COASTAL TEXAS STUDY

Coastal Texas Protection and Restoration Feasibility Study

Final Feasibility Report

Appendix C-1:

Mitigation Plan

August 2021

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1.0 INTRODUCTION

The US Army Corps of Engineers (USACE) Galveston District, in partnership with Texas General Land Office have undertaken the Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study). The purpose of the Coastal Texas Study is to evaluate large-scale coastal storm risk management (CSRM) and ecosystem restoration (ER) alternatives aimed at providing the coastal communities of Texas with a comprehensive plan providing multiple lines of defense, functioning as a system, to reduce the risk of coastal storm damages to natural and built infrastructure along the Texas Coast.

In accordance with the mitigation framework established by Section 906 of the Water Resources Development Act (WRDA) of 1986 (33 US 2283), as amended by Section 2036 of WRDA 2007 and Section of the Water Resources Reform and Development Act (WRRDA) of 2014, the Council on Environmental Quality's (CEQ) National Environmental Policy Act (NEPA) regulations (40 CFR Sections 1502.14(f), 1502.16(h), and 1508.20) and Section C-3 of Engineering Regulation (ER) 1105-2-100, the USACE has prepared this mitigation plan to ensure that project-caused adverse impacts to ecological resources are avoided or minimized to the extent practicable, and that remaining, unavoidable impacts are compensated to the extent justified.

Mitigation planning is an integral part of the overall planning process. In order to evaluate appropriate mitigation needs and options, the type, location, and level of potential adverse ecological impacts are identified and documented in the feasibility report and Environmental Impact Statement (EIS). Practicable avoidance and minimization measures were considered, followed by an assessment of potential compensatory mitigation measure and a rough order of magnitude cost for those measures. This process included close coordination with Federal and State resource agencies.

It is important to note that this recommended mitigation plan will be further refined during the Tier Two NEPA analyses and it is fully anticipated that the mitigation site size, cost, and potentially even site location, if these sites are unavailable in 10-15 years, could be modified during subsequent planning phases. Therefore, the level of detail here is at a higher level than might be typically seen in other USACE mitigation plans. The intent of this plan is to provide a worst-case scenario cost-estimate, to confirm that sufficient mitigation exists in the areas to offset the worst-case scenario losses, and document the most likely avenues for mitigation, monitoring and adaptive management.

1.1 STUDY BACKGROUND

The Coastal Texas Study is following the Corps guideline of SMART Planning, with the exception of the cost of the study and time allotted. SMART Planning encourages risk-informed decision making and the appropriate levels of detail for conducting investigations, so that recommendations can be captured and succinctly documented and completed in a target goal of 3 years and for less than $3 million in compliance with the 3x3x3 rule. It reorients the planning process away from simply collecting data or completing tasks and refocuses it on doing the work required to reduce uncertainty to the point where the PDT can make an iterative sequence of planning decisions required to complete a quality study in full compliance with environmental laws and statutes. Because of the scale of the study area, complexity of the problems, and dual purpose scope (CSRM and ER), the study has an exemption for the time and money aspect, but has still maintained the risk-informed decision making aspect.

Also because of the uncertainty and complexity of a number of the potential solutions to the problems, the Study employs a tiered NEPA compliance approach, in accordance with the Council on Environmental Quality's (CEQ's) Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR 1500—1508, specifically 1502.20). Under this structure, rather than preparing a single definitive EIS as the basis for approving the entire project, the USACE will conduct two or more rounds – or "tiers" – of environmental review. For projects as large and complex as the Study, this approach has been found to better support disclosure of potential environmental impacts for the entire project at the initial phase. Subsequent NEPA documents are then able to present more thorough assessments of impacts and mitigation need as the proposed solutions are refined and more detailed information becomes available in future phases of the project. This tiered approach also provides for a timely response to issues that arise from specific, proposed actions and supports forward progress toward completion of the overall study.

A Tier One assessment analyzes the project on a broad scale, while taking into account the full range of potential effects to both the human and natural environments from potentially implementing proposed solutions. The purpose of the Tier One EIS is to present the information considered to selected a preferred alternative, describe the comprehensive list of measures, and identify data gaps and future plans to supplement the data needed to better understand the direct, indirect, and cumulative effects of the proposed solutions.

Once refinements and additional information is gathered, USACE will shift to a Tier Two assessment, which involves preparation of one or more additional NEPA documents (either an EIS or Environmental Assessment) that build off the original EIS to examine individual components of the Recommended Plan in greater detail. Whether an EIS or EA is developed will be dependent on the significance of impacts anticipated from the action. In either situation, Tier Two assessments will comply with CEQ Regulations, including providing for additional public review periods and resource agency coordination. The Tier Two document would disclose site specific impacts to the proposed solution and identify the avoidance, minimization, and compensatory mitigation efforts to lessen adverse effects.

1.2 RECOMMENDED PLAN

The Recommended Plan includes a combination of ER and CSRM features that function as a system to reduce the risk of coastal storm damages to natural and built infrastructure and to restore degraded coastal ecosystems through a comprehensive approach employing multiple lines of defense. Focused on redundancy and robustness, the proposed system provides increased resiliency along the Bay and is adaptable to future conditions, including relative sea level change. The Recommended Plan can be broken into three groupings: a Coastwide ER plan, a lower Texas coast CSRM plan, and an upper Texas coast CSRM plan.

Coastwide ER Plan: A Coastwide ER plan was formulated to restore degraded ecosystems that buffer communities and industry on the Texas coast from erosion, subsidence, and storm losses. A variety of measures have been developed for the study area, including construction of breakwaters, marsh restoration, island restoration, oyster reef restoration and creation, dune and beach restoration, and hydrologic reconnections. Figure 1 shows the location of the ER measures and the following describes what each measure includes:

- **G-28: Bolivar Peninsula and West Bay Gulf Intracoastal Waterway (GIWW) Shoreline and Island Protection**
    - Shoreline protection and restoration through the nourishment of 664 acres of eroding and degrading marshes and construction of 40.4 miles of breakwaters along unprotected segments of the GIWW on Bolivar Peninsula and along the north shore of West Bay,
    - Restoration of 326 acres (approximately 5 miles) of an island that protected the GIWW and mainland in West Bay, and
    - Addition of oyster cultch to encourage creation of 18.0 acres (26,280 linear feet) oyster reef on the bayside of the restored island in West Bay.
- **B-2: Follets Island Gulf Beach and Dune Restoration**
    - Restoration of 10.1 miles (1,113.8 acres) of beach and dune complex on Gulf shorelines of Follets Island in Brazoria County.
- **B-12: West Bay and Brazoria GIWW Shoreline Protection**
    - Shoreline protection and restoration through nourishment of 551 acres of eroding and degrading marshes and construction of about 40 miles breakwaters along unprotected segments of the GIWW in Brazoria County,
    - Construction of about 3.2 miles of rock breakwaters along western shorelines of West Bay and Cow Trap lakes, and
    - Addition of oyster cultch to encourage creation of 3,708 linear feet of oyster reef along the eastern shorelines of Oyster Lake
- **M-8: East Matagorda Bay Shoreline Protection**
    - Shoreline protection and restoration through the nourishment 236.5 acres of eroding and degrading marshes and construction of 12.4 miles of breakwaters along unprotected segments of the GIWW near Big Boggy National Wildlife Refuge (NWR) and eastward to the end of East Matagorda Bay,
    - Restoration of 96 acres (3.5 miles) of island that protects shorelines directly in front of Big Boggy NWR, and
    - Addition of oyster cultch to encourage creation of 3.7 miles of oyster reef along the bayside shorelines of the restored island.

- **CA-5: Keller Bay Restoration**
  - Construction of 3.8 miles of rock breakwaters along the shorelines of Keller Bay in order to protect submerged aquatic vegetation (SAV), and
  - Construction of 2.3 miles of oyster reef along the western shorelines of Sand Point in Lavaca Bay by installation of reef balls in nearshore waters.
- **CA-6: Powderhorn Shoreline Protection and Wetland Restoration**
  - Shoreline protection and restoration through the nourishment of 529 acres of eroding and degrading marshes and construction of 5.0 miles of breakwaters along shorelines fronting portions of Indianola, the Powderhorn Lake estuary, and Texas Parks and Wildlife Department (TPWD) Powderhorn Ranch.
- **SP-1: Redfish Bay Protection and Enhancement**
  - Construction of 7.4 miles of rock breakwaters along the unprotected segments of the GIWW along the backside of Redfish Bay and on the bayside of the restored islands
  - Restoration of 391.4 acres of islands including Dagger, Ransom, and Stedman islands in Redfish Bay, and
  - Addition of oyster cultch to encourage creation of 1.4 miles of oyster reef between the breakwaters and island complex to allow for additional protection of the Redfish Bay Complex and SAV.
- **W-3: Port Mansfield Channel, Island Rookery, and Hydrologic Restoration**
  - Restoration of the hydrologic connection between Brazos Santiago Pass and the Port Mansfield Channel by dredging 6.9 miles of the Port Mansfield Channel, providing 112,864.1 acres of hydrologic restoration in the Lower Laguna Madre,
  - 9.5 miles of beach nourishment along the Gulf shoreline north of the Port Mansfield Channel using beach quality sand from the dredging of Port Mansfield Channel, and
  - Protection and restoration of Mansfield Island with construction of a 0.7 mile rock breakwater and placement of sediment from the Port Mansfield Channel to create 27.8 acres of island surface at a n elevation of 7.5 feet (NAVD 88).

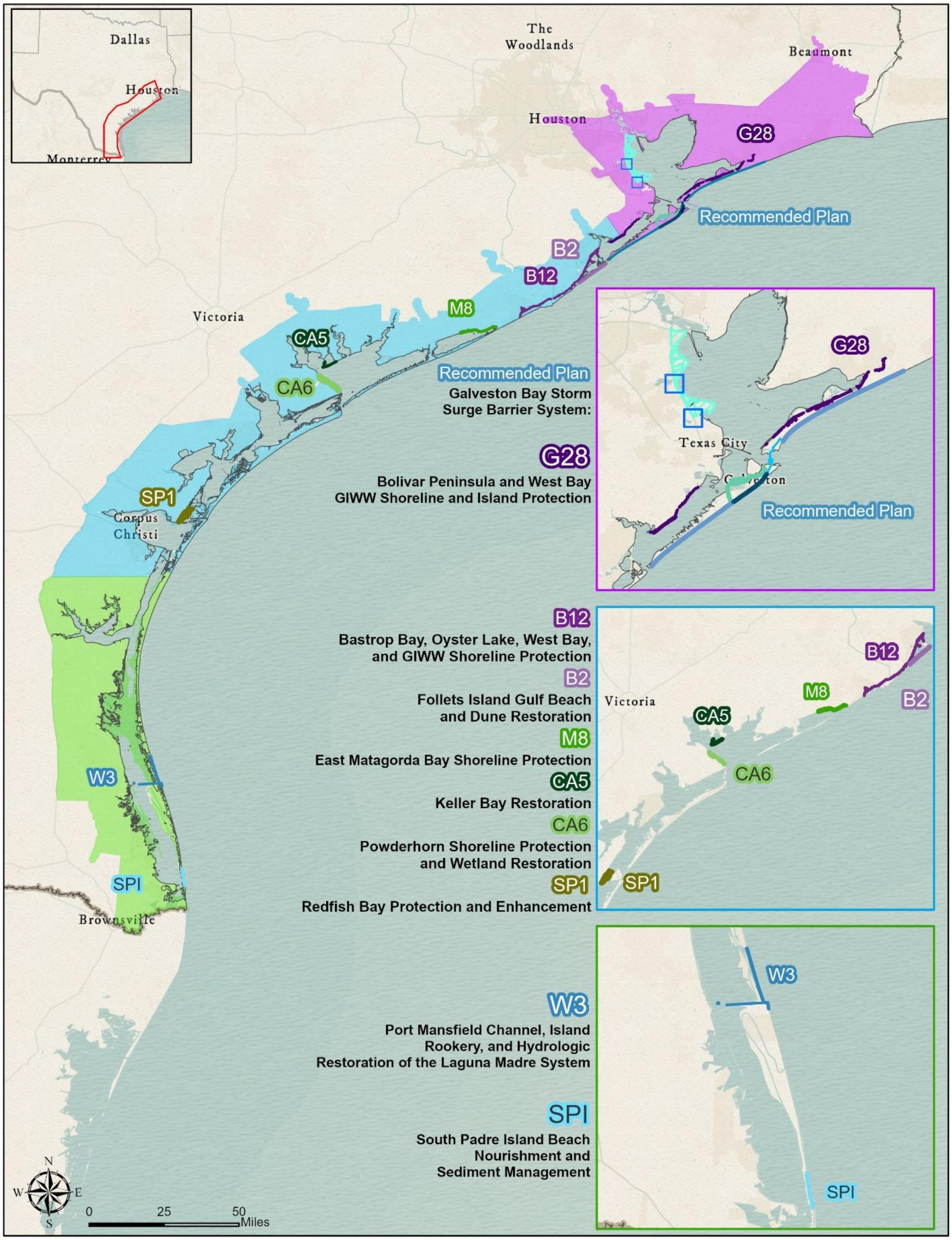

Figure 1. Recommended Plan

Lower Texas Coast Plan: The lower Texas coast component of the recommended plan includes 2.9 miles of beach nourishment at South Padre Island to be completed on a 10-year cycle for the authorized project life of 50 years (Figure 2).

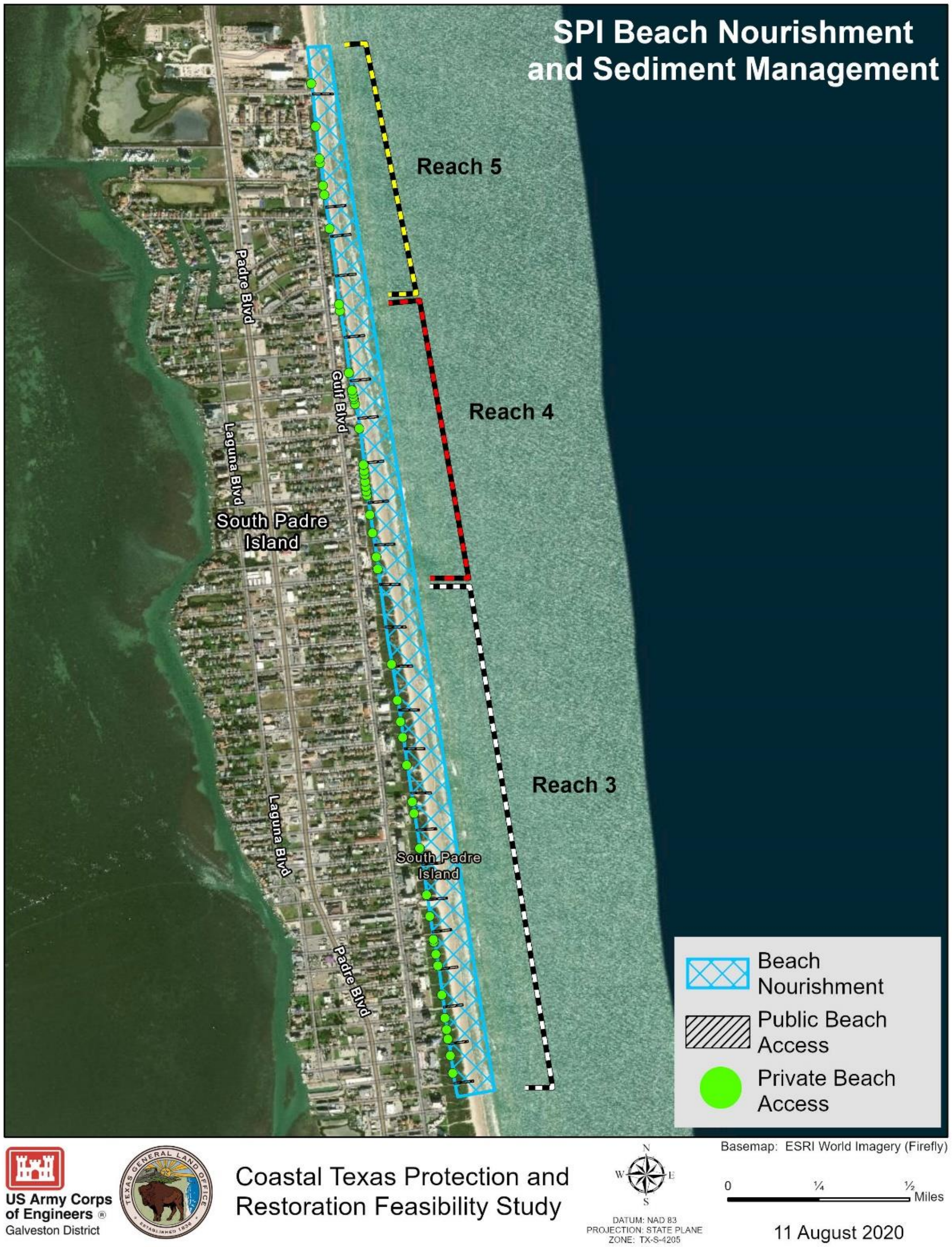

Figure 2. South Padre Island CSRM

Upper Texas Coast Plan: The upper Texas coast component of the recommended plan includes a multiple-lines-of-defense system known as the Galveston Bay Storm Surge Barrier System. The system is designed to provide a resilient, redundant, and robust solution to reduce risks to communities, industry, and natural ecosystems from coastal storm surge. The system includes a Gulf line of defense which separates the Galveston Bay system from the Gulf of Mexico to reduce storm surge volumes entering the Bay system. It also includes Bay defenses which enable the system to manage residual risk from waters already in Galveston Bay. Figure 3 shows the spatial relationship between the Gulf and Bay lines of defense. Measures which make up the system include:

- The Bolivar Roads Gate System, across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island (Figure 4);
- 43 miles of beach and dune improvements on Bolivar Peninsula and West Galveston Island that work with the Bolivar Roads Gate System to form a continuous line of defense against Gulf of Mexico surge, preventing or reducing storm surge volumes that would enter the Bay system (Figure 4);
- Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge (Figure 4);
- An 15.8-mile Galveston Ring Barrier System (GRBS) that impedes Bay waters from flooding neighborhoods, businesses, and critical health facilities within the City of Galveston;
- 2 surge gates on the west perimeter of Galveston Bay (at Clear Lake and Dickinson Bay) that reduce surge volumes that push into neighborhoods around the critical industrial facilities that line Galveston Bay; and
- Complementary nonstructural measures, such as home elevations or floodproofing, to further reduce Bay-surge risks along the western perimeter of Galveston Bay.

Within the recommended plan, it has been determined that several features, identified as “actionable” measures, have a sufficient level of site-specific detail to fully understand the context and intensity of the anticipated impacts of the feature. Therefore, the EIS has incorporated a site-specific Tier Two analysis for some features for which the measures would be fully compliant with NEPA and all environmental laws and regulations. Feature identified as “Tier One” measures will require separate independent NEPA analysis at which time additional more refined mitigation planning would occur to ensure unavoidable impacts are offset once the impacts are fully understood. Table 1 shows which measures are actionable and which are not.

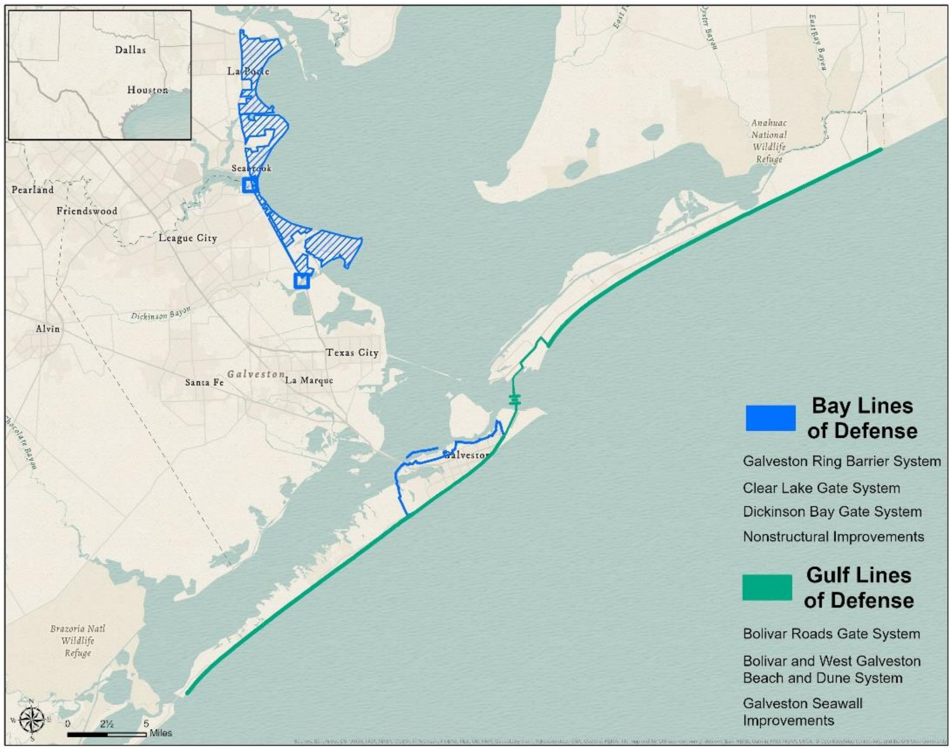

Figure 3. Galveston Bay Storm Surge Barrier System

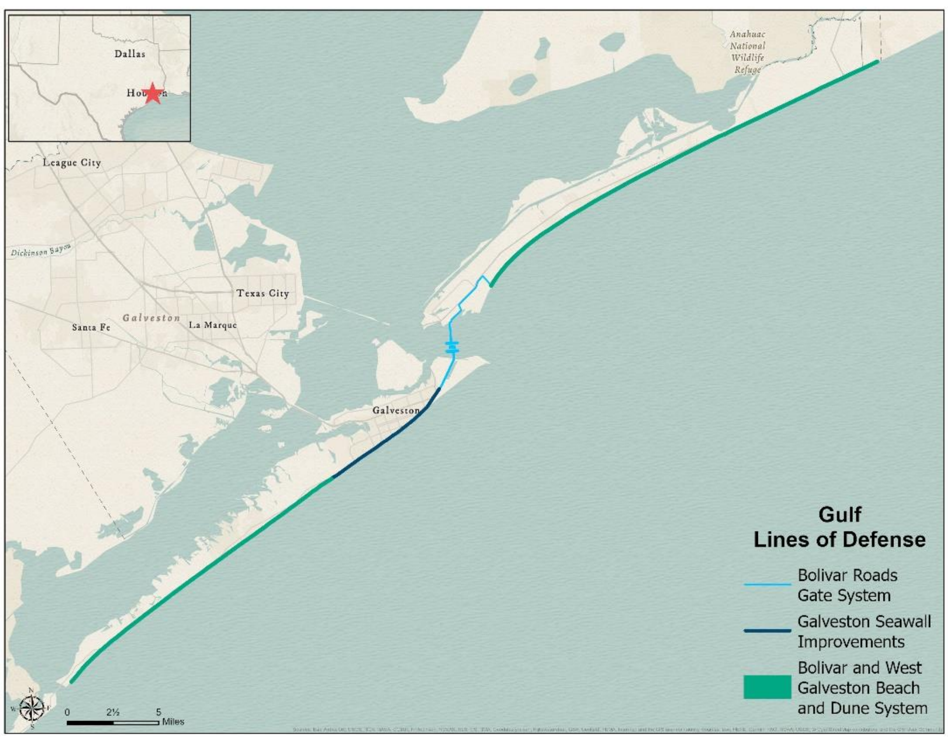

Figure 4. Gulf Lines of Defense of the Galveston Bay Storm Surge Barrier System

Table 1. Actionable and Tier One Measures of the Recommended Plan

Recommended Plan Component	Actionable*	Tier One+
G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	X	
B-2 – Follets Island Gulf Beach and Dune Restoration		X
B-12 – West Bay and Brazoria GIWW Shoreline Protection	X	
CA-5 – Keller Bay Restoration	X	
CA-6 – Powderhorn Shoreline Protection and Wetland Restoration	X	
M-8 – East Matagorda Bay Shoreline Protection	X	
SP-1 – Redfish Bay Protection and Enhancement	X	
W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration		X
South Padre Island Beach Nourishment and Sediment Management		X
Bolivar Roads Gate System		X
Bolivar and West Galveston Beach and Dune System		X
Galveston Seawall Improvements		X
Galveston Ring Barrier System		X
Clear Lake Gate System and Pump Station		X
Dickinson Bay Gate System and Pump Station		X
Nonstructural Improvements West Shore of Galveston Bay Nonstructural Measures		X

* Tier 2 NEPA, no additional NEPA anticipated

\+ Tier 1 NEPA, Requires additional NEPA and Mitigation Planning

2.0 IMPACT ASSESSMENT

Compensatory mitigation is required for unavoidable impacts to the environment that are caused by the recommended plan. The Coastwide ER features are being constructed with the intent of restoring, increasing, or creating higher quality habitats and to protect existing habitats from future degradation within the action areas. Therefore, no mitigation is required for any of the ER measures because they are not expected to cause a net loss in habitat. The South Padre Island Beach Nourishment is considered a CSRM feature but is employing a nature-based method of shoreline protection which enhances the existing habitat, so no unavoidable adverse impacts are expected from this measure. No mitigation is required for the actionable measures because they are all ER features.

However, implementation of the Galveston Bay Storm Surge Barrier System, is expected to have unavoidable adverse impacts. Impacted habitat types include estuarine emergent wetland, Palustrine emergent wetland, oyster reef and open bay bottom. The impacts to these habitats would result from direct loss and indirectly from anticipated changes in tidal flow.

The Study Team has worked to avoid and minimize environmental impacts throughout the feasibility phase. Input from the Interagency Team and public comments received during the 2018-2019 public comment period were considered in the identification of avoidance and minimize strategies. Examples of avoidance and minimization strategies that resulted in modification of recommended plan include the redesign of the Bolivar Peninsula and Galveston Island Levees to beach and dune systems and the redesign of the Bolivar Roads Gate System to reduce the permanent constriction from 28.5% to 9.5%.

To address reduced tidal flow into Galveston Bay from the proposed Bolivar Roads Gate System, the study team used Adaptive Hydraulics (AdH) modeling to predict any changes in the tidal prism and tidal amplitude and developed a spatial analysis using the NOAA Marsh Migration viewer outputs associated with a projected 1 ft. of rise in relative sea level. The study team addressed the permanent impacts to open bay bottom by the construction of the Bolivar Roads Gate System by working collaboratively with the resource agencies.

2.1 ECOLOGICAL MODELING FOR MITIGATION

This following discussion is a summary of the Ecological Modeling Appendix of the EIS (Appendix I). For more detailed information about each model and its application including detailed methodologies regarding cover types, cover type mapping, assumptions made for the applications of the models, and detailed results and spreadsheets, refer to the Ecological Modeling Appendix (Appendix I of the EIS).

2.1.1 Impact Assessment to Habitats Other Than Open Bay Bottom Habitat

An Interagency Team made up of state and federal natural resource agencies selected Habitat Evaluation Procedure (HEP) models to be used for this study. The team reviewed all USACE-certified species' models based on the range of each modeled species, existing and future cover types, and specific habitat requirements described by the models and selected from the certified lists. For cover types where no certified model would work, species model development was considered.

Initially, nine species models were identified as potentially applicable to identifying impacts. However, following further refinement during interagency workshops held in 2016 and 2017, the interagency team narrowed the selection to three certified HSI models which represent those species that were presumed to be the most responsive to the proposed CSRM actions due to the sensitivity of the variables and the life history requisites. The final list of HSI models used in assessing impacts includes Brown shrimp, American alligator, and American oyster. Each of the HEP models used are approved for regional or nationwide use in accordance with documented geographic range, best practices and its designed limitations. The ECO-PCX and the resource agencies support use of these models.

The following reasons support the final selection of each HSI model.

- **Brown Shrimp Model** (Turner and Brody, 1983) – Brown shrimp was selected to capture benefits to estuarine wetland and marsh. The HSI model variables were determined to be sensitive and responsive to marsh and wetland habitat restoration, and the model assumptions are consistent with USACE policy for habitat restoration.
- **American Alligator** (Newsom et al., 1987) – American alligator was selected to capture impacts to non-tidal palustrine wetland and marsh for analysis of the CSRM measures only. American alligator was removed from the ER model evaluation because the model application is limited to land tracts larger than 12 acres that are not isolated. All land tracts identified by the land cover datasets for the ER measures were less than 1 acre and were isolated. By consensus of the interagency team, the palustrine wetland and marsh cover types were merged with the estuarine cover type.
- **American Oyster** (Swannack et al., 2014) – The American oyster model is designed as a spatially explicit, grid-based model that calculates habitat suitability for restoration of oysters.

The NOAA C-CAP 2010 and Marsh Mitigation land cover datasets were used to evaluate and identify cover for each existing FWOP and FWP conditions for areas within the project footprint and areas indirectly affected beyond the footprint. These land cover datasets were determined to be the most applicable because they provide future conditions that incorporate migration of plant communities due to RSLR and allow for consistency and repeatability of the model evolutions. The Corps computed future rates of RSLR from years 2017 to 2085 for each of the four regions.

Each HEP model was associated with a cover type to evaluate the project-related benefits of ecosystem restoration on ecosystem resources within the project footprints.

Table 2 describes which cover type was applied to which model.

Table 2. Models used to conduct FWOP and FWP analyses

Model	Cover Type	Measure Location Where Model Applied
Brown Shrimp	Estuarine Wetland and Marsh	Bolivar Roads Gates, Galveston Ring Barrier, Dickinson Surge Gate, Clear Lake Surge Gate
American Alligator	Palustrine Wetlands	Bolivar Roads Gates, Galveston Ring Barrier
American Oyster	Oyster Reefs	Dickinson Surge Gate, Clear Lake Surge Gate

Following the completion of modeling for the CSRM measures, the net average annual habitat unit (AAHU) outputs were combined per CSRM alternative and were used to determine the mitigation requirements (net loss in AAHUs) based on projected changes in habitat. Table 3 below presents the net AAHU outputs and acres for all models within each CSRM measure.

Table 3. Net Change in AAHUs

Alternative	FWOP AAHUs	FWP AAHUs	Net Change in AAHUs	Acres (FWP 2085)
Tier 1 Measures				
Bolivar Roads Gate Structure (including Tie-Ins)	25,634	25,044	-590	38,696
Galveston Ring Barrier	44	7	-38	55
Dickson Bay Surge Gate	5	1	-4	8
Clear Lake Surge Gate	2.6	0.6	-2	4

2.1.2 Impact Assessment to Open Bay Bottom Habitat

Constructing and operating the Galveston Bay Storm Surge System would primarily impact open bay bottom habitat through loss of subtidal bay bottom habitat. This presented two challenges: how to determine the mitigation need and how to mitigate for open bay bottoms.

Challenge 1: Quantification of impacts to open bay bottom habitat are difficult because the subtidal bay bottom areas are part of a large and dynamic system for which no community-based models are available and species-specific models would only target specific habitats, not the whole system. As well, seasonal shifts in fauna and siltation further complicate selecting a species-specific model. The interagency team considered developing a model that would be better suited to quantifying open bay bottom impacts.

Challenge 2: The resource agencies and study team had significant concerns over how to mitigate for open bay bottom. Typically, the first mitigation technique considered to offset the loss is to identify low quality existing habitat and restore the habitat to increase the quality and gain lift. However, no low-quality open bay bottom habitat exists within a reasonable distance to the impact area to offset the loss (i.e. the quality of open bay bottom is consistent where present and can't be modified to create lift). The second most common mitigation technique would be to create habitat somewhere within a reasonable distance to the impact area. To create additional open bay bottom, other habitat types, such as oyster reefs, sea grass meadows, or salt marshes, would have to be converted to open bay bottom. This would result in losses to habitat types that are each substantially more productive, relatively scarce and considered significant habitats that would result in a net-loss of those habitat type that would then require mitigation for the mitigation. Terrestrial habitat could also be converted to open bay bottom, but there is concern that where terrestrial could be converted it would be too far inland to truly offset the loss and the new site would become part of an estuarine system rather than open bay system.

The interagency team worked through these challenges and identified a strategy to quantify the impacts and calculate commensurate mitigation. The team decided to use a meta-analysis developed by the National Marine Fisheries Service (NMFS) that they use to determine compensation for interim losses related to oil spills and other environmental impacts. A meta-analysis is a statistical technique that combines the results of several studies and pools them to estimate the ratio of average productivity between pairs of estuarine habitats across all three trophic levels (Peterson *et al*. 2007).

The team decided to assign a surrogate HSI score of 1.0 (optimal habitat) for open bay bottom, since all open bay bottom areas in Galveston Bay are consistent in quality and available models did not accurately reflect existing conditions of the overall system in Galveston Bay. As well, the team assumed that any location which was permanently converted to non-subtidal habitat (e.g. permanent structures and gate islands), was assumed to be a complete and permanent loss (i.e. HSI score of 0.0 or habitat not present). After the area of permanent loss was identified at each location, the HUs were calculated by multiplying the acreage by 1.0. This resulted in the total HUs/AAHUs under the existing and FWOP condition and the loss expected under the FWP condition (Table 4).

To these values, a ratio was applied to the number of open bay bottom HUs to determine the estimate of the equivalent oyster reef HUs. The ratio of average productivity across all three trophic levels between subtidal flat (open bay bottom) and oyster reef is estimated to be 8.9 to 1 (Peterson *et al.* 2008), meaning that 8.9 HUs for open bay bottom would be equal to one habitat unit of oyster reef. A total of 18.1 AAHUs of equivalent oyster reef would require mitigation (

Table 5).

Table 4. Net Change in AAHU to Open Bay Bottom

Measure	Existing/FWOP				FWP				Net Change (AAHU)
	Acres	HSI	HUs	AAHU*	Acres	HSI	HUs	AAHU	
Bolivar Roads Gate System	117.0	1.0	117.0	117.0	117.0	0.0	0.0	0.0	-117.0
Galveston Ring Barrier System	23.0	1.0	23.0	23.0	23.0	0.0	0.0	0.0	-23.0
Clear Lake Gate System	6.1	1.0	6.1	6.1	6.1	0.0	0.0	0.0	-6.1
Dickinson Bayou Gate System	15.5	1.0	15.5	15.5	15.5	0.0	0.0	0.0	-15.5
Total				**161.6**				**0.00**	**-161.6**

* HUs remain the same in all TYs; therefore, the AAHU is the same as the HU.

Table 5. Results of without project condition habitat unit conversion for Open Bay Bottom without project

Measure	Open Bay Bottom Loss (Net AAHU)	Conversion Ratio (Open Bay Bottom : Oyster Reef)	Equivalent Oyster Reef (Net AAHU)
Bolivar Roads Gate System	-117.0	8.9:1	-13.1
Galveston Ring Barrier System	-23.0	8.9:1	-2.6
Clear Lake Gate System	-6.1	8.9:1	-0.7
Dickinson Bayou Gate System	-15.5	8.9:1	-1.7
Total:	**-161.6**		**-18.1**

2.2 MITIGATION NEED

Compensatory mitigation is required for unavoidable impacts to the environment that are caused by the recommended plan. No mitigation is required for any of the ER measures, the South Padre Island Beach Nourishment or the Bolivar Peninsula and West Galveston Island Beach and Dune Improvements because no net loss in AAHUs is expected.

Implementation of the Bolivar Roads Gate Structure, Galveston Ring Barrier, Dickson Bay Surge Gate, and Clear Lake Surge Gate are expected to have unavoidable adverse impacts to various habitats as indicated by a net loss in AAHUs. Impacted habitat types are estuarine emergent wetland, palustrine emergent wetland, oyster reef and open bay bottom (Table 6).

Table 6. Impacts from Implementing the Storm Surge Barrier System

Impact	Acres	AAHUs
Direct		
Palustrine Wetlands	128.0	-20.8
Estuarine Wetlands	134.0	-59.9
Open Bay Bottom	161.6	-18.1
Oyster	6.0	-2.8
Total Direct Impacts	429.6	-101.6
Indirect		
Tidal Prism Change	1,148.0	-788.3
Total Indirect Impacts	1,148.0	-788.3
Total Impacts	1,577.6	-880.9

3.0 WETLAND MITIGATION PLANNING

3.1 MITIGATION OBJECTIVE

The primary objective of the wetland mitigation plan is to replace the significant net losses of estuarine and palustrine wetland function and services that would be impacted directly or indirectly during construction or long-term operation of the Galveston Bay Storm Surge Barrier System.

3.2 FORMULATION OF MITIGATION MEASURES

USACE and an interagency resource team made up of biologists, hydrologists, engineers, and planners from Texas Parks and Wildlife Department (TWPD), National Marine Fisheries Service, U.S. Fish and Wildlife Service (USFWS), Texas General Land Office (GLO), Natural Resource Conservation Service (NRCS), U.S. Environmental Protection Agency (EPA), Texas Water Development Board (TWDB) and others met numerous times to identify types of mitigation measures and alternatives, agree on specific locations where these mitigation alternatives could be located, discuss assumptions underlying the mitigation benefits, and select an evaluation array of mitigation alternatives.

3.2.1 Measure Identification

The team identified a total of five potential methods of wetland mitigation (Table 7), but only carried off-site wetland restoration forward for further consideration. The identified measures would apply to estuarine or palustrine wetlands.

3.2.2 Site Selection

Once it was determined that off-site wetland mitigation would be the recommend method of mitigation, the same interagency team met to identify potential wetland restoration sites. The initial array of sites were identified from recommended wetland restoration sites identified in the Texas Coastal Resiliency Master Plan and areas previously identified as a suitable location for Beneficial Use of Dredge Material as part of the Houston Ship Channel's expansion project. A total of 65 sites were initially identified. The team came up with several screening criteria to identify the final array of potential restoration sites. The screening criteria included:

General Screening Criteria

- Distance from the impact that is requiring mitigation (e.g. impacts from the Dickinson Surge Gate should be mitigated in close proximity to that site)
- Property Ownership: Ideally the target restoration area would be owned and managed by a state, federal, or special interest entity with established upland protections. The areas should be prioritized by conservation areas, national wildlife management areas, followed by wildlife management areas.

Table 7. Measures Considered to Mitigate for Wetland Losses

Measure	Description	Carried Forward	Rationale
Mitigation Bank Credits	Purchase wetland mitigation credits from an approved mitigation bank.	No	Mitigation banking sites in the service area are mainland sites and have banking instruments that specifically state that using their credits to mitigate barrier island impacts would be considered out-of-kind mitigation. This was deemed unacceptable by the resource agencies as the credits wouldn't mitigate in or near the action area or for the same kinds of functions lost. Additionally, out-of-kind mitigation is typically a last resort mitigation measure when no other options are available.
On Site Wetland Restoration	Re-establish wetlands with the goal of returning natural or historic functions and characteristics to former or degraded wetlands within the impact area.	No	Restoring wetlands within the impact area would not be feasible because the area would be permanently converted to a hardened structure or is required for operation of the structures. Attempts to restore wetlands lost due to tidal amplitude changes would fail due to the lack of hydrologic connection necessary to sustain them and not options are available to restore the hydrologic connection.
Off-Site Wetland Restoration	Re-establish wetlands with the goal of returning natural or historic functions and characteristics to a former or degraded wetlands outside of the area of loss.	Yes	Areas of degraded historic wetland occur near the impact area.
Wetland Creation	Development of a wetland where a wetland did not previously exist through manipulation of the physical, chemical and/or biological characteristics of the site.	No	All areas along the coast were historically wetlands, so areas where wetlands did not previously exist would be far removed from the impact area and not meet the objective of mitigation.
Wetland Preservation	Permanently protect ecologically important wetlands through the implementation of appropriate legal and physical mechanisms (e.g. conservation easements, title transfers, etc.)	No	High quality wetland sites near the impact areas are currently manage by state, federal, or special interest groups and would be protected from loss under their management plans.

- Prioritize areas where the mitigation site would have synergistic effects with existing, ongoing, or likely to be implemented projects where ecosystem-level/landscape scale benefits can be achieved (e.g. reduce fragmentation).
- Ability to restore a self-sustaining wetland site.
- Avoid any areas with Hazardous, Toxic, Radioactive Waste concerns (e.g. CERCLA sites, EPA or state-identified sites that require clean-up)

Estuarine Wetland Sites

- Prioritize sites within Galveston Bay
- Prioritize sites within 3 miles of a sediment source (e.g. material from a dredging project, mining upland placement area, borrow source)
- Prioritize areas that can beneficially use dredged material from a maintenance dredging project or a new work dredging project
- Ideally, the minimum site size should be at least 200 acres, unless other compelling reasons indicate otherwise (e.g. synergy or nearby site protections are exceptional, substantial lift can be gained compared to other sites)

Palustrine Wetland Sites

- Prioritize sites scaled down from larger conservation projects in the GLO Master Plan that incorporate freshwater marsh
- Availability of fill material
- Ideally, the minimum site size should be at least 200 acres, unless other compelling reasons indicate otherwise (e.g. synergy or nearby site protections are exceptional, substantial lift can be gained compared to other sites)

Based on these criteria, the interagency team narrowed the potential mitigation sites down to five estuarine wetland sites and two palustrine sites (Table 8). Each of these sites have been determined to meet most of the screening criteria and are acceptable to the resource agencies as a way to mitigate the losses.

Additionally, these sites are deemed to be cost-effective because it is unlikely that a lesser-cost site could be identified given that most of the criteria for selection directly relate to the cost to implement, even if that was not the intended purpose. For example, limiting a measure site to within 3 miles of a sediment source reduces the overall cost of the construction as compared to a site that would require pumping sediment a greater distance (i.e. greater pumping distance = higher costs). Another example is the criteria to select sites that are at least 200 acres. While there are several smaller sites that could be identified for mitigation, in order to meet the mitigation need the cumulative cost of purchasing land from multiple landowners, implementing multiple relatively small scale construction contracts, and long-term operation of multiple sites would be greater than the overall cost of constructing and operating one larger site.

Table 8. Final Array of Wetland Mitigation Sites

Mitigation Site	Description	Acres	Mitigation For
Estuarine Wetlands			
Sievers Cove	Establish a minimum of 667 acres of tidal marsh that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The marsh would be established by pumping shoaled material from the GIWW, the HSC, or using material from the Coastal Texas Project.	667	Bolivar Roads Gate System (Direct and Indirect Impact)
Greens Lake	Establish a minimum of 562 acres of tidal marsh that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The marsh would be established by pumping shoaled material from the GIWW or the Hitchcock/Highland Bayou Diversionary Canal.	562	Bolivar Roads Gate System (Indirect Impact)
Horseshoe Lake Site 1	Restore tidal marsh that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The marsh would be established by pumping shoaled material from the GIWW, the HSC, or using material from the Coastal Texas Project.	25	Bolivar Roads Gate System (Direct Impact)
Horseshoe Lake Site 2		27	
Horseshoe Lake Site 3		10	
Seabrook	Establish a minimum of 4 acres of tidal marsh that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The marsh would be established by pumping shoaled material from the Clear Creek Channel, the HSC, or using material from the Coastal Texas Project.	4	Clear Lake Surge Gate (Direct Impact)
Dickinson Bayou	Establish a minimum of 7 acres of tidal marsh that is comprised of 80% *Spartina alterniflora* stands and 20% open water. The marsh would be established by pumping shoaled material from the Dickinson Bayou, the HSC, or using material from the Coastal Texas Project.	7	Dickinson Surge Gate (Direct Impact)
Palustrine Wetlands			
Marquette	Restore 34.2 acres of dunal swale wetlands and 127.6 native prairie vegetation by excavating material where necessary to bring them to within 1-foot of the winter water table.	161.8	Galveston Island Ring Barrier (Direct Impacts)

Figure 5. Potential Mitigation Sites

3.2.3 Determination of Potential Mitigation Lift

To ensure that the mitigation plan would adequately compensate for wetland losses, the USACE worked with interagency team to determine Habitat Units (HUs) using Habitat Evaluation Procedures (HEP) methodology and comparing average annual benefits of the mitigation project (stated in terms of Average Annual Habitat Units [AAHU]) to determine the functional value of the site. The value of the mitigation site in the future without restoration was calculated and compared to the value of the site with restoration. The difference is the net gain, or lift, in functional value that can be achieved if restoration is completed. The amount of lift for each of the mitigation sites must be equal to or greater than the mitigation need. The same HSI models, along with the same assumptions applied to the ecosystem restoration features were used to calculate the lift of the site (see Appendix I of the EIS for more details on the ER assumptions and methodology).

The mitigation need for estuarine wetlands associated with direct and indirect impacts is 848.2 AAHUs and the mitigation need for palustrine wetlands associated with direct impacts is 20.8 AAHUs. As can be seen in Table 9, sufficient mitigation (876.2 AAHUs at estuarine wetland sites and 20.8 AAHUs at the palustrine wetland site) is available in the preferred mitigation sites to fully compensate for the loss of wetland function and value as a result of implementing the Galveston Island Storm Surge Barrier System. Because additional refinement to the design of the structures is required, the impacts are not fully known at this time. Additional impact analysis and subsequent mitigation planning will be required to fully understand the extent of unavoidable losses. At that time, a cost-effective incremental cost analysis (CE/ICA) would be completed to determine the most cost-effective array of mitigation sites, which would also include scaling the restoration efforts at each site to not overcompensate for the wetland losses (i.e. the sites would be scaled down to meet the mitigation need rather than completing restoration efforts above the identified need).

Table 9. Potential Lift (Net Change in AAHUs) that Can Be Gained at Each Mitigation Site

Mitigation Location	Site AAHUs	Acreage
Estuarine	**876.2**	**1,299**
Horseshoe Lake Site 1-3 (Direct Impacts)	37.6	62.0
Sievers Cove (Direct and Indirect Impacts)	491.8	667.0
Greens Lake (Indirect Impacts)	340.7	562.0
Clear Lake (Direct Impacts)	2.1	3.0
Dickinson Bayou (Direct Impacts)	4.0	6.0
Palustrine	**20.8**	**32.0**
Marquette (Direct Impacts)	20.8	32.0

3.2.4 Costs of Mitigation

The two wetland mitigation types were costed with the following assumptions:

Estuarine Wetland: There are a total of seven (7) locations ranging in size from 4 to 667-acre sites. The sites would be constructed with dredge material from the Bolivar Roads crossing. Included in the cost estimate are the following: temporary containment berms and drainage structures to reach a final elevation of +0.7 to +1.1 NAVD 88 GEOID 09) with 20% open water and initial spartina seeding. In Target Year (TY) 4-5, re-seeding Spartina; TY 5 creating sinuous circulation channels and ponds using marsh buggies to compress soil; and TY6 re-seeding/planting 10% of spartina.

Palustrine Wetland: This site is located on Galveston Island and consists of restoring dunal swale wetlands by excavating material where necessary to bring it within 1-foot of the winter water table. Each tract would need a piezometer installed and monitored for a minimum of two (2) years to establish seasonal water tables. The area would be treated with prescribed burns to remove invasive vegetation and would be replanted with locally sourced wetland and prairie plant.

The total cost of wetland mitigation, including contingency, adaptive management and monitoring, is estimated at $40,309,000 (Table 10Table 22). The non-Federal sponsor would be responsible for acquiring the lands, easements, and rights-of-ways required for construction and long-term operation of each mitigation site. The construction costs would be cost shared in the same manner as other project construction costs. However, long-term operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) of each mitigation site would be the responsibility of the non-federal sponsor. OMRR&R is not anticipated since each site is designed to be self-sustaining and adaptive management would address any deficiencies that are preventing the site from achieving ecological success. Only in an extreme unforeseen instance, such as by a natural disaster, where the site is degraded after ecological success has been determined would OMRR&R be required. There is no way to potentially predict if or what type of OMRR&R may be required and is therefore not included in the cost estimates.

Table 10. Estimated Cost of Wetland Mitigation by Site

Site	Estimated Cost ($1,000s)
Estuarine Wetlands	
Sievers Cove	$23,017
Greens Lake	$5,663
Horseshoe Lake Site 1-3	$8,385
Seabrook	$794
Dickinson Bayou	$1,050
Total	$38,909
Palustrine Wetlands	
Marquette	$1,400
Total	$1,400
Total	**$40,309**

3.3 ESTUARINE WETLANDS WORK PLAN

The following work plan is a generalized plan that would apply to all of the mitigation sites and is lacking site-specific specificity such as design heights, widths, lengths. A more detailed work plan would be developed during the Tier 2 analyses and a very detailed work plan would be finalized during PED.

3.3.1 Design and Construction

The following are general elements of the mitigation plan to implement the proposed mitigation method:

- **Geographic boundaries of the project**: Mitigation will require consideration of additional or less acreage within the vicinity of these sites as needed to accommodate the final mitigation amount to be determined during the Tier 2 analyses. The specific configuration and footprint of the mitigation sites would be further refined during PED after further consideration of detailed local site conditions such as local hydrology and geomorphology, presence/absence of natural wetland soils, historic wetland occurrence, and Wetland creation and enhancement sites would be coordinated with resource agencies to determine the most desirable arrangement and location at or around these sites.
- **Construction Methods:** Proposed mitigation would be to place dredged material into open water areas of the mitigation sites to increase the elevation of the marsh platform to an elevation consistent with a reference site marsh nearby. Where necessary, small

ponds and sinuous, interconnected channels would be created to maintain tidal connectivity and increase marsh edge.

- **Placement of Material:** Temporary containment levels would be constructed around the placement site to limit sediment movement onto adjacent marsh areas. Marsh would be constructed by pumping dredged material through a hydraulic pipeline into the restoration area allowing unconfined flow over larger areas to settle at the discharge location and fine-grained sediment to winnow through fringing marsh. Frequent pipe movement to prevent the accumulation of unsuitably high elevations of material will be necessary to obtain the appropriate marsh elevations and maintain varied topographic relief. The varied topography would allow for difference in duration of tidal inundation, create different vegetative communities, and maximize biodiversity.

- **Vegetation Establishment:** Seed of desired vegetation species would be collected from a reference site or from the degraded marsh areas prior to placement of material. Once placement of material has occurred, the collected see would be spread over areas susceptible to erosion and along the perimeter of the restored site. Interior marshes would naturally reestablish with seed source from the planted seeds.

- **Timing and Sequence:** The work plan would be enacted prior to or concurrent with construction of the surge barrier gates. The specific timing of the restoration efforts would be dependent on when the source material would be available. Wetland creation and enhancement would be completed within a few months to a couple of years of beginning construction at the mitigation site depending on the size of the site.

Construction details for the elements of the mitigation work plan will be developed during PED as part of the development of plans and specifications for procurement of services to construct the proposed mitigation. Final design dimensions and construction specifications will be shared and coordinated with TPWD, USFWS, NRCS and other resource agencies as needed.

3.3.2 Monitoring and Ecological Success

The estuarine wetland mitigation goal is restore estuarine marshes to similar ecological processes and function of natural marshes to the maximum extent practicable in order to maintain and provide valuable ecosystem services and functions. Ecological success will be measured by:

1. Marsh elevation in restored marsh restoration units (following de-watering and settlement) is sufficient to support healthy marsh (typically between +1.2 and +2.2 MSL [local datum]).

2. Average cover of 80% desirable vegetation on marsh restoration sites with less than 5% of the cover comprised of invasive, noxious, and/or exotic plant species.

3.3.3 Monitoring Plan

The monitoring plan for estuarine wetland mitigation is likely to follow the same monitoring protocols as specified for marsh restoration in Appendix K of the EIS. A brief summary of the methodology follows; however, Appendix K should be referenced for more specific details.

Monitoring of each mitigation site would occur pre-construction and again at TY1, TY2, TY3, TY5, TY10 and TY20. Monitoring efforts would focus on collecting data that would show the site is on a trajectory toward ecological success or that ecological success has been met. Monitoring would continue at a minimum until ecological success is achieved and again at least one additional time in the future (about 10 years) after ecological success is achieved to ensure continued success.

During each monitoring period, vegetation sampling would occur on a subset of the mitigation site. Sampling would be achieved by completing transects in the spring at the peak of the growing season using the same transects as previous years. Each vegetative species encountered and the percent canopy cover would be recorded. Photographs at each transect would also be taken to document conditions.

Marsh elevation monitoring can be performed in a number of ways and during future development of the work plans, the most appropriate method for the site would be selected. Potential monitoring methods include: LiDAR topographic surveys, establishment of rod-surface elevation table points (RSET), or GPS transect surveys. The intent of the monitoring is to confirm target elevations are being achieved. For purposes of this plan, LiDAR topographic surveys (to capture elevation across all acres) and GPS transect survey (to ground truth LiDAR data and recognize any changes across the transect between years) methodologies are assumed for Sievers Cove, Greens, and Horseshoe 1-3 mitigation sites. However, Seabrook and Dickinson Bayou are assumed to not require LiDAR flights and will only utilize GPS transect because one person with a GPS can complete transects across the 5 acres to gain the same elevational data without the LiDAR cost. Note: The cost per acre for LiDAR flights increase as the amount of area to survey goes down, due to required set-up costs that are assumed to be the same price whether a few acres or several thousand.

The cost of monitoring for all mitigation of each CSRM feature is shown in Table 11 and the specific monitoring costs for each mitigation site are shown in Table 12.

Table 11. Estimated Monitoring Costs by CSRM Feature

CSRM Feature	Mitigation Project Costs	Annual Monitoring Cost	Total Monitoring Cost	Percent of Project Costs
Bolivar Roads Gate System	$37,035,000	$42,105	$184,275	0.5%
Clear Lake Gate	$794,000	$1,080	$8,280	1.0%
Dickinson Gate	$1,050,000	$1,080	$8,280	0.8%
Total	**$38,879,000.00**	**$44,265.00**	**$200,835.00**	**0.5%**

Table 12. Estimated Costs of Monitoring per Mitigation Site

Parameter	Methodology	#Transects/ Sampling Points	Monitoring Frequency	Estimated Cost/Survey	Estimated Total Cost
Bolivar Roads Gate System					
Sievers Cove – 667 acres					
Elevation	LiDAR	667 ac	Yr 1, 3, 6 (3 flights)	$16,675	$50,025
Vegetation/ Elevation	Transects	7 transects	Annually (10 surveys)	$3,600	$36,000
			Total Monitoring Cost	$20,275.00	$86,025.00
Greens – 562 acres					
Elevation	LiDAR	562 ac	Yr 1, 3, 6 (3 flights)	$14,050	$42,150
Vegetation/ Elevation	Transects	5 transects	Annually (10 surveys)	$2,880	$28,800
			Total Monitoring Cost	$16,930.00	$70,950.00
Horseshoe Lake 1-3 – 62 acres					
Elevation	LiDAR	62 ac	Yr 1, 3, 6 (3 flights)	$3,100	$9300
Vegetation/ Elevation	Transects	3 transects	Annually (10 surveys)	$1,800	$18,000
			Total Monitoring Cost	$4,900.00	$27,300.00
Clear Lake Surge Gate					
Seabrook – 4 acres					
Elevation	Transects	4 transects	Yr 1, 3, 6 (3 surveys)	$360	$1,080
Vegetation	Transects	1 transect	Annually (10 surveys)	$720	$7,200
			Total Monitoring Cost	$1080.00	$8,280.00
Dickinson Bay Surge Gate					
Dickinson Bayou – 5 acres					
Elevation	Transects	4 transects	Yr 1, 3, 6 (3 surveys)	$360	$1,080
Vegetation	Transects	1 transect	Annually (10 surveys)	$720	$7,200
			Total Monitoring Cost	$1080.00	$8,280.00

3.3.4 Maintenance Plan and Long-term Site Management

Maintenance of the mitigation site would involve removal of unwanted invasive species that may take advantage of temporarily bare soils. These would be controlled by spot treatment with herbicides. Annual vegetation monitoring of the mitigation site would be used to identify the occurrence of invasive species beginning once the wetlands have been excavated.

No facilities other than potential hiking trails would be located within the mitigation sites. Any wetland crossings would be accomplished by constructing boardwalks built when the site is dry.

3.3.5 Adaptive Management

Frequent monitoring of the mitigation sites would identify problems early on and guide how to correct the problem and put the site on a trajectory toward ecological success. The most common and anticipated problems that would require adaptive management at estuarine wetland sites are the wetland platform target elevations are not being maintained and the desired minimum average cover of desirable species at the site is not achieved.

Some potential causes for not meeting and maintaining the target elevation include: loss of sediment through erosion or scour or higher than expected subsidence or RSLR rate. This could be corrected by renourishing the site using dredged material. If RSLR or subsidence are identified as the root cause, reevaluation of target elevations may be conducted, and a new target elevation established to ensure resiliency and sustainability over the 50-year performance period. Erosion control may be needed to control loss of sediment in specific areas during tidal exchanges or significant weather events. Adaptive management measures could include installation of straw wattles, erosion mats, or vegetative plantings to increase root mass and cover in areas showing the greatest sediment losses. Re-grading, construction of runnels or small berms to support the geomorphic conditions of the marsh may be required if some areas showing excessive rates of sedimentation, erosion/scour, or accretion. Additional monitoring or studies should be completed to identify the cause of soil loss/increase at the site and addressed as appropriate. The trigger for implementing adaptive management measures for elevation is that the target elevation is not sustained for at least 5 years.

Marsh vegetation may not achieve the target percent cover or structural conditions due to improper geomorphic, hydrologic, or biogeochemical conditions (e.g. erosion/scour, sedimentation, high redox potential, poor water quality including salinity, tidal influences), or natural events (e.g. loss during storm events or drought, herbivory or trampling). If a lack of seed source or invasion of undesirable species is the problem, replanting may be necessary to increase the seed back and completing removal efforts to limit the spread of undesirables may be needed followed by replanting of desirable species. However, monitoring results should be used to assess the underlying cause of inadequate cover, which may require that additional adaptive management actions be implemented to support successful replanting. For example, scouring and higher average salinity levels may prevent successful establishment of vegetative communities. Actions would be required to address scouring and the tidal influence in the area to reduce saline levels to promote desirable conditions for native species. Plant protection may also be required if monitoring indicates that failure is due to herbivory or trampling by wildlife or recreationists. Adaptive management measures related vegetation would be triggered if less than 80 percent of the average cover is made up of desirable species and/or invasive, noxious, and/or exotic plant species make up more than 5 percent of the average cover.

Table 13 shows the total estimated adaptive management costs by CSRM feature that would be expended if the management thresholds are triggered. Table 22 shows the estimated adaptive management costs and actions broken down by mitigation site. The cost assumptions presented for Sievers Cove apply to all sites with the same adaptive measures unless otherwise indicated.

Table 13. Estimated Adaptive Management Costs by CSRM Feature

CSRM Feature	Mitigation Project Costs	Total Adaptive Management Cost	Percent of Project Costs
Bolivar Roads Gate System	$37,035,000	$547,100	1.5%
Clear Lake Gate	$794,000	$20,000	2.5%
Dickinson Gate	$1,050,000	$20,000	2.5%
Total	**$38,879,000.00**	**$587,100.00**	**1.5%**

Table 14. Estimated Adaptive Management Cost by Mitigation Site

Adaptive Measure	Assumptions	Cost
Bolivar Roads Surge Gate		
Sievers Cove – 667 acres		
Renourishment of Marsh	• Assume 3% of mitigation site would need thin-layer placement (assume 6" depth) of dredged material once in 6 years. (approximately 20 acres or 16,134 yd^3) • Average incremental cost of placement for study is $10/yard[3] (assumes mob/demob and small quantity of yards per site) with the assumption that the adaptive management would be completed on the O&M cycle using the same dredge sites as initial placement.	$161,340
Minor topographic modifications	• Assume one modification (re-grading/runnel/small berms) per 300 acres (2 sites) in a 6-year period. • $15,000 for small fixes/site	$30,000
Erosion Control	• Assume installation of erosion control (e.g. straw waddles, erosion mats) in one location for every 300 acres (2 sites) at least once in 6 years • $10,000/site	$20,000
Re-planting	• Assume that 3% of vegetation may require replanting in the 10 years. (approximately 7 acres) • $2,500/acre (most likely seed, very few plugs/acre)	$17,500
Invasive and Nuisance Plant Control	• Assume that up to 1% of acreage may require treatment. (approximately 20 acres) • $2,500/acre	$50,000
	Total Cost for Mitigation Site	$278,840.00

Adaptive Measure	Assumptions	Cost
Greens Lake – 562 acres		
Renourishment of Marsh	• Assume 3% of mitigation site would need thin-layer placement (assume 6" depth) of dredged material once in 6 years. (approximately 17 acres or 13,714 yd^3) • $\$10/yard^3$	$137,140
Minor topographic modifications	• Assume one modification (re-grading/runnel/small berms) in a 6-year period. • $15,000 for small fixes/site	$15,000
Erosion Control	• Assume installation of erosion control (e.g. straw waddles, erosion mats) in one location at least once in 6 years • $10,000/site	$10,000
Re-planting	• Assume that 3% of vegetation may require replanting in the 10 years. (approximately 17 acres) • $2,500/acre	$42,500
Invasive and Nuisance Plant Control	• Assume that up to 1% of acreage may require treatment. (approximately 6 acres) • $2,500/acre	$15,000
	Total Cost for Mitigation Site	$219,640.00
Horseshoe 1-3 – 62 acres		
Renourishment of Marsh	• Assume 3% of mitigation site would need thin-layer placement (assume 6" depth) of dredged material once in 6 years. (approximately 2 acres or 1,613 yd^3) • Average $\$10/yard^3$	$16,130
Minor topographic modifications	• Assume one modification (re-grading/runnel/small berms) in a 6-year period. • $15,000 for small fixes/site	$15,000
Erosion Control	• Assume installation of erosion control (e.g. straw waddles, erosion mats) in one location at least once in 6 years • $10,000/site	$10,000
Re-planting	• Assume that 3% of vegetation may require replanting in the 10 years. (approximately 2 acres) • $2,500/acre	$5,000
Invasive and Nuisance Plant Control	• Assume that up to 1% of acreage may require treatment. (approximately 1 acre) • $2,500/acre	$2,500
	Total Cost for Mitigation Site	$48,630.00

Adaptive Measure	Assumptions	Cost
Clear Lake Surge Gate		
Seabrook		
Renourishment of Marsh	Not anticipated due to the nature of the site and ability of the containment levees to degraded naturally and when the time comes for them to be breached to rework the material into sites that are not meeting the target elevation.	$0
Minor topographic modifications	• Assume one modification (re-grading/runnel/small berms) in a 6-year period. • $5,000 for small fixes/site (due to size of site, cost assumes it can be added on to contract when breach containment levees)	$5,000
Erosion Control	• Assume installation of erosion control (e.g. straw waddles, erosion mats) in one location at least once in 6 years • $10,000/site	$10,000
Re-planting	• Assume that 3% of vegetation may require replanting in the 10 years. (approximately 0.3 acres) • $2,500/acre (most likely seed, few plugs/acre, cost assumes higher cost/acre because of small quantity)	$2,500
Invasive and Nuisance Plant Control	• Assume that up to 3% of acreage may require treatment. (approximately 0.3 acre) • $2,500/acre (cost assumes higher cost/acre because of small quantity)	$2,500
	Total Cost for Mitigation Site	$20,000.00
Dickinson Bay Surge Gate		
Dickinson Bayou		
Renourishment of Marsh	• Not anticipated due to the nature of the site and ability of the containment levees to degraded naturally and when the time comes for them to be breached to rework the material into sites that are not meeting the target elevation.	$0
Minor topographic modifications (Re-grading/Runnels/ Small Berms)	• Assume one modification (re-grading/runnel/small berms) in a 6-year period. • $5,000 for small fixes/site (due to size of site, cost assumes it can be added on to contract when breach containment levees)	$5,000
Erosion Control	• Assume installation of erosion control (e.g. straw waddles, erosion mats) in one location at least once in 6 years • $10,000/site	$10,000
Re-planting	• Assume that 3% of vegetation may require replanting in the 10 years. (approximately 0.3 acres) • $2,500/acre (most likely seed, few plugs/acre, cost assumes higher cost/acre because of small quantity)	$2,500
Invasive and Nuisance Plant Control	• Assume that up to 3% of acreage may require treatment. (approximately 0.3 acre) • $2,500/acre (cost assumes higher cost/acre because of small quantity)	$2,500
	Total Cost for Mitigation Site	$20,000.00

3.4 PALUSTRINE WETLANDS WORK PLAN

The work plan developed for this phase of planning is preliminary and is subject to change after site specific surveys have been completed. This work plan has been adapted from an intensive restoration effort at Galveston Island State Park. Based on restoration at other Marquette sites, less intensive restoration may be warranted; however, the study team opted to cost out the more intensive plan to ensure costs have been fully captured given the lack of uncertainty in site-specific hydrology and wetland conditions.

3.4.1 Design and Construction

The following are elements of the mitigation plan to implement the proposed mitigation method:

- **Geographic boundaries of the project**: Mitigation will require consideration of additional or less acreage within the vicinity of these sites as needed to accommodate the final mitigation amount to be determined during the Tier 2 analyses. The specific configuration and footprint of the mitigation site would be further refined during PED after further consideration of detailed local site conditions such as local hydrology and geomorphology, presence/absence of natural wetland soils, and historic wetland occurrence. The current costs and proposed mitigation boundary is shown in Figure 6. Wetland creation and enhancement sites would be coordinated with resource agencies to determine the most desirable arrangement and location at or around these sites.

- **Construction Methods:** Proposed mitigation would be to create interdunal swale wetlands through creation and enhancement of wetlands. Created wetlands would be excavated to a variety of depths to produce ponding level and duration representative of the range and mode of the interdunal swale wetlands being impacted by the recommended plan. They will be vegetated with the same species currently present in existing interdunal swale wetlands and reference sites. The enhanced wetlands consist of existing interdunal swale wetlands whose hydrology would be restored to natural conditions through the blocking of adjacent drainage ditches. The hydrologic enhancement would increase the prevalence of facultative wet and obligate wetland species already present.

    - **Wetland Creation:** Wetland sites would first have their boundaries outlined by a bulldozer following a set of wooden lathe stakes. The first 4 inches of top soil would then be stripped from the interior of mitigation sites where natural soils are present and stored nearby. The remaining excavation would then occur and the saved topsoil replaced. Topsoil salvaged from filled wetlands would also be laid down in a 4-inch thick layer at sites where natural topsoil was not present. Excavated material would either be used to construct new dunes or will be hauled to a designated upland disposal location. Wetlands would be constructed with 3:1 side slopes in anticipation that loose sand will blow and slump after construction. The swale bottoms would be constructed flat as their narrow width makes excavation of a diverse bottom elevation impractical and unnecessary. The long sinuous nature of the swales would provide edge habitat.

- **Wetland Enhancement:** Where appropriate, some of the excavated soils would be used to fill ditches that are currently draining wetlands to enhance the hydrology of existing wetlands. The ditch plugs would be covered with salvaged topsoil and sprigged with upland prairie vegetation in the same manner as the upland prairie buffers

- **Vegetation Establishment:** The first 4 inches of top soil from all of the swale excavation areas plus the wetland impact areas would be salvaged and later placed over the created wetlands. The seed bank within the soils would be used to establish wetland vegetation within the created wetlands. A list of target vegetation would be determined during future mitigation planning efforts.

- **Upland Prairie Buffer:** Native Strand Prairie grasses would be planted on existing dune ridges that lie between the swales containing the existing and proposed mitigation wetlands. Strand Prairie is made up of a subset of Tall-Grass Prairie species tolerant of somewhat salty soil resulting from salt spray and hurricane storm surge. Sprigs of these grasses would be grown in gallon pots in an on-site nursery from seed collected from an undetermined location, but could come from other Marquette tracts, Galveston Island State Park or nearby Follets Island. The sprigs would be transplanted onto upland areas surrounding the mitigation wetlands and on any berms built to construct the wetlands. Based on available information, it is anticipated that the planting rate would be about 784 sprigs per acre installed in multi-species clumps of four springs on a 15-foot spaced grid. Species could include: little bluestem (*Schizachyrium scoparium var. scoparium*), gulf muhly (*Muhlenbergia capillaris*), gulf dune paspalum (*Paspalum monostachyrum*), and brown seed paspalum (*P. plicatulum*).

- **Timing and Sequence:** The work plan would be enacted concurrent with construction of the surge barrier gates. Wetland creation and enhancement would be completed within two years of beginning construction at the mitigation site.

Construction details for the elements of the mitigation work plan will be developed during PED as part of the development of plans and specifications for procurement of services to construct the proposed mitigation. Final design dimensions and construction specifications will be shared and coordinated with TPWD, USFWS, NRCS and other resource agencies as needed.

Figure 6. Marquette Mitigation Site

3.4.2 Ecological Success

The wetland vegetation goal is to establish a hydrophytic dominated FACW or wetter plant community within created and enhanced wetland areas made up of species currently found at existing beachside wetlands. A five year monitoring period is specified that begins immediately after mitigation construction is complete.

Wetland Vegetation Success Criteria

1. Establishment of 30% aerial coverage of target vegetation by end of 1^{st} year following completion of mitigation construction.

2. Establishment of 50% aerial coverage of target vegetation by end of 2^{nd} year following completion of mitigation construction.

3. Establishment of 70% aerial coverage of target vegetation by end of 3^{rd} year and at the 5^{th} year following completion of mitigation construction.

4. Less than 5% aerial coverage of non-native invasive species in the mitigation area. These include guinea grass (*Urochloa maxima*), Vasey grass (*Paspalum urvilleri*), deep-rooted sedge (*Carex entreianus*), Chinese tallow (*Triadica sebiferum*), castor beacn (*Ricinus communis*), Japanese honeysuckle (*Lonicera japonica*), salt cedar (*Tamarix sp.*), and cabbage palm (*Sabal palmetto*).

Upland Prairie Buffer

The upland prairie buffer vegetation goal is to establish the four main species of tall grass prairie species (little bluestem, gulf muhly, dune paspalum, and brownseed paspalum) within the mitigation site and to exclude invasive, non-native species. A five year monitoring period is proposed and begins immediately after the initial planting of grass sprigs.

1. Success criteria include an initial 50% survival of planted sprigs as measured 60 days after their planting, with 5% cover by the four target species in year 1, 10% in year 2, 20% in year 3 and 30% in year 3, 4, and 5.

2. 30% or more aerial cover of the four target native grass species within the upland prairie buffer within five years after the initial planting with an additional 60% covered by other native prairie plants.

3. Less than 5% aerial coverage of non-native invasive species in the mitigation area. These include guinea grass, Vasey grass, deep-rooted sedge, Chinese tallow, castor beacon, Japanese honeysuckle, salt cedar, and cabbage palm.

If one or more of the success criteria are not met within the five-year monitoring period, corrective action would be taken as further described below in the Adaptive Management section of the work plan.

3.4.3 Monitoring Plan

Wetland hydrology would be monitored on an annual basis for five years beginning with wetland construction to provide information on how the created and enhanced wetlands are functioning. The gathered information will aid in diagnosing problems that may result in the failure of wetland vegetation establishment. Water level and precipitation graphs would accompany annual monitoring reports. The monitoring methods include:

1. Determination of each created or restored wetland's yearly maximum water depth through direct measurement using a yardstick during the time of year when it appears ponding is at its greatest.

2. Determination of the annual hydroperiod for two representative created wetlands through the use of continuously recording automated water level gages.

3. Documentation of rainfall as determined by an on-site gage or one of several continuous, real-time web-based stations located adjacent to the proposed mitigation site.

The monitoring methods used to evaluate success of the wetland upland buffer vegetation success criteria include:

1. Determination of plant aerial cover within each created and enhanced wetland and within the upland prairie buffers using 10 evenly spaced quadrats (1 m^2 in size) placed along a transect running the length of each mitigation unit (each created or enhanced wetland basin and each upland buffer area) on an annual basis. The data would be reported as cover by species, presence on the target list, and hydrophytic rating averaged over all of the quadrats.

2. Determination of initial percent survival of planted upland grass sprigs within the buffers by examining 25% of the planted grass clumps within 60 days of installation.

3. Determination of the presence of invasive non-native plant species within each wetland and buffer site using data from all of the above quadrats during each year of the monitoring period.

Monitoring would be completed each year for five years following the end of construction. The estimated monitoring costs for the palustrine mitigation site is approximately $28,000, or two percent of the total mitigation project cost (Table 15). While this is over the one percent threshold to be policy compliant, developing an effective monitoring plan that accurately captures the conditions and complexity of the site (wetlands intermixed with uplands and not contiguous areas) make it difficult to reduce monitoring costs to one percent or less. This site is being comprehensively restored, but the cost is relatively low compared to the area and habitat types being restored. Table 16 shows the estimated cost of the monitoring plan by monitoring parameter.

Table 15. Estimated Monitoring Costs by CSRM Feature

CSRM Feature	Mitigation Project Costs	Annual Monitoring Cost	Total Monitoring Cost	Percent of Project Costs
Ring Barrier	$1,400,000	$4,800	$28,000	2%

Table 16. Estimated Costs of Monitoring per Mitigation Site

Parameter	Methodology	#Transects	Monitoring Frequency	Estimated Cost/Survey	Estimated Total Cost
Marquette – 34 acres (wetlands), 128 acres (upland)					
Water Elevation	Stations	8 (water depth)/ 2 (gages)	Annually (5 years)	$2,400 + $4,000 automated water level gages set-up	$16,000
Vegetation (Wetland)	Transects	8 (wetlands)/ 5 (upland)	Annually (5 years)	$2,400	$12,000
			Total Monitoring Cost	$4,800.00	$28,000.00

3.4.4 Maintenance Plan and Long-term Site Management

Maintenance of the mitigation site would involve removal of unwanted invasive species that may take advantage of temporarily bare soils. These would be controlled by spot treatment with herbicides. Annual vegetation monitoring or the mitigation site would be used to identify the occurrence of invasive species beginning once the wetlands have been excavated. Prescribed fire would be first applied to the site within three years after mitigation construction has been completed. This would further control invasive species while encouraging recruitment and establishment of native species. No watering of the wetland mitigation sites is proposed or anticipated to be needed. Function of the wetlands would be wholly dependent on rainfall.

The mitigation sites would be managed as a natural area with the long-term goal of reestablishing its pre-European settlement flora and fauna. The mitigation sites would be managed using spot treatment with herbicides to remove non-native invasive species. A Wildland Fire Management Plan should be developed and enacted to conduct prescribed fire burning every 3 to 7 years to maintain the prairie. The ability to implement this long-term action on the mitigation site needs to be investigated further; however, maintaining a natural fire regime is critical to reestablishment and maintenance of the interdunal swale community.

No facilities other than potential hiking trails would be located within the mitigation sites. Any wetland crossings would be accomplished by constructing boardwalks built when the site is dry.

3.4.5 Adaptive Management

Frequent monitoring of the mitigation sites would identify problems early on and guide how to correct the problem and put the site on a trajectory toward ecological success. The most common and anticipated problems that would require adaptive management at estuarine wetland sites are the target percent cover of desirable species are not achieved and failure to achieve hydrologic regimes and/or failure to achieve wetland soil characteristics.

The same potential corrective actions described for estuarine wetlands would apply here to address vegetative cover problems. To address hydrologic regime or soil characteristic issues the root of the problem would need to be identified and addressed. The most likely corrective action would be to implement minor topographic modifications, such as the addition of drainage swales to increase water conveyance or adding/removing soils to achieve a wetland elevation that facilitates movement of water.

Table 17. Estimated Adaptive Management Costs by CSRM Feature

CSRM Feature	Mitigation Project Costs	Total Adaptive Management Cost	Percent of Project Costs
Ring Barrier	$1,400,000	$32,500	2.3%

Table 18. Estimated Adaptive Management Cost by Mitigation Site

Adaptive Measure	Assumptions	Cost
Marquette – 34 acres (wetlands), 128 acres (upland)		
Minor topographic modifications	• Assume one modification (re-grading/runnel/small berms) in a 6-year period. • $15,000 for small fixes/site	$15,000
Re-planting	• Assume that 3% of vegetation may require replanting in the 10 years. (approximately 5 acres) • $2,500/acre (most likely seed, very few plugs/acre)	$12,500
Invasive and Nuisance Plant Control	• Assume that up to 1% of acreage may require treatment. (approximately 2 acres) • $2,500/acre	$5,000
	Total Cost for Mitigation Site	$32,500.00

4.0 OYSTER MITIGATION PLANNING

4.1 MITIGATION OBJECTIVE

The primary objective of the mitigation is to replace the significant net losses of AAHUs of oyster reef habitat as close to the area of loss as possible.

4.2 FORMULATION OF MITIGATION MEASURES

Several potential measures (mitigation banks, restoration, and preservation) were considered as a means to mitigate for oyster reef impacts and to replace the lost function of existing oyster reef and to offset the loss of productivity to open bay bottoms (*Table 20*). Only one potential mitigation measure was carried forward: restoration by placing cultch directly on the bay bottom.

4.2.1 Site Selection

Potential mitigation sites in Galveston Bay were identified in consultation with the local resource agencies including TPWD, NMFS, USFWS, GLO, NRCS, EPA, and TWDB. Primary potential site identification was focused on sites targeted by TPWD for reef restoration as part of their ongoing effort to restore areas of previous reef impacted by Hurricane Ike in 2008 and Hurricane Harvey in 2017.

Several potential mitigation sites were identified; however, the sites were further limited to areas which can be successfully restricted from harvest. Because of state laws, potential mitigation sites which could have restricted harvesting is limited to areas within 1,000 feet of a bird rookery otherwise all areas would be open to harvest which would potentially jeopardize the success of the site. Additionally, the resource agencies strongly supported mitigating within or near the impact area as close as possible. From these criteria, three potential mitigation sites were identified (Table 19).

The proposed oyster mitigation sites were found to be cost-effective because of the screening criteria of the sites. While a number of sites could be identified and meet the mitigation need, the long-term operation and maintenance cost of those sites would be higher because those sites could not be effectively protected from harvest. If the site was regularly subjected to harvest the operations and maintenance (O&M) costs would need to be included and would be likely require reseeding every 5, 10 or 20 years depending on the rate of harvest. With the current sites that have been selected, the long-term success of the sites are not jeopardized by harvesting and therefore high O&M costs are not necessary making them more cost-effective than other sites.

Table 19. Potential Oyster Mitigation Sites

Mitigation Site	Description	Acres
Evia Island	Oyster reef constructed around the bird rookery at Evia Island to mitigate for impacts to open bay bottom.	30.0
Dickson Bayou	Oyster reef constructed in Dickinson Bay to mitigate for the Dickinson Bayou Surge Gate.	7.0
Alligator Point	Oyster reef constructed around the bird rookery at Alligator Island to mitigate for open bay bottom from the ring levee.	10.0

Table 20. Potential Mitigation Measures to Offset Oyster Reef Losses

Measures	Description	Carried Forward	Rationale
Mitigation Banking	Purchase mitigation bank credits.	No	No mitigation banks within the service area of the impact area offer oyster or open bay bottom credits.
Restoration: Cultch Directly on Bay Bottom	Placing cultch material (usually oyster shells, relic shells, crushed limestone, or crushed concrete), either loose or contained, so that the resulting structure lies flat along the estuary/bay bottom floor.	Yes	Potential locations are suitable for salinities and elevation where cultch can be placed directly on the bay bottom.
Restoration: Cultch on an Elevated Berm	Placing cultch material (usually oyster shells, relic shells, crushed limestone, or crushed concrete), either loose or contained, on an elevated surface (usually a berm of dredged material) above the bay bottom floor. This technique is typically used in deeper waters where there is concern of hypoxic areas or a halosaline layer that could impact oyster survival.	No	Mitigation needs to replace shallow water oyster reefs where water quality concerns are not an issue. Therefore, constructing a berm would be an unnecessary cost.
Restoration: Oyster Structures	Large, durable structures (e.g. oyster balls, pre-cast concrete structures and limestone structures) are placed in subtidal areas to create substrate to which oysters can attach. The resulting oyster reef has a significant vertical component, provides a more complex structure which oysters of varying ages and other aquatic organisms can use for habitat.	No	The size of the structures creates a potential risk to navigation particularly if the structure falls over into the navigation channel. As well, the mitigation need and subsequent ecological success can be met using lower cost measures.
Restoration: Oyster Seeding	Seed oysters, small oysters, about 2–25 mm long, are placed on existing reefs to encourage additional growth.	No	This measure would not work because there is a lack of hard substrate within shallow water areas.
Oyster Reef Creation	Creation of oyster reef through establishment of an oyster reef where oyster reef did not previously exist.	No	Galveston Bay has a long history of oyster productivity anywhere salinities and depth were conducive; therefore, any area suitable for establishment now is considered to be restoration and not creation.
Protection/ Preservation of Existing Oyster Reef	This method focuses on the protection or preservation of existing oyster reef from intensive harvest (dredging). The objective of this method is to support a sustainable oyster population, allow the reef to develop structurally over time, and possible create a source of oyster larvae to nearby reefs.	No	Areas not currently under harvest restriction are open to harvest as set in state law. In order to protect existing oyster areas susceptible to future loss would require legislative change. This has a very low potential of being supported. Also, most well established oyster reefs are currently in deep waters and mitigation needs to replace intertidal reefs.

4.2.2 Determination of Potential Mitigation Lift

In accordance with USACE planning policy, credit for mitigation was determined by using the same USACE certified habitat models to determine functional gains (or “lift”) for mitigation as was used to determine function losses of direct impacts. A description of the Oyster Habitat Suitability Index Model (Swannack et al. 2014) including the model variable assumptions, are described in the Ecological Modeling Appendix of the EIS (Appendix J). The model assumptions applicable to ER features were also applied to the mitigation sites. The following assumptions are most pertinent to evaluating the FWOP and FWP condition:

- Existing Condition/FWOP (No Restoration): Bay bottom at the each of the proposed mitigation sites is currently devoid of reef and indicative of a mud bottom with no hard substrate. It is assumed that this condition would be carried forward in the absence of mitigation through the 50-year period of analysis.
- FWP (Post-Restoration): Functional reef would not be present until TY 3, which is when initial oyster recruits could reach full adult stage and harvestable sizes.

The net change in habitat value at each mitigation site is shown in Table 21. The anticipated mitigation need for direct impacts to oysters is 2.8 AAHUs and direct impacts to open bay bottom is 18.1 AAHUs for a total oyster mitigation need of 20.9 AAHUs. The potential lift of the three proposed mitigation sites is sufficient to support 21.5 AAHUs.

Table 21. Net Change of Habitat Value at each Mitigation Site

Mitigation Location	AAHUs	Acreage
Evia Island	14.2	30.0
Dickinson Bayou	3.0	7.0
Alligator Point	4.3	10.0
Total	**21.5**	**47.0**

4.2.3 Cost of Mitigation

The oyster mitigation was costed out with the following assumption:

Oyster Reefs: Three (3) location were identified for the creation of reefs. Reef construction would consist of the following: initial /final hydrographic surveys used for quality control; and ½” to 3” gradation crushed limestone that would be used for 9” of settlement at 6” minimum above bay bottom.

The cost of oyster mitigation is shown in Table 22 by site with a total cost of $43,226,000; however, it is important to note that implementing each of these sites as planned provides more AAHU benefit than is necessary to offset the losses, so each of these sites are likely to be reduced in size which would also reduce the cost.

Table 22. Estimated Cost of Oyster Reef Mitigation by Site

Site	Estimated Cost ($1,000s)
Evia Island	$38,763
Dickinson Bayou	$661
Alligator point	$3,802
Total	**$43,226**

4.3 OYSTER WORK PLAN

4.3.1 Design and Construction

The following are elements of the mitigation plan to implement the proposed mitigation method:

- **Geographic boundaries of the project**: Mitigation will require consideration of additional or less acreage within the vicinity of these sites as needed to accommodate the final mitigation amount to be determined during the Tier 2 analyses. The specific configuration and footprint of the mitigation sites would be further refined during PED after further consideration of detailed local site conditions such as geotechnical information, presence and proximity of existing remnant reef, and consultation with resource agencies to determine the most desirable arrangement and location at or around these sites.
- **Construction methods:** The mitigation work plan proposed to add the necessary volume of clean, crushed limestone or other suitable hard substrate directly on the bay bottom to create the needed mitigation acreage.
    - The cultch veneer would be clean crushed, limestone or concrete, or other suitable substrate deemed acceptable by TPWD. Both materials have been successfully used in Galveston Bay reef restoration including those by USACE, the NFS, and TPWD. The cultch would most likely be barged in and then placed evenly over the dredged material. For planning purposes, a 6-inch thick cultch layer has been assumed in consideration of local reef restoration target relief for the recruitment layer that has been recently successfully implemented.
- **Timing and sequence:** The mitigation would be constructed concurrent or prior to the construction of the Surge Gates. The timing of mitigation to occur concurrent with the construction and impacts was conservatively assumed in the habitat modeling described in Section 2.0. The final mitigation amount and ratio will be remodeled based on the selected mitigation sites and construction schedule. With the area and volume of material involved, it is anticipated the mitigation would be constructed in a phased approach in conjunction with CSRM construction. If possible, the construction of the mitigation would be timed to target completion before or during the spawning season

(late spring to early fall) to ensure recruitment of spat soon after substrate is available. Ideally, completion would be timed before one of the two spat set peaks that typically occur in Galveston Bay. The first occurs between April and June and the second, smaller peak occurs around August.

- **Foundation:** Proper analysis will be performed and measures taken to determine and provide vertical stability of the placed berm and cultch layer. Geotechnical studies and analysis during the Tier Two planning phase and subsequently during PED would be performed to position mitigation footprints at the selected site(s) to reduce risks of settlement.

Construction details for the elements of the mitigation work plan will be developed during PED as part of the development of plans and specifications for procurement of services to construct the proposed mitigation. Final design dimensions and construction specifications will be shared and coordinated with TWPD and other resource agencies as needed.

4.3.2 Ecological Success

Criteria for restoration success would include one structural and one functional endpoint. The structural endpoint would be the number of hard bottom acres restored. The functional endpoint would be a measure of the live oyster density or recruitment onto the cultch that would be determined in coordination with TPWD. Success criteria includes:

1. Structural Endpoint: Target acres of hard bottom is established 1 year after mitigation construction is complete.

2. Functional Endpoint: At least 80% of the total live density of nearby natural reefs is achieved by the end of the 3^{rd} year post-mitigation construction.

4.3.3 Monitoring Plan

Monitoring of the mitigation sites would be conducted pre- and post-restoration to assess the success of mitigation. The specific method and techniques would be adapted to the scale of the mitigation site and would follow TPWD sample methods, where applicable and suitable for large acreages of restoration.

Structural Endpoint Monitoring

Pre-restoration and post-restoration side scan-sonar data would be collected and processed into ArcGIS data layers. This would determine the acres of reef habitat available for colonization. The purpose of pre-restoration side-scan sonar data is to determine the presence/absence of existing exposed reef within the mitigation site footprint, with the aim of confirming that existing reef is zero acres since mitigation construction should avoid placing cultch over existing reef. As a structural endpoint, the restored cultch acreage would be quantified from the post-restoration hard-bottom acreage indicated in the side-scan data. These data would determine the amount of hard bottom habitat restored that would be available for oyster recruitment.

Functional Endpoint Monitoring

The proposed methodology to monitor oyster success includes using patent tongs or similar grab sample method on a randomly stratified grid over each mitigation site. The functional endpoint monitoring would be conducted starting 2 years after the placement of cultch and continue for 3 years. The functional monitoring would be timed after spat peak periods, when possible, to ensure the selected success criteria are met. Both the amount of spat, live growth (market size ≥3 inches and sub-market size <3 inches) and amount and size of dead shell would be determined using grab sample tongs or other similar recommended methodology by TPWD. The enumeration of spat, juvenile, and adult live growth would be compared with nearby mapped natural reef comparison sites that would be confirmed to present by side-scan sonar and grab sampling.

Use of specific target live reef density of oysters per square meter (oysters/m^2) is not practical because year-to-year recruitment and live reef density is highly variable with climatic variations in salinity and annual storm and other freshwater inflow events. Therefore, sampling of mitigation reef and the comparison to natural reef would be conducted contemporaneously.

When the success criteria are met of the required structural hard-bottom acres constructed and function endpoint result of 80% of total live density of nearby natural reef, the monitoring would cease, and the mitigation project would be determined to be successful.

The estimated monitoring costs by CSRM Features are shown in Table 23. Both the Bolivar Roads Gate and Dickinson Gate features have monitoring costs that are at or less than the one percent threshold; however, the Ring Barrier is substantially higher at 4.8 percent of the project costs. The monitoring program for this feature follows the same assumptions and protocols as the other two, but the difference is in the total mitigation costs (Table 24). This project assumes minimal work is needed in comparison to the other two features, but the monitoring plan cannot be scaled down because it is important to still determine the lift of the site even if the mitigation is minimal and multiple year surveys are necessary to determine success. To do that costs more than $6,610, which is the one percent cost and is even less than the estimated annual monitoring costs. While this is not policy compliant it is warranted and not unreasonable in cost.

Table 23. Estimated Monitoring Costs by CSRM Feature

CSRM Feature	Mitigation Project Costs	Annual Monitoring Cost	Total Monitoring Cost	Percent of Project Costs
Bolivar Roads Gate System (Open bay bottom)	$38,763,000	$19,100	$84,600	0.2%
Ring Barrier (Open Bay Bottom)	$661,000	$6,940	$31,640	4.8%
Dickinson Gate	$3,802,000	$6,665	$40,240	1.0%

Total	**$43,226,000.00**	**$32,705.00**	**$156,480.00**	**0.4%**

Table 24. Estimated Costs of Monitoring per Mitigation Site

Parameter	Methodology	# Sampling Points	Monitoring Frequency	Estimated Cost/Survey	Estimated Total Cost
Bolivar Roads Gate System					
Evia Island – 30 acres					
Reef Structure	Sidescan Sonar	30 acres	Pre-construction, annually (anticipate 3 years) (4 surveys)	$15,000	$60,000
Abundance & Distribution	Quadrats/ Grab sampling	9	Semi-annually beginning in TY2 (anticipate 3 years) (6 surveys)	$4,100	$24,600
			Total Monitoring Cost	$19,100.00	$84,600.00
Dickinson Bay Surge Gates					
Alligator Point – 10 acres					
Reef Structure	Sidescan Sonar	10 acres	Pre-construction, annually (anticipate 3 years) (5 surveys)	$5,000	$20,000
Abundance & Distribution	Quadrats/ Grab sampling	3	Semi-annually beginning in TY2 (anticipate 3 years) (6 surveys)	$1,940	$11,640
			Total Monitoring Cost	$6,940.00	$31,640.00
Dickinson Bay Surge Gates					
Dickinson Bayou – 7 acres					
Reef Structure	Sidescan Sonar	7 acres	Pre-construction, annually (anticipate 3 years) (4 surveys)	$4,725	$18,900
Abundance & Distribution	Quadrats/ Grab sampling	3	Semi-annually beginning in TY2 (anticipate 3 years) (6 surveys)	$1,940	$21,340
			Total Monitoring Cost	$6,665.00	$40,240.00

4.3.4 Maintenance Plan and Long-Term Site Management

Once the cultch has been placed, no further maintenance of the site is anticipated. The cultch should remain exposed for colonization by oyster larvae and other aquatic organisms. Post construction monitoring over a five-year period post-construction would confirm the reef is stable and success has been achieved.

After the mitigation project is determined to be successful, management of the mitigation site would be the responsibility of the NFS and the regulators of the bottom of Galveston Bay, which are various governmental agencies including but not limited to TPWD and GLO. No specific long-term management activities are anticipated, as the mitigation site should be self-sustaining and would not be subjected to commercial harvest. The reefs would be subject to the same regulations that govern Galveston Bay oyster reefs.

4.3.5 Adaptive Management

Anytime during the monitoring period, if the success of the mitigation plan appears to not be meeting the success criteria, TPWD and other resource agencies would be notified so that the team can evaluate the problems and pursue ways to address the deficiencies in the mitigation. Discussion on meeting the success criteria would be included in each monitoring report. Corrective action would depend on the assessed or probable cause of the failure. Failure of the oyster mitigation site due to natural or anthropogenic drives from poor water quality, harvesting, or improper site conditions would be minimized to the greatest extent practicable through selection of a site that meets the needs of a healthy reef. The most relevant actions that could be used for adaptive management in the context of oyster reef mitigation are re-placing cultch or stirring up the cultch if substrate has subsided or is otherwise not exposed through seeding with oyster larvae as long as all other factors such as salinity and cultch were not an issue. Based on past local reef restoration projects that account for proper design, the risk of full subsidence is low.

The risk of not having adequate recruitment compared to natural reef when annual ambient salinity is low has not been an issue. For example, initial recruitment observed at Fishers Reef for the Bayport Ship Channel Improvement project during a year with prolonged low salinity averaged more than 10 times the live density of the impacted reef surveyed the year before, when salinity was not depressed. Accordingly, the risk of not meeting the desired outputs or results is not expected to be high. These factors are not expected to present.

The estimated costs of adaptive management are shown by CSRM feature in Table 25 and the estimated costs are shown by mitigation site in Table 26.

Table 25. Estimated Adaptive Management Costs by CSRM Feature

CSRM Feature	Mitigation Project Costs	Total Adaptive Management Cost	Percent of Project Costs
Bolivar Roads Gate System (Open bay bottom)	$38,763,000	$75,000	0.2%
Ring Barrier (Open Bay Bottom)	$661,000	$25,000	3.8%
Dickinson Gate	$3,802,000	$17,500	0.5%
Total	**$43,226,000.00**	**$117,500.00**	**0.3%**

Table 26. Estimated Adaptive Management Cost by Mitigation Site

Adaptive Measure	Assumptions	Cost
Bolivar Roads Surge Gate (Bay Bottom Impacts)		
Evia Island – 30 acres		
Add Substrate	• Assume that 5% of the oyster reefs would need to have cultch or other substrate added once in 3 year (approximately 1.5 acres). • $25,000/acre	$37,500
Placement of spat	• Assume that 5% of the oyster reefs (1.5 acres) would need to have hatchery spat on shell placed on the reef once in 5 years. • $25,000/acre	$37,500
	Total Cost for Mitigation Site	$75,000.00
Galveston Ring Barrier (Bay Bottom Impacts)		
Alligator Point – 10 acres		
Add Substrate	• Assume that 5% of the oyster reefs would need to have cultch or other substrate added once in 3 year (approximately 0.5 acres). • $25,000/acre	$12,500
Placement of spat	• Assume that 5% of the oyster reefs (0.5 acres) would need to have hatchery spat on shell placed on the reef once in 5 years. • $25,000/acre	$12,500
	Total Cost for Mitigation Site	$25,000.00
Dickinson Bayou – 7 acres		
Add Substrate	• Assume that 5% of the oyster reefs would need to have cultch or other substrate added once in 3 year (approximately 0.35 acres). • $25,000/acre	$8,750
Placement of spat	• Assume that 5% of the oyster reefs (0.35 acres) would need to have hatchery spat on shell placed on the reef once in 5 years. • $25,000/acre	$8,750
	Total Cost for Mitigation Site	$17,500.00

5.0 TENATIVELY SELECTED MITIGATION PLAN

Table 27 shows the nine potential mitigation sites and the net change in AAHUs that can be gained at each of the mitigation sites. A combination of all of these sites will be required despite being able to achieve the needed total mitigation at one site. This is because it was prudent to mitigate for the loss as close as possible to the impact site, so being able to do one large mitigation project, which was likely a good distance removed from the impact site would not achieve the objective of the mitigation.

Potential locations for mitigation sites, as shown in Figure 7 have been developed with the interagency team but will be refined further during future Tier 2 assessments. Ultimately, the final size of the mitigation measures (width, length etc.) may change. The type of site restoration would not change. The location of the proposed restoration could change if significant time passes and these locations are developed in the meantime or restored as part of another non-USACE project. As indicated in section 3.2.2 and 4.2.1, the proposed mitigation methods and sites are the only feasible measures capable of meeting the mitigation objective at this time and are cost-effective because no other methods are available and other sites would be more costly per AAHU.

Table 27. Potential Lift (Net Change in AAHUs) that Can Be Gained at Each of the Mitigation Sites

Mitigation Location	AAHUs	Acreage
Estuarine	**876.2**	**1,299**
Horseshoe Lake Site 1-3 (Direct Impacts)	37.6	62.0
Sievers Cove (Direct and Indirect Impacts)	491.8	667.0
Greens Lake (Indirect Impacts)	340.7	562.0
Clear Lake (Direct Impacts)	2.1	3.0
Dickinson Bayou (Direct Impacts)	4.0	6.0
Palustrine	**20.8**	**32.0**
Marquette (Direct Impacts)	20.8	20.0
Oyster	**21.5**	**47.0**
Evia Island (Direct Impacts)	14.2	30.0
Dickinson Bayou (Direct Impacts)	3.0	7.0
Alligator Point (Direct Impacts)	4.3	10.0

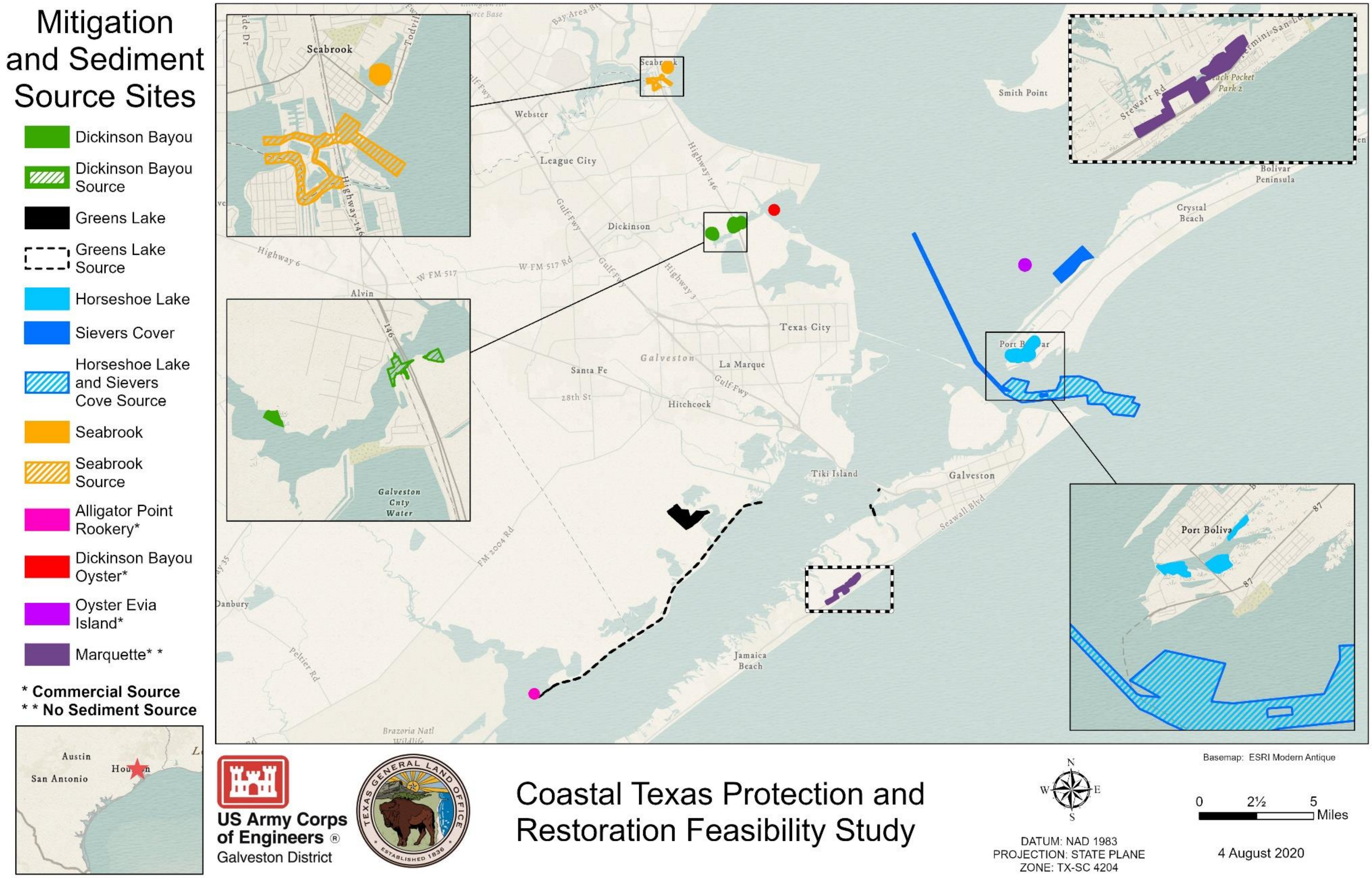

Figure 7. Potential Mitigation Site

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