water surface elevation PNE plots are not shown, as there were minimal differences between existing, Shamrock Island, and proposed conditions. Key observations from the analysis are described below. Figure 2-7 (bottom) shows PNE curves for current results at the extraction points in shown in Figure 2-7 (top).

Water Surface Elevation Results:

- Water surface elevations are almost identical for all extraction points. This is expected, as the nested grid covers a small domain where variations in water surface elevation are expected to be minimal.

Current Results:

- Current speeds for existing conditions at both extraction points are higher than those at Shamrock Island.
- Current speeds for Alt 2b are slightly higher than those at Shamrock Island.
- Alt 5 breakwaters create lower current speeds than either Shamrock or Alt 2b.

Appendix B includes water surface elevation and current velocity exceedance probabilities at multiple locations for all alternatives.

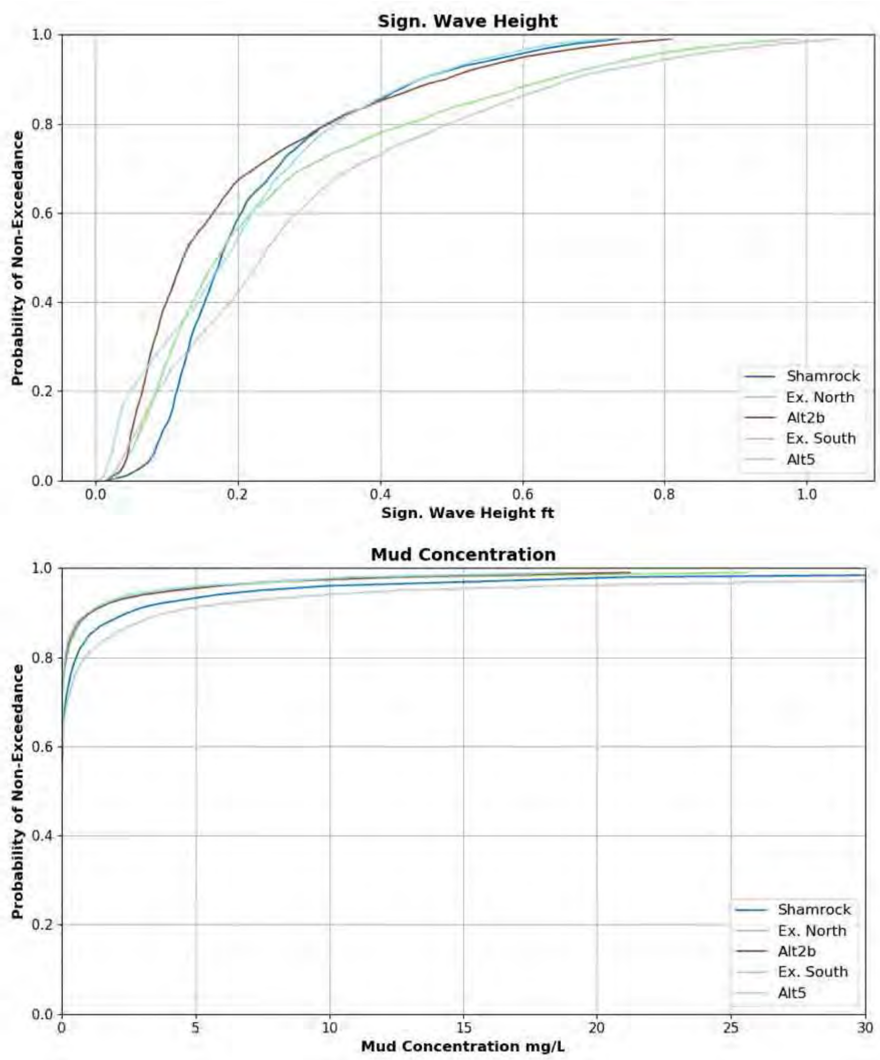

Figure 2-8. Probability of Non-Exceedance plots for wave height (top) and mud concentration (bottom).

PNE plots were also developed for significant wave height and mud concentrations. Results were extracted for existing conditions, at Shamrock Island, and for each alternative. Figure 2-8 (top) shows PNE results for significant wave heights, and Figure 2-8 (bottom) shows PNE results for mud-concentration.

Waves:

- Existing wave conditions at the project site (without breakwaters) are similar to those at Shamrock Island except at higher exceedance intervals. At higher exceedance intervals, wave heights are controlled by cold fronts with northerly winds, while lower exceedance interval waves are controlled by southerly summer winds. During these northerly wind events, the Shamrock site is protected by the breakwaters, while the project shoreline is unprotected.
- Alt 5 and Alt 2b experience significant wave heights similar to Shamrock Island due to the protection provided by proposed breakwaters.

Mud Concentrations:

- Most of the time (approximately 90%), mud concentrations are very low, with concentrations below 5 mg/L.
- As discussed earlier in the report, high mud concentrations are event driven, caused by strong wind events generating higher wave and current conditions.
- Existing conditions show slightly higher concentrations than either Alt 2b or Alt 5.
- Alt 2b and Alt 5 show mud concentrations very similar to Shamrock Island.

See Appendix B for significant wave height and mud concentration exceedance probabilities for all alternatives.

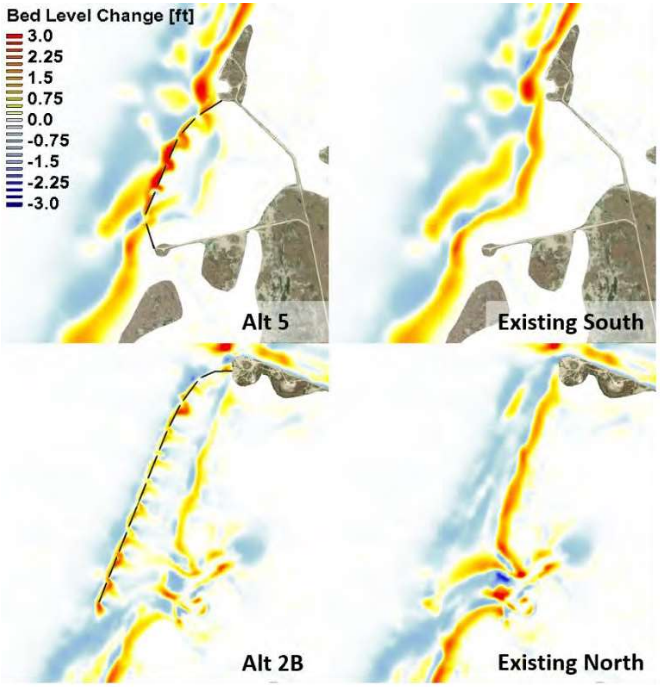

Figure 2-9. Bed level change after 2018 simulation.

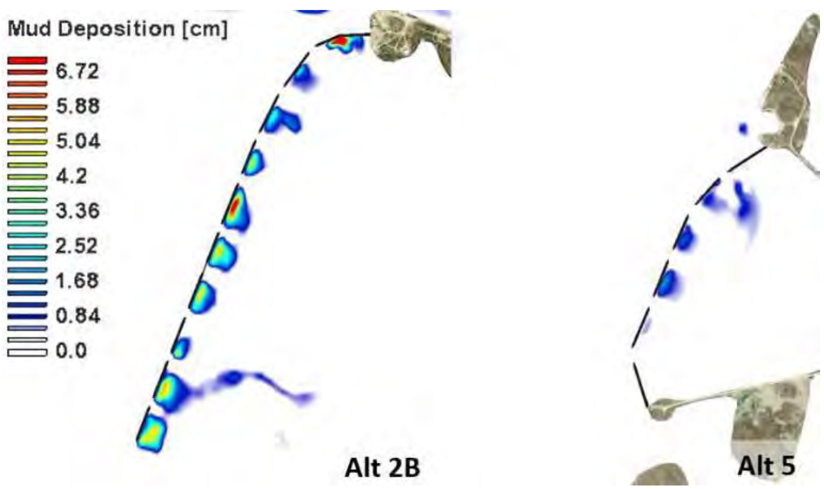

Figure 2-10. Total Mud deposition after 1-year simulation.

Sand and mud transport were modeled for the full representative year of 2018 and the bed level changes for this one year period are shown in Figure 2-9 (sand transport) and Figure 2-10 (mod transport). Warmer colors (reds) represent deposition, while cooler areas (blues) indicate areas of erosion. The sand transport module included dynamic coupling to the wave and hydrodynamic modules, since sand bed level changes affect hydrodynamics in shallow water. The mud transport module was run in a decoupled manner, using the results of the hydrodynamic and wave simulations to force erosion and deposition of mud. Analysis of sediment samples showed a sandy nearshore environment, with higher concentrations of mud in deeper water. Therefore, the mud modeling simulation used a variable percent fines technique, with 0% fines in the nearshore and up to 90% fines in deeper water. Further discussion of this modeling approach is located in Appendix A (Section A.4.4). As noted previously, only deposition of the mud in the area of interest was allowed in the model; this is logical because the project site is all sand near the shoreline. Key observations from the analysis are described below.

Sand Transport:

- Both Alt 5 and Alt 2b show some deposition between and directly behind the breakwaters, with minimal deposition in the area between the shoreline and breakwaters.
- Areas landward of a 200-ft zone around the breakwaters (where deposition is greatest and seagrass growth is unlikely) experience deposition less than 1 foot for both Alt2B and Alt 5.
- The depositional area is approximately 3 acres, representing 3.9 % of the total 78 acres behind Alt 2b. For Alt 5, the depositional area is 3 acres, representing 10.2 % of the total 34 acres behind Alt 5.

Mud transport

- Mud deposition is generally small in the project area due to energetic conditions. Sand found along the project shoreline validates this result.
- Alt 2b shows higher maximum mud deposition (3.4 inches) behind the breakwaters than Alt 5 (0.75 inches).
- Mud deposition is concentrated directly behind the breakwaters for each alternative, with minimal deposition closer to the shoreline.

Figure 2-11. Extraction Arcs for LST Analysis.

Table 2-1. Longshore transport rate comparison for Alt 2b.

Description	Net	North	South
Alt 2b [cy/yr]	13,939	2,314	16,253
Existing [cy/yr]	16,196	2,558	18,753
Absolute Change [cy/yr]	(2,257)	(244)	(2,501)
Percent Change [%]	-13.9	-9.5	-13.3

Table 2-2. Longshore transport rate comparison for Alt 5.

Description	Net	North	South
Alt 5 [cy/yr]	19,052	1,319	20,371
Existing [cy/yr]	20,213	1,419	21,633
Absolute Change [cy/yr]	(1,161)	(101)	(1,262)
Percent Change [%]	-5.7	-7.1	-5.8

The preferred alternatives were designed to create a low energy environment that minimized wave and current action. However, this lower energy environment has the potential to decrease the amount of sediment reaching downdrift shorelines. Analysis was performed to ensure that alternatives do not adversely impact downdrift shorelines. Mott MacDonald compared longshore transport rates downdrift of the structures to existing conditions transport rates, for each breakwater alternative. This comparison was performed to ensure that the final alternatives do not adversely impact downdrift shorelines. Figure 2-11 shows the extraction arcs across which longshore transport rates were calculated. North extraction arc was used for analyzing impacts from Alt 2b and south extraction arc was used for Alt 5. Table 2-1 shows the 2018 longshore transport rates for Alt 2b and a comparison with existing conditions; Table 2-2 shows the longshore transport rates for Alt 5 and a comparison with existing conditions. Key observations from the longshore transport analysis are detailed below.

Downdrift Impact Evaluation:

- Both the north and the south extraction arcs are the same length. Note the for existing conditions, LST rates are slightly higher at the south extraction arc due to larger wave conditions.
- Longshore transport is predominantly in the south direction at both alternative locations.
- Alt 2b causes a greater reduction in sediment reaching the downdrift shorelines than Alt 5.
- The greater reduction in longshore transport rates for is largely due to a greater longshore & cross shore structure length, causing interruption of more sediment transport.
- Both alternatives cause a modest disruption of longshore transport which should be further investigated and mitigated during design. Modifications may include more porous structures to allow increased sediment bypassing and/or changes in structure orientation.

2.4 Conclusions

In general, both alternatives show similar or more favorable wave, current, and suspended sediment conditions compared to seagrass areas at Shamrock Island. Conditions at the sites indicate that seagrass mitigation in the area is feasible.

Isolated areas immediately behind the proposed breakwaters showed over one foot of sand deposition, indicating that this area may not be suitable for seagrass growth. However, for Alt 2b, this depositional area is approximately 3 acres, representing only 3.9 % of the total 78 acres behind Alt 2b. For Alt 5, this depositional area is 3 acres, representing only 10.2 % of the total 34 acres behind Alt 5. This leaves approximately 75 acres for Alt 2b, and 31 acres for Alt 5 where sand deposition was less than one foot over the yearlong simulation. It should also be noted that while the area with greater than one foot of sand deposition may not be suitable for seagrass growth, it may be suitable for creating intertidal wetlands.

Longshore transport analysis showed reduction in longshore transport for both Alt 2b and Alt 5 with slightly larger reduction for Alt 2b compared to Alt 5. Reduction in longshore sediment transport rates (downdrift impacts) should be further investigated in future phases of the project. Optimization of breakwaters should be investigated to reduce potential downdrift impacts.

3 References

Delta Land Services, 2019. Conference call for hydrodynamic project constraints. Personal Communication 9/20/2019.

DHI, 2019. MIKE21 numerical modeling system.

Lloyd, 2019. Croaker Hole Bathymetry survey. Collected 2019.

Mott MacDonald, 2019. Pipeline Construction Activities: Sediment Transport Analysis. Sept. 13, 2019.

Texas Parks and Wildlife Department, 1999. Seagrass Conservation Plan for Texas.

A. Modeling Appendix

A.1 Introduction

This modeling appendix is intended to supplement the main document and provide additional detail regarding existing site conditions, model development, existing conditions analysis, preliminary alternatives analysis, and final alternatives analysis. Pertinent information from the main document is also included in this appendix for completeness and ease of reading.

A.2 Existing Site Conditions

The following sections provide an overview of data sources and existing site conditions used in the numerical modeling.

A.2.1 Datums

Tide levels at the NOAA Port Aransas station 8775237 were adopted for the project. Figure A-1 shows the location of the Port Aransas station relative to the project site. Tidal datums for Port Aransas station were collected via the NOAA tides and currents website (NOAA, 2019). Table A-1 documents the tidal datums for the tidal epoch of 1983-2001.

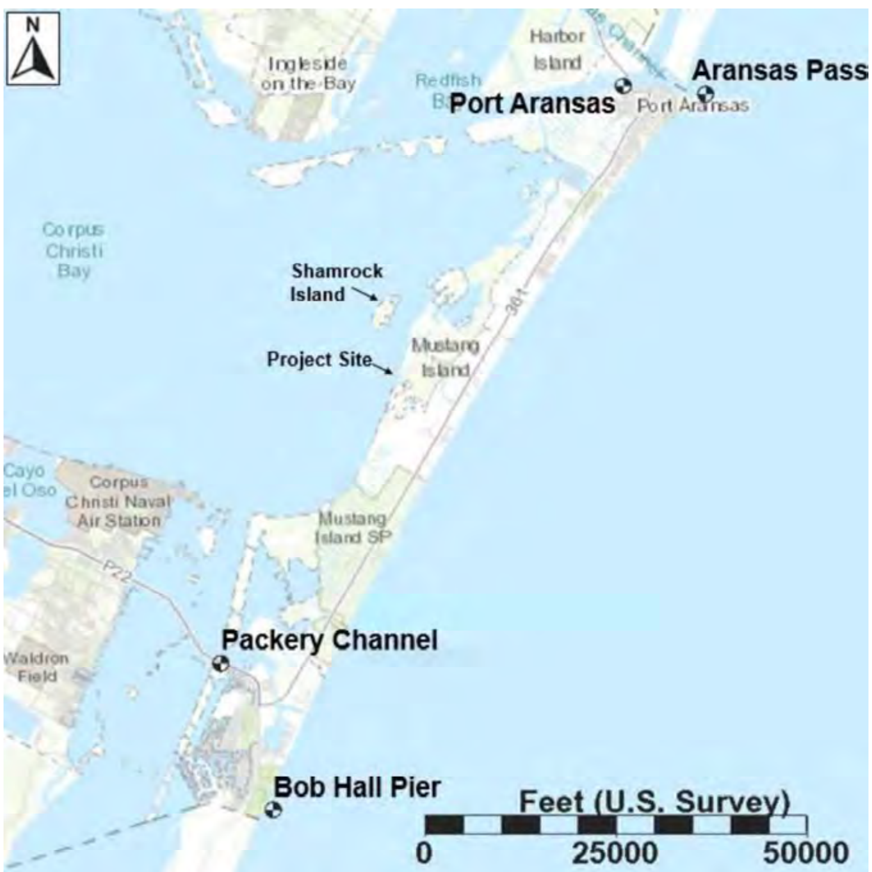

Figure A-1. NOAA Stations in the project vicinity.

Table A-1. Project datums from Port Aransas NOAA Station (8775237).

Datum	Description	Elevation [ft NAVD88]
MHHW	Mean Higher-High Water	1.10
MHW	Mean High Water	0.79
MSL	Mean Sea Level	0.45
MLW	Mean Low Water	-0.06
MLLW	Mean Lower-Low Water	-0.20

A.2.2 Bathymetry

The bathymetric and topographic surface was developed by merging elevation surfaces from six different sources. Table A-2 lists the data sources used to develop the merged elevation surface. A priority was given to each dataset based on its coverage and survey date. Where overlapping datasets occurred, the higher priority dataset was used in developing the final bathymetric and topographic surface. Figure A-2 shows each source on a map. All source elevation data were transformed to State Plane coordinates system - Texas South (NAD83) and vertical coordinates in feet relative to NAVD88 according to the datum conversions provided in Table A-1.

Table A-2. Bathymetry data source summary.

Priority	Source	Type	Resolution	Original Vertical Datum
1	2019 Croaker Hole Survey	Point Cloud	varies	MLLW
2	2018 Shamrock Seagrass Survey	Point Cloud	varies	NAVD88
3	2016 Post-Construction Shamrock Surveys	Point Cloud	varies	NAVD88
4	2013 Shamrock Survey	Point Cloud	varies	NAVD88
5	2012 Shamrock Survey	Point Cloud	varies	NAVD88
6	2007 NOAA Corpus Christi DEM	Digital Elevation Model	10 meter	MHW

The merged data are shown visually in Figure A-2. After merging the data sources, some manual cleaning of the splice boundaries between data sources was required due to the slight change in bathymetry over time. The final merged surface, shown in Figure A-3, was used for developing the numerical model, as described in Section A.3.

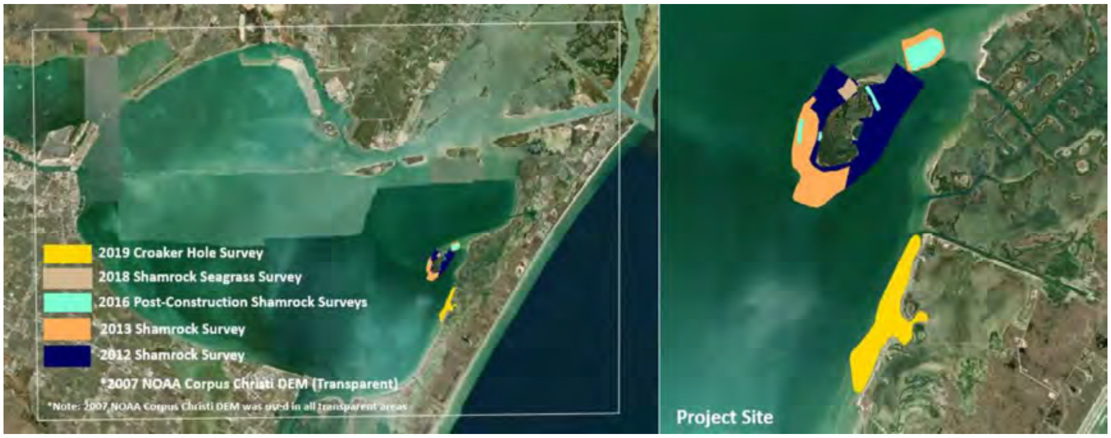

Figure A-2. Full view of bathymetric surface sources (left) and a zoomed view of the project site (right).

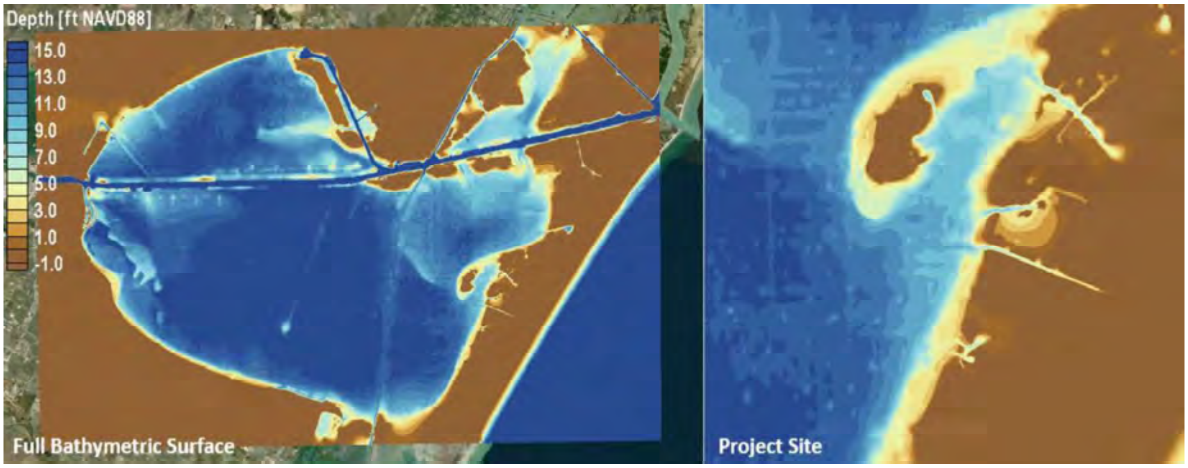

Figure A-3. Full merged bathymetric surface (left) and a zoomed view of the project site (right).

It should be noted that the 2019 Croker Hole Survey data was measured relative to Mean Lower-Low Water (MLLW) which was determined using the datums at the NOAA Packery Channel station. Therefore, this data was converted to NAVD88 according to the datums provided at the Packery Channel station. The remaining datum transformations were performed using the datums at the NOAA Port Aransas station due to its proximity to the project site.

A.2.3 Winds

Wind and tide induced currents and wind-induced waves play an important role in sediment transport in shallow areas near the project site. Wind analysis was previously conducted using Bob Hall Pier data (Mott MacDonald, 2019). The analysis found that 2018 was a representative year with regards to the wind conditions experienced at the project site. In addition, nearby wind gauges at the Port Aransas and Aransas Pass NOAA stations shown in Figure A-1 did not have a full record of winds for 2018. Therefore, the 2018 winds for Bob Hall pier were used in this study to force all model simulations.

A.2.4 Currents & Waves

No current measurements were available near the project site. However, velocity observations north of the project site in Corpus Christi Ship Channel and south of the project site at Packery Channel were included in the modeling conducted during the previous phase of the project (Mott MacDonald, 2019). The large-scale numerical model was validated at these locations and showed good agreement with measured current velocities (Mott MacDonald, 2019).

No wave measurements were available near the project site. Winds were used to generate local wind-waves at the project site using a phase-averaged spectral wind-wave growth and transformation model (Mike21SW) as described in Section A.4.1.

A.2.5 Sediment Properties

Site sediments were characterized using data from soil samples collected at the site during a geotechnical investigation, which is described in a series of spreadsheets provided by Lloyd (North Water District Laboratory Services, Inc. 2019). Grab samples were collected at 11 different locations near the Project site and Shamrock Island. Sediments were analyzed at these locations and laser grain size analysis provided detailed composition data. Figure A-4 shows the soil data collection locations, with points colored by the median (d50) grain size in mm.

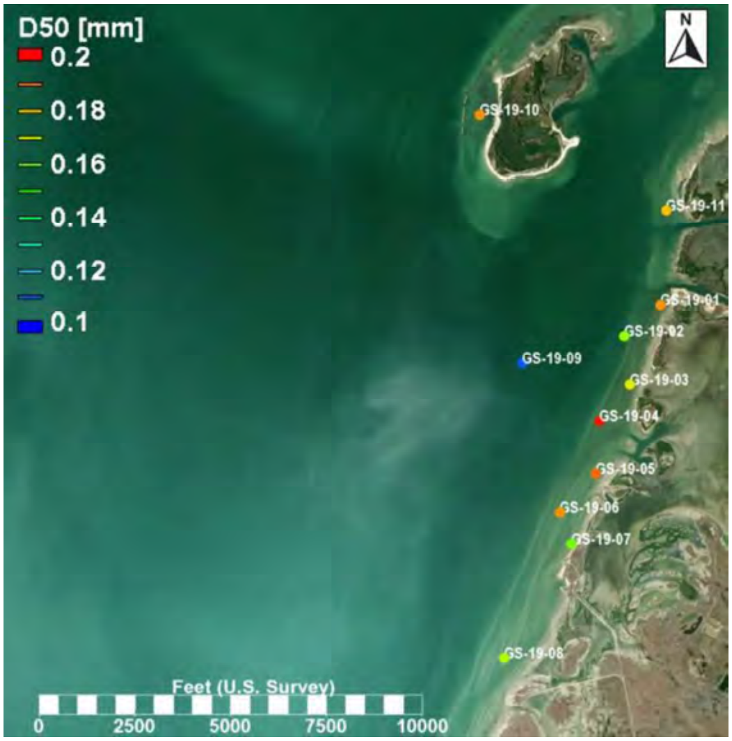

Figure A-4. Locations of sediment samples near the project site, with points colored by median grain size (d50 in millimeters).

Sediments near the project shoreline and along Shamrock Island can generally be characterized as sandy, with a mud/sand mixture in deeper waters. Figure A-5 shows the sediment composition by weight of the geotechnical samples for sand and mud (silt/clay). Most of the samples contain almost entirely sand, whereas samples GS-19-09 (located in deeper water offshore of the project shoreline) is a more even mixture of mud and sand.

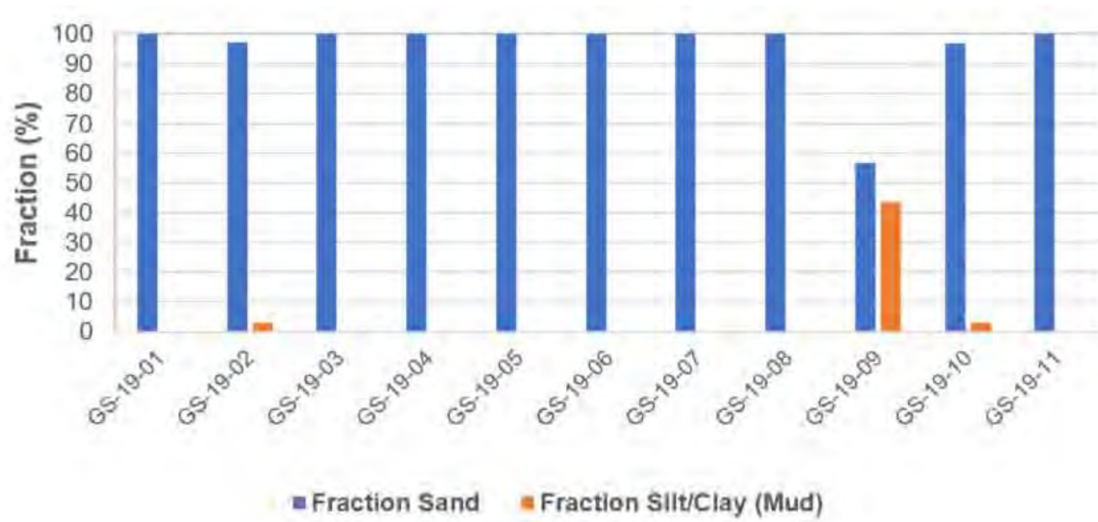

Figure A-5. Sediment content at grab samples adjacent to project sites (sand defined as 0.0625 mm material and larger).

Grain size data at sample location GS-19-02, as shown in Figure A-6, is representative of the nearshore region at the project site, with a high percentage of sand in the seabed. Grain size data at location GS-19-09 as shown in Figure A-7, is representative of the offshore area, with a higher percentage of clays/silts. Sample GS-19-10, taken near Shamrock Island, shows similar results to the nearshore project site samples, with a high percentage of sand.

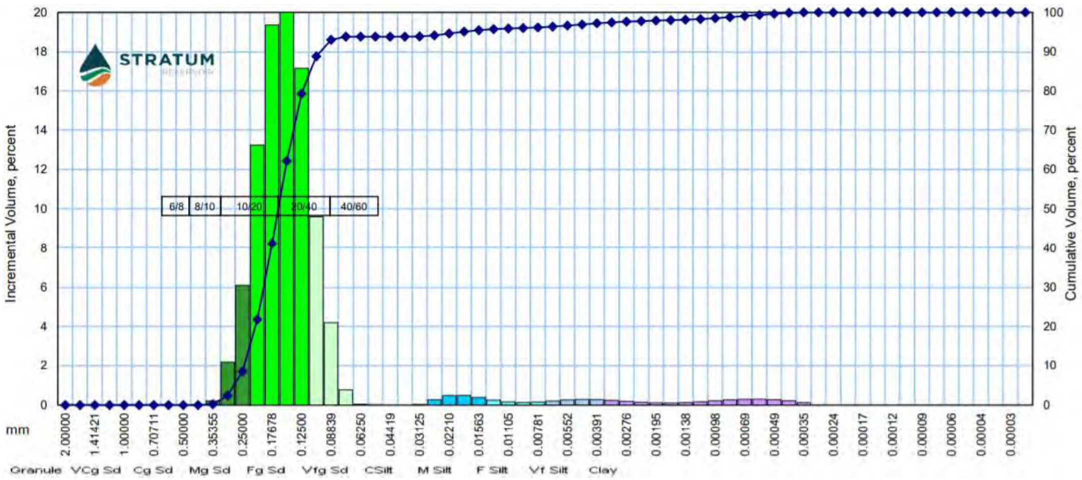

Figure A-6. Grain size distribution at point GS-19-02.

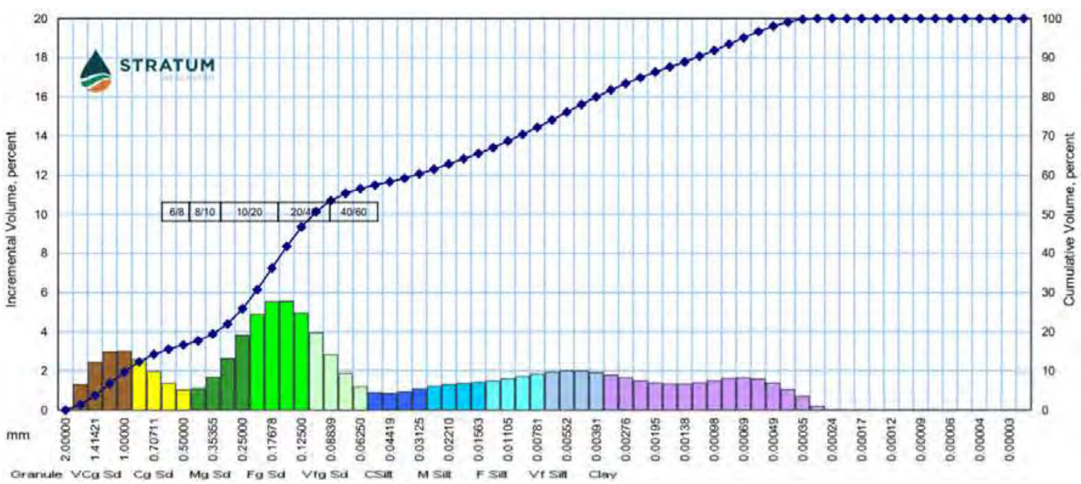

Figure A-7. Grain size distribution at point GS-19-09.

In addition, sediment data were collected from the TxSed Mapping Viewer: Texas Coastal Sediments Geodatabase (Texas General Land Office, 2019). Figure A-8 shows the available grab samples near the project site from the TxSed database, with points colored by by percent sand/gravel. Warmer colors represent higher concentrations of sand/gravel, while coolor colors represent lower concentrations (i.e higher concentrations of mud/clay at these points).

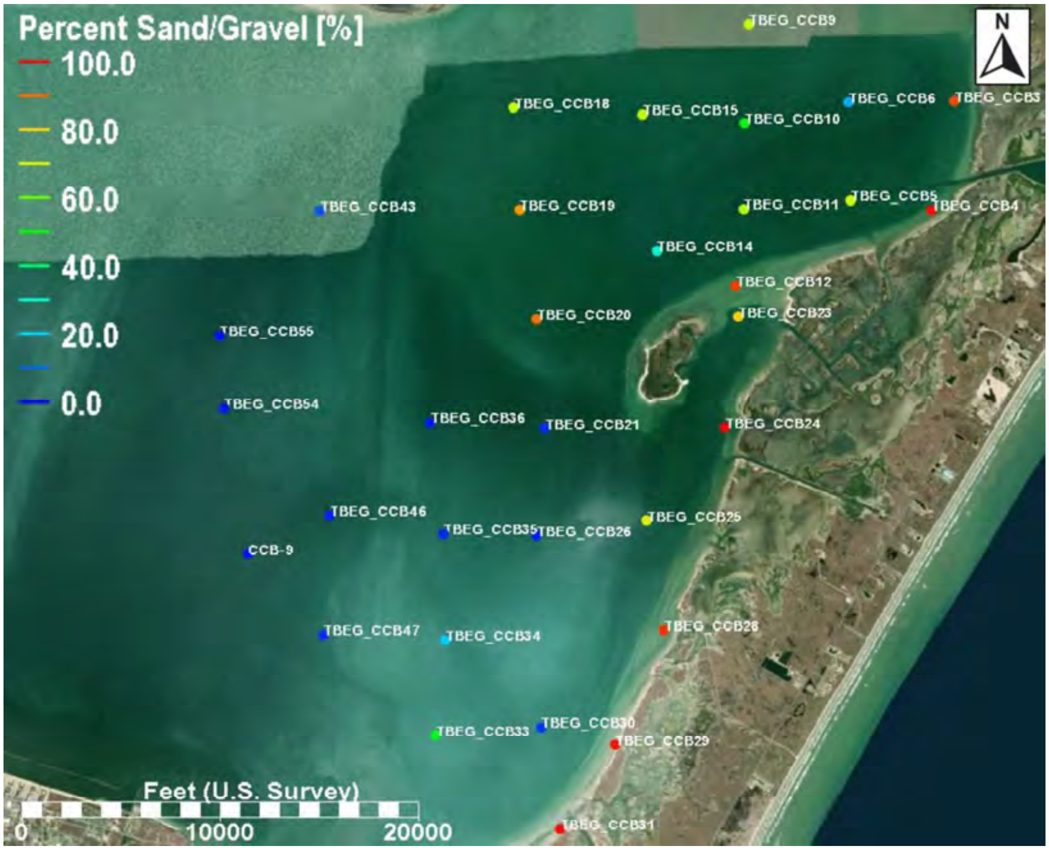

Figure A-8. Percent weight coarse sediment (sand or gravel) at the project location.

The grab sample data from TxSed show similar results to the grab samples taken at the project site, with a high concentration of sandy material near the shoreline, and silty/clayey material farther offshore in Corpus Christi Bay. Slight variability in offshore sediment was noted, with the area north-west of the project site showing a very low sand fraction (5-20%), and the area east of Shamrock Island showing a higher sand fraction (50-70%). Shamrock Island is a relic spit that was once connected to the adjacent Corpus Christi Bay Shoreline. The higher sand concentration east of Shamrock Island are hypothesized to be leftover sand deposits from the former spit's gradual westward movement. The sediment data described in this section was used during the sand transport modeling described in Section A.4.2 and mud modeling described in Section A.4.4.

A.2.6 Coastal Processes Not Included in the Analysis

Certain coastal processes were not included in the modeling because they are not anticipated to significantly vary between the proposed alternatives. The following were neglected in the hydrodynamic and sediment transport simulations:

<u>Salinity.</u> Salinity variations are not expected to cause any significant differences in sediment transport or vary between the proposed alternatives. Therefore, salinity distribution calculations were not included in the 2D modeling domain.

<u>River discharge.</u> The project site does not have nearby river inputs that would significantly affect hydrodynamics or sediment transport predictions.

3D Effects. All numerical modeling was conducted in 2D. 3D effects such as stratification and baroclinic flow are not anticipated to significantly alter hydrodynamics at the project site. If further quantification of near-bed processes is desired, it could be conducted in later stages of design for the selected alternative.

Dredging. Increased turbidity due to dredging events can impact light penetration and therefore seagrass growth. Any dredging on the nearby Gulf Intracoastal Waterway (GIWW) is expected to include appropriate turbidity mitigation and therefore not impact the project site.

A.3 Model Development

A.3.1 Overview

Numerical modeling was previously conducted to determine sediment transport patterns for construction activities in the Laguna Madre (Mott MacDonald, 2019). This large-scale model included the mitigation site in its domain. Therefore, results from the validated large-scale model were used to force a nested domain at the project site. The goal of the modeling task is to develop wave, water surface elevation, current, and sediment transport (sand and mud) conditions for existing and with-project conditions. The following sections describe the development of nested model used for this study.

A.3.2 Modeling Domain and Bathymetry

The nested model domain was selected to accurately simulate the relevant physical processes at the project site while minimizing computational expense and any boundary effects that can often occur with nested models. The model grid north boundary was placed at Flato Cut, and the southern model domain was placed at the Mustang Island State Park fish pass. The western boundary was placed seaward of Shamrock Island. These domain extents were selected to place the boundaries sufficiently far from the project site to minimize any boundary effects. It was important to include Shamrock Island in the high-resolution nested model domain since the results at areas of known seagrass behind the Shamrock Island breakwaters will be used to compare the effectiveness of the proposed alternatives. Figure A-9 shows the extents of the nested model compared to the large-scale model used in Mott MacDonald, 2019. Figure A-10 shows the full mesh resolution of the nested model, with the coloring scheme showing areas of magnitude of mesh resolution. Note the high resolution used in the mesh near the project site and Shamrock Island.

Figure A-9. Large scale mesh domain (light blue) (Mott MacDonald, 2019) compared to the nested domain (red).

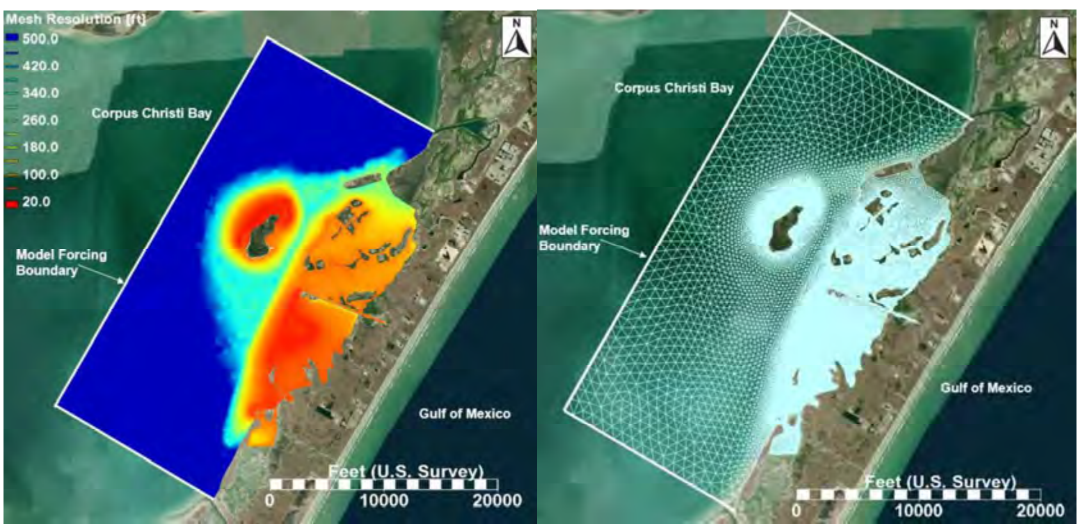

Figure A-10. Nested model domain. Coloring scheme shows mesh resolution in feet (left) while (right) shows the actual computational mesh.

The bathymetric surface that was compiled and previously described in Section A.2.2was interpolated onto the mesh and converted to meters MSL using the datum conversions shown in Table A-1.

A.3.3 Boundary Conditions

The model boundary shown in Figure A-10 was forced with water levels, currents, and wave conditions extracted from the large-scale model developed in the previous phase of this study (Mott MacDonald, 2019). Wind forcing was included in the model to accurately capture locally generated wave and current conditions. The wind forcing was included in the form of a single wind speed and direction time history, forced uniformly across the modeling grid. Winds used for forcing were taken from NOAA Station 8775870 at Bob Hall Pier (see Figure A-1for station location) and adjusted to speeds at 10-meter (33-ft) elevation. This was the same wind timeseries used to force the large-scale model (Mott MacDonald, 2019).

A.3.4 Seasonal Wave and Current Climate

The seasonality of the wave and current conditions applied at the boundary was investigated to see if any apparent trends could be identified. Wave timeseries for the full year were extracted at the northern boundary, and wave roses for each month were generated and are shown in Figure A-11. In general, winter months showed higher wave conditions, with more waves coming from the northwest to northeasterly directions. Summer months were characterized by waves primarily coming from the east to the south. These patterns match the seasonal wind analysis that was conducted in Mott MacDonald, 2019, which is valid since all waves at the project site are locally generated within the Corpus Christi Bay. Based on these seasonal wave trends, majority of the wave generated sediment transport at the project site is expected to occur during winter months since the project site is exposed to a longer northern fetch across Corpus Christi Bay. The project sits on the southeastern edge of Corpus Christi Bay, so minimal sediment transport is expected during the summer months characterized by southeasterly winds and waves.

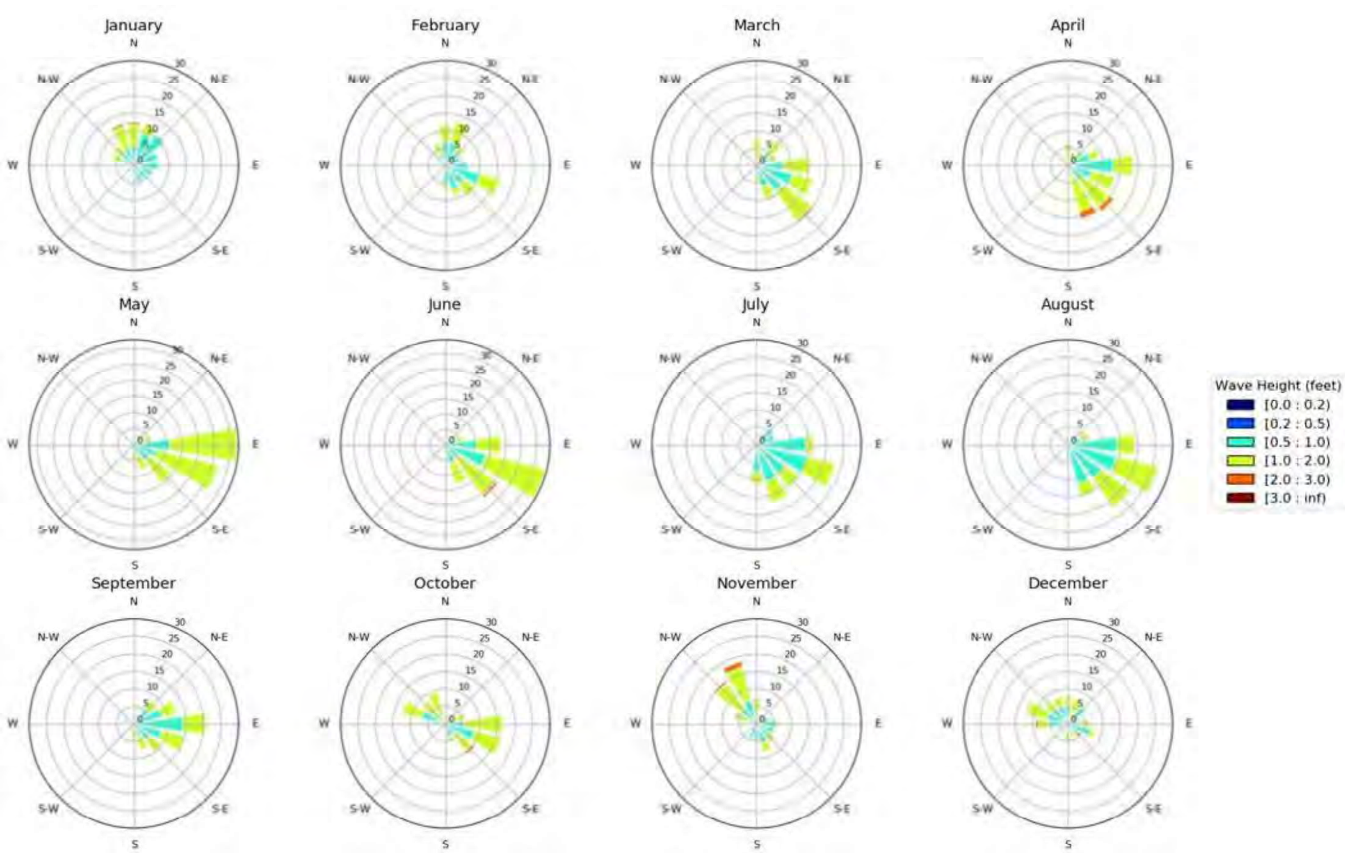

Figure A-11. Monthly wave statistics at northern boundary of nested model domain.

A similar analysis was conducted to determine if any seasonality existed in the current patterns used to force the model boundary. This analysis showed minimal seasonal differences in the current direction, with currents primarily dominated by northeast (ebb) to southwest (flood) currents for all months.

A.4 Existing Conditions Analysis

Numerical modeling was conducted to develop the understanding of existing conditions at the project site. These were then used as the baseline conditions to compare the efficiency of different proposed alternatives. The MIKE21/3 Flexible Mesh model was selected to evaluate the hydrodynamic conditions, and the sand transport module was used to model sediment transport (DHI, 2019). The spectral wave, current, and sand transport modules were fully coupled, and a full representative year (2018) was simulated to capture the complete range of typical conditions expected at the project site. This is the same year that was selected for modeling in Mott MacDonald, 2019.

A.4.1 Hydrodynamics and Wind-Waves

Example depth-averaged current fields are shown for a typical flood event (left) and ebb event (right) in Figure A-12. It should be noted that small (0.17 ft/s median current speed) current velocities are experienced along the project shoreline during typical conditions. During modeling, it was noted that the largest contributor to the nearshore current patterns were longshore currents generated by waves, and not tidal induced currents.

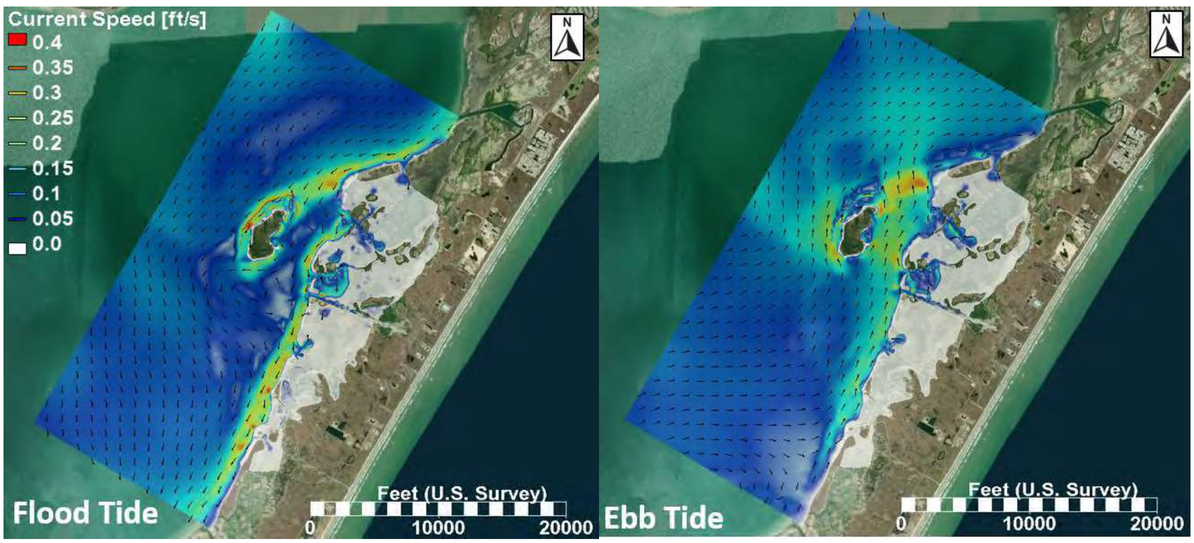

Figure A-12. Typical currents for flood tide (left) and ebb tide (right).

Seagrass growth is sensitive to the increased turbidity from resuspension of sediment by waves (TPWD, 1999). At the project site, waves act as the dominant force for sediment transport. Therefore, to accurately capture wave impacts at the proposed project site, the hydrodynamic module was fully coupled to the MIKE21SW spectral wave model. MIKE21SW captures the local wave transformation effects at the project site and includes wave effects on sediment transport. An example of a typical condition MIKE21SW significant wave heights is shown in Figure A-13. Note that for northerly events, there is a shadowing effect behind Shamrock Island, which reduces farther south along the shoreline. A wave rose (shown in Figure A-14) was developed at a point near the project shoreline (marked as “Croaker Hole Extraction Point” in Figure A-13). Similar trends are observed at the project site as observed previously at the modeling grid boundary, larger northerly waves occurring in winter months, and smaller waves occurring in summer months due to the predominant southeasterly winds.

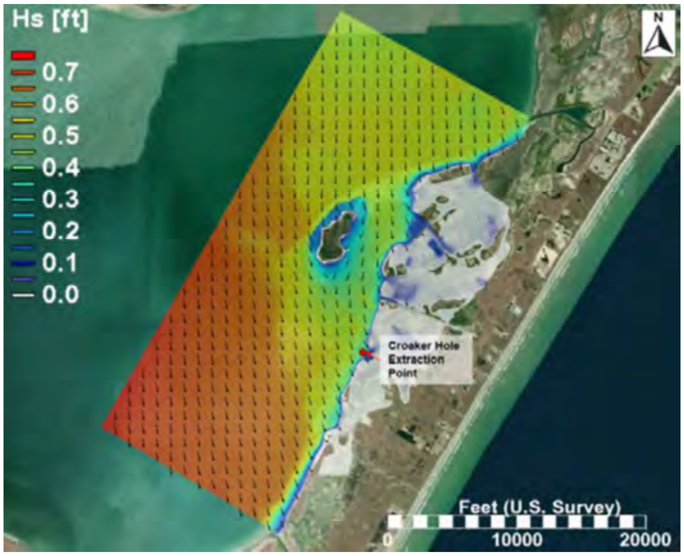

Figure A-13. Typical wave conditions at the project site. Wind conditions during this model timestep was 6.4 knots from 332 deg TN. Extraction point used for monthly wave roses labeled.

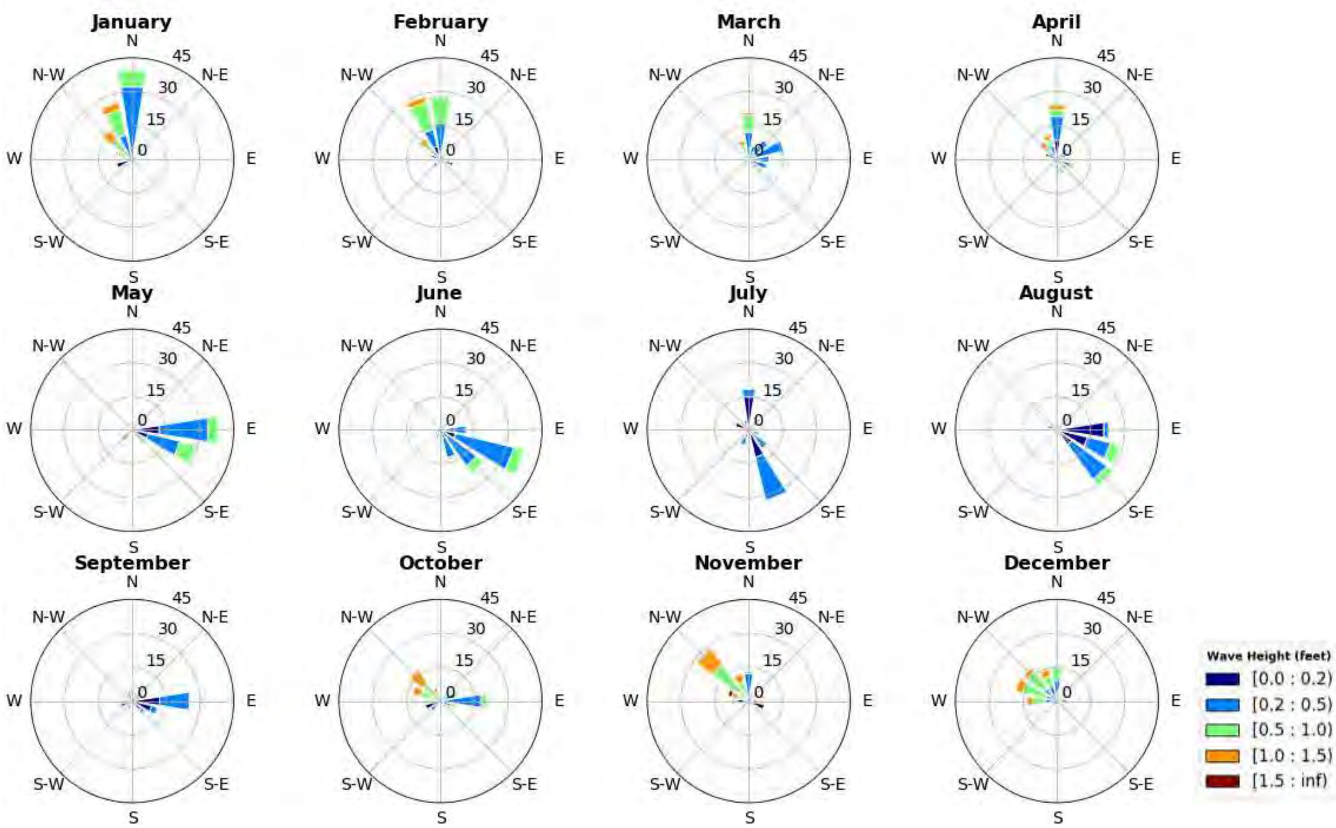

Figure A-14. Nearshore monthly wave roses for extraction point near croaker hole for modeled conditions.

A.4.2 Sand Transport Modeling

As discussed previously, the sand morphology model was fully coupled to the hydrodynamic model. Bed updates from the morphology model were passed to the hydrodynamic models, and the hydrodynamic and wave conditions were used by the morphology model to quantify sediment transport. In general, the strongest sediment transport trends appear to occur in winter months, mainly driven by wind-waves from the northwest-to-northeast directions, generated by cold fronts. Sediment transport slows in the summer months when southeastern winds reduce the wave energy impacting the project site. Table A-3 lists the parameters used in the sand transport module.

Table A-3. Parameters used in sand transport Module.

Parameter	Units	Value
Median Grain Size	mm	0.179
Grading Coefficient	--	1.4
Maximum Bed Level Change	m/day	10
Morphological Acceleration	--	None

Overall, the 2018 morphology simulation shows slight erosion in the offshore region and deposition in the nearshore environment. It is hypothesized that this shoreward movement of sediment is caused by the strong wave conditions in winter months and that the spring and summer months serve to spread this sediment in the nearshore environment with tide-generated currents. Figure A-15 shows the change in bed level results for the 2018 existing conditions simulation. The positive bed level change represented by warm colors represent deposition and negative bed level change represented by cooler colors represent erosion.

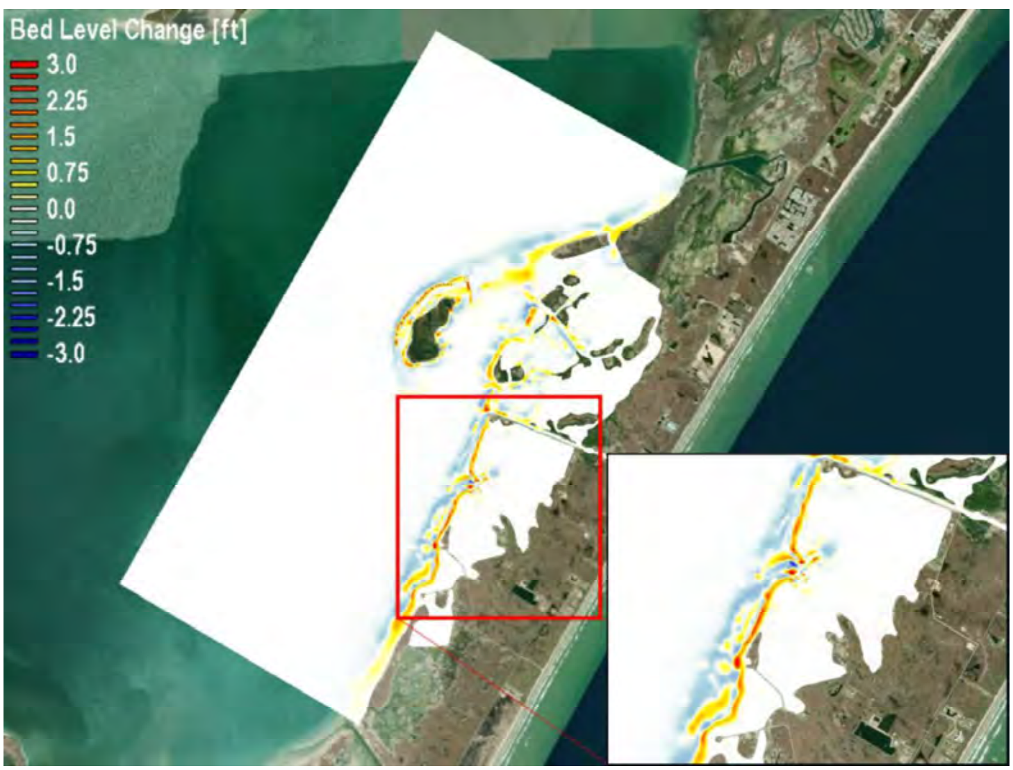

Figure A-15. Bed-level change [ft] for existing conditions 2018 simulation. Inset shows a zoomed view of the project site.

A.4.3 Shoreline Change Comparison

In order to qualitatively compare transport trends seen in the model to real-world data, a shoreline change analysis was conducted using the CoastSat Python toolbox (Vos et al. 2019). CoastSat is a global shoreline mapping toolbox that uses sub-pixel resolution shoreline detection techniques to map shorelines from publicly available Sentinel-2 satellite imagery. To assess recent trends in morphology at the project site, shorelines were extracted from Sentinel-2 satellite imagery from 2016 to present.

Aerials with excessive cloud cover or poor shoreline detection were manually removed from the dataset. . Figure A-16 shows the extracted shorelines at the islands near the project site, as well as the transects where the shoreline analysis was conducted. These shorelines were used to assess seasonal changes at the project site and qualitatively assess the model performance.

Figure A-16. Shorelines and transects from CoastSat (Vos et al. 2019) analysis.

Shoreline change was quantified by the distance from the mean shoreline. The mean shoreline was determined by analyzing shoreline positions along all three transects and determining a mean offset distance. Then, each shoreline was quantified as distance from this mean shoreline. A 60-day rolling mean was applied to smooth the shoreline change timeseries and minimize the effects of outliers on the seasonal trend analysis. The seasonal shoreline trend analysis showed a general trend of shoreline accretion in the fall and winter months, with erosion or minor accretion in the spring and summer months. This is likely due to the wind patterns at the project site, which generate northerly wave conditions during the winter, and little to no waves during the spring and summer. Figure A-17 shows the seasonal shoreline change analysis, with the raw data in blue, and the smoothed 60-day rolling mean data in green. The x-axis shows shows the time each shoreline measurement was taken, and the y-axis shows the distance from the mean shoreline position along each transect.

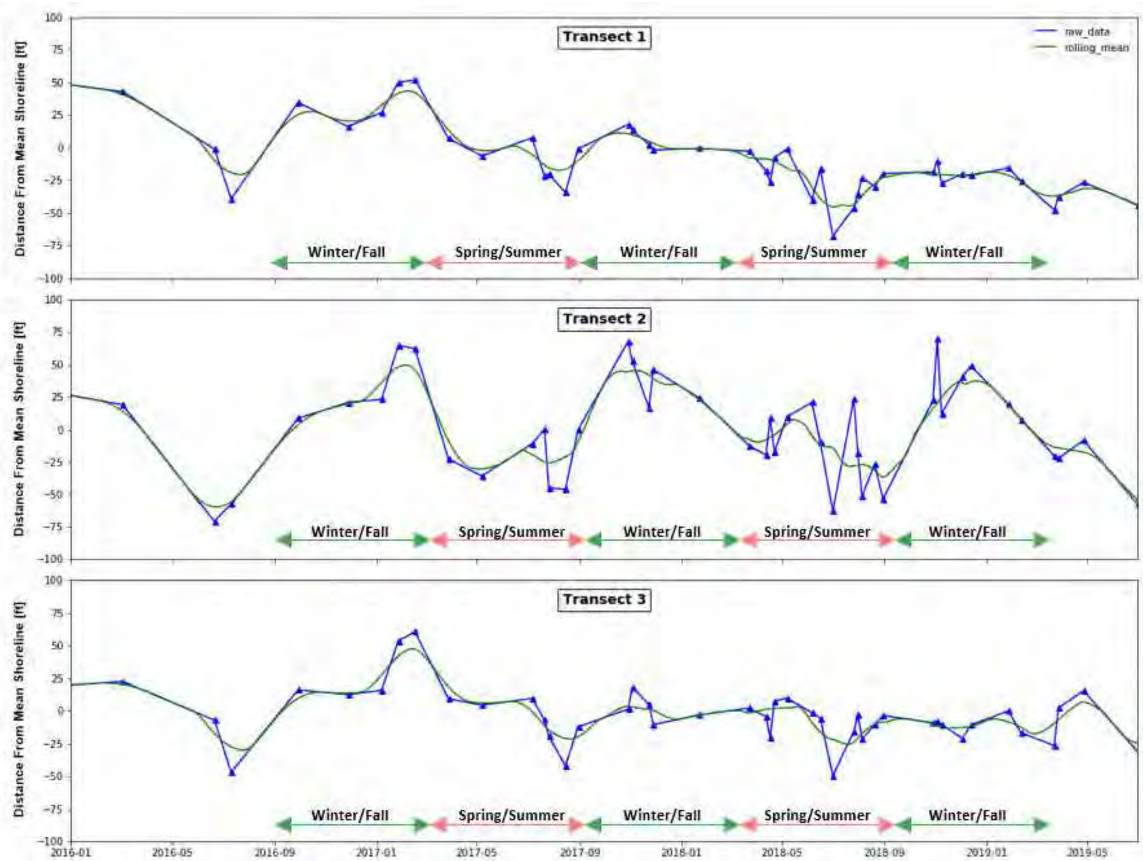

Figure A-17. Seasonal shoreline change analysis.

The CoastSat analysis matches the general trends shown by the morphology model. The model showed an accretionary nearshore environment in winter months, with less accretion and some erosion during the spring and summer months. This qualitative analysis helps show that the model is capturing the general sediment transport trends at the project site.

A.4.4 Mud Modeling

The sediment data near the project site discussed in Section A.2.5 shows high concentrations of sand in the nearshore environment, with increasing mud fraction as you move farther offshore. Therefore, the nearshore morphological response to the proposed alternatives is expected to be controlled by sand movement. However, sustained suspension and transport of the fine-grained sediment (mud) could cause increased turbidity in the water column, which would decrease light penetration and reduce the likelihood of seagrass growth. Therefore, modeling of fine-grained sediments was also conducted using the MIKE21 Mud Transport (MT) module to determine whether sustained periods of high suspended sediment concentrations or fine-grained sediment deposition can occur at the proposed mitigation site. As previously noted, light penetration through water column has a significant impact on seagrass growth (TPWD, 1999). Light penetration is reduced due to substrate presence in the water, which can include suspended sediments, phytoplankton, or dissolved organic matter (TPWD, 1999). In this study, it is assumed that the dominating variable impacting the light penetration at the project site is suspended sediments, and therefore no quantification of phytoplankton or dissolved organic matter levels was performed. If either of these parameters is believed to impact the project site, they should be verified in the field via in-situ measurements.

The mud modeling was conducted using results from the year-long simulation of waves and currents using the MIKE21FM-SW coupled module described in Section A.4.1. The results of this yearlong model simulation were used to force the mud module. As shown in Section A.2.5, the composition of the bay bottom offshore of the project site varies with the model domain. Therefore, three separate zones were identified with varying mud compositions as shown in Figure A-18.

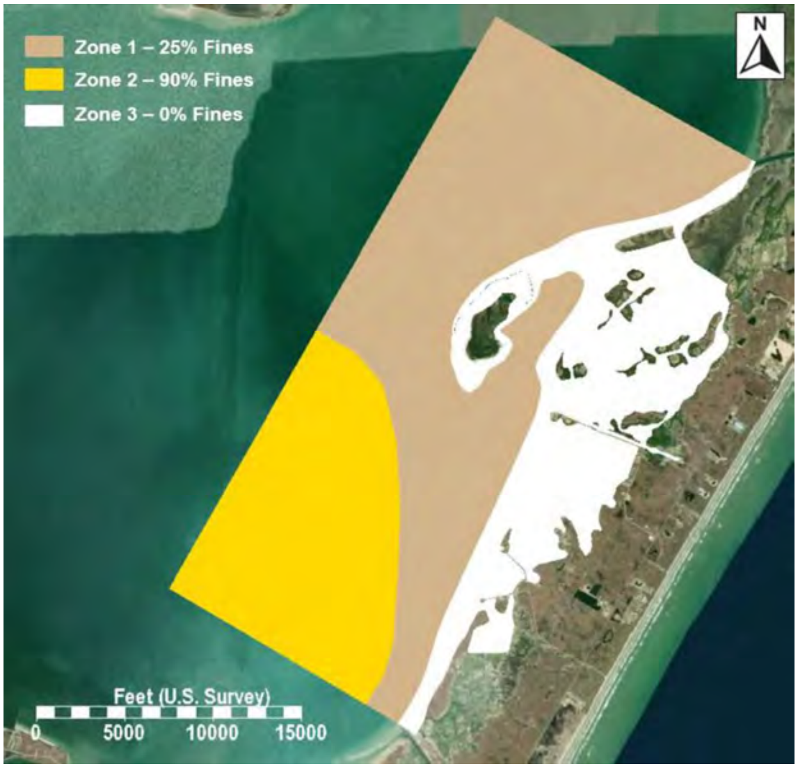

Figure A-18. Zones used in mud transport modeling.

Mud transport is highly dependent on the input parameters used in the model. For the silt/clay fraction (mud), critical shear stress for erosion, critical shear stresses for deposition, and fall velocities are required. SedFlume studies, which take grabs samples and determine shear stresses in flume tests, in large estuaries (e.g. San Francisco Bay) for silt and clay have suggested that reasonable values for critical shear for erosion are in the range of 0.28 Pa. For fine-grained sediments, SEDflume studies are generally conducted to directly measure site-specific erosion rate and its variation with depth below the sediment-water interface. Critical shear stress for deposition of 0.1 Pa was taken from Mehta (1986), who carried out extensive deposition tests. No SedFlume or similar data were available for the project site, and these values have been used on previous projects with successful calibration efforts; therefore, these values were used in the model. It should be noted that these values do not affect TSS values before initial deposition.

Whitehouse et al (1958) sampled clays from Texas bays and Gulf of Mexico waters. Sampleswere collected in Copano Bay, Aransas Bay, Mesquite Bay and San Antonio Bay nearRockport, and St. Joseph and Matagorda Islands. Settling velocities were determined by pipette analysis ranged from 0.12 to 0.18 mm/sec. Therefore, a middle range fall velocity of 0.15 mm/sec was chosen for simulation of both silt and clay. Given that clays make up a significant portion of the non-sand sediments in the nearshore areas, this is expected to be a reasonable fall velocity for simulation of clays, and conservative for silts, and hence conservative overall for mud (combination of both silt and clay).The model also includes increased settling at high concentrations (flocculation), which was specified to occur at concentrations above 300 mg/L (0.3 kg/m^3). A summary of the key parameters used in mud modeling is shown in Table A-4.

Table A-4. Summary of mud transport module input parameters.

Parameter	Units	Value
Density of Sediment	Kg/m^3	2650
Concentration for flocculation	Kg/m^3	0.3
Concentration for hindered settling	Kg/m^3	10
Settling Velocity	mm/s	0.15
Critical Shear for Deposition	N/m2	0.1
Critical Shear for Erosion (fines)	N/m2	0.28
Density of bed layer	Kg/m^3	400
Bed Roughness	m	0.001

Analysis of the mud model results indicates that mud transport is highly event-driven. Suspension and transport of the fine-grained offshore sediments primarily occur during large wave events. Once suspended, minimal deposition of mud occurs for existing conditions at the project site. For the proposed alternatives, it is possible that reduced currents behind the proposed breakwaters could cause increased mud deposition compared to existing conditions. This will be examined further in Section A.6. Figure A-19 shows a full year timeseries of mud concentrations along the project shoreline. The spikes in high concentrations are highly correlated with larger wind-wave events.

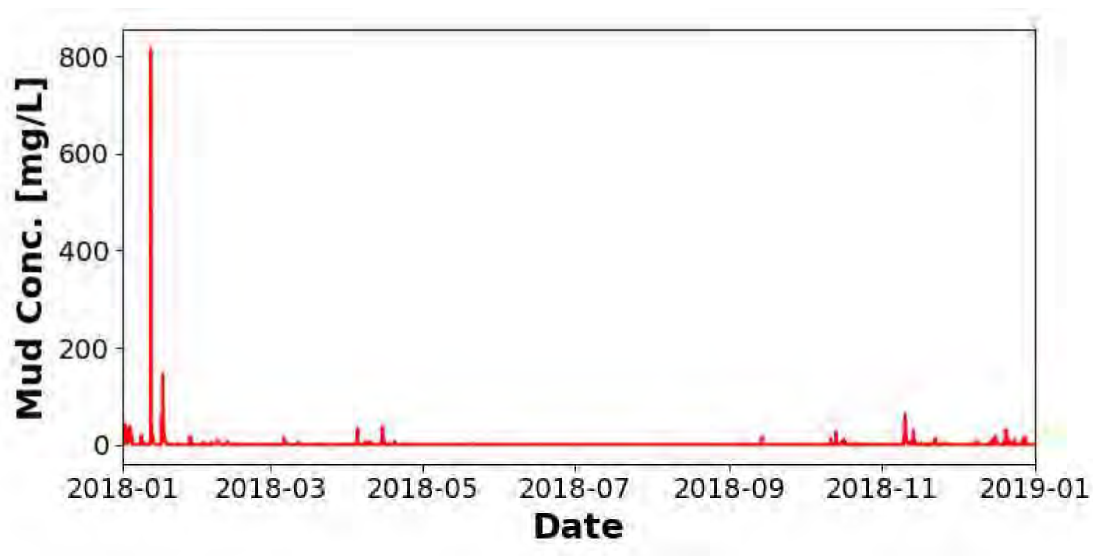

Figure A-19. Concentration timeseries of suspended sediments.

A.5 Preliminary Alternatives Analysis

Conceptual structural alternatives (breakwaters) were developed to provide a conducive environment in the lee of the structures for seagrass growth. The goal of the proposed breakwaters is to reduce wave heights behind them as greatly as possible (Delta Land Services, 2019). While there is some guidance provided for acceptable current speeds (5-100 cm/s per Delta Land Services, 2019), a comparison was made to a nearby seagrass site at Shamrock Island to assess the performance of the proposed breakwaters. An initial proposed breakwater layout was provided by Lloyd. Seven additional alternatives were developed by MM in coordination with Lloyd and Delta Land Services, as part of the numerical modeling effort. The alternatives analyzed as part of this study are introduced in the following section. Preliminary alternatives analysis was conducted to identify the two best performing alternatives to be used in the final alternatives analysis.

A.5.1 Alternatives Evaluated

In total eight alternatives were analyzed as part of this preliminary alternatives analysis. Figure A-20 shows the seven alternatives developed by MM in coordination with Lloyd, as well as the original alternative proposed by Lloyd. The alternatives are concentrated at two sites, seaward of the Croaker Hole complex (Lloyd – Alt. 2b), and a second set at a small cove south of Croaker Hole, where aerial examination shows existing seagrass, indicating the potential for favorable growing conditions (Alt. 3 – Alt. 5). A full summary of the alternatives modeling and results is discussed in Section A.5.2.

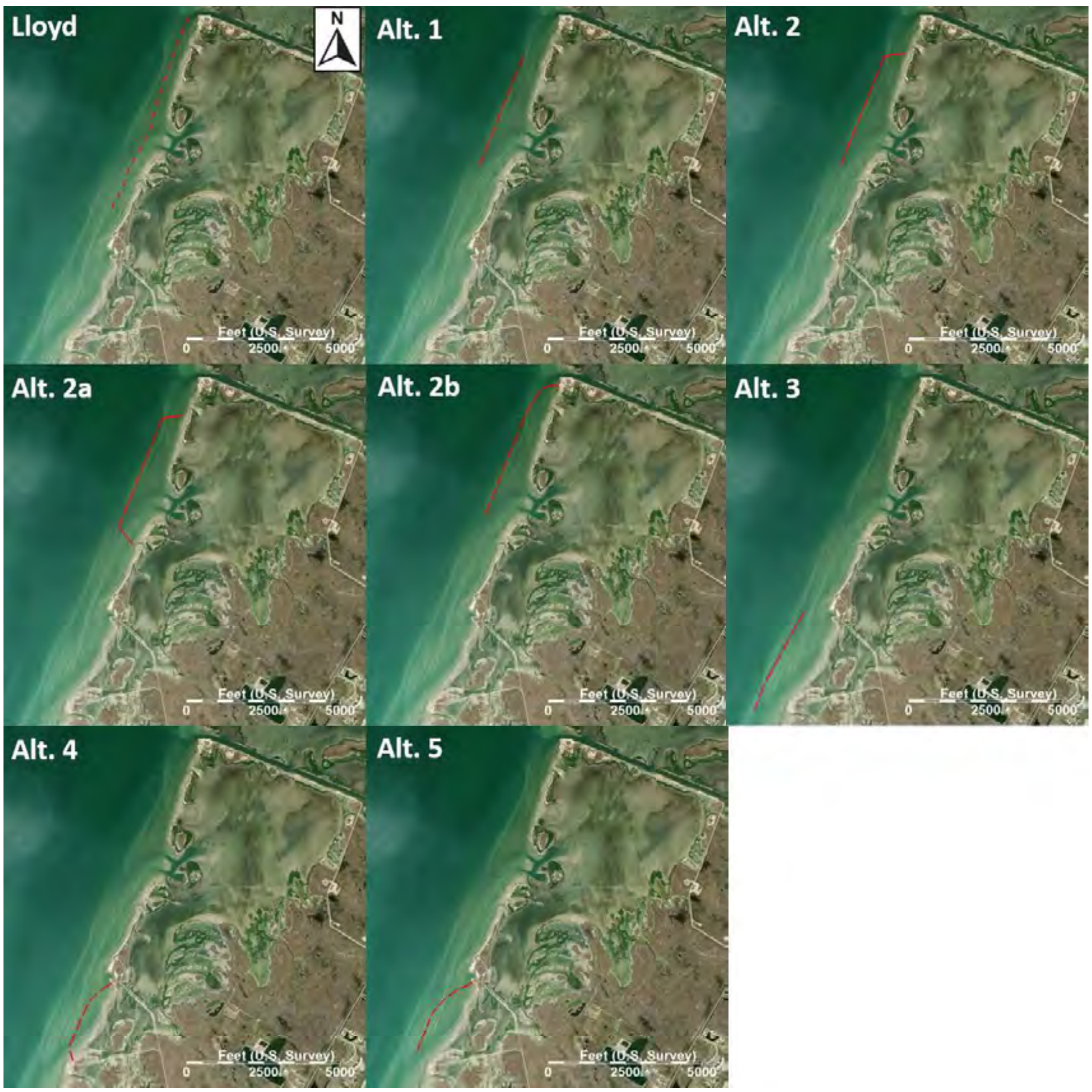

Figure A-20. Alternatives modeled during preliminary alternatives analysis.

A.5.2 Alternatives Analysis Results

The alternatives shown in Figure A-20 were all modeled for two separate month-long simulations. The modeled months were a high (January) and low (July) energy month. The model results were presented to Lloyd on December 9th, 2019 to aid in the selection of the final two alternatives which were modeled for a full year and further analyzed. The alternatives array presentation is shown in full in Appendix C. The model results were compared to determine which alternatives produced wave, current, and sediment transport, and mud transport conditions closest to those behind the Shamrock Island breakwaters in areas of known seagrass. The July simulation for southeasterly winds and mild conditions show little change for differentalternative scenarios. The January simulation showed significant differences between the alternatives. Results were extracted at a single extraction point placed at the 2.6-foot MSL depth contour for each alternative, as shown in Figure A-21. The 2.6-foot MSL contour for extraction points was chosen based on the observation that high seagrass concentration was present at similar contour at Shamrock Island.

Figure A-21. Extraction point locations (all at approx. 2.6-foot MSL depth) used for comparison.

To compare the current, wave, and suspended sediment distributions that occurred during the January simulation, box and whisker plots were developed for each parameter. Box and whisker plots show the median, upper and lower quartile, and any outliers. Figure A-22 shows the box and whisker plots for all alternatives measures for the January model results, as well as a graphic explaining how to read the box and whisker plots.

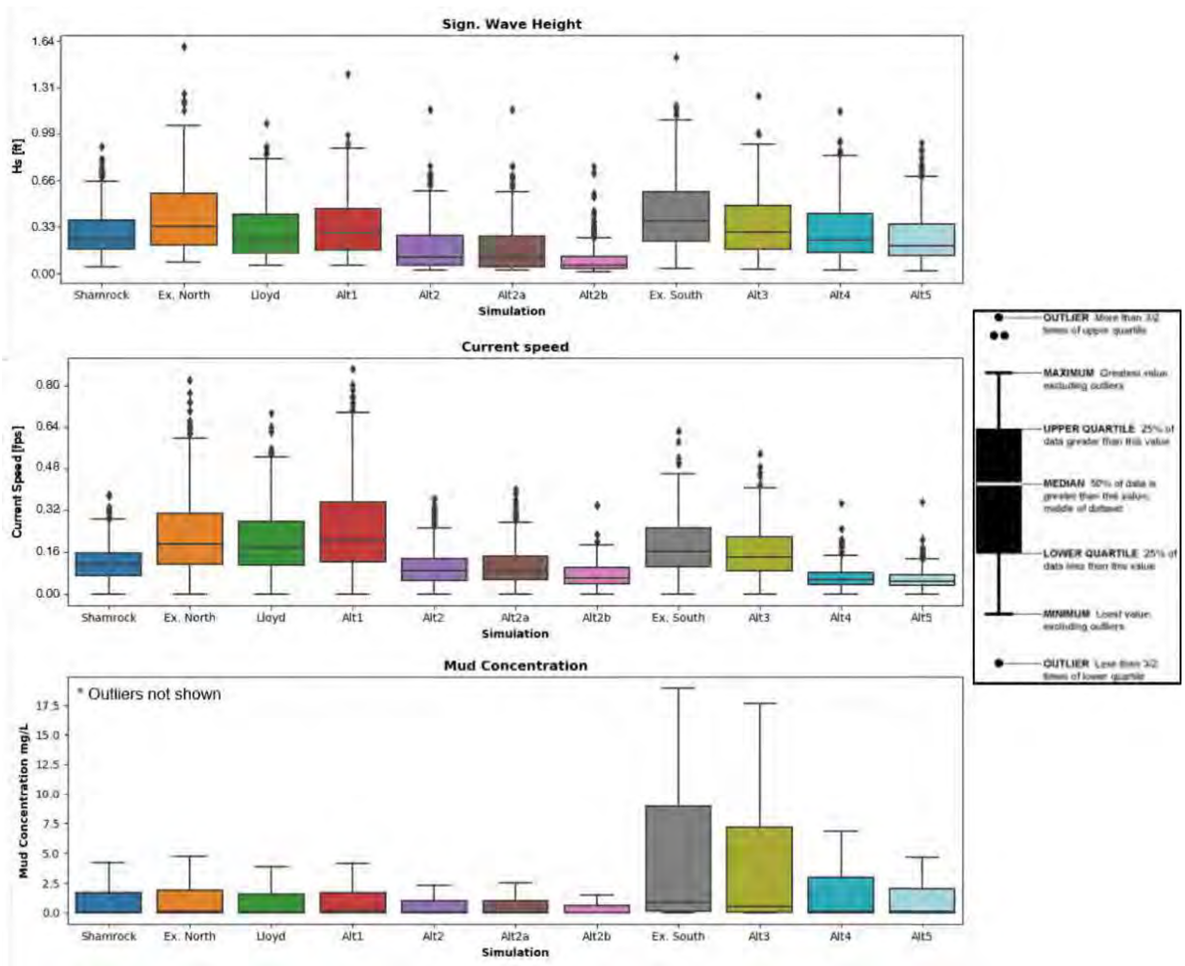

Figure A-22. Box and whisker plots for all alternatives for January simulation.

The results shown in Figure A-22 indicate a few key findings:

- Existing conditions at both the north and south extraction points show higher wave heights and current speeds than the Shamrock Island comparison site
- Alternatives with shore perpendicular structures show the greatest reduction in current speed from existing conditions (i.e. Alt 2, 2a, 2b and Alt 4-5).
- Total suspended sediment concentrations are slightly higher at the south site (Alternatives 3-5). However, since suspended sediment concentration is event-driven, a longer timeframe should be simulated to draw any definitive characteristics about TSS concentrations.

A list of pros and cons of each alternative was developed and is presented in Appendix C. Based on the observations listed above and the presentation shown in Appendix C, Alt 2B and Alt 5 were recommended by Mott MacDonald and were selected by Lloyd for yearlong simulations and further analysis. Section A.6 details the yearlong model results and analysis.

A.6 Final Alternatives Analysis

Modeling simulations for the full year of 2018 were conducted to analyze the effectiveness of the final two selected alternatives. Since seagrass growth is a complicated process with many influencing factors, an area of known seagrass at Shamrock Island was identified and used for comparison. Each modeled alternative was compared to the Shamrock Island site to assess its performance. Relevant hydrodynamic, wave, and morphological modeling parameters were extracted at both the project site and Shamrock Island for each modeled alternative to assess performance. Statistical plots were developed for each parameter to assess the distribution of conditions behind the proposed alternatives for a full representative year.

A.6.1 Hydrodynamic and Wind-Wave Results

Hydrodynamic and wave modeling was conducted for the full year of 2018. Figure A-23 and Figure A-24 show the median (50th percentile) and 95th percentile conditions for waves and currents, respectively. The median and 95th percentile conditions were calculated using the extraction points shown in Figure A-21 as reference, and do not necessarily correspond to the same timestep for Alt 2b and Alt 5.

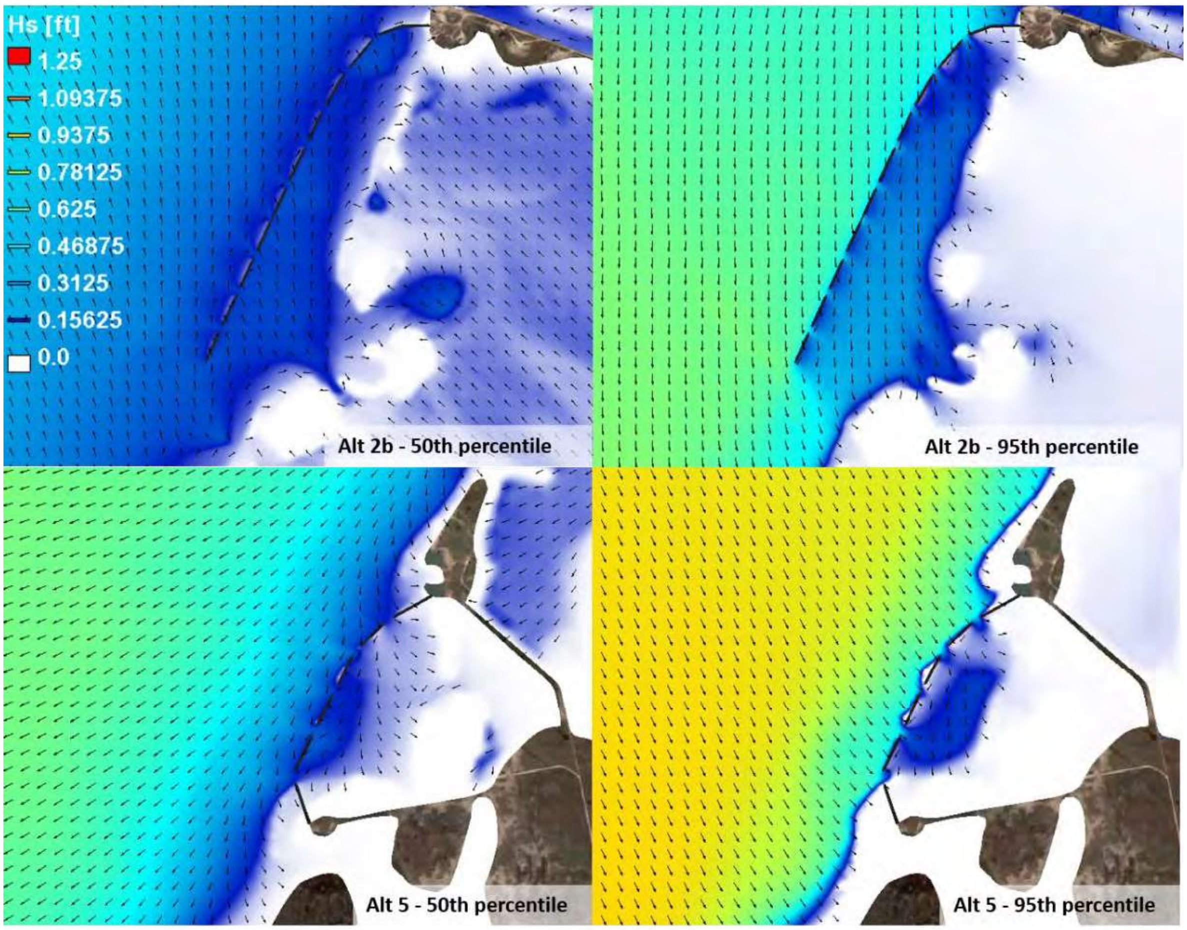

Figure A-23. Spatial results extract at timestep corresponding to median (50th percentile) and 95th percentile wave heights.

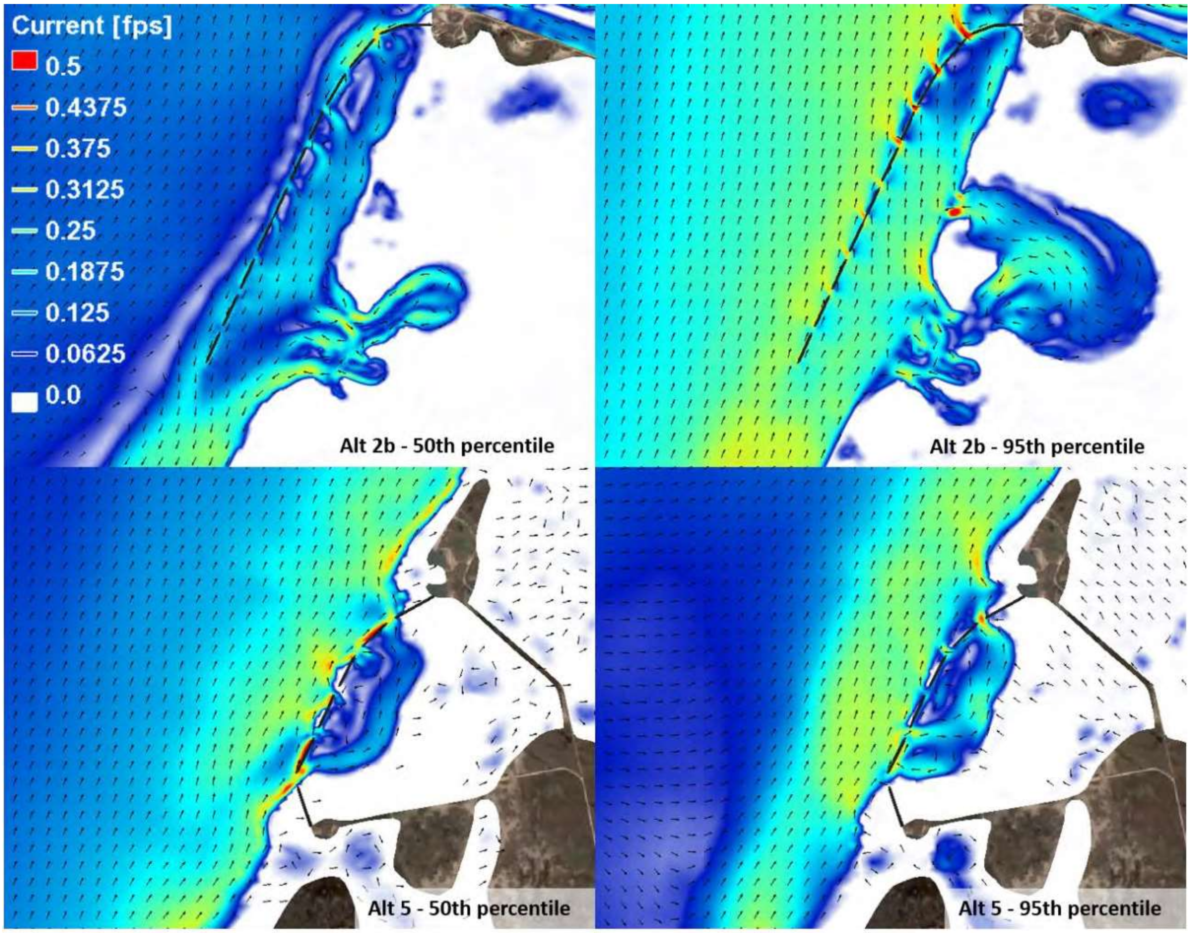

Figure A-24. Spatial results extract at timestep corresponding to the median (50th percentile) and 95th percentile current speeds.

These spatial figures illustrate a few key findings:

- Wave heights are significantly reduced by the proposed breakwaters at both Alternative locations.
- Current speeds behind Alt 2b are slightly higher than Alt 5. This is likely due to the lack of a southern shore perpendicular structure. During southerly (ebb) tidal flows, currents are unobstructed to the project site. However, note that as shown in Section 2.3 of the main report, current speeds behind Alt 2b are similar to those at Shamrock Island.

The spatial figures shown above, and the distributions of wave and current conditions shown in 2.3 of the main report illustrate the effectiveness of the alternatives in reducing wave and current conditions.

A.6.2 Morphology Modeling Results

Morphology modeling was conducted to determine the bedform changes due to sand transport, quantify any changes in longshore transport rates, analyze suspended solids concentrations, and determine any mud deposition behind the proposed structures. PNE curves of suspended sediment concentrations, and figures illustrating sand morphology and mud deposition are shown in Section 2.3 of the main report. Also shown in the main report are tables showing yearly changes in longshore transport rates. Analysis of existing conditions shows that longshore transport rates are primarily north to south. Longshore transport rates south of each structure are reduced compared to existing conditions, with a 5.7%

reduction in net transport for Alt 5 and a 13.9% reduction for Alt 2b. As Alt 5 is slightly set back in a cove it impedes the southerly moving longshore transport to a lesser extent when compared to Alt 2b which explains the lower reduction in downdrift longshore transport south of Alt 5.

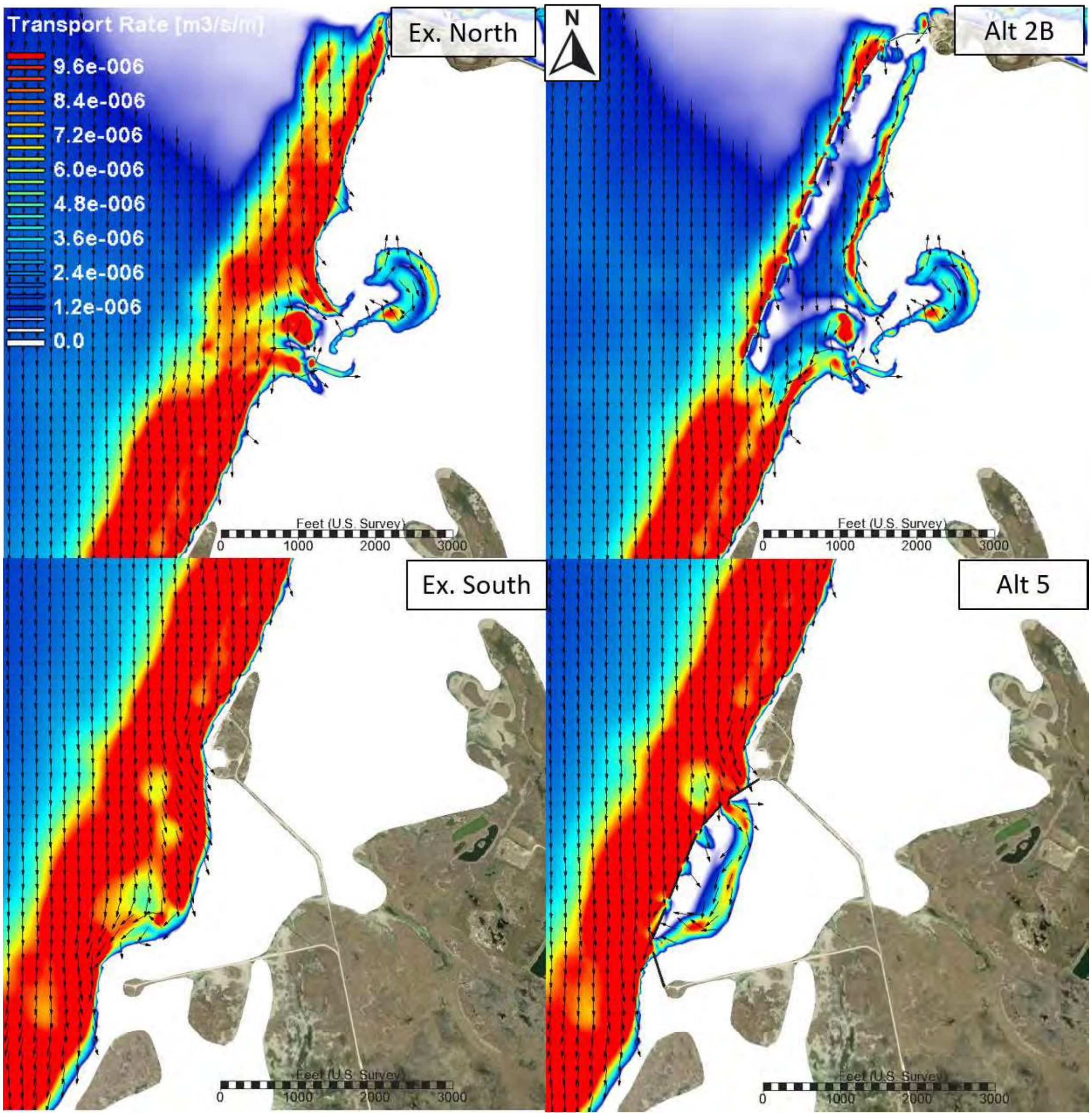

Figure A-25. Transport rate on Jan. 1 12:00, 2018 (high transport event).

Figure A-25 shows instantaneous longshore transport results for Alt 2b and Alt 5 for a high transport event, extracted from model results on January 1st, 2018 at 12:00 with winds coming from the northeast and longshore transport directed from the northeast to southwest. Note the reduced longshore transport rates along a longer section of shoreline for Alt 2b, compared to the smaller area of impact for Alt 5. This difference explains why the yearly longshore transport rate downdrift of Alt 5 is less impacted than Alt 2b.

A.7 References

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B. Probability of Non-Exceedance Tables

Table B-1. Water Surface Elevation Probability of Non-Exceedance

Probability of Non-Exceedance	Shamrock [ft NAVD88]	Ex. North [ft NAVD88]	Alt2b [ft NAVD88]	Ex. South [ft NAVD88]	Alt5 [ft NAVD88]
0.05	-0.54	-0.54	-0.55	-0.55	-0.55
0.1	-0.39	-0.39	-0.40	-0.40	-0.40
0.25	-0.14	-0.14	-0.14	-0.14	-0.14
0.5	0.15	0.14	0.14	0.14	0.14
0.75	0.41	0.41	0.41	0.42	0.42
0.9	0.67	0.67	0.67	0.68	0.68
0.95	0.85	0.84	0.85	0.85	0.85
0.99	1.20	1.19	1.20	1.20	1.20

Table B-2. Current Speed Probability of Non-Exceedance

Probability of Non-Exceedance	Shamrock [ft/s]	Ex. North [ft/s]	Alt2b [ft/s]	Ex. South [ft/s]	Alt5 [ft/s]
0.05	0.03	0.04	0.03	0.04	0.02
0.1	0.04	0.06	0.04	0.06	0.03
0.25	0.07	0.09	0.07	0.10	0.04
0.5	0.13	0.17	0.13	0.16	0.07
0.75	0.18	0.28	0.20	0.23	0.11
0.9	0.24	0.48	0.26	0.31	0.16
0.95	0.27	0.61	0.30	0.35	0.18
0.99	0.33	0.85	0.38	0.43	0.23

Table B-3. Wave Height Probability of Non-Exceedance

Probability of Non-Exceedance	Shamrock [ft]	Ex. North [ft]	Alt2b [ft]	Ex. South [ft]	Alt5 [ft]
0.05	0.08	0.04	0.04	0.04	0.02
0.1	0.09	0.06	0.05	0.05	0.03
0.25	0.12	0.10	0.07	0.11	0.07
0.5	0.18	0.17	0.12	0.23	0.18
0.75	0.29	0.36	0.27	0.42	0.30
0.9	0.46	0.64	0.49	0.67	0.46
0.95	0.58	0.77	0.60	0.82	0.56
0.99	0.73	0.98	0.81	1.04	0.72

Table B-4. Mud Concentration Probability of Non-Exceedance

Probability of Non-Exceedance	Shamrock [mg/L]	Ex. North [mg/L]	Alt2b [mg/L]	Ex. South [mg/L]	Alt5 [mg/L]
0.05	1.0E-12	8.1E-25	3.9E-25	3.4E-29	3.1E-23
0.1	3.3E-09	6.0E-19	2.7E-20	1.8E-22	4.8E-19
0.25	7.3E-05	7.2E-11	1.3E-11	3.9E-13	2.4E-11
0.5	1.1E-02	4.6E-04	4.7E-05	5.6E-04	4.7E-04
0.75	3.1E-01	9.4E-02	6.3E-02	4.5E-01	6.2E-02
0.9	2.5E+00	1.0E+00	1.1E+00	3.9E+00	9.8E-01
0.95	7.4E+00	4.1E+00	4.3E+00	1.3E+01	3.6E+00
0.99	4.3E+01	2.6E+01	2.1E+01	8.7E+01	1.9E+01