COASTAL TEXAS PROTECTION AND RESTORATION FEASIBILITY STUDY

COASTAL **TEXAS** STUDY

DRAFT ENVIRONMENTAL IMPACT STATEMENT

OCTOBER 2020

US Army Corps of Engineers®
Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

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This Draft Environmental Impact Statement is a product of the U.S. Army Corps of Engineers - Galveston District and the Texas General Land Office.

COVER PHOTOS:
Top: Galveston Island Marsh Restoration Program planting
Bottom: Hurricane Ike approaching the Texas Coast in 2008

Draft EIS Executive Summary

In November 2015, the U.S. Army Corps of Engineers (USACE) in partnership with the non-Federal Sponsor (NFS), the Texas General Land Office (GLO), began the Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study) to determine the feasibility of alternatives to enhance, restore, and sustain the environment, economy, and culture of the Texas coast. This Draft Environmental Impact Statement (DEIS) and associated Draft Feasibility Report document the examination and selection of the Recommended Plan (RP).

The environmental, engineering, economic, and social analyses were conducted in accordance with USACE procedures and guidance to determine which Alternative best addresses the coastal hazards that negatively impact the Texas coast. Following identification of the TSP, the impacts of each of the alternatives considered were evaluated in accordance with the procedures under the National Environmental Policy Act (NEPA). The USACE and GLO identified the alternative during the TSP Milestone Meeting, held on May 30, 2018. The Chief of Planning and Policy approved the release of the Draft Integrated Feasibility Report and Environmental Impact Statement in October 2018 for concurrent public review, policy review, and Independent External Peer Review. The USACE Project Delivery Team (PDT) and the GLO analyzed and addressed comments received during the concurrent reviews which led to extensive changes in the proposed plan. This is a second DEIS with a separate associated Draft Feasibility Report (DFR-EIS) to allow for public and policy review of the updated proposed plan. After the review period is closed, the PDT and GLO will again analyze and address comments received. The comments received will then be used to assist with the development of the Final Feasibility Report (FFR) and Environmental Impact Statement (EIS) which will lead to a Chief’s Report, tentatively planned for May 2021.

Since the study presents a recommended Federal action, the USACE must satisfy the NEPA process to ensure that all alternatives and potential impacts are disclosed, and public comments are included. Through the NEPA scoping process, agency coordination, and the many iterations of the NEPA alternatives screening process, the study team considered 92 different components and potential alternatives before ultimately arriving at a reasonable range of alternatives carried forward in the draft Feasibility Report (FR) and draft EIS (DEIS).

The Coastal Texas 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 additional environmental reviews for certain measures included in the Recommended Plan. For projects as large and complex as the Coastal Texas 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 needed 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 considering the full range of potential effects to both the human and natural environments from implementing proposed solutions. The purpose of the Tier One EIS is to present the information considered in selecting 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 environmental 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 depend 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 of the proposed solution and identify the avoidance, minimization, and compensatory mitigation efforts to lessen adverse effects.

Actionable Measures. The Recommended Plan includes several proposed measures that currently have enough design detail to complete the environmental review. These are identified in this DEIS as "actionable measures", because this report provides a complete environmental review consistent with NEPA for these measures. The Environmental Consequences of the proposed actionable measures are described in Chapter 5 –Environmental Consequences for the Actionable Measures.

Tier One Measures. The measures included in the Recommended Plan that will require Tier Two environmental review are referred to as "Tier One Measures" because this report is the Tier One assessment for these measures. The Environmental Consequences of the proposed Tier One Measures are described in Chapter 4 – Environmental Consequences for the Tier One Measures.

Table ES-1-1 identifies which measures are actionable and which are Tier One Measures.

Table ES-1-1. Actionable and Tier 1 Measures of the Recommended Plan

Recommended Plan (RP) 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	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 Surge Gate System		X
Dickinson Surge Gate System		X
Non-structural Measures		X

* Requires additional NEPA analysis and environmental compliance consultation

There are numerous advantages to the Tiered NEPA approach:

- Increases opportunities for agency and public involvement, because they are engaged in broad decisions about the basic project concept and location (Tier 1) and are engaged again about detailed siting and mitigation issues (Tier 2).
- Allows for a wide range of alternatives to be considered in the NEPA process (in Tier 1), while also allowing for in-depth consideration of local issues (in Tier 2).
- Facilitates consideration of indirect and cumulative impacts on a broad scale – for example, an indirect and cumulative impacts analysis could be included in a Tier 1 study and then incorporated by reference in individual Tier 2 studies.
- Allows timing of final NEPA approval (Tier 2) to be more closely correlated with actual timing of project construction, because Tier 2 studies can be completed over time as construction funding becomes available.
- Provides a framework for integrating infrastructure planning with land use or natural resource planning efforts, because a Tier 1 EIS may be more compatible than following a traditional EIS process with the timing and level of detail of land use and resource planning studies.
- In Tier 2 environmental reviews, issues which may delay the progress of one Tier 2 section will not delay the entire project as progress can still be made on the other Tier 2 sections.

Additionally, all the measures in the Recommended Plan (RP) that have mitigation to offset environmental impacts are Tier 1 Measures that will have subsequent environmental review. The additional analyses will include an updated inventory of the affected environment and the anticipated impacts. In addition, this Tiered NEPA approach provides additional opportunities for the public to provide input on the proposed project as the project details are further developed and impacts are assessed.

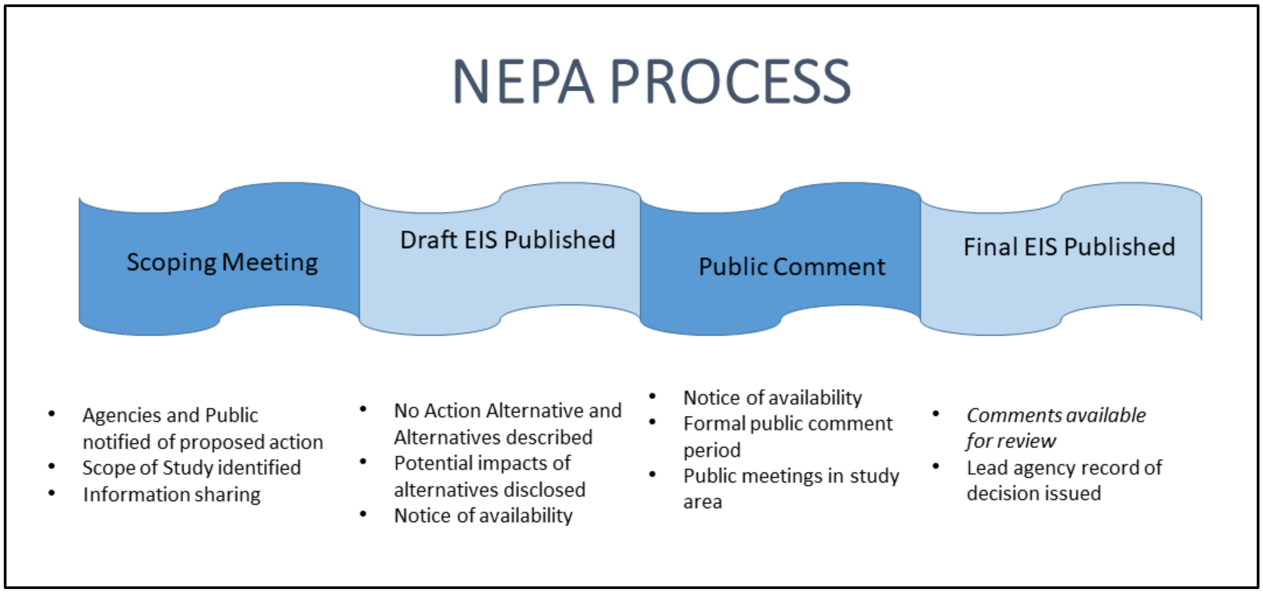

Figure ES-1: Typical NEPA Process

What is included in an EIS?

- ***Executive Summary:*** A summary of the EIS, including the major conclusions, area of controversy, and the issues to be resolved.
- ***Table of Contents:*** Assists the reader in navigating through the EIS.
- ***Purpose and Need Statement:*** Explains the reason the agency is proposing the action and what the agency expects to achieve.
- ***Alternatives:*** Consideration of a reasonable range of alternatives that can accomplish the purpose and need of the proposed action.
- ***Affected Environment:*** Describes the environment of the area to be affected by the alternatives under consideration.
- ***Environmental Consequences:*** A discussion of the direct and indirect environmental effects and their significance.
- ***List of Preparers:*** A list of the names and qualifications of the persons who were primarily responsible for preparing the EIS.
- ***List of Agencies, Organizations, and Persons*** to whom the EIS were sent.
- ***Index:*** The index focuses on areas of reasonable interest to the reader.
- ***Appendices (if needed):*** Appendices provide background materials prepared in connection with the EIS.

AUTHORITY

The Coastal Texas Study is being performed under the standing authority of Section 4091, Water Resources Development Act of 2007, Public Law 110-114.

> "Sec. 4091. Coastal Texas Ecosystem Protection and Restoration, Texas.
>
> (a) In General. — The Secretary shall develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ER in the coastal areas of the State of Texas.
>
> (b) Scope. — The comprehensive plan shall provide for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.
>
> (c) Definition. — For purposes of this section, the term ''coastal areas in the State of Texas'' means the coastal areas of the State of Texas from the Sabine River on the east to the Rio Grande River on the west and includes tidal waters, barrier islands, marshes, coastal wetlands, rivers and streams, and adjacent areas."

STUDY PURPOSE & NEED

The study effort focused on two core USACE missions, Coastal Storm Risk Management (CSRM) and Ecosystem Restoration (ER). CSRM required development and evaluation of coastal storm risk from storm surges and erosion associated with tropical events. The ER mission focused upon formulation and evaluation of actions to increase the net quantity and quality of coastal ecosystem resources by maintaining or restoring critical or degraded coastal ecosystems and fish and wildlife habitat.

As a powerful economic engine and an invaluable environmental treasure, the Texas coast is integral to the success of the State and the Nation. Its natural resources, such as beaches, dunes, wetlands, oyster reefs, and rookery islands, provide more than just recreational opportunities. They play a critical role in protecting coastal communities from storm surge and flooding. These coastal resources also contribute to the State and national economies by safeguarding and supporting industries. This includes petroleum refining, petrochemical, chemical and plastics manufacturing, waterborne commerce through the expansive network of Texas ports, commercial and recreational fishing, and tourism.

Population centers in and around the barrier islands and coastal areas are essential to support the region's industry. The same physical conditions that make the area vulnerable to coastal storms provide the setting for continued growth of industry and residential areas for the where employees live. The region is growing, and jobs are being created because the country needs what flows from Texas's coast. This includes tourism, recreational fishing, commercial fishing, and the State's ports, intracoastal waterways, and energy production. Texas's transportation and energy hubs cannot be replicated anywhere else. As long as there is a need for what the Texas coast provides ecologically and economically, residents, businesses, and local stakeholders will continue to work and make the Texas coastline their home, all while adapting to changing coastal conditions.

Feasibility Report and EIS Purpose

- Summarize the development and comparison of alternative approaches to reduce risk of coastal storm damage and restore the Texas Coast
- Describe the current decision point in selecting a plan and seek public comment
- Disclose potential impacts of plans considered to comply with NEPA

STUDY SCOPE

The Federal authorization for the Coastal Texas Study directs that the study's scope be a comprehensive approach for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.

A concerted effort was made to ensure that scoping and evaluation was inclusive. An interagency team of Federal, State, and local agencies, as well as Tribal nations were invited to meet monthly to discuss study progress and formulation issues related to the Coastal Texas Study. Study team members shared updates on pending decisions and sought comment and approval of methods to assess performance and impacts of features proposed to reduce risk and restore habitat and natural coastal processes. Interagency workshops were held throughout the planning process to consider restoration measure performance metrics, screen and refine restoration alternatives, review assumptions, and discuss and evaluate impacts, mitigation planning, adaptive management measures and many other aspects of the project.

Study Scope

- Defines the range of the study, which issues should be considered, and the relative range of solutions to evaluate
- Study Authority states the scope is to create a thorough plan for the protection, conservation, and restoration of critical resources, habitat, and infrastructure (roads, fire stations, hospitals, etc.) from the impacts of coastal storms, hurricanes, erosion, and subsidence
- "Scoping" was the first phase of the study when the public and various agencies, including the Texas Parks and Wildlife Department and U.S. Fish and Wildlife Services, shared concerns and project ideas
- Coastal Texas Study team included concepts developed by others - Texas A&M, Rice SSPEED Center, Gulf Coast Community Protection and Recovery District, and international agencies

LOCATION

The study area for the Coastal Texas Study consists of the entire Texas Gulf coast from the mouth of the Sabine River to the mouth of the Rio Grande, and includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent areas that make up the interrelated ecosystems along the coast of Texas. The study area encompasses 18 coastal counties along the Gulf coast and bayfronts that are in the Texas Coastal Zone Boundary from the Texas Coastal Management Program. The study area has been divided into four sections: upper Texas coast, mid to upper Texas coast, mid Texas coast, and lower Texas coast. The upper Texas coast encompasses the Sabine Pass to Galveston Bay area and includes Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria counties. The mid to upper Texas coast is comprised of the Matagorda Bay area and includes Matagorda, Jackson, Victoria, and Calhoun counties. The mid Texas coast covers the Corpus Christi Bay area and includes Aransas, Refugio, San Patricio, Nueces, and Kleberg counties. The lower Texas coast encompasses the South Padre Island area and includes Kenedy, Willacy, and Cameron counties.

Location

- Study area includes 18 counties along Texas Gulf coast
- Includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, borrow sources, and adjacent areas that make up the interrelated ecosystems along the coast of Texas

STUDY NON-FEDERAL SPONSOR

The GLO is the NFS for the Coastal Texas Study. Following the execution of a feasibility cost share agreement in November 2015, the GLO actively participated in the scoping of the study and contributed a non-Federal cost share, which includes work-in-kind and contracting with GLO professional service providers. The GLO worked alongside the USACE on the DIFR-EIS (released in 2018) in the formulation and screening process and has continued throughout the entire Coastal Texas Study process.

While the GLO has served as the non-Federal sponsor for the feasibility study phase, due to the scale of the project, a modified arrangement is necessary for the subsequent phases of the project, including Preconstruction Engineering and Design (PED), Construction, and Operations and Maintenance. The State of Texas (encompassing its various entities, including the GLO) has indicated in a Letter-of-Intent that it intends to serve as the non-Federal sponsor, with support from local entities, for future phases of the Coastal Texas Protection and Restoration Plan program, pending legislation to be considered in the 2021 Texas legislative session. Accordingly, local entities such as counties, cities, levee improvement districts, drainage districts, municipal utility districts, or other special taxing entities may elect to, or be created to, support the State of Texas and the USACE in the implementation of this project.

PROBLEMS AND OPPORTUNITIES

Significant environmental and economic impacts result from the continual erosion of the Texas coastline, with specific impacts to wildlife areas, wetlands, barrier islands, and residential and commercial property (**Figure ES-2**). Relative sea level rise (RSLR), which is a combination of land subsidence and sea level rise, is expected to increase the potential for coastal flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future.

The specific problems identified for the Coastal Texas Study include problems related to:

- Coastal communities including residential populations and the petrochemical industry becoming increasingly vulnerable to life safety and economic risks due to coastal storm events;
- Critical infrastructure throughout the region including hurricane evacuation routes, nationally significant medical centers, government facilities, universities, and schools becoming more at risk of damage from coastal storm events;
- Existing Hurricane Flood Protection Systems, including systems at Port Arthur, Texas City, and Freeport, which do not meet current design standards for resiliency and redundancy and will be increasingly at risk from storm damages due to RSLR and climate change;
- Degradation of nationally significant migratory waterfowl and fisheries habitats, oyster reefs, and bird rookery islands within the study area occurring due to storm surge erosion; and

- Water supply shortages due to increasing conflicts between municipal and industrial water supply and the ecological needs of coastal estuaries and ecosystems.

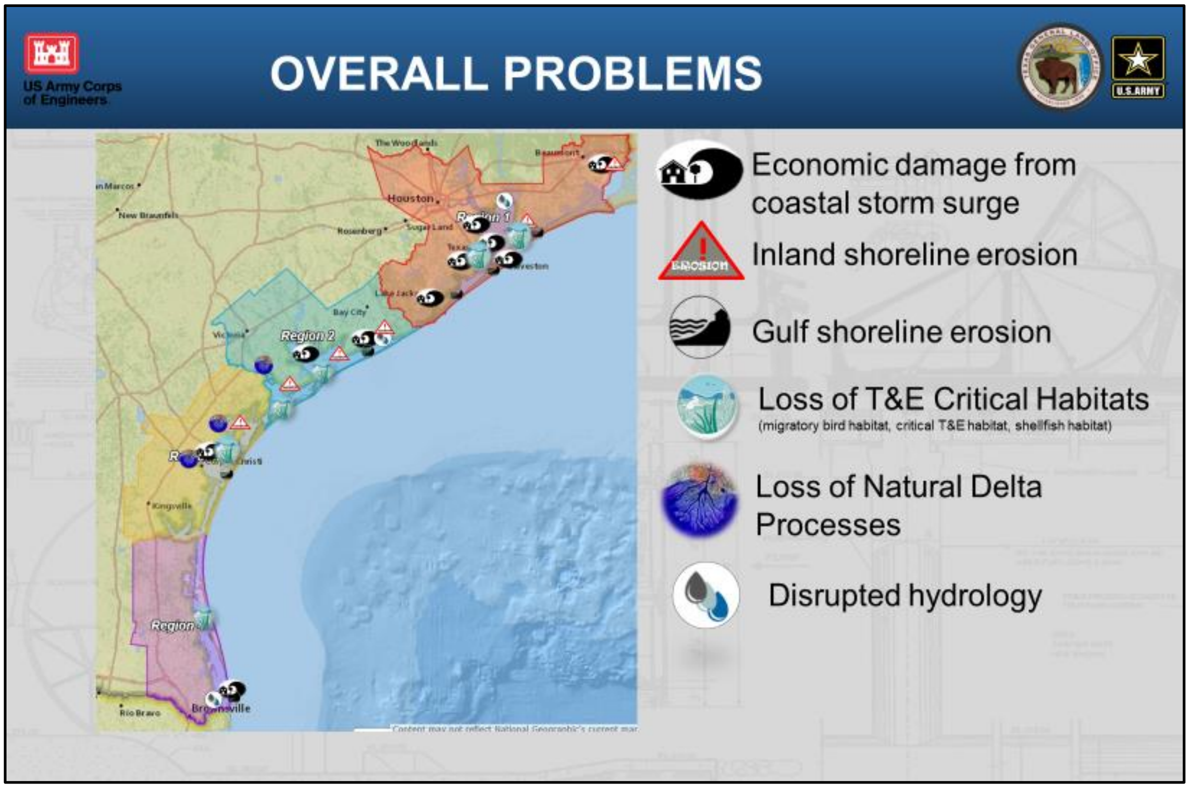

Figure ES-2: Overall Problems Identified for the Coastal Texas Study

The specific opportunities identified for the Coastal Texas Study include the opportunity to:

- Provide CSRM alternatives to reduce the risks to public, commercial, and residential property, real estate, infrastructure, and human life;
- Reduce the susceptibility of residential, commercial, and public structures and infrastructure to hurricane-induced storm damages;
- Increase the reliability of the Nation's energy supply by providing alternatives that will potentially lessen damages to refinery infrastructure caused by coastal storm events;
- Enhance public education and awareness to coastal storm risk;
- Restore the long-term sustainability of coastal and forested wetlands that support important fish and wildlife resource within the study area;
- Restore the barrier island environments to promote long-term sustainability of the fish and wildlife resources that rely upon those ecosystems;

- Improve the water quality in coastal waters through marsh and oyster reef restoration;
- Use available sediment within the system beneficially;
- Support programs that promote long-term erosion reduction of the Gulf coast and bay shorelines and limit erosion potential during future coastal storm events;
- Protect threatened and endangered species habitat; and
- Enhance ecotourism and recreational opportunities.

PLANNING OBJECTIVES

The main objective of the Coastal Texas Study is to recommend an alternative that will reduce the risk to lives and property associated with coastal storms in addition to providing ecological benefits, including enhancing shoreline stability and restoring coastal ecosystems. The objectives were developed from problem and opportunity statements and were used to guide the plan formulation for the RP. The proposed alternatives were evaluated throughout the study and in greater detail as the alternative screening progressed.

Environmental policies require that fish and wildlife resource conservation be given equal consideration with other study purposes in the formulation and evaluation of alternative plans. In the evaluation process, care was given to preserve and protect significant ecological, aesthetic, and cultural values, and to conserve natural resources. Alternative plans were formulated to reduce the risk of damages from coastal storms, as well as avoid environmentally significant resources. Where impacts could not be avoided, impacts were quantified, and a mitigation plan was formulated.

FORMULATION OF ALTERNATIVE PLANS

The objective of the Coastal Texas Study is to develop a comprehensive plan that will help manage risks associated with coastal storms within the study counties while avoiding and minimizing impacts to the region's environmental resources. The study team recognized that risk reduction alternatives will include traditional CSRM and ER components, which work together to reduce habitat loss over time and enhance the performance of other measures over time. Distinction between CSRM and ER features is necessary within the report to identify objectives, quantify the benefits of each, and document the formulation process; however, the RP is formulated to achieve an integrated system of risk reduction actions.

CSRM and ER measures were developed and evaluated through several iterations of screening and assembled into alternatives to address specific needs for the Texas coast. Consistent with the USACE SMART planning concepts, screening and evaluation of these alternatives relied largely on available existing information. The final array consists of a No-Action Alternative and two final action alternatives, the Coastal Barrier Alternative and the Bay Rim Alternative, which each include three components, a CSRM measure to address storm surge in the upper Texas coast, a CSRM measure to address erosion in the lower Texas coast, at South Padre Island, and an ecosystem restoration plan for eight (8) areas along the coast. The primary difference between the two final alternative plans is the alignment of the CSRM measure in the upper Texas coast. The CSRM measure planned for South Padre Island, as well as the ER measures along the coast, do not vary across the final two action alternatives.

Feasibility analysis is a standardized process to ensure that Federal recommendations are evaluated consistently.

- How were different project ideas identified (Plan Formulation)?
- How were they compared to select a plan (Alternatives Analysis)?
- What could solve the problems? (measures)
- Do those actions meet project objectives? (performance)
- Do those actions avoid constraints? (implementable)
- Can the measure be constructed and maintained to address the damages or problems (Engineeringly Feasible)?
- Do they produce more benefits than costs (Economically Justified)?
- Do they meet project objectives without unacceptable environmental impacts (Environmentally Acceptable)?

The RP is the plan that best meets these objectives.

***Public and agency review begins with the release of the Draft FR and DEIS and continues through Tiered NEPA compliance and beyond.**

The Galveston Bay Storm Surge Barrier System includes a combination of a beach and dune system along the Bolivar Peninsula and West Galveston, in addition to a Galveston ring barrier system, a nonstructural feature on the west side of Galveston Bay with storm surge gate systems at Dickinson Bayou and Clear Lake, beach nourishment and sediment management in portions of South Padre Island, and ecosystem restoration along the coast. The upper Texas coast CSRM system connects to beach and dune at McFaddin Wildlife Refuge, crosses Bolivar Peninsula and Galveston Island with a storm surge barrier system across Bolivar Roads.

The Bay Rim Alternative includes a combination of CSRM features such as levees and floodwalls, along the West Galveston Bay Rim that extends westward around Texas City, it includes storm surge gates systems at Clear Lake and at Dickinson Bay, in addition to the same Galveston ring barrier system (GRBS), beach nourishment and sediment management in portions of South Padre Island, and ecosystem restoration along the coast that are in the Coastal Barrier Alternative. The West Galveston Bay Rim CSRM system begins at Baytown and extends down the entire westside of Galveston Bay, around Texas City, and ends near the Galveston-Brazoria county line.

The proposed upper Texas coast CSRM measure addresses that storm surge may potentially cause the most substantial impacts. Therefore, the engineering analysis presented in Appendix D of the 2018 DIFR-EIS supported conceptual development of the distinct alignments, originally Alternative A and Alternative D2 (as referenced in Appendix D), to achieve CSRM and assess impacts of those features. The current DFR and associated appendices further explain additional analysis of the modifications to a dual dune system instead of a levee along Bolivar Peninsula and West Galveston Island, updates to the GRBS, and South Padre CSRM. It also includes detailed information on the ER measures.

This EIS presents the results of the CSRM and ER alternatives analysis and selection of the RP through an iterative process based on economic, engineering, social, and environmental factors. The performance of the CSRM and ER Final Array of Alternatives was measured, then evaluated and compared against other CSRM or ER alternatives to identify a RP. The evaluation included a comparison of the future without-project condition and the future with-project condition.

RECOMMENDED PLAN

The Upper Coast CSRM Coastal Barrier Alternative is a system wide plan that best meets the study objectives, and when compared to the other action alternatives and the No-Action Alternative, most effectively reduces risk from coastal storms and habitat loss (see Figure ES-3 below). The RP consists of the Coastal Barrier Alternative, the South Padre Island CSRM Measure, and the Coastwide ER Alternative 1.

Recommended Plan (RP)

- Coastal Barrier – Beach and Dune along Bolivar Peninsula and Galveston Island to reduce storm surge
  - Surge gates within Bolivar Roads including two 650’ sector gates for ship traffic, two 125’ sector gates for other vessels, 15 Vertical lift gates and shallow water gates for water flow
  - Tie-in structures consisting of floodwalls and levees
  - Galveston Island Ring Barrier System, including improvements to the Seawall, floodwalls, levees and gate system at Offatts Bayou
  - Storm Surge gate Systems at Clear Lake and Dickinson Bayou
  - Non-Structural Improvements along West side of Galveston Bay
- South Padre Island Risk Reduction = Beach and Dune Nourishment and Sediment Management
- Ecosystem Restoration = 8 projects along areas of the Texas Coast (see map below)

The Coastal Barrier Alternative is a risk reduction system made up of the following features: beach and dune nourishment (dual dune system with beach in front), Galveston Ring Barrier System consisting of floodwalls (inverted T-walls), floodgates (both highway and railroad floodgates), seawall improvements, drainage structures, pump stations, and surge barrier gates. The most complex feature of the Coastal Barrier Alternative is at Bolivar Roads between Bolivar Peninsula and Galveston Island, which includes surge barrier gates that are made up of navigable floating sector gates, lift gates and shallow water environmental gates, and a combi-wall made up of vertically driven piles with a battered support pile and a reinforced concrete cap. In addition, to address wind-driven surge within Galveston Bay storm surge gate systems with associated pump stations will be located at Clear Lake and Dickinson Bayou.

The South Padre Island CSRM Measure consists of approximately 2.9 miles of beach nourishment along the barrier island on the Gulf and includes a 10 year renourishment interval.

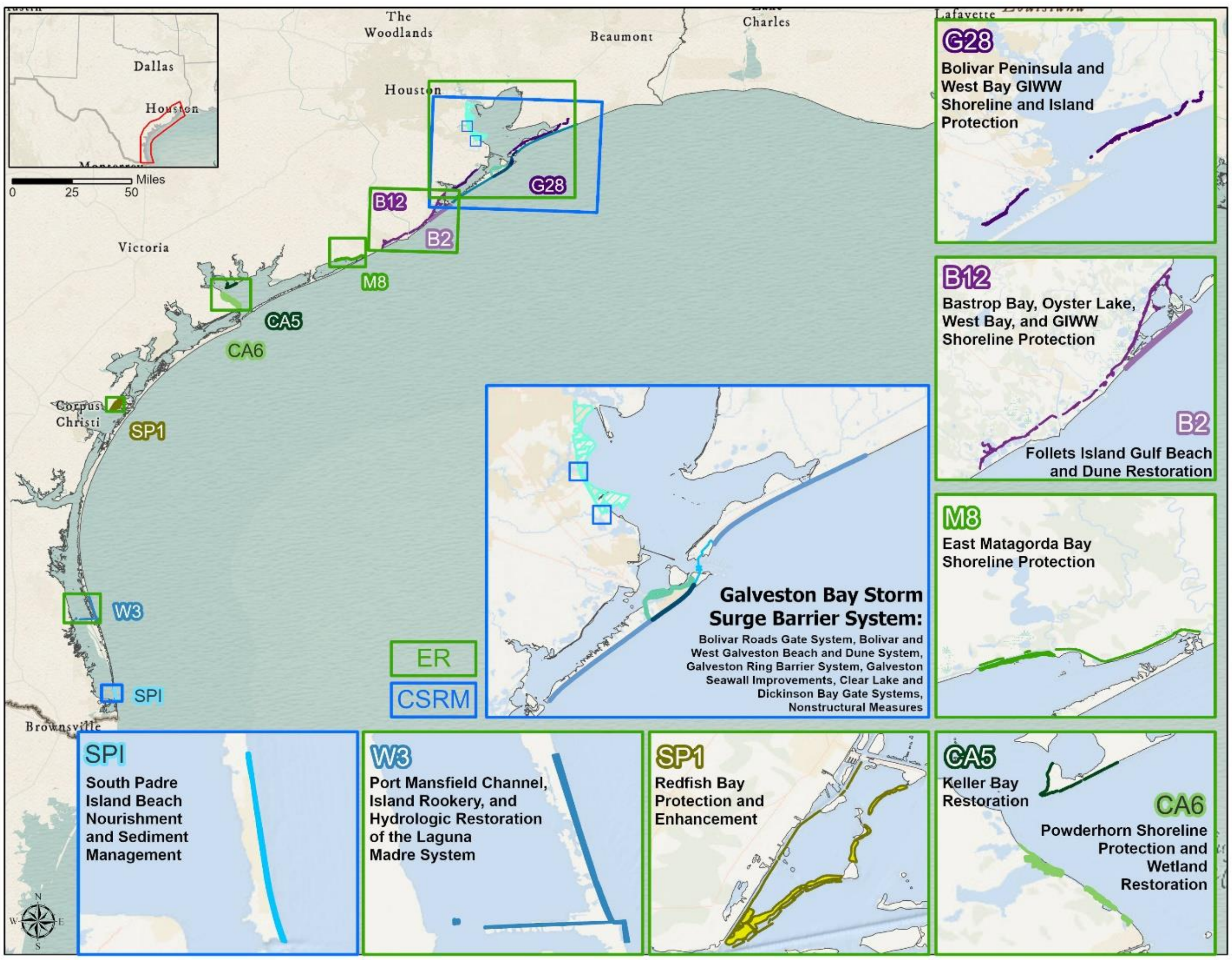

Figure ES-3: Recommended Plan

The ER component of the RP (Coastwide ER Alternative 1) has been formulated to address habitat loss and degradation from coastal processes through ER measures that are intended to restore and create habitat and support structural CSRM efforts by providing a natural buffer from coastal storms. The ER measures proposed in this study are a combination of features formulated in specific geographic locations to restore diverse habitats and provide multiple lines of defense. They include shoreline stabilization using breakwaters, marsh restoration, island restoration, beach and dune restoration, and restoration of large-scale hydrologic connectivity.

Ecosystem Restoration

Beach Restoration B-2 W-3	• Place beach quality sand on beaches • May include dune restoration or creation • Creates habitat for many organisms, including threatened and endangered species
Breakwater G-28 CA-6 B-12 M-8 CA-5 W-3 CA-6	• Rock to be placed along the shoreline to reduce waves • Reduces erosion
Marsh Restoration G-28 B-12 CA-6 M-8	• Add sediment to existing wetlands and areas that were previously wetlands • Plant wetland plants • Creates habitat for many species, including commercially and recreationally important fish, crabs, and shrimp
Island Restoration G-28 M-8 SP-1 W-3	• Restore and/or create islands • Islands help protect shorelines and submerged aquatic vegetation (SAV) • Provides habitat; especially for nesting birds (rookeries)
Oyster Reef M-8 SP-1 CA-5 B-12 G-28	• Place material for oysters to grow on (clutch, reef balls, or other similar materials) • Increases oyster population, provides habitat for other organisms, and helps reduce wave energy

The Coastal Barrier Alternative and South Padre Island CSRM Measures fulfill the focused CSRM planning objectives and maximize net benefits, consistent with protecting the environment in accordance with national environmental studies, applicable Executive Orders, and other Federal planning requirements. Likewise, the Coastwide ER Alternative 1 includes measures that would restore the natural features of the Texas coast, including beach and dune complexes, oyster reefs, bird rookery islands, and wetland and marsh complexes, which work to support a diverse array of habitats and conditions necessary for coastal resiliency and mitigation of damages caused by coastal storms and RSLR.

ENVIRONMENTAL COMPLIANCE

The Notice of Intent to file the EIS was published in the *Federal Register* on March 31, 2016. The U.S. Fish and Wildlife Service (USFWS) actively participated in the impacts evaluation and environmental modeling and is preparing a draft Fish and Wildlife Coordination Act Report; their preliminary recommendations were incorporated into the DIFR-EIS and additional recommendations are given in this EIS. The USACE prepared a Draft Biological Assessment (BA) for the Actionable Measures and that BA has been submitted to the USFWS and National Marine Fisheries Service for continuing consultation. The BA has determined that the Recommended Plan may affect but is not likely to adversely affect three species of sea turtle (green, Kemp's ridley, and loggerhead), due in part to dredging and fill material placement associated with construction activities, especially those activities where the action area includes beaches on the Padre Island National Seashore and South Padre Island. As currently proposed, several of the Tier One measures would likely have adverse effects to federally-listed threatened and endangered species and their critical habitats. The PDT has worked closely with the Services to identify many possible routes of effect that the Tier One Measures could have on federally listed threatened and endangered species and their critical habitats and those consultations will continue into the Tier Two environmental reviews.

The USACE is proposing to execute a Programmatic Agreement among USACE, the Texas State Historic Preservation Office, and any NFS to address the identification and discovery of cultural resources that may occur during the construction and maintenance of proposed or existing facilities. There is potential for new construction and improvements to existing structures to cause effects on historic properties; however, the numbers of properties that may be affected are not extensive. Intensive cultural resources investigations to identify and evaluate any historic properties within proposed construction areas will be conducted prior to construction.

POTENTIAL ENVIRONMENTAL IMPACTS

This DEIS addresses the potential impacts of the proposed features on human and environmental resources identified during the public interest review. Alternative plans were formulated to reduce the risk of damages from coastal storms as well as avoid impacting environmental resources. When impacts could not be avoided, they were minimized to the extent practicable then quantified, and a mitigation plan (see Appendix J) was formulated. The following provides a brief description of the potential impacts that were identified.

Strategic planning initiatives were integrated during the development of the features to minimize and mitigate impacts associated with the structures. For example, the Bolivar Roads Gate System has been improved since the 2018 DIFR-EIS release to create less constriction, allowing for more water exchange between the Gulf and the Bay. Studies conducted by the USACE show that the re-designed measure would reduce impact on tidal exchange, salinity, larval transport and wetlands. While these impacts are highly reduced, there are still some anticipated unavoidable impacts and those are discussed throughout the DEIS.

Potential Environmental Impacts

- **Measures designed to avoid and minimize impacts**
  - The projects mitigate for impacts that cannot be avoided.
  - Mitigation is an action or feature taken to compensate for the lost resource.
- **DIRECT impacts to wetlands in Galveston Bay**
  - Tie-In Structures and Galveston Ring Barrier System will go through wetlands (exact alignment will be refined in future planning and design phases, which will change the estimated amount of impacts) and will have Tier Two NEPA Evaluation.
  - These impacts will be mitigated by constructing wetlands in another location within the Galveston Bay system.
- **INDIRECT impacts to wetlands in Galveston Bay**
  - Surge barriers may impact the flow of water through Bolivar Roads.
  - Modeling estimated the amount of the potential impacts to wetlands from the barrier.
  - Wetland impacts will be mitigated by constructing wetlands in another location within the Galveston Bay system.
- **Positive impacts from Ecosystem Restoration include reduced erosion, habitat creation, and protection of existing habitat**

Permanent beneficial effects on land use, socioeconomics, aesthetics, and recreation would result from the placement of additional beach nourishment along segments of beach that are further described in this report. The RP would result in wider beaches available for recreational use by local citizens and tourists at some locations. There would be minor, temporary and permanent adverse effects on land use, navigation, recreation, and aesthetics due to the installation of the permanent storm surge barriers, pump stations, and floodwalls at Wiggins Pass and its adjacent state and local parkland, and at the storm surge barrier, pump station; at the floodwalls at Doctors Pass; and at the floodgates at Tamiami Trail and Bonita Beach Road.

The Coastal Barrier Alternative would provide a level of protection to tidal and freshwater wetlands by reducing storm surge and other erosional forces during storms. The South Padre Island CSRM Measure would restore the beach and dune complex along South Padre Island and would likely help preserve existing wetland and marsh habitats on the bayside of the measure by providing increased protection from storm surges. Additionally, habitat restoration measures would restore the natural features of the Texas coast that provide habitat for many Federally threatened and endangered species and State species of concern, provide protection to upland areas from flooding caused by RSLR and storm surge, and stabilize the coastline by absorbing energy from ocean currents and vessel wakes.

PUBLIC INVOLVEMENT, REVIEW, AND CONSULTATION

Extensive public scoping, stakeholder communication, and resource agency coordination has been maintained throughout the development of the RP. Information regarding CSRM and ER problems and opportunities were collected during a series of scoping meetings in 2012 and 2014. Numerous additional stakeholder meetings and Resource agency meetings were held monthly from 2016 to present to provide an opportunity for agency feedback and study progress updates. Additional meetings/workshops were held to discuss specific study topics such as ER screenings, habitat evaluation methodology (models), mitigation, etc.

Seven Public Hearings were held in 2018 with the release of the DIFR-EIS. The public comments and policy review led to a revised plan, which included removing the levee system along Bolivar Peninsula and West Galveston Island and increasing the size of the beach restoration measure in those areas so that the updated beach and dune measure could provide both ER and CSRM purposes (dual purpose measure). The updated design for the Bolivar Peninsula and West Galveston beach and dune system includes two dunes and a 195-foot-wide beach. In addition, an International Gate workshop was held that provided additional input into the Bolivar Roads Gate System, leading to a change from a single 1200’ sector gate to two 650’ sector gates, reducing the number of vertical lift gates to 15 by using wider gates, 300’ instead of 100’ and creating shallow water environmental gates to reduce impacts to the shallow waters near Bolivar Peninsula and the organisms that use those waters.

Public outreach meetings were held to keep the public informed on the project updates since the 2108 DIFR-EIS release. These ranged from professional conference presentations, meetings for specific stakeholder that would be directly impacted like those living in proximity to the proposed Galveston Ring Barrier, meetings with NGOs, and many others. Three Public Open houses were held in the Upper Texas Coast in early 2020 to allow the public to ask questions and learn about the project changes and inform them of the second draft release of the feasibility report and EIS.

MAJOR FINDINGS AND CONCLUSIONS

The Coastal Barrier Alternative is identified as the RP. In the upper Texas coast, the "Coastal Barrier with complementary system of nonstructural measures" associated with the Coastal Barrier Alternative was identified as the RP and the National Economic Development (NED) plan as determined by the evaluation criteria for the upper coast of Texas. This portion of the plan reduces economic damage from coastal storm surge flooding to businesses, residents, and infrastructure in the areas of the Galveston Bay system. One of the key differences between the Coastal Barrier Alternative and the Bay Rim Alternative is satisfying the planning objectives of risk reduction to critical infrastructure and enhancing the functionality of existing storm surge risk reduction systems. The Coastal Barrier Alternative fully meets both planning objectives since both the region's critical infrastructure and existing storm surge risk reduction systems would be within the system.

The coastwide Alternative 1 for ER is the NED plan. With the inclusion of a coastwide range of ER measures, such as gulf beach and dune restoration, GIWW, bay shoreline and island protections, and island rookery and hydrologic restoration. The plan meets many of the planning objectives set forth in the beginning of the study. Additionally, many of the ER measures included in the plan would supplement many of the overall CSRM planning objectives by serving as a natural buffer from some storm impacts to the area's infrastructure.

Consistent with current USACE guidance, the planning efforts focused on developing and comparing distinctly different plans based on the general geographic location for addressing risk reduction. The RP is considered the NED plan when focusing on the general geographic location and features. As explained above a Tiered NEPA strategy is being implemented. As the details on all the measures that are not actionable at this time are developed, additional environmental review on those measures will take place. Supplemental Environmental Assessments (EAs) or EISs will be developed dependent on the level of impacts.

To ensure that all applicable laws and policies are addressed for the RP, this DEIS and accompanying DFR will undergo public, policy, and technical review. The PDT will address any outstanding issues raised during the review and confirm the analyses in this EIS and recommendations to move forward with development and completion of a FFR and EIS.

What's Next?

- Draft Report is reviewed by the **public** (with time to send comments for study team review), **resource agencies, USACE and GLO leadership, and external technical experts.**
- PDT addresses issues raised during the review period.
- USACE Chief of Planning and Policy Review considers public comment and confirms analyses and recommendations at the Agency Decision Milestone.
- PDT prepares and publishes a Final Feasibility Report and Environmental Impact Statement (FFR and EIS) for public, state, and agency review.
- A Chief's Report is prepared.
- The Recommended Plan is refined in the Design Phase
- Supplemental EIS or EA are prepared for Tier One Measures as design are refined.
- Construction is dependent upon Congressional authority and funding.
- The project will be maintained after construction by a local sponsor.

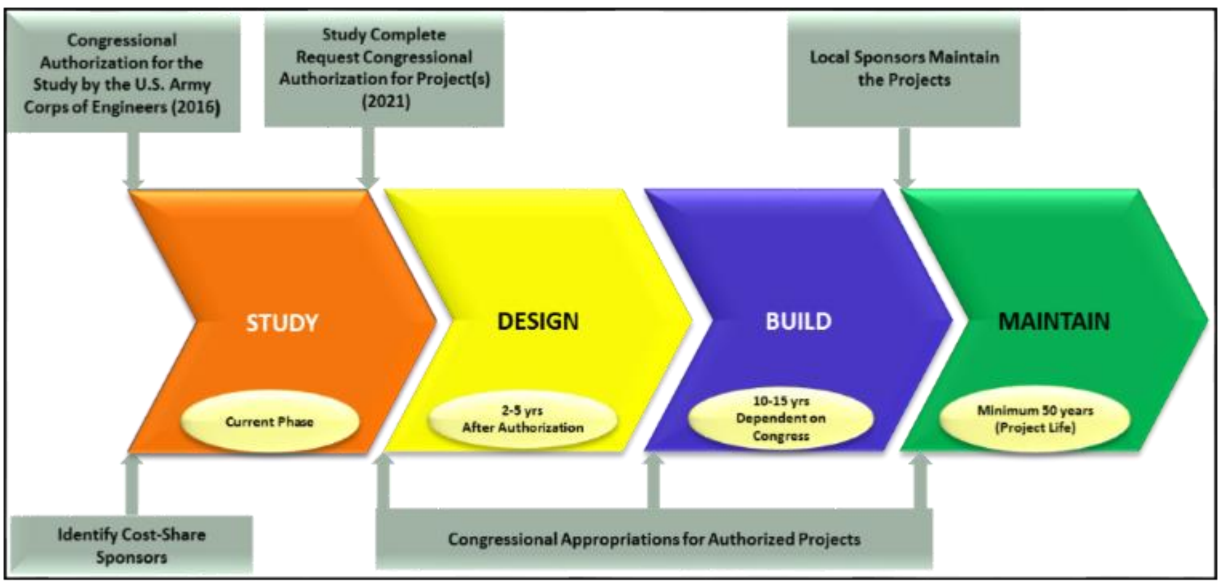

Figure ES-4: Next Steps in the Coastal Texas Study Project

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Acronyms

AAHU	Average Annualized Habitat Units
ACE	Annual Chance Exceedance
APE	Area of Potential Effects
AQCR	Air Quality Control Region
BA	Biological Assessment
BCR	Benefit-to-cost ratio
BMP	Best Management Practice
BO	Biological Opinion
CAA	Clean Air Act
CAR	Coordination Act Report
CBRA	Coastal Barrier Resources Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
CO2	Carbon dioxide
CO2e	Carbon dioxide-equivalent
CWA	Clean Water Act
CY	Cubic Yards
EC	Engineer Circular
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EJ	Environmental Justice
EOP	Environmental Operating Principles
EO	Executive Order
EPA	US Environmental Protection Agency
EQ	Environmental Quality
ER	Engineering Regulation
ERDC	Engineer Research and Design Center
ESA	Endangered Species Act
°F	Degrees Fahrenheit

FCSA	Feasibility Cost Sharing Agreement
FEMA	Federal Emergency Management Agency
FEPP	Flood Emergency Preparedness Plan
FPPA	Farmland Protection Policy Act
FR	Feasibility Report
FRM	Flood Risk Management
FM	Farm to Market Road
FWCA	Fish and Wildlife Coordination Act
FWOP	Future Without Project
FY	Fiscal Year
GHG	Greenhouse Gases
GLO	General Land Office
H&H	Hydraulics and Hydrology
HGB	Houston-Galveston-Brazoria Airshed
HSC	Houston Ship Channel
HTRW	Hazardous, Toxic and Radioactive Waste
HQUSACE	Headquarters US Army Corps of Engineers
I-	Interstate
IPCC	Intergovernmental Panel on Climate Change
LERRDS	Lands, Easements, Rights-of-ways, Relocations, and Disposal Areas
LF	Linear Feet or Foot
MBTA	Migratory Bird Treaty Act
MCY	Million Cubic Yards
MLLW	Mean Lower Low Water
MLT	Mean Low Tide
MOVES	Motor Vehicle Emissions Simulator
MSA	Metropolitan Statistical Area
MSL	Mean Sea Level
NAA	Nonattainment Area
NAAQS	National Ambient Air Quality Standards
NAVD	North American Vertical Datum
NED	National Economic Development

NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NFS	Non-Federal Sponsor
NGO	Non-governmental Organization
NPL	National Priority List
NRHP	National Register of Historic Places
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrous oxides
NRC	National Research Council
NRCS	Natural Resource Conservation Service
NSI	National Structure Inventory
O&M	Operations and Maintenance
OMRR&R	Operation, Maintenance, Repair, Replacement and Rehabilitation
OSE	Other Social Effects
P&G	Principles and Guidelines
PCB	Polychlorinated biphenyl
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
PGL	Planning Guidance Letter
P.L.	Public Law
RCRA	Resource Conservation and Recovery Act
RED	Regional Economic Development
RSLC	Relative Sea Level Change
RSLR	Relative Sea Level Rise
SIP	State Implementation Plan
SAV	Submerged Aquatic Vegetation
SH	State Highway
SHPO	State Historic Preservation Officer
SOC	Species of Concern
TCEQ	Texas Commission on Environmental Quality
TCMP	Texas Coastal Management Plan
TPWD	Texas parks and Wildlife Department

TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
US	United States
USACE	United States Army Corps of Engineers
USCG	US Coast Guard
USDA	US Department of Agriculture
USGS	US Geological Survey
VOC	Volatile organic compound
WMA	Wildlife Management Areas
WRDA	Water Resources Development Act
WRRDA	Water Resources and Reform Development Act

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1.0 PURPOSE AND NEED FOR THE ACTION

The US Army Corps of Engineers (USACE) in partnership with the Non-Federal Sponsor (NFS), the Texas General Land Office (GLO), are conducting the Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study) to determine the feasibility of alternatives that would enhance, restore, and sustain the environment, economy, and culture along the Texas coast.

In accordance with the National Environmental Policy Act (NEPA) of 1969 (42 United States Code [USC] 4321 et seq.)[1], the USACE and GLO have prepared this Draft Environmental Impact Statement (DEIS) to disclose the impacts of constructing large-scale coastal storm risk management (CSRM) and ecosystem restoration (ER) alternative plans to restore and enhance the State's ecologic coastal features and reduce the risk of coastal storm damage. In fulfillment of these and all other legal, regulatory, and policy requirements, this DEIS describes the purpose and need for the action, the range of alternatives considered, and discloses the environmental impacts of the alternatives.

The companion document to the DEIS is the Coastal Texas Protection and Restoration Study Draft Feasibility Report, which describes the formulation process to identify the Recommended Plan.

1.1 BACKGROUND

The Texas coast is an integrated network of built infrastructure and natural environments that should be considered in partnership to understand and achieve coastal resiliency. The state's natural coastal environments contribute resources and invaluable ecosystem services – such as cultural and recreational benefits, seafood, flood prevention, and habitat productivity – that bolster business development, improve quality of life, and attract people to Texas. The built environments along the coast provide the support services, transportation and infrastructure systems that allow communities, businesses and families to grow and flourish up and down the coast. A coastline that maintains a strong ecological foundation is resilient in response to coastal hazards.

Along the Texas coast, vital resources critical to the economic and environmental welfare of the Nation are at risk from coastal storm damage. Forty percent of the Nation's petrochemical industry, 25 percent of national petroleum-refining capacity, eight deep-draft ports, and 750 miles of shallow-draft channels (including 400 miles of the Gulf Intracoastal Waterway [GIWW]) are present in the study area. Critical transportation infrastructure will continue to be at risk from coastal storm damages. Without a comprehensive plan to protect, restore, and maintain a robust coastal ecosystem and

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[1] The final rule to update the Council on Environmental Quality's (CEQ) regulations (40 CFR 1500-1508, 1515, 1516,1517, and 1518) for Federal agencies to implement the National Environmental Policy Act went into effect on September 14, 2020. This DEIS was substantially complete before the regulations were effective, therefore this document is proceeding under the 1978 regulations and their existing agency NEPA procedures.

reduce the risks of storm damage to industries and businesses critical to the Nation's economy and security, the area will continue to be at risk from coastal storms. The health and safety of Texas coastal communities will also continue to suffer without a comprehensive plan.

As a powerful economic engine and an invaluable environmental treasure, the Texas coast is integral to the success of the State and the Nation. Its natural resources, such as beaches, dunes, wetlands, oyster reefs, and rookery islands, provide more than just recreational opportunities. They play a critical role in protecting coastal communities from storm surge and flooding. These coastal resources also contribute to the State and national economies by safeguarding and supporting industries. This includes petroleum refining, petrochemical, chemical and plastics manufacturing, waterborne commerce through the expansive network of Texas ports, commercial and recreational fishing, and tourism.

A concentration of this critical network of infrastructure and industries within the State's coastal region evolved over time because of the area's important and abundant natural resources. For example, the large, natural harbor on the lee side of Galveston Island is sheltered from the strong coastal wind. This created opportunities for commerce and industry to invest and grow in the region. The location of the port was the reason that development grew on and around the barrier islands in the upper coast. As the transportation network surrounding the port expanded, agricultural, manufacturing, and petrochemical investments followed. Continued funding for roadways, railways, and water access signaled a commitment to industries who rely upon the infrastructure that not only serves the Houston and Galveston area, but also the State and the Nation.

Federal investment in harbor access up and down the Texas coast, and expenditures in port capacity have been consistent over time. Recent industry investments in refinery capacity draw residents and support services to reside and work in the coastal region. Population centers in and around the barrier islands and coastal area are essential to support the region's industry. The same physical conditions that make the area vulnerable to coastal storms provide the setting for continued growth of industry and residential areas for the where employees live.

The region is growing, and jobs are being created because the country needs what flows from Texas's coast. This includes tourism, recreational fishing, commercial fishing, and the State's ports, intracoastal waterways, and energy production. Texas' transportation and energy hubs cannot be replicated anywhere else. As long as there is a need for what the Texas coast provides ecologically and economically, residents, businesses, and local stakeholders will continue to work and make the Texas coastline their home, all while adapting to changing coastal conditions.

The Texas coast, however, is subject to coastal erosion, relative sea level rise (RSLR), coastal storm surge, habitat loss and water quality degradation. These coastal hazards place the environmental and economic health of the coast at risk, which negatively impacts the state and national economy. In addition, severe events such as Hurricane Rita, Hurricane Ike, Hurricane Dolly, and most recently Hurricane Harvey cause further ecological and economic devastation to the Texas coast, emphasizing the need for enhanced resiliency of the coast to prevent future damage and loss.

1.1.1 Study Authority

The Coastal Texas Study is being performed under the standing authority of Section 4091, Water Resources Development Act of 2007, Public Law 110-114, which directed the Secretary of the Army, acting through the USACE, to “develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration in the coastal areas of the State of Texas.

The study effort focused on two core USACE missions, CSRM and ER. CSRM required development and evaluation of coastal storm risk from storm surges and erosion associated with tropical events. The ER mission focused upon formulation and evaluation of actions to increase the net quantity and quality of coastal ecosystem resources by maintaining or restoring critical or degraded coastal ecosystems and fish and wildlife habitat.

The Flood Risk Management (FRM) authority addresses inundation risk, typically in inland areas, distinct from storm surge induced flooding and erosion. FRM was also authorized for the study, and was considered in the design of features and evaluation of performance proposed CSRM measures within the Coastal Texas Recommended Plan. This included the potentially detrimental impact of rainfall on the proposed CSRM measures, and the incidental benefits of the proposed measures on local drainage system performance. Several separate FRM studies are authorized in the Houston region, and will apply appropriate models and analysis to evaluate flood risks. The Coastal Texas study doesn’t independently authorize or study FRM measures, but that the Recommended Plan was developed to consider, harmonize with and support current and future FRM projects in the study area.

1.1.2 Study Participants

1.1.2.1 USACE

The primary role of USACE is to lead the study and the design and construction of an identified project. USACE assembled a multidisciplinary team of individuals from across the country to participate in the study, complete technical analyses, and prepare the decision documents. The multi-functional Project Delivery Team (PDT) conducting the study includes technical experts including hydrologic and civil engineers, planners, economists, biologists and cultural resource specialists. Each team member is responsible for identifying water resources problems and formulating solutions within their area of expertise. The PDT is supported by members of the USACE’s Cost Engineering Center of Expertise (MCX) and National Planning Centers of Expertise (PCX’s), including those for Coastal Storm Risk Management, Flood Risk Management, and Ecosystem Restoration.

1.1.2.2 Texas General Land Office (GLO)

The Non-Federal Sponsor (NFS) for the Coastal Texas Study is the Texas General Land Office. The GLO is the oldest state agency in Texas and was formed in 1836 to determine who owned what and where after the Texians and Tejanos won independence. Today, the GLO primarily serves the schoolchildren, veterans, and the environment of Texas. The agency does so by preserving history, maximizing state revenue through innovative administration and through the prudent stewardship of state lands and natural resources, including helping Texas recover from natural disasters and managing coastal resources.

Specifically related to the coast, the GLO is responsible for the management of tidally influenced streams and riverbeds out 10.3 miles into the Gulf of Mexico. This includes responsibility to implement the Texas Coastal Management Program under the Coastal Zone Management Act. To achieve these legislatively mandated responsibilities, the GLO operates various coastal programs, projects and partnerships that work together to address erosion, loss of habitat.

The primary role of GLO throughout the study as a member of the PDT is to actively participate in the discussions, decisions and reviews with the USACE and resource agencies; share knowledge and experience of the project area, local conditions, environment, and design and maintenance issues related to the measures and alternatives under consideration; and identify a plan with a federal interest, which may or may not include a locally preferred plan.

It should be noted that USACE Civil Works projects require participation of a non-Federal sponsor through all phases of project development, including feasibility, preconstruction engineering and design (PED), construction, and operations and maintenance (O&M). The GLO has agreed to serve as the non-Federal sponsor for the feasibility study phase only, which concludes with the approval of the Feasibility Report and EIS.

Project Partnership Agreements will need to be executed for subsequent phases of this project, including PED, construction, and O&M. While it is possible the State of Texas may serve as the non-Federal sponsor for subsequent phases, other local entities such as counties, cities, levee improvement districts, drainage districts, municipal utility districts, or other special taxing entities may elect to, or be created to support implementation of this project.

1.1.3 Study Area

The enabling legislation for the study defines the study area as the “coastal areas of the State of Texas from the Sabine River on the east to the Rio Grande River on the west and includes tidal waters, barrier islands, marshes, coastal wetlands, rivers and streams, and adjacent areas.” This includes all 18 coastal counties, which for study purposes have been divided into four areas: upper Texas coast, the mid to upper Texas coast, the mid Texas coast, and the lower Texas coast (Figure 1-1).

Texas has 367 miles of coastal within which 21 major river basins terminate, bringing fresh water into the individual bays and estuaries which dominate the Texas coast. The Texas shoreline itself is characterized by seven barrier islands: Galveston, Follets, Matagorda, St. Joseph's (San José), Mustang, Pares, and Brazos. Bolivar Peninsula also acts like a barrier island due to its location along the Gulf shoreline. These barrier islands serve as the backbone for the Texas Gulf Coast. A key feature of the study is the GIWW, which parallels the Texas coast and can be found directly behind the barrier island system.

For purposes of this study, the location of potential improvements or other alternative plans were limited to areas within the Texas Coastal Zone Boundary. The coastal zone is defined as "Coastal waters and adjacent shorelands extending inland only to the extent necessary to control shorelands where the uses of which have a direct and significant impact on coastal waters." Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent developed lands are all included.

1.1.4 Project History

The study effort was initially funded by Congress in 2014, which initiated a USACE led reconnaissance study. The reconnaissance study established the Federal interest in pursuing a feasibility study related to coastal storm risk management and ecosystem restoration along the entire coast of Texas.

After completion of the reconnaissance study, a Feasibility Cost Sharing Agreement was signed in November 2015, officially designating the GLO as the non-Federal sponsor and initiating development of a Feasibility Report and EIS. During this time, the study team identified a number of potential solutions to the problems in the study area and began assessing the technical feasibility of each, as well as each potential solution's performance in terms of damages prevented and habitats restored, the economic cost of constructing and maintaining, and the potential short- and long-term environmental impacts on the natural and human environment. The findings and recommendations of this phase of the study were presented in a draft Integrated Feasibility Report and EIS (DIFR-EIS) that was released for public and agency review in October 2018.

During the 106-day public comment period, over 1,799 comments were received. Commenters expressed concern over including/excluding certain features, potential impacts of proposed solutions, and the lack of detail provided. Comments also suggested that the DIFR-EIS did not provide a clear representation of the Tentatively Selected Plan (TSP). In response to the significant and valuable feedback, the study team performed additional analyses and refined the TSP, Feasibility Report, and environmental impacts analysis that would address a number of their concerns.

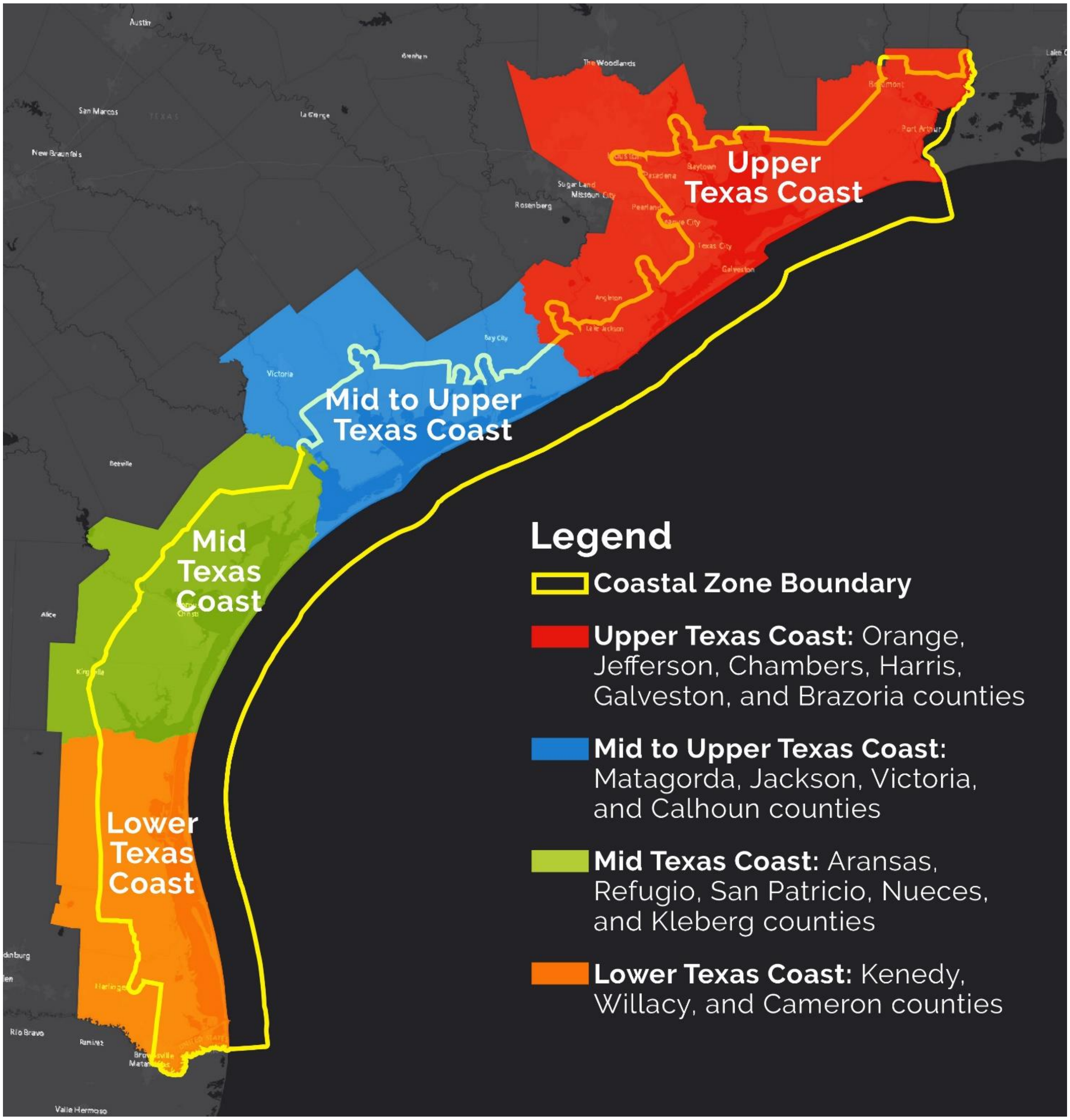


Figure 1-1. Coastal Texas Study Area and Regions

To improve the clarity of the overall project, it was determined that the Feasibility Report and EIS should be independent documents. Additionally, a tiered approach to the NEPA analysis is being undertaken. This strategy provides subsequent and more detailed NEPA analyses, which will include additional public engagement and public review periods. The tiered approach provides for a timely response to issues that arise from specific, proposed actions and supports forward progress toward completion of the overall study. Section 1.4 below describes this approach in more detail.

A number of the concerns raised over the TSP presented in the DIFR-EIS have been addressed through refinements to the plan. A notable change is the removal of the proposed levee on Bolivar Peninsula and Galveston Island. To compensate for this change, the beach restoration profile (height and width) has been increased to provide additional risk reduction. While increasing beach and dune profiles does not provide the same level of risk reduction as the previously proposed levee system, it does provide increased risk reduction compared to the previous design which was specifically for ecosystem restoration. Using an enhanced beach and dune system on Bolivar Peninsula and Galveston Island to provide more natural coastal storm risk management is consistent with numerous comments received during the 2018 DIFR-EIS report comment period. The additional area of beach restoration also improves habitat in this area under existing and future conditions. A second notable change includes the removal of the proposed gate structure near High Island on the GIWW. The specific changes to the proposed solutions are further described in Chapter 2 of this EIS and in Chapter 2 of the Feasibility Report.

1.1.5 Previous Actions and Activities

The Federal Government, the State of Texas, and local entities have worked together for over 100 years to implement policies and projects to protect our coastal communities from hazards, to restore our vital ecosystems, and to advance economic development. The results of these many partnerships now define the Texas coast. Some of the projects implemented by USACE and their partners along the coast include:

Federal CSRM Systems:

- Galveston Seawall
- Freeport Hurricane Flood Protection System
- Lynchburg Pump Station Levee System
- Matagorda Hurricane Flood Protection System
- Port Arthur Hurricane Flood Protection System
- Orange County Coastal Storm Risk Management (under construction)
- Texas City Hurricane Flood Protection System

Federal Navigation:

- Brazos Island Harbor (Brownsville Ship Channel)
- Corpus Christi Ship Channel
- Freeport Ship Channel
- Galveston Harbor Channel
- Gulf Intracoastal Waterway (GIWW)
- Houston Ship Channel
- Matagorda Ship Channel
- Sabine-Neches Waterway
- Texas City Ship Channel

In recent years, numerous USACE led or locally led studies have evaluated coastal storm risk management and ecosystem restoration needs along the Texas Coast. These studies represent a wealth of information which was utilized heavily in the development of the entire Coastal Texas Study. While these prior studies did not always result in similar recommendations, each study provided valuable input, often from different viewpoints, which was considered in detail and broadened the inclusiveness of the Coastal Texas Study. Summaries of relevant recent studies are provided below:

Texas Coast Hurricane Study Feasibility Report, 1978. This USACE Civil Works feasibility study investigated ways of reducing losses from hurricane flooding and determined the feasibility of constructing protective measures for long reaches of the coast. From this study came hurricane flood protection proposals for the City of Galveston, Baytown, La Marque/Hitchcock, and Angleton, Texas. The study introduced closure gates to navigation channels among traditional flood protection systems such as pumps, levees, and floodwalls.

Coastal Texas Protection and Restoration Study, Final Reconnaissance 905(b) Report, 2015. This USACE Civil Works reconnaissance study established Federal interest in pursuing a feasibility study related to coastal storm risk management and ecosystem restoration along the entire coast of Texas.

Texas A&M University, Galveston – "Ike Dike" Studies. For over 10 years, Texas A&M University Galveston has studied the feasibility, benefits, and challenges of constructing a coastal barrier, stretching from Freeport in the west to Sea Pines Park in the east, to protect the Houston-Galveston region, including Galveston Bay, from hurricane storm surge. This work produced numerous reports, papers, presentations, and other sources of information which were utilized by the Coastal Texas Study team.

Rice University – Galveston Bay Park Plan Studies. For nearly 10 years, Rice University and the Severe Storm Prediction, Education, and Evacuations from Disasters (SSPEED) Center has studied different alternatives for protecting critical resources in the Houston-Galveston region from hurricane storm surge. This includes a recent proposal, titled the Galveston Bay Park Plan, which proposes mid-bay solutions developed in concert with navigation channel improvements to augment hurricane protection within Galveston Bay. This work produced numerous reports, papers, presentations, and other sources of information which were utilized by the Coastal Texas Study team.

Sabine Pass to Galveston Bay Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study, 2017. This USACE Civil Works feasibility study evaluated improvements to the existing Port Arthur and Freeport Hurricane Flood Protection Systems in addition to a new coastal levee system in Orange County. The Bipartisan Budget Act of 2018 funded the implementation of these projects, which are currently in the design phase and moving towards construction. This study excluded the Galveston Bay system, which was being studied separately as part of the Coastal Texas Study.

Gulf Coast Community Protection and Recovery District Storm Surge Suppression Study, 2018. This GLO funded effort, executed by a local special purpose district, investigated the feasibility of reducing the vulnerability of the upper Texas coast to storm surge and flood damages in the aftermath of Hurricane Ike in 2008. This study covered a six-county region, including Brazoria, Galveston, Harris Chambers, Jefferson, and Orange counties. This study provided extensive inputs to the Coastal Texas Study.

Texas Coastal Resiliency Master Plan, 2017 & 2019. This State-wide master plan aims to bolster coastal resiliency in Texas through improved coastal management and the identification of critically needed ecosystem projects or improvements. This plan also provides a framework for communities or other stakeholders to implement measures in support of this vision. This study provided extensive inputs to the Coastal Texas Study regarding ecosystem restoration activities.

Jefferson County Ecosystem Restoration Feasibility Study, 2019. This USACE Civil Works study investigated the feasibility of providing shore protection and related improvements with the objective of protecting and restoring environmental resources on and behind the beach, in the area between Sabine Pass and the entrance to Galveston Bay. The recommended ecosystem restoration plan for Jefferson County would restore marsh and GIWW shoreline features that stabilize and sustain critical marsh resources. The study area considered in this study has been excluded from the area of consideration for the Coastal Texas Study.

Houston Ship Channel Expansion Channel Improvement Project, 2020. This USACE Civil Works feasibility study examines the feasibility of improving navigation on the Houston Ship Channel. The Coastal Texas Study was coordinated closely with this study, due to the critical navigation considerations of constructing a surge protection system within Galveston Bay.

1.2 PURPOSE AND NEED

1.2.1 Purpose

This study is being conducted to determine the feasibility of constructing a large-scale, comprehensive CSRM and ER plan to restore and enhance the State's ecologic coastal features and reduce the risk of coastal storm damage. The study will specifically investigate two purposes, CSRM and ER, to achieve the mission:

Develop and evaluate coastal storm damage risk reduction measures for Texas residents, industries, and businesses, which are critical to the Nation's economy (CSRM).

Increase the net quantity and quality of coastal ecosystem resources by maintaining and restoring coastal Texas ecosystems and fish and wildlife habitat (ER).

The intent of the CSRM and ER structural and nonstructural features is to provide coastal communities with a multiple-lines-of-defense strategy to become more resilient and less vulnerable to coastal hazards. This would help protect the vital coastal ecosystem, the health and safety of residents and visitors in the coastal communities, and the industries within those communities, all of which are critical to the economic wellbeing of the State and the Nation.

1.2.2 Need

Along the Texas coast, vital resources critical to the social, economic, and environmental welfare of the nation are at risk. Historically and currently, the Texas coast is vulnerable to tropical storms and hurricanes that take human life, flood homes and businesses, and damage coastal ecosystems. The damages from hurricanes and tropical storms could become more severe as wind speed is projected to increase with higher sea levels and rising ocean temperatures. When tropical disturbances negatively impact the Texas coast, the immediate fallout and the continued aftermath affect more than the people who live in these coastal counties. The Texas coast is an economic engine—home to ports, oil and gas refineries, corporate headquarters, military bases, petrochemical facilities and numerous other enterprises. The shutdown of even a single Texas port can impact State and national economies for a significant period of time as experienced in 2008 when Hurricane Ike came ashore near Houston and Galveston.

Texas is one of the states most impacted by hurricanes and storm surge, ranking among the top states in at-risk property value, historic storm damages, and historic number of direct hurricane hits. Over recent history, significant hurricane storm surge events have impacted every region of the Texas coast, including every major bay system. Absent additional protection, the risk associated with hurricane storm surge is anticipated to increase over time for multiple reasons including: continued population growth and economic expansion within at-risk coastal areas, forecasted increases in storm intensity due to changes in climate patterns, and forecasted increases in relative sea level.

Shoreline erosion is also a significant threat to the Texas coast. On average, the Texas shoreline is retreating 4 feet per year with some areas experiencing losses greater than 30 feet per year making these rates some of the highest in the Nation. Shoreline erosion threatens coastal habitats, recreational amenities, and residential, transportation, and industrial infrastructure. Absent the protection or restoration of these critical coastal features, the risks associated with coastal erosion are anticipated to increase. As the shoreline retreats, sensitive ecosystems are destroyed and the ability of the natural coastline to defend against hurricane surge is diminished, which will be exacerbated by projected future conditions.

Relative sea level rise, which is a combination of land subsidence and sea level rise, exacerbates the existing vulnerabilities associated with coastal living and is expected to increase the potential for coast flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future. Current forecasts indicate that relative sea levels could rise by 1 to 6 feet over the next 50 years. Depending on the severity and rate of sea level change, there could be significant impacts on communities along the Texas coast. For example, a 4-foot increase in sea level could affect a quarter of interstates and arterials and nearly 75 percent of port facilities on the Gulf coast (Climate Change Science Program, 2008). Furthermore, relative sea level rise degrades the primary lines of defense and exacerbate storm surge concerns.

Without a comprehensive plan to protect, restore and maintain a diverse coastal ecosystem and reduce the risks of storm damage to homes and businesses, the nation's economy and the health and welfare of the coastal communities will continue to be at risk from coastal storms.

1.2.3 Study Scope

The study effort has been structured to focus on two core USACE missions, CSRM and ER. Specific to CSRM, the study aimed to develop and evaluate various coastal storm damage risk reduction measures primarily related to the management of storm surges associated with tropical events. Specific to ER, the study aimed to increase the net quantity and quality of coastal ecosystem resources by maintaining or restoring critical or degraded coastal ecosystems and fish and wildlife habitat.

It should be noted that the study team elected to not consider another core USACE mission, Flood Risk Management (FRM), as a component of the study. FRM relates to the management of rainfall induced flooding, typically in inland areas, compared to storm surge induced flooding generally associated with CSRM. Although included in the study authority, FRM was omitted from this study as it was determined that adequate authorities and programs already exist to address FRM in the study area, separate from the Coastal Texas Study. Furthermore, it was determined that formulation of FRM specific measures could be better accomplished through more focused drainage basin specific planning efforts authorized under different authorities, such as Section 216 of the Rivers and Harbors Flood Control Act of 1970 (PL 91-611).

Although FRM was not included as a component of this study, rainfall impacts were considered in the study process. This includes both the potentially detrimental impact of rainfall on the proposed CSRM measures, as well as the incidental benefits the proposed measures may have on the performance of local drainage systems.

1.3 OVERVIEW OF THE PROJECT DELIVERY PROCESS

Standard USACE project delivery consists of the agency leading the study, design, and construction of authorized water resource projects. Nonfederal sponsors typically share in study and construction costs, providing the land and other real estate interests and identifying locally preferred alternatives if different than the USACE identified plan.

Congressional authorization and appropriations processes are critical actions in a multistep process to deliver a USACE project. The standard process consists of the following basic steps:

- Congressional study authorization is obtained in a Water Resources Development Act (WRDA) or similar authorization legislation.
- USACE performs a feasibility study, if funds are appropriated.

- Congressional construction authorization is pursued. USACE can perform preconstruction, engineering, and design while awaiting construction authorization, if funds are appropriated.
- Congress authorizes construction in a WRDA or similar authorization legislation, and USACE constructs the project, if funds are appropriated.

The process is not automatic and is reliant on appropriations by Congress to perform the study and construct the project. Without Congressional authorization USACE cannot proceed with the next step. Major steps in the process are shown in **Figure 1-2**.

1.3.1 Feasibility Study

The feasibility study is the first stage of development for a potential Federal water resources development project and where the SMART Planning process is applied. The purpose of the feasibility study is to identify, evaluate and recommend to decision makers an appropriate, coordinated and workable solution to identified problems and opportunities. The Federal objective of any USACE project planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements.

A wide range of alternatives will be investigated and the alternative with the greatest net economic benefit must be identified (the National Economic Development [NED] Plan). It is also during the feasibility stage that NEPA compliance takes place and environmental documentation is prepared. The NEPA process and associated documentation is used to tie the impact analysis together and discuss effects and compliance with other environmental laws that are applicable to the study.

A feasibility report documents the study results and findings, including the formulation of alternatives, the selection process of the recommended alternative, and the costs and benefits of that recommended plan. The final feasibility report provides a sound and documented basis for decision makers and stakeholders regarding the recommended solution. A feasibility study ends when the Chief of Engineers signs a Chief's Report and submits it, the Final Feasibility Report, and associated NEPA documentation to the Assistant Secretary of the Army (ASA(CW)). The ASA(CW) then submits the report documentation to the Office of Management and Budget (OMB), where they review the report to ensure it is consistent with Administration policies and priorities and provides clearance to release the report to Congress. The ASA(CW) then submits the report to Congress for consideration of authorization to construct the recommended project.

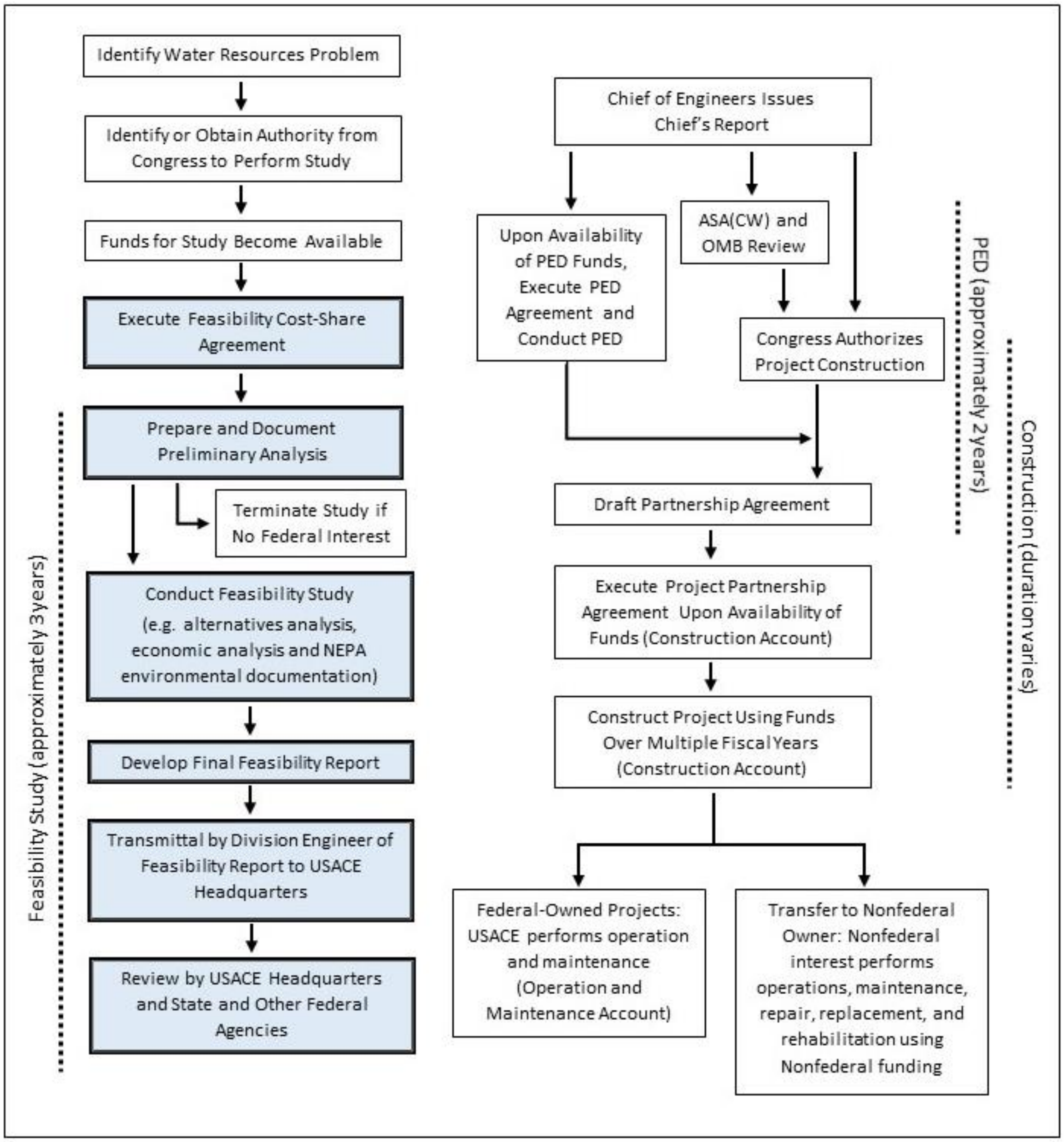


Figure 1-2. Major Steps in USACE Project Development and Delivery Process

A feasibility study works progressively through the six-step planning process in four main phases. The four phases of the study process are: Scoping, Alternative Evaluation and Analysis; Feasibility-Level Analysis, and Chief's Report development. There are four key decision points or milestones that mark significant decisions along the way to an effective and efficient study: Alternatives Milestone, Tentatively Selected Plan Milestone, Agency Decision Milestone, and Chief's Report Milestone. While some general guidelines have been provided, the exact duration of each phase varies depending on the work required to make the next decision. However, the end goal is to complete the study within three years. See **Figure 1-3** for a brief description of actions completed during each phase of the study and typical duration in months for each phase.

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 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. The following are key concepts of the SMART Planning process:

- Uncertainty and Level of Detail. The approach to level of detail, data collection, and models is based on what is necessary to support decision to be made. The level of detail required to make planning decisions will grow progressively more detailed over the course of the study, as the study team moves from an array of alternatives to a single recommended alternative. Final feasibility studies will have an adequate level of detail required by law and regulation for a Chief's Report and recommendation to Congress for an authorized project but would not have sufficient detail to make the project ready for construction. The expense and time of collecting more data, developing a new model, or analyzing multiple alternatives to a high level of detail must be justified, rather than assumed.
- Vertical Team Integration. Early and ongoing vertical team engagement of decision makers. Districts will be responsible for executing studies with district staff forming the Project Delivery Team (PDT). However, a coordinated USACE District, Division, and Headquarters Vertical Team will be deployed throughout the project development process in a One-Corps approach to identify and resolve policy, technical and legal issues early in the process.
- Alternative Comparison and Selection. There is no single "best" plan, and there are a variety of approaches (quantitative and qualitative) to multi-criteria decision making and plan selection of the NED plan. A full array of alternatives will be considered and evaluated. However, feasibility-level design work will focus on the agency recommended plan and a Locally Preferred Plan (LPP) if appropriate.

The Coastal Texas Study follows the SMART Planning guidance of risk informed decision-making but has been granted a waiver for time and cost, which allows up to $19 million to be spent on the study over a six-year period. The primary driver for this exemption is the scale of the study area and that this study has two purposes including reducing the risk of flood damages and evaluating ecosystem restoration features. Throughout the study process, the PDT has relied on the use of existing information, where appropriate, and risk-informed decision making to identify the TSP and subsequent RP presented in the Draft Feasibility Report.

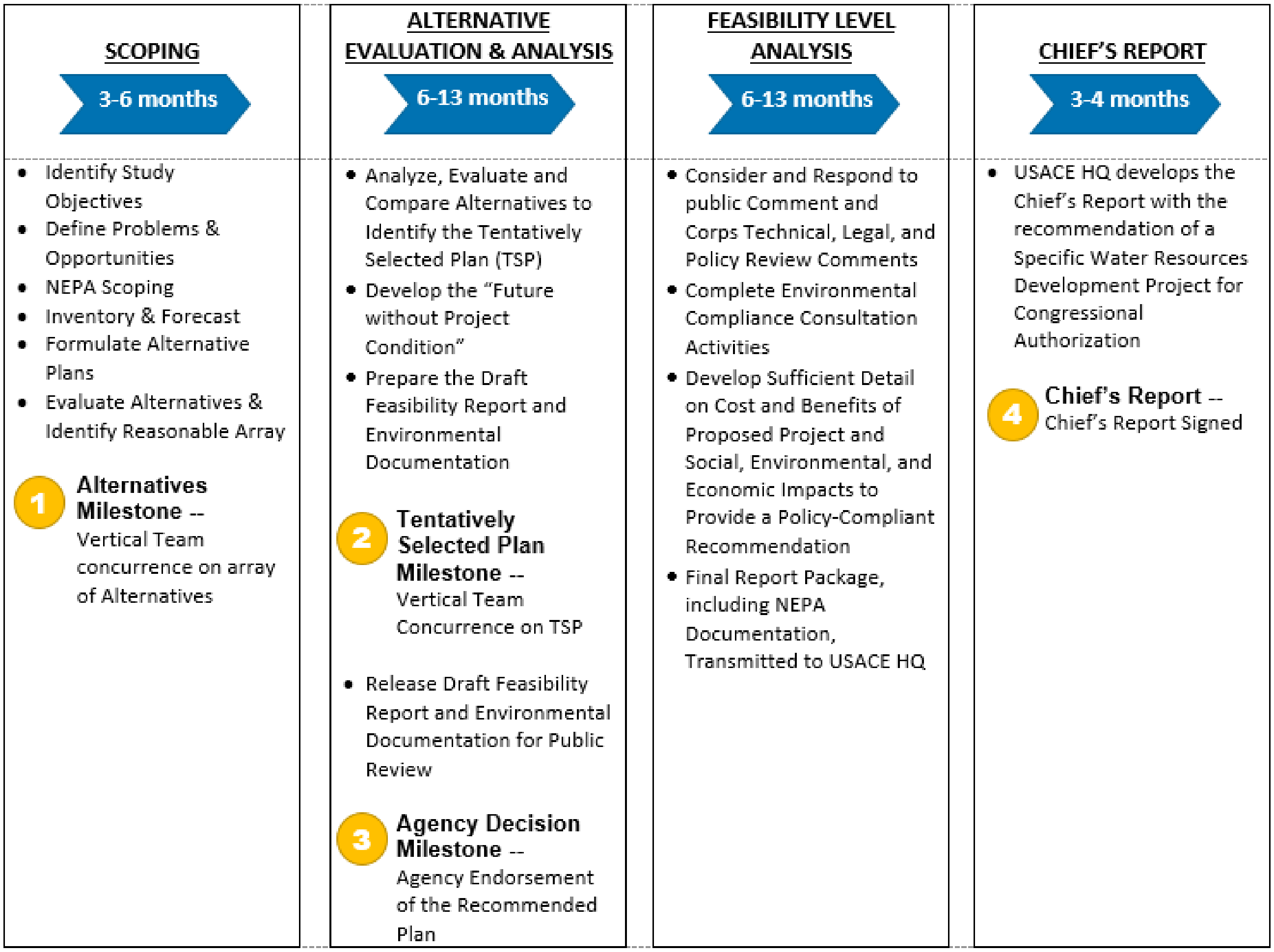


Figure 1-3. Phases of a USACE Feasibility Study.

1.3.2 Preconstruction Engineering and Design

USACE preconstruction engineering and design (PED) of a project may begin after the Chief's Report subject to the availability of appropriations. PED consists of finalizing the project's design, preparing construction plans and specifications, and drafting construction contracts for advertisement. USACE work on PED is subject to the availability of USACE appropriations. Once funded, the average duration of PED is two years, but the duration varies widely depending on the size and complexity of a project.

1.3.3 Construction and Operation and Maintenance

Once the project receives congressional construction authorization, federal funds for construction are sought in the annual appropriations process. Once construction funds are available, USACE typically functions as the project manager; this is, USACE staff, rather than the nonfederal project sponsor, is usually responsible for implementing construction. Although some construction may be performed by USACE personnel and equipment, the majority of work typically is contracted out to private engineering and construction contractors.

Post-construction ownership and operations responsibilities depend on the type of project. When construction is complete, USACE may own and operate the constructed project or ownership and maintenance responsibilities may transfer to the nonfederal sponsor.

1.4 NEPA COMPLIANCE

The National Environmental Policy Act (NEPA) is a Federal Law that serves as the Nation's basic charter for environmental protection. While NEPA does not require an agency to achieve particular environmental results, it does require an agency to take a hard look at the potential environmental impacts of a proposed Federal action. NEPA promotes better decision making by ensuring that high quality environmental information is available to agency officials and the public before the agency decides whether and how to undertake a major Federal action. When integrated with the USACE planning process, the NEPA process provides a robust framework for engaging stakeholders, evaluating impacts, and formulating recommended actions which achieve a study's planning objectives, while avoiding or minimizing environmental impacts. To comply with NEPA, a Federal agency must prepare an Environmental Impact State (EIS) if it is proposing actions that may significantly affect the quality of the natural and human environment.

The Coastal Texas 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 additional environmental reviews for certain measures included in the Recommended Plan. For projects as large and complex as the Coastal Texas 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 needed 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 considering the full range of potential effects to both the human and natural environments from implementing the proposed solutions. The purpose of the Tier One EIS is to present the information considered in selecting 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 environmental effects of the proposed solutions.

Once refinements are made and additional information is gathered, USACE will begin Tier Two assessments, 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 a Tier Two 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.

This DEIS contains two levels of review. First, the DEIS is the Tier One assessment for the measures in the Recommended Plan that require future Tier Two environmental reviews. Second, this DEIS contains complete environmental reviews for nine project measures that could provide benefits soon after construction and currently have enough design detail to complete the impact analysis. In this document the measures requiring subsequent environmental review are referred to as Tier One Measures and the measures where further environmental review might not be necessary are referred to as Actionable Measures.

- **Actionable Measures.** These measures are referred to as "actionable measures", because this report provides a complete environmental review consistent with NEPA for these measures. These measures are comprised of features routinely constructed within the Galveston District (*e.g.* breakwaters, beneficial use of dredge material, construction of bird islands, and beach nourishment) and have a level of certainty with the current designs to support complete environmental reviews. The Environmental Consequences of these actionable measures are described in Chapter 5 of this DEIS.
- **Tier One Measures.** The measures included in the Recommended Plan that will require Tier Two environmental review are referred to as "Tier One Measures" because this report is the Tier One assessment for these measures. The Environmental Consequences of the Tier One Measures are described in Chapter 4 of this DEIS.
- The measures included in the Recommended Plan are listed near the end of Chapter 2 of this DEIS and the designation as to whether they are Actionable Measures or Tier One Measures is clearly stated in that section.

1.4.1 Public Participation in the NEPA Process

In accordance with USACE planning guidelines and NEPA requirements, a proactive approach has been taken to engage the public, resource agencies, industry, local governments, and other interested parties in the Coastal Texas Study planning process and through development of the EIS. This included regular and continued coordination over the five-year study period, starting in 2014 with a series of Scoping Meetings and extending through a series of Public Meetings to review of the Feasibility Report and EIS in 2020.

Each round of public engagement activities included public meetings in each of the study regions. Highlights of this multi-year outreach program include:

- Eight Scoping Meetings in 2014 to announce initiation of the reconnaissance/feasibility studies and to solicit input on storm risk reduction and habitat restoration.
- Publication of the Notice of Intent to Prepare a Draft Environmental Impact Statement in the Federal Register on March 31, 2016, as well as solicitation of scoping comments from Federal, State, and local agencies, Tribal Nations, and other interested organizations and the public.
- Monthly interagency coordination meetings with Federal, State, and local agencies.
- Regular updates to the study website (https://coastalstudy.texas.gov).
- Monthly resource agency meetings to seek agency feedback and provide study progress updates. Additional meetings/workshops were held to discuss specific topics such as ER screening, modeling needs, assumptions, and forecasts, mitigation, and impacts of proposed solutions.
- Seven Public Meetings in 2018 to provide the public with updated information about the study scope and schedule and to solicit public comments for consideration on the Draft Integrated Feasibility Report and EIS (DIFR-EIS) and the proposed Tentatively Selected Plan (TSP)
- Twenty community-based work group sessions, hosted by the Non Federal Sponsor in partnership with local leaders.
- Three Public Meetings in 2019/2020 to update stakeholders on study progress.
- Over 60 presentations or briefing sessions at conferences, professional meetings, and other public and private events.

Engagement activities have been integral to the planning process, as it has generated thousands of comments and suggestions which informed study planners of key concerns and helped to shape and refine the Recommended Plan. Most significantly, input received on the DIFR-EIS in 2018 and input from subsequent community-based workgroups led to refinements in plan formulation which resulted in the Recommended Plan presented in this report.

A more detailed summary of all outreach, review and consultation activities with both the general public and applicable Federal, State and local agencies is provided in Chapter 7 and Appendix M of Feasibility Report.

1.5 DOCUMENT STRUCTURE

This DEIS discloses impacts that would result from implementation of the No Action and two CSRM and six ER alternatives that were analyzed in detail.

The DEIS is organized within the framework of nine chapters followed by appendices. The general content of each chapter are as follows:

Chapter 1. Purpose and Need for Action. This chapter includes a description of the proposed action and a brief summary of information relevant to the proposal, including a description of the purpose and need for agency action, project objectives, and public involvement strategies that were used to inform the public about the study and the study process. Additionally, this chapter describes the decision framework that will be used for the study and a description of the DEIS document structure.

Chapter 2. Alternatives. This chapter includes a description of the No Action Alternative and six Ecosystem Restoration Alternatives and two Coastal Storm Risk Management Alternatives (including the selected alternative) that could accomplish the proposed action and the reasonable range of alternatives that were considered but not carried forward for detailed analysis.

Chapter 3. Affected Environment. This chapter describes in detail the existing conditions (affected environment) of physical resources and baseline conditions that could be affected by the Project.

Chapter 4. Tier 1 Environmental Consequences. This chapter presents an overview of the potential environmental impacts anticipated to result with implementation of the CSRM measures.

Chapter 5. Actionable Measure Environmental Consequences. This chapter presents an in-depth analysis of the potential environmental impacts anticipated to result with implementation of the actionable measures.

Chapter 6. Compliance with Other Laws and Regulations. This chapter demonstrates how the preferred alternative (Tentatively Selected Plan) complies with applicable environmental laws, executive orders, and policy.

Chapter 7. Public Involvement. This chapter provides a summary of the public involvement and interagency coordination actions taken throughout the study process.

Chapter 8. List of Preparers. This chapter includes the list of individuals who prepared the document.

Chapter 9. References. This chapter includes a complete list of references used in the preparation of the document.

Chapter 10. Index. This chapter contains an index of key terms and subjects found within the document.

Appendices. The appendices provide supplemental, detailed information used in the analysis of the alternatives.

Additional information, including more detailed descriptions of the range of alternatives, the plan formulation and feasibility study process, and technical analyses for assessing the performance of alternatives can be found in the Feasibility Report and associated appendices.

This DEIS examines the environmental impacts anticipated to result with implementation of the Proposed Action and other action alternatives described in Chapter 2. The following environmental resource areas are being considered in detail for the Project:

- Land Use and Ownership
- Air Quality
- Climate
- Geology and Soils
- Hydrology
- Water Resources
- Floodplains
- Wetlands
- Vegetation
- Terrestrial and Aquatic Species
- Protected Species and Habitats
- Historic and Cultural Resources
- Socioeconomics
- Environmental Justice
- Aesthetics/Visual Resources
- Noise
- Recreation
- Hazardous, Toxic and Radioactive Wastes
- Transportation/Navigation

2.0 ALTERNATIVES ANALYSIS

The chapter summarizes the formulation process for identifying measures and alternatives, alternatives that were considered in detail, and alternatives considered but eliminated from detailed analysis. While similar to the Plan Formulation Chapter in the Main Report, this alternatives analysis focuses on the information required by the Council on Environmental Quality (40 CFR 1502) and the USACE procedures for implementing NEPA (33 CFR 230). The study authorization directed the PDT to evaluate CSRM and ER solutions. These two purposes were authorized in recognition that the study area is vulnerable to both coastal storms and the gradual processes that wear away natural coastal areas and habitats. While the CSRM and ER measures were formulated to be complementary, as part of the multiple lines of defense strategy, the formulation processes do vary. Therefore, in this chapter the formulation processes applied to CSRM and ER will be discussed separately. The recommended plan will be the combined endorsement for CSRM and for ER.

An initial draft Integrated Feasibility Report and Environmental Impact Statement for the Coastal Texas Protection and Restoration Study (DIFR-EIS) was published in the Federal Register on Friday, October 26, 2018. The detailed Alternatives screening that was described in the DIFR-EIS is hereby incorporated by reference. In consideration of commentary received during the public comment period, the PDT, with permission from the Vertical Team, decided to separate the Feasibility Report from the Environmental Impact Statement to reduce the complexity of the documentation and to make it easier for the reader to hone in on particular topics. For the discussions included in this Chapter, the Feasibility Report will be referred to as the Main Report. Also, Appendix A to the Main Report will be referred to as the Plan Formulation Appendix and Appendix D will be referred to as the Engineering Appendix.

The project alternatives are based on a preliminary level of design (i.e. not construction ready), which the PDT used to assess primary differences in performance, cost, and impacts. Refinements were made to design elements since the 2018 draft report and further refinements will be made during PED for the recommended alternative. Between this draft and final EIS, alternatives would be subject to refinement taking into account public and agency comments received during the DEIS review period. Tier One Measures will have public engagement consistent with the CEQ and USACE regulations in the subsequent environmental review. This chapter is a summary of the plan formulation process. Appendix A of the Feasibility Main Report contains more details regarding the measures and alternatives considered.

2.1 ALTERNATIVE FORMULATION PROCESS

The Federal water resources planning process was used to identify a tentatively selected plan (TSP) which was described in the 2018 DIFR-EIS. First the problems and opportunities related to coastal storm risks and resiliencies were defined and then specific planning objectives and constraints were identified. A full list of the defined problems and opportunities can be found in Section 3.1.1 of the Plan Formulation Appendix. Also, detailed discussions on the planning objectives and constraints can be found in Section 3.2 of the Plan Formulation Appendix. Various structural and non-structural management measures were identified that achieved the planning objectives and avoided planning constraints. Management measures were screened out based on how well they met the study objectives and formulation criteria. Some measures were dropped from further consideration at that point. Measures were then combined to form alternatives. Alternatives were then screened out based on feasibility, cost, and environmental impacts to identify the preferred alternative.

2.2 COASTAL STORM RISK MANAGEMENT PLAN FORMULATION

2.2.1 Coastal Storm Risk Management Objectives and Strategies

The primary objective of the CSRM measures is to reduce flood damages to property and infrastructure, and increase the resilience of coastal populations from storm surges. Measures were derived from a variety of sources including prior studies (*e.g.* Sabine Pass to Galveston Bay, 2017), the public scoping process, and the PDT. A full list of the specific objectives identified for CSRM is located in Table A3 of the Plan Formulation Appendix.

The CSRM plan formulation approach focused on the following strategies:

- Reduce the susceptibility of residential, commercial, and public structures and infrastructure to hurricane-induces storm damages,
- Build redundancy into the alternatives to increase the reliability of the system,
- Develop a plan that performs under a wide range of conditions (e.g. range of storm severity, storm tracks, tides, forecast accuracy at the time of the event, and probabilistic rates of sea level rise), and
- Limit the exposure and vulnerability of existing structures

The PDT focused on opportunities that would create multiple lines of defense which include both man-made features, such as levees, and natural features including coastal wetlands and sediment balanced beach and dune systems. The purpose of the multiple lines of defense was to take advantage of redundancy and to identify measures that complement each other to increase resiliency.

2.2.2 Development of Coastal Storm Risk Management Measures

Region specific goals and objectives were developed from the expanded problems and opportunities which are discussed in detail in Section 3.2 of the Plan Formulation Appendix. As previously discussed, measures were developed using input received from the NEPA public scoping process; information from previous and ongoing studies, collaboration with the Interagency Coordination Team, and from the professional judgment of the PDT. The initial measure list included a total of 92 different measures across all 4 planning regions, 29 of which were CSRM measures. The CSRM measures and alternatives were formulated to achieve National Economic Development (NED) principles and objectives. The complete list of measures is provided in Table A-2 of the Plan Formulation Appendix.

A management measure is a feature or an activity that can be implemented at a specific geographic site to address one or more planning objectives. They can be used individually or combined with other management measures to form alternative plans. Measures were developed to address problems and to capitalize upon opportunities. The objective of the ecosystem restoration (ER) measures was to restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition, while coastal storm risk management (CSRM) measures are proposed to reduce flood damage to property and infrastructure, and increase the resilience of coastal populations from storm surge damage.

2.2.3 Region 1 CSRM Alternatives

The PDT was encouraged to identify a conceptual array of comprehensive, plans, tailored to the regions, that would reduce risks of flooding caused by storm surge and coastline degradation while considering a full range of risks to people, environment, property, and economy as well as infrastructure, construction, operations, and maintenance costs. This approach was similar to the Louisiana Coastal Protection and Restoration Authority (CPRA). The conceptual formulation strategy explored whether three different general geographic strategies (Gulf Shoreline Focus, Back/Mid Bays Focus, and Upper Bay Focus) could achieve project goals. Additional discussions and visualization of the approaches is included in section 4.1.2 of the Plan Formulation Appendix. The following themes were identified for CSRM in Region 1.

- **Gulf Front Coastal Barrier:** This conceptual strategy involves preventing storm surge from entering Galveston Bay. This would be achieved by placing a barrier system across Bolivar Peninsula and Galveston Island with a series of gates at Bolivar Roads to connect the system. The PDT determined that this strategy would likely require improvements to the Galveston seawall, a ring barrier along the west and north ends of Galveston Island to address wind-driven surges from the bay, and nonstructural measures to complement the system.
- **Coastal Barrier behind the GIWW Coastal:** This conceptual strategy is similar to the Gulf Front Coastal Barrier in that it involves preventing storm surges from entering Galveston Bay, however the alignment would utilize the Texas City Dike and the GIWW to minimize direct impacts to the barrier islands. This strategy would require the placement of a series of gate structures that would run from the end of the Texas City Dike to the north shoreline of the GIWW north of Bolivar Peninsula. The PDT determined that this strategy would also likely require improvements to the Texas City Levee System, the Texas City Dike, and would still require

improvements to the Galveston seawall, a ring barrier along the west and north ends of Galveston Island to address wind-driven surges from the bay, and nonstructural measures to complement the system. Early discussions on this conceptual strategy identified potential navigation issues because the location of the gate structures would be close to the intersections of the Houston Ship Channel (HSC), the GIWW, and the Texas City Ship Channel.

- **Mid Bay Barrier:** This conceptual strategy was developed to avoid some of the navigation impacts that would be incurred by the two previous conceptual strategies by placing a surge barrier near the middle of Galveston Bay. The system would start on the east side of Galveston Bay near Smith Point, it would continue across the bay, crossing the ship channel, and tying into the existing Texas City Levee System. Improvements to this existing levee system would be included. The plan also addresses flooding on Galveston Island with a levee system. The PDT determined that this strategy would still likely require improvements to the Galveston seawall, a ring barrier along the west and north ends of Galveston Island to address wind-driven surges from the bay, and some nonstructural measures on Galveston Island to complement the system. Early discussions on this conceptual strategy identified potential environmental issues because the footprint of the barrier would cross a number of very large and productive oyster reefs.
- **Upper Bay:** This conceptual strategy was developed to potentially reduce impacts to navigation by focusing on a levee system on the west side of Galveston Bay along SH 146 from Texas City to the Hartman Bridge. This strategy would require a surge gate and barrier at the Hartman Bridge crossing of the HSC. The levee system would be located such that there would be structures east of the levee outside of the system. The PDT determined that nonstructural measures would be needed to address existing surges and any surges induced into the area by the levee system. The plan would eventually tie into the existing Texas City Levee System. Improvements to this existing levee system would also be included. This strategy would also require improvements to the Galveston seawall, a ring barrier along the north side of Galveston Island, and nonstructural measures to address any existing structures that would be located on the bayside of the levee.

2.2.3.1 Initial Array of Alternatives for Region 1

2.2.3.1.1 Alternative A: Coastal Barrier with Complementary Nonstructural Measures

This alternative was developed using the “Gulf Front Coastal Barrier” conceptual strategy which includes measures that provide a “first line of defense” from storm surge flooding at the Gulf interface. The Gulf front strategy protects the highest number of structures and critical facilities of any of the alternatives formulated. The alignment would also provide risk reduction to the critical GIWW by maintaining the existing geomorphic features along Bolivar Peninsula and Galveston Island. The strategy included preventing storm surge from entering the Galveston Bay with a barrier system across Bolivar Peninsula, a closure at the pass at Bolivar Roads, improvements to the Galveston seawall, and a barrier along the west end of Galveston Island. The barrier is similar to other proposals that have been released to the public, such as the Gulf Coast Community Protection and Recovery District's (GCCPRD) Central Region Alternative (CR #1) – Coastal Spine or Texas A&M University at Galveston's Ike Dike. The team originally evaluated a levee/floodwall system across Bolivar Peninsula and Galveston Island similar to the GCCPRD's plan (**Figure 2-1**); however, due to the overwhelming public opposition to those features they were reformulated into a dual purpose (CSRM and ER) beach and multiple dune systems for Bolivar Peninsula and Galveston Island west of the Seawall (**Figure 2-2**).

To address wind-driven surges in the bay, which could impact both the back side of Galveston Island and the upper reaches of the bay, nonstructural measures, such as ring levees and closures on key waterways, have been included in the system. This CSRM alternative was formerly referred to as Alternative A in the previous draft report.

This alternative is consistent with all the study goals. Specifically, the Gulf front alignment creates a first line of defense that protects the most residential, commercial, public structures and infrastructure from hurricane-induced storm damages than any other alternative formulated. Also, having a robust first line of defense provides the greatest opportunity to build redundancy into the system thereby increasing the reliability of the system. While there would be navigation safety concerns, environmental concerns and construction concerns associated with this alternative, the preliminary analyses performed by the PDT revealed that there were possible ways to design these measures so that these impacts can be effectively mitigated.

Navigation Safety Concerns: This alternative has Navigational Safety concerns; however, preliminary analysis from the PDT showed that the location of the barrier at Bolivar Roads is in a location that is far enough from channel intersection, and in a place that generally has bidirectional movement of vessels so that it can be configured to minimize impacts to Navigation Safety beyond any of the other barrier alternatives. While numerous recreational fishing vessels transit the Bolivar Roads area to fish at the Galveston jetties and offshore environment, there is not as much recreational activity in the immediate vicinity of Bolivar Roads as there is in the middle of the Bay or along the Texas City Dike.

Environmental Concerns: This alternative would have direct and indirect impacts to habitats in the Galveston Bay Area, including critical habitat for piping plover. Additionally, since the barrier would be located at the primary exchange point between the Gulf of Mexico and the Galveston Bay, one of the largest estuaries on the Gulf Coast, the potential for adverse indirect impacts could be far reaching. That said, a preliminary survey of state-of-the-art gate technologies in use around the world, revealed that the technologies are reducing channel constriction and adult fish passage modeling is helping to refine designs that minimize ecological impacts. While the Surge Barrier would impact some saltwater marsh, the direct impacts at Bolivar Roads would mostly be to subtidal mud bottom which is crossed by the entranced channel for the HSC and has been dredged for nearly a century.

Construction Concerns: This alternative has several construction concerns including the complexity of building a series of gates across an approximately 2-mile-long waterway that includes one of the busiest deep draft navigation channels in the world. The Entrance Channel provides deep water access to the Port of Galveston, the Port of Texas City, and the Port of Houston. Construction in this area would require the creation of a temporary bypass channel able to maintain this large number of vessels. While this will require careful planning, the USACE is adept at dredging and it may create opportunities for the beneficial use of dredge material that could restore valuable marsh and beach habitats.

Figure 2-1 2020 version of Alternative A

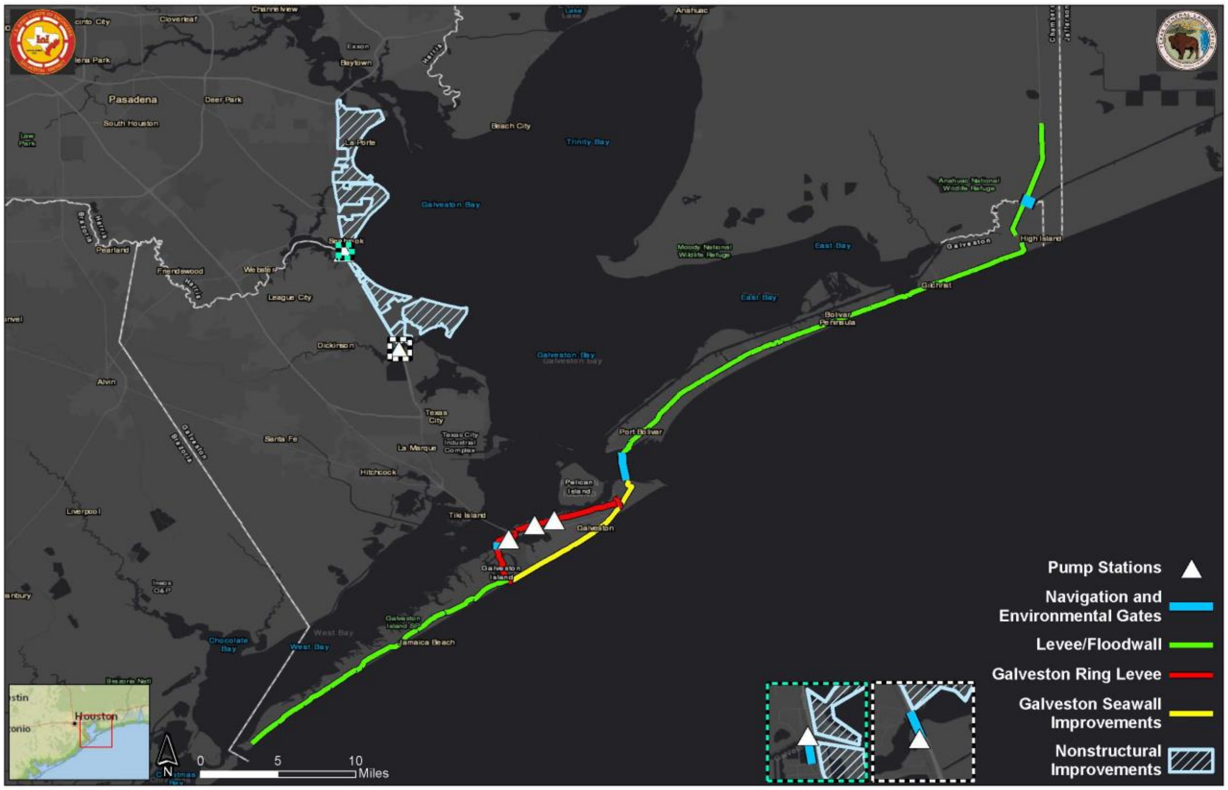


Figure 2-2. 2018 version of Alternative A

2.2.3.1.2 Alternative B: Coastal Barrier behind GIWW with Complementary System of Nonstructural Measures

This alternative was developed using the “Coastal Barrier behind the GIWW Coastal” conceptual strategy which is to address storm surge flooding at the Gulf interface but with an alignment that avoids impacts to the unique barrier landforms: Bolivar Peninsula, Galveston Island, and west Galveston Bay. The strategy included preventing storm surge from entering Galveston Bay by placing a navigation gate across the Houston Ship Channel, north of the Bolivar Roads Pass. The system includes a barrier across Bolivar Peninsula, but the barrier would be set back north of the GIWW and would connect some of the existing dredge disposal sites to avoid the habitat along Bolivar Peninsula. The closure north of the pass at Bolivar Roads would tie into the existing Texas City Dike. The dike would require significant improvements to be able to address coastal storm surge. The system would then tie into the existing Texas City Levee system, with improvements to that system, and would include additional improvements further west into the communities of Hitchcock and Santa Fe. Due to the uncertainties associated with induced stages on the city of Galveston, the alternative would include a ring levee around the city. Also, as explained in the sections above, to address wind-driven surges in the bay’s upper reaches, nonstructural measures, closures on key waterways, Dickinson Bayou, and Clear Lake was included. **Figure 2-3** provides an overview of the features included with a Coastal Barrier behind the GIWW. This CSRM alternative was formerly referred to as Alternative B in the previous draft report.

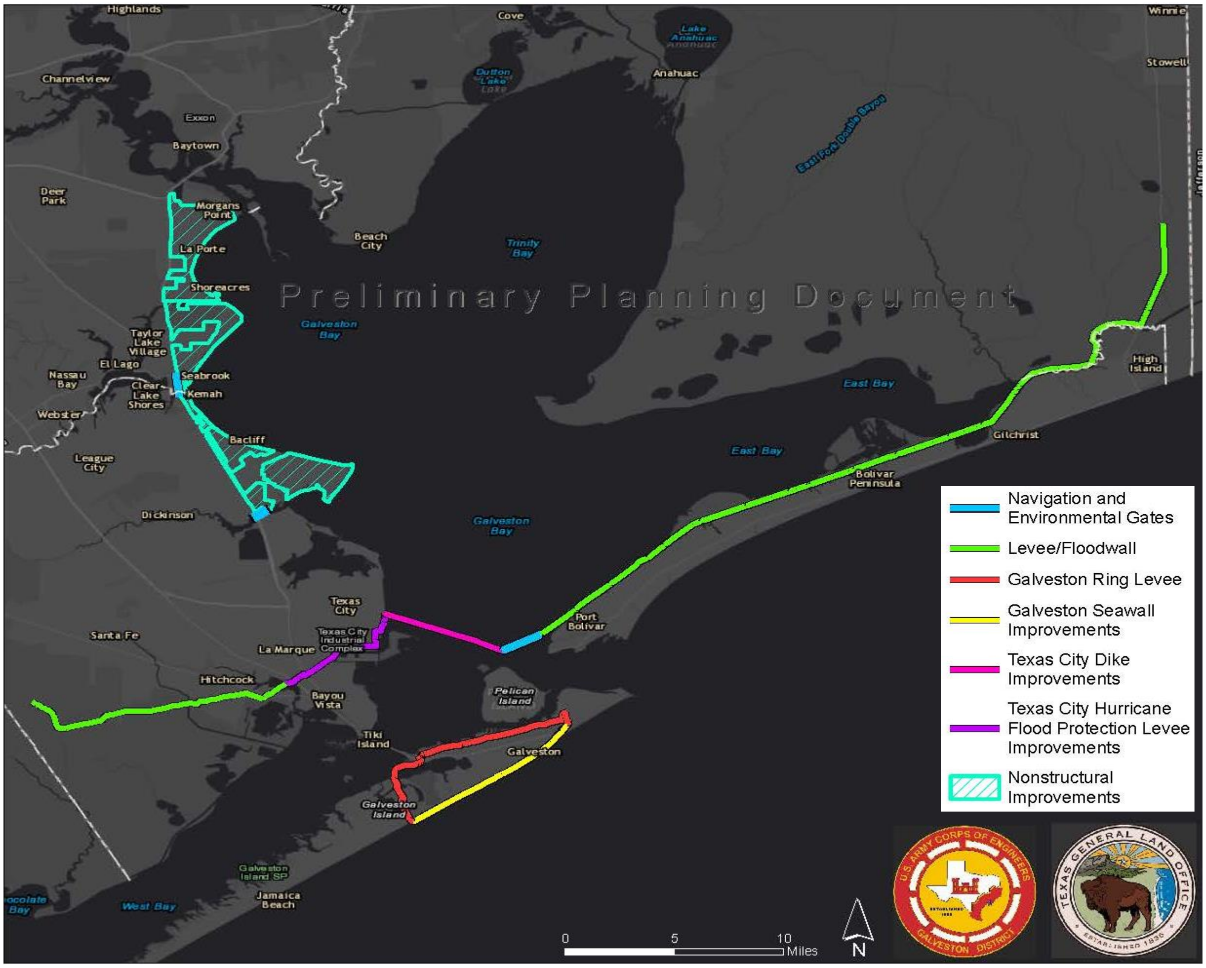


Figure 2-3. Alternative B: Coastal Barrier behind GIWW with Complementary System

Due to both navigation safety and construction concerns, Alternative B. Coastal Barrier behind the GIWW was removed from further consideration.

Navigation Safety Concerns: This alternative would force interactions between deep draft ships and shallow draft tugs and barges because it would be located adjacent to and north of the intersection of the HSC and the GIWW. The Texas City Ship Channel spurs off the HSC in the immediate vicinity of that intersection too. The presence of a gate structure so close to two of the busiest navigation intersections in the country would cause unacceptable navigation safety problems that would require major realignment of the navigation channels to address. To contextualize the issue, the Houston-Galveston Navigation Safety Advisory Committee has implemented an alternate route that allows mariners to avoid the Bolivar Roads/Houston Ship Channel intersection. Known as the Bolivar Roads Alternate Inbound Route, or BRAIR (**Figure 2-4**). The passage acts much like a freeway on-ramp. Westbound traffic exiting Bolivar Roads may enter the ship channel via the Bolivar roads Alternate Inbound Route and continue inbound, rather than navigating the difficult 105-degree turn at the intersection. The alternative would impact this route since barge traffic would be redirected

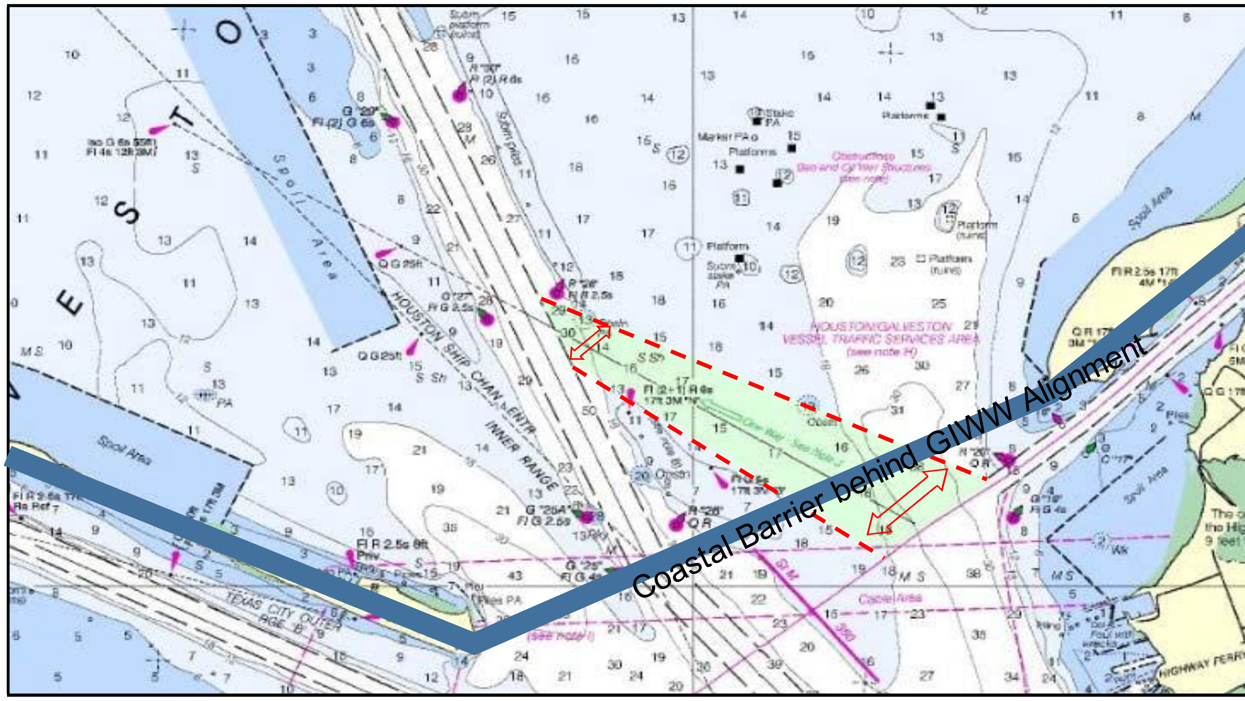


Figure 2-4 Alternative B: Coastal Barrier behind GIWW

Construction Concerns and Impacts to a Regionally Significant Recreational Facility: Part of the construction activities for this alternative would be to raise the exiting Texas City Dike to provide risk reduction from surges from the Gulf. The dike's existing structure consists of a 28,200-foot-long (approximately 5.34 miles) pile dike paired with a rubble-mound dike that runs along the south edge of the pile dike (USACE, 2007). The Texas City Dike was built to protect the Texas City Channel from cross currents and excessive silting, but not necessarily storm surge. In discussions with the PDT, it was determined that the foundation of the existing structure would have to be improved to increase its existing height. This action would have significant impacts on the current recreation use on the dike. The dike includes recreation features such as asphalt and crushed gravel parking areas, roughly three-quarter miles of beaches, four boat ramps (two with running water for fish cleaning stations), ten concrete picnic shelters, and one wheelchair accessible pier. The Dike's Samson-Yarbrough boat ramp was the busiest on Galveston Bay, and the dike as a whole was the second-busiest boat launch site in the state (Aulds, 2010). Many of the features would be impacted during construction or would have to be relocated after construction.

2.2.3.1.3 Alternative C: Mid-bay Barrier

This alternative was developed using the “Mid Bay Barrier” conceptual strategy which avoids some of the navigation impacts at Bolivar Roads, by placing a surge barrier near the middle of Galveston Bay. This alignment is similar to the recommendation in a USACE Texas Coast Hurricane Study released in 1979. The system would start on the east side of Galveston Bay near Smith Point and would continue across the bay, crossing the ship channel. The barrier across Galveston Bay also include environmental control gates to maintain flows between the upper Galveston Bay and Lower Galveston Bay and small gates to address small recreational vessels moving through the system. The system would tie into the existing Texas City Levee system. Improvements to this existing levee system would be included and require additional improvements farther west into the communities of Hitchcock and Santa Fe. The plan also addresses flooding on Galveston Island with a levee system (**Figure 2-5**). Due to the limited open-water area north of the system, wind-driven surges in the bay's upper reaches are not expected to be a concern, which is why the nonstructural measures, ring levees, and closures on key waterways were dropped from consideration. This CSRM alternative was formerly referred to as Alternative C in the previous draft report.

Due to concerns with the design complexity (Operation, Maintenance, Repair, Replacement, and Rehabilitation), Environmental Impacts, and Navigation Safety, Alternative C was not carried forward for more detailed analysis.

Operation, Maintenance, Repair, Replacement, and Rehabilitation Concerns: In order to maintain flows between the upper Galveston Bay and Lower Galveston Bay, the structure would include environmental gates (vertical lift gates) to maintain the natural water circulation in the bay when the system is open. Preliminary analysis led to estimates that over 100 environmental gates would be needed to maintain the existing circulation in the bay. In addition to the significant cost for constructing these gates, there would be very high costs associated with operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) of these gates. OMRR&R with environmental gates typically include maintenance for backup generators/systems, yearly testing of all of the gates, dive inspections, gate adjustments, rehab, and replacements.

Direct and Indirect Environmental Impacts: Due to the location and size of the required underwater footprint for the mid-bay closure, the alternative would have significant impacts on Galveston Bay's oyster reefs. Historically, the creation and widening of the Houston Ship Channel has increased the area of oyster productivity northward in the bay. This is due in part to the penetration of more saline water into the upper estuary and increased current velocities, extending the area of oyster productivity northward. Over 2,500 acres of reef have developed along this channel (Powell et al., 1994). The current alignment would have significant direct impacts to the historic "Redfish Oyster Reef" near the middle of Galveston Bay and the reefs along the Houston Ship Channel near the proposed navigation gate (**Figure 2-6**).

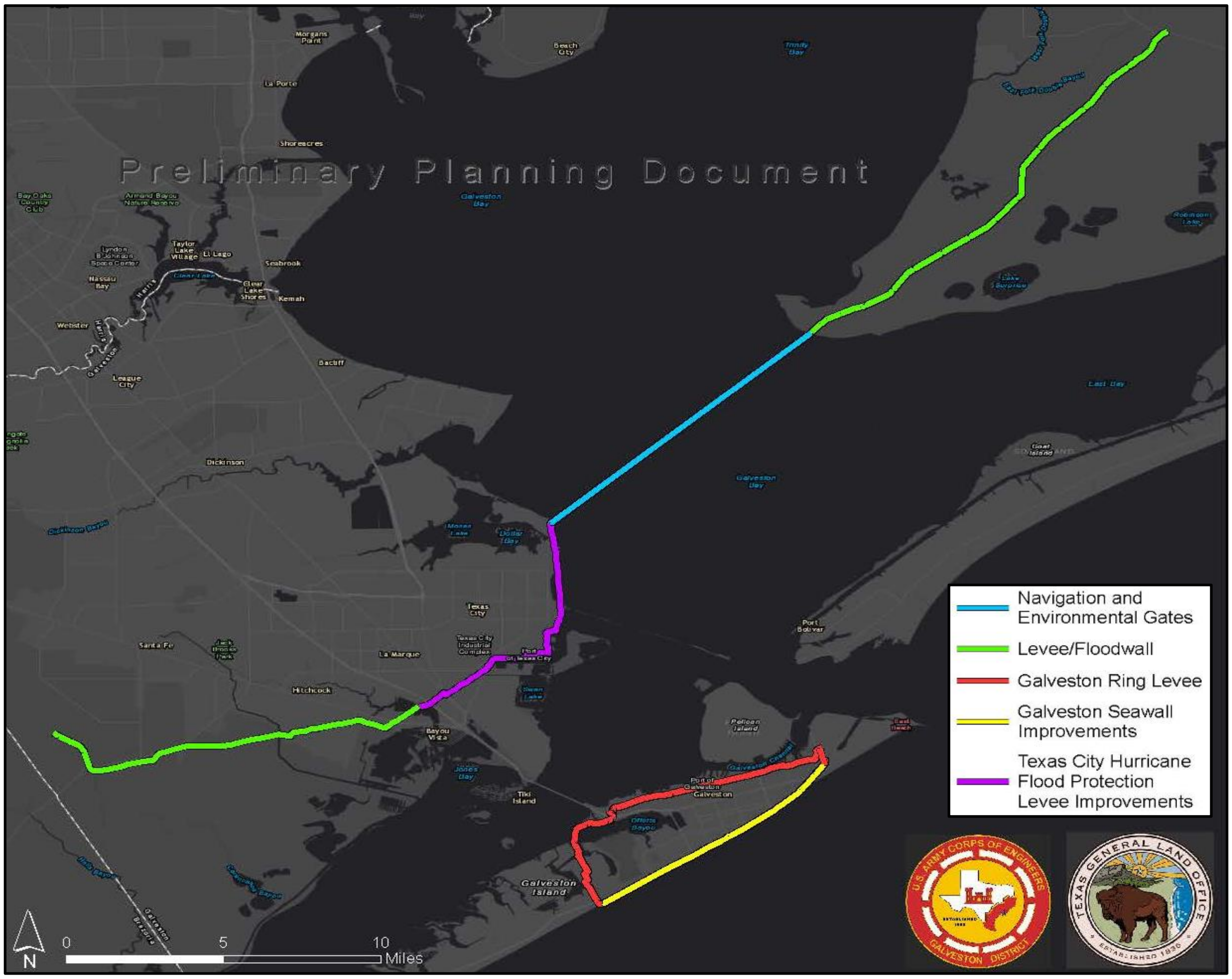


Figure 2-5. Mid-bay Barrier

Based on a desktop analysis the Mid-bay Alternative would directly impact approximately 240 acres of oyster reefs. Indirect impacts for this alternative were not modeled, however the engineering team pointed out that the alignment places the environmental gates in a location that would bisect the bay which would likely have numerous impacts to water circulation for the system. Today, the bulk of the Trinity River flow exits Trinity Bay along the southern shore and wraps around Smith Point, and flows across Mattie B. Reef and Tom Tom Reef, reaching nearly to the Bolivar Peninsula before becoming entrained in the seaward flowing water at Bolivar Roads. This circulation pattern has likely existed for many decades, but its intensity has dramatically increased as the Houston Ship Channel became deeper and Redfish Reef ceased to function as a circulation barrier (Lester and Gonzalez, 2011). Even with the environmental structures in the open position, the support structures for the gate could function as a circulation barrier, changing the circulation pattern across local reefs.

Navigation Concerns: Galveston Bay includes one of the Nation’s largest recreation boating and sailing fleets, including multiple yacht clubs along the west side of the bay. Vertical clearances and keel clearances may force some of the recreational vessels through the large gate near the center of the system, adding to vessel congestion and safety concerns.

Inducements to Galveston Island: The engineering team pointed out that placing a surge barrier on the Bay side of Galveston Island and Bolivar Peninsula would induce flood elevations on those coastal barriers due to surge build up during a tropical storm. Detailed modeling was not done to quantify those effects for the Mid-bay Alternative, however, these effects would require increased scaling for the Galveston Island ring barrier and other induced impacts.

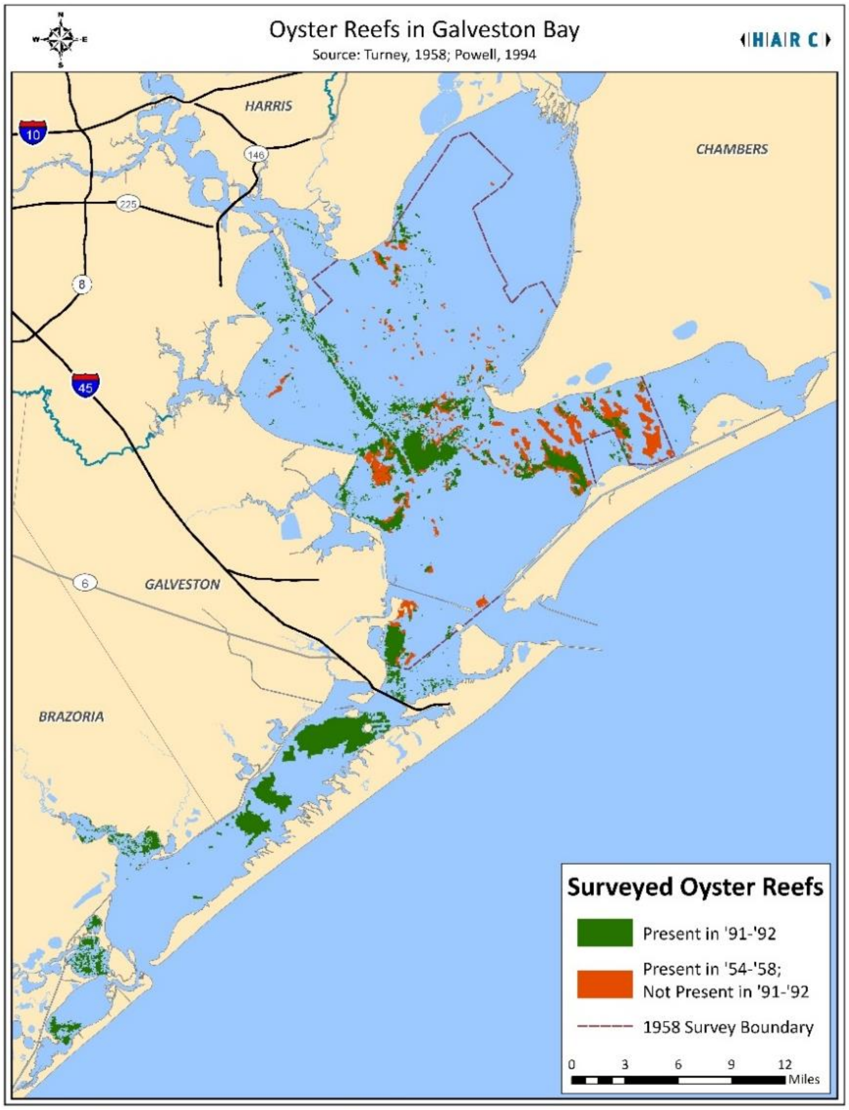


Figure 2-6. Oyster Reefs in Galveston Bay

2.2.3.1.4 Alternative D1: Upper Bay Barrier -- SH 146 Alignment Barrier

This alignment was similar to GCCPRD's Reach 2, Texas City Extension North (SH-146) alignment, which included a levee system paralleling SH 146 from Texas City to the Fred Hartman Bridge (**Figure 2-7**). The levee system placed approximately 10,000 structures east of the levee outside of the system. In order to address this concern, nonstructural measures were included to address existing surges and any surges induced into the area by the levee system. This plan would require a surge gate at the Fred Hartman Bridge. This CSRM alternative was formerly referred to as Alternative D1 in the previous draft report.

Preliminary analysis revealed that the Bay Rim Barrier was going to have more CSRM benefits, fewer inducements, fewer construction concerns, and similar environmental impacts. For those reasons the SH 146 Alignment Barrier was screened out early in the process and the Bay Rim Alternative was carried forward for more detailed analysis.

Performance Concerns: The first issue was related to the overall project objective of reducing risk to critical infrastructure (e.g., medical centers, government facilities, universities, and schools) from coastal storm surge flooding. An evaluation of the FWOP condition surges and economic damages determined that the area surrounding the system is one of the highest reaches for economic damages. Once a levee is constructed near SH 146, modeling showed that it would induce higher flood stages and damages in the area outside of the levee system (**Figure 2-8**). Economic modeling estimated that over $175 million in average annual damages would be included in the area without addressing the inducements.

Construction Concerns: A site visit of the SH-146 alignment and meeting with the Texas Department of Transportation highlighted significant relocation and construction concerns. SH-146 is already a highly developed area, and construction is underway to expand the entire highway from a 6- to 12-lane freeway. Much of the existing rights-of-way or corridors necessary to build a levee system would be unavailable because of the expanded highway. Also, a significant number of vehicle and railroad gates would have to be added to the system to work with the existing infrastructure. Many of these concerns were documented at some of GCCPRD's public forums. Based on these concerns and because this alignment does not meet some of the project's key objectives, it was removed from consideration.

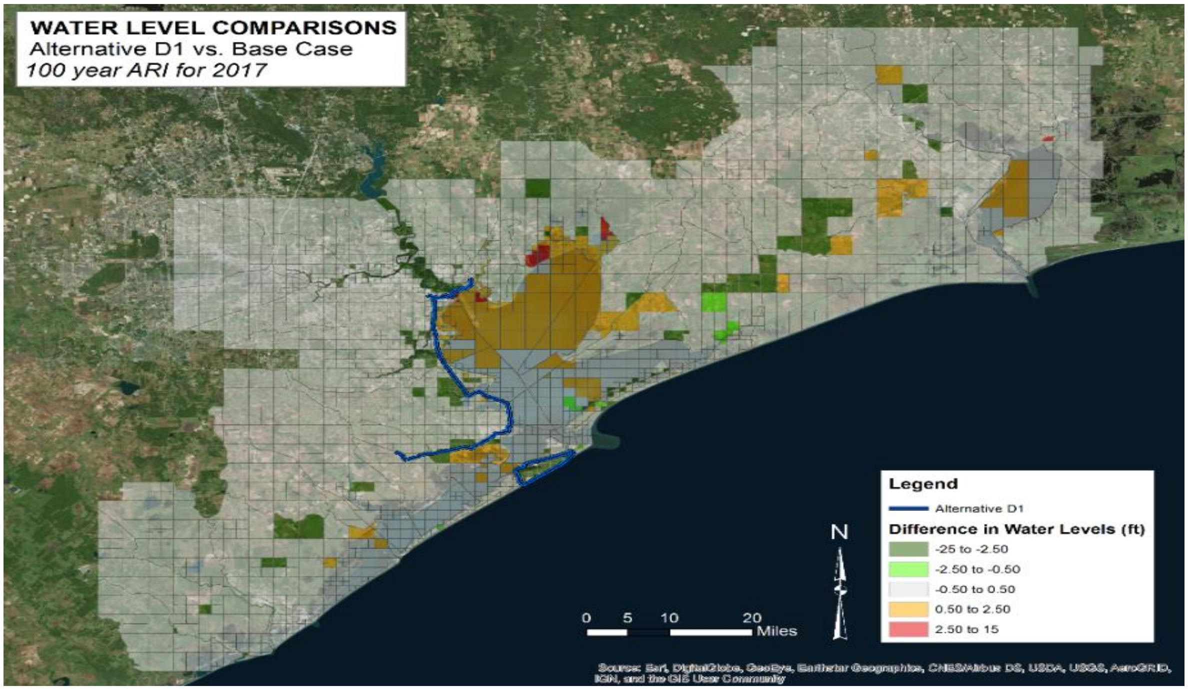


Figure 2-7. FWOP vs FWP stages for SH 146 Alignment Barrier

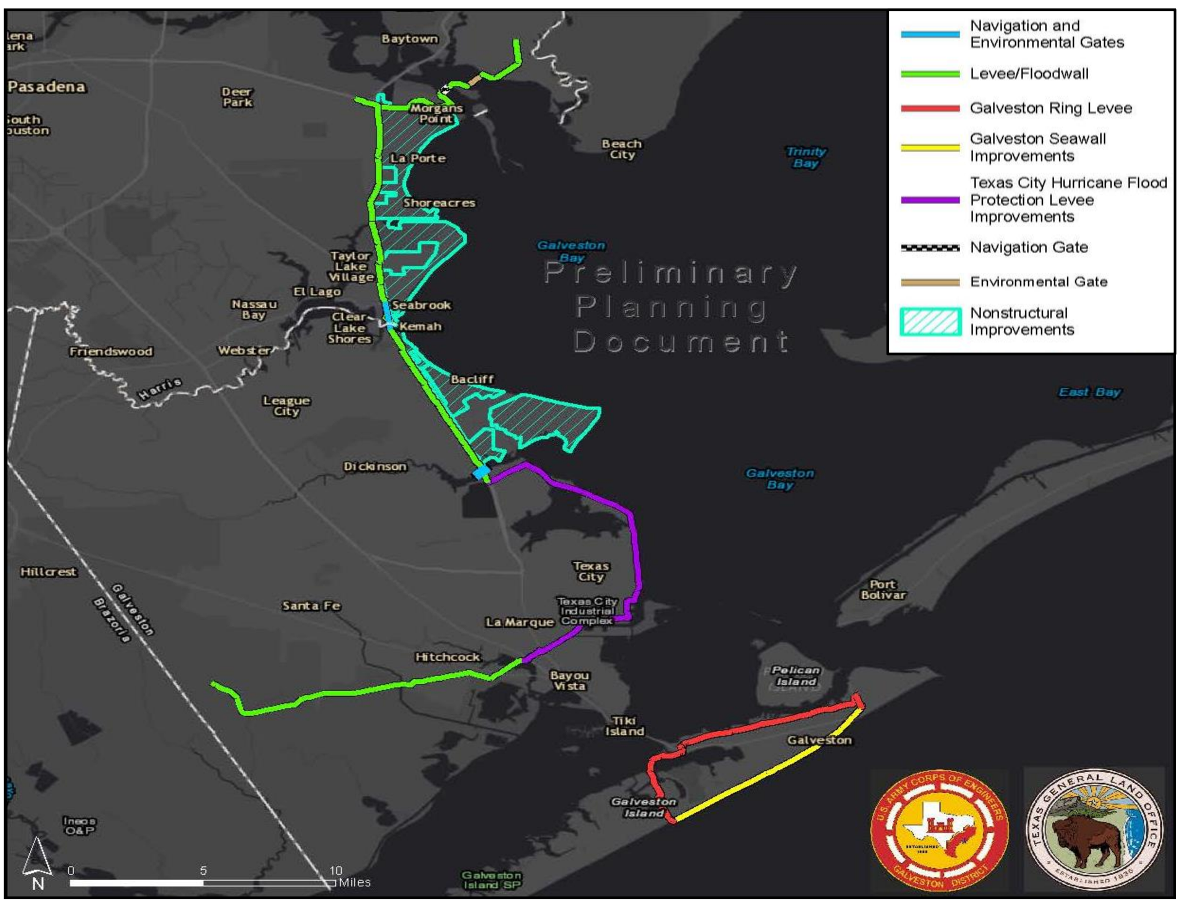


Figure 2-8. Alternative D1 SH 146 Alignment Barrier

2.2.3.1.5 Alternative D2: Upper Bay Barrier -- Bay Rim Barrier

This was the second alignment of the two alternatives formulated using the "Upper Bay" conceptual strategy, which was developed to potentially avoid a majority of the navigation impacts by focusing on a levee system on the west side of Galveston from Texas City to the Fred Hartman Bridge. This alignment moved the barrier out to an area near the shoreline along the west side of Galveston Bay instead of adjacent to SH 146 (**Figure 2-9**), which allowed for protection of an additional 10,000 structures that would have been outside the system under the 2018 designs. This was assumed to be achieved by constructing a levee or floodwall system along the existing bay rim, although future considerations during design could incorporate designs similar to the New Orleans Lakefront, where the system is built out into the lake for some reaches which would allow for fewer residential and commercial relocations but would increase environmental impact.

This alignment would tie into the existing Texas City Levee system and includes improvements to that system. The plan includes additional improvements farther west into the communities of Hitchcock and Santa Fe. The plan includes a surge gate and barrier at the Fred Hartman Bridge. The plan also addresses flooding on Galveston Island with a levee system, which rings the island. As with the other plans, the team is also investigating the opportunities to integrate ecosystem features and CSRM features by reviewing the beach and dune restoration features along Bolivar Peninsula and Galveston Island. The ecosystem features should also increase the resiliency of the CSRM features. This CSRM alternative was formerly referred to as Alternative D2 in the 2018 draft report.

Alternative D2 is consistent with the study goals and would provide CSRM benefits for a large portion of the region with no identified need for nonstructural measures on the West Side of Galveston Bay. Since this alternative does not require a barrier structure near the entrance channel or in the Bay, this Alternative would not affect navigation. While there were concerns with this Alternative, the PDT agreed that it was a good candidate to move forward for more detailed analysis because there were likely engineering and mitigation solutions that could address these concerns. Additionally, the alternative complemented the ER measures proposed for Region 1 and was consistent with the multiple lines of defense planning strategy. Also, not having the open water barrier system at the entrance to the Bay would likely mean that there would have fewer indirect environmental impacts. That said, it was clear that the large amount of levee that would have to be constructed for this alternative would have a larger footprint than the structural components of Alternative A and therefore would likely have larger direct environmental impacts. Also, without a barrier structure to prevent surges from entering the Bay, the version of the Galveston Ring Levee and Seawall improvement measures that would be included in this Alternative would have to be larger to accommodate the higher water elevations. In addition, this Alternative would require more pump stations to ensure that flooding from rain events could be quickly removed from the system to prevent inducements.

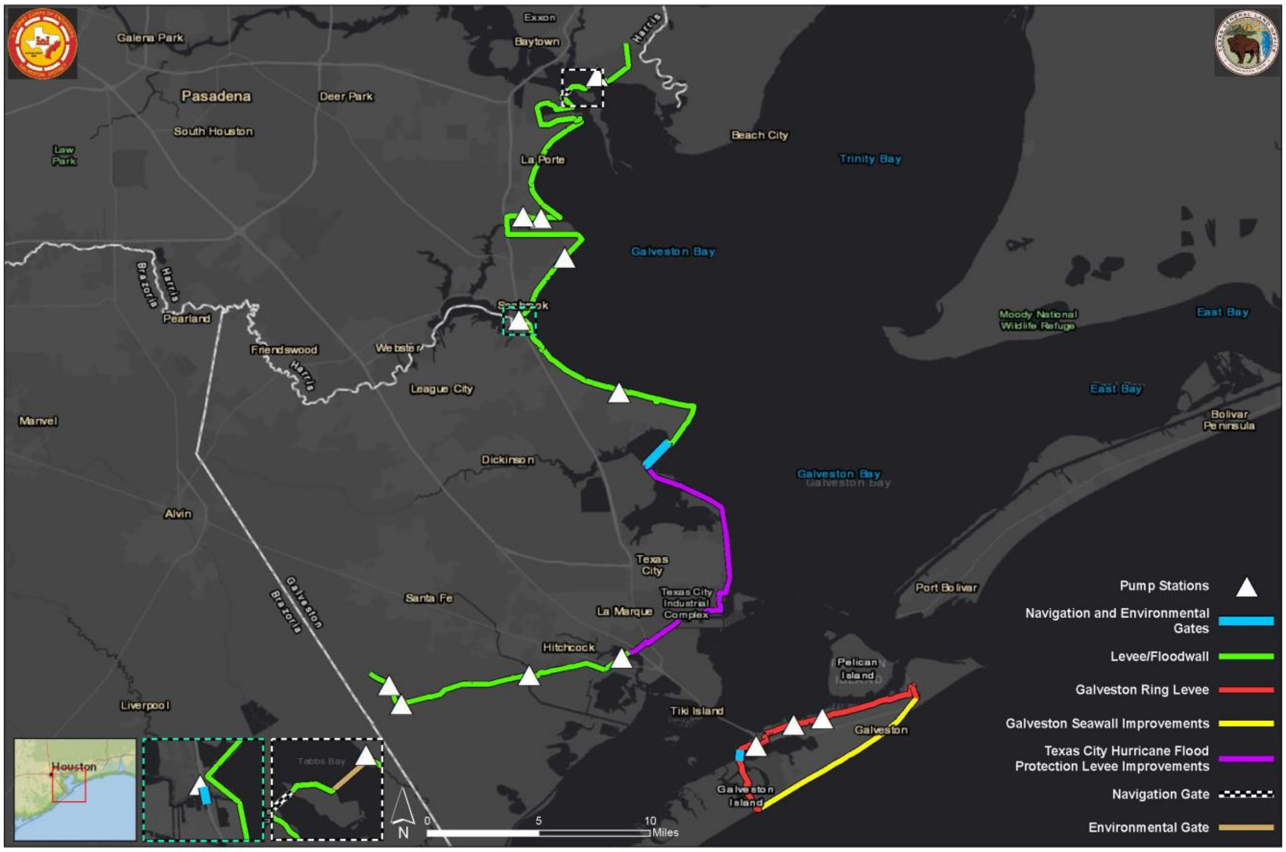


Figure 2-9. Alternative D2: Upper Bay Rim; Bay Rim Barrier

2.2.3.1.6 Standalone Nonstructural Alternative

Section 73 of the WRDA of 1974 requires consideration of nonstructural alternatives in CSRM studies. Examples of nonstructural measures include flood proofing, relocation of structures, flood warning and preparedness systems (including associated emergency measures), and regulation of floodplain uses. They can be considered independently or in combination with structural measures. Nonstructural measures reduce flood damages without significantly altering the nature or extent of flooding.

The team initially evaluated a nonstructural raising or a buyout program in the entire area of Region 1. The nonstructural assumption was based on 100 percent participation rate and would have included removing or modifying over 64,000 residential and nonresidential structures receiving flood damage by the stage associated with the 0.01 (100-year) annual chance exceedance (ACE) event in 2035 and 2085 under without-project conditions. The PDT determined that a nonstructural treatment as a standalone plan does not achieve the project goals and objectives for a variety of reasons. Based on initial stakeholder and study sponsor discussions, it is highly likely a voluntary program would receive very little participation due to the number of structures potentially removed from the community. Residents may not want to volunteer for buyouts because of the economic cost of relocation and the social costs of breaking up a community or uprooting a family. Also, as seen with Hurricane Harvey impacts, relocating residents away from the coastal surge doesn't necessarily remove all flooding risk from residents.

The PDT recommended that smaller increments of nonstructural measures be carried forward to complement the structural measures where cost effective risk reduction can be achieved. The approach of using a combination of complementary structural and nonstructural measures would allow structural measures to provide multiple lines of defense for the region while using nonstructural measures to provide risk reduction to areas that are determined to still have higher levels of vulnerability with the structural measures in place.

2.2.3.2 Detailed Description of Region 1 CSRM Alternatives Carried Forward for Detailed Analysis

Once the decision was made to carry Alternatives A and D2 forward for more detailed analysis, the PDT began to refine the measures and to conduct detailed analysis on the performance and effects of these Alternatives on resources. This section includes descriptions of the measures that make up these two alternatives for the NEPA required analysis. For more technically detailed descriptions please see the Engineering Appendix to the Main Report.

2.2.3.2.1 Alternative A: Coastal Barrier with Complementary Nonstructural Measures

Bolivar Roads Gate System: As part of the primary line of defense, the Storm Surge Gate at Bolivar Roads would be operated to reduce storm surge volumes from entering Galveston Bay. The system includes a 2-mile-long series of gate structures that cross the Houston Ship Channel, between Bolivar Peninsula and Galveston Island. This measure would accommodate vessel traffic with two 650-foot-wide sector gates with a 60-foot deep sill and two 125-foot-wide sector gates with a 40-foot-deep sill. Additional gates in the system include eight Shallow Water Vertical Lift Gates (300-foot-wide opening; 20-foot-deep sill), seven Deep Water Vertical Lift Gates (300-foot-wide opening; 40-foot-deep sill), 16 monolith gates (16-foot-wide opening, 5-foot-deep sill), and three manmade islands to hold the sector gates when open that would total 110.0 acres. This measure would also include a tie in structure that would connect the gate system to the Bolivar section of the Beach and Dune System. This tie in feature would be comprised of 5,300-linear-foot of combi-wall with a top of structure elevation of 21.5-foot and approximately 3.3 miles of levee that would have a 5:1 slope on the gulf facing side, a 3:1 slope on the interior side, a crest width of 10-foot, and a crest height of 12-foot. The levee would be constructed by hauling in clean commercially sourced clay material.

Gate Operation: The gate structures would be closed in advance of approaching surges associated with tropical storms and would be opened as soon as it was safe to do so. In addition to storm surges, it is anticipated that the gates would need to be occasionally closed for testing and maintenance activities. The gate structures would be kept in the fully open position as much as possible (most of the time) to minimize impacts to navigation and to minimize indirect environmental impacts by maximizing tidal exchange between the Gulf of Mexico and Galveston Bay. An operation manual for the gate structures will be developed once the design progresses in the pre-construction engineering and design phase for the project. The operation manual will include procedures for coordination with Federal Agencies, State Agencies, local governments, and local stakeholders on the operation of the gate structures.

Bolivar and West Galveston Beach and Dune System: 44 miles of beach and dune segments on Bolivar Peninsula and West Galveston Island that work with the storm surge gate to form a first line of defense against Gulf of Mexico surge, preventing or reducing storm surge volumes that would enter the bay. The Bolivar Peninsula beach and dune system spans 25 miles of Gulf shoreline of Bolivar Peninsula from 2.0 miles east of State Highway 87 to the end of Biscayne Beach Road. The construction includes a two-dune system which will have a seaward dune elevation of 12.0 feet' and a landward dune elevation of 14.0 feet. The sediment source for the Bolivar Peninsula Beach and Dune feature would be the Sabine and Heald Banks located approximately 30 miles offshore from Bolivar Peninsula. The feasibility estimate for the Bolivar Peninsula Beach and Dune feature would require an initial volume of 22.1 million cubic yards of sand material with a 6- to 10-year re-nourishment cycle, depending on erosion rates, that would include an additional 1.9 million cubic yards of sand material for each cycle. The re-nourishment periods and volumes were determined by the engineering team who used a lifecycle analysis.

Galveston Sea Wall Improvements: A modification of the existing 10-mile seawall on Galveston Island to provide an additional 2-3 feet of storm surge defense.

Galveston Ring Barrier System: This is a 23.5-mile ring barrier that prevents bay waters from flooding neighborhoods, businesses, and critical health facilities in the City of Galveston. This measure includes the construction of 52,842 linear feet of Floodwall (T design), a 125-foot-wide sector gate with a 15-foot-deep sill at Offatts Bayou, 42 road gates, seven railway gates, dredging for a new entrance channel to the Crash Boat Basin, 16 drainage structures, and six pump stations. This also includes nonstructural measures for the neighborhood of Channelview which would be outside of the system.

Clear Lake Gate System: The storm modeling conducted by the team revealed that even with the Bolivar Roads Gate System, there is enough water in Galveston Bay to allow storms to cause flooding on the west side of Galveston Bay. To address this issue the PTD formulated the Clear Lake Gate System, the Dickinson Bayou Gate System, and the Nonstructural Measures on the West Side of Galveston Bay. The system will have a 17-foot-elevation and will include a 75-foot-wide sector gate with a 12-foot-deep sill, a 20,000 cfs pump station, and 9,950 linear feet of combi-wall to tie the system to higher elevation.

Dickinson Bayou Gate System: The system will have an 18-foot elevation and will include a 100-foot-wide sector gate with a 12-foot-deep sill, a 19,500 cfs pump station, and sections of combi-wall to tie the system to higher elevation.

Nonstructural Measures on the West Side of Galveston Bay: Complementary non-structural measures to manage bay-surge risks along the perimeter of west Galveston Bay. The measures would include voluntary home elevations and flood proofing of commercial properties with small berms and other similar measures.

2.2.3.2.2 Alternative D2: Upper Bay Barrier -- Bay Rim Barrier

Alternative D2 includes a Region 1 CSRM barrier to potentially avoid most of the navigation impacts by focusing on a levee system on the west side of Galveston from Texas City to the Hartman Bridge instead of trying to address surges at the Gulf interface. The Region 1, Upper Bay Barrier-Bay Rim, consists of 400,000 feet of levee, 163,000 feet of floodwall, 122 two-lane highway gates, ten four-lane highway gates, 37 drainage closure structures, and 18 railroad gates (details by measure included in **Table 2-1**). This Alternative includes several of the measures that make up Alternative A and those include the Galveston Sea Wall Improvements, the Galveston Ring Barrier System, the Clear Lake Gate System, and the Bolivar and West Galveston Beach and Dune System (formerly ER measure G-5). Additionally, there would be navigation gates, environmental gates, and combi-wall at the Houston Ship Channel, Clear Creek Channel, Dickinson Bay, Offatts Bayou, and Highway Bayou Diversion Channel. Since the Bay Rim Barrier is a linear feature, the following includes descriptions of the measures by reach and provides a summary of the features by reach.

The system starts near Tri City Beach Road and Highway 99 in Baytown, Texas with 2.5 miles of elevated two-lane road. This reach was called the Upper Bay Reach and continues southwest until reaching the Houston Ship Channel and Tabbs Bay Reach. For planning purposes, the elevation of this reach was set at an elevation of 18 feet.

The Houston Ship Channel and Tabbs Bay Reach crossing consists of a 4,000-foot combi-wall crossing Tabbs Bay with a series of 100-foot environmental gates to connect the north bank of the bay with Hog Island.

A temporary bypass channel would first be constructed between the north bank and Hog Island to allow for the construction of the sector gate and combi-wall across the Houston Ship Channel. Once on Hog Island, 2,800 feet of levee would be constructed along the shore of the island to the west side of island where the risk reduction system would cross the Houston Ship Channel at the Lower End of Morgan's Point Cut reach near Station 57+00.000 with a combi-wall and sector gate. The 3,070-foot crossing of the ship channel at this point would consist of combi-wall and a sector gate to accommodate the existing channel width of 530 feet. The channel in this reach is maintained to a depth of –48 MLLW, which includes an advanced maintenance depth. The north and south perimeter dike of the Spillman Island Placement Area would than become a part of the system to just west of the Barbour's Cut Basin.

The next reach, the Bay Perimeter Reach, would start on the west side of Barbour's cut at the Spillman Island Placement Area. The entire alignment would turn south and follow the bay rim until reaching the existing Texas City Hurricane Flood Protection Project, 9,180 feet northwest of the Moses Lake gate structure. Floodwalls would be used to avoid impact to the port facilities along the bay rim, and due to the existing structure, most of the reaches would consist of floodwall sections. There would need to be drainage closure structures or pump stations on features to address rainfall flooding during storm events in areas protected by floodwalls. Currently the following drainage features have been included for a drainage closure structure and/or pump station: Buffalo Bayou, a drainage ditch just north of South Blackwell Street, Deer Creek, Little Cedar Bayou, Taylor Bayou (Diversion to Bayport), the Clear Creek Second Outlet discharge channel, Clear Creek, Pine Gully, Harris County Flood Control District Ditch F222-00-00, and the NRG Energy Power Plant Outfall, if the alternative is carried forward, additional watershed analysis would have to be performed to refine the pump station and drainage requirements.

Once reaching Clear Lake, a gate structure identical to the Clear Lake Gate System discussed in Alternative A would be constructed. The 1.3-mile crossing across Dickinson Bay east of SH 146 would consist of a combi-wall, a sector gate across the current authorized 100-foot channel and would have a sill depth of 12-foot-deep sill. A series of 100-foot environment gates would be installed to maintain tidal influence. The system would tie into the existing Texas City Hurricane Flood Protection Project 9,180 feet northwest of the Moses Lake gate structure.

The next reach in the plan includes the modernization of the existing Texas City Hurricane Flood Protection system. The reach consists of 49,479 feet of levee, 7,096 feet of floodwall, and would include the inspection and rehabilitation of 22 drainage closure structures. The existing wall through the petrochemical facilities would be improved modernized and raised to account for future sea level rise. The modernization effort includes improvements to 20 two-lane highway gates, 3 four-lane highway gates, five railroad gates, and the Moses Lake gate structure. Modernization and rehabilitation effort would be required for the La Marque and Skyline pump stations also. The reach would continue until it reaches the Texas City Terminal Railway, where the Texas City West Levee Extension would start.

The Texas City West Levee Extension consists of constructing 53,980 feet of levee, 5,530 feet of floodwall, three drainage closure structures, 6 two-lane highway gates, 1 four-lane highway gate, and two railroad gates. A vertical gate structure would be required on Highland Bayou Diversion Channel to prevent storm surge up the bayou. Pump stations would be located at Highland Bayou, (4,225 cubic feet per second), Highland Bayou Diversion Channel (6,265 cubic feet per second), Willow Bayou, (1,453 cubic feet per second), and Cloud Bayou, (1,873 cubic feet per second).

The system parallels the railroad on the south side with combi-wall for 1,650 feet until it reaches Highland Bayou where a drainage closure structure would be constructed downstream of the railroad bridge. The system continues southwest on the south side of the railroad with floodwall crossing Highway 6, Martin Luther King Avenue, a Texas City Terminal Railway spur, and Burlington Northern Santa Fe Railroad mainline track. The system would turn northwest paralleling the Burlington Northern Santa Fe Railroad with levee crossing Harbor Drive and turn west continuing with levee crossing Basford Bayou with a drainage closure structure and Highland Bayou Diversion Channel with a vertical gate. The system would continue south of the community of Hitchcock and parallel FM 2004 on the south side until reaching Tacquard Ranch Road. At that point the system would turn north crossing FM 2004 and parallel the Briscoe Canal on the east side crossing Cloud Bayou with a drainage closure structure and Vacek Street and tie into high ground northwest of Vacek Street and north of Winging Trail Street.

As discussed in Section 4.3.4, the Region 1, Upper Bay Barrier-Bay Rim would leave significant storm surge risk to the city of Galveston and could induce surges in the area. Due to this concern a Galveston Ring Levee/Floodwall alignment was included with this plan. The Galveston Ring Levee/Floodwall alignment would remain the same as for Alternative A. Also, the 2018 analysis for the Bay Rim Barrier included ER measure G-5 which was the refined to the Bolivar and West Galveston Beach and Dune System and is included in the measure.

2.2.3.2.3 No Action Alternative

Under this alternative, no Federal action would be taken and the risks to communities would remain into the future. This alternative is carried forward because it serves as a baseline to comparing the benefits and costs of doing one of the alternatives with doing nothing. As well, this alternative is required by NEPA.

Table 2-1. Alternative D2 Measure Information

Feature/ Reach	Levee (LF)	Wall (LF)	Hwy Gate/2-Lane	Hwy Gate/4-Lane	RR Gates	Pump Station	Drainage Structure Closure	Entrance Channel Navigation Gate – 1,200 LF	Navigation Gate	Vertical Gate
Baytown to Tabb Bay	200,074									
Tabbs Bay Env Gates										25
HSC1		4,400				1		1		
Bay Perimeter1	69,550	78,900	49		8	4	9		2	
Ext TC HFPL2	49,479	7,096	20	3	5	2	22			1
W. Ext TC HFPL3	53,980	5,530	6	1	2	4	3			2
Galv Seawall		41,651	7							
Galv Ring Levee	26,303	70,488	46	6	4	3	2		1	
TOTALS:	399,386	209,065	128	10	19	14	38	1	3	28

1. Houston Ship Channel Nav. Gate, Clear Lake, Dickinson & Offatts Bayou
2. Existing Gate at Moses Lake
3. Gates at Highland Bayou & Highland Bayou Diversion Channel

2.2.3.3 Evaluation and Comparison Region 1 CSRM Alternatives

The following sections compare the impacts of the alternatives. A more-detailed discussion of environmental impacts for the two action alternatives is included in Chapters 4 and 5 of this DEIS. For more detail on the economic and engineering actions of the two action alternatives see Chapter 2 of the Main Report. Additional information on the ecological modeling can be found in Appendix I and the mitigation plan is included in Appendix J of this DEIS. Since both Alternatives A and D2 would include the Bolivar and West Galveston Beach and Dune System, the Galveston Ring Barrier, and gate structures in Clear Lake and Dickinson Bayou, the comparisons of these alternatives is focused on a direct comparison of the effects of the Coastal Barrier (Alternative A) and the Bay Rim Barrier (Alternative D2). The following is a summary, while more detailed discussion follows.

Environmental Impacts: Alternative A has higher anticipated Environmental Impacts due to the potential indirect impacts to the Galveston Bay System from the anticipated reduction in tidal amplitude that would be caused by the Bolivar Roads Gate System and the direct impacts to piping plover critical habitat at Bolivar Flats that would result from the installation of the Tie-In Structure on Bolivar Peninsula

Residual Risks: Alternative A has a much lower residual risk than Alternative D2 for several reasons. First, Alternative D2 would include an additional 75 two-lane highway gates, 4 four-lane highway gates, 15 railroad gates, 8 pump stations, 34 drainage structures, 71 miles of levee and 18.4 miles of floodwall over Alternative A. The levee and floodwall would also include numerous transition points which represent additional residual risk concerns. Second, the proximity of the measure to highly developed areas means that there is a high likelihood that a system failure would impact developed areas. This would be true of a pump station failure during a flood event or a failure in the system during a surge event. Finally, the alignment for the Bay Rim Barrier is sandwiched between developed area and the Galveston Bay. If additional space is needed for the measure, there would either be impacts to property owners or Galveston Bay.

Conversely, Alternative A would use a gulf front alignment to provide regional risk reduction. In the event of a system failure, the Galveston Bay Estuary would provide a natural buffer between the Coastal Barrier and the mainland. Also, Alternative A has far fewer transitions and gate structures. Finally, Alternative A takes advantage of and builds on the existing protection afforded by the barrier resources that exist in the Galveston Bay System. When comparing the Alternatives, the PDT took a system wide approach and determined that Alternative D2 has an unacceptable residual risk which renders it impracticable.

Construction Schedule and Real Estate Risks: The footprint of Bay Rim Barrier (Alternative D2) includes a large number of commercial and private properties with structures and piers that may have to be relocated or condemned. Since the Bay Rim

Barrier would have to be constructed in its entirety to provide CSRM risk reduction, the real estate risks jeopardize the practicability of the Alternative.

Navigation Impacts: While at first it appears that Alternative D2 would have fewer impacts to navigation than Alternative A, the impacts anticipated at Bolivar Roads were reduced by including two 650-foot wide sector gates to allow for two-way deep draft vessel traffic and two 125-foot-wide sector gates to accommodate vessels that would rather avoid the deep draft traffic. Additionally, the impacts to the Coast Guard Anchorage Areas would be offset by creating new anchorage space at one of the locations shown in the Engineering Appendix.

Adaptability of the System to RSLR: Alternative D2 would be more expensive and would take longer to adapt if RSLR rates occur at the higher rate. This is because the entire 71 miles of levee and 18.4 miles of floodwall would have to be raised. It would be a similar effort to the original construction. Whereas, the measures in Alternative A are being designed with contingency for RSLR because the incremental cost for doing that could be justified given the configuration of the Coastal Barrier.

HTRW: Alternative D2 has much higher risks associated with encountering HTRW because it requires the construction of a continuous 100-mile system that would include approximately 89 new miles of levee and floodwall. The system would cross industrial areas near the Houston Ship Channel, the Houston Port Authority, industrial facilities in La Marque and Texas City. The desktop analysis identified 147 HTRW sites near the Bay Rim Alternative and 8 that intersect the alignment. More detailed information can be found in the HTRW Appendix. Alternative A and D2 share the risks with the measures they have in common, undoubtably the Coastal Barrier has far less risk of encountering HTRW. This HTRW issue challenges the practicability Alternative D2 because federal policy requires the non-federal sponsor to provide a clean.

2.2.3.3.1 Environmental Impacts

The environmental team, in collaboration with the resource agencies, determined which Habitat Suitability Index (HSI) models would be used to evaluate these impacts (**Table 2-2**). The models selected were all approved models and were coordinated with the Ecosystem Planning Center of Expertise and the vertical team. The models determine a HSI based on specific variables for each species. The values of the variables chosen for all of the models were selected collaboratively with the Interagency Team. The species models are used to represent the habitat, not necessarily that specific species. Habitat evaluation for directly impacted areas measured the quality of each habitat category (the HSI value) multiplied by the quantity of each habitat category (acres) resulting in habitat unit measurements. Habitat Evaluation Procedure (HEP) then used target years, forecast changes in habitat over time, to calculate Average Annual Habitat Units (AAHUs). The HEP was then applied to determine mitigation requirements for loss of or degraded habitat due to construction of CSRM features.

A systemwide model was used to determine the impacts of the proposed project on hydrology and salinity to estimate indirect impacts. Due the limited day to day interaction of Alternative D2 with large open water areas, indirect impacts were assumed to be negligible. Due to a partial closure at the Bolivar Roads from Alternative A's structure, reduced tidal flow and a change in the tidal amplitude may occur (Lackey & McAlpin 2020 and McAlpin et al., 2019). The structure consists of a series of gates including two sets of 650-foot-wide floating sector gates, which require islands to be built to store the gates when not closed for storms. These islands, along with the structural base of the other gates, reduces the opening in Bolivar Roads. The updated design for the Bolivar Roads Gate System would reduce of the opening at the pass by 9.5 percent when in the open position. This closure amount may be further optimized in future phases of the study process to reduce impacts to the hydrology of Galveston Bay system.

Table 2-2. Habitats Impacted Based on NOAA C-CP Classification and the Models Used to Calculate Mitigation Requirements for Each Habitat

Habitat Impacted	Model Used
Palustrine Emergent Wetland	American Alligator (Newsom et al., 1987)
Estuarine Emergent Wetland	Brown Shrimp (Turner and Brody, 1983)
American Oysters	Oyster Model (Swannack et al., 2014)
Open Bay Bottom	HSI values converted to Oyster Model (Swannack et al., 2014) using productivity meta-analysis (Peterson et al.)

The team developed a methodology for determining the indirect impacts to estuarine marshes within the Galveston Bay System from the constriction at Bolivar Roads. 3D Adaptive Hydraulics (ADH) modeling was used to predict hydrological impacts, changes in tidal prism, and tidal amplitude that may occur from the proposed CSRM gates. A change in tidal amplitude was assumed to create a situation where the high tides are lower, and the low tides are high than in a FWOP condition (McAlpin et al., 2018). It was assumed that a change in tidal amplitude will affect tidal marsh since the potential would exist for marsh at the upper bound of the cover type to experience less inundation, while marsh at the lower bounds of the area would experience potentially constant inundation.

To generate an estimate of indirect tidal marsh impacts due to the presence of a CSRM structure across Bolivar Roads, a spatial analysis was developed using the NOAA Marsh Migration viewer outputs associated with a projected 1 foot of RSLR. It was assumed that 2035 would represent the condition to apply potential effects from the CSRM structure on tidal marsh, which corresponds to approximately 1 foot of sea level rise based on USACE

RSLR curves. For the analysis, only tidally influenced cover types, which included estuarine and brackish wetlands were included.

Updated ADH modeling of the Galveston Bay System determined that approximately 1-inch (2 centimeters) would be eliminated from the tidal amplitude if a CSRM structure were placed across Bolivar Roads (Lackey & McAlpin., 2020). The reduction was assumed to be symmetric about the high and low tide. Using GIS, the acreage of marsh effected by the change was calculated. The resolution of the GIS data was o.5-foot, so the analysis was conducted at that resolution and the results were divided by 6 to derive a conservatively proportional impact acreage. Using the o.5-foot resolution data, the acreage of the effected tidal marsh was estimated at 6,887 acres. The 6,887 was then divided by 6 to account for the resolution issues and this resulted in an estimated impact acreage of 1,148 acres of estuarine marsh. It is important to note that the exact number could vary depending on wetland loss prior to construction, which could be caused by sea level rise, subsidence, hurricanes, or other factors. Also, the indirect number is based on a conservative estimate related to the optimized percent closure. The team will continue to further optimize the percent closure through feasibility design.

The direct impacts from the alternatives to wetlands (palustrine and estuarine), oyster reef, and open bay bottom were determined using GIS and NOAA Marsh Migration viewer outputs associated with a projected 1 foot of RSLR. The HEP tool was again applied to calculate the AAHUs of impacted palustrine wetland, estuarine marsh, oyster reef, and open bay bottom and the AAHUs and associated number of acres of mitigation that would be needed to address these impacts. **Table 2-3** shows the results from the ecological modeling performed to quantify impacts and the required mitigation for the CSRM alternatives.

The HEP methods used to assess the losses to open bay bottom habitat associated with the FWP scenarios for Alternatives A and D2 included the use of a meta-analysis (combined the results of numerous studies to estimate the ratios of average productivity across all three trophic levels between pairs of estuarine habitats (Peterson *et al.*)) to estimate equivalent oyster habitat units (Swannack et al., 2014) that would offset the predicted loss of open bay bottom habitat units.

Since Alternatives A and D2 both include several highly similar CSRM measures in Region 1, specifically, the Galveston Ring Barrier System, the Galveston Sea Wall Improvements, the Clear Lake Gate System, and the Dickinson Bayou Gate System, the direct impacts from those measures were presumed to be the same for both alternatives even though it is likely the alignments would vary.

For the environmental impact assessment, the Team decided to assume that the floodwall for Alternative D2 would be built on the existing bay rim, however, it's worth noting that if the alignment had to be shifted into the bay, similar to the New Orleans Lakefront system, direct impacts to open bay bottom and oyster reef would be higher.

Table 2-3. Ecological Impact and Mitigation for Region 1 CSRM Alternatives

Impact/Mitigation	Alternative A (Coastal Barrier)		Alternative D2 (Bay Rim)	
	Acres	AAHUs	Acres	AAHUs
IMPACTS:				
Direct				
Palustrine Wetlands	128.0	–11.8	227.1	–41.6
Estuarine Wetlands	134.0	–59.9	172.0	–94.5
Open Bay Bottom	161.6	–18.1	44.6	–5.0
Oyster	6.0	–2.8	6	–2.8
Total Direct Impacts	429.6	–92.6	449.7	–143.3
Indirect				
Tidal Prism Change	1,148	–789		
MITIGATION:				
Direct Impacts				
Palustrine Wetlands	21.0	12.1	62.0	42.1
Estuarine Wetlands	93.0	59.9	138.0	95.0
Oyster	7.0	3.0	7.0	3.0
Mitigation Direct Subtotal	121.0	75.0	200.0	137.1
Mitigation Indirect Subtotal	1,207.0	816.3		
Total Mitigation	1,328.0	891.3	200.0	137.1

The results of the impact analysis show a higher total impact acreage and mitigation requirement for Alternative A than for D2, based on the modeling and the assumptions Alternative D2 is predicted to have fewer potential environmental impacts. While this is the conclusion of the analysis, it is worth noting that there would likely be some indirect effects to salinities and circulation from the proposed Gate Structure near Tabbs Bay; however, the potential impacts were not tabulated. Also, Alternative D2 would include approximately 71 miles of additional levee and 18.4 miles of additional floodwall over Alternative A which would cross numerous small waterbodies and certainly have adverse indirect affects which were not captured in this analysis. Additionally, Alternative D2 has a higher total for direct impact average for both estuarine wetlands, palustrine wetlands, and for the overall total direct impacts to the evaluated sensitive habitats. There is greater uncertainty in the precision of calculating indirect impacts on such a large scale. It was noted in several interagency meetings that the daily tidal amplitudes in the Galveston Bay System often vary by greater than an inch due to the wind direction and velocity. Also, the uncertainties of RSLR further complicate these calculations. Throughout the assessment of the environmental impacts, the PDT has worked to identify and use the highest possible range of potential impacts in the calculations to reduce the risk of underestimating the mitigation requirements that will be refined in future Tier Two studies.

It is also worth noting that Alternative D2 would involve the discharge of dredged and/or fill material into 137.1 more acres of wetlands than Alternative A. This is largely in part to the scale of the Bay Rim Barrier and the siting in a more inland location.

Detailed discussions on the environmental consequences of the CSRM Alternatives in Region 1 are described in Chapter 4 of this DEIS.

Federally Listed Threatened and Endangered Species and Critical Habitat

The Tie-in feature included in Alternative A, has the potential to adversely impact 35 acres of critical habitat at Bolivar Flats through the discharge of fill material to construct the levee and combi wall that comprise the Tie-in feature. The PDT has worked to minimize these impacts be designing the alignment to impact the least amount of habitat possible while still protecting as many structures as possible. Consultation with the Service is planned to continue into the subsequent Tier Two environmental review for this measure. The final resolution to this issue will involve mitigation. The current mitigation plan includes marsh restoration at Horseshoe Lake which is approximately 0.7 miles for the impact site and includes known foraging habitat for piping plovers.

Additionally, the Bolivar Roads Gate System included in Alternative A has the potential to cause indirect impacts to the Piping plovers critical at habitat Big Reef, Unit TX-35. If the Gate System changes the pattern or increase water velocities it could lead to the erosion of this critical habitat.

Since the rufa red knot (*Calidris canutus rufa*) is known to use some of the habitat that Piping plovers prefer and they have been observed in the Bolivar Flats and Big Reef areas, it is also safe to assume that Alternative A would affect this species as well. Again, consultation with the Service is planned to continue into the subsequent Tier Two environmental review for the measures that would affect this species and its preferred habitats. It is likely that mitigation for impacts to the habitat will be required.

The Bay Rim Barrier included in Alternative D2 could affect Texas Prairie Dawn (*Hymenoxys texana*) either directly or indirectly. Texas prairie dawn are most frequently found at the base of small mounds in grasslands and in areas with slightly salt soils. The Bay Rim Barrier also has the potential to impact the Attwater Prairie Chicken (*Tympanuchus cupido attwateri*) in the places where it crosses coastal prairie. Large contiguous barrier systems like the Bay Rim Alternative have the potential to fragment scarce habitats like coastal prairie which can have an indirect adverse impact on numerous species, especially the Attwater Prairie Chicken.

2.2.3.3.2 Impacts to Navigation

For Alternative A, the PDT identified a concern that the constriction in the Galveston Entrance Channel that would be caused by the presence of the Bolivar Roads Gate System could increase velocities through in the immediate vicinity of the measure and in other parts of the Galveston Bay System. The results of the ADH modeling for this initial analysis showed very little difference between with-structure and base conditions (Lackey and McAlpin, 2020). The hydrodynamics at the location of the gated structure show slight increase in velocity magnitudes due to eddy formations, and slight increase in water surface elevation across the structures. These patterns should be reviewed in coordination with navigation requirements such that the final design provides for safe navigation throughout the typical tidal conditions for the area. It is understood that more detailed and advanced physical and computational modeling will be conducted during the PED phase to resolve the 3D circulation and forcing around the gated structure.

Also, the 2020 design for the Bolivar Roads Gate System includes two 650-foot-wide sector gates with a -60-foot sill depth that can accommodate the largest vessels that transit the HSC. Additionally, having two of these large sector gates will allow for two-way traffic and redundancy so navigation can proceed if one of the gates need to be closed for maintenance. The measure also includes two 125-foot-wide sector gates, one on either side of the 650-foot gates to accommodate smaller vessels with a navigation option that does not have a mast restriction. Finally, the depth of the sills and overhead clearance of the vertical lift gates included in the system may be able to accommodate smaller recreational vessels.

A ship simulation was performed on the 2018 configuration and alignment for the Bolivar Roads Gate System. However, the simulation provided valuable insight into how ship would have to approach a structure in the recommended location. During PED, a comprehensive physical and numerical model study plan and navigation simulation study will be developed and implemented to finalize the final alignment and required gate opening.

The alignment for Bolivar Roads Gate System will impact Anchorage Areas A, B, and C near the Houston Entrance Channel. The proposed location and construction of the sector gate island would result in Area B being unusable. While portions of anchorage space in Areas A and C would be lost parts of these anchorage areas would still be usable. To address these impacts, the Engineering Team met with local stakeholders (Pilots, Port Facilities, industry Captains, and the Coast Guard) and developed two alternative anchorage sites that could have the same value as the existing anchorage areas. One of the options would be to expand the remaining sites by dredging them to expand their size to match the surface area of the existing Anchorage Areas. The other option was to dredge a new site to the south of and adjacent to the Texas City Channel. Additional detail on these measures and investigations can be found in section 4.2.3 of the Engineering Appendix.

While the PDT has worked to refine the design of the Bolivar Roads gate to improve the navigational safety there is no way to remove all of the hazards associated with navigation. However, Alternative D2 would also have impacts on interactions between deep draft ships and shallow draft tugs and barges. Alternative D2 includes a navigation gate near the Fred Hartman Bridge. Under the FWOP conditions, the channel in this section includes a deep draft channel with a north- and south-bound shallow draft channel adjacent to the deep draft channel. If a gate is built at this location, the shallow draft traffic would likely be forced to use the deep draft channel to transition through the gate. Two adjacent shallow draft gates were considered but there is limited space in the upper reaches of the channel to place two additional gates.

Another difference between the two alternatives is that Alternative D2 leaves much of the navigation infrastructure at risk from storm surges, since many of the ports and channels would be outside of the system. Storm surge can move large amounts of sediment into the navigation channel during an event, adding to the annual O&M cost of dredging. Coastal Storms pose a major risk to the GIWW. Approximately 83 million tons of cargo with a commercial value estimated at $25 billion travels on the Texas GIWW annually. Past Coastal Storms like Hurricane Ike and Hurricane Harvey caused debris and excess shoaling to obstruct and shut down the GIWW for prolonged periods of time.

Both Alternatives A and D2 include similar gate structures at mouths of Clear Lake, Dickinson Bayou, and Offatts Bayou which also have the potential to adversely impact navigation. Additional analysis is needed on these measures in PED to minimize any impacts to navigation.

2.2.3.3.3 Hazardous, Toxic, and Radioactive Waste (HTRW)

The alignment for Alternative D2 crosses a number of developed and industrial areas. Specifically, the highest concentration of HTRW sites are located in Galveston, La Marque, Texas City, and in between Seabrook and Deer Park. Many of the HTRW sites identified within 1 mile of the Upper Bay Barrier are EPA registered facilities and TCEQ PST sites (**Table 2-4**). While Alternative A is not free from HTRW risk, the configuration and nature of the Coastal Barrier makes it more adaptable than the Bay Rim Alternative.

Table 2-4. HTRW sites Alternative D2

Feature Type	1-mile Radius	Intersect
EPA National FRS Major Sites	44	5
TCEQ Petroleum Storage Tank Sites	83	1
TCEQ Active Air Monitoring Sites	7	1
TCEQ Superfund Sites	2	0
TCEQ Radioactive Sites	1	0
TCEQ MSW Sites	7	1
Power Plants	3	0
Total	147	8

2.2.3.3.4 Storm Surge Performance

The Advanced Circulation Model and Coastal Storm Modeling System were used to evaluate approximately 2,000 simulated storm scenarios to create probabilistic water levels for the Coastal Barrier (Alternative A), the Bay Rim Barrier (Alternative D2), and the FWOP scenario (No Action Alternative). Additional information concerning the Storm Surge Modeling can be found in the Engineering Appendix and in Melby et. al (2020).

2.2.3.3.5 Benefits and Costs

Cost estimates for Alternatives A and D2 were formulated using inputs from the GCCPRD report (2015) and other recent USACE studies. Additional information on the cost development can be found in the Engineering Appendix (Appendix D). The USACE NED procedure manuals for coastal and urban areas recognize four primary categories of benefits for flood risk management measures: inundation reduction, intensification, location, and employment benefits. Most of the benefits attributable to a project alternative result from the reduction of actual or potential damages caused by inundation. Inundation reduction includes the reduction of physical damages to structures, contents, and vehicles and indirect losses to the national economy. The Economic Appendix (Appendix E) to the Main Report provides a detailed description of the methodology used to determine NED damages and benefits under existing and future conditions and the projects costs. The results of the economic analysis for Alternative A and Alternative D2 are represented in **Table 2-5**.

Table 2-5. Cost Estimates, Net Benefits, and Benefit Cost Ratios

Criteria	Alternative A	Alternative D2
Project Cost Range	\$14.2 – \$19.9 billion	\$18.2 – \$23.8 billion
Net Benefits	\$571 – \$294 million	\$255 – \$544 million
Benefit-Cost Ratios	1.8 – 0.6	1.3 – 0.5
Net Benefits (With GDP Impacts)	\$1,192 – \$14 million	\$923 – \$237 million
Benefit-Cost Ratios (With GDP Impacts)	2.7 – 1.0	2.0 – 0.8

2.2.3.3.6 Adaptability to Relative Sea Level Rise

Since both alternatives would be constructed over 10 to 15 year period, there would be opportunities to reevaluate RSLR for both Alternatives A and D2. However, the designs put forth in this feasibility report for the Bolivar Roads Barrier System, the Clear Lake Gate, the Galveston Ring Barrier System, and the Dickinson Bayou Gate are overbuilt to account for a smaller up front cost to provide contingency. However, in the case of

Alternative D2, there would be significant cost risk for adaptation due to the significant number of floodwall sections required as compared to Alternative A.

2.2.3.3.7 Residual Risks

While Alternative D2 is predicted to have fewer environmental impacts than Alternative A, Alternative D2 comes with a much higher residual flood and life safety risk than Alternative A. This elevated residual risk comes from the high number of operational components, the proximity of the Bay Rim alignment to developed areas (residential, commercial, industrial areas and critical infrastructure), and risks of induced flood impacts from extreme flood events.

The Interagency Performance Evaluation Task Force's (IPETF), post event investigations of Hurricane Katrina and the modeling of the Greater New Orleans HSDRRS both determined that as operational components are added to the system, the risk of system failure increases. One of the key lessons learned from the IPETF's post-Katrina investigations was that it is critical to use a system approach when assessing risk to make practicable, rational, and defensible decisions when recommending and designing hurricane risk reduction systems. The application of this principle has lowered risk and improved system performance for the greater New Orleans area. Alternative D2 includes the following additional operational components more than Alternative A: 75 two-lane highway gates, 4 four-lane highway gate, 15 railroad gates, 8 pump stations and 34 drainage structures. Also, Alternative D2 includes a 1200-foot-wide sector gate on the HSC near Hogg Island that is comparable to the Bolivar Roads Gate System that is included in Alternative A.

In the case of Alternative D2, the residual risk is also high due to the proximity of the levee alignment to developed areas. With Alternative D2, a system failure or overtopping of the levee by storm surge during extreme events would immediately inundate vulnerable populated areas and key emergency service routes. Alternative A is set farther away from the developed areas of the study area and therefore has a lower residual risk in the event of system failure or extreme overtopping events. The nonstructural measures included in Alternative A also reduce this residual risk. Galveston Bay's storage capacity also plays a key value in reducing the residual risk for Alternative A. It not only provides a storage basin for exceedance surge events; it also avoids inducing flood damage during extreme rain events, such as Hurricane Harvey. Alternative D2 includes multiple drainage and pump stations, which could have been overwhelmed by a historic event like Hurricane Harvey.

Residual risks can be mitigated by incorporating redundancy into the system; however, with Alternative D2 the limited available space due to the proximity of developed areas to the alignment would mean that numerous residential developments, commercial facilities and industrial facilities would be impacted to acquire more space to incorporate redundant features in vulnerable areas. Additionally, the components in Alternative D2 that increase the residual risk (highway closures, railroad closures, and drainage features) are the most expensive components in the system, if redundant features were incorporated, the costs would likely render the Alternative infeasible.

2.2.3.3.8 Construction Schedules and Real Estate Risks

Preliminary construction schedules for alternatives were formulated to calculate annual cost streams and Benefit Cost Ratios. In most cases, project benefits cannot start accruing until a "closed" risk reduction system is in place, which would require, at a minimum, all structures and levees to be constructed. For planning purposes, the team assumed construction ending for both systems in 2035 to compare benefits; however, there are some significant differences between the alternatives and potential construction options between alternatives.

For Alternative D2, the footprint of Upper Bay Barrier-Bay Rim (Alternative D2) includes a significant number of properties with structures and piers that may have to be relocated or condemned. There is a high likelihood that real estate acquisition could extend the construction completion schedule and could include condemnation proceedings. Unlike with Alternative A, all structures must be completed prior to any risk reduction being realized.

With Alternative A, it may be possible to construct only the Bolivar Roads Gate System first, which would provide some coastal storm risk reduction to the region allowing them to obtain an initial level of benefits before the entire system is constructed. Currently, the existing landscapes of Bolivar Peninsula and Galveston Island provide a level of risk reduction from smaller storms. Only building the large surge gate with the ecosystem features of beach and dune restoration features along Bolivar Peninsula and Galveston Island would obtain an interim risk reduction.

2.2.3.3.9 Comparison to No Action

The no action alternative was considered in all the impact modeling as the FWOP scenario. Under the future without project scenario the regional resiliency to coastal storm surges would continue to be lost as erosion and RSLR continue to weaken the natural buffers that provide protection from Coastal Storms. Recent tropical storms in the Gulf of Mexico have illustrated that it is not a matter of if, but it is a matter of when one of these large storms is going to hit. That said, the no action alternative would leave the region vulnerable to potential catastrophic impacts. For those reasons the no action alternative is not the preferred alternative.

2.2.3.4 National Economic Development Plan

Alternative A was selected as the CSRM Region 1 alternative to include in the recommended plan and is considered the NED plan for Region 1 as determined by the evaluation criteria for the upper coast of Texas. It fulfilled the focused CSRM planning objectives for Region 1, and it reasonably maximized net benefits, consistent with protecting the Nation's environment in accordance with national environmental statutes, applicable Executive Orders, and other Federal planning requirements.

2.2.4 Region 2 CSRM Alternatives

The Matagorda Hurricane Flood Protection Project (HFPP) is a Federally-authorized, non-Federally operated and maintained project located in Matagorda County. A series of periodic inspections gave the system an unacceptable rating due to the amount of damage recorded along the system's culvert and drainage system. The PDT considered potential improvements to the system by reviewing external water surface elevations derived from a coast-wide AdCirc modeling effort using a suite of synthetic storms. There is a specific need in the area for an enhancement of the culvert and drainage components of the levee system, focusing on the use of a medium sized pumping station and the installation of lift stations to address internal flooding; however, the PDT determined such an effort is more appropriate for a shorter duration study and authority than the scale of the Coastal Texas Study. Therefore, the measure was not included in the final array of measures.

2.2.5 Region 4 CSRM Alternatives

Erosion along South Padre Island was included on the list of problems and opportunities within Region 4. A dense concentration of structures is located along the gulf shore of City of South Padre Island which has experienced a period of erosion that varied from 2 to 25 feet per year from 1800 to 1935. Jetty construction in 1935 led to erosion immediately north of the jetty. Erosion since the 1980s has been between 5 and 25 feet per year in the northern portion, and 18 feet per year when storm impacts are included.

A history of beneficial use placements since 1988, conducted in conjunction with the Texas General Land Office (GLO) and city of South Padre Island under a cooperative agreement with the USACE, has maintained sediment within the coastal zone along this heavily used stretch of coast. The periodic projects have beneficially used material from Brazos Santiago Pass to nourish the Gulf beach to counter the ongoing erosion.

The initial model results show that the annual benefits exceed the annual project costs within reaches 3 and 4 for all scales of beachfill, since these 2 miles are the most erosive reaches. Based on the nourishment volumes and intervals, the TSP recommended a profile with a 12.5-foot dune and 100-foot-wide berm with a 10-year renourishment cycle; however, the range of potential benefits based on varying profiles was also assessed and is presented in the feasibility report.

The GLO has indicated that they are interested in exploring a larger extent of beachfill along South Padre Island; however, they have not identified a Locally Preferred Plan, which would be required if the large extent preferred. Further refinement was undertaken in the third formulation phase, when the NER and NED plans published in the 2018 Draft Feasibility Report were refined to create a cost effective, comprehensive and efficient Recommended Plan.

2.3 ECOSYSTEM RESTORATION

An ER measure is a feature (a structural element that requires construction or assembly on-site) or an activity (a non-structural action) that can be combined with other management measures to form alternative plans. ER measures were specifically developed to capitalize on opportunities that address the problems related to the current trend of ecosystem degradation throughout the coastal Texas area. However, ER measures that are anticipated to be studied or constructed under another authority or program were removed from further consideration.

The GLO is comprehensively analyzing ecological restoration projects which may contribute to coastal resiliency. Measures identified in the Coastal Texas Study, which were also included in the Coastal Resiliency Master Plan projects were eliminated from further consideration if it appeared that the corresponding Coastal Resiliency Master Plan projects had a high probability of being constructed in the near future. Consistency of Coastal Texas Study measures to the GLO Coastal Resiliency Master Plan projects supports a systematic approach. The purpose of this is to maximize the synergy among restoration programs along the Texas Coast.

2.3.1 Ecosystem Restoration Goals and Objectives

As the nation's environmental engineer, the USACE manages one of the largest federal environmental missions in the United States. The focus of the USACE's ecosystem restoration program is on water-related ecosystem projects, including restoration of wetland, riparian, and aquatic systems. The USACE's goal for its environmental mission is to restore ecosystem structure and processes, manage our land, resources and construction activities in a sustainable manner, and support cleanup and protection activities efficiently and effectively, all while leaving the smallest footprint behind. The Coastal Texas Study goals and objectives were developed with the USACE's environmental mission goal as its basis.

ER measures that were being considered or constructed under another authority or program were removed from further consideration. Consequently, the first step in the screening process is comparison of ER measures for consistency with study goals and objectives (**Table 2-6**). (NOTE: Goals and Objectives developed for the AM&M have since been revised for consistency with the revised Ecosystem Restoration Strategy.) For an ER measure to be carried forward, it must be consistent with both study goals and at least one or more study objective. Those ER management measures that did not meet the goals and objectives screening criteria were removed from further consideration.

Table 2-6. Ecosystem Restoration Goals and Objectives

Goals
Goal #1: Promote a resilient and sustainable coastal ecosystem by reducing future land loss and restoring and enhancing coastal wetlands in order to achieve and sustain a coastal ecosystem that can support and protect the environment, economy, and culture of coastal Texas.
Goal #2: Maintain or establish natural landscape features and hydrologic processes that are critical to sustainable ecosystem structure and function and that provides diverse fish and wildlife habitats.
Objectives
Objective #1 Shoreline Protection (SP): Reduce/prevent shoreline erosion to barrier system shorelines, estuarine bay shorelines, and channel shorelines.
Objective #2 Hydrologic Connectivity (HC): Improve hydrologic connectivity into sensitive estuarine systems.
Objective #3 Barrier Beach, Dune and Back Marsh Restoration (BD): create, restore, nourish and protect barrier beach, dune, and back marsh.
Objective #4 Oyster Reef Restoration (OR): create, restore, nourish, and protect important oyster reefs.
Objective #5 Estuarine Bay Systems Restoration (EB): create, restore, nourish, protect important estuarine wetlands, seagrass beds, tidal flats, etc.
Objective #6 Migratory Bird Habitat Restoration (MB): create, restore, and protect important habitat used by migratory birds
Objective #7 Bird Island Rookeries Restoration (BI): create, restore, and protect important islands used as bird rookeries.
Objective #8 Restore Habitat Used by Threatened and Endangered Species and species of concern (TE): create, restore and protect designated critical habitat used by threatened and endangered species.

2.3.2 ER Measures

Ecosystem restoration management measures (ER measure) were developed and derived from a variety of sources including: NEPA public scoping process; consideration of the existing and future without project conditions, the conceptual ecological model (CEM) process; prior restoration projects; analysis of previous reports and projects with similar problems, needs, and opportunities; coordination with resource agencies, local governmental, or landowner groups, and scientific data from prior studies; as well as the professional judgment of the interagency PDT. The initial array included a total of 63 ER measures across the four Regions. For a complete list of the Initial measures see Table A-2 in the Plan Formulation Appendix.

2.3.2.1 Screening Criteria

The screening of ER measures was conducted in accordance with ER 1105-2-100 (Planning Manual) by a multi-disciplinary PDT consisting of experts from state and Federal agencies. The selected measures were developed and screened based upon experience with previous restoration efforts in the coastal Texas area, knowledge of the coastal Texas area, conventional scientific theory, best professional judgment, and consideration of the Study goals and objectives.

When developing the ER Measure Screening Criteria, two general assumptions were made, the first assumption is when combining restoration measures, effective, and efficient restoration must include elements from all three lines of defense (barrier system, the bay system and deltaic systems) for holistic restoration. The second general assumption was that the most critical ecological elements (e.g., highly productive bird rookery islands, critical seagrass beds, etc.) would be carried over for combination into alternatives with larger critical landscape features.

Measures that were screened out but could be effective in combination with another measure were combined to accomplish study goals and meet established criteria. The following screening criteria were developed by the interagency PDT to determine which measures meet the ER goals and objectives:

- **Restores Critical or Key Geomorphic Landscape Structural Feature or Framework:** Maintains or protects the integrity of the barrier island, back barrier marsh, estuarine wetlands, or a key geomorphic structure such as a landbridge.
- **Restores Fundamentally Impaired Hydrologic Connections:** Does the ER measure restore hydrologic and sediment connectivity at the local or immediate area, the sub-basin area, multiple sub-basin areas surrounding the ER measure, the bay basin scale, watershed or regional scales?
- **Wetland Elevation – Sustainability:** This criterion is the net acres of emergent wetlands at the end of the project period of analysis (target year 50), which compares the future with-project acreage to the future without-project acreage.
- **Area of Protection:** How much total area of wetlands, shoreline (barrier beach shoreline and bay shorelines), etc. is protected? It is important to protect self-sustaining wetlands from excessive erosional forces.
- **Ecosystem Influence Area:** How much total area does the measure affect beneficially (both directly and indirectly)? This is not just the HEP benefit area, which encompasses the area of direct measurable impacts. But also includes the predicted indirect impacts area in the watershed that would be positively

influenced/benefited by the measure (e.g. storm surge protection, flood water retention, factors that extend project impacts beyond the direct impact area.

- **Organism and Materials Linkages:** Does the project allow a natural level of exchange of organisms and materials, such as detritus, nutrients, water and sediments consistent with the sustainability of the ecosystem? By definition, shoreline protection projects do not allow a natural level of exchange. Even when well designed with fish dips, etc., the level of organism and material linkage is moderately less than the natural system.
- **Infrastructure:** What is the net impact of the project on coastal infrastructure within the ecosystem influence area? Critical infrastructure includes any structures relating to communities (cities, towns, or villages), major oil and gas facilities (such as those where people go to work every day), flood protection/hurricane protection levees, hurricane protection routes, major roads/highways, major navigation channels (e.g., GIWW, etc.), and ports. Non-critical infrastructure includes any secondary roads, minor roads, minor navigation channels/canals, minor oil and gas facilities (small wellheads, tank batteries, compressor stations, and pipelines), and camps.
- **Project Synergy:** This criterion is meant to capture the ecosystem-level benefits of ongoing or multi-phased projects or those that provide a synergistic effect with other projects.

ER measures that were retained for further consideration based on their ability to meet the study goals and objectives were subjected to a second round of evaluation. Each were refined in coordination with the interagency team who met on a monthly basis throughout the feasibility study. Several measures were combined and presented as a single measure during the interagency refinement and screening since they had complementary function, location, and/or dependency. The interagency team also screened out measures after considering cost effectiveness and available resources in comparison to other similar measures within the same region and setting. This final refinement reduced the array of ER measures from 22 to 9. The measure descriptions below indicate which measures were combined. The final array of measures included a beach restoration measure, G-5, which was later refined to provide some risk reduction with a higher dune and removed from the ER plan.

Additional information on the screening process for the ER measures is located in Plan Formulation Appendix of the Feasibility Main Report. It provides a detailed list of the rationale used for the screening process.

Adaptability and Relative Sea Level Rise (RSLR)

The refinement of ER measures also included an assessment of current and future condition of wetland inundation images under the RSLR curves for each proposed footprint and surrounding area.

The PDT identified vulnerable areas at different points in time for the low, intermediate, and high rates of RSLR to evaluate the performance and cost effectiveness across different sea level change scenarios. The comparison confirmed that RSLR threatens critical geomorphic ecosystem features and habitat along the Texas coast under all RSLR scenarios, varying only in how quickly the water level reaches that height. A “tipping point”/break point is evident when the water level increases by 2.7 feet, when estuarine environments in Texas evolve into open water or unconsolidated shoreline.

Given the significant scale of the intervention necessary to restore marsh and estuarine environments in Texas, an adaptive measure was formulated in anticipation of sea level change impacts. Out year nourishment was proposed as an adaptive measure for adjacent habitat identified as vulnerable to loss when water level increases by 2.7 feet. While this out-year nourishment is not included in the recommended plan, it is included in the Monitoring and Adaptive Management Plan, and the PDT considered it important to disclose this risk and begin the NEPA process for the thin layer placement of dredge material that may be necessary to maintain the health of ecosystems sensitive to RSLR (e.g. coastal marshes).

A description of the final array of ER measures, their anticipated benefits, and the expected FWOP conditions for each measure are described below. The recommended plan does not include out-year nourishment due to the USACE requirement that the ER measures be self-sustaining which precludes continuing construction. Under lower rates of RSLR, the tipping point will occur later, and the out-year nourishment may not be necessary or may occur later. Out-year nourishment is still considered for NEPA compliance purposes, so that if the NFS decides to pursue out-year nourishment, they will not have to replicate work that has already completed. The Monitoring and Adaptive Management Plan (Appendix K) discusses the data collection and thresholds that will trigger restorative actions if necessary.

2.3.2.2 Final Array of ER Measures

Detailed designs for all the ER measures, except the Bolivar and West Galveston Beach and Dune System, are included in the Engineering Appendix of the main report. A more detailed description of the Bolivar and West Galveston Beach and Dune System is included in Section 5 of the Engineering Appendix, since it was refined to provide some risk reduction with a higher dune and removed from the ER plan.

2.3.2.2.1 The Bolivar Peninsula and West Galveston Beach and Dune System (formerly ER measure G-5)

Restore, create, and/or enhance approximately 25 miles of Gulf shoreline from High Island on Bolivar Peninsula to the Galveston East Jetty and about 18 miles of Galveston Island shoreline west of the Galveston seawall.

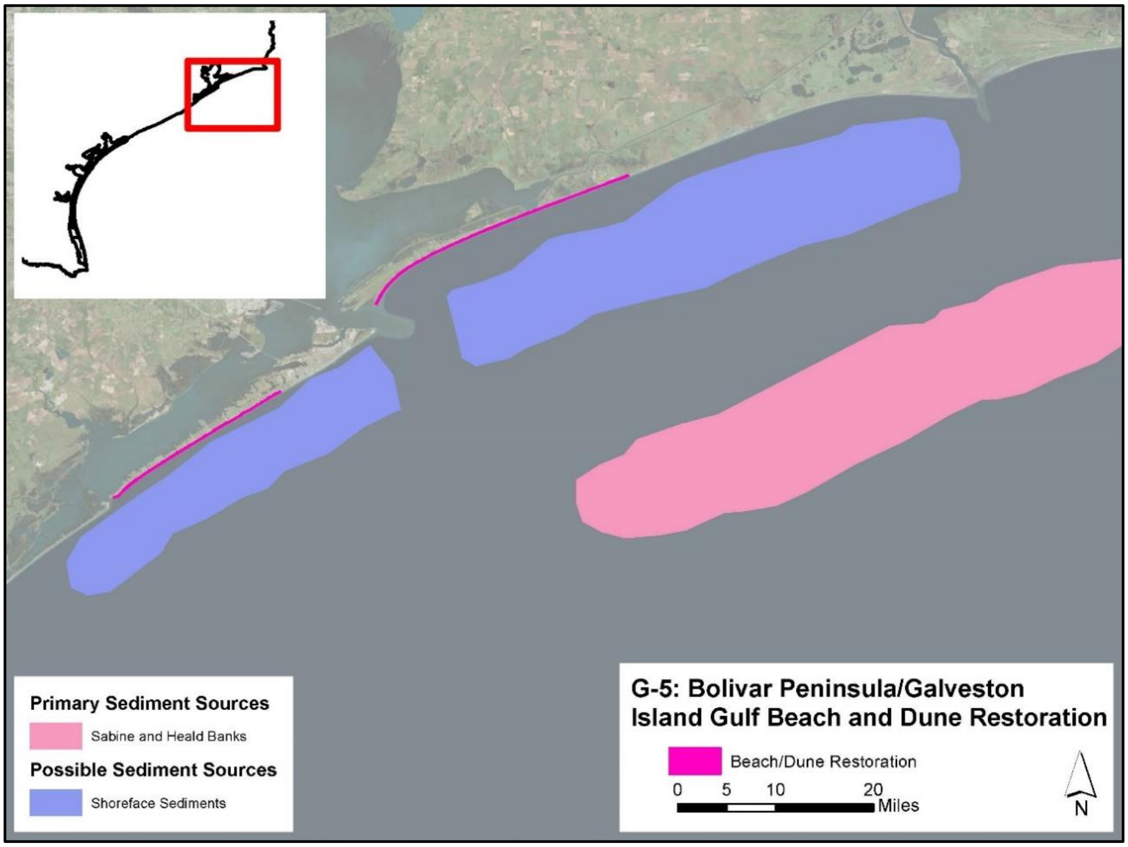


Figure 2-10. Location of the Dual Purpose Beach and Dune Measure for Bolivar Peninsula and Galveston Island with Borrow Sources

Measure G-5 has been redesigned as a dual-purpose measure (both CSRM and Ecosystem Restoration). Comments received during the first public comment period expressed concern about the impacts of the CSRM levee originally proposed on Bolivar Peninsula and Galveston Island, and it was determined to be infeasible to implement the measure in consideration of the public concerns. In response, the levee was removed from the plan and the beach measure was refined to increase the height of the dune and the width of the berm to provide some risk reduction and ecosystem restoration benefits.

This refinement does not afford the same level of risk reduction as the levee but removed the impacts to access and land use. Notable changes to the design include: a two-dune configuration, and wider beach face (shown in **Figure 2-10** as a berm), and a higher elevation for the dune crests. **Figure 2-11** shows a typical cross section for the dual-purpose design and **Figure 2-12** shows a typical cross section from the previous G-5 measure. A more detailed description of the measure can be found in Section 5.3 of the Engineering Appendix to the Feasibility Report.

A single dune with a clay core was considered as a variation to the measure; however, it was determined that constructing a single dune would require a substantially taller dune which would interfere with visual resources, recreational access, and property values along the beach.

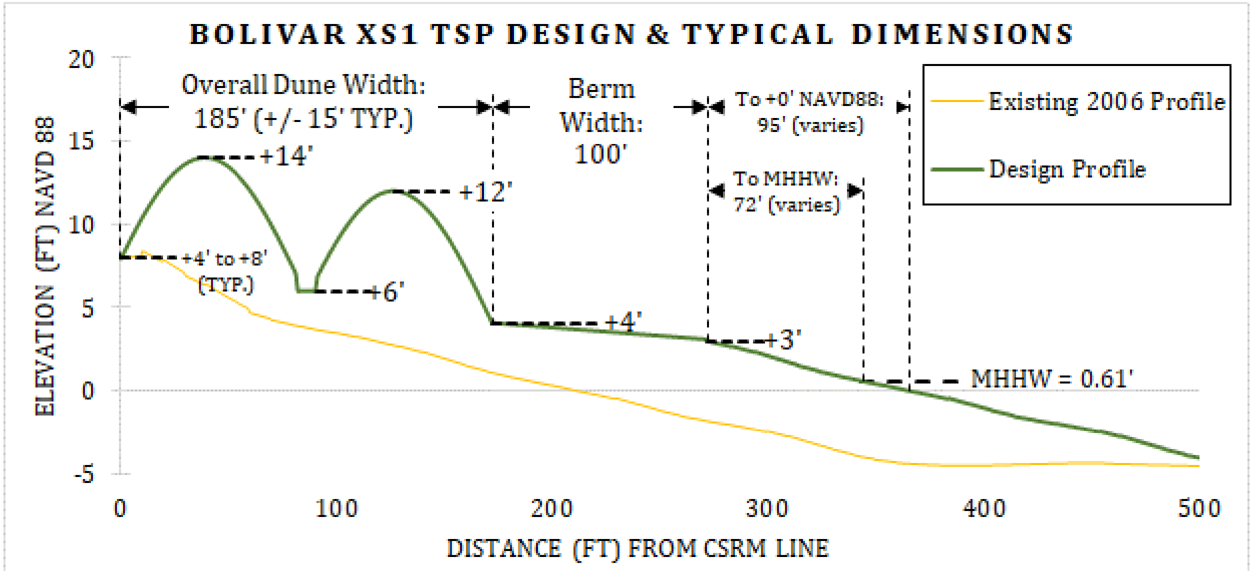


Figure 2-11. Typical Cross-Section for the Dual Purpose Beach and Dune Measure for Bolivar Peninsula

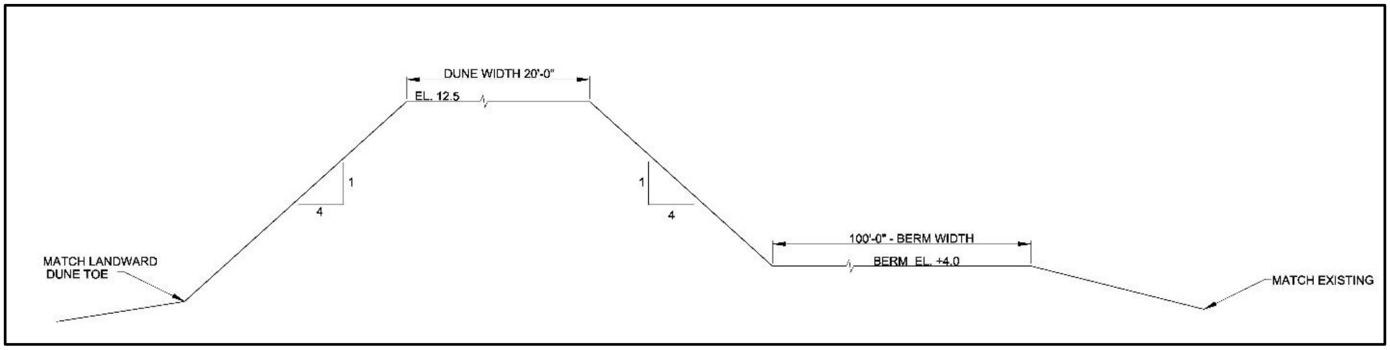


Figure 2-12. Typical Cross-Section for ER Measure G-5 before it was redesigned as a dual purpose measure

The measure would be constructed using sand sediment from an offshore sediment source (Sabine and Heald Banks). The current design for the dual-purpose beach and dune measure does not include a core or structure, only sand and native plants. The design team used a Kemp's Ridley sea turtle ecological model to optimize the ecological benefits and to ensure that the design for the dual-purpose beach and dune measure was to restore historic geomorphic beach contours to Galveston Island and Bolivar Peninsula.

Uncertainty regarding the precise location of the sand source(s) has limited the PDT's ability to identify impacts under NEPA, therefore this measure will need to have a Tier Two NEPA study to finish environmental compliance. The Bureau of Ocean Energy Management (BOEM) is a Cooperating Agency on the Coastal Texas Study and is conducting investigations on sediment availability and the sediment characteristics (e.g. grain size, chemical composition, color) in the offshore areas off of the Texas Coast. This Tier One EIS has advanced the review for this measure as far as possible given the available information.

Project Benefits. The project will decrease the likelihood of erosion and breaches to beaches, dunes, and wetlands caused by storm surge and sea level rise. It would protect the wildlife in these habitats, and also protect SH 87 and Farm-to-Market Road 3005, both of which are the only evacuation routes for Bolivar Peninsula and to the west end of Galveston Island, respectively. Several coastal communities, including Pirate's Beach, Jamaica Beach, the Silverleaf Seaside Resort, Vista Del Mar, Terramar, and Baywater would gain the benefits of the project.

Future Without-Project. The Gulf shoreline is eroding at a rate of up to 5.7 feet per year along this area of the Bolivar Peninsula and at 8.2 feet per year on the identified section of Galveston Island (BEG, 2016). If this project does not occur, much of the existing 5,000 acres of Gulf beach, dunes, and wetlands in this area will be lost in 50 years. Loss of these ecosystems will increase susceptibility of inland habitat and infrastructure to damage during storms.

2.3.2.2.2 Measure G-28, Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

This measure consists of shoreline protection and restoration utilizing 40.4 miles of rock breakwater at a crest height of 10 feet with 2H:1V side slopes and a base width of 46 feet, 18 acres of oyster creation, 664 acres of marsh restoration, and 5 miles of island restoration (**Figure 2-13**).

The construction of the rock breakwaters will reduce the erosion occurring along unprotected segments of shoreline for approximately 27 miles of the GIWW on Bolivar Peninsula and 9 miles of shoreline along the north shore of West Bay. No breakwaters would be constructed where portions of the GIWW shoreline are stabilized by adjacent dredged material placement areas. The island and marsh restoration would occur through the beneficial use of dredge material from the GIWW and material displaced from the dredging associated with the Region 1 CSRM coastal barrier bypass channel. The 5 miles of island restoration would total 251 acres of that once protected the GIWW and the mainland in West Bay. Additionally, 18 acres of oyster cultch would be placed to the south of the island restoration to provide a diversity of habitats, and some erosion protection for the restored islands. Measures G-12 East and G-12 West were combined with G-13 East and G-13 West to create measure G-28.

Figure 2-13. ER Measure G-28 with borrow sources

Project Benefits. Breakwaters are a proven method to greatly reduce, and sometimes reverse, the loss of marsh habitat that erodes along the GIWW due to barge wakes and channel fetch. The shorelines and marshes in these areas would be restored and protected from storm surge and erosion and from the effects of sea level rise. Beyond the ecological lift just described, this project also would reduce maintenance dredging of the GIWW.

Ancillary benefits can be expected when the ecological habitat is restored in this way. Aside from the ecological losses caused by the erosion along the GIWW, the erosion adversely effects navigation by reducing the channel’s shelter from wind, waves, and fetch and by increasing operation and maintenance costs due to higher shoaling rates.

Protecting the shoreline of Bolivar Peninsula reduces the likelihood it will breach to the Gulf since, at 3 feet of sea level rise, portions of the peninsula may narrow to less than 2,000 feet wide. Breaching could increase salinities in East Bay, which impact bay habitat.

Future Without-Project. If the habitat along the shoreline is not protected, approximately 18,000 acres of existing intertidal to high marsh along the south shore of the GIWW through Bolivar Peninsula and the north shore of West Bay would be inundated at a sea level rise of 3 feet (NOAA, 2017). This marsh habitat also serves as a buffer from some storm impacts to area infrastructure.

2.3.2.2.3 Measure B-2 – Follets Island Gulf Beach and Dune Restoration

This measure would restore, protect, and/or enhance the beach and dune complex on approximately 10 miles of Gulf shoreline on Follets Island in Brazoria County, Texas (**Figure 2-14**).

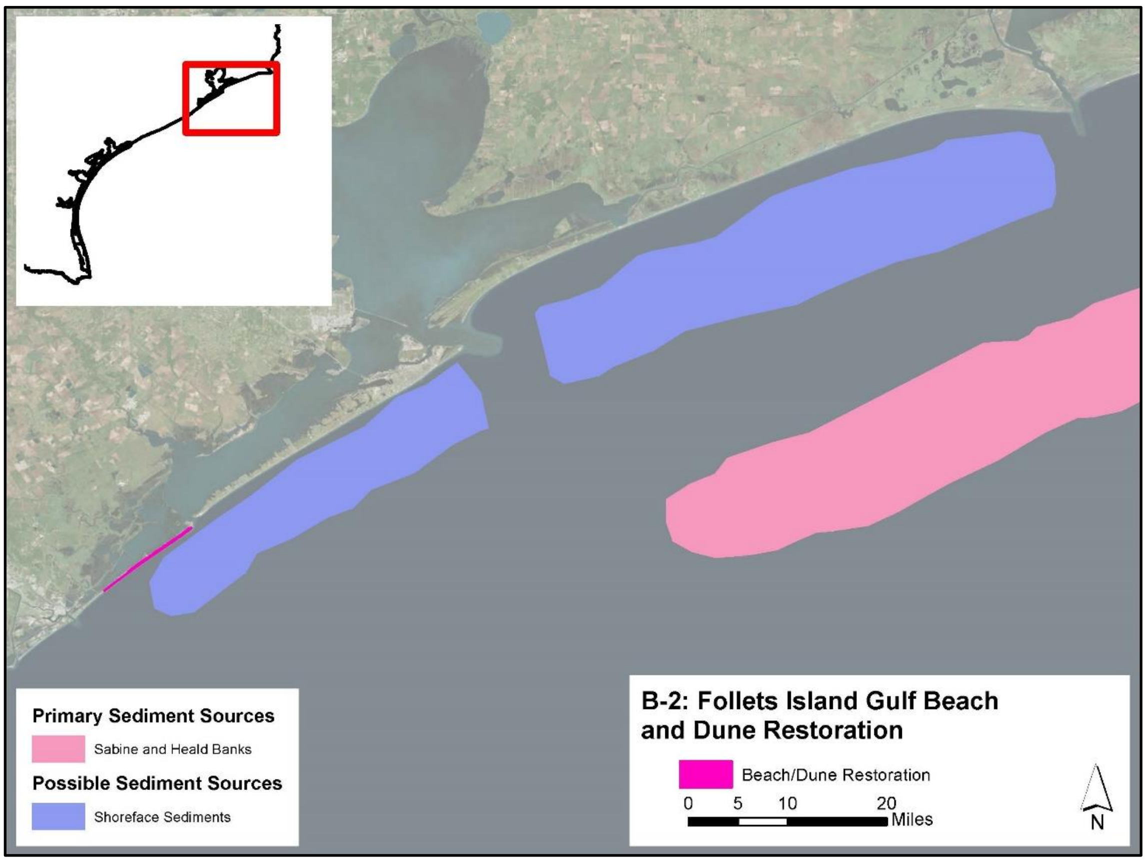


Figure 2-14. ER Measure B-2 Follets Island Gulf Beach and Dune Restoration with Borrow Source.

Project Benefits. A restored shoreline on Follets Island will guard against beach and dune breaches caused by erosion, storm surge, and sea level rise. This will protect inland wetlands, seagrass meadows, and other habitats. All of which shield SH 257 from the effects of storm surge, the only road accessing and providing evacuation capability to the east towards Galveston Island and to the west towards Freeport.

The beach, dune, wetland, and seagrass meadow ecosystems along Follets Island are the first line of defense for Bastrop, Christmas, and Drum bays, and the Brazoria NWR and various residential developments on the mainland. Christmas Bay is a designated Gulf Ecological Management Site because of its relatively undeveloped shorelines, high water quality, and unique mix of seagrass meadows, oyster reefs, and smooth cordgrass marsh; it is also a TPWD Coastal Preserve.

Uncertainty regarding the precise location of the sand source(s) has limited the PDT's ability to identify impacts under NEPA, therefore this measure will need to have a Tier Two NEPA study to finish environmental compliance. The Bureau of Ocean Energy Management (BOEM) is a Cooperating Agency on the Coastal Texas Study and is conducting investigations on sediment availability and the sediment characteristics (e.g. grain size, chemical composition, color) in the offshore areas off of the Texas Coast. This Tier One EIS has advanced the review for this measure as far as possible given the available information.

Future Without-Project. The Gulf shoreline in this area is eroding at a rate of 13 feet per year (BEG, 2016). Over the next 50 years, more than 200 acres of existing beaches and dunes that protect homes, infrastructure, and habitat may be washed away due to erosion and severe storms. The critical evacuation route of SH 257 would be substantially threatened because of its proximity to the shoreline. Currently, some sections of the highway are within 180 feet of the shoreline. A breach at Follets Island into Christmas Bay would substantially affect the dynamics of the unique features of Christmas Bay.

2.3.2.2.4 Measure B-12 – West Bay and Brazoria GIWW Shoreline Protection

This measure would restore, create, and/or enhance critical areas of shoreline in the bay complex of Bastrop Bay, Oyster Lake, Cowtrap Lake, and the western side of West Bay. This would be accomplished through several methods. Breakwaters would be used along the GIWW and along the land that separates Oyster Lake from West Bay. In Oyster Lake cultch would be added near the approximately 0.7 miles of shoreline that is expected to breach into West Bay. To maintain and protect the GIWW shoreline that is identified as an "unconsolidated shore" using the NOAA (2017) marsh migration layer at 2.5-foot sea level rise, a one-time marsh nourishment of 19,794 acres would occur in year 2065. Measure B-5 (Bastrop Bay, Oyster Lake, and West Bay Shoreline Protection) was combined with measure B-6 (Brazoria County GIWW Shoreline Protection), because they are not considered separable elements and cannot stand alone, these combined measures were renamed to B-12 (**Figure 2-15**).

Project Benefits. This restoration will protect this bay complex from being breached by West Bay. This would safeguard the critical shoreline in this bay complex from erosion, and the effects of storm events, vessel wakes, and sea level rise. This also will preserve the marsh, oysters, colonial waterbird rookeries, and other habitats in this bay complex.

Future Without-Project. If this project does not occur, 10 miles of shoreline in this bay complex and more than 6,000 acres of intertidal marsh and freshwater wetland along the north side of the GIWW will be inundated with 3 feet of sea level rise. The Brazoria NWR will lose valuable wetland habitat. Patterns of sedimentation flow will change, which will negatively affect the oyster reefs in Bastrop Bay and Oyster Lake. The conversion of large expanses of wetlands to open water also will adversely affect navigation in the GIWW.

Figure 2-15. ER Measure B-12 Brazoria GIWW

2.3.2.2.5 Measure CA-5 – Keller Bay Restoration

This measure would use breakwaters and/or living shorelines to restore, protect, create, and/or enhance approximately 5 miles of shore along Matagorda Bay between Matagorda and Keller Bays. Oyster reef balls would be added to protect and enhance about 2.3 miles of western shoreline along Sand Point, which separates the two bays (**Figure 2-16**). In the future, nourishment of 623 acres of marsh along the back side of the initial restoration would be conducted to maintain and protect areas identified by NOAA (2017) as “unconsolidated shore” with a 2.5-foot sea level rise.

Project Benefits. This project will prevent the breaching of the Matagorda and Keller Bays shoreline into Keller Bay. This would reduce erosion to preserve and enhance the intertidal marsh and oysters in Keller Bay.

Future Without-Project. If a breach into Keller Bay occurs, erosion will accelerate, and currents will be modified. This will lead to the degradation and loss of oysters and over 250 acres of intertidal marsh in Keller Bay along the Matagorda and Keller Bays shoreline.

Figure 2-16. ER Measure CA-5: Keller Bay Restoration

2.3.2.2.6 Measure CA-6 – Powderhorn Shoreline Protection and Wetland Restoration

This measure would restore and reduce erosion to approximately 6.7 miles of Matagorda Bay shoreline with breakwaters and marsh restoration. This area fronts the communities of Indianola, Magnolia Beach, and Alamo Beach, and the Powderhorn Lake Estuary (**Figure 2-17**).

Project Benefits. This shoreline is primarily used for recreation. The restoration will enhance the economic value of this area and protect the intertidal marsh and ecological integrity of Powderhorn Lake Estuary.

Future Without-Project. Without this project more than 300 acres of intertidal marsh/open water complex would erode and submerge at a 3-foot sea level rise if the shoreline breaches. Another effect of not implementing this project is the significant widening of the mouth of Powderhorn Lake. This type of transformation would change the lake's salinity regime and increase wave generated erosion and lead to a decline or loss of marsh.

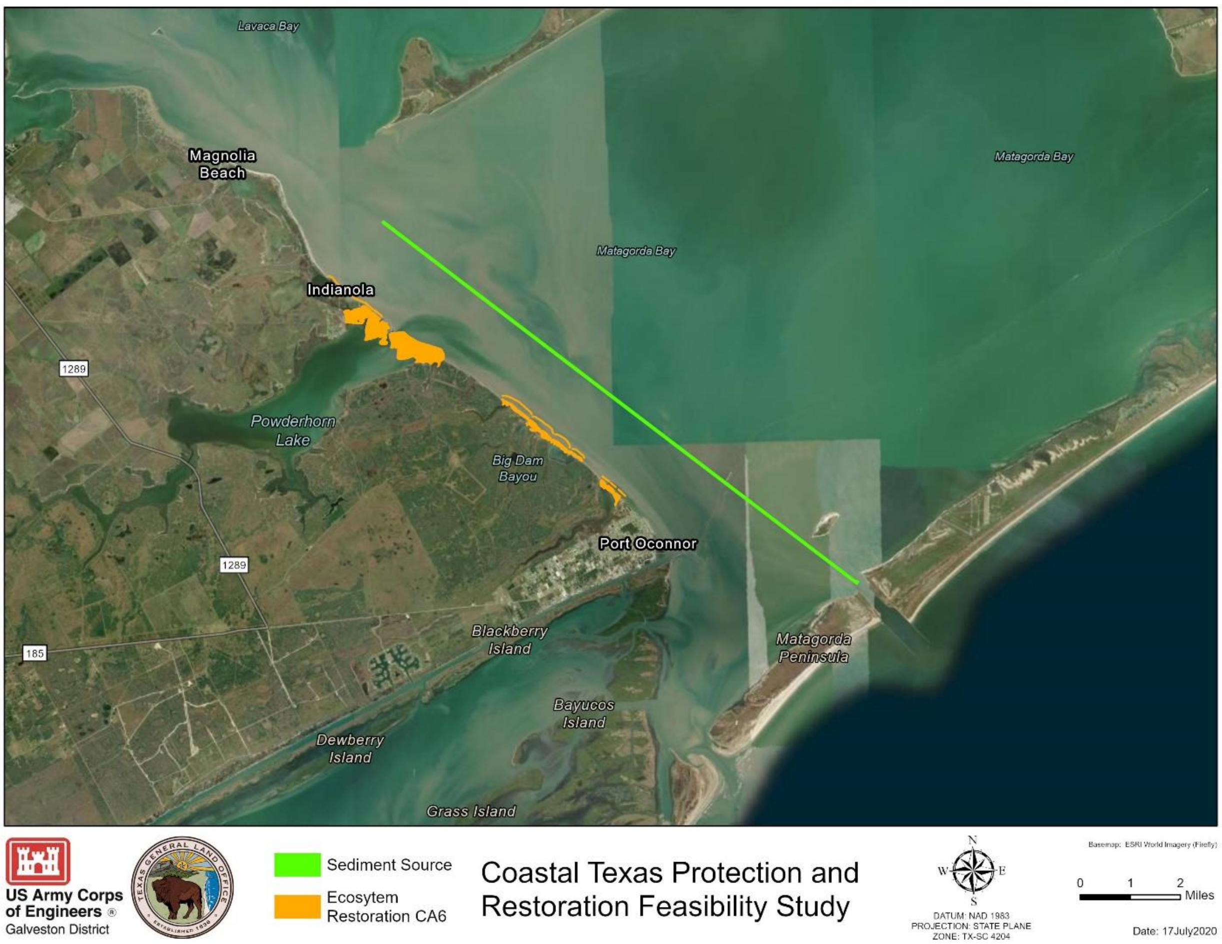


Figure 2-17. ER Measure CA-6: Powderhorn Shoreline Protection and Wetland Restoration.

2.3.2.2.7 Measure M-8 – East Matagorda Bay Shoreline Protection

This project would use living shorelines and/or breakwaters to restore, protect, create, and/or enhance approximately 12 miles of shoreline and associated marsh along the Big Boggy NWR shoreline and eastward to the end of East Matagorda Bay. About 3.5 miles of shoreline directly in front of Big Boggy NWR also will be enhanced by adding a breakwater on the south side of the GIWW. In addition, the islands adjacent to the GIWW and the oyster reefs behind the adjacent islands on the bayside will be restored (**Figure 2-18**). Subsequently, in the future, a one-time marsh nourishment of 6,034 acres would occur in the areas designated by NOAA (2017) as "unconsolidated shore" at 2.5-foot sea level rise.

Project Benefits. This project will mitigate the effects of breaches, erosion, sea level rise, storm events, and vessel wakes to protect the GIWW shoreline and marshes in this area.

Future Without-Project. If this project does not occur, the following areas may convert to open water at 3-foot sea level rise: 1) more than 2,000 acres of intertidal marsh and wetlands around the Pelton, Kilbride and Boggy lakes complex in the Big Boggy NWR along the north shore of the GIWW and west of the Chinquapin community; and 2) over 7,000 acres of intertidal marsh and wetlands to the east of Big Boggy NWR towards Bay City at the east end of Matagorda Bay. This will increase wave erosion along the north shore and on marsh, reefs, and islands in East Matagorda Bay and south of the GIWW.

Figure 2-18. ER Measure M-8: East Matagorda Bay Shoreline Protection

2.3.2.2.8 Measure SP-1 – Redfish Bay Protection and Enhancement

This measure would use breakwaters and/or living shorelines, BU material, and oyster reef balls to restore, create, and/or enhance the island complex of Dagger, Ransom, and Stedman islands in Redfish Bay (**Figure 2-19**). Breakwater and islands would protect submerged aquatic vegetation (SAV) within Redfish Bay and it is assumed about 200 acres of additional SAV will form between the breakwaters and islands.

Project Benefits. This project will prevent loss of islands to protect extensive seagrass meadows and support coastal waterbirds and fisheries.

Future Without-Project. Not restoring this island complex would result in continued erosion and will expose the area to greater wave action from the deep draft navigation in the Corpus Christi Ship Channel. This could threaten approximately 2,000 acres of seagrass meadows and damage the habitat for coastal waterbirds and fisheries.

Figure 2-19. ER Measure SP-1: Redfish Bay Protection and Enhancement

2.3.2.2.9 Measure W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

This project would restore the Port Mansfield Channel area by implementing the following: 1) use beach and dune restoration to improve and maintain the geomorphic function of the Gulf shoreline north of the Port Mansfield Channel through the barrier island; 2) protect and restore Mansfield Island with 3,696 feet of rock breakwater and barrier island restoration; and 3) restore and maintain the hydrologic connection between the Laguna Madre and the Gulf with dedicated dredging of a portion of the Port Mansfield Channel. W-1 and W-2 were combined to create one measure, W-3, in which the material dredged from the channel would be used beneficially for beach nourishment and for additional restoration of Mansfield Island (**Figure 2-20**).

Project Benefits. Currently, jetties block the prevailing south to north longshore current. This project would restore sediment transport north of the Port Mansfield Channel jetties. This would prevent the eminent breach of the barrier island and maintain access to visitors and National Park Service staff. Restoration of sediment transport would support dune development and help control erosion along the Gulf shore. This would help protect the critical habitat for wintering piping plovers and the primary U.S. nesting beach for the endangered Kemp’s Ridley sea turtles.

Restoring Mansfield Island would increase the size and elevation of the island to mitigate erosion due to sea level rise, storms, and vessel wakes. Lastly, the hyper-salinity in the Laguna Madre would be reduced, improving the habitat.

Future Without-Project. If this project does not occur, erosion on the north side of the pass would continue at a rate of 14 feet per year (BEG, 2016). The beach and dune system would erode toward washovers, which can increase the likelihood of system breaches. Increased water exchange with the Gulf would result in salinity, circulation, and habitat changes in the Laguna Madre.

Without the project, the area would not be protected by the effects of sea level rise. With an expected 2-foot RSLR by 2085, dune areas can transition to brackish intertidal wetlands on the back side of South Padre Island and increase the possibility of breaches in the barrier island. RSLR of 2 feet combined with ongoing erosion would completely convert the 3-acre Mansfield Island used by colonial waterbirds to unconsolidated tidal flats.

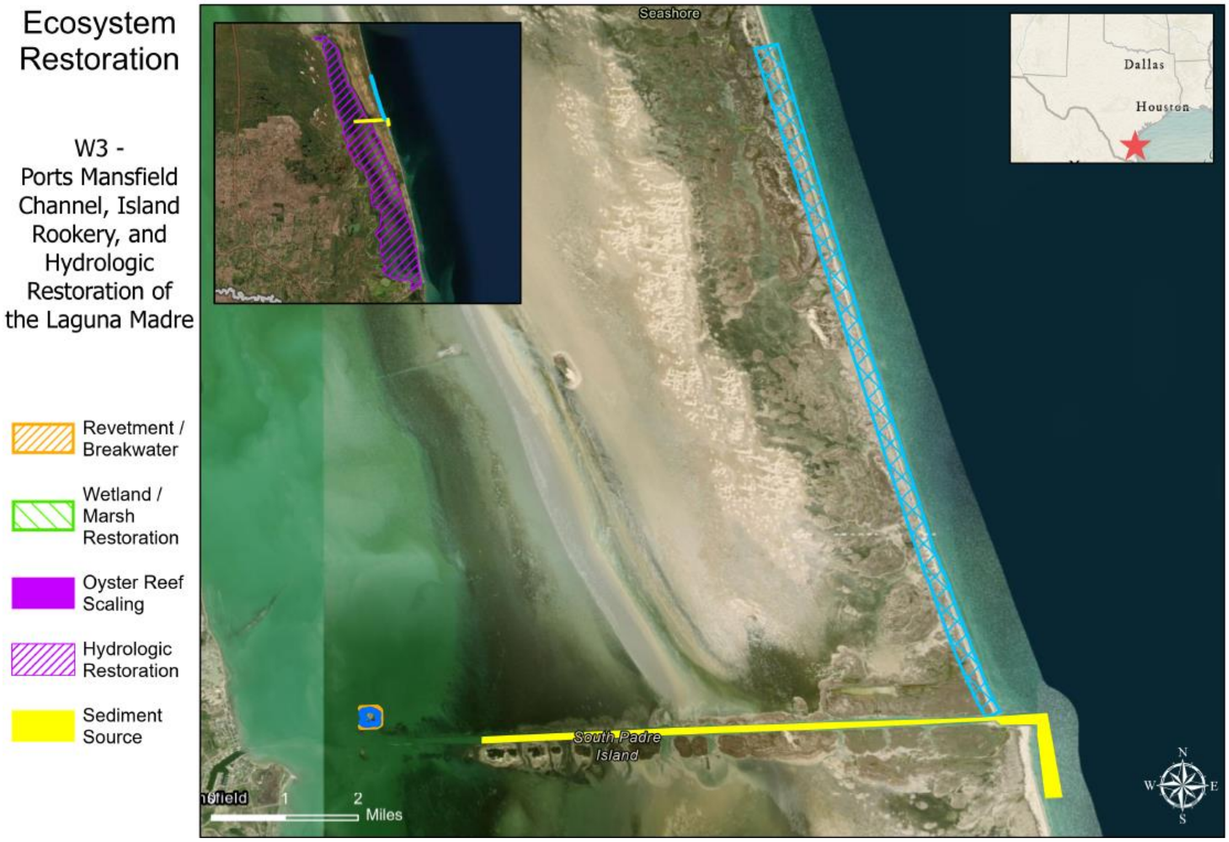


Figure 2-20. ER Measure W-3: Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

2.3.2.2.10 Construction Cost Estimates of ER Measures

Cost estimates were derived by applying unit costs from comparable restoration measures proposed in adjacent projects in the district. The costs included real estate acquisition, mobilization and demobilization, and transportation costs from specific borrow areas to the feature locations.

The PDT identified multiple sediment sources for each measure to ensure adequate sediment is available to construct all measures. In several instances, a portion of the necessary sediment would be available from nearer sources, but the cost estimate reflects the cost of dredging and transporting from the largest, and possibly farthest, source. This approach recognized that certain cost savings may be achieved at the time of construction by using closer sources but ensured that the cost estimate reflected the highest cost source.

The costs were presented as a high and low range by considering the highest and lowest acceptable contingencies for each action to reflect uncertainty (**Table 2-7**). The costs were also estimated for each scale of the measure, with initial construction as a separate alternative, and out-year construction undertaken at an assumed year in the future.

Table 2-7. Costs to Construct the ER Measures, FY18 Price Levels ($1,000s)

Measure	Initial Low Estimate	Initial High Estimate	Initial Average Estimate	Continuing Low Estimate	Continuing High Estimate	Continuing Average Estimate	Total of Average Initial and Continuing Construction Estimates
G-28	757,074	989,345	873,210	0	0	0	873,210
B-2	433,386	600,155	516,771	517,313	724,238	620,776	1,137,547
B-12	517,262	717,713	617,488	0	0	0	617,488
CA-5	46,692	65,369	56,031	0	0	0	56,031
CA-6	64,078	88,280	76,179	0	0	0	76,179
M-8	149,971	209,720	179,846	0	0	0	179,846
SP-1	274,405	384,164	329,285	0	0	0	329,285
W-3	36,098	50,039	43,069	433,173	606,442	519,808	562,877

2.3.3 ER Alternative Development Strategy

The ER measures were assembled into alternatives through a systematic combination of management measures based upon specific restoration strategies to narrow the universe of possible solutions to a concise group of initial alternatives.

The formulation strategy is based on the concept that natural landforms provide lines of defense against coastal storms. The concept of lines of defense is also related to protection of coastal ecosystems and human infrastructure from storm damage caused by hurricanes and tropical storms coming ashore from the Gulf. The series of barriers provided first by the barrier islands, then by living shorelines, and finally coastal marshes can reduce the physical impacts of storm surges and winds which enter the bays. This combination of lines of defense and ER is intended to provide redundant levels of protection and restoration for both humans and Texas coastal ecosystems.

1st Line of Defense and Ecosystem Restoration – Barrier Systems:

Barrier islands, shorelines and headlands, as well as tidal inlets form the first line of defense for the nine major estuarine bays and the residential, industrial and recreational structures therein. They are the boundary between the Gulf and estuarine and the terrestrial ecosystems. These features include barrier beach, dune, back marsh, and shallow open-water areas along the inland side of barrier islands. Coastal barriers also provide habitat for various marine, estuarine, and terrestrial organisms as well as stopover habitat for migrating neotropic birds. Coastal barrier systems provide protection to the wetlands, bays, and estuaries located behind the barrier systems. These features influence tidal prisms, limit storm surge heights, retard saltwater intrusion, and limit mechanical erosion by reducing wave energy at the margins of coastal wetlands. Coastal barrier systems and other features of the coastal landscape (e.g., shoals, marshes, and forested wetlands) can provide a significant and potentially sustainable buffer from wind-wave action and storm surge generated by tropical storms and hurricanes.

2nd Line of Defense and Ecosystem Restoration – Estuarine Bay System:

Bay shorelines, inlets, and bordering estuarine marshes form the third line of defense and ER. As the barrier systems are eroded, fragmented, and lost, the tidal prism seeks to re-establish dynamic equilibrium between the higher energy Gulf forces moving tidal waters faster and higher into the upper parts of the estuary thereby subjecting bay shorelines and estuarine wetlands to greater Gulf forces of wind and wave erosion and higher salinities. These changes can cause estuarine marsh loss and shoreline erosion. Estuaries provide habitat for ecologically, commercially and recreationally important fish and wildlife. Estuaries are particularly important nursery habitat for many organisms with early life stages depending on salinities below Gulf salinities. Estuarine shorelines also provide important habitat for migrating neotropic birds.

Associated with estuarine bay systems are adjacent bird rookery islands, oyster reefs, and submerged vegetation beds. Each of these habitat features are typically isolated and relatively small features, as in the case of bird rookery islands. Despite this, when considered from a wholistic perspective, the combination of these features within an estuarine bay system can have significant local, regional, and especially important to the NER requirements for the study, national importance. In addition, strategic placement and numbers of bird rookery islands, oyster reefs, submerged vegetation beds and living shorelines can also function as terraces to slow down waves and sediments, reduce fetch and create EFH.

3rd Line of Defense and Ecosystem Restoration – Bayhead Deltas:

The third line of defense and ER involves conserving, restoring, and protecting bayhead deltas. Managing freshwater inflows to optimize salinity, sediment and nutrient regimes helps sustain deltas and their associated habitats. Developing sediment management strategies would maximize delta accretion and sustain important wetland habitats provided by healthy deltas. Opportunities to manage hydrologic connectivity could also help benefit delta wetlands. The land and wetland habitat provided by deltas further protects human infrastructure and estuarine ecosystems.

Similar to barrier and estuarine bay systems there are adjacent bird rookery islands, reefs, and SAV, which provide benefits similar to those previously described for barrier systems and bay systems.

Six ER alternatives were developed using the formulation strategies. Originally, two scales were developed for the measures to investigate the scale and the budget implications for addressing an unknown landscape in light of RSLR scenarios. The second scale assumed there would be out-year nourishment for the measures based on their vulnerability to RSLR. Unfortunately, based on USACE policy the formulated out-year nourishment is considered a continuing construction activity and is not consistent with NER plans, therefore it have been removed from the recommendation. Measures G-5, B-2 and W-3 will not have out-year nourishment in any alternative where they are included. Table 2-8 presents the list and title of the alternatives, while **Table 2-9** shows which measures are associated with each alternative. **Figures 2-14 through 2-21** illustrate the combination of measures that comprise the alternatives.

Table 2-8. List of Fully Formed ER Alternatives

Alternative/Scale	Strategy/Description
No-Action	No-Action
Alternative 1	Coastwide All-Inclusive Restoration Alternative
Alternative 2	Coastwide Restoration of Critical Geomorphic or Landscape Features
Alternative 3	Coastwide Barrier System Restoration
Alternative 4	Coastwide Bay System Restoration
Alternative 5	Coastwide ER Contributing to Infrastructure Risk Reduction
Alternative 6	Top Performers

Table 2-9. ER Measure Included in Each Alternative

	ER Measures							
Alternative	**G28**	**B2**	**B12**	**CA5**	**CA6**	**M8**	**SP1**	**W3**
1	•	•	•	•	•	•	•	•
2		•	•		•			•
3	•	•						•
4	•		•	•	•	•	•	
5	•	•	•					
6	•	•	•		•			

2.3.3.1 ER Benefit Quantification

The final justification of ER alternatives requires quantification of ecological lift in the form of net Average Annual Habitat Units (AAHUs) between the future without-project and future with-project (FWP) condition. The improvement in habitat suitability was evaluated with the Habitat Evaluation Procedure (HEP). HEP is a widely accepted approach for quantitative evaluation of measures or management activities that cause environmental changes and to predict ecological impact of measures. The net change in AAHU by measure is shown in **Table 2-10** and the net change in AAHU by alternative is presented in

Table 2-11. Additional detail on the ecological modeling and HEP can be found in Appendix I.

Table 2-10. Average Annual Habitat Units by Measure and Scale

Measure	FWOP (AAHUs)	FWP (AAHUs)	Net Change in AAHUs	Acres (2085 FWP)
G-28	20,327	30,339	10,012	1,144
B-2	54	608	554	216
B-12	30,357	31,618	1,261	1,993
M-8	10,769	10,992	223	2,526
CA-5	1	266	265	1,176
CA-6	901	919	18	620
SP-1	11	2,201	2,190	3,679
W-3	14,911	22,307	7,396	41,883

Table 2-11. Net AAHUs by Alternative

Alternative	FWOP (AAHUs)	FWP (AAHUs)	Net Change in AAHUs	Acres (FWP 2085)
Alt 1	77,887	99,787	21,920	55,353
Alt 2	46,223	55,452	9,230	46,828
Alt 3	35,292	53,254	17,962	45,359
Alt 4	62,922	76,872	13,970	11,138
Alt 5	50,738	62,565	11,827	5,469
Alt 6	51,639	63,484	11,845	6,089

2.3.3.2 Cost Effectiveness/Incremental Cost Analysis

Environmental restoration benefits are measured in habitat units or some other physical unit, while costs are measured in dollars. Therefore, benefits and costs cannot be directly compared. Two analyses are conducted to help planners and decision makers identify plans for implementation, though the analyses themselves do not identify a single ideal plan. These two steps are cost effectiveness and incremental cost analysis, or CE/ICA. These techniques are described in the Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies (U.S. Water Resources Council, 1983).

Cost effectiveness compares the annual costs and benefits of plans under consideration to identify the least cost plan alternative for each possible level of environmental output, and for any level of investment, the maximum level of output is identified.

Incremental cost analysis of the cost-effective plans is conducted to reveal changes in costs as output levels are increased. Results from both analyses are presented graphically to help planners and decision makers select plans. For each of the plans identified through incremental cost analysis, an “is it worth it?” analysis is then conducted for each incremental measure or plan to justify the incremental cost per unit of output to arrive at a recommended plan.

For this study, the multiple CE/ICA runs were informative, and supported refinement of alternative plans to ensure the maximum ecological lift was achieved for incremental costs.

2.3.3.3 Best Buy Plans

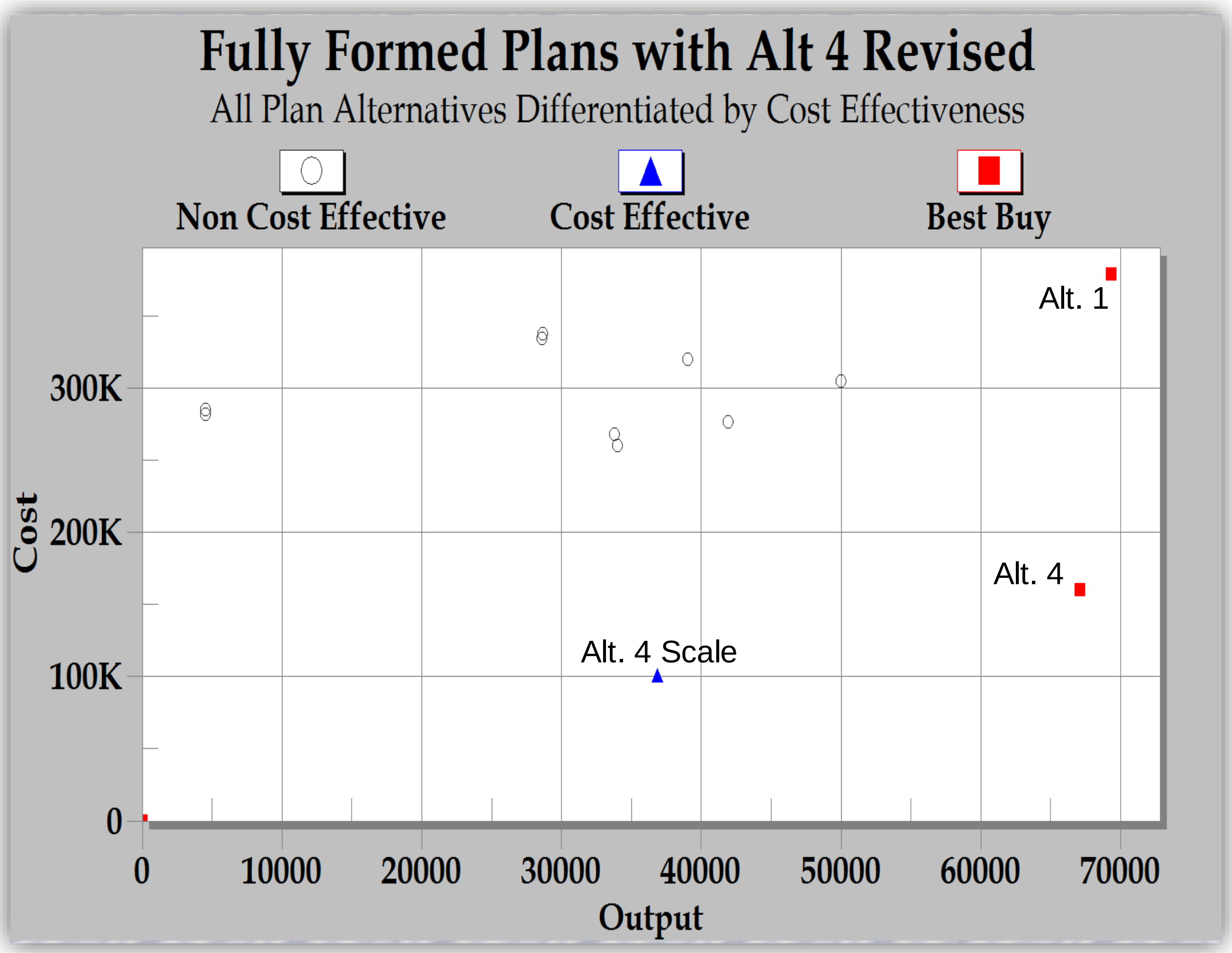
The alternatives formulated according to the strategy were evaluated within the Institute for Water Resources Planning Suite to identify cost effective alternative plans. A cost-effective plan alternative is defined as one where no other plan alternative can achieve the same level of output at a lower cost, or a greater level of output at the same or less cost. A subset of cost-effective plan alternatives is identified as “best buy plans.” Best buy plans are cost-effective plan alternatives that provide the greatest increase in environmental output for the least increase in cost per unit of output.

The final screening iteration to identify the NER plan requires estimation of the ecological lift, or benefits, between the future-without and future with-project conditions for each alternative in Average Annual Habitat Units (AAHUs). These metrics were used to confirm they are cost effective and identify the “Best Buy” plans. Cost effectiveness compares the annual costs and benefits of plans under consideration to identify the least cost plan alternative for each possible level of environmental output, and for any level of investment, the maximum level of output is identified. Incremental cost analysis of the cost-effective plans is conducted to reveal changes in per unit output costs as output levels are increased.

From the cost-effective alternatives, Alternatives 1, 2 and 4 were identified as "Best Buy" plans. Alternative 1: Coastwide All-Inclusive Restoration is the largest alternative and includes all ER measures (G-28, B-2, B-12, M-8, CA-5, CA-6, SP-1, and W-3). This alternative would restore natural features and provide diverse habitat within the coastal ecology and support natural conditions to withstand coastal storm conditions that cause land and habitat loss. After comparing the Best Buy plans, reviewing the study objectives, Alternative 1 was identified as the lowest cost comprehensive plan.

2.3.3.4 Comparison of Final Array of Coastwide ER Alternative Plans

The final array of ER plans includes Alternative 1 and Alternative 4. These were chosen based on the results of the formulation strategy and the CE/ICA analysis. Alternative 4 includes measures G28, B12, M8, CA5, CA6, SP1, and W-3; a combination that would restore habitats which offer significant ecological lift and protect bay shorelines, inlets and estuarine marshes, which slow down waves and sediments and reduce wind-generated waves.



Alternative 1: Coastwide All-Inclusive Restoration is the largest alternative and includes all ER measures (G28, B2, B12, M8, CA5, CA-6, SP-1, and W-3). This alternative would restore natural features, which provides diverse habitat within the coastal ecology and support natural conditions to withstand coastal storm conditions that cause land and habitat loss.

ER measures B-2 is included in Alternative 1 and not Alternative 4. B-2 creates beach habitat, which provides an ecological lift in the study area greater than the AAHUs of the beach footprint. Beach habitats generate significant lift to biodiversity through multiple routes:

Threatened and endangered (T&E) species rely upon beach environments. Beach nourishment adds nesting habitat for multiple species of sea turtles. The Kemp's Ridley sea turtle, the most critically endangered sea turtle species in the world, uses the middle and upper Texas coast beaches for nesting. Protecting Texas Gulf coast beaches is especially important for this species, as Texas is one of only two areas in the world where they are known to nest. Narrow, eroded beaches deter sea turtle nesting. Loss of beaches and barrier islands with sea level rise presents threats to the long-term survival of the species. Additionally, warmer water temperatures are predicted to drive the species northward causing Kemp's Ridley sea turtles to nest more frequently on the upper Texas coast similar to their nesting frequency on South Padre Island.

Piping plover and red knot are specific T&E species who forage, flourish, and nest in and around the beach areas. Texas is estimated to winter more than 35 percent of the known population of piping plovers (Campbell, 2003). Generally, adult and young plovers return to the same areas each year. They feed on beaches and tidal flats at high tide. Loss of sandy beach is a primary threat for this species. Critical Habitat has been designated along the Texas coast, including on Bolivar Peninsula and Galveston Island, for wintering piping plovers. Building beach habitat to maintain barrier islands would also maintain plover habitat. The threatened rufa red knot uses similar habitat to the piping plover and winters on the Texas coast. Habitat loss is a primary threat to this species. Like plovers, rufa red knots return to the same wintering areas each year during migration. Creation of beach habitat and maintaining that habitat in suitable areas, like in Texas, is key to protecting this species.

Multiple bird species rely on coastal beach habitats for forage. Food sources include crabs, bivalves and other invertebrates that themselves rely on healthy beaches.

Beach restoration along the Texas coast reduces the risk of over proliferation of certain habitats at the expense of others, promoting biodiversity.

Beach habitats also provide a physical barrier between ecologically significant habitats of the Gulf and bay. The salinity differences between estuarine and gulf waters yield distinct ecosystems, which support multiple species. When saltwater enters freshwater marshes, there is a loss of freshwater vegetation. Loss of vegetation leads to more erosion as plants are not present to trap sediment to maintain a barrier, and fewer plants leads to fewer species of birds and fishes.

Acres of estuarine environment are maintained in the face of short-term storm conditions and long-term RSLR. While the applicable model does not capture AAHUs as a result, a portion of the preserved estuarine environment is the result of beach restoration.

Without a natural dune system on Bolivar Peninsula, salt water will flood the marsh, resulting in the loss of marsh habitat at a rate of 15-45 feet/year. Beaches absorb high-impact waves and stop or delay intrusion of water inland.

The combination of recommended actions to restore and maintain the habitats along the Texas coast are unavoidably massive in scale in order to effectively address historic losses and impairments and to ensure impactful intervention. The scale of the effort necessitates phasing of the actions and adaptive efforts to ensure the effectiveness of the intervention in the life cycle of the plan.

2.3.4 National Ecosystem Restoration Plan

After comparing the Best Buy plans, reviewing the study objectives, Alternative 1, the Coastwide All-Inclusive Restoration is the NER plan because it restores ecosystems on a scale necessary to address the system wide challenges discussed. Alternative 1 also restores natural features and provide diverse habitat within the coastal ecology and support natural conditions to withstand coastal storm conditions that cause land and habitat loss.

2.4 RECOMMENDED PLAN

After evaluation of the performance and impacts of the final array of ER and CSRM alternatives, the TSP was defined as the Alternative A CSRM measure for Galveston Bay, the South Padre Island beach nourishment measure, and the lowest-cost comprehensive ER measure, Alternative 1. Specifically, the Alternative A CSRM measure for Galveston Bay and the South Padre Island beach nourishment measure were identified as the NED plan, while the Coastwide ER Alternative 1 met the ER goals of the study and was classified as the NER 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 2-21** 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 an elevation of 7.5 feet (NAVD 88).

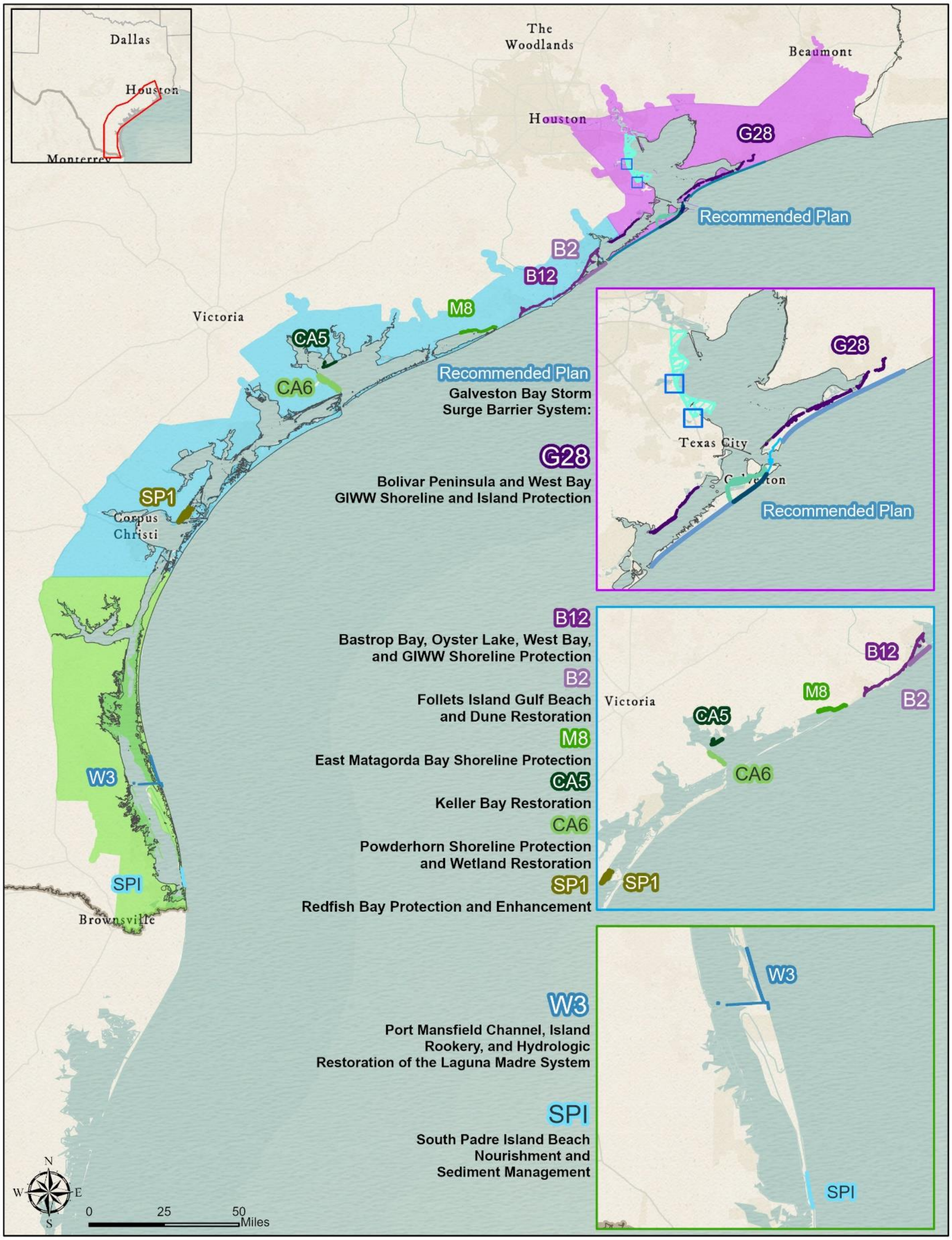


Figure 2-21. Coastwide ER Measures of the Recommended Plan

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 2-22**).

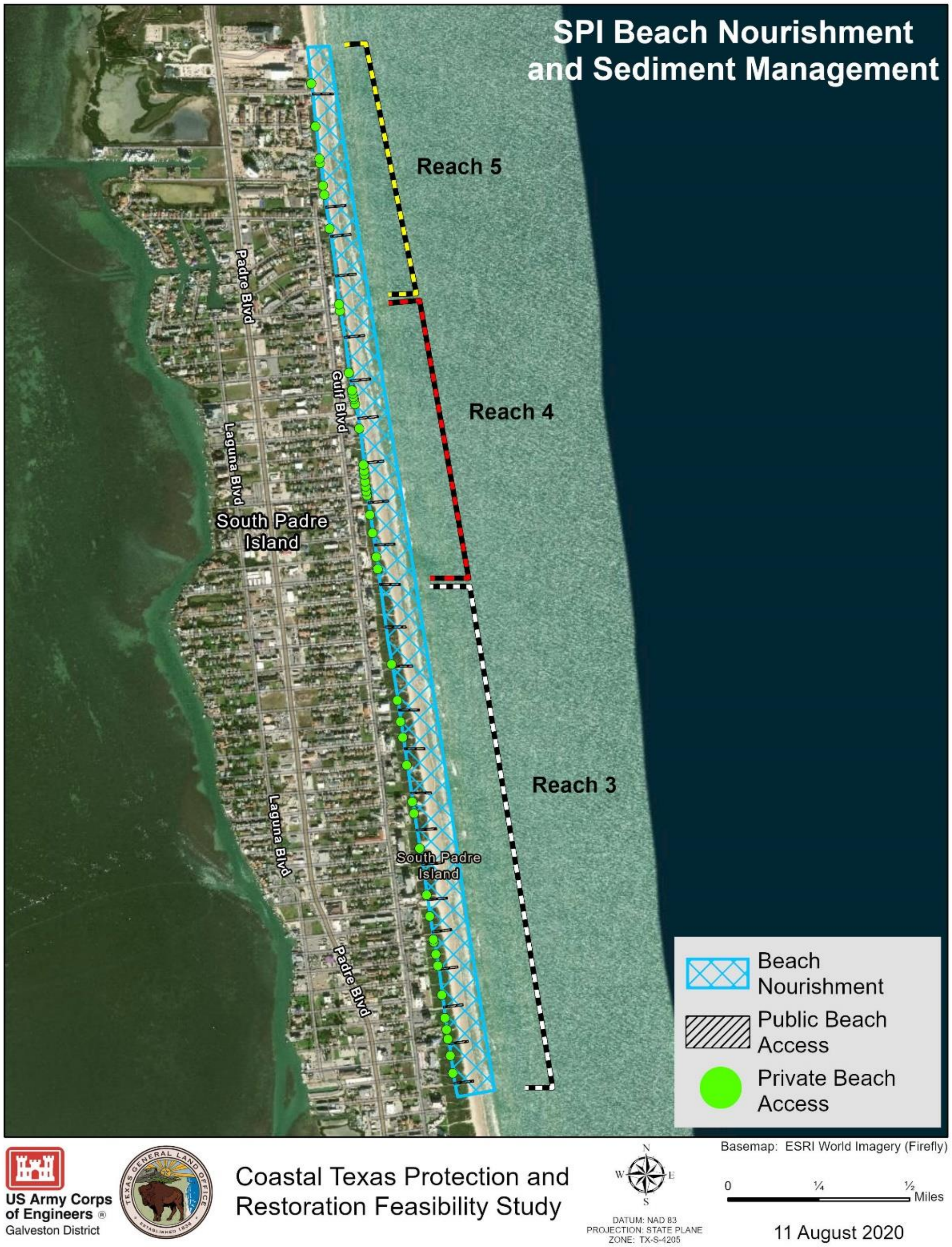


Figure 2-22.South Padre Island CSRM

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 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 2-23 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 2-24**);
- 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 2-24**);
- Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge (**Figure 2-24**);
- An 18-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 non-structural 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, including MSFCMA. Feature identified as "Tier One" measures will require separate independent NEPA analysis at which time additional EFH consultation would occur to ensure full compliance with MSFCMA once the impacts are fully understood. **Table 2-12** shows which measures are actionable and which are not.

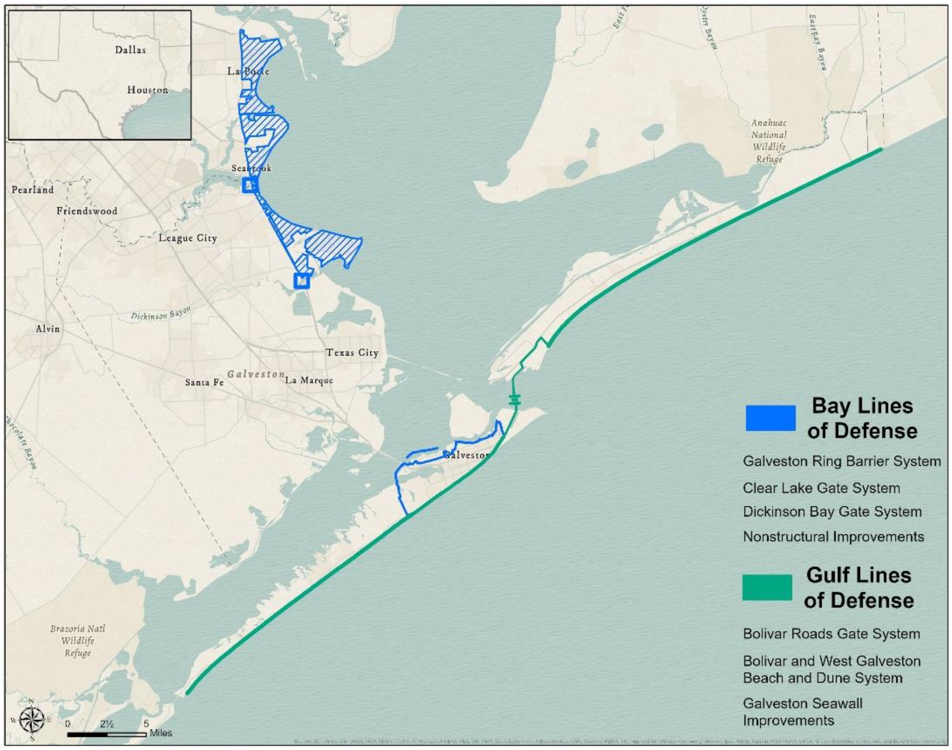


Figure 2-23. Galveston Bay Storm Surge System

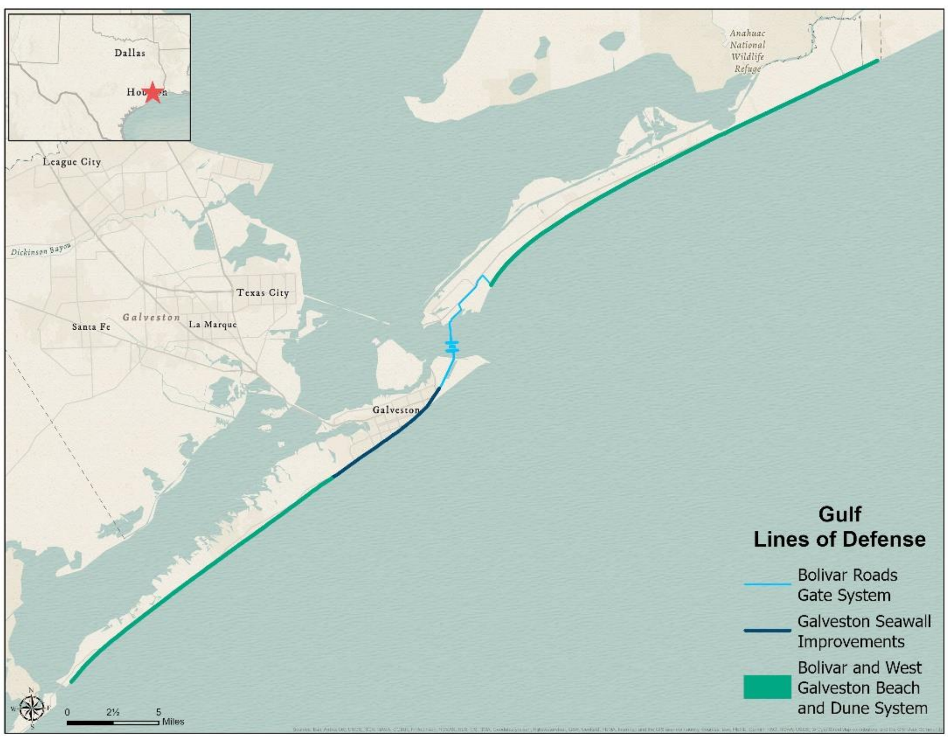


Figure 2-24. Gulf Lines of Defense of the Galveston Bay Storm Surge System

Table 2-12. 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	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 Surge Gate		X
Dickinson Surge Gate		X
Non-structural Measures		X

* Tier 2 NEPA, additional NEPA is only anticipated if substantial design changes are made during PED

+ Tier 1 NEPA, Requires additional NEPA, environmental compliance and public involvement

2.4.1 Tiered NEPA

As discussed in Chapter 1, a Tiered NEPA approach is being applied to the environmental review for this project. Two primary drivers for selecting the tiered NEPA approach are the likelihood that in the time between the end of the feasibility and the start of the construction enough time will have passed to justify reassessing the affected environment and second, the likelihood that additional design information will warrant additional assessment. The tiered NEPA approach allows the PDT and the interagency team to focus on the decisions ready for discussion now, allows for additional public participation once as the design progresses, and allows for the consideration of avoidance, minimization, and mitigation planning using more up to date information.

One of the advantages of tiering a NEPA analysis is that it allows for discussions of issues once they are ready for consideration. The TSP includes several structural measures that function together to form the Coastal Barrier in Region 1. A broad analysis of the full range of the direct and indirect impacts to the human environment have been identified and described using all available information (for more information see Chapter 4 of this EIS). However, some of the finer scale discussions on avoidance, minimization, and mitigation for these measures will not be possible until the designs for these measures are advanced. For example, the possible interactions between marine organisms and the gates are discussed in this EIS and we have done modeling to predict the changes in tidal velocities that could occur with the project. These predicted changes in tidal velocities inform the consideration of potential impacts to these species. However, finer scale interactions, like the potential for the structures to create eddies and other turbulences, are dependent on more precise design details that won't be available until additional engineering analysis is performed. Since many of the gate structures are in areas that are important for various life stages of numerous species, small changes in these areas can be impactful to the ecosystem as a whole. In this example a tiered NEPA strategy would provide opportunity for both the broad level considerations (Tier One) and for the finer scale analysis (Tier Two).

For the Coastal Texas Study, all the CSRM measures located in Region 1 are considered Tier One Measures. These Tier One Measures include the Bolivar Roads Gate System, the Galveston Ring Barrier System, the Galveston Seawall Improvements, the Clear Lake Gate System, the Dickinson Bayou Gate System, and the Non-Structural Improvements on the West Shore of Galveston Bay.

Additionally, the Bolivar and West Galveston Beach and Dune System are also Tier One Measures. This is because USACE is in the process of narrowing down the exact locations of the borrow sources necessary to construct these measures. Using the results of previous studies USACE and BOEM have determined that sufficient volumes of appropriate sediments exist within the Sabine and Heald Bank complexes to construct the measures. USACE is currently collaborating with BOEM (Cooperating Agency for this Study) on a reconnaissance investigation into the locations of sediment sources in the Sabine and Heald Bank areas. The USACE plans to use the result of the reconnaissance investigation to identify candidate areas for detailed assessment. The results of these investigations will be used to identify the borrow sites necessary for the construction of these measures.

The Actionable Measures in the recommended plan were identified as those that:

- Have a low risk of adverse impacts;
- Have a low risk of needing significant design modifications; and
- Have benefits that are not solely tied to other measures (while acknowledging that the full system would amplify the benefits of the measures).

The actionable measures all include work that is common in the USACE and in the Galveston District. These familiar activities include breakwater construction, oyster reef restoration, beach nourishment, and the beneficial use of dredge material to restore marshes and to create islands for bird nesting habitat. The Galveston District has successfully constructed these types of measures in all the Study Regions. Additionally, all these measures would restore and maintain natural habitats that increase resiliency to coastal storms and to flooding. These habitats include beaches, dunes, marshes, oyster reefs and islands. The footprints and plans for these measures have been purposefully designed in collaboration with the interagency team to avoid adverse impacts and to maximize the ecological and resilience benefits.

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3.0 AFFECTED ENVIRONMENT

This chapter describes the existing condition of resources in the study area. With this being the Second Draft Report for this Study, the existing conditions have been updated as of May 2020.

The structure of this chapter includes two important components including:

- **Regulatory Framework:** This section describes the applicable federal, state, and local laws, regulations and policies that apply to the topic being discussed. Details of federal and state regulations which require permits or other approvals or are relevant to several categories are briefly mentioned in this section and discussed in greater detail in Chapter 6 – Compliance with Applicable Laws, Policies, and Plans. Some resources will not have a regulatory framework but are described for a more complete understanding of the study area.
- **Existing Conditions:** This section describes the local and regional conditions that provide the baseline condition and sufficient context for evaluating effects of the alternatives.

3.1 GENERAL OVERVIEW OF THE STUDY AREA

The study area for the Coastal Texas Protection and Restoration Study (Coastal Texas Study) consists of the entire Texas Gulf coast from the mouth of the Sabine River to the mouth of the Rio Grande, and includes the Gulf of Mexico (Gulf) and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent areas that make up the interrelated ecosystems along the coast of Texas (**Figure 1-1**). The study area encompasses 18 coastal counties along the Gulf coast and bayfronts. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. Ecoregions serve as a spatial framework for the research, assessment, and management of ecosystem components and are also critical for structuring and implementing ecosystem management strategies. The study area closely corresponds to the U.S. Environmental Protection Agencies (EPA) level IV ecoregions (EPA, 2007).

3.1.1 Existing Conditions

The Texas coast is an ecologically diverse and nationally significant coastline. The biological and economic productivity of the Texas coast is extraordinary. The coastline maintains native plant and animal populations, provides nurseries, nesting, and foraging areas for fish and wildlife, which reduce the impacts of coastal hazards to the human environment.

Texas' 367 miles of Gulf shoreline and 3,300 miles of estuarine shoreline host hundreds of thousands of acres of beach and dune systems, lagoons, seagrass beds, oyster reefs, and tidal marshes. More than 95 percent of commercially and recreationally important Gulf of Mexico (Gulf) finfish and shellfish, and 75 percent of the Nation's migratory waterfowl depend on these wetlands at some point in their life cycle. These biological and geomorphic systems are the foundation for much of the coast's productivity, economy, and quality of life.

The Texas Gulf coast's contributions to the regional and the national economy are many, ranging from energy and agricultural industries, the port system and military transportation, to commercial fisheries, tourism, and recreation.

Texas is one of the Nation's top states for waterborne commerce, with Texas' coast ports generating over $82.8 billion in economic value to the region. More than 500 million tons of cargo pass through Texas ports annually, including machinery, grain, seafood, oil, cars, retail merchandise, and military freight. The State's maritime system is a critical gateway to international trade and provides Texas with a multitude of economic opportunities through the movement of waterborne commerce. Texas is one of the Nation's leading states in the maritime industry, handling 15.8 percent of total U.S. cargo between 2007 and 2011. Texas ports managed 20.1 percent of the Nation's total export tonnage during this period, making it the Nation's leading export state. Texas ports are also home to four of the eight largest refineries in the country (providing 25 percent of national refinery capacity) and most of the National Petroleum Reserve. Port Arthur is also the number one port for military deployments, and the GIWW is the third busiest shallow draft channel in the United States.

The GIWW plays a key role in all of the economic sectors. It is the Nation's third busiest inland waterway, with the Texas portion handling over 63 percent of its traffic. Over $25 billion cargo passes annually through the 406-mile section of the GIWW that runs along the Texas coast.

Three Texas ports are designated by the Department of Defense as "strategic military ports," providing surface deployment and distribution for strategic military cargo worldwide. The Port of Beaumont, Port of Port Arthur, and the Port of Corpus Christi all serve in the U.S. Maritime Administration's National Port Readiness Network, supporting deployment of U.S. military forces during defense emergencies.

Although the Texas Gulf coast is ecologically diverse and industrial sectors play a key role on our national economy, the people living and working in the coastal region are, by far, the most valuable and vulnerable assets. Texas' 18 coastal counties make up less than 6 percent of the State's land area but contain 24 percent of the State's population. The population living within the coastal counties of Texas is expected to increase from 6.1 million in 2010 to 7 million in 2020, and to over 9 million by 2050.

Numerous protected lands have been established along the Texas Gulf Coast and within the study area that demonstrate the ecological, cultural, and recreational diversity of Texas. Some of these areas were created to provide opportunities for hunting, fishing, wildlife viewing, and environmental education. Administration of these areas is provided under Federal and state governance or by private organizations.

More than one-quarter of the Texas's population has lived within the coastal counties with over 6.4 million residents in the study area, over 80 percent of those residing along the upper Texas coast (Wilson and Fischetti, 2010, U.S. Census Bureau, 2018). Within the study area, numerous coastal communities are at risk from storm surge, where approximately 673,346 structures are located. Over 3,500 critical infrastructures, including electricity, gas distribution, water supply, transportation, education, and community services (e.g., police, fire department, etc.) are at risk. Severe storm surge events threaten the health and safety of residents living within the study area. Loss of life, injury, and post flood health hazards may occur in the event of catastrophic flooding. There are 140 medical care facilities, 364 police stations/sheriff's offices, and 672 fire stations (parish and volunteer) located within the study area (NOAA, 2018). Within the study area, 14.8 percent of the population fell below the poverty level, much of those populations are found in the lower coastal counties. Minority residents make up 16 percent of the population in the study area. Recreation and tourism play a large role in the study area, with over 50 NWRs, WMAs, State Parks, preserves, etc.; outstanding fishing, birding, and waterfowl hunting opportunities; and nature tourism opportunities.

3.1.2 Location of the Study Area

As described in Chapter 1, the study area has been divided into four sections: Upper Texas Coast, Mid to Upper Texas Coast, Mid Texas Coast, and Lower Texas Coast.

The Upper Texas Coast (UTC) study area encompasses the Sabine Pass to Galveston Bay area and includes Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria counties. The UTC study area includes two primary bay systems (Sabine Lake and Galveston Bay) and several large watersheds (Sabine, Neches, Trinity, San Jacinto, and Brazos rivers). The Galveston Bay area is recognized as nationally significant by Federal designation of the Galveston Bay National Estuary Program. The broad range of salinities and flat topography allows the region to support a wide variety of habitats, including tidal and freshwater coastal marshes; shallow bay waters, which support seagrass beds, tidal flats, and reef complexes; coastal prairie with small wetland depressions; and forested riparian corridors. Extensive oyster reef habitat occurs in the southern part of Sabine Lake and throughout the Galveston Bay complex. Areas of the Big Thicket National Preserve are spread across inland areas of the upper coast. Since roughly 75 percent of the bird species in North America either live in or pass through this area seasonally, the Big Thicket National Preserve was designated a Globally Important Bird Area by the American Bird Conservancy in 2001 (National Park Service [NPS], 2016a). A barrier peninsula (Bolivar) and island (Galveston) separate Galveston Bay from the Gulf, while the remainder of the upper coast is bounded by barrier headlands such as the Freeport area. Important large navigation channels in this region include the Sabine-Neches Waterway, Houston Ship Channel, and the Freeport Harbor Channel.

The Mid to Upper Texas Coast (MUTC) study area is comprised of the Matagorda Bay area and includes Matagorda, Jackson, Victoria, and Calhoun counties. The MUTC study area includes several bay systems (Matagorda Bay, Lavaca Bay, Espiritu Santo Bay, and parts of San Antonio Bay). Primary watersheds feeding these bays include the Colorado, Lavaca, and Guadalupe rivers, which forms the boundary between the mid to upper coast; deltas of the Colorado and Guadalupe rivers also occur in the region. Matagorda Bay is the largest of the bay systems in the mid to upper coast and includes numerous minor estuaries. Notable features of the mid to upper coast include Half Moon Reef (a historic oyster reef that was successfully restored and continues to undergo additional restoration actions), Mad Island Preserve and Mad Island Wildlife Management Area (WMA), Matagorda Island State Park, and several National Wildlife Refuges (NWR) (The Nature Conservancy [TNC], 2016a). Like many areas in the upper coast, the broad range of salinities and flat topography allows the region to support a wide spectrum of habitats, including tidal and freshwater coastal marshes; shallow bay waters that support seagrass beds, tidal flats, and reef complexes; coastal prairie with small wetland depressions; and forested riparian corridors. Extensive seagrasses and mangroves occur in Espiritu Santo Bay, near Pass Cavallo, and seagrass is also relatively prevalent immediately behind Matagorda Island and Matagorda Peninsula. Important large navigation channels in this region include the Matagorda Ship Channel and the Victoria Barge Canal.

The Mid Texas Coast (MTC) study area covers the Corpus Christi Bay area and includes Aransas, Refugio, San Patricio, Nueces, and Kleberg counties. The MTC study area includes several bay systems (Corpus Christi Bay, Copano Bay, Aransas Bay, Nueces Bay, portions of San Antonio Bay, and the Upper Laguna Madre, including Baffin Bay). Primary watersheds feeding these bays include the Mission River, Aransas River, Nueces River, and Los Olmos Creek (which forms the boundary between the mid to lower coast). This area includes the barriers of North Padre Island, San Jośe Island, Mustang Island, and portions of Matagorda Island. Padre Island National Seashore is owned and managed by the NPS and is the longest stretch of undeveloped barrier island in the world (NPS, 2016b). The Nueces River Delta is a unique resource found in the area that has many interest groups working to restore and conserve it and its ecological functions (Lloyd, 2016). Extensive seagrasses occur throughout the area, and unique hard reefs occur within Baffin Bay; these unique hard reefs were formed from either remnant beach rock, or fossilized serpulid worm reefs. The Upper Laguna Madre is also a defining feature of the Texas coast as it is the northernmost portions of a hypersaline lagoon, described further below (Tunnell and Judd, 2002). Important large navigation channels in this region include the Corpus Christi Ship Channel and the La Quinta Channel.

The Lower Texas Coast (LTC) study area encompasses the Padre Island area and includes Kenedy, Willacy, and Cameron counties, and is dominated by the Lower Laguna Madre, which is one of five hypersaline lagoons in the world. High overall temperatures and evaporation rates, combined with low rainfall and freshwater input, drive the high salinity (Tunnel and Judd, 2002). Average salinity along the Laguna Madre is 36 parts per thousand (ppt) (EPA, 1999). Main watersheds that flow into the Lower Laguna Madre include Arroyo Colorado and the Rio Grande. The Laguna Madre is shallow, averaging approximately 3.3 feet deep, and, including the South Bay and the Bahia Grande complex, contains approximately 180,000 acres of shallow flats (Tunnel and Judd, 2002). The main outlet into the Gulf for the southern reach of the Lower Laguna Madre is Brazos Santiago Pass, through which passes the deep-draft Brazos Island Harbor navigation channel.

3.1.3 Land Use

Land use is the term used to describe the human use of land. It represents the economic and cultural activities (e.g. agricultural, residential, industrial, mining, and recreational uses) that are practiced at a given place. Public and private lands frequently represent very different uses.

This section discusses land use regulation, designations and zoning, and existing land uses found in the study areas.

3.1.3.1 Lands with Special Management

3.1.3.1.1 Regulatory Framework

- Coastal Zone Management Act of 1972: This act established the Federal Coastal Zone Management Program (CZMP; Public Law 92-583, 86 Stat. 1280, 16 USC §§ 1451-1464, Chapter 33). The CZMP is a federal-state partnership that provides a basis for protecting, restoring, and responsibly developing coastal resources. The CZMA defines coastal zones wherein development must be managed to protect areas of natural resources unique to coastal regions. Texas has developed and enacted the Coastal Management Plan (CMP), in which any Federal and local actions must be consistent with management plans. The Texas General Land Office enforces consistency of the plan for Texas. States must define areas that comprise their coastal zone and develop management plans and protect these unique resources through enforceable policies of state CZMP. Texas defines its coastal zone as the area seaward of the Texas coastal facility designation line, up to three marine leagues into the Gulf.

- Coastal Barrier Resources Act of 1982 and subsequent amendments (CBRA): This Law encourages the conservation of hurricane prone, biologically rich coastal barriers by restricting federal expenditures that encourage development, such as federal flood insurance. Statutory exemptions for federal expenditures are included for specified activities that can demonstrate consistency with the purposes of the Act.

- Executive Orders Concerning Floodplain Management: EO 13690 was enacted on January 30, 2015 to amend EO 11988, enacted May 24, 1977, in furtherance of the NEPA of 1969, as amended (42 USC 4321 et seq.), the National Flood Insurance Act of 1968, as amended (42 USC 4001 et seq.), and the Flood Disaster

Protection Act of 1973 (PL 93-234, 87 Star.975). The purpose of the EO 11988 was to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. EO 13690 builds on EO 11988 by adding climate change criteria into the analysis. However, EO 13690 was partially repealed by EO 13807, Presidential Executive Order on Establishing Discipline and Accountability in Environmental Review and Permitting Process for Infrastructure to increase infrastructure investment.

The EOs state that each agency shall provide and shall take action to reduce the risk of flood loss, to minimize the impacts of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for: acquiring, managing, and disposing of Federal lands and facilities; providing Federally undertaken, financed, or assisted construction and improvements; and conducting Federal activities and programs affecting land use, including, but not limited to, water and related land resources planning, regulation, and licensing activities.

Federal agencies are required to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

- US FWS Refuge Improvement Act: requires the USFWS to monitor the status and trends of fish, wildlife, and plants in each refuge. The guiding policies require a compatibility determination for any use that occurs on a refuge. A compatible use is one which, in the sound professional judgment of the Refuge Manager, will not materially interfere with or detract from fulfillment of the Refuge System Mission or purposes.

3.2 EXISTING CONDITIONS

Numerous protected lands have been established along the Texas Gulf Coast and within the study area that demonstrate the ecological, cultural, and recreational diversity of Texas. These areas were created to provide opportunities for hunting, fishing, wildlife viewing, and environmental education. Administration of these areas is provided under Federal and state governance or by private organizations.

3.2.1 Coastal Zone

Under the Coastal Zone Management Act, the Texas General Land Office (GLO) is responsible for implementing the Texas Coastal Management Plan (TCMP) that was developed for Texas. The goals of the Texas Coastal Management Program (CMP) are:

- to protect, preserve, restore, and enhance the diversity, quality, quantity, functions, and values of coastal natural resource areas (CNRAs);
- to ensure sound management of all coastal resources by allowing for compatible economic development and multiple human uses of the coastal zone;
- to minimize loss of human life and property due to the impairment and loss of protective features of CNRAs;
- to ensure and enhance planned public access to and enjoyment of the coastal zone in a manner that is compatible with private property rights and other uses of the coastal zone;
- to balance the benefits from economic development and multiple human uses of the coastal zone, the benefits from protecting, preserving, restoring, and enhancing CNRAs, the benefits from minimizing loss of human life and property, and the benefits from public access to and enjoyment of the coastal zone;
- to coordinate agency and subdivision decision-making affecting CNRAs by establishing clear, objective policies for the management of CNRAs;
- to make agency and subdivision decision-making affecting CNRAs efficient by identifying and addressing duplication and conflicts among local, state, and federal regulatory and other programs for the management of CNRAs;
- to make agency and subdivision decision-making affecting CNRAs more effective by employing the most comprehensive, accurate, and reliable information and scientific data available and by developing, distributing for public comment, and maintaining a coordinated, publicly accessible geographic information system of maps of the coastal zone and CNRAs at the earliest possible date;
- to make coastal management processes visible, coherent, accessible, and accountable to the people of Texas by providing for public participation in the ongoing development and implementation of the Texas CMP; and
- to educate the public about the principal coastal problems of state concern and technology available for the protection and improved management of CNRAs.

Within this plan there are 20 enforceable policies and 16 critical natural resource areas (CNRAs). Those policies applicable to the study are in (**Table 3-1**). Any Federal undertaking within the CZMA boundary must be consistent with the enforceable policies and must not adversely affect CNRAs. Adverse effect for the purposes of the TCMP are

"Effects that result in the physical destruction or detrimental alteration of a CNRA." Anticipated impacts to CNRAs from implementation of the Recommended Plan have been analyzed in the consistency determination in Appendix F.

Table 3-1 Coastal Zone policies applicable to the Texas Coastal Study

Policy	Applicability
§ 501.15 Policy for Major Actions	Yes
§ 501.16 Policies for Construction of Electric Generating and Transmission Facilities	N/A
§ 501.17 Policies for Construction, Operation, and Maintenance of Oil and Gas Exploration and Production Facilities	N/A
§ 501.18 Policies for discharges of Wastewater and Disposal of Waste from Oil and Gas Exploration and Production Activities	N/A
§ 501.19 Policies for Construction and Operation of Solid Waste Treatment, Storage, and Disposal Facilities	N/A
§ 501.20 Policies for Prevention, Response and Remediation of Oil Spills	N/A
§ 501.21 Policies for Discharge of Municipal and Industrial Wastewater to Coastal Waters	N/A
§ 501.22 Policies for Nonpoint Source (NPS) Water Pollution	N/A
§ 501.23 Policies for Development in Critical Areas	Yes
§ 501.24 Policies for Construction of Waterfront Facilities and Other Structures on Submerged Lands	N/A
§ 501.25 Policies for Dredging and Dredged Material Disposal and Placement	Yes
§ 501.26 Policies for Construction in the Beach/Dune System	Yes
§ 501.27 Policies for Development in Coastal Hazard Areas	Yes
§ 501.28 Policies for Development Within Coastal Barrier Resource System Units and Otherwise Protected Areas on Coastal Barriers	Yes
§ 501.29 Policies for Development in State Parks, Wildlife Management Areas or Preserves	Yes
§ 501.30 Policies for Alteration of Coastal Historic Areas	
§ 501.31 Policies for Transportation Projects	N/A
§ 501.32 Policies for Emission of Air Pollutants	Yes
§ 501.33 Policies for Appropriations of Water	N/A
§ 501.34 Policies for Levee and Flood Control Projects	N/A

3.2.2 Coastal Barrier Resources

The Coastal Barrier Resources Act (CBRA) (16 U.S.C. 3501 et seq.) encourages the conservation of hurricane prone and biologically rich coastal barriers. No new expenditures or financial assistance may be made available under authority of any Federal law for any purpose within the System Units of the John H. Chafee Coastal Barrier Resources System (CBRS) including: construction or purchase of roads, structures, facilities, or related infrastructure, and most projects to prevent the erosion of, or otherwise stabilize any inlet, shoreline, or inshore area. However, the appropriate Federal officer, after consultation with the U.S. Fish and Wildlife Service (Service), may make Federal expenditures and financial assistance available within System Units for activities that meet one of the CBRA's exceptions (16 U.S.C. 3505). The CBRA imposes no restrictions on actions and projects within the CBRS that are carried out with State, local, or private funding. Any response from the Service to a CBRA consultation request is in the form of an opinion only. The Service has not been granted veto power. The responsibility for complying with the CBRA and the final decision regarding the expenditure of funds for a particular action or project rests with the Federal funding agency.

There are two types of units within the CBRS, System Units and Otherwise Protected Areas (OPAs). OPAs are denoted with a "P" at the end of the unit number (e.g., "FL-64P"). Most new Federal expenditures and financial assistance, including Federal flood insurance, are prohibited within System Units. The only Federal spending prohibition within OPAs is on Federal flood insurance; other Federal expenditures are permitted. Consultation with the Service is not needed if the proposed action or project is located within an OPA. However, agencies providing disaster assistance that is contingent upon a requirement to purchase flood insurance after the fact are advised to disclose the OPA designation and information on the restrictions on Federal flood insurance to the recipient prior to the commitments of funds.

Since Congress authorized the USACE to study CSRM and ER along the Texas Coast several measures included in the tentatively selected plan intersect with CBRS units, these locations are included in **Table 3-2**. The USACE used the USFWS's CBRS online mapping tool (http://www.fws.gov/cbra/Maps/Mapper.html) to identify the CBRS unit locations and numbers. Additional information on the project locations can be found in the attached project maps and the ecosystem restoration project plans. Also, as part of our ongoing coordination with the Service, electronic KMZ and Shape files have been shared for all the project measures.

Table 3-2. List of project measure locations that cross CBRS Units

Measure	Authority	Location	CBRS Units Effected
G-28: Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	Ecosystem Restoration	Along 27 miles of GIWW shoreline from High Island to Port Bolivar in Chambers and Jefferson counties, Texas	T02A and T03A
B-2: Follets Island Gulf Beach and Dune Restoration	Ecosystem Restoration	Along 10.1 miles of Gulf shoreline on Follets Island in Brazoria County, Texas	T04
B-12: West Bay and Brazoria GIWW Shoreline Protection	Ecosystem Restoration	Along 43 miles of GIWW shoreline from just east of Oyster Lake to just west of the Cedar Lakes in Brazoria and Matagorda counties, Texas. This measure also includes an area on the west side of west Galveston Bay just east of Oyster Lake	T04, T05, and T06
W-3: Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	Ecosystem Restoration	This measure contains multiple parts, the portion in the CBRS unit is a one mile-long borrow source on the northernmost part of South Padre Island in Willacy County, Texas	T11
Bolivar Peninsula Beach and Dune System	Dual purpose: Ecosystem Restoration and Coastal Storm Risk Management	Along 22.8 miles of Gulf shoreline from approximately 2 miles east of State Highway 87 to the end of Biscayne Beach Road.	T02A and T03A
Bolivar Peninsula Tie-In feature for the Bolivar Roads Surge Barrier	Coastal Storm Risk Management	This feature is approximately 2.8 miles long, starts near the shoreline interface with the north Jetty, runs along State Highway 87, and ties into the Bolivar Peninsula Beach and Dune System near the end of Biscayne Beach Road in Galveston County, Texas	T03A

3.2.3 Floodplains

A floodplain is an area that is flooded when a bayou, creek, or river overflows its banks. The bed and banks of the watercourse are incised by the “normal” flow that is present most of the time. Large rains occur periodically, and they generate more runoff than the watercourse can hold. These rainfall events, which have a return frequency determined by statistical analyses, can generate floods.

There are more frequently inundated floodplains, and there are those that flood much less frequently. These different frequencies of flooding areas assigned a percent chance of occurrence in any one year. In this way, the 50% chance of flood (i.e. a 50% chance of occurring in any year) is said to be the two-year flood (i.e. expected to recur on average once every two years) and a 1% chance event has a 1 in 100 chance of occurring in any year and is said to be the 100-year flood. Similarly, the 0.2% chance storm has a 1 in 500 chance of occurring in any year and is called a 500-year event. However, there is no guarantee that an event will not happen again until a given number of years have passed. Instead, the years following a 100-year event each have a 1% chance of occurring again in any of those years.

Flooding in the study area is caused by a number of problems including natural conditions such as the regions climate, limited slope, poorly drained soils, and overflows from other watersheds, as well as human induced reasons including the increase in impervious surface, inefficient/insufficient localized drainage systems, and construction restricting floodplain functions.

Average annual precipitation in the study area is approximately 60 inches per year and this includes many intense storm events, which is problematic given that in the focused study area is susceptible to coastal flooding from tropical storms, hurricanes, and during periods of heavy precipitation. As a result, flooding is common. Lands directly along the Gulf Coast are most susceptible to flooding from tidal surges. Alterations of natural topography, primarily to drain inland areas of the watershed, have exacerbated flooding.

All areas in the study area, except for those areas behind levees, are in the 100-year coastal floodplain with designation based on high velocity coastal flooding from wave actions, base flood elevation and flood hazard factors. Another important consideration is that there are some components of the measures that are within OPAs, as described previously, in which flood insurance is not available for structures that are newly built or substantially improved on or after October 1, 1983.

3.2.4 Fish and Wildlife Management Areas

A number of areas have been specifically set aside in the study area to aid in the conservation and management of fish and wildlife species. Federal management areas include National Wildlife Refuges managed by the US Fish and Wildlife Service and National Seashores managed by the National Park Service. Wildlife management areas (WMAs) and state parks are managed by the state agency Texas Parks and Wildlife

(TPWD). In addition, there are several non-profit organizations, including Houston Audubon Society and The Nature Conservancy, have also acquired land in the study area to conserve and manage important bird areas. **Figure 3-1** shows the location of each of the fish and wildlife management areas.

Table 3-3. Protected Lands within the Study Area

Refuge Name	Management	Acreage	County	Types of Habitat	General Description
Upper Texas Coast					
Goose Island State Park	State (TPWD)	321	Aransas	estuarine marsh; oak mottes; tidal flats	This park boasts fishing, camping and boating. The "Big Tree" at the park is more than 1,000 years old and one of the largest live oak trees in the Nation.
Brazoria National Wildlife Refuge (NWR)	National (USFWS)	44,413	Brazoria	wetlands; prairies; woody thickets; salt and mud flats; lakes and streams	This refuge boasts 400 species of birds, 95 species of reptiles and amphibians, and 130 species of butterflies and dragonflies.
Bryan Beach State Recreation Park	State (TPWD)	885	Brazoria	coastal prairie	The park is regularly maintained by the City of Freeport. Recreation activities include sunbathing, camping, birding, and fishing.
Christmas Bay Coastal Preserve	State (GLO/TPWD)	4,831	Brazoria	prairies; salt marshes; oyster reefs	The preserve contains about 250 acres of seagrass beds and has minimal man-made alterations to the landscape.
Justin Hurst Wildlife Management Area (WMA)	State (TPWD)	15,612	Brazoria	coastal dunes; Gulf shoreline; bay	The WMA is part of the Central Coast Wetlands Ecosystem Project, which provides research on biological conservation, outdoor demonstrations, and public hunting.
Nannie M. Stringfellow WMA	State (TPWD)	3,664	Brazoria	coastal bottomland; hardwood forest	The WMA is part of the Coastal Bottomlands Mitigation Bank to improve the forest and grasslands as wildlife habitat.
San Bernard NWR	National (USFWS)	57,698	Brazoria, Matagorda	salt and freshwater marshes; ponds; coastal prairies; bottomland forests	The Columbia bottomland forest contains some of the largest live oak stands in Texas and provides habitat for wintering and nesting birds. The refuge was designated an "Internationally Significant Shorebird Site" and is popular for waterfowl hunting and fishing.
Guadalupe Delta WMA	State (TPWD)	7,410	Calhoun, Victoria, Refugio	coastal marsh; man-made wetlands; riparian forest	The freshwater discharge of the Guadalupe River contributes to the low salinity of the bay system. The wetland habitat provides food and forage for wildlife such as white-faced ibis, herons, white-tailed hawk, and peregrine falcons.

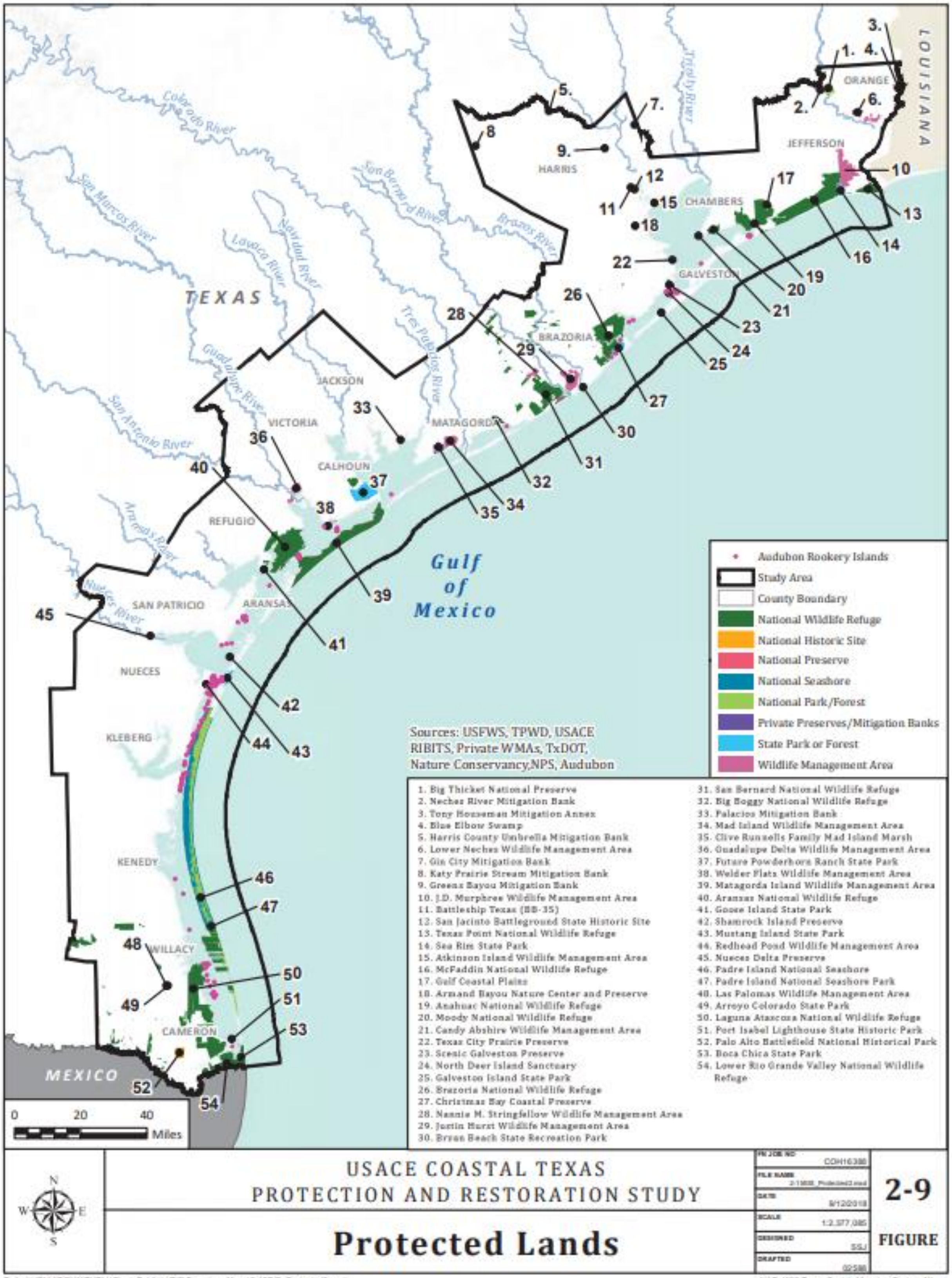


Figure 3-1. Protected Lands within the Study Area

3.3 AIR QUALITY

3.3.1 Regulatory Framework

Air quality is protected under several provisions of the Clean Air Act (CAA), including the national ambient air quality standards (NAAQS). Air quality regulatory oversight is administered by the EPA and Texas Commission on Environmental Quality (TCEQ). More in depth discussion of the specifics of the law and regulatory oversight are provided in Chapter 6.

The NAAQS consists of numerical standards for air pollution caused by "Criteria" air pollutants identified by the EPA. These air quality standards are given "primary" and "secondary" status for protecting public health and welfare, respectively. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. "Criteria" pollutants include carbon monoxide, nitrogen dioxide, ozone, lead, particulate matter with particles less than 10 microns in diameters, particulate matter with particles less than 2.5 microns in diameter, and sulfur dioxide. Areas meeting NAAQS are classified as being in "attainment" and areas persistently exceeding NAAQS, or that contributes to ambient air quality in a nearby area that fails to meet standards, is classified as a "non-attainment area (NAA)." NAA are subject to preparing and complying with air quality plans (State Implementation Plans [SIP]) containing emission reduction strategies for those areas designated.

3.3.2 Existing Condition

The study area includes 18 counties in Texas, of those counties, 4 exceed the ozone standard (**Table 3-4**; TCEQ, 2016c). These nonattainment counties within the study area include Chambers, Galveston, Brazoria, and Harris counties and are categorized by the TCEQ as "special inventory," meaning that although emissions do not exceed the NAAQS ozone standard, it remains under close supervision. These classifications are subject to change, however, and in October 2015 the EPA lowered the ozone standard from 0.075 to 0.070 parts per million (EPA, 2016d).

The TCEQ is responsible for developing a comprehensive plan to maintain NAAQS compliance. In cooperation with county officials, local city governments, and other State agencies, the TCEQ submits a State Implementation Plan (SIP) to the EPA for approval. The SIP contains background information, action plans, contingency measures, schedules, and reporting requirements for reducing and maintaining air quality standards (TCEQ, 2017b).

The 2014 emissions total shown in **Table 3-5** is provided by the EPA's National Emissions Inventory (NEI) (EPA, 2016k, 2016l). Emissions inventory data are compiled and submitted by the TCEQ from annual emissions inventory questionnaires, mobile and area source emissions programs, and technical data (TCEQ, 2017c). The 2014 NEI contains the most recent available data and compiles emissions from point source, area, highway, and off-highway sources. The table is categorized by the county and criteria pollutants.

Table 3-4. TCEQ's Current Designation for Counties within the Study Area

Designation	Counties	
Nonattainment	Brazoria	Galveston
	Chambers	Harris
Attainment/Special Inventory	Jefferson	Kleberg
	Orange	Nueces
	Calhoun	Refugio
	Jackson	San Patricio
	Matagorda	Cameron
	Victoria	Kenedy
	Aransas	Willacy

Source: TCEQ (2016c).

According to the TCEQ, Galveston, Harris, Chambers, Fort Bend, Liberty, Montgomery, Waller and Brazoria County are currently categorized as "moderate" nonattainment area under the 2008 8-hour Ozone (O3) NAAQS (TCEQ, 2018a). The air quality in the region around Galveston Bay (Galveston, Harris, Brazoria, and Chambers) are currently categorized as 'attainment' for all other criteria pollutants: lead (Pb), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and particulate matter (PM2.5 and PM10). There are currently 13 air monitoring stations managed by the TCEQ used to monitor for air quality around the CSRM project area (TCEQ, 2017d) (**Table 3-5**). Monitoring stations are located around industrial facilities and large population centers. There is one air quality monitoring station located on Galveston Island, seven monitoring stations located around Texas City, one monitoring stations located on Smith Point, two monitors near Seabrook, and three monitoring stations located near La Porte-Baytown.

Jefferson and Orange county monitors have shown decreases in ozone levels and are currently in attainment (TCEQ, 2016d). Victoria County is in special inventory and currently meets Federal standards for ozone and all other NAAQS and is designated attainment by the TCEQ (2016c). Nueces County is currently meeting Federal standards for all NAAQS and is in attainment (TCEQ, 2016d). Cameron County is currently meeting Federal standards for ozone and all other NAAQS and is in attainment (TCEQ, 2016d).

Table 3-5 Summary of Air Emissions Inventory for Counties along the Texas Coast, 2014

County	CO (tpy)	NOX (tpy)	PM10 (tpy)	PM2.5 (tpy)	SO2 (tpy)	VOC (tpy)
Orange	15,697	10,903	1,087	974	4,436	6,978
Jefferson	28,936	19,643	3,016	2,641	13,754	16,975
Chambers	10,384	4,746	661	564	272	5,907
Harris	383,358	85,027	15,650	12,185	11,673	67,582
Galveston	28,403	14,898	2,192	1,901	2,721	8,788
Brazoria	30,574	12,695	2,856	2,466	819	10,522
Matagorda	9,494	3,554	620	513	63	4,575
Jackson	3,432	2,086	155	130	37	2,436
Victoria	12,225	6,065	597	488	109	3,208
Calhoun	8,615	7,116	780	667	491	3,980
Aransas	6,385	2,822	144	125	79	2,681
Refugio	2,253	1,605	89	78	8	3,957
San Patricio	9,704	5,982	543	451	137	4,744
Nueces	34,129	14,146	2,468	2,111	1,042	12,806
Kleberg	3,680	1,386	134	119	17	2,792
Kenedy	1,518	1,728	37	32	8	1,297
Willacy	2,264	981	82	71	5	1,190
Cameron	32,065	6,109	684	527	125	5,193

Source: EPA (2016k, 2016l). tpy = tons per year

3.4 CLIMATE

3.4.1 Regulatory Framework

The regulatory framework for climate mainly consists of its potential to affect other resources, such as vegetation, marine environments, wildlife, socioeconomics, etc., particularly under future conditions when temperature and precipitation frequencies could change.

- ECB 2018-14: The engineering bulletin provides guidance for assessing the impacts of climate change on project hydrology, including potential nonstationary data. The ECB requires a qualitative assessment of potential long-term risks to project performance but does provide for quantitative assessment of projected hydrologic changes to projects, in necessary.
- ER 1100-2-8162, Incorporating Sea Level Rise in Civil Works Programs: The policy provides guidance for incorporating the direct and indirect physical effects of projected future sea level change (SLC) across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects.

3.4.2 Existing Condition

Within the study area, temperatures range from winter lows to summer highs with warming temperatures in the spring and cooling temperatures in the fall. Rainfall is the main form of precipitation along the coast and tends to occur most frequently and in greatest amounts in the spring and late summer/early fall. Rainfall rates decrease, and temperatures increase moving south along the coast. Coastal relative humidity averages slightly more than 60 percent over the year (Nielsen-Gammon, 2016).

During El Niño periods, when Pacific waters are warmer than normal, the Texas coast is typically wetter and cooler than normal in the winter. Freshwater inflows to estuaries may increase and bay salinities may decrease. When Pacific waters are cooler than normal, the La Niña pattern is in place, and winters are warmer and dryer than normal resulting in droughts, reduced freshwater inflows, and increased bay salinities (Tolan, 2007).

During the winter, rapid drops in temperature occur 10 to 20 times a year with the passage of fast-moving cold fronts called “blue northers.” The rapid temperature drops, sometimes to below freezing, have caused massive fish and sea turtle mortality events along the coast. In some instances, dolphins have been affected. Freezing temperatures are relatively uncommon along the coast, but more likely to be experienced along the upper coast than the lower coast (Martin and McEachron, 1996). High velocity winds associated with these events cause “blow outs” of the bays when water levels may drop more than a foot below normal low tide. Low pressure systems can form in the Gulf during the winter causing long periods of steady rains along the coast. In rare cases these systems can strengthen, generating high winds and water levels substantially above high tide

(Contreras, 2003). Prevailing southerly and southeasterly winds blow warm, humid air from the Gulf onshore much of the year. High temperatures in the 80- and 90-degrees Fahrenheit (°F) occur in the summer along the coast (Nielsen-Gammon, 2016).

The Southern Regional Climate Center (National Oceanic and Atmospheric Administration [NOAA], 2016a) summarized the climate for the Texas coast 1981 to 2010 (**Table 3-6**).

Table 3-6. Average annual temperature and total rainfall for Texas Coastal cities (1981 – 2010)

City	Average Temperature (°F)	Total Rainfall (inches)
Beaumont	68.59	60.42
Galveston	71.22	50.76
Port O'Connor	70.66	35.93
Corpus Christi	72.11	32.49
South Padre Island	74.28	25.83

Source: NOAA (2016a).

These conditions were influenced by a strong El Niño during 2016. Average temperatures in Texas coastal counties ranged from <1 to 3°F above normal. Rainfall in the Sabine Lake and Galveston areas was 16 to more than 20 inches above normal (NOAA, 2016a).

Coastal climate in Texas is characterized by episodic storms and unusual weather events that are documented in the monthly report, "Storm Data." During 2015 to 2016, unusual weather events along the Texas coast included temperatures below freezing for several hours in Kenedy County, severe hail storms in Harris and Jefferson counties, and tornadoes and severe flooding along most of the Texas coast caused by Hurricane Patricia, which crossed from the Pacific through Mexico during October 2015 (National Centers for Environmental Information, 2016).

History of Severe Storms and Hurricanes

The probability of hurricane landfall on the Texas Coast is about one every 6 years. (Roth, 2010). The most active area for hurricanes over the past 160 years is the upper Texas coast with 28 landfalls, followed by the mid Texas coast with 25 landfalls, and lastly the lower Texas coast with 15 landfalls. Hurricane Ike (2008) was the costliest storm in Texas causing over $29.5 billion worth of damage (**Table 3-7**). The top three costliest storms for Texas have all occurred since 2000, one of which (Allison) only reached tropical storm status (Blake et al., 2011).

Table 3-7. Costliest Texas Storms (1900 – 2010)*

Name	Year	Category	Landfall	Cost of Damage
Ike	2008	2	Galveston	$29.5 billion
Rita	2005	3	Sabine Pass	$12.0 billion
Allison	2001	TS	Freeport	$9.0 billion
Alicia	1983	3	Galveston	$2.0 billion
Dolly	2008	1	South Padre Island	$1.1 billion
Celia	1970	3	Corpus Christi	$930 million
Allen	1980	5	South Padre Island	$700 million
Carla	1961	5	Port O'Conner	$300 million

Source: Blake et al. (2011), Handbook of Texas Online (2017).

* Not adjusted for inflation and include adjusted National Flood Insurance Program flood damage amounts beginning in 1995.

TS = tropical storm

3.5 GEOLOGIC RESOURCES

3.5.1 Regulatory Framework

The regulatory framework for geology and soils mainly consists of its potential to affect other resources including air quality, water, and navigation.

Section 402 of the Clean Water Act, National Pollutant Discharge Elimination System: The section regulate discharges of pollutants into the water of the US by requiring all construction sites on an acre or greater of land discharging wastewater or stormwater directly from a point source (a pipe, ditch, or channel) into a surface water of the United States to obtain permission under the National Pollutant Discharge Elimination System (NPDES) permit.

Mineral Resources

There are numerous federal, state, and local laws and ordinances regarding mineral exploration, development, and production. However, for this analysis, access to existing development and exploration for minerals are most likely to be impacted by any proposed project. Under Texas law, land ownership includes two distinct sets of rights, or "estates": the surface estate and the mineral estate. Initially, these two estates were owned by the same person and they may continue to be owned together by one person. However, in many cases in Texas, especially where there has been extensive historical oil and gas development, it is common for the mineral estate and surface estate to be owned by different people. The division, or “severance”, of the mineral estate and surface estate occurs when an owner sells the surface and retains all or part of the minerals.

Regardless of whether the mineral estate and surface estate are held by one owner or have been severed, Texas law holds that the mineral estate is dominant. This means that the owner of the mineral estate has the right to freely use the surface estate to the extent reasonably necessary for the exploration, development, and production, of the oil and gas under the property. The right to freely use the surface estate for the benefit of the mineral estate may be exercised by the mineral owner, or a lessee, such as a company or individual that takes a lease and operates the property for the mineral owner.

Mineral owners and lessees have broad rights to use the surface for the purpose of exploring for and producing oil and gas. These rights include the right to: conduct seismic testing; drill wells at locations they select; enter and exist well sites and other facilities; build, maintain, and use roads for access to and from well sites and facilities; build and use pipelines to serve wells and facilities on the property; use surface and subsurface water on the leased premises for drilling and production operations; and drill and operate injection wells to enhance lease recovery and dispose of lease-produced water.

3.5.2 Existing Condition

3.5.2.1 Geology

The regional geology influences the topography, quality and presence of groundwater resources, the presence and characteristics of soils, the occurrence and severity of geologic hazards such as faults and areas of subsidence also influences the depth to groundwater. The geology of an area includes bedrock materials and mineral deposits. Soils refers to unconsolidated earthen materials overlaying bedrock or other parent material.

This section primarily describes the regional geologic setting which includes all 18 coastal counties along the Texas gulf coast. Unless otherwise noted, the descriptions here apply to all the study area.

The geological setting of the Texas coastline and the major geomorphological features have been developed through a combination of fluvial, coastal, and marine processes occurring over the last 125,000 years (Anderson et al., 2016). Anderson et al. (2016) used sedimentological analysis including detailed lithological descriptions, identification of sedimentary structures, grainsize analysis, seismic stratigraphic analysis, macro- and micro-faunal analyses, magnetic susceptibility and clay mineralogy, hundreds of radiocarbon dates, oxygen isotope profiles, and micro-paleontological data to determine the geological record and reconstruct the evolution of the Texas coast. By evaluating relative age assignments of sea level transgressions and regressions, a geological record interpretation was developed for the depositional environments created during the sea level changes within the last 125,000 years. This analysis helped to develop the history of the geology and geomorphology of the Texas coast.

The Beaumont Formation, or Beaumont clays, is a Pleistocene formation present across the Texas coast composed of the oldest coastal deposits. Bernard et al. (1970) and Fisher et al. (1972) originally defined the Beaumont Formation as a fluvial delta with shallow marine deposits and barrier-strand plain-Chenier unit that formed 35,000 to 400,000 years ago. The Beaumont Formation is present in large areas of the former coastal plains and continental shelf

Blum and Price (1998) dated the age of the Beaumont Formation using the nearby Colorado River system, showing that the representative period of the deltaic and fluvial deposition spanned from 85,000 to 400,000 years ago. These deposits consisted of multiple fluvial and deltaic cycles of river valley incision and filling as responses to sea level changes (Blum and Price, 1998). The Beaumont Formation also includes ancient barrier islands and beach deposits created before 35,000 years ago, which can be observed in Rockport, Port O'Connor, Ingleside, and on the north shorelines of West and East Galveston bays (Fisher et al., 1972).

According to Anderson et al. (2016), with the slowdown of sea level rise in the last 2,000 to 9,000 years, the current coastline became a mix of sandy barrier island environments, marsh-swamps, bay-estuary-lagoons, inlets and offshore shorefaces, and fluvial-deltaic systems that covered the Beaumont Formation. These new depositional environments consist of a wide range of sands, silts, and clays in different geomorphological environments. The post-Beaumont Formation coastal deposits correspond to reworked deposits from these alluvial, fluviatile, and aeolian processes being placed in the new created coastal environments. Following the slowdown of sea level rise, the coastal environment has been characterized by sandy lowlands that are subject to severe shoreline retreat and limited sediment supply (Anderson et al., 2016).

The general geologic setting of the Texas coast described by Morton and Peterson (2005, 2006a, 2006b) is summarized below:

Sabine Pass to the Colorado River. This area is made up of two headlands that are flanked by a barrier island. The eastern portion of the headland extends from Sabine Pass to Bolivar Peninsula, and the western portion includes the Brazos River and delta complex extending from Follets Island to the eastern portion of Matagorda Peninsula. It is composed of deltaic sand and mud deposits transported by the Brazos and Colorado rivers, thus changing the orientation around the western headland. Broken shells and rock fragments, resulting from long-term erosion and altering of older deposits from the surf zone, make up the beach sediments along both headlands. A source of sediment for adjacent barrier islands (i.e., Bolivar Peninsula, Galveston Island, Follets Island, and Matagorda Peninsula) is long-term erosion of the headlands. When these barrier islands with numerous beach ridges formed, there was abundant sand supply and subsequent seaward advancement of the Gulf shoreline (Morton and Peterson, 2005).

Aransas Pass to Mansfield Channel. This area is characterized by wide, long, sandy barrier islands (Mustang and Padre islands) that are mostly undeveloped. Due to the abundant sand supplied by the longshore currents in the Gulf, these islands have continued to increase in size. Wide beaches and densely vegetated high continuous dunes characterize the area except for north of Mansfield Channel. Two natural inlets (Aransas Pass and Packery Channel) occur in this area due to the low tidal range and high sand supply in the littoral system. Following the deepening of Aransas Pass for navigation in 1930, Packery Channel closed but was reopened in 2004 to allow small boats shorter access to the Gulf. Along this portion of the Texas coast, beaches change from a northeast to southwest orientation to a north-south orientation and are composed of fine sand with some broken shell except in the area known as Big Shell Beach. Shells are concentrated here because the area falls in the zone of convergence of longshore currents, which flow from the northeast and south at different times, and the winds blow sand from the beach leaving the shell deposits (Morton and Peterson, 2006a).

Mansfield Channel to the Rio Grande. This area is mostly undeveloped and made up of South Padre Island, a long, narrow, sandy barrier island, and Brazos Island, a deltaic headland with a sandy beach. As sea level rose, these areas narrowed and retreated landward as the Rio Grande sand supply decreased, forming the Rio Grande delta and barrier island. The barrier island exhibits wide beaches, high, sparsely vegetated dunes, which are cut by numerous washover fans, and in some areas during droughts have migrated across the barrier island into the Laguna Madre. Brazos Santiago Pass is the only natural tidal inlet in the area due to the low tidal amplitude and evaporation commonly exceeding precipitation in the area. Beaches are composed of fine sand with some broken shell that erode from underlying deltaic sediments (Morton and Peterson, 2006b).

As natural conditions occur along the coastline, several factors indirectly impact the regional and local geologic settings including shoreline retreat or accretion, land loss due to relative sea level rise (RSLR), and subsidence. RSLR effects may be translated into higher water elevations, increased sediment transport, and exposure of new geologic stratigraphy to erosion altering the composition of the sedimentary environment.

3.5.2.2 Mineral Resources

Texas leads the United States in overall energy production including oil and gas exploration and production, power generation, and renewable and sustainable energy generation. The Texas Gulf coastal zone, specifically the upper Texas coast, has been developed for oil and gas exploration since the late 1800s to early 1900s when drilling began in the upper Texas coast area (Handbook of Texas Online, 2016). Oil and gas exploration and production bolstered the economies of many coastal cities and increased the development of the coastal region with service, supply, and manufacturing facilities associated with oil and gas production. The opening of the Houston Ship Channel in 1914 further enticed large oil refineries to the Houston area. Similarly, the development of the Corpus Christi Ship Channel in 1926 boosted oil and gas exploration and production-related facilities in Corpus Christi, Refugio, and Port Lavaca.

In recent times, the energy sector along the Texas coast has increased its renewable energy production as well. Two coastal wind farms, located in south Texas, provide renewable energy from wind power contributing to Texas's 12,000-megawatt wind power capacity. Supporting wind power generation, several large wind equipment manufacturing facilities have been built in the Houston region (State of Texas, 2014).

The presence of energy production activities along the Texas coast including oil and gas exploration and production facilities has resulted in a large pipeline network within the coast zone. While intricate pipeline networks are associated with each oil or natural gas field, several large diameter transmission pipelines cross the coastal bays and GIWW. The upper and mid-Texas coast contain the densest network of oil and gas pipelines beginning in Orange County and ending in Nueces County. Oil and gas pipelines in south Texas are generally located in or near Brownsville, Texas in Cameron County (American Petroleum Institute, 2014; U.S. Energy Information Administration, 2016).

Widespread mineral mining for sulfur, silica, sand and gravel, salt, stone, heavy metals, perlite, gypsum, and clay is present along the entire Texas Gulf coast; however, it is more prevalent in the upper coast around the cities of Beaumont, Port Arthur, Houston, and Freeport. Mining activities are distributed sparsely throughout the mid and southern coast. Most mineral mining in these areas is within the areas of Port Lavaca, Corpus Christi, and Brownsville. Mining activities are near more developed cities and ports along the Texas coast (BEG, 2016).

Texas Gulf Coast sediments consist of unconsolidated, lenticular deposits of clays, silts and sands with occasional organic beds generated in shallow water, marsh-dominated depositional environments.

3.5.2.3 Soils

3.5.3 The Upper Texas Coast (UTC)

The soils located in the northern extents of Orange County are associated with the western coastal plain and flatwoods soil types. The deep soils, Otanya-Kirbyville-Evadale occur on low relief uplands and flat plains. These areas are generally wet and have poor drainage. These soils are characteristic of the southern tertiary uplands. Similar upland soils consisting of Woodtell-Pinetucky-Conroe can be found in northern Harris County. These are deep soils found on interstream divides and low ridges. The Gulf coast prairie soils are the largest proportion of soils found in the upper Texas coast. Beaumont-League-Labelle soils are found in Orange and Jefferson counties; while the Katy-Wockley-Gessner soils are found in north central Harris County. Lake Charles-Bernard-Edna soils occur in southern Harris County, northern Galveston County, and northern Brazoria County. The band along the coastline is the Gulf coast saline prairie consisting of Harris-Surfside-Francitas soils. These soils are formed in nearly level quaternary sediments on coastal lowland plains (Natural Resources Conservation Service [NRCS], 2008).

Most of the prime farmlands in this area are found in historic alluvial terraces, flatwoods, wet plains, and woodlands (NRCS, 2006). The prime farmland soil associations in the six-county region are Aris fine sandy loam, Asa silt-clay loam, Bernard-Edna clay loam, Bissonet loam, Brazoria clay, Clemville silty clay loam, Katy fine sandy loam, Lake Charles clay, Mocarey loam, Mocarey-Algoa complex, Mocarey-Cieno complex, Mocarey-Leton complex, Norwood silty loam, Pledger clay, Spurger fine silty loam, Texla silty loam, and Vamont clay. Agricultural crops include corn, cotton, grain, and sorghum. Pastures and hayfields include adapted bahiagrass and Bermudagrass (Soil Conservation Service [SCS, now the NRCS], 1976).

The Mid to Upper Texas Coast (MUTC)

This area consists of the floodplains, Gulf coast prairie, and Gulf coast saline marshes. The coastline is separated into two distinct saline prairie types. The coastline of Matagorda County is Harris-Surfside-Francitas soils, while the coastline of Calhoun County is Mustang-Daggerhill-Barrada soils (NRCS, 2001a). Central Matagorda County along the Colorado River and other freshwater drainages are floodplain soils: Pledger-Brazoria-Norwood. Floodplain soils are formed in the nearly level alluvium of streams and are subject to inundation during floods. Norwood soils have an irregular distribution of organic material. Brazoria and Pledger soils are heavy clays with high shrink swell potential. Southern Victoria and Jackson counties and northern Calhoun and northwest Matagorda counties have Gulf coast prairie soils of the Laewest-Dacosta-Edna series (NRCS, 2008).

The prime farmlands soil associations for this area are Asa silty loam, Brazoria clay, Clemville silty clay loam, Dacosta-Contee complex, Dacosta sandy clay loam, Edna fine sandy loam, Faddin loam, Faddin fine sandy loam, Fulshear fine sandy loam, Inez fine sandy loam, Katy fine sandy loam, Laewest clay, Laewest silty clay, Norwood silty clay loam, Pledger clay, Telferner fine sandy loam, and Texana fine sandy loam. These soils are primarily used to grow rice, soybean, corn, pecans, and sorghum. The lands are also used to grow turfgrass like St. Augustine and bermudagrass and pastures for dallisgrass, common bermudagrass, coastal bluestem, kleingrass, Pensacola bahiagrass, and native hay meadows (NRCS, 2001a).

The Mid Texas Coast (MTC)

The northern reaches of Aransas County and the soils of the eastern half of Refugio County are the Laewest-Dacosta-Edna soils of the Gulf coast prairie. The majority of San Patricio and Nueces counties are in the Gulf coast plain with dominant soils being in the Victoria-Orelia-Edroy series (NRCS, 2008). The Victoria clay has a high shrink-swell potential and in undisturbed areas, forms gilgai depressions (SCS, 1988). The southwestern corner of Nueces and western half of Kleberg counties also lie within the Rio Grande plain but are dominated by Nueces-Sarita-Falfurrias soils. Central Kleberg County lies in the upland Gulf coast plain also containing Victoria-Orelia-Edroy soil. The Gulf coast saline prairie of the mid coast is dominated by Mustang-Daggerhill-Barrada soils, which are on low coastal terraces and plains along the barrier islands (NRCS, 2001b).

The mid coast is predominantly open grassland and used for rangelands and wildlife habitat. Most of the prime farmlands in this area reside on historic open grassland areas with scattered trees and shrubs. Prime farmland soil classes in the area include Banquete clay, Calallen sandy clay loam, Clareville loam, Clareville clay loam, Colmena fine sandy loam, Cranell sandy clay loam, Czar sandy clay loam, Monteola clay, Odem fine sandy loam, Orelia fine sandy loam, Palalote sandy loam, Pharr fine sandy loam, Raymondville clay loam, Raymondville complex, Sinton loam, Sinton clay, Victoria clay, and Willacy fine sandy loam. Because of the slope and fine soil, erosion is a major problem. Corn, sorghum, and cotton are important agricultural crops in the region (SCS, 1979, 1988).

The Lower Texas Coast (LTC)

The area is bisected by the dry Rio Grande plain to the west and Gulf coast saline prairie to the east. The Rio Grande plains of the lower coast contain Nueces-Sarita-Falfurrias soils in Kenedy County and McAllen-Hildago-Brennan soils in Willacy and Cameron counties. The Nueces-Sarita association is from Eolian sand deposits and is relatively flat and well draining. Mustang-Daggerhill-Barrada soils are found along the coastline as part of the Gulf coast saline prairie in the lower coast (NRCS, 2008). The Rio Grande series consists of well-drained calcareous soils with little slope on the floodplains of the Rio Grande. The Willacy and Willamar series are saline soils on deltas and coastal terraces (SCS, 1977).

Irrigated lands in this area are used to grow cotton, sorghum, corn, grapefruit, oranges, sugarcane, onions, potatoes, cabbage, lettuce, and beets. Common bermudagrass, coastal bermudagrass, African stargrass, and angleton bluestem are grown to feed livestock. Examples of prime farmland soil types are Camargo silty clay loam, Cameron sandy clay loam, Hidalgo sandy clay loam, Laredo silty clay loam, Laredo-Reymosa complex, Matamoros silty clay, Matamoros-Rio Grande complex, Olmitos silty clay, Racombes sandy clay loam, Raymondville clay loam, Rio Grande silty clay loam, and Willacy fine sandy loam. Wind erosion of fine sandy sediments is a large concern in the region (SCS, 1977).

3.6 WATER RESOURCES

3.6.1 Regulatory Framework

The following laws, EO, and local ordinances are applicable to surface water resources in the study area. The Federal laws and EO are further described in Chapter 6.0.

- **Houston-Galveston Subsidence District Regulatory Plan (2013):** To address the issues associated with land surface subsidence and compaction, the 64th Texas State Legislature authorized the establishment of the Houston-Galveston Subsidence District to regulate and reduce groundwater withdrawals in Harris and

Galveston counties. Subsequently, the Texas Legislature established the Fort Bend Subsidence District. Each district has an approved regulatory plan that establishes policy in the areas of groundwater regulation, permits, and enforcement. Overall, the goal of the plans is to reduce groundwater withdrawal to no more than 20 percent (10% in regulatory Area 1, which includes the Houston Ship Channel area of the study area) of the total water demand.

- **Clean Water Act (CWA):** The law was created to establish a basic structure for regulating pollutant discharges into the waters of the US, provides the EPA the authority to implement pollution control programs, and establish water quality standards for contaminants in surface waters, to name a few purposes of the Act.
- **Section 303(d) and 305(b):** 305(b) requires states to assess the water quality of the waters of the state (both surface and groundwater) and prepare a comprehensive report documenting the water quality. In addition, Section 303(d) requires states to prepare a list of impaired waters on which total maximum daily loads (TMDL) or other corrective actions must be implemented. See Chapter 6 for more information.
- **Section 402:** This section regulates the discharge of wastewater or storm water from municipal, industrial, and commercial facilities and construction sites.
- **Rivers and Harbors Act:** Section 9 and 10 of the Act prohibits the unauthorized obstruction (including bridge construction) or alteration of any navigable waters of the US (i.e. waters subject to ebb and flow of the tide), unless the work has been authorized by permit from the US Coast Guard and the USACE.
- **National Flood Insurance Act:** The Act created the National Flood Insurance Program (NFIP). The intent of the NFIP was to reduce future flood losses through the adoption of local floodplain management regulations, and to provide a premium-based insurance mechanism to protect property owners against potential losses.
- **Executive Order 11988, Floodplain Management:** The EO requires federal agencies to avoid, to the extent possible, the short- and long-term adverse impacts associated with occupancy and modification of floodplains. Federal agencies are to avoid direct and indirect support of floodplain development wherever there is a practicable alternative.
- **City Floodplain Management Regulations:** Each incorporated area has developed their own floodplain management regulations, which are compliant with the NFIP. These regulations also specify construction specifications for finished flood elevations and detention requirements for new construction actions occurring within the floodplains.

- **30 TAC §307, Texas Surface Water Quality Standards (TSWQS).** Establishes surface water quality standards applicable to all surface waters in the state.

3.6.2 Existing Conditions

The existing conditions for water resources are described for jurisdictional waters, watersheds, surface water, groundwater, and water quality.

3.6.2.1 Jurisdictional Waters

Under the Clean Water Act, jurisdictional waters (WOTUS) includes all territorial seas and traditional navigable waters; perennial and intermittent rivers and streams and lakes, ponds, and impoundments that contribute surface water flows to traditional navigable waters; and wetlands that have a direct hydrologic connection to jurisdictional waters. The USACE general definition of a navigable water is "those waters subject to the ebb and flow of the tide shoreward to the mean high water mark and/or are presently used, or have been used in the past, or may be susceptible to transport interstate or foreign commerce."

For purposes of this assessment, any wetlands found within the 100-year floodplain and within 1,500 feet of the ordinary high-water mark are also considered WOTUS. A desktop review of potential wetlands was identified using the USFWS National Wetland Inventory (NWI) data (USFWS 2014), USGS National Land Cover Database (NLCD) 2016 dataset (Homer et al. 2020), and TPWD Ecological Classifications Project mapping (TPWD 2009). A formal wetland delineation following the 2010 Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region was not completed. The available information (e.g. USGS, TPWD, and NWI mapping; proximity to navigable rivers, interstate waters, territorial seas, and the ordinary high water mark; hydrology; and soil types) is sufficient to make some assumptions regarding the presence/absence and location of jurisdictional WOTUS in lieu of completing field surveys for this phase of the study. Additional field surveys may be necessary to confirm the presence/absence of wetlands.

Upper Texas Coast (UTC)

Within the upper Texas coast (Sabine Lake to the Galveston Bay system), wetland systems are like southwestern Louisiana marshes, where the elevational gradients are gradual, freshwater inflows are relatively higher, and salinity gradients are extended (with freshwater wetlands inland transitioning into brackish and intermediate marsh, and the gradient ending in the tidal salt marshes within the bays) (Moulton et al., 1997).

Within the upper Texas coast, swamps are the wettest type of forested wetlands and are typically persistently inundated, located from east Houston to Louisiana (Mitsch and Gosselink, 2007). The dominant vegetation is bald cypress, water tupelo (*Nyssa aquatica*), water hickory (*Carya aquatica*), planertree (*Planera aquatic*), and willow oak (*Q. phellos*). Yaupon (*Ilex vomitoria*), sugarberry (*Celtis laevigata*), dwarf palmetto (Sabal minor), and elm can be found in the understory. Bottomland hardwood forests are also part of this complex and are flooded less frequently than swamps. Bottomland hardwood forests are dominated by willow oak, water oak (*Q. nigari*), overcup oak (*Q. lyrata*), cherrybark oak (*Q. pagoda*), laurel oak (*Q. laurifolia*), green ash (*Fraxinus pennsylvannica*), red maple (*Acer rubrum*), black willow (*S. nigra*), water tupelo, and others. Understory vegetation often consists of dwarf palmetto, Cherokee sedge (*Carex cherokeensis*), deciduous holly (*Ilex decidua*), yaupon, and many others.

Coastal flatwood wetlands are unique forested wetlands found between the Louisiana border and the Houston area. Longleaf and loblolly pines (*Pinus palustris* and *P. taeda*, respectively) and hardwood trees are commonly found within the drier parts of the wetland, while willow (*Salix spp.*), laurel oak, swamp chestnut oak (*Q. michauxii*), and dwarf palmetto are found in wetter areas. The soil is typically loamy with a claypan subsoil below 30 inches. Precipitation and run-off inundate the wetlands keeping soils wet during the winter and early spring and dry the rest of the year. Historically, these wet and upland areas experience regular fire to maintain pine dominance. The biggest threats to these wetlands are from the timber industry, which can overharvest pine trees and hardwoods (Texas A&M AgriLife Extension, 2017b).

On the upper coast, potholes and marshes occur in complexes with pimple mounds (small hummocks 1 to 2 feet tall) and intermound flats. This complex pattern, formed thousands of years ago by ancient rivers and bayous, has been modified through time by climatic (especially wind) and biotic forces. Potholes and marshes maintain their hydrology through direct precipitation, runoff from adjacent flats, and occasionally local groundwater. Prairie potholes and pimple mounds provide habitat for a variety of wildlife and plants such as cattails, buttonbush (*Cephalanthus occidentalis*), black willow, water lilies (*Nymphaea spp.*), American alligator (*Alligator missippiensis*), American bullfrogs (*Rana catesbeia*na), ribbon snakes (*Thamnosis spp.*), wading birds, shorebirds, waterfowl, butterflies (Lepidoptera), and dragonflies (Odonata). During periods of drought, wildlife can be found concentrated around the potholes. Today urban sprawl and agricultural fill threaten prairie potholes and marshes. Since the 1950s, more than 29 percent (235,000 acres) of freshwater marshes have been lost (Texas A&M AgriLife Extension, 2017d).

Estuarine emergent wetlands are mostly concentrated at the upper and mid-Texas coast; estuarine shrub-scrub wetlands were most abundant in the mid-Texas coast in Espiritu Santo Bay, south of Port O'Connor, and at the southern end of South Padre Island (Moulton et al., 1997). Estuarine unvegetated flats are more common around the lower Texas coast in the Lower Laguna Madre. Some of these tidal wetlands are subject to daily tidal ranges (i.e., low salt marsh), where others are only subject to tidal influence during high tides or storm events (i.e., high salt marsh); the upper and lower limits of the tidal range control the extent and location of estuarine wetlands. Freshwater inflows and sea water also maintain the salinity of the marsh and influence plant community composition (NOAA, 2017d). These wetlands can be a few feet wide where the intertidal range is thin due to shoreline geomorphology or can occupy large areas covering thousands of acres (Texas A&M AgriLife Extension, 2017f). Relative to the tidal range and salinity gradients transitioning from fresh to saline, marsh types include brackish and intermediate, which occur at tidal elevations between the mean high-water line and the annual high tide line, and salt marsh, which occur at tidal elevations between the mean tide line and the mean high tide line (NOAA, 2017d).

Brackish and intermediate marshes grade inland from salt marshes. The dominant species in brackish and intermediate marshes can include saltmarsh bulrush (*Scirpus robustus*) or bulrush (*Juncus spp*.); seashore saltgrass and saltmeadow cordgrass are co-dominant species. Brackish and intermediate marshes are subjected to periodic pulses of salt water, but saline influences are attenuated by high freshwater influences (Mitsch and Gosselink, 2007). Salinity ranges in brackish and intermediate marshes can be from 3 to 10 ppt (Louisiana Department of Wildlife and Fisheries, 2005). They dominate the interior marshes of the Sabine, Galveston Bay, and Matagorda Bay systems (USACE, 2015a). Brackish and intermediate marshes are generally more productive and diverse relative to salt marshes (Mitsch and Gosselink, 2007).

Salt marshes are located along the bay shorelines and higher salinity areas of the estuarine systems. Subjected to regular tidal inundation, low saline marsh is dominated by smooth cordgrass (*Spartina alterniflora*) and often accompanied by seashore saltgrass, blackrush (*Juncus romerianus*), saline marsh aster (*Aster tenuifolius*), and saltmeadow cordgrass (*S. patens*). The dominant species in high salt marsh, which is subject to less-frequent tidal inundation, is often glasswort (*Salicornia spp.*) and shoregrass (USACE, 2015a). Black mangrove (*Avicennia germi*nans) is also becoming a more common salt marsh species along the Texas coast and can persist in both low and high salt marsh areas (Armitage et al., 2015).

Lower Texas Coast (LTC)

The lower Texas coast is characterized by the Upper and Lower Laguna Madre, which is one of the few hypersaline lagoons in the world. Wind-tidal flats, lower rainfall, low and flat elevation, the Rio Grande delta, and arid rangeland are also defining characteristics of the lower Texas coast (Tunnell and Judd, 2002).

The lower coast riparian wetlands are unique forested wetlands associated with riverine areas from the San Antonio River to southern Texas. These freshwater, depressional wetlands are maintained by river runoff and regular flooding events and provide habitat for belted kingfishers (*Megaceryle alcyon*), rails (Rallidae), green treefrogs (*Hyla cinerea*), rare ocelots, and Gulf coast jaguarundis (*Herpailurus yagouaroundi*). Plants found within the riparian areas are common hackberry, retama (*Parkensonia accumulata*), huisache, Texas ebony (*Ebonopsis ebano*), and dwarf palmetto. The riparian corridors are threatened due to overgrazing, channel dredging, water diversion, damming of rivers upstream, and invasive plant species (Texas A&M AgriLife Extension, 2017c).

Tidal Wetlands

Fringing the Laguna Madre are unique tidal wetland areas consisting of broad, nearly unvegetated wind-tidal flats. These wind-tidal flats are not regularly flooded by tides. They are only occasionally flooded when strong winds push shallow water from the Laguna onto the low flats, or during annual high tides. The cycle of irregular flooding and drying causes salt to build up on the surface of the flats (Tunnell and Judd, 2002). These wind-tidal flats are inhospitable to most vascular plants but are often covered by vast mats of blue-green algae. These habitats may look barren, but they support rich invertebrate populations that, in turn, attract large numbers of shorebirds and wading birds (Texas A&M AgriLife Extension, 2017f). They are considered a "Special Aquatic Site" under 40 CFR 230. The unique processes that result in wind-tidal formations only exist in several locations worldwide, including the Persian Sea, Red Sea, and eastern Mediterranean Sea (Morton and Holmes, 2009).

Barrier Island Interior Wetlands

Padre Island is the longest undeveloped barrier island in the world. Island interior wetlands provide an important source of fresh water for species. Although these wetlands are primarily fresh water, storm events and extreme tides occasionally introduce salt into these barrier island wetlands. Wetland plants are similar to those found in other freshwater marshes but may include some brackish-water species due to elevated soil salinity and occasional tidal inundation in some areas. Typical species include saltmeadow cordgrass, cattails, bulrushes, coastal water-hyssop (*Bacopa monnieri*), pennywort (*Hydrocotyle spp.*), spikerushes, flatsedges, sedges (*Carex spp.*), burhead (*Echinodorus spp.*), marsh fimbry (*Fimbristylis castanea*), white-topped sedge, frogfruit (*Phyla nodiflora*), seashore paspalum (*Paspalum vaginatum*), bushy bluestem (*Andropogon glomeratus*), and other grasses. The availability of fresh water attracts species of frogs (Ranidae), turtles (Testudines), raccoons (*Procyon sp.*), feral pigs (*Sus scrofa*), waterfowl, wading birds, and shorebirds (Texas A&M AgriLife Extension, 2017g).

Texas Coastal Sand Sheet Wetlands

The topography of the area is generally flat but with rolling vegetated dunes, blowouts, and wetlands (Carr, 2007). Because of the dry climate, most of the water supplied to the wetlands is from groundwater percolating through the sandy soils. These wetlands support plant assemblages that reflect the range of salinity found in these depressions. The fresher wetlands have species like California bulrush (*Schoenoplectus californicus*), common three-square bulrush (*Scirpus pungens*), spikerushes (*Eleocharis spp.*), flatsedges (*Cyperus spp.*), cattails, white-topped sedge (*Rhyncospora coloratum*), paspalum grasses (*Paspalum spp.*), Gulf cordgrass, and other water-tolerant grasses. The more saline wetlands have more salt-tolerant species like shoregrass (*Distichlis littoralis*), saltgrass, sea oxeye daisy (*Borricchia frutescens*), Carolina wolfberry (*Lycium carolinensis*), seablight (*Sueda maritima*), and Gulf cordgrass. Most of the sand sheet region is used for livestock grazing and hunting. The sandy wetlands also support black-bellied whistling ducks (*Dendrocygna autumnalis*), mottled ducks (*Anas fulvigula*), least grebes (*Tachybaptus dominicus*), Virginia opossums (*Didelphis virginiana*), toads

(Bufonidae), and livestock. Development and livestock overgrazing currently threaten the sand sheet wetlands (Texas A&M AgriLife Extension, 2017e).

Seagrasses

Although seagrasses occur throughout the entire coast, about 75 percent of seagrasses occur within the Laguna Madre in the lower Texas coast (Handley et al., 2007). Shoalgrass (*Halodule wrightii*), turtlegrass (*Thalassia testudinum*), manateegrass (*Syringodium filiforme*), widgeongrass (*Ruppia maritima*), and clovergrass (*Halophilia engelmannii*) can all be found in shallow (generally <5 feet water depth depending on water clarity) Texas coastal water (TPWD, 1999). Although seagrasses are generally declining in most parts of the Texas coast, seagrass beds within the Upper Laguna Madre and Corpus Christi Bay have been generally expanding or are stable (Moulton et al., 1997). For example, between the 1950s and 2002 to 2004 within the Texas Barrier Island Coastal Bend, seagrass beds increased in area at Harbor Island and North Padre Island by 70 percent and 78 percent, respectively (Moulton et al., 1997) (Table 3-8).

Seagrass plays an important part in stabilizing the seafloor substrate and nutrient accumulation. Seagrass communities are an important part of the ecosystem generating high primary productivity and acting as nurseries for recreational and commercial fisheries such as red drum, brown shrimp, and black drum and foraging habitat for manatees, sea turtles, herons, and egrets. Threats to seagrass meadows include natural disturbances such as hurricanes and strong currents, and human impacts such as dredging channels, propeller damage from boats, urbanization, and pollution runoff.

Table 3-8. Seagrass information for bays along the Texas Coast

Location	Seagrass (acres)	Trends
Sabine Lake System	minimal to none	–
Galveston Bay	519	decreasing
Matagorda Bay	2,716	decreasing
San Antonio Bay System	10,638	decreasing
Corpus Christi Bay	6,346	fluctuates with inflow, stable
Upper Laguna Madre	55,456	increase since 1950s
Lower Laguna Madre	114,095	decrease since 1950s

Source: Handley et al. (2007), TPWD (1999).

3.6.2.2 Hydrology and Hydraulics

Hydrology is the science that deals with the properties, circulation and distribution of water on and under the surface of the earth and in the atmosphere from the amount of precipitation until it returns to the atmosphere through evapotranspiration or is discharged into the oceans. Hydraulics is the science that deals with practical applications of runoff flowing through a channel. Collectively, hydrology and hydraulics are referred to as "H&H".

Watersheds and Surface Water

The study area encompasses several major Texas river basins and eight coastal basins with each coastal basin named according to the major river basins that border them. These river and coastal basins include:

Upper Coast River and Coastal Basins: Sabine River Basin, Neches River Basin, Neches-Trinity Coastal Basin, Trinity River Basin, Trinity-San Jacinto Coastal Basin, San Jacinto River Basin, San Jacinto-Brazos Coastal Basin, Brazos River Basin, and the Brazos-Colorado Coastal Basin;

Middle Coastal River Basins: Brazos-Colorado River Basin (western portion), Colorado River Basin, Colorado-Lavaca River Basin, Lavaca River Basin, Lavaca-Guadalupe River Basin, Guadalupe River Basin, a portion of the San Antonio River Basin, and a small portion of the San Antonio-Nueces River Basin; and

Lower Coast Basins: Nueces-Rio Grande River Basin and the Rio Grande River Basin. The river basins vary greatly in size, length, flow, and precipitation making the Texas coast a diverse hydrologic environment. **Table 3-9** below summarizes a few key hydrologic parameters of the major river basins connected to the Texas coastal zone.

3.6.2.2.1 Upper Texas Coast (UTC)

Sabine River Basin

The Sabine River Basin straddles the Texas and Louisiana border. The basin is approximately 360 miles in length and has a total contributing area of 9,756 square miles with 76 percent of the river basin residing in Texas, and the remaining area residing in Louisiana (SRA, 2016). In Texas, the Sabine River Basin begins in Hunt County, flows southeasterly to Grocer Lake at the Texas-Louisiana border, and then flows south to the Sabine-Neches Estuary, commonly referred to as Sabine Lake (TWDB, 2016e). The Sabine Lake Estuary is part of the Neches-Trinity Coastal Basin and is formed by the confluence of the Sabine and Neches rivers. The Sabine Lake Estuary's 5-mile tidal outlet at Sabine Pass connects the lake to the Gulf, allowing for upstream drainage of flows from the Sabine River into the Gulf. The average annual precipitation within the Sabine River Basin ranges from 40 to 60 inches, with approximately 61 inches of precipitation per year received at the coast (TWDB, 2016d). The major contributing stream systems within the basin are the Sabine River, Lake Fork Creek, Big Sandy Creek, and Big Cow Creek. The major reservoirs in the basin are Lake Fork Reservoir, Lake Tawakoni, and Toledo Bend Reservoir. Toledo Bend Reservoir is the largest of the lakes with a surface area of 181,619 acres, with a normal impoundment capacity of 4,447,000 acre-feet (SRA, 2016). The water level within the Toledo Bend Reservoir fluctuates approximately between 1 and 5 feet (TPWD, 2018a).

Table 3-9 Texas River Basin Average Flows and Average Annual Precipitation

River Basin	Basin Area (square miles)	River Length (miles)	Average Flow (acre-feet per year)	Average Annual Precipitation (inches per year)
Sabine	9,756	360	5,864,000	60 at coast, range of 40–61
Neches	9,937	416	4,323,000	60 at coast, range of 41–60
Trinity	17,913	550	5,727,000	55 at coast, range of 29–60
San Jacinto	3,936	85	1,365,000	55 at coast, range of 44–56
Brazos	45,573	840	6,074,000	50 at coast, range of 17–54
Colorado	42,318	865	1,904,000	45 at coast, range of 13–41
Lavaca	2,309	117	277,000	45 at coast, range of 36–46
Guadalupe	5,953	409	1,422,000	35 at coast, range of 27–39
San Antonio	4,180	238	562,700	40 at coast, range of 27–39
Nueces	16,700	315	539,700	30 at coast, range of 22–31
Rio Grande	182,215	1,896	645,500	25 at coast, range of 8–21

Source: TWDB (2016c, 2016d).

The Sabine River Tidal segment is contained within Orange County and extends from the confluence with Sabine Lake to Morgan Bluff. The tidal segment is 29 miles long, and no water quality concerns have been identified by the TCEQ within this intertidal area. About midway upstream of the tidal segment is Blue Elbow Swamp. Canals and ditches, which were constructed in the early 1900s, have changed natural flow patterns within Blue Elbow Swamp, including the Little Cypress Bayou, which has been channelized through the swamp to the Sabine River for the purpose of reducing floods in developed areas (TCEQ, 2016b). On the south end of the tidal segment, the mouth of the Sabine River has the largest volume of water discharged of any Texas river, which is about 46.2 percent of the total annual mean inflow into the Sabine Lake Estuary of 14 million acre-feet (Sabine and Neches BBEST, 2009).

The sediment yield of the entire Sabine Lake Estuary region (including the Sabine and Neches rivers) is calculated to be approximately 14 tons per square mile per year. Most of the materials are likely to be organics, sediments derived from shoreline erosion, bedload sediments, sediments transported by marine and coastal processes, and fluvial inputs from local watersheds (Phillips and Slattery, 2007).

In 2012, the Sabine River Basin experienced extreme drought, which caused low lake and reservoir levels and low flows within the river and creeks throughout the basin but resulted in minor water restrictions and elevated bacteria levels (SRA, 2012; Texas Water Resources Institute, 2017).

Neches River Basin

The Neches River Basin is approximately 416 miles long and has a drainage area of 9,937 square miles (TWDB, 2016e). Beginning in southwest Van Zandt County, the river flows southeasterly through the pinewoods of east Texas, into highly industrialized areas in Orange and Jefferson counties, to its confluence with the Sabine River at the Sabine Lake Estuary and to the Gulf. The average annual precipitation ranges from 41 to 60 inches across the basin, and averages approximately 60 inches of precipitation per year at the coast (TWDB, 2016d). The major stream systems within the basin are the Neches River, the Angelina River, Attoyac Bayou, Village Creek, and Pine Island Bayou. There are four major reservoirs within the basin: Lake Palestine, B.A. Steinhagen Lake, Lake Tyler, and Sam Rayburn Reservoir, with the first two being along the Neches River itself (TCEQ, 2016a). Sam Rayburn Reservoir is the largest reservoir in the basin with a surface area of 114,500 acres and a maximum depth of 80 feet. The water level of the reservoir fluctuates by an average of 7 feet annually, which is more than any other major reservoir within the Neches River Basin (TPWD, 2016b). The Neches River Tidal segment runs from the confluence with the Sabine Lake Estuary to just upstream of Interstate Highway 10 in Orange County. The average discharge in the Neches River near the upper end of the tidally influenced river segment was 3,625 cubic feet per second (cfs) in 2014 (USGS, 2016a).

The Sabine Lake Estuary acts as the main link between the Neches River and the Gulf.

Neches-Trinity Coastal Basin

The Neches-Trinity Coastal Basin consists of a total drainage area of 769 square miles and a length of 132 miles. The basin is situated in eastern Texas, located in Jefferson and Chamber counties. The average annual precipitation in the basin is approximately 60 inches. Waterbodies within the basin include Taylor Bayou, Shallow Prong Lake, the GIWW, Alligator Bayou, Hillebrandt Bayou, and Willow Marsh Bayou. The Intracoastal Waterway Tidal segment stretches from the confluence with Galveston Bay in Galveston County to the confluence with the Sabine-Neches/Port Arthur Canal in Jefferson County. The tidal section includes the Taylor Bayou Tidal, 4.8 miles downstream of State Highway (SH) 73 in Jefferson County (TWDB, 2016d).

The Sabine Lake Estuary has an average salinity of 5 ppt, the lowest average salinity of any major Texas estuary. It receives freshwater inflows from its major rivers, the Sabine and Neches rivers, as well as from runoff from the surrounding coastal watersheds summing to approximately 14 million acre-feet per year on average (Sabine and Neches BBEST, 2009). Precipitation near the Sabine Lake Estuary ranges from approximately 54 to 60 inches per year and drains from an area of 45,320 acres (TWDB, 2016e). The water quality of the Sabine Lake Estuary is generally good (Sabine and Neches BBEST, 2009).

The Sabine-Neches Canal Tidal segment runs from the confluence with Sabine Pass at the southern tip of Pleasure Island to the Sabine Lake Seawall at the northern tip of Pleasure Island (Lower Neches Valley Authority, 2010). The dredging of canals and ditches in the area, such as the Sabine-Neches Waterway, has resulted in a disruption of the natural patterns of water flow in swamps. These navigation channels have also made it possible for salt water to intrude on the fresh water upstream. The Sabine-Neches Waterway extends from the Gulf through a channel to the cities of Port Arthur, Beaumont, and Orange, and continues through the Sabine River Channel (USACE, 2012b).

Trinity Water Basin

The Trinity River Basin begins near the Dallas-Fort Worth area, drains southeast to Trinity Bay and eventually into the Gulf (TWDB, 2016f). The Trinity River Basin is approximately 550 miles long and drains approximately 17,913 square miles including the large metropolitan areas of the city of Dallas, Fort Worth, and Houston. The major river systems in the basin include Cedar Creek, Clear Fork Trinity River, East Fork, Elm Fork Trinity River, Lower Trinity River, Main Stem Trinity River, Mountain Creek, Village Creek, Richland Creek, and West Fork Trinity River (Trinity River Authority [TRA], 2010).

The Trinity River Basin flow is highly variable. Precipitation in the lower portion of the basin is approximately 53 inches annually. During the summer months, flows in various streams throughout the basin are low, sometimes dry. The flows can be largely influenced by effluent discharge from industrial facilities and municipal wastewater plants as well as by releases from reservoirs (TRA, 2010).

Water control features along the Trinity River include reservoirs such as Benbrook, Grapevine, Lavon, Lewisville, Navarro Mills, Bardwell, Joe Pool, Ray Roberts, and Lake Livingston. Additional water diversions include exports to adjacent basins. An estimated 1,114 million gallons per day are taken from the Trinity River and exported to adjacent basins to meet increasing municipal and industrial water demands (TRA, 2010).

Most upstream sediment loads are captured by Lake Livingston and the Lake Livingston Dam. Lake Livingston surveys show sediment yields of 2 to 387 tons per square miles per year, with a mean of 275. The lower Trinity River has a high rate of alluvial sediment storage and acts as a bottleneck for sediment material to the river mouth (Phillips et al., 2004).

Trinity-San Jacinto River Basin

The Trinity-San Jacinto River Basin is a relatively small coastal plain with an area of 247 square miles from the headwaters in Walker County and flows south to Galveston County.

Precipitation in the basin ranges from 50 to 60 inches per year (TWDB, 2016d). The area receives inflows from its major rivers, the Trinity and San Jacinto rivers, as well as surface runoff from the surrounding coastal watersheds (TCEQ, 2016c). Another major source of fresh water to this basin is Goose Creek, which had an average discharge of 13.5 cfs in 2014 (USGS, 2016b).

San Jacinto River Basin

The San Jacinto River Basin is approximately 85 miles long and drains approximately 3,936 square miles, including the large metropolitan area of the city of Houston. The San Jacinto River Basin begins in Walker County and drains southeast to Galveston Bay (TCEQ, 2016d). The major river systems in the basin include the east and west fork of the San Jacinto River, Caney, Cypress, Peach and Spring Creek, and Luce and Buffalo bayous. Precipitation in the lower San Jacinto River Basin near the Gulf is estimated between 50 and 55 inches annually (TWDB, 2012, 2016b). Water control features along the San Jacinto River include reservoirs and lakes such as Addicks Reservoir, Barker Reservoir, Lake Conroe, Lake Houston, Lewis Creek Reservoir, Sheldon Reservoir, and Gulf Coast Water Authority Reservoir (TWDB, 2016g). Flow within the upper San Jacinto River Basin is controlled by releases from Lake Conroe and flows in the lower end of the basin are influenced by Lake Houston and Buffalo Bayou.

Rapid growth in the region has not only significantly increased demand on the water within the river, it has also increased the concentration of bacterial and nutrient loading in the river. Galveston Bay receives over 60 percent of the wastewater discharge (by volume) in the State of Texas, which has historically caused elevated levels of pollutants within Galveston Bay (Galveston Bay National Estuary Program, 1995). The watersheds of the east and west fork of the San Jacinto River have been placed on the EPA's 303(d) list of impaired waters due to its elevated levels of bacteria. The San Jacinto River flows into the Houston Ship Channel, where heavy boat and industrial activity further impair the water quality, contributing to the Houston Ship Channel being added to the 303(d) list of impaired waters due to the presence of PCB and Dioxins (Houston-Galveston Area Council [H-GAC], 2014). Flows from the San Jacinto River Basin ultimately drain into Galveston Bay, an estuary home to various fish and shellfish species (Texas Living Waters Project, 2013).

San Jacinto-Brazos River Basin

The San Jacinto-Brazos Basin is located between the San Jacinto and Brazos River basins and drains approximately 1,440 square miles. The main river systems within the basin include Armand Bayou, Bastrop Bayou, Chocolate Bayou, Clear Creek, Dickinson Bayou, Oyster Creek, and the Old Brazos River Channel. The San Jacinto-Brazos River Basin drains to various bays including West Bay, Clear Lake, Moses Lake, Chocolate Bay, Bastrop Bay, Christmas Bay, Drum Bay, Texas City Ship Channel, Bayport Channel, and Lower Galveston Bay. Annual precipitation in the basin is estimated between 35 and

70 inches (TWDB, 2016d). Sources of inflow to the streams in the basin include treated wastewater, industrial discharge, and urban runoff (TWDB, 2016d, 2016g).

Brazos River Basin

The Brazos River Basin begins in Lubbock County and flows to the Gulf near Freeport. The entire Brazos River Basin stretches 840 miles and drains approximately 45,573 square miles, which is the largest drainage area of all the basins in Texas (TWDB, 2016h; TCEQ, 2016e). Salt Fork, Double Mountain Fork, and Clear Fork are three of the major river systems that join the main stem of the Brazos River. The Brazos River itself has the largest average annual flow volume of the rivers in Texas. The Brazos River Authority Reservoir System includes Possum Kingdom Lake, Lake Granbury, and Lake Limestone. A fourth reservoir for the system is in the planning stages, Allens Creek. There are several more lakes in the basin whose primary purpose is flood control, Proctor, Whitney, Aquila, Belton, Stillhouse Hollow, Georgetown, Granger, and Somerville lakes. The levels of the lakes fluctuate based on water needs and climatic conditions (Brazos River Authority, 2016).

The Brazos River Tidal section runs approximately 25 miles from its confluence with the Gulf to SH 322 in Brazoria County. Flow just downstream of Lake Whitney averaged 3,516 cfs in 2015, and flow just downstream of Proctor Lake averaged 419 cfs in 2015 (USGS, 2016c, 2016d). The amount of suspended sediments has decreased since the mid-1980s due to dam and reservoir construction, changes in land use, and sand and gravel mining (Dunn and Raines, 2001).

Brazos-Colorado River Basin

The Brazos-Colorado River Basin is a region of flat coastal plains located between the Brazos and Colorado River basins. The basin drains approximately 1,850 square miles. The river systems within the basin are the San Bernard River and Caney Creek (TCEQ, 2016f).

3.6.2.2.2 Mid to Upper Texas Coast (MUTC) and Mid Texas Coast

The mid to upper and mid Texas coast (Galveston Bay system to Corpus Christi Bay) is also characterized by large bays and estuaries, with river inflows. Freshwater inflows in the mid-Texas coast decreases from north to south, where more fresh water contributes to Galveston and Matagorda bays, and less freshwater inflow is experienced in Corpus Christi Bay. The fresh water to salt marsh gradient is typically reduced in the mid-Texas coast relative to the upper Texas coast. Additionally, coastal prairie becomes more dominant, with less forested wetlands, as compared to the upper Texas coast (Moulton et al., 1997).

Colorado River Basin

The Colorado River Basin begins in Dawson County and drains southeast toward Matagorda Bay, eventually draining into the Gulf. It drains approximately 42,318 square miles. The Colorado River flows approximately 865 miles before draining into Matagorda Bay. Reservoirs and lakes along the Colorado River include Inks Lake, Lake Marble Falls, Lake Austin, Lake Travis, Lake Buchanan, and Lady Bird (formerly Town) Lake (TPWD, 2016c). The major river systems within the Colorado River Basin include the Concho, Llano, Pedernales, San Saba, Pecan Bayou, Beals Creek, Champion Creek, Elm Creek, Oak Creek, Onion Creek, and Redgate Creek (TWDB, 2016i). Precipitation in the Lower Colorado River Basin is estimated at over 45 inches in the Gulf Coast Plain near the Gulf (TWDB, 2012, 2016d). The stability of the ecosystems within Matagorda Bay rely predominantly on freshwater inflows from the Colorado River, Lavaca River, Navidad River, Tres Palacios Creek, and Lavaca Bay.

Colorado-Lavaca River Basin

The Colorado-Lavaca River Basin is located between the Colorado and Lavaca River basins. The basin drains approximately 939 square miles from Wharton County down to Tres Palacios Bay. The basin is primarily used for agriculture, urbanization, and industrialization. The main tributary within the basin is Tres Palacios Creek (TWDB, 2010).

Lavaca River Basin

The Lavaca River Basin begins in Fayette County, continues through the southern part of Jackson County, eventually making its way to Lavaca Bay. Precipitation in the basin is around 40 inches per year (TWDB, 2012). The two major river systems are the Lavaca and Navidad rivers. Navidad River upstream of Lake Texana had an average discharge of 558.9 cfs in 2015 (USGS, 2016e). The Lavaca River Basin has the smallest area in Texas (2,309 square miles) and the second shortest length, spanning 74 miles (TWDB, 2016c). The major reservoir within the Lavaca River Basin is Lake Texana, which has a surface area of 9,727 acres and maximum depth of 58 feet. The lake fluctuates up to 15 feet and has a tannin stained to muddy clarity (TPWD, 2016d).

The Lavaca River Tidal segment is 23 miles long and stretches from the confluence with Lavaca Bay in Calhoun/Jackson County to a point 5.3 miles downstream of U.S. Highway 59 in Jackson County (TCEQ, 2017a).

Lavaca-Guadalupe River Basin

The Lavaca-Guadalupe River Basin begins along the border of DeWitt and Victoria counties and flows in a southeastern direction to its confluence with San Antonio Bay in Calhoun County. Average annual precipitation is approximately 42 inches (TWDB, 2016b). The major river systems within the basin include the Guadalupe River, Garcitas Creek, Victoria Barge Canal, Marcado Creek, and Arenosa Creek. The basin has a drainage area of 998 square miles including the principal drainage system, the Victoria Barge Canal (TWDB, 2016d).

Guadalupe River Basin

The Guadalupe River Basin begins in southwestern Kerr County and flows southeasterly to Guadalupe Bay, which is part of the San Antonio Bay system. The average annual precipitation in the basin is approximately 35 inches on the Texas coast (TWDB, 2016d). The major river systems within the basin are the Guadalupe River, Blanco River, San Marcos River, Plum Creek, and Coleto Creek (TCEQ, 2016g). The Guadalupe River Basin stretches 409 miles and has a drainage area of 5,953 square miles (Bureau of Economic Geology [BEG], 1996). The two major reservoirs along the Guadalupe River are Canyon Lake and Coleto Creek Reservoir (TCEQ, 2016g). Canyon Lake is the larger of the two reservoirs with a surface area of 8,308 acres and a maximum depth of 125 feet. The lake is also spring fed and lake levels fluctuate moderately (TPWD, 2016e).

The Guadalupe River Tidal segment stretches from the confluence with Guadalupe Bay in Calhoun/Refugio County to the Guadalupe-Blanco River Authority Saltwater Barrier, 0.4 mile downstream of the confluence of the San Antonio River in Calhoun/Refugio County. The average discharge in the Guadalupe River just upstream of the Salt Water Barrier was 619.2 cfs in 2014 (USGS, 2016f).

The Eagle Ford Shale, a geologic formation that is being tapped to extract oil and natural gas, lies underneath the DeWitt and Gonzales counties within the Guadalupe River Basin (Eagle Ford Shale, 2015). The concentration of oil and gas wells along the shale requires the consumption of large amounts of water during the recovery of petroleum resources. Consequently, water demands have been affected by the hydraulic fracturing industry within the watershed (Guadalupe-Blanco River Authority, 2013).

San Antonio River Basin

The San Antonio River Basin begins in Kerr and Medina counties and drains southeast toward the Gulf. The entire San Antonio River Basin drains approximately 4,180 square miles, including the large metropolitan area of the city of San Antonio. The major river systems include the San Antonio River, Medina River, Leon Creek, Salado Creek, and Cibolo Creek. The longest river in the basin is the San Antonio River, which flows approximately 240 miles before it drains into the Guadalupe River, upstream of San Antonio Bay (Lower San Antonio River Sub-Basin Study Design Workgroup, 2009). Water diversions along the San Antonio River include reservoirs and lakes such as Calaveras Lake, Medina Lake, Olmos Reservoir, and Victor Braunig Lake (USGS, 2001).

Precipitation in the Lower San Antonio River Basin near the Gulf is estimated between 35 and 40 inches annually (TWDB, 2012, 2016b). Based on USGS gauge data from 1924 to 2017, it is estimated that the San Antonio River (at USGS Gauge 8188500) has had an average discharge of 1,079 cfs (USGS, 2016g). Flows from the San Antonio River Basin ultimately drain into San Antonio Bay. The stability of the ecosystems within the bay rely predominantly on freshwater inflows from the San Antonio and Guadalupe rivers. TPWD data indicate that recent heavy drought in Texas has led to an increase in salinity within the bay (Stanzel and Dodson, 2014). Water in the bay flows to the Gulf through Pass Cavallo, Aransas Pass, and Cedar Bayou (USGS, 2001).

San Antonio-Nueces River Basin

The San Antonio-Nueces River Basin is located between the San Antonio and Nueces River basins. The basin drains approximately 3,100 square miles from Karnes County down to Copano Bay and Aransas Bay along the Gulf coast. The two largest river systems within the basin are the Aransas and Mission rivers, which flow approximately 28 miles and 41 miles, respectively. Additional tributaries include Aransas Creek and Poesta Creek (Nueces River Authority, 2010).

Nueces River Basin

The Nueces River Basin extends from Edwards County to Nueces Bay in the Gulf near Corpus Christi. The main river systems within the basin include the Atascosa and Frio rivers, which converge into the Nueces River. Branching from these major rivers are tributaries, such as San Miguel Creek, Hondo Creek, Sabinal River, and Leona River. The basin stretches 315 miles and has a drainage area of 16,700 square miles. The major reservoirs along the Nueces River include Choke Canyon Reservoir and Lake Corpus Christi covering 47,891 surface acres (TCEQ, 2016h). Choke Canyon Reservoir is the larger of the two reservoirs, receiving an average of 49.8 cfs from San Miguel Creek and 187.9 cfs from the Frio River (USGS, 2016h, 2016i).

The Nueces River Tidal section starts at the confluence with Nueces Bay in Nueces County for 12 miles to Calallen Dam in Nueces/San Patricio County. Part of the Nueces and its tributaries flows into the crevices of the Edwards Aquifer Balcones Fault Zone resulting in stream flows that consists mostly of stormwater downstream of the recharge zone (TCEQ, 2016h). The water levels in the artesian zone have decreased due to drought and water demand, negatively impacting habitats that rely on flows from the San Marcos and Comal springs (USACE, 2012c).

3.6.2.2.3 Lower Texas Coast (LTC)

Nueces-Rio Grande Basin

The Nueces-Rio Grande Basin is located between the Nueces River and the Rio Grande basins. The basin drains approximately 10,442 square miles from Webb County down to the Laguna Madre, Baffin Bay, and Oso Bay along the Gulf coast. The two largest river systems in the basin are Petronila Creek and Arroyo Colorado River, which flow approximately 58 miles and 89 miles, respectively (Nueces River Authority, 2010).

Rio Grande Basin

The Rio Grande Basin begins as snow melt in the southern Colorado Rockies and drains southeast towards the Gulf. The Rio Grande Basin is approximately 1,901 miles long and drains approximately 333,500 square miles, including areas within Mexico (International Boundary and Water Commission [IBWC], 2016). The Rio Grande is split into three main reaches: Upper Rio Grande, Middle Rio Grande, and Lower Rio Grande (New Mexico Office of the State Engineer, 2016a). The Lower Rio Grande extends from Elephant Butte

Dam to the Gulf. Contributing ephemeral streams include Las Animas Creek, Cuchio Negro, and Percha Creek. Flows in the Lower Rio Grande are controlled by releases from Elephant Butte and Caballo reservoirs (New Mexico Office of the State Engineer, 2016b). Water diversion between Mexico and the United States between Elephant Butte and Fort Quitman, south of El Paso, utilizes all the available surface water in the section of the Rio Grande. Flows south of Fort Quitman is comprised predominantly by surface runoff from the surrounding basin (U.S. Bureau of Reclamation and Rio Grande Regional Water Authority, 2013).

Precipitation within the basin ranges from approximately 10 inches per year in the Trans-Pecos region in west Texas to over 25 inches in the Lower Rio Grande Valley near the Gulf (TWDB, 2012).

Primary demands on the water within the river come from municipal and agricultural use. Approximately 75 percent of the water in the Rio Grande is currently allocated for agricultural use (IBWC, 2016). Several segments of the Rio Grande have been listed as Section 303(d) impaired streams. Along with water quality concerns, increasing demand on water and abundance of invasive aquatic species in the Rio Grande has jeopardized the stability of ecosystems along the river, particularly those supporting endangered species (New Mexico Office of the State Engineer, 2016c).

3.6.2.3 Groundwater

The major aquifer spanning the Texas coast from the Louisiana border to the Mexico border is the Gulf Coast Aquifer. The Gulf Coast Aquifer is comprised of three main aquifers: the Chicot, the Evangeline, and the Jasper Aquifers (TWDB, 2016j). The Gulf Coast Aquifer covers an area of approximately 41,879 square miles. Availability of fresh water in 2010 was approximately 1,825,976 acre-feet per year. Rapid growth in the region has caused an increase in withdrawal of water from the aquifer, reducing water levels up to 350 feet and causing subsidence throughout the aquifer (TRA, 2010).

3.6.2.3.1 Upper Texas Coast (UTC)

The upper coast study area overlies the Gulf Coast Aquifer. In Texas, the aquifer parallels the Gulf coastline from Louisiana to the border of Mexico, and contains various interconnected layers, some of which are aquicludes (impervious clay or rock layers). From bottom to top, the four main water-producing layers are the Catahoula, Jasper, Evangeline, and Chicot with the Evangeline and Chicot being main sources of fresh groundwater in the region. The maximum total sand thickness of the Gulf Coast Aquifer ranges from 700 feet in the south to 1,300 feet in the north. Freshwater saturated thickness averages about 1,000 feet. The principal source of fresh groundwater in the upper coast area is precipitation. Most precipitation runs off and becomes streamflow or evaporates immediately. Only a small fraction of rainfall infiltrates to the aquifer’s zone of saturation. A large percentage of the water that reaches the zone of saturation rapidly returns to the surface as spring water, which supports the base flow of area streams. The availability of groundwater sources for domestic supply or recreational use throughout most of the study area is limited due to saltwater intrusion, which is a significant source of natural contamination, especially in the deeper Gulf Coast aquifer layers, because of the proximity to the Gulf. Under normal conditions, a layer of salt water underlies the lighter freshwater layer with a well-defined interface between the two layers. At any point, especially near the coast, deeper aquifers may be filled with salt water, very shallow aquifers may contain all freshwater, and an intermediate aquifer may be contained in the interface between the two.

3.6.2.4 Water Quality

Section 305(b) of the Clean Water Act (CWA) requires states to assess surface and ground water quality and prepare comprehensive reports documenting water quality, which states submit to the USEPA biannually. In addition, Section 303(d) of the CWA requires states to prepare a list of impaired waters based on Total Maximum Daily Loads of pollutants and specify corrective actions. The Texas Commission of Environmental Quality enforces state water quality standards and prepares the state's comprehensive report for submittal to USEPA.

The Texas Surface Water Quality Standards establish explicit goals for the quality of streams, rivers, lakes, and bays throughout the state. The Standards are developed to maintain the quality of surface waters in Texas so that it supports public health and enjoyment and protects aquatic life, consistent with the sustainable economic development of the state.

Water quality standards identify appropriate uses for the state's surface waters, including aquatic life, recreation, and sources of public water supply (or drinking water). The criteria for evaluating support of those uses include dissolved oxygen, temperature, pH, dissolved minerals, toxic substances, and bacteria. Statewide standards may be revised on a site-specific basis when sufficient information is available.

The TCEQ has individually defined and assigned a unique identification number to surface waters in the state. The major surface waters of the state are grouped into 25 basins, with each basin assigned a number. The waters are further separated into segments, with each segment having relatively homogeneous chemical, physical, and hydrological characteristics. A water quality segment provides a basic unit for assigning site-specific water quality standards, based on designated uses, for implementing a watershed-based approached to water quality management programs. Segments are identified as classified or unclassified. Classified waters include most rivers and their major tributaries, major reservoirs, bays, estuaries, and the Gulf of Mexico. Classified segments refer to water bodies that have designated uses defined in the Texas Surface Water Quality Standards (TSWQS) and are protected by general or site-specific water quality criteria and screening levels. Unclassified waters are usually the smaller waterbodies and tributaries where data may be lacking or is not available, and where designated uses are not defined in the TSWQS. The state presumes a high aquatic life use designation for unclassified waters, and these waters are protected by the general standards and screening levels corresponding to the high aquatic life use designation until data is available or generated through a Use Attainability Analysis study or otherwise.

The State of Texas' Commission on Environmental Quality has released the 2020 Texas Integrated Report of Surface Water Quality and the 2020 Texas 303(d) list. These can be found at the department's website:

https://www.tceq.texas.gov/waterquality/assessment/305_303.html.

The following discussion provides an overview of coastal water quality in the context of water quality standards and the past focus on monitoring impacts of regulated discharges. Information about waterbodies discussed below is derived primarily from comparison of water quality monitoring conducted by the state and its partners to established criteria and screening concentrations (TCEQ, 2015a). These categories of water quality impacts are included in the water quality descriptions that follow:

Bacteria levels that are elevated or exceed criteria (TCEQ, 2014): Water quality criteria for bacteria are set to protect humans from encountering pathogenic organisms while engaged in recreational activities in, on, or around waterbodies (EPA, 2001). These criteria are also set to prevent humans from ingesting pathogenic organisms with the consumption of oysters and other shellfish. Although these criteria are used to regulate disinfection of municipal treated wastewater and nonpoint source pollution from animal production facilities, elevated bacteria levels may have natural causes associated with warm-blooded wildlife using waterbodies.

Nutrients, nitrates, and phosphorus: The TCEQ has not established water quality criteria for nutrients in estuaries, but it has identified screening-level concentrations intended to indicate possible nutrient enrichment (TCEQ, 2012, 2014). Concern for elevated nutrients is based on their potential contribution to harmful algal blooms, phytoplankton blooms that lead to low dissolved oxygen conditions, and epiphytic growths of algae that can smother seagrasses (EPA, 2001).

Dissolved oxygen criteria (TCEQ, 2014): Bacterial utilization of ammonia and carbonaceous compounds from treated wastewater and nonpoint sources of pollution can depress oxygen concentrations in waterbodies to levels harmful to aquatic life (EPA, 2001).

Toxic substances: Water quality criteria (TCEQ, 2014) have been established for a wide variety of heavy metals and synthetic organic compounds to prevent toxicity in water to aquatic organisms and minimize the bioaccumulation of these contaminants to levels hazardous to aquatic biota and humans. Fish consumption advisories are included below, which have been issued by the TDSHS. Fish consumption advisories remain in effect until adequate data have been collected and analyzed indicating there is no longer a threat to human health.

Water and sediment quality along the Texas coast are measured by various agencies and organizations. Freshwater inflow to Texas estuaries reflects the pattern of decreasing rainfall rates from east to west across the State. Sabine Lake receives more freshwater inflow than any other estuary in the State. The Laguna Madre in south Texas is one of a handful of hypersaline lagoons in the world where evaporation rates frequently exceed freshwater inflow (Tunnell and Judd, 2002).

Dramatic swings in freshwater inflow and sediment and nutrient loading occur in Texas estuaries. Extended droughts with reduced freshwater inflow are punctuated by episodic, severe flooding from tropical storms and hurricanes, which tends to occur in late summer and early fall. Since that time, the State of Texas has studied freshwater inflows and has estimated how much fresh water is delivered to each estuary.

A list of 303(d) waters for counties within the study area may be found here: https://www.tceq.texas.gov/waterquality/assessment/305_303.html.

3.6.2.4.1 Upper Texas Coast (UTC)

The greater Galveston Bay area encompasses three separate classified water quality segments within Basin 10 of the San Jacinto River Basin: San Jacinto River Tidal (Segment 1005), Tidal (Segment 1006), and Buffalo Bayou Tidal (Segment 1007). There are also several water quality Segments in Basin 24 of the Bays and Estuaries. These segments have multiple designated uses including High Aquatic Life Use (ALU), Recreation Use (RU), General Use (GU), Fish Consumption Use (FCU), and Oyster Waters Use (OWU). Overall, segments with an Aquatic Life Use Designation meet minimum Dissolved Oxygen (DO) levels. All segments have nutrient concerns (e.g. nitrate-nitrite, ammonia, or phosphorus), which exceed state screening levels but do not meet the definition of “impaired.” Seven of twelve segments list Chlorophyll α as a concern. Two segments do not meet OWU designation due to bacteria levels, while another segment partially meets the OWU designation. This does not mean that oysters cannot be harvested or consumed from these areas. It means that after certain weather events like heavy rain that certain health department restrictions apply on harvested oysters before being sold for consumption. None of the tidal segments of the river basins listed above meets FCU as the Texas Department of State Health Services (DSHS) has imposed fish consumption advisories. These advisories are due to high levels of either polychlorinated biphenyls (PCB) and/or dioxins in edible fish tissue. This does not mean that all fish have consumption advisories; only that certain fish like catfish have recommended limits for weekly or month consumption. In conclusion, the only impairments in the study area are the OWU and FCU. All other parameters used to assess the designated uses of each segment, particularly DO, have met the minimum levels established in the State standards.

Studies have been conducted on sediments in the greater Galveston Bay area for possible contaminants. Sediment throughout the area shows the presence of constituents of concern. However, extensive historical sediment testing has shown Effects Low Range (ELR) exceedances to be relatively rare, and concentration trends have been decreasing.

Water quality criteria, desired uses, and nutrient and chlorophyll a screening criterion were generally met in water and sediment samples throughout the Sabine and Neches coastal system. Bacterial levels exceeded criteria at some locations, and dissolved oxygen in some coastal waters were below criteria. The Neches River Tidal had one measurement of the pesticide, malathion, exceeding its criterion in water (TCEQ, 2015a). A fish consumption advisory has been issued for the area that recommends limiting consumption of Gafftopsail Catfish (Bagre marinus) due to polychlorinated biphenyl (PCBs) contamination (TDSHS, 2011). Fish consumption advisories remain in effect until the state evaluates new data indicating pollutant concentrations are below levels believed hazardous to humans.

The GIWW between Sabine Lake, Galveston Bay, and the Sabine-Neches Ship Channel each exceeded bacteria criteria on one occasion. The tidally influenced reach of Taylor Bayou in the same area also exceeded bacteria criteria on one occasion and chlorophyll a criterion in several samples. Lead in sediment higher than recommended criteria was detected in nine samples in Alligator Bayou (TCEQ, 2015a).

Gulf near-shore waters in Jefferson and Chambers counties had some bacteria and chlorophyll a measurement above criteria (TCEQ, 2015a).

The Trinity River and San Jacinto River watersheds and the coastal basin between the San Jacinto and Brazos rivers contribute flow to much of the north end of the Galveston Bay complex. Elevated nutrients, chlorophyll a, and bacteria were found in some of these tidal streams, particularly near urbanized watersheds. The tidal reach of Greens Bayou had elevated pesticide levels (DDT and DDD) in sediment. Patrick Bayou, in its tidally influenced reach, had toxic sediments and mercury and hexachlorobutadiene in sediment above criteria. The tidal reach of Vince Bayou also had toxicity measured in sediments (TCEQ, 2015a).

The Galveston Bay ecosystem experiences a variety of water quality issues. During the assessment period, many of the primary bays, secondary bays, and tidal streams had elevated bacteria, chlorophyll a, nutrients, bacteria above suitable levels for oyster-harvest waters, and depressed oxygen levels. High copper in water was also found in Clear Lake. Elevated concentrations of nutrients and low oxygen appeared most frequently in estuaries near urbanized watersheds (TCEQ, 2015a). Protected and restored wetlands may play a role in managing pollutant loading from increasingly urbanized watersheds (Novitzki et al., 1997). Bays further from human development (i.e., Christmas Bay) had high nutrients and bacteria less frequently. Although concentrations of nutrients and chlorophyll a exceed screening criteria used by TCEQ, ammonia, total phosphorus, and chlorophyll a declined from 1987 to 2009 in the Galveston Bay system (Lester and Gonzalez, 2011).

The tidally influenced reach of the Brazos River experienced some chlorophyll a measurement above screening criteria. The San Bernard River where it is tidally influenced had bacteria and chlorophyll a level above criteria. The tidal waters of Caney

Creek in the Sargent area exhibited low oxygen and elevated bacteria levels (TCEQ, 2015a).

Two widespread fish consumption advisories have been issued for the Galveston Bay system:

- Fish and Shellfish Consumption Advisory 50 applies to all portions of the Galveston Bay complex in Brazoria, Chambers, Galveston, and Harris counties because of dioxins and PCBs in all catfish species, spotted seatrout, and blue crab in Upper Galveston Bay and dioxins and PCBs in all species of catfish in Galveston Bay including Chocolate Bay, East Bay, Trinity Bay, and West Bay (TDSHS, 2013a).
- Fish and Shellfish Consumption Advisory 55 applies to the Houston Ship Channel and adjoining waters including the San Jacinto River below Lake Houston in Harris County because of dioxins and PCBs in all fish species and blue crab (TDSHS, 2015).

3.6.2.4.2 Mid to Upper Texas Coast (MUTC)

Along the middle to upper coast in the Matagorda/Lavaca Bay complex, some areas had elevated bacteria and oxygen levels below criteria (TCEQ, 2015a). A fish and crab consumption advisory are in effect for portions of Lavaca Bay due to mercury contamination (TDSHS, 2000).

East Matagorda Bay had bacteria above suitable levels for oyster-harvest waters while no water or sediment quality issues were identified in the Matagorda Bay/Powderhorn Lake complex (TCEQ, 2015a). In the Tres Palacios Bay area, low oxygen was detected in Tres Palacios Harbor. Bacteria above suitable levels for oyster-harvest waters and bacteria above the recreational assessment criteria were also found. Water or sediment issues were not identified around the Lavaca and Chocolate bay systems except for some areas with bacteria above suitable levels for oyster-harvest waters. Keller Bay also had some bacteria measurements above suitable levels for oyster-harvest waters. Low oxygen was measured in the tidal reach of Garcitas Creek. Carancahua Bay exhibited some measurements with elevated bacteria, total phosphorus, chlorophyll a, and bacteria above suitable levels for oyster-harvest waters. West Carancahua Creek in its tidal reach had some oxygen levels below criteria (TCEQ, 2015a).

The tidally influenced reach of the Colorado River had nitrate levels above screening levels. Oxygen levels were occasionally depressed, and chlorophyll a was sometimes high in Tres Palacios Creek's tidal reach (TCEQ, 2015a).

The TDSHS (2000) issued a revised fish consumption advisory for a portion of Lavaca Bay prohibiting the take of all fish and crabs because of mercury contamination. Concentrations of mercury in water were below the TCEQ human health criterion for saltwater fish in the 2.5 square mile portion of Lavaca Bay included in the TDSHS advisory during sampling conducted in 2002 and 2003 (Gill, 2004).

3.6.2.4.3 Mid Texas Coast (MTC)

San Antonio Bay to the Aransas Bay complex including Espiritu Santos Bay in the east and Copano Bay to the west did not exhibit water quality issues. Bacteria above suitable levels for oyster-harvest waters were occasionally high in San Antonio, Hynes, Guadalupe, Copano, Port, and Mission bays (TCEQ, 2015a).

Elevated chlorophyll a was detected in Little Bay. St. Charles Bay exhibited occasional depressed oxygen levels. Some recreational beaches in Corpus Christi Bay had bacteria levels above criteria. Elevated copper in water was detected in Nueces Bay and Conn Brown Harbor. The Corpus Christi Inner Harbor, with limited mixing, sometimes had nitrates and ammonia above screening criteria. Oso Bay and Oso Creek on the south side of Corpus Christi Bay had high bacteria, nitrates, total phosphorus, and chlorophyll a and low oxygen levels at times. The Victoria Barge Canal had several measurements of chlorophyll a and nitrates above screening levels (TCEQ, 2015a).

The Guadalupe River's tidal reach had some measurements of elevated nitrates. The tidal portions of the Mission and Aransas rivers each had one bacteria sample exceeding the recreational criterion. The tidally influenced part of the Nueces River experienced elevated chlorophyll a on several occasions (TCEQ, 2015a).

3.6.2.4.4 Lower Texas Coast (LTC)

The tidal reach of the Arroyo Colorado has more water quality issues than other estuarine waters in this region. Extensive stretches of the Arroyo have elevated bacteria, nitrates, and chlorophyll a contributing to low oxygen levels (TCEQ, 2015a). This area has extensive row crop agriculture and some of its tributaries also exhibit occasional elevated ammonia, nitrates, chlorophyll a, and bacteria (Arroyo Colorado Watershed Partnership, 2007). Petronila Creek where it is influenced by tides experiences high concentrations of bacteria, pH, total phosphorus, and chlorophyll a. The tidal Rio Grande had occasional chlorophyll a and nitrates above screening concentrations (TCEQ, 2015a).

The Laguna Madre north of the Arroyo Colorado sometimes has low oxygen and chlorophyll a above screening criteria. Near its confluence with the Arroyo Colorado, the Laguna Madre had measurements of bacteria, including bacteria above suitable levels for oyster-harvest waters, chlorophyll a, nitrates, and ammonia above criteria. The Laguna Madre south of the Arroyo Colorado has also had episodes of depressed oxygen. The Baffin Bay complex has had high levels of chlorophyll a. Tidal tributaries to that complex have had elevated bacteria, chlorophyll a, total phosphorus, and nitrates. The Brownsville Ship Channel occasionally had low oxygen levels and elevated bacteria. The Port Isabel Fishing Harbor also had elevated bacteria levels (TCEQ, 2015a).

3.7 BIOLOGICAL RESOURCES

The Galveston Bay estuary habitat types include uplands, wetlands, open-bay water, open-bay bottom, oyster reefs, sea grass meadows, and intertidal mud flats. Existing habitat within the proposed project footprint includes developed and urbanized land, armored and natural shorelines, beaches, tidal flats, brackish to saltwater wetlands, submerged aquatic vegetation (SAV), oyster reefs, uplands, sand dunes, coastal prairie, and Chenier plains (USFWS, 2017a). The South Padre Island measure is located on South Padre Island, which consists of sand dunes, beach, grasslands, marshes, and tidal flats (NPS, 2018). The ER measures are located through the lower, middle, and upper Texas Coast. Habitats found within the ER measures include developed and urbanized land, armored and natural shorelines, tidal flats, brackish to saltwater wetlands, SAVs, dunes, uplands, oyster reefs, hypersaline lagoon, barrier islands, coastal prairie, sand dunes, beaches, mudflats, and bottomland hardwood forests (USFWS, 2017a).

3.7.1 Regulatory Framework

There are several laws, executive orders, and regulations that provide oversight of fish and wildlife and their habitats. These are further described in section 3.8 and in Chapter 6.0. The following describe laws and executive orders that apply to a broad range of wildlife and vegetative communities:

- **Fish and Wildlife Coordination Act:** The Act requires Federal agencies to first consult with USFWS and in some instances National Marine Fisheries Service (NMFS), as well as state fish and wildlife agencies regarding potential impacts on fish and wildlife resources, and measures to mitigate these impacts.
- **Executive Order 13112 on Invasive Species:** The EO directs Federal agencies to prevent the introduction and control the spread of invasive species. Invasive species are defined by the EO as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health."

3.7.2 Existing Conditions

Blair (1950) categorizes Texas into seven biotic provinces: the Austroriparian, Texan, Tamaulipan, Chihuahuan, Navahonian, Kansan, and Balconian. The study area is located within the Austroriparian (upper Texas coast), Texan (upper to mid Texas coast), and Tamaulipan (lower Texas coast) Biotic Provinces.

The Austroriparian Biotic Province is situated in the eastern border of Texas and extends southward to Galveston County on the Gulf coast. Habitat in this province is typically wetter and more forested than the lower Gulf coast. According to Blair (1950), at least 47 mammal species, 29 snake species, 10 lizard species, 2 land turtle species, 17 anuran (frogs and toads) species, and 18 urodele (salamanders and newts) species occur within the region.

The Texan Biotic Province stretches from Galveston Bay to western Calhoun County (Blair, 1950). Regional climate is moist subhumid with some excess rainfall. Wildlife habitats include beach, shell ramp-barrier flats, dredged material, saltwater marsh, brackish to freshwater marsh, fresh to brackish lakes, inland freshwater marsh, grassland, and riparian forest (McGowen et al., 1976). The Texan Biotic Province supports a diverse fauna composed of a mixture of species common to neighboring provinces. At least 49 species of mammals are known to have occurred in the Texan province in recent times, in addition to over 300 avian species, 39 snake species, 16 lizard species, 2 land turtle species, 18 anuran species, and 5 urodele species (Blair, 1950).

The Tamaulipan Biotic Province regional climate is semiarid and hot with little moisture for plant growth. The vertebrate fauna of the region is typified by neotropical and plains species. Wildlife habitats include upland prairies, salt marshes, tidally influenced lowlands, barrier islands, saline lagoons, and coastal prairies. According to Blair (1950) there are 61 mammalian species, over 300 avian species, 38 species of snakes, 19 species of lizards, and at least 5 species of amphibians.

3.7.2.1 Habitats

3.7.2.1.1 Coastal Wetlands (Marshes)

Wetlands are areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. The Texas coast has a highly diverse coastal wetland community. Vegetative communities found in the area are indicative of saline, brackish, intermediate, and freshwater wetlands and marshes. Coastal marsh habitats provide important functions of improving water quality in the estuarine ecosystem, providing flood control benefits and buffering inland habitats from tropical storm-generated tidal surges. In addition, marshes are extremely biologically productive and diverse and provide detrital input, which is the basis for the estuarine food chain.

Salt marshes experience the greatest daily tidal fluctuation of the marsh types and have well developed drainage systems. Water salinity averages 18 parts per thousand, which leads to a marsh type with the least diverse vegetation. Smooth cordgrass/oystergrass (*Spartina alterniflora*) typically dominate salt marshes and are often accompanied by seashore saltgrass (*Distichlis spicata*), blackrush (*Juncus roemerianus*), saline marsh aster (*Symphiotrichum tenuifolium*) and marshhay cordgrass. Glasswort dominates high salt marshes where tidal inundation is less frequent.

Brackish marshes (salinity range of 5.0 to 18.0 ppt with an average of about 8.0 ppt) grade inland from salt marsh and are found at the fringes of large water bodies and behind the beach barriers. This marsh type is also subjected to daily tidal action, but also receives some freshwater influence, and its water depths normally exceed that of salt marsh. Water salinity ranges from 5.0 to 18.0 ppt with an average of about 8.0 ppt. Plant diversity is greater than that of salt marshes. The dominant species in low brackish marsh is saltmarsh bulrush (*Bolboschoenus robustus*), while seashore saltgrass and marshhay cordgrass are co-dominant species in high brackish marsh.

Intermediate marshes are subjected to periodic pulses of saltwater and maintain a year-round salinity in the range of 3 to 4 ppt. They grade inland from brackish marsh and dominate interior marshes. The diversity and density of plant species are relatively high with marshhay cordgrass the most dominant species in high marshes. Co-dominant species in low marsh are seashore paspalum (*Paspalum vaginatum*), Olney bulrush (*Schoenoplectus americanus*), California bulrush/giant bulrush (*S. californicus*), and common reedgrass/Roseau cane (*Phragmites australis*); bulltongue (*Sagittaria lancifolia*) and sand spikerush (*Eleocharis montevidensis*) are also frequent. Submerged aquatics such as pondweeds and southern waternymph (*Najas guadalupensis*) are abundant in intermediate marsh.

Freshwater marshes lie between the intermediate marsh and the coastal prairies and dominate in upstream reaches of the Neches River. This marsh type is normally free of tidal influence and has year-round average water salinity of 0.5 to 1.0, and rarely increases above 2.0 ppt, with slow drainage. The greatest diversity of plants is supported by fresh marsh, with local species composition governed by frequency and duration of flooding, topography, substrate, hydrology, and salinity. Co-dominant species in low marsh are maidencane (*Panicum hemitomon*), giant cutgrass (*Zizaniopsis miliacea*), and bulltongue. Codominant species in high marsh are squarestem spikerush (Eleocharis quadrangulata) and marshhay cordgrass. Many submerged and floating-leafed plants are present in this marsh type. Other characteristic species include American lotus, watershield (*Brasenia schreberi*), duckweed (*Lemna spp.*), and fanwort (*Cabomba caroliniana*).

Brackish and saline marshes provide important year-round habitat for many shorebird and colonial-nesting waterbird species, and are the primary nursery habitat for larval and post-larval stages of many commercially and recreationally-important fish and shellfish species, including white and brown shrimp (*Litopenaeus setiferus* and *Farfantepenaeus aztecus*), blue crab (*Callinectes sapidus*), red drum (*Sciaenops ocellatus*), flounder (*Paralichthys ssp.*), and speckled sea trout (*Cynoscion nebulosus*). Some of the more common mammals using coastal marshes include raccoon (*Procyon lotor*), river otter (*Lutra canadensis*), bobcat (*Lynx rufus*), nine-banded armadillo (*Dasypus novemcinctus*), swamp cottontail rabbit (Sylvilagus aquaticus), Virginia opossum (*Didelphis virginiana*), muskrat (*Ondatra zibethicus*), nutria (Myocaster coypus), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), and feral hog.

Common reptiles include American alligator, western cottonmouth (*Agkistrodon piscivorus*), speckled kingsnake (*Lampropeltis getula*), red-eared slider (*Trachemys scripta*), and snapping turtle (*Chelydra serpentina*). Amphibians are absent in the areas south of the GIWW within the focused study area due to impacts from tidal salinity exacerbation in former fresh and intermediate marshes. Common amphibians north of the GIWW include the pig frog (*Rana grylio*), southern leopard frog (*R. sphenocephala*), Gulf Coast toad (*Bufo valliceps*), and bullfrog.The lesser siren (*Siren intermedia*) and three-toed amphiuma (*Amphiuma tridactylum*) are probably common though seldom-seen amphibians found in freshwater marshes. Other amphibians common to marsh habitats are the green treefrog (Hyla cinerea), eastern narrow-mouthed toad

(*Gastrophryne carolinensis*), Great Plains narrow-mouthed toad (*G. olivacea*), Blanchard's cricket frog (*Acris crepitans blanchardi*), squirrel treefrog (*H. squirella*), and the bronze frog (*R. clamitans*).

Invertebrate populations are an essential food resource for migratory birds and estuarine fish species. Various amphipods, midges, mysid shrimp, grass shrimp, crayfish, and numerous crabs are present within all marsh habitats in the study area. Some of these invertebrates occur in tremendous quantities. Mosquitoes, biting flies, chiggers, and imported fire ants (*Solenopsis invicta*) are also common. Common butterfly species include monarch (*Danaus plexippus*), little yellow (*Pyristitia lisa*), and Gulf fritillary (*Agraulis vanillae*) butterflies. Common dragonfly species include the common green darner (*Anax junius*) and seaside dragonlet (*Erythrodiplax berenice*). Native rangia clams (Rangia cuneata) historically occurred throughout the focused study area, thriving in intermediate and brackish marshes, but have been reduced in numbers by saltwater intrusion throughout the system. Periwinkle snails (Littoraria irrorata) are found in the salt marshes and in the brackish marsh with the higher salinity levels where smooth cordgrass has become established. Fiddler crabs (*Uca sp.*) are found from the high tide line in high marshes to the intertidal zone across portions of the project area.

Wetland Trends

The estuarine gradients and freshwater inflows can vary in each coastal ecoregion, and these variables affect the type and extent of wetlands present (**Figure 3.2**). Similarly, seagrasses can vary across each coastal ecoregion. The Texas Gulf coast has generally been losing estuarine (saltwater) intertidal wetlands since wetlands were first mapped in the 1950s, although some gains have been observed near the San Bernard NWR region (Moulton et al., 1997; White et al., 2006). Losses of estuarine emergent wetlands (marshes) are due to subsidence, RSLR, and ecological succession to estuarine intertidal scrub-shrub (mangrove) wetlands and conversion to open water or upland. Losses approached approximately 1,600 acres per year from 1955 to 1992. **Table 3-10** summarizes the changes in estuarine intertidal wetlands, including emergent scrub-shrub and non-vegetated (tidal flats) from 1955 to 1992 (Moulton et al., 1997).

White et al. (2006) provides additional information that also indicates regional differences in wetland trends from 1950s to 2002. General wetland trends data by region include:

- Approximately 30 percent loss of estuarine marsh within the Brazos River Delta region;
- Approximately 27 percent increase of estuarine marsh within the San Bernard NWR region; and
- Approximately 31 percent loss of estuarine marsh within the Caney Creek area.

Table 3-10. Estuarine Intertidal Wetland Loss and Gain Trends on the Texas Gulf Coast

Year	Intertidal Emergent (acres)	Intertidal Scrub-Shrub (acres)	Intertidal Non-Vegetated (acres)
1955	387,211	2,563	236,414
1992	355,632	4,966	205,972
Net Change	–31,579	+2,403	–30,442
Average Loss or Gain per Year	–853	+65	–823

Source: Moulton et al. (1997).

3.7.2.1.2 Non-Tidal Wetlands within the Study Area

Riverine Forested Wetlands

Riverine forested wetlands are found on the floodplains of rivers and large streams. The main source of water for this habitat is from overtopped riverbanks and flooding.

Prairie Potholes and Marshes

Prairie potholes and marshes occur on the prairie from just west of Beaumont to the Rio Grande. These wetlands once covered vast expanses of prairie before urbanization and agriculture destroyed most of them. Approximately 30 percent of prairies were once wetlands. The difference between a pothole and a marsh is mainly size; marshes occur in larger and generally less well-defined depressions than potholes.

On the upper coast, potholes and marshes occur in complexes with pimple mounds (small hummocks 1 to 2 feet tall) and intermound flats. This complex pattern, formed thousands of years ago by ancient rivers and bayous, has been modified through time by climatic (especially wind) and biotic forces. Potholes and marshes maintain their hydrology through direct precipitation, runoff from adjacent flats, and occasionally local groundwater. Prairie potholes and pimple mounds provide habitat for a variety of wildlife and plants such as cattails, buttonbush (*Cephalanthus occidentalis*), black willow, water lilies (*Nymphaea spp.*), American alligator, American bullfrogs (*Rana catesbeiana*), ribbon snakes (*Thamnosis spp.*), wading birds, shorebirds, waterfowl, butterflies (Lepidoptera), and dragonflies (Odonata). During periods of drought, wildlife can be found concentrated around the potholes. Today urban sprawl and agricultural fill threaten prairie potholes and marshes. Since the 1950s, more than 29 percent (235,000 acres) of freshwater marshes have been lost (Texas A&M AgriLife Extension, 2017d).

The coastal sand sheet wetlands covers parts of Kleberg, Kenedy, and Willacy counties was formed from sand blown in from the Gulf coast and shaped by the wind.

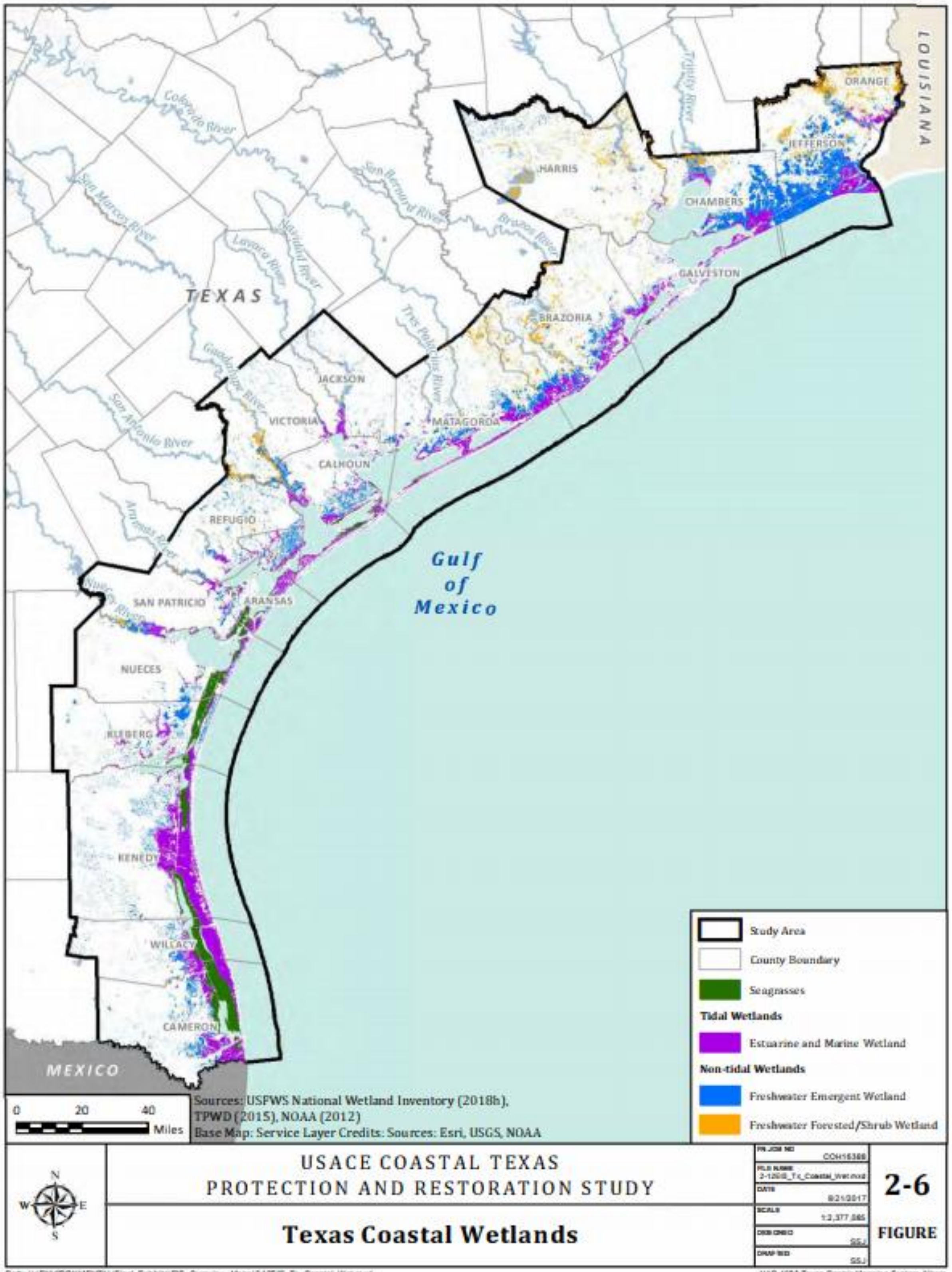


Figure 3-2 Texas Coastal Wetlands

3.7.2.1.3 Upper Texas Coast

The Texas Gulf coast is highly complex and ecologically diverse, with obvious differences in geomorphology between the upper, mid, and lower coast. Within the upper Texas coast (Sabine Lake to the Galveston Bay system), wetland systems are like southwestern Louisiana marshes, where the elevational gradients are gradual, freshwater inflows are relatively higher, and salinity gradients are extended (with freshwater wetlands inland transitioning into brackish and intermediate marsh, and the gradient ending in the tidal salt marshes within the bays) (Moulton et al., 1997).

Within the upper Texas coast, swamps are the wettest type of forested wetlands and are typically persistently inundated, located from east Houston to Louisiana (Mitsch and Gosselink, 2007). The dominant vegetation is bald cypress, water tupelo (*Nyssa aquatica*), water hickory (*Carya aquatica*), planertree (*Planera aquatic*), and willow oak (*Q. phellos*). Yaupon (*Ilex vomitoria*), sugarberry (*Celtis laevigata*), dwarf palmetto (*Sabal minor*), and elm can be found in the understory. Bottomland hardwood forests are also part of this complex and are flooded less frequently than swamps. Bottomland hardwood forests are dominated by willow oak, water oak (*Q. nigari*), overcup oak (*Q. lyrata*), cherrybark oak (*Q. pagoda*), laurel oak (*Q. laurifolia*), green ash (*Fraxinus pennsylvannica*), red maple (*Acer rubrum*), black willow (*S. nigra*), water tupelo, and others. Understory vegetation often consists of dwarf palmetto, Cherokee sedge (*Carex cherokeensis*), deciduous holly (Ilex decidua), yaupon, and many others.

Coastal flatwood wetlands are unique forested wetlands found between the Louisiana border and the Houston area. Longleaf and loblolly pines (*Pinus palustris* and *P. taeda*, respectively) and hardwood trees are commonly found within the drier parts of the wetland, while willow (*Salix spp.*), laurel oak, swamp chestnut oak (*Q. michauxii*), and dwarf palmetto are found in wetter areas. The soil is typically loamy with a claypan subsoil below 30 inches. Precipitation and run-off inundate the wetlands keeping soils wet during the winter and early spring and dry the rest of the year. Historically, these wet and upland areas experience regular fire to maintain pine dominance. The biggest threats to these wetlands are from the timber industry, which can overharvest pine trees and hardwoods (Texas A&M AgriLife Extension, 2017b)

3.7.2.1.4 Mid to Upper Texas Coast and Mid Texas Coast

The upper-mid and mid-Texas coast is also characterized by large bays and estuaries, with river inflows. Freshwater inflows in the mid-Texas coast decreases from north to south, where more fresh water contributes to Galveston and Matagorda bays, and less freshwater inflow is experienced in Corpus Christi Bay. The fresh water to salt marsh gradient is typically reduced in the mid-Texas coast relative to the upper Texas coast. Additionally, coastal prairie becomes more dominant, with less forested wetlands, as compared to the upper Texas coast (Moulton et al., 1997).

On the mid coast, pecan hickory (*Carya illinoensis*), elms, water oak, live oak, green ash, common hackberry (*Celtis occidentalis*), sugarberry, and sycamore (*Platanas* *occidentalis*) often dominate the forests; the understory is like that of the upper coast. Salamanders (Urodela), bald eagles (*Haliaeetus leucocephalus*), white-tailed deer, barred owls (*Strix varia*), American beavers (*Castor canadensis*), river otters (*Lutra canadensis*), swamp rabbits (*Sylvilagus aquaticus*), and bass and sunfishes (Centrarchidae) feed, nest, and roost in this habitat. Agriculture, timber harvesting, swamp draining, human development, and changes to hydrology has decreased forested wetlands. Forested wetlands are one of the most threatened ecosystems. Since the 1950s Texas has lost more than 96,000 acres (about 11 percent) (Texas A&M AgriLife Extension, 2017a).

3.7.2.1.5 Lower Texas Coast

The lower Texas coast is characterized by the Upper and Lower Laguna Madre, which is one of the few hypersaline lagoons in the world. Wind-tidal flats, lower rainfall, low and flat elevation, the Rio Grande delta, and arid rangeland are also defining characteristics of the lower Texas coast (Tunnell and Judd, 2002).

The lower coast riparian wetlands are unique forested wetlands associated with riverine areas from the San Antonio River to southern Texas. These freshwater, depressional wetlands are maintained by river runoff and regular flooding events and provide habitat for belted kingfishers (*Megaceryle alcyon*), rails (Rallidae), green treefrogs (*Hyla cinerea*), rare ocelots, and Gulf coast jaguarundis. Plants found within the riparian areas are common hackberry, retama (*Parkensonia accumulata*), huisache, Texas ebony (*Ebonopsis ebano*), and dwarf palmetto. The riparian corridors are threatened due to overgrazing, channel dredging, water diversion, damming of rivers upstream, and invasive plant species (Texas A&M AgriLife Extension, 2017c).

The coastal sand sheet that covers parts of Kleberg, Kenedy, and Willacy counties was formed from sand blown in from the Gulf coast and shaped by the wind. The topography of the area is generally flat but with rolling vegetated dunes, blowouts, and wetlands (Carr, 2007). Because of the dry climate, most of the water supplied to the wetlands is from groundwater percolating through the sandy soils. These wetlands support plant assemblages that reflect the range of salinity found in these depressions. The fresher wetlands have species like California bulrush (*Schoenoplectus californicus*), common three-square bulrush (*Scirpus pungens*), spikerushes (*Eleocharis spp.*), flatsedges (*Cyperus spp.*), cattails, white-topped sedge (*Rhyncospora coloratum*), paspalum grasses (*Paspalum spp.*), Gulf cordgrass, and other water-tolerant grasses. The more saline wetlands have more salt-tolerant species like shoregrass (*Distichlis littoralis*), saltgrass, sea oxeye daisy (*Borricchia frutescens*), Carolina wolfberry (*Lycium carolinensis*), seablight (*Sueda maritima*), and Gulf cordgrass. Most of the sand sheet region is used for livestock grazing and hunting. The sandy wetlands also support black-bellied whistling ducks (*Dendrocygna autumnalis*), mottled ducks (*Anas fulvigula*), least grebes (*Tachybaptus dominicus*), Virginia opossums (*Didelphis virginiana*), toads (Bufonidae), and livestock. Development and livestock overgrazing currently threaten the sand sheet wetlands (Texas A&M AgriLife Extension, 2017e).

3.7.2.1.6 Tidal Wetlands within the Study Area

Estuarine Wetlands

Estuarine wetlands are tidally influenced wetlands that occur throughout the Texas Gulf coast; however, estuarine wetlands are on a declining trend due to sea level rise, subsidence, and hydrological modifications (Moulton et al., 1997; Mitsch and Gosselink, 2007). Estuarine or tidal wetlands can range from being vegetated marshes, to unvegetated mud and barren sand flats found on the bay side of the coastal barrier islands (Texas A&M AgriLife Extension, 2017f).

Barrier Island Interior Wetlands

The Texas barrier islands were created about 4,000 years ago from wave action and sediment deposition from rivers and creeks. Coastal winds and waves created ridges, troughs, and flats between sand dunes where water could collect.

Seagrasses

Seagrass can be found along the Texas Gulf coast between the coastal barrier islands and mainland. There is approximately 235,000 acres of seagrass in Texas (TPWD, 1999).

Upper Texas Coast, Mid to Upper Texas Coast, and Mid Texas Coast

Estuarine emergent wetlands are mostly concentrated at the upper and mid-Texas coast; estuarine shrub-scrub wetlands were most abundant in the mid-Texas coast in Espiritu Santo Bay, south of Port O'Connor, and at the southern end of South Padre Island (Moulton et al., 1997).

Padre Island is the longest undeveloped barrier island in the world. Island interior wetlands provide an important source of fresh water for species. Although these wetlands are primarily fresh water, storm events and extreme tides occasionally introduce salt into these barrier island wetlands. Wetland plants are similar to those found in other freshwater marshes but may include some brackish-water species due to elevated soil salinity and occasional tidal inundation in some areas. Typical species include saltmeadow cordgrass, cattails, bulrushes, coastal water-hyssop (*Bacopa monnieri*), pennywort (*Hydrocotyle spp.*), spikerushes, flatsedges, sedges (*Carex spp.*), burhead (*Echinodorus spp.*), marsh fimbry (*Fimbristylis castanea*), white-topped sedge, frogfruit (*Phyla nodiflora*), seashore paspalum (*Paspalum vaginatum*), bushy bluestem (*Andropogon glomeratus*), and other grasses. The availability of fresh water attracts species of frogs (Ranidae), turtles (Testudines), raccoons (Procyon sp.), feral pigs (*Sus scrofa*), waterfowl, wading birds, and shorebirds (Texas A&M AgriLife Extension, 2017g).

Lower Texas Coast

Estuarine unvegetated flats are more common around the lower Texas coast in the Lower Laguna Madre. Some of these tidal wetlands are subject to daily tidal ranges (i.e., low salt marsh), where others are only subject to tidal influence during high tides or storm events (i.e., high salt marsh); the upper and lower limits of the tidal range control the extent and location of estuarine wetlands. Freshwater inflows and sea water also maintain the salinity of the marsh and influence plant community composition (NOAA, 2017d). These wetlands can be a few feet wide where the intertidal range is thin due to shoreline geomorphology or can occupy large areas covering thousands of acres (Texas A&M AgriLife Extension, 2017f). Relative to the tidal range and salinity gradients transitioning from fresh to saline, marsh types include brackish and intermediate, which occur at tidal elevations between the mean high-water line and the annual high tide line, and salt marsh, which occur at tidal elevations between the mean tide line and the mean high tide line (NOAA, 2017d)

Fringing the Laguna Madre are unique tidal wetland areas consisting of broad, nearly unvegetated wind-tidal flats. These wind-tidal flats are not regularly flooded by tides. They are only occasionally flooded when strong winds push shallow water from the Laguna onto the low flats, or during annual high tides. The cycle of irregular flooding and drying causes salt to build up on the surface of the flats (Tunnell and Judd, 2002). These wind-tidal flats are inhospitable to most vascular plants but are often covered by vast mats of blue-green algae. These habitats may look barren, but they support rich invertebrate populations that, in turn, attract large numbers of shorebirds and wading birds (Texas A&M AgriLife Extension, 2017f). They are considered a “Special Aquatic Site” under 40 CFR 230. The unique processes that result in wind-tidal formations only exist in several locations worldwide, including the Persian Sea, Red Sea, and eastern Mediterranean Sea (Morton and Holmes, 2009).

3.7.2.1.7 Beaches and Dunes

Beaches are the transition from land to sea. In the lower portion of the beach where sediments are covered frequently by water, aquatic organisms thrive. However, in areas at and just above the high tide zone, conditions are particularly harsh. The lack of water makes life difficult for aquatic or terrestrial species, and the dry sand is easy to heat and cool, resulting in strong swings in temperature. In oceanfront dunes, this high beach area also experiences strong swings in salinity, from highly saline conditions during dry weather caused by salt spray being concentrated by evaporation, to being diluted of salt during intense rains. Therefore, except in specialized habitats (such as the wrack line, where rotting organic material forms both food and a mechanism for water storage), very few animals and no true plants can live in this zone.

In the wrack zone (base of supratidal zone), a small oasis of life in the otherwise dry and barren sand forms. Here, the debris (e.g. seashells, animal remains, decomposing seaweed and sea grasses, and other materials) left by the high tide forms a narrow band along the shore. The rich organic content of this area provides a reservoir of water and food for the animals found in this area. Species present are usually cryptic species that emerge from the sand at night or when the tide is high, but only in the small number of areas where a significant sand veneer is present over the clay ridges. Some of the species include crabs, sand hoppers/beach fleas, worms, beetles, spiders, and flies. Because of the abundance of arthropods and worms, the wrack zone is prime foraging habitat for shorebirds. Shorebird counts are conducted along the Texas Coast between March 22 and May 17 during two-week intervals. The most abundant species observed are typically American avocet (*Recurvirostra americana*), western sandpiper (*Calidris mauri*), long-billed and short-billed dowitchers (*Limnodromus scolopaceus* and *L. griseus*, respectively), semipalmated sandpiper (*C. pusilla*), pectoral sandpiper (*C. melanotos*), black-bellied plover (*Pluvialis squatarola*), dunlin (*C. alpine*), sanderling (*C. alba*), willet (*Catoptrophorus semipalmatus*), semi-palmated plover (*Charadrius semipalmatus*), least sandpiper (*C. minutilla*), and snowy plover (*Charadrius alexandrines*). Common nesting shorebird species include the willet, killdeer (Charadrius vociferous) and black-necked stilt (*Himantopus mexicanus*). Colonies of nesting birds including least terns (*Sterna antillarum*) and black skimmers (*Rynchops niger*) occur on beaches and washover terraces.

Texas beaches change shape regularly and move landward (retreat) or seaward (advance) in response to wind, waves, currents, the short and long-term relative sea level rise, and the supply of sand. However, in the focused study area, short-term changes can be variable and long-term changes, combined with a well-documented lack of coarse-grained sand supply, and long-term sea level rise generally creates a long-term retreat scenario. Shoreline retreat has accelerated from historic rates of -20 feet per year to as much as -40 feet per year in some parts of the focused study area.

The backbeach and dune is a more productive habitat than other areas in the shoreline system. Both contain a mosaic of salt-tolerant plants, which are adapted to shifting sands, high winds, and rising waters. These plants help form dunes by trapping wind-blown sand, while their roots help stabilize the dunes and protect the dune from erosion. Species found growing here include seapurslane (*Sesuvium portulacastrum*), saltmeadow cordgrass/ marshhay cordgrass, (*Spartina patens*), bitter panicum (*Panicum amarum*), Virginia dropseed (*Sporobolus virginicus*), white morninglory (*Ipomoea stolonifera*), camphor daisy (*Rayjacksonia phyllocephala*) goat-foot morninglory (*I. pescaprae*), glassworts (*Salicornia spp.*), sea-lavender (*Limonium carolinianum*), and busy sea-ox-eye (*Borrichia frutescens*). The beach ridge that separates the Gulf from interior marshes historically was sufficiently high enough to prevent sea water inundation from the Gulf of Mexico except for significant storm surge episodes associated with tropical storms and hurricanes. The frequency of such inundation was on the order of years to a decade or more. However, the frequency of storms producing significant wave energies has increased exacerbating the eroded shoreface and exposed clay pan. Because this area is sand starved, normal non-storm wave energies meant to nourish the beach continues to erode the shoreface. The historic dune system has been removed over the years by ongoing annual erosion, unseasonably high tides, and large-scale storm events and hurricanes, which has resulted in the loss of approximately 54% of the dune system leaving approximately 12 miles of dunes. In 2008, Hurricane Ike flattened much of the remaining beach ridge and moved a significant amount of sand outside the active profile reducing the dune crest to an elevation that now routinely allows sea water inundation into the formerly fresh and brackish marsh.

3.7.2.1.8 Open Bay Habitats

Saline open water habitat is generally shallow and turbid and not likely to support any rooted vascular plants. Phytoplankton are the most likely plant or animal species to occur in this habitat. Salinity in open water habitats have a significant influence on plant and animal community composition. The salinity gradient supports high floral and faunal species.

The open bay is comprised of phytoplankton and nekton. Phytoplankton (microscopic algae) are the major primary producers (plant life) in the open bay, taking up carbon through photosynthesis and nutrients for growth. Phytoplankton are fed upon by zooplankton (small crustaceans), fish, and benthic consumers. Nekton assemblages (organisms that swim freely in the water column) consist mainly of secondary consumers, which feed on zooplankton and smaller nekton (Armstrong et al., 1987; Britton and Morton, 1989). Diverse and abundant phytoplankton and nekton communities occur throughout the entire study area and are discussed below.

Texas bay systems support a diverse nekton population including fish, shrimp, and crabs. Some of these are resident species, spending their entire life in the bay, whereas others are migrant species spending only a portion of their life cycle in the estuary (Armstrong et al., 1987). Many of these species are estuarine-dependent, migrating through passes of the Gulf to use the submerged aquatic vegetation of the estuarine systems in the bay system as nursery habitat (Tunnel and Judd, 2002).

Dominant nekton species inhabiting Texas estuaries include blue crab, white shrimp, brown shrimp, pink shrimp (*Farfantepenaeus duorarum*), Atlantic croaker, bay anchovy, code goby (*Gobiosoma robustum*), black drum, Gulf menhaden, hardhead catfish, pinfish (*Lagodon rhomboides*), sheepshead (*Archosargus probatocephalus*), silversides, southern flounder (*Paralichthys lethostigma*), spot (*Leiostomus xanthurus*), and spotted seatrout (Nelson et al., 1992; Pattillo et al., 1997). These species are ubiquitous along the Texas coast and are unaffected by salinity changes. Seasonal differences occur in abundance with the fall usually the lowest in biomass and number. Newly spawned fish and shellfish begin migrating into the bays in winter and early spring with the maximum biomass during the summer (Parker, 1965).

Open-bay bottom in Texas bay systems include all unvegetated subtidal areas with various sediment types. They are open systems that greatly interact with the overlying waters and adjacent habitats (Armstrong et al., 1987; Tunnel and Judd, 2002). Benthic organisms are divided into two groups: epifauna, such as crabs and smaller crustaceans, which live on the surface of substrate, and infauna, such as mollusks and polychaetes that burrow into the substrate (Green et al., 1992). Mollusks and other infaunal organisms are filter feeders that strain suspended particles from the water column. Other infauna, such as polychaetes, feed by ingesting sediments and extracting nutrients. Many of the epifauna and infauna feed on plankton, which are fed upon by numerous fish and birds (Armstrong et al., 1987; Lester and Gonzales, 2011).

Upper Texas Coast

Phytoplankton in Sabine Lake are comprised primarily of both fresh water and marine diatoms and green algae. Species composition changes seasonally with minimum abundance occurring in the winter and maximum in the summer. Zooplankton are most abundant during the summer and early fall, coinciding with higher salinities. The dominant species is the copepod Acartia tonsa, with several other marine copepods also present. Commensurate with higher salinities, the higher numbers are found in the lowest reaches of the estuary. Freshwater species, including rotifers and cladocerans, are the dominant taxa near the mouth of the rivers. Abundance of zooplankton is lowest in the winter and spring and highest in the summer and fall, which is the opposite in other estuaries (with the exception of Galveston Bay) (Armstrong et al., 1987).

Galveston Bay has the highest primary productivity of all Texas bays (Armstrong et al., 1987). Phytoplankton, including diatoms, green algae, blue-green algae, dinoflagellates, euglenoids, cryptophytes, and golden-brown algae are the primary producers of the open bay. They take up carbon by photosynthesis and pass it through the food chain to the primary consumers, zooplankton and phytoplanktivorous (plant-eating) fishes (Armstrong et al., 1987; Sheridan et al., 1989; Lester and Gonzalez, 2011). Zooplankton consists mainly of copepods, cladocerans, chaetognaths, and larval stages of fish, shrimp, and crabs. They are important because they are the basis of the food chain and are the source of food for all larval and juvenile fish. Zooplankton are limited by turbidity (which limits the phytoplankton production and therefore food availability) and currents that can carry them out to sea and away from concentrated food masses. It appears that zooplankton production in Galveston Bay is also directly related to water temperature and inversely related to salinity (Armstrong et al., 1987).

The Beaumont-Port Arthur area bay system includes Sabine Lake. Mud and sandy mud are the dominant sediment types in the system. Generally, muds occupy the slightly deeper eastern half of Sabine Lake, whole sandier sediments occur in the western half. Benthic macroinvertebrates found in these sediments are primarily polychaetes, bivalves, gastropods, and crustaceans (White et al., 1987).

The Galveston-Houston area bay system includes the Galveston, Trinity, East, and West bays. Mud and sandy mud are the dominant sediment types in this system, with sand at bay margins. Sandy sediments are associated with flood-tidal deltas at Bolivar Roads and San Luis Pass and with modern barrier islands. Benthic macroinvertebrates found in these sediments are primarily polychaetes, bivalves, gastropods, and crustaceans (White et al., 1985).

Mid to Upper Texas Coast

In Lavaca Bay, phytoplankton species composition changes seasonally with maximum abundance occurring in the winter and minimum in the summer, dominated by diatoms. Zooplankton are most abundant during the spring, with the minimum occurring in the fall. The dominant species are the copepod *Acartia tonsa* and *Barnacle nauplii*. They are important because they are important food for larval and juvenile fish. Zooplankton are limited by turbidity (which limits the phytoplankton production and therefore food availability) and currents, which can carry them out to sea and away from concentrated food masses (Armstrong et al., 1987). It is expected that plankton assemblages in Matagorda Bay would be like those of Lavaca Bay.

The Bay City-Freeport area bay system includes the Matagorda, East Matagorda, and Tres Palacios bays. Mud and sandy mud are the dominant sediment types in this system, with sandier sediments occupying the bay margins of Matagorda Peninsula and locally along bay margins. Benthic macroinvertebrates found in these sediments are primarily polychaetes, bivalves, gastropods, and crustaceans (White et al., 1988)

Mid Texas Coast

In Aransas Bay, diatoms make up most phytoplankton assemblages composed mainly of *Coscinodiscus spp.* in the winter and *Rhizosolenia alata* in the summer. Blue-green and green algae dominate the upper portions of the Mission-Aransas Estuary, whereas diatoms dominate the lower. Diatoms (*Thalassionema nitzschioides, Thalassiothrix frauenfeldii,* and *Chaetoceros spp.*) make up over 70 percent of the phytoplankton community in Corpus Christi Bay. In Nueces Bay and the Upper Laguna Madre, the same diatoms dominate abundance, especially during the winter months, followed by the dinoflagellate *Ceratium furca* (Tunnell et al., 1996). Areas of the Upper Laguna Madre, where salinities exceeded 60 ppt, had few to no plankton present (Armstrong et al., 1987).

The Port Lavaca area bay system includes Powderhorn Lake, and the Matagorda, Caranchua, Lavaca, Keller, Cox, Chocolate, Espiritu Santo, San Antonio, Hynes, Guadalupe, Mesquite, and Aransas bays. Mud and sandy mud are the dominant sediments types in this bay-estuary-lagoon system. Benthic macroinvertebrates found in these sediments are primarily polychaetes, bivalves, gastropods, and crustaceans (White et al., 1989a).

The Corpus Christi area bay system includes the Laguna Madre, and the Corpus Christi, Nueces, Oso, Redfish, Aransas, Copano, Port, and Mission bays. Mud is the dominant sediment type throughout this bay-estuary-lagoon system; however, sandier sediments occur along bay margins and are found in higher abundance in the Laguna Madre and Redfish Bay. Benthic macroinvertebrates found in the sediments of this bay-estuary-lagoon system are primarily pelecypods, gastropods, crustaceans, and polychaetes (White et al., 1983)

Lower Texas Coast

Due to the lack of freshwater inflow and the resulting high salinities, the Lower Laguna Madre is relatively phytoplankton free. Diatoms dominate phytoplankton collections in the Lower Laguna Madre with highest densities at stations with lower salinities and lowest densities at stations with salinities above 30 ppt (Armstrong et al., 1987; Tunnel and Judd, 2002). In the Bahia Grande, dominant plankton assemblages consist of green algae, such as diatoms and cyanobacteria, which are highest in the winter and spring (Hicks et al., 2010). Red algae and floating Sargassum are also common in the Lower Laguna Madre (Tunnel and Judd, 2002).

With respect to the Upper and Lower Laguna Madre, the hypersaline waters can affect fish osmotic balance and decrease dissolved oxygen; however, fish occupying these areas are euryhaline (able to tolerate a wide range of salinities) and better able to cope with the harsh conditions (Gunter, 1967).

The Kingsville area bay system is comprised of the Laguna Madre, Baffin Bay, and Alazan Bay. Mud, sand, and muddy sand are the dominant sediment types. Benthic macroinvertebrates found in the sediments of the bay-estuary-lagoon system are primarily polychaetes, bivalves, gastropods, and crustaceans (White et al., 1989b).

The Lower Laguna Madre and South Bay systems include flat areas of mud and sand that contribute large quantities of nutrients and food, making these substrates some of the most important components of this habitat type. The distribution of the benthic macroinvertebrates is primarily influenced by bathymetry and sediment type. Benthic macroinvertebrates found in the sediments of the Lower Laguna Madre are primarily polychaetes, bivalves, gastropods, and crustaceans (White et al., 1986).

3.7.2.1.9 Oyster Reef

Eastern oysters (*Crassostrea virginica*) are present in all bay systems from Sabine Lake to Corpus Christi Bay, and South Bay (**Figure 3-3**). They provide ecologically important functions. Few oysters are present in the Upper Laguna Madre, Baffin Bay, or Lower Laguna Madre. Oyster reefs are formed where a hard substrate and adequate currents are plentiful. Currents carry nutrients to the oysters and take away sediment and waste filtered by the oyster. Most oyster reefs are subtidal or intertidal and found near passes, cuts, and along the edges of marshes. Oysters can filter water 1,500 times their own volume per hour, which, in turn, influences water clarity and phytoplankton abundance (Lester and Gonzalez, 2011; Powell et al., 1992). Due to their lack of mobility and their tendency to bioaccumulate pollutants, oysters are an important indicator for detecting contamination (Lester and Gonzalez, 2011).

While oysters can survive in salinities ranging from 5 to over 40 ppt, they thrive from 10 to 25 ppt, which is the level where pathogens and predators are limited. The lower salinity is critical for osmotic balance. Oysters can survive brief periods of salinities less than 5 ppt by remaining tightly closed. Oysters will remain closed until normal salinities return or until they deplete their internal reserves and perish. In contrast, oyster drills (*Thais haemastoma*), welks (Buccinidae), and crabs' prey on oysters during long periods of high salinities. *Perkinsus marinus* (Dermo) is the most common and deadly oyster pathogen in the bays and is a primary factor affecting habitat suitability (Cake, 1983).

Many organisms, including mollusks, barnacles, crabs, gastropods, amphipods, polychaetes, and isopods, live on oyster reefs, forming a very diverse community (Sheridan et al., 1989). Oyster reef communities are dependent upon food from the open bay and marshes. Many organisms feed on oysters including black drum, crab, and gastropods, such as the oyster drill (Lester and Gonzales, 2011; Sheridan et al., 1989). When oyster reefs are exposed during low tides, shore birds will use the reef areas for resting (Armstrong et al., 1987).

In Texas, all molluscan shellfish must be harvested from areas that have been approved or conditionally approved as designated by the TDSHS (2016). This status is subject to change to prohibited or restricted by the TDSHS at any time due to extreme weather conditions, oil spills, and red tides. Currently, oysters are approved for harvesting from the following bay systems: Galveston, West Galveston, Freeport area, East Matagorda, Matagorda, Lavaca, San Antonio, Espiritu Santo, Copano, Aransas, Mesquite, Corpus Christi, Lower Laguna Madre, and South bays (TDSHS, 2016). However, the majority (over 90 percent) of oysters harvested commercially and recreationally come from the Galveston, Matagorda, and San Antonio bay systems (TPWD, 2016f).

The eastern oyster populations living in South Bay are genetically distinct from other oysters inhabiting the Texas coast and have adapted to the hypersaline conditions (Tunnel and Judd, 2002). This population is thought to be a remnant of when the Rio Grande flowed into the area (White et al., 1986).

Globally, an estimated 85 percent of oyster habitat has been lost with the remaining populations in poor condition, and in the last 100 years there has been an estimated 88 percent decline in oyster biomass in the United States (Baggett et al., 2014). Gulf oyster landings are the highest in the world; however, overall oyster biomass and abundance has suffered serious declines (Beck et al., 2011; Zu Ermgassen et al., 2012). This decline has been mainly due to overharvesting; however, other factors include coastal development and dredging causing habitat loss or degradation, diseases, sedimentation, and pollution (Coen and Luckenbach, 2000; Beck et al., 2011; Baggett et al., 2014).

Galveston Bay is an example where historically oyster shell was commercially harvested as construction material to build roads. Oyster shell was removed from the bay, some of which were live, greatly reducing the oyster reef habitat area. This practice was prohibited in 1969 and oyster reefs have been increasing since. In response to the decline in oyster populations, restoration activities have increased to help prevent further loss of these habitats. Additionally, Hurricane Ike in 2008 covered 60 percent of oyster reef habitat in Galveston Bay as the storm surge moved through; it is still unknown how long it will take reefs to recover (Lester and Gonzales, 2011).

Many organisms, including mollusks, plychaetes, barnacles, crabs, gastropods, amphipods, and isopods, can be found living on the oyster reef, forming a very dense community. Oyster reefs are dependent upon food resources from the open bay and marshes. Many organisms feed on oysters including fish, such as black drum (*Pogonias cromis*), crabs (*Callinectes spp.*), and gastropods such as the oyster drill. When oyster reefs are exposed during low tides, shore birds use the reef areas as resting places.

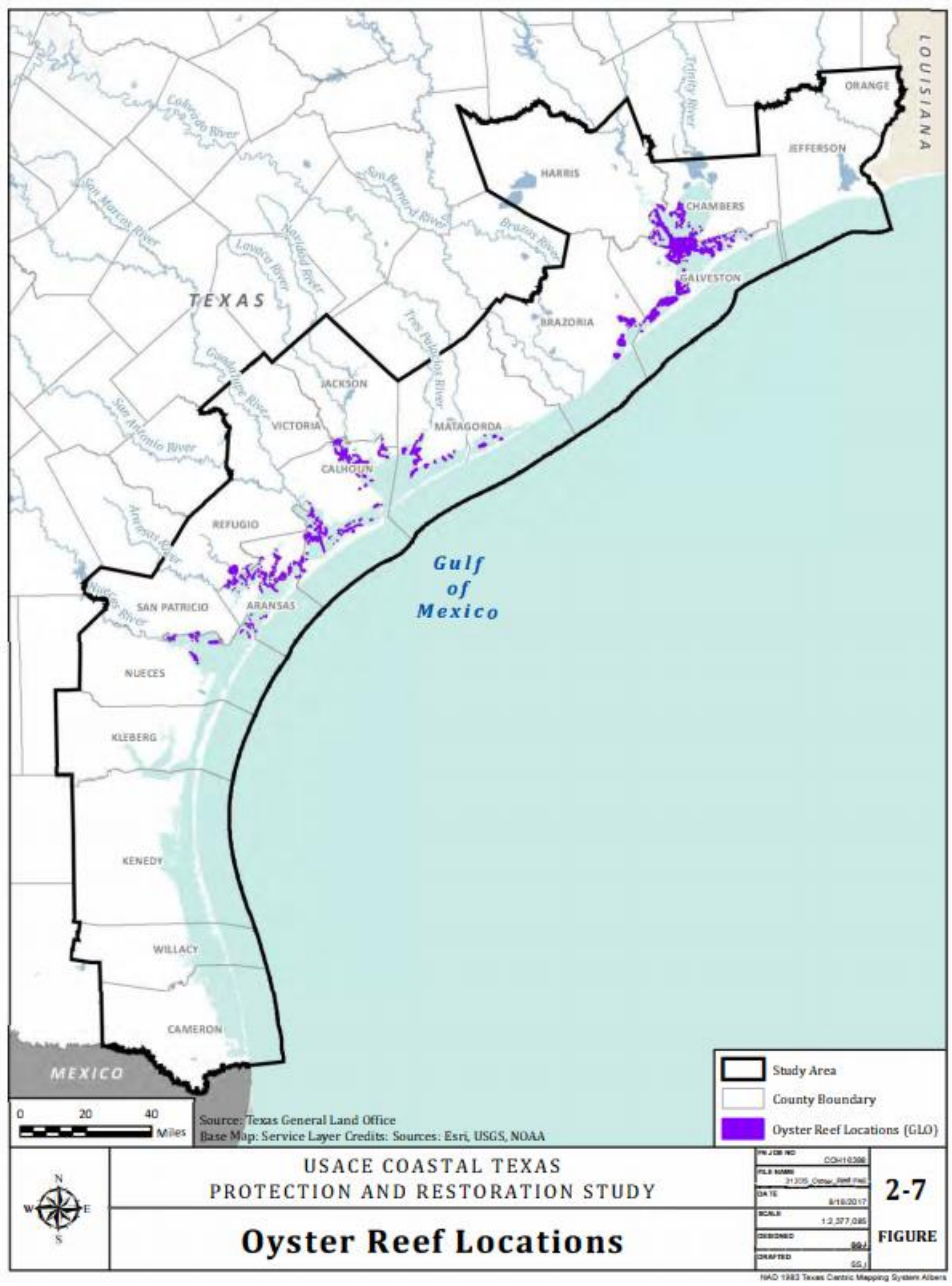


Figure 3-3 Oyster Reef Locations

Table 3-11 shows the historic and current extent of oyster reefs in Texas bays. There has been a decline in oyster reef habitat in all bay systems, except for Sabine Lake which has increased, with Matagorda Bay having the greatest loss (Baggett et al., 2014).

Table 3-11 Historic and Current Oyster Reef in Texas

Location	Historic Reef (acres)	Current Reef (acres)	Difference (acres)
Sabine Lake*	640	1,186	546
Galveston Bay	31,987	26,664	–5,322
Matagorda Bay	41,197	5,506	–35,691
San Antonio Bay	6,397	5,313	–1,084
Corpus Christi Bay	8,316	716	–7,600
Laguna Madre (Upper and Lower, Baffin Bay)	1,919	168	–1,751

Source: Baggett et al. (2014).

** Includes Texas and Louisiana.*

3.7.2.1.10 Offshore Habitats

The southern boundary of the focused study area includes offshore habitats found in the Gulf of Mexico. The nearshore is predominantly composed of coarse sediments, while fine sediments are found in the deeper areas beyond the 260-foot contour (GMFMC, 2004). Sediment type plays an important role in determining community structure. Each species has optimal habitat and tolerance limits regarding sediment particle size and chemical composition that influences the distribution of fauna in nearshore waters (Britton and Morton, 1989). There are few seagrasses or attached algae found in the offshore sands due to the strong currents and unstable sediments. Most of the bottom surface is populated with macroinfauna such as an occasional hermit crab (Paguroidea), portunid crab (Portunidae), or ray (Batoidea). Even though there is little life on the sand surface itself, the overlaying waters are highly productive. Phytoplankton are abundant, including microscopic diatoms, dinoflagellates, and other algae. Several species of crustaceans, bivalves and gastropods are found in offshore sands. One of the most common species occurring in shallow offshore sands is the sand dollar (*Mellita quinquiesperforata*) and several species of brittle stars (Ophiuroidea). The most abundant infaunal organism, with respect to the number of individuals, are the polychaetes (Capitellidae, Orbiniidae, Magelonidae, and Paraonidae).

Oil and gas production platforms provide hard substrate that can form diverse ecosystems. After some of these structures are decommissioned, resource agencies and the energy company will partner to intentionally placed these structures to serve as artificial reefs. While there are numerous artificial reefs in Texas' Coastal Zone, these structures are generally found in open water like the middle of a bay or offshore and would likely not be effected by project measures. Artificial reefs are colonized by a diverse array of microorganisms, algae, and sessile invertebrates including shelled forms (barnacles, oysters, and mussels), as well as soft corals (bryozoans, hydroids, sponges, and octocorals) and hard corals (encrusting, colonial forms). These organisms provided habitat and food for many motile invertebrates and fishes. Five species of sea turtles are found in the Gulf of Mexico waters south of the focused study area: leatherback (Dermochelys coriacea), hawksbill (Eretmochelys imbricata), loggerhead (Caretta caretta), green (Chelonia mydas), and Kemp's ridley (*Lepidechelys kempii*). Offshore waters are important feeding, resting, and migratory corridors for each of the species.

Much of the faunal diversity lies buried in the sand and relies on phytoplankton for food (Britton and Morton, 1989). Bivalves found in offshore sands include the blood ark (*Anadara ovalis*), incongruous ark (*Anadara brasiliana*), southern quahog (*Mercenaria campechiensis*), giant cockle (*Dinocardium robustum*), disk dosinia (*Dosinia discus*), pen shells (*Atrina serrata*), common egg cockle (*Laevicardium laevigatum*), cross-barred venus (*Chione cancellata*), tellins (*Tellina spp.*), and the tusk shell (*Dentalium texasianum*). Many gastropods are common, including the moon snail (*Polinices duplicatus*), ear snail (*Sinum perspectivum*), Texas olive (*Oliva sayana*), Atlantic auger (*Terebra dislocata*), Salle's ager (*Terebra salleano*), scotch bonnet (*Phalium granulatum*), distorted triton (*Distorsio clathrata*), wentletraps (*Epitonium sp.*), and whelks (*Busycon spp.*). Crustaceans inhabit these waters including white and brown shrimp (both commercially sought species), rock shrimp (*Sicyonia brevirostris*), blue crabs, mole crabs (*Albunea spp.*), speckled crab (*Arenaeus cribrarius*), box crab (*Calappa sulcata*), calico crab (*Hepatus epheliticus*), and pea crab (*Pinotheres maculatus*) (Britton and Morton, 1989).

3.7.2.1.11 Seagrass Meadows

Seagrass can be found along the Texas Gulf coast between the coastal barrier islands and mainland. There is approximately 235,000 acres of seagrass in Texas (TPWD, 1999). Although seagrasses occur throughout the entire coast, about 75 percent of seagrasses occur within the Laguna Madre in the lower Texas coast (Handley et al., 2007). Shoalgrass, turtlegrass, manateegrass, widgeongrass, and clovergrass can all be found in shallow (generally <5 feet water depth depending on water clarity) Texas coastal water (TPWD, 1999). Although seagrasses are generally declining in most parts of the Texas coast, seagrass beds within the Upper Laguna Madre and Corpus Christi Bay have been generally expanding or are stable (Moulton et al., 1997). For example, between the 1950s and 2002 to 2004 within the Texas Barrier Island Coastal Bend, seagrass beds increased in area at Harbor Island and North Padre Island by 70 percent and 78 percent, respectively (Moulton et al., 1997) (**Table 3-12**).

Seagrass plays an important part in stabilizing the seafloor substrate and nutrient accumulation. Seagrass communities are an important part of the ecosystem generating high primary productivity and acting as nurseries for recreational and commercial fisheries such as red drum, brown shrimp, and black drum and foraging habitat for manatees, sea turtles, herons, and egrets. Threats to seagrass meadows include natural disturbances such as hurricanes and strong currents, and human impacts such as dredging channels, propeller damage from boats, urbanization, and pollution runoff (Texas Statewide Seagrass Monitoring Program, 2015a, 2015b).

Table 3-12 Seagrass information for bays along the Texas Coast

Location	Seagrass (acres)	Trends
Sabine Lake System	minimal to none	–
Galveston Bay	519	decreasing
Matagorda Bay	2,716	decreasing
San Antonio Bay System	10,638	decreasing
Corpus Christi Bay	6,346	fluctuates with inflow, stable
Upper Laguna Madre	55,456	increase since 1950s
Lower Laguna Madre	114,095	decrease since 1950s

Source: Handley et al. (2007), TPWD (1999).

3.7.2.1.12 Estuarine and Riverine Habitats

Estuarine and riverine habitats support a diverse assemblage of biotic communities, including perennial and intermittent streams/creeks, emergent and forested wetlands, and several impoundments and drainages. Perennial creeks in the study area include: Buffalo Bayou, White Oak Bayou, a portion of Brays Bayou and the tributaries of each of these bayous. The study area contains several intermittent natural and artificial tributaries to the perennial bayous. Typical riverine habitat features along these creeks and streams include woody debris, overhanging vegetation, undercut banks, gravel and artificial cover (i.e. broken cement, tires, culverts, armoring). Creeks and wetlands are subject to changing hydrology due to the frequency and duration of rainfall events, resulting in typically slow moving, pooled, or saturated conditions punctuated by short periods of faster moving water in channels and across the landscape (sheet flow).

Some freshwater fish species use estuarine systems, particularly when salinities are less than 5 ppt. Conversely some estuarine and marine fish live in freshwater systems. Because many estuaries extend miles upstream into tidal rivers there can be considerable overlap between fresh water and estuarine nekton (fish and swimming invertebrates) communities.

Sampling nekton communities of 16 tidal streams from the Sabine River Basin south to the Nueces River tidal indicated salinity is the parameter with the greatest effect on nekton in tidal streams (Tolan, 2008). Over 105 species of nekton were sampled with seines and otter trawls. Species typically found in these tidal streams included bay anchovy (*Anchoa mitchilli*), western mosquitofish (*Gambusia affinis*), Gulf menhaden (*Brevoortia patronus*), white shrimp (*Litopenaeus setiferus*), grass shrimp (*Palaemonetes sp.*), silversides (*Menidia sp*.), blue catfish (*Ictalurus furcatus*), Atlantic croaker, and blue crab. Blue catfish tend to inhabit larger rivers and can be found in estuaries with salinities up to 15 ppt (Hendrickson and Cohen, 2015).

Recreational freshwater fish species commonly found in brackish waters of estuaries include largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), and crappie (*Pomoxis spp.*). A few species considered to be freshwater fish, gizzard shad (*Dorosoma cepedianum*) and alligator gar (*Atractosteus spatula*), live in streams with salinities of 0 ppt and can be common in estuaries where salinities exceed 30 ppt (Hendrickson and Cohen, 2015). Some marine species, striped mullet (*Mugil cephalus*), hogchokers (*Trinectes maculatus*), skipjack herring (*Alosa chrysochloris*), and Atlantic needlefish (*Strongylura marina*), move over 100 river miles upstream in rivers connected to the coast (pers. comm. David Buzan, 2017).

Other species migrate from fresh water into or through the estuary to spawn. American eels (*Anguilla rostrata*) leave estuaries and freshwater systems hundreds of miles from the coast after decades of maturing in fresh water to spawn in the Atlantic Ocean (Hendrickson and Cohen, 2015). Larval American eels migrate through the Atlantic to enter estuaries and rivers in Texas. Freshwater prawns, Macrobrachium, also migrate downstream to spawn in estuaries with young prawns swimming back upstream for tens to hundreds of miles (Reimer et al., 1974)

Freshwater habitats in the study area are primarily derived from rainfall runoff and wastewater treatment plant effluent and as a result most of the freshwater habitats generally provide poor aquatic habitat. This low habitat can be attributed to the sources of stream flow, fluctuating water levels, high nutrient levels and algal growth, shallow water depths, and high-water temperatures.

As part of the TCEQ water quality monitoring, bioassessments of streams are completed and assigned an Aquatic Life Use (ALU) based on the amount of dissolved oxygen, habitat characteristics, species assemblages, sensitive species presence, species diversity, species richness, and trophic structure (**Table 3-12).** The surveys are extremely useful in understanding the aquatic systems, but also the aquatic life (fish, benthic macroinvertebrates) and aquatic ecology of the systems. Biological assemblages reflect overall ecological integrity (i.e. chemical, physical, and biological integrity). TCEQ uses this data to assess water quality; however, this study can benefit from the assessment of Aquatic Life Attributes in the absence of fishery surveys.

Table 3-13 Aquatic Life Use Subcategories (30 TAC §307.7(b)(3)(A)(i))

ALU Subcategory	Dissolved Oxygen Criteria (mg/L)	Aquatic Life Attributes					
	mean/min	Habitat	Species Assemblage	Sensitive Species	Diversity	Species Richness	Trophic Structure
Exceptional	6.0/4.0	Outstanding natural variability	Exception or Unusual	Abundant	Exceptionally High	Exceptionally High	Balanced
High	5.0/3.0	Highly Diverse	Usual association of regionally expected species	Present	High	High	Balanced to Slightly Imbalanced
Intermediate	4.0/3.0	Moderately Diverse	Some expected species	Very low in abundance	Moderate	Moderate	Moderately Imbalanced
Limited	3.0/2.0	Uniform	Most regionally expected species absent	Absent	Low	Low	Severely Imbalanced
Minimal	2.0/1.5	Uniform	Absent	Absent	Low	Low	Imbalanced

None of the tidally influenced stream segments are considered "Exceptional," Approximately 108.6 miles of stream are classified as "Intermediate" where the stream is characterized as having moderate habitat variability and some aquatic species are present but not in high numbers. Approximately 126.9 miles of stream are classified as "Limited". These streams are typically uniform in habitat structure and have minimal to no aquatic species present. Many of the streams that are classified as Limited in the study area have been channelized and armored. There are about 13.4 miles of the downstream portions of the Buffalo and Brays bayous that are considered "Minimal." In these areas, the channel is highly disturbed and urbanized. There may be a few aquatic species found in these reaches but in general the diversity is low and limited to species that are tolerant of low-quality environments.

Because of lower quality habitat, organisms typically occurring in these parts of the study area have a high tolerance for several physical and chemical variables. Organisms here generally exhibit adaptations that include dormant or resistant life-history stages, mechanisms for rapid dispersal, high reproduction potential, or behavioral adaptations allowing exploitation of these habitats during favorable conditions. Species adapted to rapid colonization of disturbed habitats may include many algal and zooplankton species, aquatic insects with winged adult stages, and small fish species that migrate into intermittent tributaries from perennial stream habitats to spawn.

Physical and chemical components are responsible for supporting the lowest trophic levels within an aquatic system. These lower trophic levels are comprised of microscopic plants (phytoplankton) and microscopic animals (zooplankton) that support the food chain for all other larger organisms. Phytoplankton populations in the study area are generally low density because of flushing during periods of high rain. During low-flow periods, high plankton population densities are encountered in isolated pools, where light and nutrient conditions are suitable for development. Species composition and densities are highly variable among adjacent isolated pools in the same stream channel. Zooplankton communities occupy different types of aquatic systems. Within large rivers and streams, rotifers are generally the dominant zooplankton, while in pooled water, cladocerans and copepods are usually dominant. Most zooplankton communities in the study area are dominated by rotifers.

The benthic macroinvertebrates of freshwater systems form a highly diverse group of organisms with a wide variety of functions in the aquatic community. In addition to serving as a major food source for vertebrate predators such as fish, macroinvertebrates have important roles as herbivores, detritivores, and carnivores. The Order that comprise most macroinvertebrates in the study area include Insecta, Mollusca (mussels and snails), Oligochaeta (aquatic earthworms), and Crustacea (crawfishes and shrimp). Macroinvertebrate composition is greatly influenced by substrate type. The greatest diversity generally occurs on gravelly substrates. Many species require a current to satisfy food and respiratory needs and cannot survive in a standing-water environment. The unionid mussels (Unionidae), crawfishes (Cambaidae), prosobranch snails (Gastropoda), and the larvae of dragonflies (Odonata), caddisflies (Trichoptera), and midgeflies (Chironomidae) usually reach maximum development in running waters. Common mussels known from perennial streams include round pearlshell (*Glebula rotundata*), paper pondshell (*Anodonta imbecillis*), yellow sandshell (*Lampsilis teres*), and giant floater (*Anodonta grandis*).

Based on the size and degree of variation of in waterbodies, fish communities also vary significantly. The larger creeks contain a more diverse fish community and support larger species such as alligator gar (*Lepisosteus spatuala*), channel catfish (*Ictalurus punctatus*), blue catfish (*I. furcatus*), and green and bluegill sunfish (*Lepomis spp.*). Gizzard shad (*Dorosoma cepedianum*), sunfishes (*Lepomis spp.*) and several species of minnows (Cyprinidae) are important forage species. Reduced water quality limits the commercial and recreational importance of any aquatic species. Most aquatic wildlife are freshwater species; however, saltwater species, such as red drum (*Sciaenops ocellatus*) and brown shrimp (*Farfantepenaeus aztecus*) have been found inland beyond the saltwater wedge.

Many of the stream segments that are intermittent or size limting to gamefish may contain minnows (*Notropis spp.*), western mosquitofish, topminnows (*Fundulus spp.*), and darters (*Etheostoma spp.*). Pooled areas tend to be heavily dominated by sunfish that are widely distributed in area streams where sufficient water is present. Fish communities in impounded waters are primarily dependent on stocking efforts. Several species of sunfish, largemouth bass (*Micropterus salmoides*), and channel catfish are the most common species for recreational fishing in these ponds.

3.7.2.1.13 Coastal Prairies

Coastal Prairies in the study area are located along the Gulf coast just inland from the coastal marsh, typically north of the GIWW. The coastal prairie is similar in many ways to the tallgrass prairie of the Midwestern United States. It is estimated that, in pre-settlement times, there were nine million acres of Coastal Prairie, with over 6.5 million in Texas. Today, substantially less than one percent of the Coastal Prairie remains with remnants totaling less than 65,000 acres in Texas.

While much of the former prairie has been converted to pasture for cattle grazing, the majority has been altered for growing rice, sugarcane, forage, and grain crops. Fragmented remnants of the historic native tallgrass Coastal Prairie occur in the study area; however, most tracts are less than 100 acres in size and are privately owned and are in danger of development or conversion to other kinds of agriculture.

Native salty prairie habitats are found on low-lying coastal ridges and flats which are slightly higher in elevation than the adjacent marshes. Plant communities typical of native salty prairie can also be found on elevated man-made features including dredged material disposal sites and levees. The dominant plant species is Gulf cordgrass (*Spartina spartinae*), while knotroot bristlegrass (*Setaria parviflora*), bushy bluestem (*Andropogon glomeratus*), seaside goldenrod (*Solidago sempervirens*), western ragweed (*Ambrosia *psilostachya*), saltmarsh aster (*Symphyotrichum tenuifolium*), seepweed (*Suaeda spp.*), and bigleaf sumpweed (*Iva frutescens*) are common. Remnant native prairie species can be found on slightly drier, non-saline, upland sites. They occur on non-saline soils. Typical native prairie remnants in the study area are mid- and tallgrass species such as little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), brownseed paspalum (*Paspalum plicatulum*), Eastern gammagrass (*Tripsacum dactyloides*), and Gulf Coast muhly (*Muhlenbergia capillaris*). Numerous forbs, legumes, and one native shrub, southern wax myrtle, are also present.

Remnant tracts of tallgrass and salty prairie can still be found in some parts of the Texas Coast. These areas, just slightly higher in elevation than nearby marsh, provide important nesting, foraging, and migration habitat for waterfowl and thousands of other wildlife (**Figure 3-4**). Even in its altered state, the biological community routinely hosts red-tailed hawks (*Buteo jamaicensis*), red-shouldered hawk (*Buteo lineatus*), turkey vulture (*Cathartes aura*), American kestrel (*Falco sparverius*), white-tailed kite (*Elanus leucurus*), northern harrier (*Circus cyaneus*), short-eared owl (*Asio flammeus*), LeConte's sparrow (*Ammadramus leconteii*), seaside sparrows (*A. maritimus*), dickcissel (*Spiza americana*), and eastern meadowlark (*Sturnella magna*). Waterfowl, sandpipers, and other shorebirds are abundant during the fall, winter, and spring months, paralleling and often surpassing other regions with longstanding traditions as crucial stopover areas for these species.

3.7.2.1.14 Urban Environment

In urban areas, approximately 90 percent of the area is comprised of impervious surface and the remainder of the area is comprised of landscaped ornamental plant communities within residential, commercial, and industrial areas. Ornamental plantings of woody species include crepe myrtle (*Lagerstroemia indica*), loblolly pine (*Pinus taeda*), and other species of trees, shrubs, and bushes. Bermuda grass (*Cynodon dactylon*) and Saint Augustine grass (*Stenotaphrum secundatum*) are the most common herbaceous plants within landscaped areas and parks.

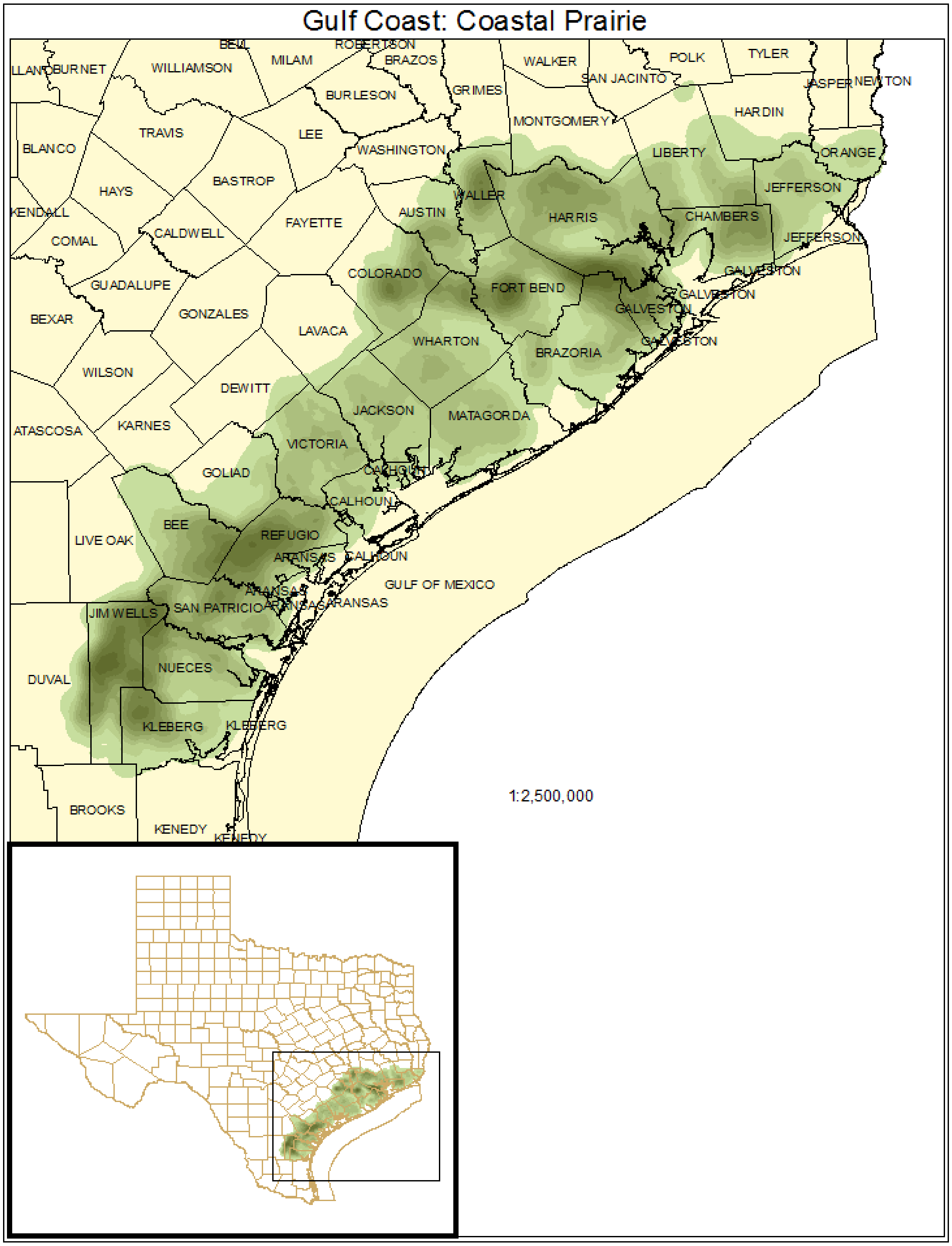


Figure 3-4 Coastal Prairie within the study area

Source:https://tpwd.texas.gov/landwater/land/programs/landscape-ecology/ems/emst/herbaceous-vegetation/texas-louisiana-coastal-prairie

3.8 SPECIAL STATUS SPECIES OR HABITATS

This section describes a variety of species and their habitats that are listed as occurring or could occur in the project area and that have protections enacted by law.

3.8.1 Regulatory Framework

Chapter 6.0 includes a detailed description and analysis for each of the laws and regulations briefly described here.

- **Endangered Species Act:** The purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. Section 7 of the ESA requires that federal agencies prevent or modify any projects authorized, funded, or carried out by the agencies that are "likely to jeopardize the continued existence of any endangered species or threatened species, or result in the destruction or adverse modification of critical habitat of such species."
- **Migratory Bird Treaty Act:** The Act includes provisions for protection of all migratory birds, including basic prohibitions against any taking not authorized by Federal regulation. All wild birds, with the exception of starling and house sparrow, are covered by the MBTA.
- **Bald and Golden Eagle Protection Act:** The Act provides for the protection of bald and golden eagles by prohibiting take, possession, sale, purchase, barter, offer to sell, transport, export or import of any bald or golden eagle, alive or dead, including any part, nest, or egg unless allowed by permit.
- **Magnuson-Stevens Fishery Conservation and Management Act:** The Act established procedures designed to identify, conserve, and enhance Essential Fish Habitat (EFH) for those species regulated under a federal fisheries management plan (FMP).
- **Marine Mammal Protection Act:** The Act mandates an ecosystem-based approach to marine resource management and protects all marine mammals in US waters by prohibiting activities that "harass, hunt, capture, or kill" any marine mammal or attempt to do so.
- **TAC 65.175, 65.176, and 69.8:** The Texas legislature authorized regulations pertaining to the management, regulation, and protection of native animals and plants listed as state threatened or endangered.

3.8.2 Existing Conditions

3.8.2.1 Federally Listed Species

The Endangered Species Act (ESA) of 1973, as amended, was enacted to provide a program for the preservation of threatened and endangered species and to provide protection for the ecosystems upon which the species depend for their survival. All

Federal agencies are required to implement protection programs for these designated species and use their authorities to further the purpose of the ESA. The USFWS and NMFS are the primary agencies responsible for implementing the ESA. The USFWS is responsible for terrestrial flora and fauna, including freshwater species, while the NMFS is responsible for non-bird marine species.

Wildlife species may be classified as threatened or endangered under the Endangered Species Act (ESA) of 1973 and protection of the species is overseen by the USFWS (non-marine species) and NMFS (marine species).

The USFWS and NMFS have identified 25 Federally-listed threatened and endangered species as potentially occurring in the study area (**Table 3-14**). The ESA defines a threatened species as "a species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" and an endangered species as "a species that is in danger of extinction throughout all or a significant portion of its range" (50 CFR 424.02; USFWS, 2015a). Species are discussed briefly in the following sections. Inclusion on the list does not imply that a species occurs in the study area, but only acknowledges the potential for its occurrence in those counties.

Twenty-five ESA-listed, candidate or proposed for listing species have been identified in the 2017 Planning Aid Report (PAL), in the USFWS Official Species List dated December 30, 2019, on the NMFS Texas' Threatened and Endangered Species List and/or as specifically identified for consideration by either the USFWS or NMFS staff (Table 3-14). One additional species (least tern [*Sterna antillarum*]) was also listed as an endangered species potentially occurring in the action areas; however, consideration of this species is only necessary when wind energy projects are being proposed. Since this project is not a wind energy project, the species is not considered. Critical habitat (CH) has been designated for seven species; however, not all of the CH is found in or near the action areas.

3.8.2.2 State Listed Species

Nine of the 25 species have also been listed as threatened or endangered under ESA including: whooping crane, oceanic whitetip shark (*Carcharhinus longimanus*), five whale species, loggerhead sea turtle (*Caretta caretta*), and Texas prairie-dawn flower. These species will not be further discussed in this section and information regarding them can be found in the Threatened and Endangered Species section of this Chapters 4 and 5 of this EIS and in Appendix A, the Biological Assessment. The three species of birds listed under ESA that were not considered further are also listed by the State of Texas and are considered here.

Table 3-14. ESA-listed Species Identified by USFWS or NMFS as Potentially Occurring in the Action Area

Species	Scientific Name	Jurisdiction	Status	CH*
Birds				
Piping Plover	*Charadrius melodus*	USFWS	Threatened	Yes
Rufa Red Knot	*Calidris canutus rufa*	USFWS	Threatened	No
Whooping Crane	*Grus americana*	USFWS	Endangered	Yes
Northern Aplomado Falcon	*Falco femoralis septentrionalis*	USFWS	Endangered	No
Eastern Black Rail	*Laterallus jamaicensis jamaicensis*	USFWS	Threatened with 4(d) rule	No
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	USFWS	Endangered	No
Clams				
Texas Fawnsfoot	*Truncilla macrodon*	USFWS	Candidate	No
Fish				
Oceanic Whitetip Shark	*Carcharhinus longimanus*	NMFS	Threatened	No
Giant manta ray	*Manta birostris*	NMFS	Threatened	No
Mammals				
Sei whale	*Balaenoptera borealis*	NMFS	Endangered	No
Bryde's Whale	*B. edeni*	NFMS	Endangered	No
Fin whale	*B. physalus*	NMFS	Endangered	No
Gulf Coast Jaguarundi	*Herpailurus (=Felis) yagouaroundi cacomitli*	USFWS	Endangered	No
Ocelot	*Leopardus (=Felis) pardalis*	USFWS	Endangered	No
Sperm whale	*Physeter macrocephalus*	NMFS	Endangered	No
West Indian Manatee	*Trichechus manatus*	UFWS/NMFS	Threatened	Yes
Plants				
Texas Ayenia	*Ayenia limitaris*	USFWS	Endangered	No

Species	Scientific Name	Jurisdiction	Status	CH*
South Texas Ambrosia	*Ambrosia cheiranthifolia*	USFWS	Endangered	No
Slender Rush-pea	*Hoffmannseggia tenella*	USFWS	Endangered	No
Texas prairie dawn-flower	*Hymenoxys texana*	USFWS	Endangered	No
Reptiles				
Loggerhead sea turtle	*Caretta caretta*	USFWS/NMFS	Threatened	Yes
Green sea turtle	*Chelonia mydas*	USFWS/NMFS	Threatened	Yes
Leatherback sea turtle	*Dermochelys coriacea*	USFWS/NMFS	Endangered	Yes
Hawksbill sea turtle	*Eretmochelys imbricata*	USFWS/NMFS	Endangered	Yes
Kemp's Ridley sea turtle	*Lepidochelys kempii*	USFWS/NMFS	Endangered	Proposed

* CH designated for the species; however a 'Yes' does not indicate presence in the action area. See Chapter 4.0 for presence/absence.

A review of the description of each species provided by TPWD, occurrence data on NatureServe and the Texas Natural Diversity Database (TXNDD) (2020), and consultation with resource agencies helped to determine the potential occurrence of the species in the study area. A total of 9 species are recorded as occurring within the study area or suitable habitat exists within the study area. While 13 species are either outside the known range of the species or no suitable habitat exists in the study area.

3.8.2.3 Marine Mammals

The Marine Mammal Protection Act of 1972 was established to prevent the decline of marine mammal species and populations. It prohibits the taking (harassment, injury, killing) and importing of marine mammals and products into the United States. As cooperating agencies, NMFS and USFWS were consulted during preparation of the 2018 DIFR-EIS and this DEIS and Feasibility Report to solicit information on marine mammals inhabiting the proposed project area and identify data gaps and potential risks regarding possible project alternatives. Scientists have documented 28 marine mammals living in the Gulf of Mexico including whales, dolphins and one species of coastal sirenian (West Indian manatee). No seals, sea lions or sea-going otters are present in the Gulf. Twenty-one species of cetaceans regularly occur in the Gulf and are identified in the NMFS Gulf of Mexico Stock Assessment Reports (BOEM 2012, Waring et al. 2014)). The West Indian manatee (*Trichechus manatus*), is also listed in the stock reports as a rare species in the Texas region (Davis et al. 2000). In the northern Gulf, 18 species of marine mammals (listed below in order of abundance) are common:

- Pantropical spotted dolphins (*Stenella attenuata*),
- Spinner dolphins (*Stenella longirostris*),
- Clymene dolphins (*Stenella clymene*),
- Bottlenose dolphins (*Tursiops truncatus*),
- Striped dolphins (*Stenella coeruleoalba*),
- Melon-headed whales (*Peponocephala electra*),
- Atlantic spotted dolphins (*Stenella frontalis*),
- Risso's dolphins (*Grampus griseus*),
- Short-finned pilot whales (*Globicephala macrorhynchus*),
- Rough-toothed dolphins (*Steno bredanensis*),
- False killer whales (*Pseudorca crassidens*),
- Pygmy sperm whales (*Kogia siga/breviceps*),
- Sperm whales (*Physeter macrocephalus*),
- Pygmy killer whales (*Peponocephala electra*),
- Killer whales (*Orcinus orca*),
- Cuvier beaked whales (*Ziphius cavirostris*),
- Fraser dolphins (*Lagenodelphis hosei*), and
- Bryde's whales (*Balaenoptera brydei*). (Davis et al. 2000)

The two species of concern primarily discussed in this Study are the common bottlenose dolphin (*Tursiops truncatus*) and the Federally-threatened West Indian manatee (*Trichechus manatus*).

Note that pantropical spotted dolphins and striped dolphins, while abundant in the northern Gulf of Mexico, are not common to the northwestern Gulf of Mexico region (Waring et al. 2014). Common bottlenose dolphins are frequently seen in open waters of the SNWW or in shallow waters along the coastline. Common bottlenose dolphins are known to inhabit bays, estuaries, and nearshore waters of Texas. Currently, there are six bay, sound, and estuary (BSE) stocks found in Texas, and a seventh stock located near the Texas/Louisiana border and a nearshore coastal stock, all of which are considered "strategic" (Hayes et al., 2018; Waring et al., 2013). The "Galveston Bay, East Bay, Trinity Bay" stock is thought to contain the largest population of common bottlenose dolphins of the six BSE stocks found in Texas. While it is thought that the BSE stocks are relatively discrete, research using genetic data suggests there may be some overlapping of adjacent stocks as evidenced by documented clinal variation along the Gulf coast. Hayes et al. (2018) state that marine mammals are vulnerable to many stressors and threats including disease, biotoxin, pollution, habitat alteration, vessel collisions, human feeding of and activities causing harassment, interactions with commercial and recreational fishing gear, energy exploration activities and oil spills, and other types of human disturbance, such as underwater noise. Other stressors thought to be specific to Galveston Bay include hypoxia, adverse weather, and freshwater inflows. Although dolphins in Galveston Bay are often associated with areas of human impact and anthropogenic activities, these risks when combined with limited and outdated information on population structure, abundance, or mortality led NOAA to assign Galveston Bay a "high priority" ranking for stock assessment research and the highest risk score for the Texas coast in the assessment (Phillips and Rosel, 2014). A more-detailed discussion is included in Chapter 4, of this DEIS. In general, dolphins are quite common in estuarine waters and nearshore coastal habitats. Other species of dolphins and whales prefer deeper offshore waters; therefore, it is unlikely that any of these species would occur in the study area.

The West Indian manatee occurs as an occasional vagrant within estuarine habitats, though historically they were considered common in south Texas, with 66 records in Texas dating back to 1912. Manatee in Texas may stray from populations in either Florida or Mexico as an extension of their natural seasonal migration in warm weather or possibly in response to Gulf conditions during notably active hurricane seasons (Würsig, Jefferson et al., 2000). Historical records indicate that West Indian manatees inhabited Cow Bayou (Würsig 2017); however, there are no recent records documenting the species, and they are considered extremely rare in Texas. Manatees can live in shallow coastal waters, estuaries, bays, rivers, and lakes, but prefer rivers and estuaries to marine habitats.

3.8.2.4 Bald and Golden Eagles

The Bald and Golden Eagle Protection Act protects the two eagle species. USFWS has outlined sites on McFaddin NWR and nearby Anahuac Lake that serve as concentration areas for Bald Eagles (*Haliaeetus leucocephalus*); however, birds could be found throughout the coast. Breeding may occurs in wooded areas in the study area but for the most part the coastal regions where work may occur lack large old-growth trees or snags. Because of the species relatively large home range and the abundance of suitable foraging habitat in the study area, it is reasonable to expect that they will continue to use the area. The study area is located outside the range of the golden eagle.

3.8.2.5 Migratory Birds

The Migratory Bird Treaty Act (MBTA) of 1918 makes it illegal to kill, possess, transport, buy, sell, or trade any migratory bird parts, nest, or eggs unless a valid Federal permit is issued (USFWS, 2017b). There are several NWRs, WMAs, parks, protected areas, and dredge islands areas along the Texas Gulf Coast that provide nesting habitat and support rookeries for migratory birds. The USFWS lists 59 migratory species that may use or have the potential to use the islands and other land areas near the project area.

The study area has one of the greatest concentrations of colonial waterbirds in the world such as breeding Reddish egret (*Egretta rufescens*), roseate spoonbill (*Platalea ajaja*), brown pelican (*Pelecanus occidentalis*), and large numbers of herons and egrets (Ardeidae), ibis (Threskiornithinae), terns (Sternidae), and skimmers (Rynchopidae). The region provides critical intransit habitat for migrating shorebirds including buffbreasted sandpiper (*Tryngites subruficollis*), Hudsonian godwit (*Limosa haemastica*), and for most neotropical migrant forest birds of eastern North America.

The region is one of the most important waterfowl areas in North America with both wintering and migration habitat for significant numbers of continental duck and goose populations using the Central and Mississippi Flyways. Coastal wetlands are primary wintering sites for dabbling ducks, including northern pintail (*Anas acuta*), gadwall (*Anas strepera*), red head (*Aythya americana*), lesser scaup (*Aythya affinis*), and white-fronted geese (*Anser albifrons*). These crucial wetlands winter more than half of the Central Flyway waterfowl population. The region also supports year-round habitat for over 90 percent of the continental population of mottled ducks (*Anas fulvigula*), and serves as a key breeding area for whistling ducks (*Dendrocygna spp.*) and purple gallinule (*Porphyrio martinicus*). In addition, hundreds of thousands of waterfowl use the region as stopover habitat while migrating to and from Mexico and Central and South America. The most important waterfowl habitats in the area are coastal marsh, shallow estuarine bays and lagoons, and wetlands on agricultural lands on rice prairies.

3.8.2.6 Essential Fish Habitat

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) establishes procedures for identifying Essential Fish Habitat (EFH) and required interagency coordination to further the conservation of federally managed fisheries. EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” EFH is separated into estuarine and marine components. The estuarine component is defined as “all estuarine waters and substrates (mud, sand, shell, rock, and associated biological communities; sub-tidal vegetation (seagrasses and algae); and adjacent inter-tidal vegetation (marshes and mangroves).” Estuarine components are found in the tidally influenced portion of the study area. The marine component is defined as “all marine waters and substrates (mud, sand, shell, rock, and associated biological communities) from the shoreline to the seaward limit of the Exclusive Economic Zone” (GMFMC 2004).

Estuaries along the Texas coast often contribute to the shellfish resources of the Gulf. Shellfish species range from those located only in brackish wetlands to those found mainly in saline marsh and inshore coastal waters. Multiple species of penaeid shrimp are expected to occur in the vicinity of the proposed project areas; however, brown shrimp and white shrimp are the most numerous (Nelson et al., 1992). At least eight species of portunid (swimming) crabs are common residents of the coastal and estuarine waters of the northern Gulf. Brown shrimp, white shrimp, blue crabs, and Eastern oyster are the primary shellfish located throughout Texas that comprise a substantial fishery (Turner and Brody, 1983).

Life histories of many Gulf fish can be characterized as estuarine-dependent. These species typically spawn in the Gulf, and their larvae are carried inshore by currents. Juvenile fish generally remain in these estuarine nurseries for about a year, taking advantage of the greater availability of food and protection that estuarine habitats afford. Upon reaching maturity, estuarine-dependent fishes migrate to sea to spawn (returning to the estuary on a seasonal basis) or migrate from the shallow estuaries to spend the rest of their lives in deeper offshore waters (Pattillo et al., 1997).

Fish and macroinvertebrate species of special concern that occur in the vicinity of the project areas include those with designated EFH and those of commercial and recreational value. In 1996, the MSFCMA mandated the identification of EFH for all Federally managed species. For a list of commercial and recreational fisheries species within and adjacent to the project areas, refer to **Table 3-16**. The categories of EFH that occur within the project area include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, and seagrasses. Additionally, portions of the project area are in marine waters and include the marine water column and unconsolidated marine water bottoms.

Information from the habitat descriptions from the Gulf of Mexico Fishery Management Council (GMFMC) Fishery Management Plans (FMPs), the EFH FEIS and 5-Year review and the Gulf council data portal were used to provide the following summary of what EFH and managed species (and associated life stages) are present in the project area (GMFMC 2004, 2005, 2016 and 2019).

Table 3-15 lists the species that NMFS and the GMFMC identify in the study project area as EFH. The categories of EFH that occur within the project areas include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, seagrasses, and mangroves. Additionally, portions of the study area are in marine waters and include the marine water column and unconsolidated marine water bottoms.

Table 3-15 Species identified as EFH in the Study Area

Common Name*	Species Name*	Coastal Region		
		Upper	Mid	Lower
Brown shrimp	*Farfantepenaeus aztecus*	X	X	X
Pink shrimp	*Farfantepenaeus duorarum*	X	X	X
White shrimp	*Litopenaeus setiferus*	X	X	X
Blacknose shark	*Carcharhinus acronotus*	X	X	X
Atlantic angel shark	*Squatina dumeril*			X
Spinner shark	*Carcharhinus brevipinna*	X	X	X
Silky shark	*Carcharhinus falciformis*		X	X
Finetooth shark	*Carcharhinus isodon*		X	X
Bull shark	*Carcharhinus leucas*	X	X	X
Blacktip shark	*Carcharhinus limbatus*	X	X	X
Dusky shark	*Carcharhinus obscurus*		X	
Tiger shark	*Galeocerdo cuvier*	X	X	X
Lemon shark	*Negaprion brevirostris*	X	X	X
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	X	X	X
Scalloped hammerhead shark	*Sphyrna lewini*	X	X	X
Great hammerhead shark	*Sphyrna mokarran*	X	X	X
Bonnethead shark	*Sphyrna tiburo*	X	X	X
Red grouper	*Epinephelus morio*	X	X	X
Gag grouper	*Mycteroperca microlepis*	X	X	X
Scamp	*Mycteroperca phenax*	X	X	X
Cobia	*Rachycentron canadum*	X	X	X
Dolphin	*Coryphaena hippurus*		X	X
Greater amberjack	*Seriola dumerili*	X	X	X
Lesser amberjack	*Seriola fasciata*	X	X	X
Red snapper	*Lutjanus campechanus*	X	X	X
Gray snapper	*Lutjanus griseus*	X	X	X
Lane snapper	*Lutjanus synagris*	X	X	X
Vermilion snapper	*Rhomboplites aurorubens*	X	X	X

Common Name*	Species Name*	Coastal Region		
		Upper	Mid	Lower
Red drum	*Sciaenops ocellatus*	X	X	X
Little tunny	*Euthynnus alletteratus*	X	X	X
King mackerel	*Scomberomorus cavalla*	X	X	X
Spanish mackerel	*Scomberomorus maculatus*	X	X	X
Sailfish	*Istiophorus platypterus*		X	X
Blue marlin	*Makaira nigricans*			X

Source: NMFS (2009); NOAA (2013, 2016).

* Species according to Page et al. (2013).

3.8.2.7 Invasive Species

Invasive species are non-native species whose populations tend to grow and spread, and cause harm to native biodiversity, the economy, or health. Invasive species are one of the most pervasive, widespread threats to indigenous biota. The introduction and establishment of invasive species can have substantial impacts on native species and ecosystems. Invasive species capable of spreading and invading into new areas are typically generalists that can easily adapt to new environments and are highly prolific and superior competitors and/or predators. Some are very specialized and more efficient and effective than their native competitors at filling a niche. Generally, invasive species can invade and begin to alter an ecosystem within a few decades because they have few natural predators or diseases in the ecosystem. Additionally, growth or reproductive characteristics enable them to outcompete other plants or animals in the ecosystem. They compete for resources, alter community structure, displace native species, and may cause extirpations or extinctions. Invasive species often benefit from altered and declining natural ecosystems by filling niches of more specialized and displaced species with limited adaptability to changing environments. Noxious species similarly deteriorate habitats and cause damage, except that the species are native. These species tend to spread after disturbance to the soil surface, such as agriculture plantings, landscaping, wildfires, erosion, etc. A wide variety of invasive plant species have invaded most habitats of the study area including:

- Chinese tallowtree,
- Deep-rooted sedge (*Cyperus entrerianus*)
- Salt cedar (*Tamarix spp.*),
- Narrowleaf cattail (*Typha angustifolia*),
- Common reed (*Phragmities australis*),

- Mesquite,
- Bahiagrass,
- Brazilian vervain (*Verbena brasiliensis*),
- Chinese privet, bermudagrass,
- Chinaberry (*Melia azedarach*),
- Spadeleaf (*Centella asiatica*).
- Water hyacinth (*Eichhornia crassipes*),
- Alligator weed (*Alternathera ohiloceroides*),
- Water lettuce (*Pistia stratiotes*),
- McCartney rose (*Rosa bracteata*),
- Vasey grass (*Paspalum urvillei*),
- Johnsongrass (*Sorghum halepense*),
- Eurasian water milfoil (*Myriophyllum spicatum*),
- Hydrilla (*Hydrilla verticillata*),
- Common salvinia (*Salvinia minima*),
- Giant salvinia (*S. molesta*),
- Japanese honeysuckle (*Lonicera japonica*), and
- Red imported fire ants, nutria, and feral hogs.

Invasive native (noxious) plant species include eastern baccharis (*Baccharis halimifolia*), bigleaf sumpweed (*Iva frutescens*), rattlebox (*Sesbania drummondii*), common reed (*Phragmities communis*) and cattail (*Typha spp.*).

3.9 CULTURAL RESOURCES

3.9.1 Regulatory Framework

- **National Historic Preservation Act:** Is intended to preserve historic and archaeological sites in the United States of America.

3.9.2 Existing Conditions

The human landscape was examined over a broad study area encompassing over 18,000 square miles of the Texas Gulf Coast across 18 counties. For the purposes of this study, the coast was divided into four regions, the Upper Texas Coast, the North Central Texas Coast, the South-Central Coast, and the Lower Texas Coast. Over 5,200 cultural resources have been documented along the Texas Coast within this study area. These resources include prehistoric and historic archeological sites, historic buildings and structures, historic and archeological districts, and cemeteries. Properties listed on the National Register of Historic Places (NRHP) include 506 properties, of which 14 are National Historic Landmarks (NHL).

Table 3-16. Cultural Resources in the Study Area

Region Name	Sites	NRHP Properties	NRHP Districts	Cemeteries
Upper Texas Coast	2097	311	34	418
North Central Texas Coast	577	117	1	121
South Central Texas Coast	950	17	4	79
Lower Texas Coast	390	16	6	94
Totals	**4014**	**461**	**45**	**712**

3.9.2.1 Upper Texas Coast

This region comprises the upper Texas coast (Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria Counties) and has been occupied by humans since the Paleoindian period dating to around 11,500 BP. There are over 2,000 prehistoric and historic archeological sites within the region. The region is characterized by dense woodlands in the east that transition to coastal prairies in the west and extensive bay and estuarine systems along the coast. The region is primarily drained by the Sabine River, the Trinity River, the San Jacinto River, Buffalo Bayou, and the Brazos River. Sediments in the region are generally fluvial sandy and silty clays overlying Pleistocene aged clay. Prehistoric sites are commonly found within these upper sediments along streams and rivers and along the shorelines of the bays and gulf coast, close to prime areas for resource exploitation. These sites include campsites, dense shell middens, and cemeteries, which contain projectile points, stone, bone, and shell tools, aquatic and terrestrial faunal remains, hearth features, ceramics, and in some cases, human remains and associated funerary objects. Historic aged resources in the region consist of farmsteads and ranches, houses, buildings, bridges, tunnels, oil industry structures, cemeteries, lighthouses, shipwrecks, and the ruins of these buildings and structures. Although historic resources can occur anywhere, these sites tend to be concentrated in small towns and urban areas, along roads, and within current and historic navigation paths. Shipwrecks may also occur in numerous locales due to the dynamic nature of the sea floor and bay bottoms and the lack of navigation improvements until the latter part of the 19th century. These dynamic conditions can result in shifting shoals and reefs that endanger ships as well as bury their wrecks as shorelines and bars migrate through time.

There are several NHLs, including the San Jacinto Battlefield, the Battleship Texas, the Tall Ship Elissa and the Spindletop Oil Field, as well as NHL Districts, such as the Galveston Strand Historic District and the Galveston East End Historic District. There are 345 National Register Properties and 418 cemeteries within the region. Many of these historic properties are located in urban areas and are primarily historic houses, commercial and government buildings, and structures represented by the Navy Park Historic District, Houston Heights, Galveston Central Business District, Durazno Plantation, Varner-Hogg Plantation, Fort Travis, Washburn Tunnel and others. Other National Register sites and districts located throughout the area include the Apollo Mission Control Center, the Space Environment Simulation Laboratory, the Saturn V Launch Vehicle, the Point Bolivar and Sabine Pass Lighthouses, the Beaumont Commercial District, the Jefferson Historic District, the Port Arthur-Orange Bridge, the W. H. Stark House, the Old Wallisville Townsite, Fort Anahuac, and the Chambers and Jefferson County Courthouses. The majority of these cultural resources are vulnerable to damage or destruction from hurricane storm surge.

3.9.2.2 North Central Texas Coast – Matagorda Bay

Human habitation along the north central coast in the vicinity of Matagorda Bay (Matagorda, Jackson, Victoria, and Calhoun Counties) has only been identified in the region as early as 7,500 BP. This region is similar to the upper Texas Coast with broad coastal estuarine systems and bays and coastal prairies further inland but lacks the dense woodlands of eastern Texas. The Colorado, Lavaca, San Antonio, and Guadalupe rivers are the major drainages in the region. Sediments in the region consist of fluvial deposits and delta formations overlying Pleistocene aged clay. There are 577 recorded prehistoric and historic archeological sites in the region, which are similar in nature and location to sites along the upper Texas Coast; however prehistoric sites are primarily located adjacent to brackish estuarine systems. Shell midden sites are especially common in the region along the shorelines and upland areas adjacent to rivers and bays and on the barrier islands. The central Texas Coast is more rural than the upper Texas Coast and while historic sites are located in small urban centers, farmsteads, ranches, and plantations can occur across the region. Shipwrecks are also common in the region and are subject to the same formation processes as the upper coast.

There are 118 historic properties recorded within the region and one these includes the South Bridge Street Historic District in Victoria, Texas. The vast majority of the historic properties are also within the city of Victoria including the City of Victoria Pumping Plant, the Old Brownson School, Trinity Lutheran Church, and others. Outside of Victoria, historic properties include the Matagorda Island Lighthouse in Port O'Connor, the Texana Presbyterian Church in Edna, and the Hotel Blessing in Blessing.

3.9.2.3 South Central Texas Coast – Corpus Christi Bay

The south-central Texas Coast around Corpus Christi and Baffin Bays (Refugio, Aransas, San Patricio, Nueces, and Kleberg Counties) is very similar environmentally and culturally to the north central coast. There are 950 archeological sites recorded within the region. The primary drainages for this region include the Aransas and Nueces Rivers as well as Petronilla and Chiltipin Creeks. Prehistoric sites in the region are concentrated on the shorelines of Copano, Corpus Christi, and Baffin Bays, as well as along the rivers and streams that drain into these bays. Numerous sites have also been identified on the barrier islands. Both prehistoric and historic archeological sites are similar to those in the upper and north central coast, but, similar to the north central coast, show an increase in the number of shell middens.

There are 21 historic properties listed in the region with many of these located in Corpus Christi and Rockport. Some notable properties include the Ragland Mercantile Company Building, the Nueces and Refugio County Courthouses, the Tarpon Inn, Fulton Mansion, and the Henrietta King High School. Historic districts include the Aransas Pass Light Station, the Broadway Bluff Improvement, and the James McGloin Homestead. Two NHLs include the USS Lexington in Corpus Christi and the King Ranch. The King Ranch is a NHL District that covers over two-thirds of Kleberg County.

3.9.2.4 Lower Texas Coast – Padre Island

The lower Texas coast (Kenedy, Willacy, and Cameron Counties) exhibits some evidence of human habitation as early as 11,500 BP. This region is primarily drained to the south by the Rio Grande and is characterized by a broad aeolian sand sheet in the north, the Rio Grande delta in the south and a small portion of coastal prairie dividing the two. There are 390 archeological sites recorded in the region, primarily along the shores of the Laguna Madre, and on the barrier islands. Archeological investigations in the region have not been sufficient to clearly identify regional chronology or settlement patterns. However, the archeological record suggests that groups in these areas utilized the inland areas along the Rio Grande and the coastal areas either based on seasonal or territorial constraints. As such, prehistoric sites can be expected within fluvial terraces along streams and rivers and in upland terraces along the shorelines of the bays. Furthermore, the widespread deposition of aeolian clays has established stable clay dunes or lomas, which have a high probability for archeological sites, but are also at high risk from erosion from wind and water.

There are 22 historic properties listed within the region. Almost all of these properties are located in Brownsville or along the Rio Grande including the Cameron County Courthouse, Southern Pacific Railroad Passenger Depot, the Charles Stillman House, the Immaculate Conception Church, and La Nueva Libertad. Outside of Brownsville, properties include the Point Isabel Lighthouse in Port Isabel, the Brazos Santiago Depot at Boca Chica, and the Old Lyford High School in Lyford. There are six historic districts in the region and five of these are NHLs. These NHLs include Fort Brown, Palo Alto Battlefield, Palmito Ranch Battlefield, and Resaca de la Palma Battlefield, which are associated with the Mexican War and the Civil War. The King Ranch NHL is also located in the region and occupies a large portion of Kenedy and Willacy Counties.

3.9.3 Cultural Resources Considerations

There are over 5,200 cultural resources recorded within the study area. Many of these resources have national and regional significance and are either listed on or are eligible for inclusion in the NRHP. Additionally, almost all cultural resources within the four regions are at risk from hurricane storm damage to varying degrees. Those resources at highest risk are archeological sites along coastal and bay shorelines where storm surge wave action and flooding can cause severe erosion, historic buildings and structures that can be destabilized or destroyed by wave action and flooding, and submerged resources, such as shipwrecks, which can be exposed and dispersed by shifting sea floor and bay bottom during violent storm events. Indirectly, cultural resources whose owners lack sufficient money or resources to rehabilitate damaged properties could be lost entirely.

Structural and non-structural alternatives for reducing storm risk also pose a threat to cultural resources in the study area as these can involve both direct and indirect impacts. Direct impacts could include damage to surface and subsurface resources from levee or wall construction and associated borrow areas, erosion from redirected storm waters into archeologically or historically sensitive areas, dredging for beach and dune nourishment, and impacts from landscape modification of ecosystem restoration features. Indirect impacts could include visual impacts from obstructions such as levees and walls, increased unregulated construction/renovation in newly protected areas, and noise impacts from increased traffic in protected areas and along evacuation routes.

3.10 SOCIOECONOMICS AND ENVIRONMENTAL JUSTICE

3.10.1 Regulatory Framework

- **Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations:** The EO directs Federal agencies to identify and address the disproportionately high and adverse human health or environmental effects of their actions on minority and low-income populations, to the greatest extent practicable and permitted by law.

- **Executive Order 13045, Protection of Children:** The EO directs Federal agencies to ensure that its policies, programs, activities, and standards address disproportionate environmental health and safety risks to children.

3.10.2 Existing Conditions

3.10.2.1 Population

More than one-quarter of the Texas's population has lived within the coastal counties with over 6.4 million residents in the study area, over 80 percent of those residing along the upper Texas coast (Wilson and Fischetti, 2010, U.S. Census Bureau, 2018). Within the study area, numerous coastal communities are at risk from storm surge, where approximately 673,346 structures are located. Over 3,500 critical infrastructures, including electricity, gas distribution, water supply, transportation, education, and community services (e.g., police, fire department, etc.) are at risk. Severe storm surge events threaten the health and safety of residents living within the study area. Loss of life, injury, and post flood health hazards may occur in the event of catastrophic flooding. There are 140 medical care facilities, 364 police stations/sheriff's offices, and 672 fire stations (county and volunteer) located within the study area (NOAA, 2018). Within the study area, 14.8 percent of the population fell below the poverty level, much of those populations are found in the lower coastal counties. Minority residents make up 16 percent of the population in the study area. Recreation and tourism play a large role in the study area, with over 50 NWRs, WMAs, State Parks, preserves, etc.; outstanding fishing, birding, and waterfowl hunting opportunities; and nature tourism opportunities.

Communities along the Texas coast include the major cities of Houston, Galveston, Corpus Christi, Brownsville, and the major communities of Freeport, Port Arthur, Texas City, League City, Baytown, Matagorda, Palacios, Port O'Connor, Port Lavaca, Rockport, Port Aransas, South Padre, and Port Isabel. All of these areas have historically suffered extensive damage from hurricanes and tropical storms. The impact of preparing for, mitigating, and recovering from these damages has placed a significant physical and emotional burden on both individuals and communities. Most recently, Hurricanes Rita in 2005 and Ike in 2008 caused significant damage to homes and businesses. In this section, socioeconomic and other social effects data for the Texas coast provide a context from which to evaluate potential effects of the proposed action.

Recent population trends in the Coastal Texas Study area are shown in **Table 3-17**. Since the 1960s, more than one-quarter of Texas's population has lived within the coastal counties (Wilson and Fischetti, 2010). Even with historical hurricane events, the coastal populations in Texas has historically increased. The population of the study area in 2017 was over 6.4 million residents, with over 80 percent of those residents residing along the upper Texas coast (U.S. Census Bureau, 2018a).

Table 3-17 Current Population Trends in the Study Area

Coastal Area	County	Population Trends							
		2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Upper	Brazoria	314,453	319,274	324,433	330,170	337,782	345,738	353,828	362,457
	Chambers	35,445	35,683	36,489	37,350	38,283	39,059	40,283	41,441
	Galveston	292,470	295,609	301,059	306,662	313,609	321,305	329,306	335,036
	Harris	4,107,854	4,180,816	4,262,689	4,353,517	4,452,695	4,551,362	4,617,041	4,652,980
	Jefferson	252,453	253,397	251,458	253,022	252,708	254,889	255,954	256,299
	Orange	82,013	82,337	82,889	82,816	83,245	83,928	84,508	85,047
	Subtotal	**5,084,688**	**5,167,116**	**5,259,017**	**5,363,537**	**5,478,322**	**5,596,281**	**5,680,920**	**5,733,260**
Mid-to Upper, Mid	Aransas	23,181	23,228	23,462	23,897	24,581	24,834	25,275	25,572
	Calhoun	21,311	21,356	21,575	21,735	21,805	21,881	21,942	21,744
	Jackson	14,090	14,044	14,267	14,609	14,721	14,792	14,851	14,805
	Kleberg	32,033	32,026	32,092	32,016	31,850	31,398	31,347	31,088
	Matagorda	36,705	36,681	36,543	36,506	36,494	36,762	37,117	36,840
	Nueces	340,261	343,225	347,848	352,781	356,452	360,437	361,529	361,221
	Refugio	7,375	7,319	7,252	7,273	7,354	7,320	7,293	7,224
	San Patricio	64,430	64,455	65,265	66,134	66,638	67,084	67,262	67,215
	Victoria	86,883	87,530	89,067	90,058	90,988	92,082	92,379	92,084
	Subtotal	**626,269**	**629,864**	**637,371**	**645,009**	**650,883**	**656,590**	**658,995**	**657,793**
Lower	Cameron	407,590	412,917	415,370	417,095	418,838	419,579	421,766	423,725
	Kenedy	417	436	444	435	431	433	428	417
	Willacy	22,225	22,166	22,198	22,027	21,943	21,882	21,760	21,584
	Subtotal	**430,232**	**435,519**	**438,012**	**439,557**	**441,212**	**441,894**	**443,954**	**445,726**
Total		**6,141,189**	**6,232,499**	**6,334,400**	**6,448,103**	**6,570,417**	**6,694,765**	**6,783,869**	**6,836,779**

Source: U.S. Census Bureau (2018a)

Housing trends parallel population growth, with most households located in the metropolitan areas of Galveston, Houston, and Corpus Christi (**Table 3-18**).

Table 3-18. Housing Trends in the Study Area

Coastal Area	County	Housing Unit Trends							
		2010	2011	2012	2013	2014	2015	2016	2017
Upper	Brazoria	118,856	120,703	122,554	124,817	126,875	130,236	133,488	136,364
	Chambers	13,395	13,625	13,853	14,190	14,528	14,932	15,272	15,598
	Galveston	132,782	134,455	136,040	137,724	139,626	142,322	144,478	146,439
	Harris	1,601,877	1,614,336	1,629,134	1,653,440	1,681,500	1,718,277	1,749,027	1,768,827
	Jefferson	104,755	105,628	106,149	106,913	107,057	107,874	108,229	108,582
	Orange	35,387	35,585	35,933	36,110	36,265	36,700	37,005	37,264
	Subtotal	2,007,052	2,024,332	2,043,663	2,073,194	2,105,851	2,150,341	2,187,499	2,213,074
Mid-to Upper, Mid	Aransas	15,381	15,479	15,556	15,654	15,789	15,981	16,175	16,381
	Calhoun	11,422	11,467	11,524	11,590	11,778	11,858	11,934	11,989
	Jackson	6,590	6,594	6,596	6,602	6,614	6,632	6,649	6,666
	Kleberg	12,790	12,787	12,811	12,845	13,246	13,267	13,306	13,301
	Matagorda	18,815	18,858	18,902	18,956	19,053	19,261	19,331	19,400
	Nueces	141,184	141,916	142,616	143,580	145,454	147,615	148,548	149,500
	Refugio	3,726	3,723	3,720	3,725	3,724	3,741	3,741	3,743
	San Patricio	26,552	26,641	26,723	26,861	27,044	27,257	27,971	28,419
	Victoria	35,423	35,445	35,508	35,629	36,073	36,878	36,993	37,042
	Subtotal	271,883	272,910	273,956	275,442	278,775	282,490	284,648	286,441
Lower	Cameron	142,177	143,330	144,413	145,526	146,782	148,200	149,467	151,023
	Kenedy	232	232	232	232	232	233	233	233
	Willacy	7,044	7,049	7,059	7,087	7,125	7,215	7,338	7,367
	Subtotal	149,453	150,611	151,704	152,845	154,139	155,648	157,038	158,623
Total		**2,428,388**	**2,447,853**	**2,469,323**	**2,501,481**	**2,538,765**	**2,588,479**	**2,629,185**	**2,658,138**

Source: U.S. Census Bureau (2018a).

According to the Federal Emergency Management Agency (FEMA, 2018) flood claims from storm surge and rainfall damages for the study area paid between 1978 and 2018 totaled $13.5 billion (**Table 3-20**). (Note: FEMA flood claims occur due to a property experiencing inundation regardless of the source of flooding; however, in the study area, the majority of the flooding experienced derives from a combination of storm surge and heavy rainfall associated with tropical events. The subject study is limited to addressing the risk of damages from flooding derived from hurricane storm surge and does not address flooding associated with rainfall events, even those associated with a hurricane or tropical storm event.)

Table 3-19 FEMA Flood Claims in the Study Area

Coastal Area	County	Number of Claims	Total Nominal Dollar Amount*	Average Dollar Amount per Claim
Upper	Brazoria	17,700	620,738,513	35,070
	Chambers	1,247	68,316,685	54,785
	Galveston	50,857	2,543,551,930	50,014
	Harris	132,858	8,270,089,134	62,248
	Jefferson	14,818	912,029,492	61,549
	Orange	8,880	833,783,137	93,894
Mid	Aransas	4,639	184,452,594	39,761
	Calhoun	481	6,274,860	13,045
	Jackson	164	2,626,922	16,018
	Kleberg	214	1,499,652	7,008
	Matagorda	1,603	23,702,877	14,787
	Nueces	3,155	39,927,580	12,655
	Refugio	62	1,502,342	24,231
	San Patricio	984	10,499,494	10,670
	Victoria	534	10,581,990	19,816
Lower	Cameron	3,408	51,995,534	15,257
	Kenedy	3	51,486	17,162
	Willacy	286	2,417,255	8,452
	Total	**241,893**	**13,584,041,477**	

Source: FEMA (2018)

3.10.2.2 Environmental Justice

To determine whether a project has a disproportionate effect on potential environmental justice communities (i.e., minority or low-income population), the demographics of an affected population within the vicinity of a project must be considered in the context of the overall region. Guidance from the Council on Environmental Quality (CEQ) states that "minority populations should be identified where either: (1) the minority population of the affected areas exceeds 50 percent, or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis (CEQ 1997)."

The Environmental Justice study area contains all census tracts and census block groups located within the study area. **Table 3-20** shows the racial characteristics of the study area. Overall, minority residents make up 16 percent of the population in the study area.

3.10.2.3 Economy

Growth in employment, business, and industrial activity is expected to follow economic trends in the local, regional, and national economies. The region's economic anchors of the petrochemical, fishing, and shipping industries remain firmly tied to their proximity to the Gulf and its oilfields; however, without flood risk management alternatives, the stability of employment, business, and industrial activity associated with these economic drivers could be adversely affected in over periods of time.

High poverty rates negatively impact the social welfare of residents and undermine the community's ability to assist residents in times of need. Within the study area, 14.8 percent of the population fell below the poverty level, with a large percent of the population below the poverty line found in the lower coastal counties (**Table 3-21**).

3.10.2.4 Commercial Fisheries

The TPWD Rockport Marine Laboratory collects commercial and recreational fisheries data for the Texas coast. Ten years of data (2006 to 2015) for the commercial and recreational fisheries were obtained from Darin Topping and Mark Fisher at the Rockport Marine Laboratory in October 2016. Species included in the commercial fisheries data are black drum, flounder, sheepshead, mullet, and other. Shellfish include blue crab, eastern oyster, brown and pink shrimp, white shrimp, and other. Species included in the recreational fisheries data are spotted seatrout, red drum, southern flounder, red snapper (Lutjanus campechanus), and king mackerel.

Table 3-20. Racial/Ethnic Characteristics in the Study Area

Coastal Area	County	Percent White	Percent Black or African American	Percent American Indian and Alaska Native	Percent Asian	Percent Native Hawaiian and Other Pacific Islander	Percent Some Other Race	Percent Two or Races	Percent Total Population - Hispanic or Latino	Percent Total Population - Not Hispanic or Latino
Upper	Brazoria	74.2	13.0	0.4	6.1	--	4.3	2.0	29.2	70.8
	Chambers	86.7	8.0	0.1	1.4	--	2.4	1.3	21.1	78.9
	Galveston	77.9	13.1	0.4	3.3	--	2.6	2.8	23.6	76.4
	Harris	63.3	18.9	0.4	6.7	0.1	8.4	2.2	41.8	58.2
	Jefferson	58.4	33.9	0.4	3.5	--	1.9	1.8	19.0	81.0
	Orange	87.9	8.1	0.4	1.1	--	0.5	1.9	6.8	93.2
Mid	Aransas	88.2	1.7	0.7	1.0	--	2.9	5.5	26.3	73.7
	Calhoun	86.4	2.8	--	4.7	0.2	1.4	4.5	47.8	52.2
	Jackson	87.1	7.3	0.1	0.2	0.1	2.8	2.4	31.6	68.4
	Kleberg	86.3	3.9	0.5	2.0	--	5.7	1.6	71.9	28.1
	Matagorda	76.8	10.6	0.3	2.1	0.2	6.5	3.4	40.7	59.3
	Nueces	87.4	3.9	0.5	1.9	0.1	4.6	1.7	62.6	37.4
	Refugio	81.2	5.0	0.2	0.1	--	7.3	6.2	49.3	50.7
	San	92.1	1.9	0.6	1.0	--	2.5	2.0	56.1	43.9
	Victoria	86.7	6.6	0.2	1.3	0.1	2.9	2.2	45.5	54.5
Lower	Cameron	93.0	0.6	0.2	0.6	--	4.7	0.9	89.0	11.0
	Kenedy	97.3	--	--	0.2	--	2.5	--	71.1	28.9
	Willacy	96.2	0.7	0.2	0.1	--	2.3	0.5	87.8	12.2
Average		83.7	7.8	0.3	2.1	0.04	3.7	2.4	45.6	54.4

Source: U.S. Census Bureau (2018a)

* Values reflect price levels at the time the claim was processed.

Table 3-21. Poverty Level in the Study Area

Coastal Area	County	Percent Below Poverty Level*
Upper	Brazoria	7.9
	Chambers	7.7
	Galveston	10.2
	Harris	14.4
	Jefferson	15.9
	Orange	11.3
	Upper Coast Average	11.2
Mid	Aransas	11.5
	Calhoun	14.4
	Jackson	8.8
	Kleberg	15.3
	Matagorda	18.3
	Nueces	12.8
	Refugio	14.9
	San Patricio	11.8
	Victoria	11.1
	Mid Coast Average	13.2
Lower	Cameron	29.2
	Kenedy	16.1
	Willacy	35.5
	Lower Coast Average	26.9
	Study Area Average	**14.8**

Source: U.S. Census Bureau (2018b)

* Percent of families and people whose income in the past 12 months is below the poverty level.

In Texas, commercial landings in the bays from 2006 to 2015 averaged 20.6 million pounds of fish with an average value of $28.0 million and 95.5 million pounds of shellfish with an average value of $232.4 million. **Table 3-22** and **Figure 3-6** show TPWD commercial landings and value (ex-vessel value) for all Texas bay systems from 2006 to 2015. The Upper Laguna Madre, Lower Laguna Madre, and Galveston Bay produce the highest commercial finfish harvest from all Texas bay systems, representing 47.5, 17.3, and 15.1 percent, respectively, of the total finfish landings. While East Matagorda Bay and Sabine Lake produce the least with 0.1 and 0.2 percent, respectively. The Upper Laguna Madre produced 9.7 million pounds with a value of $9.5 million. Black drum is the most commercially caught species in Corpus Christi Bay, Upper Laguna Madre, and Lower Laguna Madre, representing 44.6, 97.9, and 74.3 percent of the total catch. Mullet is the only other fish species collected in significant numbers from the Lower Laguna Madre at 12.4 percent (pers. com. D. Topping [TPWD], 2016).

Table 3-22. Commercial Landings and Values by Bay System, 2006 to 2015

Bay System	Fish		Shellfish		Total Combined	
	Pounds	Value	Pounds	Value	Pounds	Value
Sabine Lake	45,272	$188,038	5,064,516	$5,143,620	5,109,788	$5,331,658
Galveston Bay	3,106,632	$4,488,176	46,268,367	$122,359,116	49,374,999	$126,847,292
Matagorda Bay	1,188,943	$2,619,944	10,230,949	$23,301,144	11,419,892	$25,921,088
East Matagorda Bay	19,786	$104,550	154,525	$252,068	174,311	$356,618
San Antonio Bay	598,265	$800,409	16,703,598	$42,022,980	17,301,863	$42,823,389
Aransas Bay	718,988	$2,418,969	15,560,727	$37,154,255	16,279,715	$39,573,224
Corpus Christi Bay	1,601,657	$3,712,742	1,067,999	$1,462,062	2,669,656	$5,174,804
Upper Laguna Madre	9,746,031	$9,521,444	175,014	$215,833	9,921,045	$9,737,277
Lower Laguna Madre	3,558,791	$4,158,333	322,126	$468,619	3,880,917	$4,626,952

Source: Personal communication with Darin Topping (October 19, 2016) from TPWD, Rockport Marine Lab, Rockport, Texas.

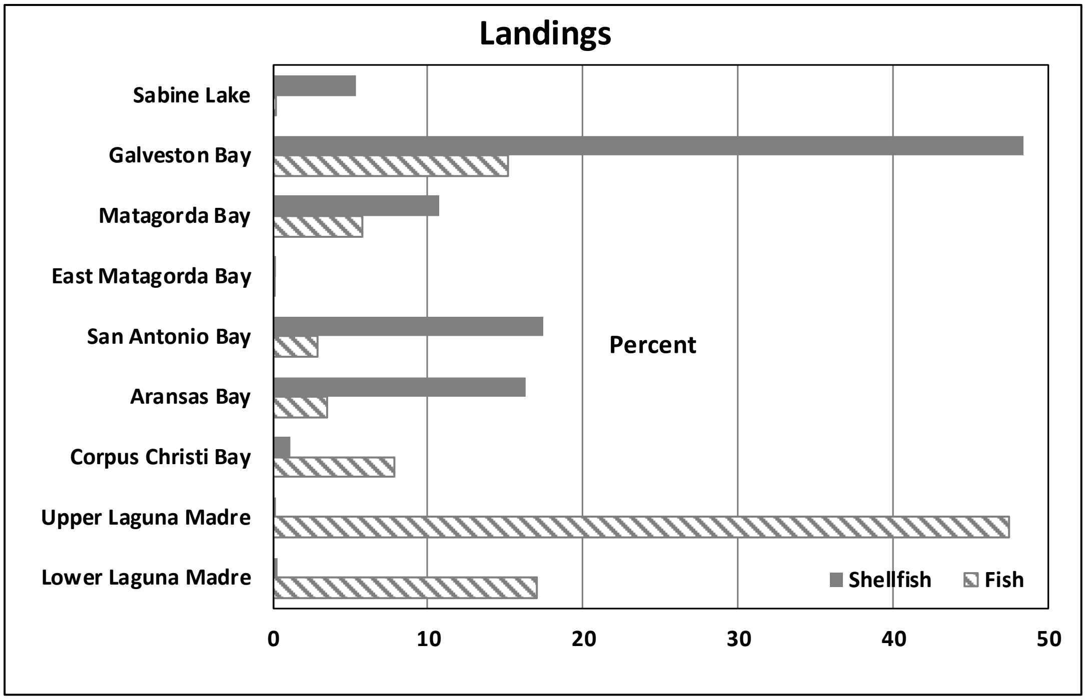
From 2006 to 2015, Galveston, San Antonio, Aransas, and Matagorda bays produced the highest commercial shellfish harvest from all Texas bay systems, representing 48.4, 17.5, 16.3, and 10.7 percent, respectively, of the total shellfish landings while the least is from East Matagorda Bay (0.2%), Upper Laguna Madre (0.2%), Lower Laguna Madre (0.3%), and Corpus Christi Bay (1.1%). Galveston Bay produces 43.3 million pounds with a value of $122.4 million (pers. com. D. Topping [TPWD], 2016).

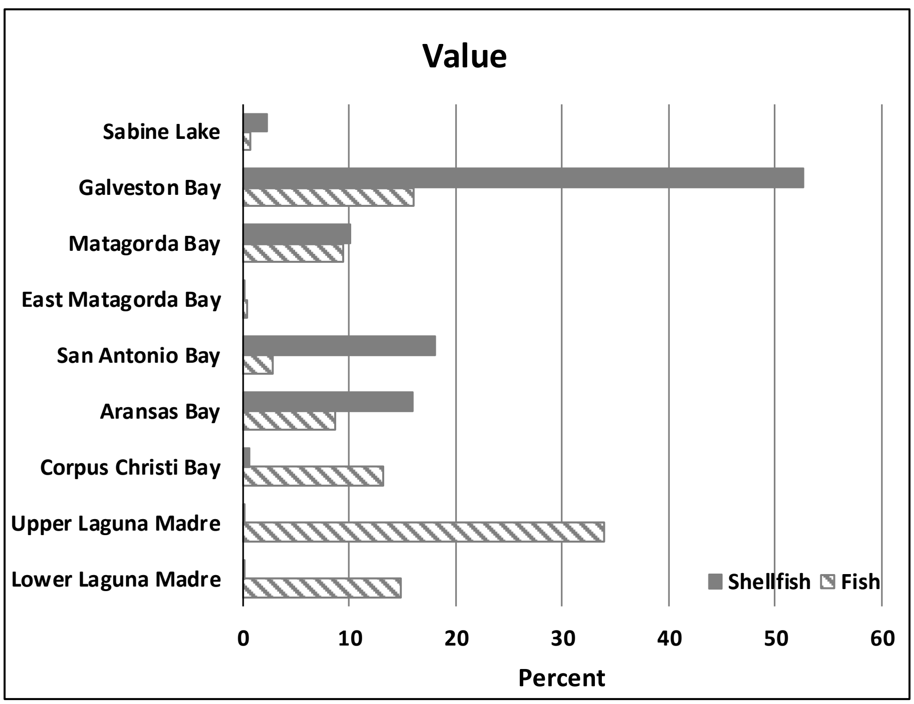
Table 3-24 crab harvest comes from Galveston (33.4%), Aransas (17.8%), San Antonio (17.7%) bays, and Sabine Lake (17.2%). Almost half the eastern oysters are harvested from Galveston Bay (48.9%), with San Antonio, Aransas, and Matagorda bays making up the remaining harvest. Galveston Bay produces over half (52.2%) of the brown, pink, and white shrimp harvest (76.4%). Most black drum are collected from the Upper Laguna Madre (55.7%), flounder from East Matagorda Bay (25.3%) and Aransas Bay (22.4%). Sheepshead are harvested mainly from Galveston, Matagorda, and East Matagorda bays and mullet from the Lower Laguna Madre and Galveston Bay (pers. com. D. Topping [TPWD], 2016).

Table 3-23. Percent of Total Shellfish and Finfish Landings by Bay System, 2006 to 2015

Bay System	Blue Crab	Eastern Oyster	Brown/ Pink Shrimp	White Shrimp	Black Drum	Flounder	Sheeps-head	Mullet
Sabine Lake	17.2	0	0.5	0.8	0.1	0	0.2	2.2
Galveston Bay	33.4	48.9	52.2	76.4	14.0	6.2	34.9	27.3
Matagorda Bay	10.3	8.5	21.5	13.3	2.3	25.3	21.0	0.4
East Matagorda Bay	0.4	0.1	0	0	0	0.3	0	0.4
San Antonio Bay	17.7	22.4	11.8	3.4	2.7	13.5	20.9	0.2
Aransas Bay	17.8	20.1	8	4.7	1.8	22.4	11.7	4.8
Corpus Christi Bay	1.5	0	6	1.3	6.8	11.2	8.3	4.3
Upper Laguna Madre	0.6	0	0	0	55.7	2.7	0.6	1.5
Lower Laguna Madre	1.1	0	0	0	16.5	18.4	2.4	58.9

Source: Personal communication with Darin Topping (October 19, 2016) from TPWD, Rockport Marine Lab, Rockport, Texas.





Source: Personal communication with Darin Topping (October 19, 2016) from TPWD, Rockport Marine Lab, Rockport, Texas.

Figure 3-5. Percent of Commercial Landings and Value of Fish and Shellfish

The TPWD divides the Gulf off Texas into five grid zones (17 through 21 from north to south). From 2006 to 2015, a total of 24.1 million pounds of fish and 55,500 pounds of shellfish were commercially harvested from all Gulf grid zones combined, with a total value combined of $76.1 million. Commercially harvested species include black drum, flounder, sheepshead, mullet, and other. Shrimp are also commercially harvested from this area of the Gulf; however, the data are only available Gulf-wide, not by grid zone through TPWD. Snapper make up the majority of the commercial Gulf harvest, followed by grouper (Serranidae) then cobia (Rachycentron canadum) (pers. com. D. Topping [TPWD], 2016).

Gulf Shrimp landings data by Texas ports were obtained through the National Marine Fisheries Service (NMFS) Annual Commercial Landings Statistics. From 2006 to 2015, a total of 767.8 million pounds of shrimp were commercially harvested in the Gulf with a value of $1.7 billion. Brown shrimp comprised the majority of the commercial shrimp harvest in the Gulf, 526.2 million pounds with a value of $1.1 billion, followed by white shrimp at 240.8 million pounds with a value of $635.9 million (NMFS, 2016a).

3.11 TRANSPORTATION

3.11.1 Regulatory Framework

- **Airport Operating Certificates (Title 14 CFR Part 139)/Circular 50/5200-33B/Memorandum of Agreement with FAA:** USACE must take into account whether the proposed action could increase wildlife hazards. The Federal Aviation Administration (FAA) recommends minimum separation criteria for land-use practices that attract hazardous wildlife to the vicinity of airports.

3.11.2 Existing Conditions

Transportation refers to the movement of people, goods, and/or equipment on a surface transportation network that can include many different types of facilities serving a variety of transportation modes, such as vehicular traffic, public transit, and non-motorized travel (e.g., pedestrians and bicycles). The relative importance of various transportation modes is influenced by development patterns and the characteristics of transportation facilities. In general, urban areas tend to encourage greater use of public transit and/or non-motorized modes of transportation, especially if pedestrian, bicycle, and transit facilities provide desired connections and are well operated and well maintained. More dispersed and rural areas tend to encourage greater use of passenger cars and other vehicles, particularly if extensive parking is provided and/or transit systems are unavailable.

3.11.2.1 Navigation

Texas ports and waterways consist of a mix of deep-draft and shallow-draft commercial ports, fishing and recreational ports, and the GIWW, with roughly 270 miles of deep-draft channels (greater than 15 feet deep) and 750 miles of shallow-draft channels (less than 15 feet deep) (**Figure 3-6**) (Demirbilek and Sargent, 1999; USACE, 2012e). These ports and waterways are major contributors to the economy and security of the State of Texas and the Nation, and additionally serve as key gateways for domestic and international freight movement. With its system of ports and waterways, Texas is ranked first in the Nation in overall tonnage throughput, ranked second in the Nation for waterborne commerce, moving over 500 million tons of cargo annually in recent years, and handles more than one-quarter of the total foreign tonnage throughput in the United States (Texas Ports Association, 2017; TxDOT, 2016b).In total, Texas ports activities contribute over $280 billion in economic value, generates over $6.5 billion in local and State tax revenue, and over $9 billion in Federal import tax revenue annually (TxDOT, 2016b).

Ports are classified by depth (deep-draft and shallow-draft) and the markets they serve. Typically, the ports market is categorized as comprehensive, specialized, and niche. Comprehensive ports handle multiple cargo types to include but not limited to autos, dry bulk, containers, liquid bulk, and military. Specialized ports are equipped to handle large volumes of one cargo type, such as chemicals, petrochemicals, aluminum ore, or agricultural fertilizer. Niche ports provide nontraditional services or handle cargo that is very specific, and typically not serviced by other ports, for example, serving as an asset to the seafood industry. Texas ports accommodate all three categories of the typical ports market place (TxDOT, 2016b).

3.11.2.2 Commercial Waterborne Commerce

Commercial waterborne commerce in Texas is supported by ports with 11 major deep-draft channels (25 feet or deeper) and six ports with shallow-draft channels, all of which are linked by the GIWW and connected to the Gulf, one of the world's most important oil and gas production and refining regions, to statewide, national, and international markets (**Table 3-24** and **Table 3-25**) (TxDOT, 2014b). Of the top 10 busiest ports in the Nation in terms of waterborne tonnage, Texas ports account for three of the top 10: Port of Houston, Port of Beaumont, and Port of Corpus Christi (USACE, 2015b). The Port of Houston is the largest port in Texas handling 248 million tons of cargo (USACE, 2016). The Houston Ship Channel region alone accounts for $336 million of daily economic activity, represents 6.2 percent of total U.S. port activity, generates $16.2 billion in annual tax revenue for the Nation, and provides for $285 billion in national economic output. The Port of Beaumont serves as the world's second largest military seaport, along with leading the Nation in the amount of military exports in support on the Global War on Terrorism (USACE, 2012e).

Linking Texas's deep-water commercial ports and shallow-water commercial and recreational ports is the GIWW, a man-made and protected waterway stretching 1,050 miles along the Gulf from Brownsville, Texas, to St. Marks, Florida. It is the Nation's third-busiest inland waterway after the Mississippi and Ohio rivers. Within Texas, the GIWW consist of 406 miles of channel with the main channel extending 379 miles from the Sabine River to Brownsville, handling 63 percent of the entire GIWW's traffic and moving approximately 73 million tons of cargo per year, consisting predominantly of petroleum and chemical-related products (TxDOT, 2016a, 2017).In addition, the GIWW facilitates the transport of over $31 million annually in wholesale seafood products; total coastwide seafood landings in 2012 was estimated to be 90.5 million pounds and valued at more than $213 million (NMFS, 2016e; TxDOT, 2014b).

In June 2016, the Texas segment of the GIWW was designated by the U.S. Maritime Administration as the Marine Highway 69 corridor. The Marine Highway 69 connects commercial navigation channels, ports, and harbors within the State of Texas, and provides relief to landside transportation corridors that are experiencing traffic congestion, excessive air emissions, and other environmental challenges (TxDOT, 2016a).

The USACE, in partnership with non-Federal sponsors, is responsible for maintenance of these channels to their authorized dimensions. However, the extent of maintenance dredging activities is dependent upon annual Congressional appropriations, which may be below the USACE's capabilities to perform its annual navigation channel maintenance, resulting in deferred maintenance for a channel or reach, and which may affect the volume of maintenance dredged material available to be used beneficially for ER or CSRM beachfill features (Gulf of Mexico Alliance, 2010). On average, the USACE dredges between 30 and 40 million cubic yards (mcy) of maintenance dredged material on an annual basis. Approximately 4 mcy of maintenance dredged material is beneficially used annually to restore marshes or renourish beaches (USACE, 2012e). **Table 3-26** displays the average annual volume of sediments dredged by USACE for the Federally-authorized navigation channels it has responsibility for maintaining along the Texas coast.

Table 3-24. Texas Deep-Draft Port Dimensions, Statistics, and Rankings

Ports	Official Name	Classification	Channel Depth (feet)	Channel Width (feet)	Length (miles)	Port Ranking	Cargo (million tons)
Port of Orange	Orange County Navigation and Port District	Niche	30	200	30	150	0.8
Port of Beaumont	Port of Beaumont Navigation District of Jefferson County	Comprehensive	40	400	40	5	84.5
Port of Port Arthur	Port of Port Arthur Navigation District	Specialized	40	450	19	20	35.2
Port of Houston	Port of Houston Authority	Comprehensive	45	530	61	2	248
Port of Texas City	Texas City Terminal Railway Company	Specialized	40–45	1,200	27	15	41.3
Port of Galveston	Board of Trustees of the Galveston Wharves	Comprehensive	45	1,200	9	52	9.9
Port Freeport	Port Freeport	Comprehensive	45	400	8	33	19.6
Calhoun Port Authority	Calhoun Port Authority	Specialized	36	200	24	76	4.9
Port of Corpus Christi	Port of Corpus Christi Authority of Nueces County, Texas	Comprehensive	45	300	35	6	82
Port Isabel	Port Isabel-San Benito Navigation District	Niche	36	200	21	N/A	N/A
Port of Brownsville	Brownsville Navigation District	Specialized	42	250	21	66	7.3

Source: TxDOT (2016a); USACE (2016).

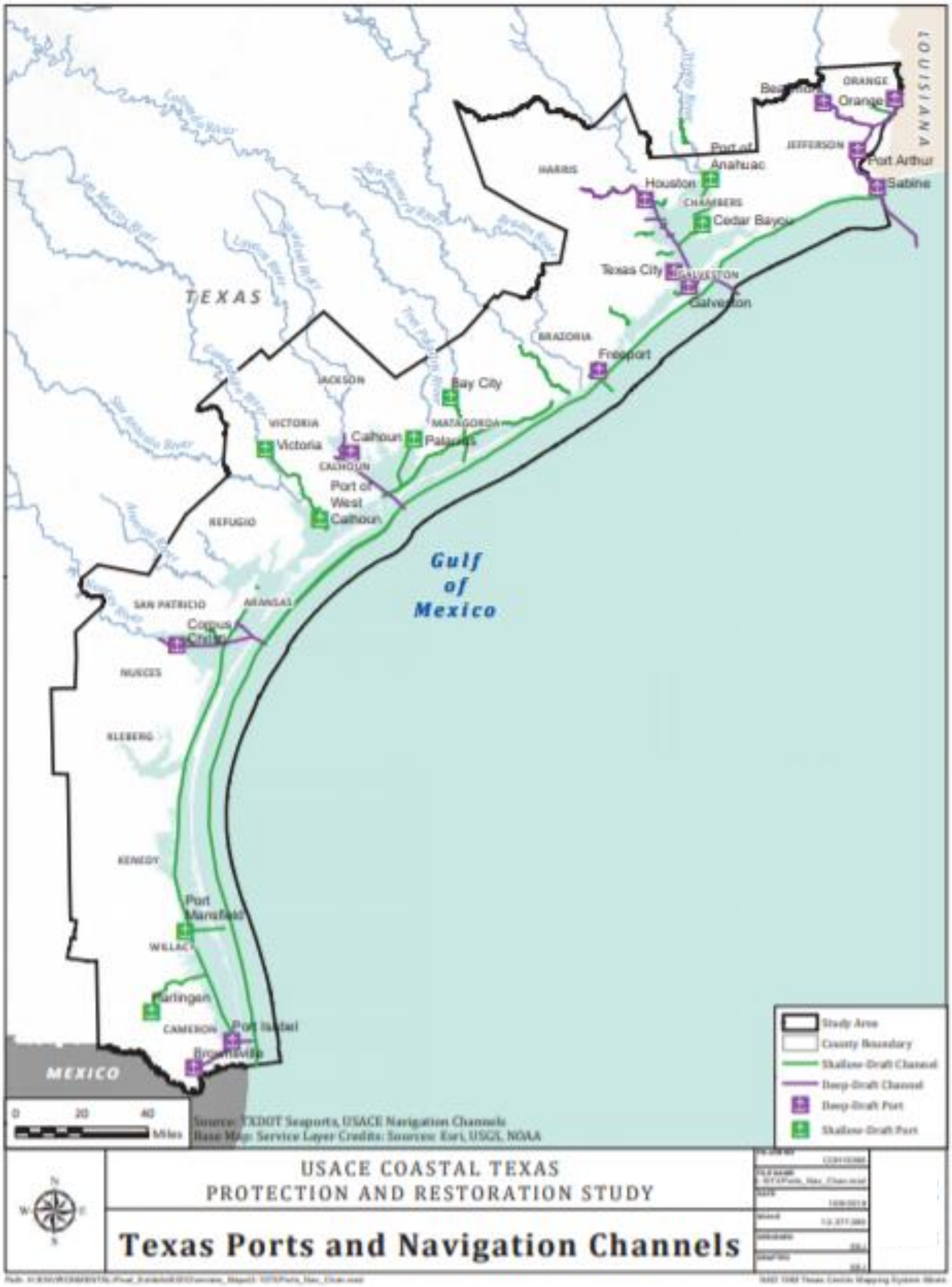


Figure 3-6. Texas Ports and Navigation Channels

Table 3-25. Texas Shallow-Draft Port Dimensions, Statistics, and Rankings

Ports	Official Name	Classification	Channel Depth (feet)	Channel Width (feet)	Length (miles)	Port Ranking	Cargo (million tons)
Cedar Bayou	Cedar Bayou Navigation District, Chambers-Liberty Counties Navigation District	Niche	11	N/A	N/A	N/A	N/A
Port of Bay City	Port of Bay City Authority Matagorda County, Texas	Niche	12	200	12+	N/A	N/A
Port of Palacios	Matagorda County Navigation District No. 1	Niche	12	125	4	N/A	N/A
Port of Victoria	Victoria County Navigation District	Specialized	12	125	35+	74	5.1
Port of West Calhoun	West Side Calhoun County Navigation District	Niche	12	N/A	N/A	N/A	N/A
Port of Harlingen	Port of Harlingen Authority	Niche	12	125	25+	N/A	N/A

Source: TxDOT (2016a); USACE (2015b, 2016).

Table 3-26. USACE Average Annual Maintenance Dredging Volumes in Coastal Texas

Navigation Channel	Total Quantity Sediment Dredged Annually (cubic yards)
Sabine-Neches Waterway Port Arthur Canal, Turning Basin, Junction Area, and Taylors Bayou	3,000,000
Sabine-Neches Waterway Outer Bar and Bank Channel	2,500,000
Texas City Channel Main Channel and Turning Basin	1,500,000
Galveston Harbor Channel	2,000,000
Houston Ship Channel Morgan's Point to Exxon and Barbour's Cut Channel	2,500,000
Houston Ship Channel-Bayport Flare and Redfish Reef to Morgan's Point	3,500,000
Galveston Harbor-Galveston Entrance Channel and Houston Ship Channel – Bolivar Roads to Redfish	2,500,000
Freeport Harbor – Entrance Channel	2,600,000
Matagorda Ship Channel Matagorda Peninsula to Point Comfort	3,000,000
Corpus Christi Ship Channel Entrance Channel	1,000,000
Corpus Christi Ship Channel Inner Basin to Viola Turning Basin/ La Quinta Channel	2,500,000
Brazos Island Harbor Brownsville Jetty Channel	400,000
GIWW, Corpus Christi to Port Isabel	1,500,000
GIWW, Galveston Causeway to Bastrop Bayou	1,000,000
GIWW, Rollover to Causeway	800,000
GIWW, Turnstake to Live Oak	600,000
GIWW, High Island to Rollover and Bolivar Flare	800,000
GIWW, Channel to Victoria Lower and Middle Reach	1,500,000

Source: USACE (2015c).

3.12 AESTHETICS/NOISE

3.12.1 Regulatory Framework

- **NEPA:** The Act establishes that the Federal government use all practicable means to ensure safe, healthful, productive, and aesthetically and culturally pleasing surroundings for all Americans (42 US 4331[b][2])
- **ER 1100-2-100:** USACE Policy states that aesthetic resources must be protected along with other natural resources. Planning guidance specifies that the federal objective of water-related resource planning is to contribute to the NED consistent with protected the nation's environment. Established USACE goals include: 1) preservation of unique and important aesthetic values; and 2) restoration and maintenance of the natural and human-made environment in terms of variety, beauty, and other measure of quality.
- **Noise Control Act of 1972:** The Act directs Federal agencies to comply with applicable Federal, State, and local noise control regulations. In 1974, the EPA provided information suggesting continuous and long-term noise levels in excess of 65 dBA are normally unacceptable for noise-sensitive land uses such as residences, schools, churches, and hospitals. However, in 1982, the EPA transferred the primary responsibility of regulating noise to state and local governments.
- **Texas Penal Code, Section 42.01(c)(2):** Under Texas State code, a noise is presumed unreasonable if the noise exceeds 85 dBA at any time of day. This applies to all unincorporated areas of the study area.
- **Ordinances for other Cities in the Study Area:** Most city noise ordinances specify prohibited actions or time restrictions for noise producing activities such as construction activities, but do not specify unacceptable measurable levels of noise.

3.12.1.1.1 Noise

A brief background in sound is helpful in understanding how humans perceive various noise levels. Noise is a measurement of sound pressure level measured in decibels (dB). The human ear perceives sound, which is a mechanical energy, as pressure on the ear. The sound pressure level is the logarithmic ratio of that sound pressure to a reference pressure and is expressed in dB. Environmental sounds are measures with the A-weighted scale of the sound level meter. The A-weighted scale simulates the frequency response of the human ear, by giving more weight to middle frequency sound and less weight to the low and high frequency sounds. A-weighted sound levels are designated as dBA. As shown in **Table 3-27**, the threshold of human hearing is defined as 0 dBA; very quiet conditions (e.g. a library) are approximately 40 dBA; levels between 50 and 70 dBA define the range of normal daily activity; levels above 70 dBA are considered noisy, and then loud, intrusive, and deafening as the scale approaches 130 dBA.

Table 3-27 Common Noise Levels

Sound Source	dBA
Military jet, air raid siren	130
Amplified rock music	110
Jet takeoff at 500 meters	100
Freight train at 30 meters	95
Train horn at 30 meters Heavy truck at 15 meters	90
Busy city street, loud shout Busy traffic intersection	80
Highway traffic at 15 meters, train	70
Predominantly industrial area Light car traffic at 15 meters, city or commercial areas or residential areas close to industry	60
Background noise in an office Suburban areas with medium density transportation	50
Public library	40
Soft whisper at 5 meters	30
Threshold of hearing	0

Background noise is the cumulation of all perceptible, but not necessarily identifiable, noise sources (such as traffic, airplanes, and environmental sounds) that create a constant ambient noise baseline. Although extremely loud noises can cause temporary or permanent damage, the primary effect of environmental noise is annoyance. The range of human hearing spans from the threshold of hearing (near 0 dBA) to exceeding the threshold of pain (120 dBA). In general, humans will notice a change of sound greater than 3 dBA. Noise levels greater than 85 dBA can cause temporary or permanent hearing loss, if exposure is prolonged.

Similar to noise levels, vibration velocity levels are also measured in decibels and is typically expressed as “VdB” to reduce the potential for confusion with sound decibels. In contrast to airborne noise, ground-borne vibration is not a phenomenon that most people experience every day. The background vibration velocity level in residential areas is usually 50 VdB or lower, well below the threshold of perception for humans which is around 65 VdB. Most perceptible indoor vibration is caused by sources within buildings such as operation of mechanical equipment, movement of people, or slamming of doors. Typically, outdoor sources of perceptible ground-borne vibration are construction equipment, steel-wheeled trains and traffic on rough roads. If the roadway is smooth, the vibration from traffic is rarely perceptible (FTA 2006).

3.12.2 Existing Conditions

3.12.2.1 Noise

There are many different sources of noise that contribute to the ambient noise environment throughout the study area. Waterborne transportation activities that contribute to the ambient noise environment include ship traffic, barges, commercial fishing/shrimping vessels, sport and recreation boats, and dredging vessels. Other forms of transportation that contribute to the ambient noise environment include automobiles, trucks, recreational vehicles, and airplanes. Noise sources related to recreation and commercial enterprises include public beaches, restaurants and nightclubs, retail stores, marinas, and hotels. Multiple types of industry also contribute to the existing noise environment, including heavy industry, such as petroleum refineries; light industry, such as manufacturers of consumer electronics and clothing; and port activities like importing and exporting cargo.

Noise-sensitive receptors are facilities or areas where excessive noise may disrupt normal human or wildlife activities, cause annoyance, or loss of business. Land uses such as residential, religious, educational, passive recreational, and medical facilities are more sensitive to increased noise levels than are commercial and industrial land uses. Common examples of noise-sensitive receptors in the study area include residential communities, schools, motels and hotels, parks and other outdoor recreation areas, and coastal wildlife areas such as habitat for colonial nesting birds.

The existing noise environment within the study area varies greatly and is generally influenced by the surrounding land uses concentrated in any particular area. For example, industrial and commercial land uses have a higher ambient noise level when compared to areas composed primarily for residential land uses. Transportation corridors within the study area also contribute significantly to ambient noise levels. Noise levels generally in the vicinity of highways, major roadways, railroads and airports, are higher than in the surrounding areas and generally decrease the further away from the corridor.

3.12.2.2 Visual

The assessment of the existing conditions describes (1) visual character and visual quality and (2) viewer exposure and sensitivity. The visual character includes components of the landscape and the relationship between the natural environment and the built environment, and the visual quality of the viewers' perception of visual resources that compose the visual character of the study area.

Significant development occurs in and around the major cities and ports. The aesthetic view within these areas is characteristic of an urban environment with commercial and residential structures, including single and multi-story buildings, roadways, signs, and lighting. In and around the ports, industrial facilities and navigation traffic are common. Outside of these areas, natural features, such as marshes, the Gulf of Mexico, and the beach and dune are present throughout the coast. Many of these areas have degrade but still contain some semblance of the characteristic features such as vegetation and wildlife.

3.13 RECREATION

3.13.1 Regulatory Framework

Tourists visiting the Texas coast in 2014 spent $19.7 billion traveling in this region, over $10.4 million at hotels and motels alone. In the upper coast, cruise business is a major economic driver at the Texas ports. The business generated over $1.3 billion for the Texas economy in 2014. This was a 5.6 percent increase from the previous year. Along with the port calls of 1.06 million passenger and crew visits at the two cruise ports of Houston and Galveston, the cruise industry generates over 20,000 jobs and is estimated to have a total wage impact of $1.42 billion (General Land Office [GLO], 2016).

Outstanding fishing, birding, and waterfowl hunting opportunities, as well as family outings to the beach, make the coast the second most popular tourist destination in Texas, keeping the economy strong and creating jobs for both coastal residents and inland workers. Ecotourism is also a major sector in coastal Texas. The Texas coast hosts hundreds of miles of nature tourism opportunities. In the Rio Grande Valley alone in 2011, ecotourism contributed more than 6,613 jobs. An excellent example of nature tourism, or avitourism, is the Great Texas Coastal Birding Trail, the largest nature trail in the nation, with over 300 birding sites available along the Texas coast (GLO, 2016).

3.13.2 Existing Condition

Tourists visiting the Texas coast in 2014 spent $19.7 billion traveling in this region, over $10.4 million at hotels and motels alone. In the upper coast, cruise business is a major economic driver at the Texas ports. This business generated over $1.3 billion for the Texas economy in 2014. This was a 5.6 percent increase from the previous year. Along with the port calls of 1.06 million passenger and crew visits at the two cruise ports of Houston and Galveston, the cruise industry generates over 20,000 jobs and is estimated to have a total wage impact of $1.42 billion (GLO, 2016).

3.13.2.1 Recreational Fisheries

The Texas coast, along with its waterways and open-water access, is an important destination for Texas residents to participate in Hunting, fishing, and wildlife viewing interests. According to Stokes and Lowe (2013), 7.8 million state residents and non-residents participated in some form of fishing, hunting, and wildlife-watching-related recreation, and the combined economic impact of these recreational activities totaled over $5 billion in annual spending and $181 million in State and local annual tax revenue generated. Fishing alone accounted for approximately $1.85 billion in economic activity, and hunting and wildlife viewing across the state accounted for over $43.5 billion in annual economic value.

All Texas bay systems and estuaries provide a range of recreational opportunities. Boating access to these areas is facilitated by shallow-draft ports and the GIWW. Most of the deep-draft ports in Texas do not allow recreational access or boating due to security concerns. However, the deep-draft channels and outlets leading to the Gulf are used extensively by private and charter recreational vessels. Texas ports predominantly used for fishing and recreational purposes and that do not handle commercial cargo are listed in **Table 3-28**.

Table 3-28. Texas Fishing and Recreational Ports

Ports	Name
Port of Sabine Pass	Sabine Pass Port Authority
Anahuac	Chambers-Liberty Counties Navigation District
Rockport/Fulton/Cove	Aransas County Navigation District No. 1
Port of Port Mansfield	Willacy County Navigation District

Source: TxDOT (2016a).

According to the National Marine Manufacturers Association (2008), the economic significance of recreational boating for the combined Texas Congressional Districts in which the proposed ER and CSRM alternative plans are affected totaled $416 million in 2008 (**Table 3-29**). Further, the number of participants residing in areas potentially impacted by the proposed ER and CSRM alternative plans exceeded 80,000 in 2008 (**Table 3-30**). The economic significance of recreational boating and recreational boating by participant within the Texas Congressional Districts of the 112th Congress of the United States (January 2011–2013) and associated counties is outlined in (**Tables 3-29 and 3-30**) below.

Table 3-29. Economic Significance of Recreational Boating

Congressional District/Counties	Total Direct Economic Effects (Craft and Trip Spending)			Secondary Effects, Total Impact of Craft and Trip Spending			
	Sales (million $)	Direct Jobs	Labor Income (million $)	Sales (million $)	Jobs	Labor Income (million $)	Value Added (million $)
9th/Fort Bend and Harris	8	89	3	21	183	7	12
14th/Aransas, Brazoria, Calhoun, Chambers, Fort Bend, Galveston, Jackson, Matagorda, Victoria, Wharton	108	1,182	36	284	2,434	92	155
15th/DeWitt, Duval, Goliad, Hidalgo, Jim Wells, Karnes, Live Oak, Refugio, San Patricio	25	272	8	66	563	21	36
22nd/Brazoria, Fort Bend, Harris	65	707	22	170	1,456	55	93
25th/Bastrop, Caldwell, Colorado, Fayette, Gonzales, Hays, Lavaca, Travis	39	426	13	103	880	33	56
27th/Cameron, Kennedy, Kleberg, Nueces, San Patricio, Willacy	45	492	15	119	1,015	39	64

Source: National Marine Manufacturers Association (2008); U.S. Census Bureau (2013).

Table 3-30. Number of Recreational Boating Participants Impacted

Congressional District/Counties	Number of Registered Boats in the District				Number of Boating-related Businesses and Employment	
	Power-boats	Personal Watercraft	Sail-boats	Number Registered Boats	Number Recreational Boating Businesses	Number Persons Employed
9th/Fort Bend and Harris	2,482	550	93	3,125	10	28
14th/Aransas, Brazoria, Calhoun, Chambers, Fort Bend, Galveston, Jackson, Matagorda, Victoria, Wharton	31,278	3,789	1,318	36,385	153	616
15th/Bee, Brooks, Cameron, DeWitt, Duval, Goliad, Hidalgo, Jim Wells, Karnes, Live Oak, Refugio, San Patricio	9,284	1,022	101	10,407	11	82
22nd/Brazoria, Fort Bend, Harris	17,969	3,724	841	22,534	80	675
25th/Bastrop, Caldwell, Colorado, Fayette, Gonzales, Hays, Lavaca, Travis	13,561	2,226	445	16,232	24	149
27th/Cameron, Kennedy, Kleberg, Nueces, San Patricio, Willacy	13,745	1,995	584	16,324	82	412

Source: National Marine Manufacturers Association (2008); U.S. Census Bureau (2013).

3.14 HAZARDOUS, RADIOACTIVE AND TOXIC WASTE

3.14.1 Existing Conditions

The presence of potential Hazardous, Toxic, and Radioactive Waste (HTRW) concerns along the Texas coast including hazardous materials, hazardous waste, and potential contamination by current or past industrial or other activities are discussed below. Potential HTRW concerns were identified through a review of State and Federal databases cataloguing permitted facilities and activities regulated by these agencies, such as the TCEQ and the EPA. In addition, port activities are discussed below. Engineer Regulation 1165-2-132 provides guidance for Civil Works projects regarding consideration of issues and problems associated with potential HTRW, which may be located within project boundaries or may affect or be affected by USACE Civil Works projects. HTRW includes any material listed as a "hazardous substance" under the Comprehensive Environmental Response, Compensation and Liability Act, 42 United States Code (USC) 9601 et seq. Potential HTRW concerns will be identified following the selection of the recommended plan. A desktop HTRW assessment will be conducted to identify the existence of, and potential for, HTRW contamination, which could impact or be impacted by the recommended plan. This assessment will follow guidance provided by Engineer Regulation 1165-2-132 and consists of a review of recent and historic aerial photographs and a review of Federal, State, and local regulatory agency database information.

3.14.1.1 Upper Coast

The Texas coast from Orange and Jefferson counties along the Texas-Louisiana border south to Brazoria County is a highly urbanized region with major industrial and commercial development along the coastal zone. According to the TCEQ and EPA, these commercial and industrial activities and associated HTRW concerns are centered around the coastal cities and ports of Orange, Beaumont, Port Arthur, Houston, Galveston, Pasadena, Baytown, Deer Park, La Porte, Texas City-La Marque, Dickinson, League City, Friendswood, and Freeport (**Figure 3-7**) (EPA, 2016b, 2016c; TCEQ, 2007a, 2015b, 2016i, 2016j). Sabine Lake, in Orange and Jefferson counties, contains three ports: Orange, Beaumont, and Port Arthur. The Port of Orange, on the Sabine River, is dominated by numerous petrochemical facilities, shipbuilding yards, and tug, barge, and offshore petroleum drilling platform repair facilities. The Port of Beaumont is located along the Neches River upstream of Sabine Lake. The port includes a petroleum terminal that receives crude oil by rail and truck as well as several industrial facilities for the shipping and receiving of military equipment, forestry products, steel, crude oil, cargo, aggregate, bulk grain storage, and potash. Port Arthur is located 19 miles to the north of the Gulf and contains several petroleum and chemical facilities (Gulf South Research Corporation, 2015; TxDOT, 2014a).

Galveston Bay has shoreline in Chambers, Harris, and Galveston counties. Highly industrialized areas within the cities of Houston, Pasadena, Baytown, Deer Park, La Porte, Texas City-La Marque, Dickinson, League City, and Friendswood contain numerous petrochemical facilities and oil storage facilities. Refining and petrochemical activities are most prominent in eastern portions of Harris County along the Houston Ship Channel (Lester and Gonzales, 2011). The Port of Houston, a 25-mile-long complex located along the Houston Ship Channel, has the world's second largest petrochemical complex and the Nation's busiest port regarding foreign tonnage (Port of Houston, 2018a).

The Port of Freeport industrial complex consists of aggregate facilities, petrochemical sites, petroleum processing and refining plants, natural gas gathering systems, and chemical manufacturing plants (USACE, 2012d). Imports to the Port of Freeport include aggregates, chemicals, crude oil, and liquefied natural gas (LNG). Exports from the port include chemicals, resins, and LNG (TxDOT, 2014a).

3.14.1.2 Middle to Upper Coast

South of Brazoria County, the Texas coast along Matagorda, Jackson, Victoria, and Calhoun counties are less densely developed for industrial and commercial purposes. According to the TCEQ and EPA, these commercial and industrial activities and associated HTRW concerns are most prominent in the cities located throughout Matagorda and Calhoun counties with Port Lavaca and Palacios containing the highest volume of regulated sites (EPA, 2016b, 2016c; TCEQ, 2007a, 2015b, 2016i, 2016j).

Matagorda Bay is home to the Port of Bay City and the Port of Palacios. Located along the Colorado River southwest of Bay City, Texas, the Port of Bay City is predominantly utilized for the shipping and receiving of cargo (Port of Bay City Authority, 2016). To the west, the Port of Palacios consists mainly of commercial fishing; however, recent industrial growth includes tugboat and barge manufacturing, recreational vessel manufacturing, and bulk transportation of fertilizer, grain, gravel, and building materials (Matagorda County Navigation District No. One, 2016). In addition, several inland industrial facilities including chemical manufacturing, plastics production and refining, and pipe manufacturing are located within Matagorda County (Matagorda County Economic Development Corporation, 2016).

Point Comfort and Port Lavaca are along the shoreline of Lavaca Bay at the mouth of the Lavaca River in Calhoun County. The Calhoun Port Authority facilities, in Point Comfort, include liquid cargo facilities that support chemical and petrochemical activities. The top commodities of the port are chemicals, fertilizers, petroleum products, and bauxite (TxDOT, 2014a). Industrial activities surrounding Port Lavaca and Point Comfort consist of chemical, plastic resin, and petrochemical production and metals manufacturing (City of Port Lavaca, 2015).

The Port of West Calhoun is located along the eastern shoreline of San Antonio Bay. Port facilities at the Port of West Calhoun include commercial seafood production and oil and natural gas exploration (TxDOT, 2014a)

3.14.1.3 Middle Coast

Industrial and commercial development increases along the Texas coast from San Antonio Bay to Baffin Bay, which includes Aransas, Refugio, San Patricio, Nueces, and Kleberg counties. Refugio, San Patricio, and Nueces counties contain the largest volume of regulated sites, which are centrally located around the cities of Rockport, Aransas Pass, Port Aransas, Portland, and Corpus Christi. According to the TCEQ and EPA, these commercial and industrial activities and associated HTRW concerns are most prominent along the coast between Rockport and Corpus Christi, which contain the highest volume of regulated sites (EPA, 2016b, 2016c; TCEQ, 2007a, 2015b, 2016i, 2016j).

The Port of Corpus Christi is the fifth largest U.S. port and includes cargo shipping and receiving facilities for offshore drilling, wind turbine production, steel and steel pipe production, and heavy machinery. In addition, several facilities in and around the port contribute to increasing volumes of chemicals, crude oil, and petroleum products (Port of Corpus Christi, 2016).

Industrial activities in Corpus Christi and the surrounding area consist of steel pipe production and iron ore, shale oil, and natural gas production including five petroleum refineries (Corpus Christi Regional Economic Development Corporation, 2016).

3.14.1.4 Lower Coast

The southernmost section of the Texas coastline includes Kenedy, Willacy, and Cameron counties. According to the TCEQ and EPA, HTRW concerns are most prominent in Port Isabel and the Port of Brownsville. Fewer regulated facilities are present near Harlingen and Port Mansfield in Cameron and Willacy counties, respectively (see Figure 2-10) (EPA, 2016b, 2016c; TCEQ, 2007a, 2015b, 2016i, 2016j).

Port Isabel's top commodities are concrete, sand, and aggregate; however, the port also serves oil service vessels, concrete manufacturers, and boat construction and repair facilities (TxDOT, 2014a).

The Port of Brownsville's top commodities consist of steel products, iron ore, petroleum products, and lubricants (TxDOT, 2014a). Industrial activities in Brownsville and the surrounding area consist of advanced and heavy manufacturing, automotive production, medical equipment production, and aviation services (Brownsville Economic Development Council, 2016). As part of the Rio South Texas Economic Council, the Port of Brownsville also serves as a gateway to both domestic and international industrial centers. Numerous advanced manufacturing and aerospace design facilities are located in the area and in neighboring cities of Reynosa and Matamoros in Mexico (Rio South Texas Economic Council, 2010)

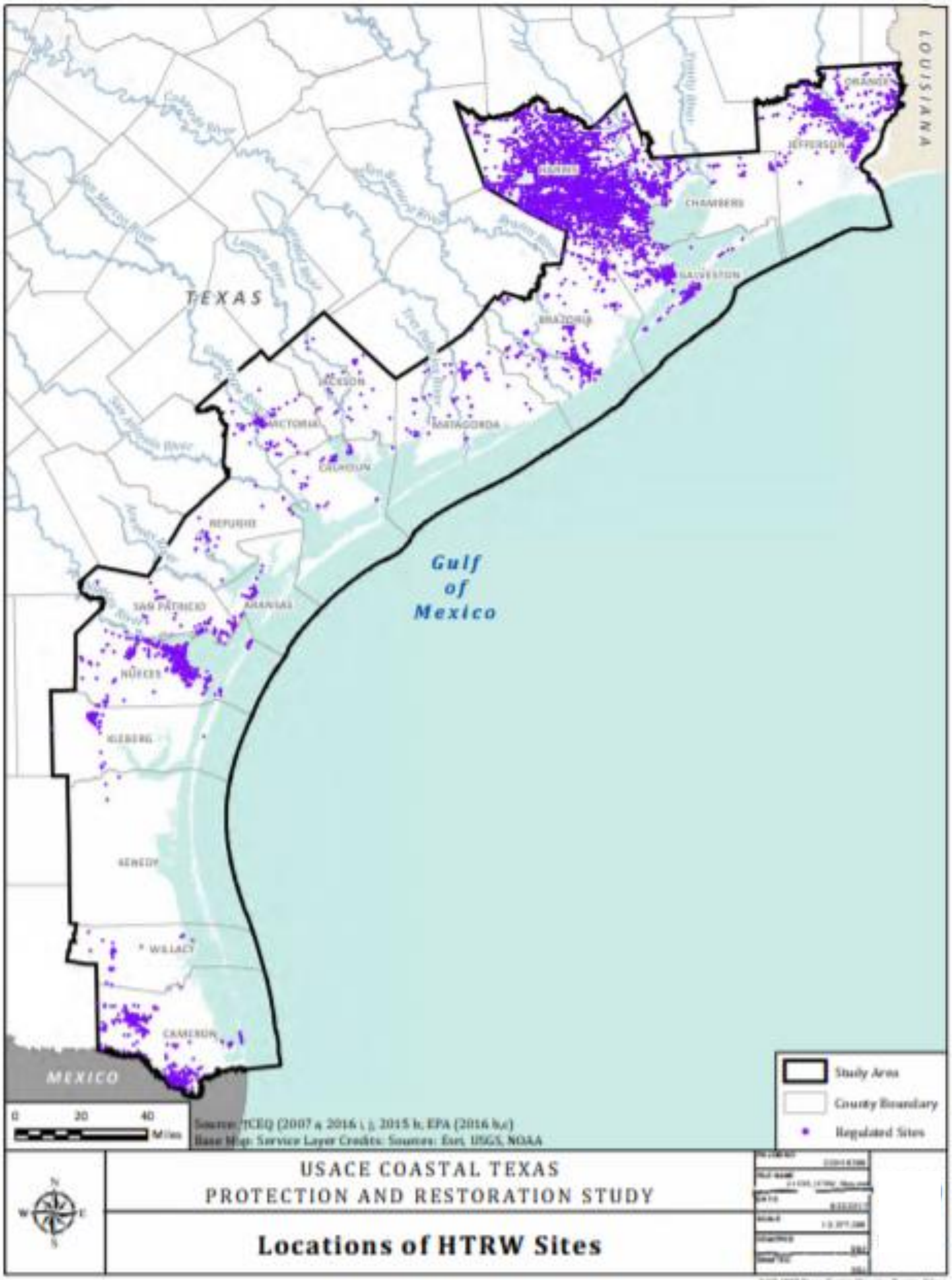


Figure 3-7. Location of HTRW Sites

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4.0 ENVIRONMENTAL CONSEQUENCES: TIER ONE MEASURES

4.1 INTRODUCTION

This chapter describes the environmental consequences for the Tier One Measures included in the alternatives carried forward for detailed analysis and comparison. The Tiered NEPA approach involves a two-step process, the development of a Tier One EIS that makes broad level decisions, followed by Tier Two NEPA Studies that use additional information from the continued development of the measures to conduct the future environmental impact analyses. All the Tier One Measures will have subsequent environmental reviews that will include discussions of environmental consequences consistent with the relevant environmental laws and regulations. The environmental consequences for the Tier One Measures were identified using the information provided by the engineering analysis which include assumptions about future conditions. For this Tier One analysis, a more detailed mitigation plan than what was presented in the 2018 DIFR-EIS has been developed. The mitigation plan was developed assuming current site availability and conditions while acknowledging that the Tier Two analyses will provide more detailed information about the impacts and mitigation opportunities closer to the construction timeframe.

The Tier One Measures discussed in this chapter include all the CSRM measures for Region 1 for both action alternatives and ER measure B2 which is included in the all-inclusive ER Alternative. This Chapter will analyze impacts to resources on Bolivar Peninsula, Galveston Island, the Brazoria County Gulf beaches, Harris County, Chambers County, and Galveston Bay System.

The alternatives analysis, presented in Chapter 2, identified two alternative plans that were carried forward for detailed analysis. While these two alternatives are based on separate conceptual strategies for CSRM in Region 1, they both contain the same ER measures and the South Padre Island CSRM Measure. The Environmental Consequences discussions were presented in two separate chapters to allow for clear discussion on the Tier One and Actionable Measures. Since both action alternatives contain the same Actionable Measures, separating the environmental consideration chapters didn’t alter the comparison.

This Chapter includes descriptions of environmental consequences, mitigation measures for potential impacts, and other environmental considerations for implementing the Tier One Measures of the Coastal Texas Study. The terms consequences, impacts, and effects are considered synonymous in this analysis. The CEQ Regulations define effects or impacts as changes to the human environmental from the proposed action or alternatives that are reasonably foreseeable and have a reasonably close causal relationship to the proposed action or alternative. Many of the discussions in this chapter were written before the effective date (September 14, 2020) of the updated CEQ regulations and discuss effects in terms of direct, indirect, and cumulative. The 1978 CEQ Regulation Guidance[2] defined the following categories of effects or impacts:

- **Direct Impacts:** caused by an action included in a plan alternative and occurring at the same time and place.
- **Indirect Impacts:** caused by an action included in a plan Alternative that would occur later in time or further removed in distance.
- **Cumulative Impacts:** caused from incremental impact of an action added to other past, present, and reasonably foreseeable future actions. Cumulative Impacts are described near the end of this chapter and in Chapter 5 for the actionable measures.

Impacts are described as either beneficial or adverse. Beneficial impacts result in a positive change in the condition of the resource when compared to the No Action alternative. Adverse impacts result in a negative change in the condition of the resource when compared to the No Action alternative. Impacts are also described in terms of duration. Temporary impacts would not persist long after implementation of the management action. Long-term impacts would be permanent or continuous over the period of analysis.

Finally, impacts are described in relation to their significance. The 1978 CEQ regulations require consideration of both context and intensity[3] when determining the significance of an impact on a resource. Context means considering the extent of the impact such as in a national, regional, or local setting.

The following factors can be considered in determining the severity of impact (40 CFR 1508.27):

- Impacts that may be both beneficial and adverse. A significant effect may exist even if the federal agency believes that on balance the effect will be beneficial.
- The degree to which the proposed action affects public health or safety.
- Unique characteristics of the geographic area, such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands wild and scenic rivers, or ecologically critical areas.

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[2] The updated CEQ regulations remove the required categories (direct, indirect, and cumulative) for effect discussion. 40 CFR 1508.1(G) states that effects should generally not be considered if they are remote in time geographically remote, or the product of a lengthy causal chain. Effects do not include those effects that the agency has no ability to prevent due to its limited statutory authority or would occur regardless of the proposed action. Cumulative impact as defined in 40 CFR 1508.7 (1978) is repealed.

[3] The 2020 updated CEQ regulations replace the term “context” with “potentially affected environment” and “intensity” to “degree.”

- The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
- Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or be breaking it down into small component parts.
- The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historic resources.
- The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act.
- Whether the action threatens a violation of federal, state, or local law or requirements imposed for the protection of the environment.

The following descriptors are used in the body of this chapter for consistency in describing impact intensity in relation to significance.

- **No or Negligible Impact:** The impact would cause no discernible change in the environment and would therefore not require any mitigation.
- **Less than Significant:** This impact would cause no substantial adverse change in the environment and would not require mitigation. Less than significant determinations also apply to impacts that are determined to be significant based on the significance criteria, but for which mitigation could be implemented to avoid or reduce the environmental effects to less than significant levels.
- **Significant and Unavoidable:** This impact would cause a substantial adverse change in the environment that cannot be avoided or mitigated to a less than significant level if the project is implemented.
- **Too Speculative for Meaningful Consideration:** An impact may have a level of significance that is too uncertain to be reasonably determined and would therefore be considered too speculative for meaningful consideration. Where some degree of evidence points to the reasonable potential for significant impacts, the section may explain that a determination of significance is undetermined, but is still assumed to be “significant”, as described above. In other circumstances, after thorough investigation, the determination of significance may still be considered too speculative to be meaningful. This is an impact for which the degree of significance cannot be determined for specific reasons, such as unpredictability of

the occurrence or the severity of the impact, lack of methodology to evaluate the impact, or lack of an applicable significance threshold.

4.2 BRIEF DESCRIPTIONS OF THE ALTERNATIVES WITH EMPHASIS ON THE MEASURES REQUIRING TIER TWO NEPA

For detailed descriptions of the two alternatives please see Chapter 2 of this EIS or the Engineering Appendix. **Tables 4-1** provide the Habitat Suitability Index (HIS) models used for calculating mitigation acreages and AAHUs. Table 4-3 summarizes the calculated direct impacts, indirect impacts, and mitigation for the CSRM measures by alterative. Also, the numbers from the 2018 report (before project updates were applied) are include for reference and comparison. **Table 4-2** includes the cover types and acreages that would be impacted by ER measure B-2.

4.2.1 No Action Alternative (Future Without Project Condition)

The No Action Alternative represents the expected future condition if neither of the action alternatives is approved, therefore no Federal action would be taken to manage coastal storm risk or to construct ER measures. Under this scenario, the resiliency of the Texas Coastal Zone to Coastal Storms would continue to decrease from the effects of erosion, subsidence, and RSLR. Also, the productive ecosystems would remain vulnerable to damage from coastal storms. The No Action Alternative is the NEPA benchmark for assessing environmental effects of the proposed project.

4.2.2 Alternative A: Coastal Barrier with Complementary Nonstructural Measures

Alternative A is the Coastal Barrier with complementary Nonstructural Measures which is based on a gulf front concept and would include a Surge Barrier at Bolivar Roads, a Ring Barrier System around Galveston Island with associated nonstructural measures, improvements to the Galveston Seawall, the Bolivar and West Galveston Beach and Dune System, Gate Systems at Clear Lake and Dickinson Bayou, and nonstructural measures on the west side of Galveston Bay. Both Alternative A and Alternative D2 include ER measure B-2 which is only ER measure in the final array that is a Tier One Measure and is included in the discussions in this Chapter.

4.2.3 Alternative D2: Bay Rim Barrier

Alternative D2 is the Bay Rim Barrier which is based on the Upper Bay conceptual strategy that would install a levee system along the perimeter of Galveston Bay from the Houston Ship Channel to the existing Texas City levee system. The system would also extend the existing southwestern terminus of the Texas City Levee west to include Hitchcock and Santa Fe. The Bay Rim Alternative would include a sector gate on the HSC near the Fred Hartman State Highway 146 Bridge, and navigable storm surge gate systems at Clear Lake and Dickinson Bay (closer to Galveston Bay than the similar structure in Alternative A). This measure would also include the Galveston Ring Barrier System, improvements to the Galveston Seawall, and the Bolivar and West Galveston

Beach and Dune System. As mentioned above ER measure B-2 is included in both action alternatives and is the only Tier One ER Measure.

4.2.4 B-2: Follets Island Gulf Beach and Dune Restoration

The B-2 ER Measure would use sand from an offshore borrow source to restore approximately 10 miles of beach and dune system starting just west of San Luis Pass and running toward the City of Surfside in Brazoria County, Texas. The restored beach would have a 400-foot berm width and a dune with a 12-foot tall crest elevation. It should be noted that the ER measures only include a onetime placement of sand material because USACE policy requires ER measures to be self-sustaining and re-nourishment cycles are not considered policy compliant. Engineering analysis was performed on ER measure B-2 and, while the coastal processes would slowly erode the measure, the analysis shows that the project would provide benefits for the 50-year modeling period. Project length was the most influential variable in prolonging the benefits from the measure and with the 10-mile project length, project benefits were projected for at a minimum the 50-year horizon. Whereas, the dual purpose (ER and CSRM) Bolivar Peninsula and Galveston Island Beach and Dune Measure is formulated with re-nourishment cycles because the CSRM authority allows for re-nourishment as an operation and maintenance activity. The Tier One analysis assumed a 10-year re-nourishment cycle for the Bolivar Peninsula and Galveston Island Beach and Dune Measure.

Since the Coastwide All-Inclusive Restoration Alternative was selected as the preferred alternative for the ER Measures, all the ER measures formulated are included for consideration in combination with both Alternative A and Alternative D2. ER Measure B-2 is considered a measure that requires Tier Two NEPA study and an additional report because there is still some uncertainty regarding the precise location and footprint of the offshore borrow source. BOEM is a cooperating agency on this project and they are currently conducting a reconnaissance investigation in the vicinities of Heald and Sabine Banks. USACE has partnered with BOEM and intends to use the result of their reconnaissance investigation as a starting point for further detailed investigations into the location, quantity, and properties of offshore sediments. Based on the results of other past investigations, the PDT is confident that the volume and quality of sand exists within the Sabine and Heald Banks to construct ER measure B-2 and the Bolivar Peninsula and Galveston Island Beach and Dune System. The Holly Beach restoration project in Cameron Parish, Louisiana used material from a borrow source near Sabine Bank that had similar environmental requirements for the material quality as the upper Texas coast. In the next phase of the study, the PDT intends to conduct additional surveys to identify the exact location(s) of the borrow material.

4.2.5 Synopsis of direct and indirect impacts from the action alternatives

The direct cover types for CSRM and ER measures that would be affected during initial construction are presented below (**Tables 4-2** and **4-3**). The information for the 2018 design for the Coastal Barrier (Alternative A) is included in the tables for reference, but the discussions in this Chapter will focus on the analysis performed on 2020 design for the Coastal Barrier.

4.2.6 Description of Methods Used to Quantify and Qualify Impacts to Cover Types (Palustrine Wetlands, Estuarine Wetlands, and Open Water)

Several sections included in this Chapter contain discussions on direct and indirect impacts to palustrine (freshwater) wetlands, estuarine wetlands (saltmarsh), and open water areas. A geospatial analysis was conducted using the NOAA C-CAP 2010 landcover dataset for estuarine and palustrine wetlands to estimate the potential area of affected wetland and marsh habitats. The NOAA Marsh Migration viewer outputs associated with a projected 1-foot of RSLR were then applied. Then HEP modeling procedures were used to calculate the AAHUs of impacted palustrine wetland, estuarine marsh, and open bay bottom. **Table 4-4** displays the results from the ecological modeling performed to quantify impacts and the mitigation for the CSRM alternatives.

The environmental team, in collaboration with the resource agencies, determined which HSI models would be used to evaluate these impacts (**Table 4-1**). The models selected were all USACE approved models and the model selection and application was approved by the Ecosystem Planning Center of Expertise and the vertical team. The HSI models use variables that correspond to an aspect of a particular habitat that indicate the suitability or preference of a species. The species are chosen based on their known use of the habitat and the ability of a particular model to correspond to a specific ecosystem. The values of the variables chosen for all the models were selected collaboratively with the Interagency Team. The species models are used to represent the habitat, not necessarily that specific species. Habitat evaluation for directly impacted areas measured the quality of each habitat category (the HSI value) multiplied by the quantity of each habitat category (acres) resulting in habitat unit measurements. Habitat Evaluation Procedure (HEP) then used target years and forecasted changes in habitat over time to calculate Average Annual Habitat Units (AAHUs). This procedure was then applied to determine mitigation requirements to offset the potential impacts anticipated from the CSRM features.

Table 4-1 HSI model by Habitat Type

Habitat Impacted	Model Used
Palustrine Emergent Wetland	American Alligator (Newsom et al., 1987)
Estuarine Emergent Wetland	Brown Shrimp (Turner and Brody, 1983)
American Oysters	Oyster Model (Swannack et al., 2014)
Open Bay Bottom	HSI values converted to Oyster Model (Swannack et al., 2014) using productivity meta-analysis (Peterson et al.)

Table 4-2 Comparison of the Ecological Modeling Results for the total impacts and mitigation calculated for the 2018 and 2020 configurations of Alternative A

Impact/Mitigation	Alternative A (Coastal Barrier)		Alternative D2 (Bay Rim)	
	Acres	AAHUs	Acres	AAHUs
IMPACTS:				
Direct				
Palustrine Wetlands	128.0	–11.8	227.1	–41.6
Estuarine Wetlands	134.0	–59.9	172.0	–94.5
Open Bay Bottom	161.6	–18.1	44.6	–5.0
Oyster	6.0	–2.8	6	–2.8
Total Direct Impacts	429.6	–92.6	449.7	–143.3
Indirect				
Tidal Prism Change	1,148	–789		
MITIGATION:				
Direct Impacts				
Palustrine Wetlands	21.0	12.1	62.0	42.1
Estuarine Wetlands	93.0	59.9	138.0	95.0
Oyster	7.0	3.0	7.0	3.0
Mitigation Direct Subtotal	121.0	75.0	200.0	137.1
Mitigation Indirect Subtotal	1,207.0	816.3		
Total Mitigation	1,328.0	891.3	200.0	137.1

Table 4-3 Region 1 CSRM Measures Direct Habitat Cover Type Acres

CSRM Measure	Developed/ Upland [1]	Palustrine Emergent Wetland [2]	Estuarine Emergent Wetland [3]	Oyster Reef	Open Water	Dune [4]	Supra-tidal [5]	Inter-tidal [6]	Total Acres
Alternative A: Coastal Barrier (2020)	167.5	128.7	122.3	5.7	2,746.6	–	–	–	3,170.8
Alternative A: Coastal Barrier (2018)	1,520.9	512.5	338.0	–	2,154.0	–	–	–	4,525.3
Upper Bay Barrier – Bay Rim	1,371.2	227.1	172.0	0.03	564.0	–	–	–	2,334.3

[1] Includes bare land, cultivated crops, deciduous forest, develop (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes freshwater wetland and marsh

[3] Includes saline and brackish wetland and marsh

[4] Subaerial habitats ≥5 feet North American Vertical Datum of 1988 (NAVD 88) and encompasses foredune, dune, and rear dune

[5] Occurs from 2.0 to 4.9 feet NAVD 88. This habitat type primarily encompasses swale and may include low-elevation dune and beach habitat.

[6] Occurs from 0 to 1.9 feet NAVD 88. This habitat type encompasses intertidal marsh, mudflats, beach, and any other habitats within that elevation range on the Gulf side and bayside of the barrier island.

Source: NOAA (2017i, 2017j)

Table 4-4 ER Measures Direct Habitat Cover Type Acres

ER Measure	Developed/ Upland [1]	Islands / Bird Rookeries	Estuarine Emergent Wetland [2]	SAV	Oyster Reef	Open Water	Dune [3]	Supra-tidal [4]	Inter-tidal [5]	Total Acres
B-2	79.6	–	–	–	–	624.3	220.7	168.3	20.9	1,113.8

[1] Includes bare land, cultivated crops, deciduous forest, develop (low, medium, high, open space), evergreen forest, grassland/herbaceous, mixed forest, pasture/hay, and shrub/scrub

[2] Includes saline and brackish wetland and marsh

[3] Subaerial habitat ≥ 5 feet NAVD 88 and encompasses foredune, dune, and rear dune

[4] Occurs from 2.0 to 4.9 feet NAVD 88. This habitat type includes swales and low-elevation dune and beach habitat.

[5] Occurs from 0 to 1.9 feet NAVD 88. This habitat includes intertidal marsh, mudflats, beach, and any other habitats within that elevation range on the Gulf side and bayside of the barrier island.

Source: NOAA (2017i, 2017j).

4.3 PHYSICAL RESOURCES

4.3.1 Geomorphology and Coastal Processes

4.3.1.1 Sediment Transport

4.3.1.1.1 No Action Alternative

Under the no action alternative, there would be no CSRM measures constructed and no ER measures would be implemented. Under this scenario current sediment deficits would likely continue to increase at the observed rate. It is expected that anthropogenic interruption of fluvial sediment supplies to the Galveston Bay System will continue. Since the no action alternative does not include construction of structures in the water or on land, sediment transport during storm events would occur in the same way that it does today. Under this scenario, the continued erosion of the coastal barriers is expected and the vulnerability of those landforms to breaching will increase.

As discussed in Chapter 3, issues impeding sediment transport have caused long-term and ongoing deficits within the Galveston Bay System and along the beaches that line Texas's upper coast (USACE 2010b). Fluvial sediment supplies that nourish the Gulf have been highly altered (Dunn and Raines, 2001) and the presence of navigation channels act as sediment sinks (USACE 2010b). The reduction in sediment supply to bay shorelines has resulted in or caused the disintegration of marsh systems, deltas, inlets, bird island habitat, oyster reefs, and other eco-geomorphologic systems (Moya et al., 2012). Current regional trends for beach sediment transport include longshore transport from Port Arthur to south of Corpus Christi and an opposing current that transports sediment in a northerly direction from the Mexico coastline toward Corpus Christi (Freese and Nichols, Inc., 2016).

4.3.1.1.2 Alternative A

Coastal Barrier Alternative

The implementation of Alternative A, the Coastal Barrier, would include the construction of several measures designed to prevent coastal storm surge from inundating developed areas. These measures include the Bolivar Roads Surge Barrier System, the Galveston Ring Barrier System, the Galveston Seawall improvements, the Clear Lake Gate, and the Dickinson Bayou Gate. These structural measures have the potential to impact sediment transport in several ways. First, the closed configuration of these gates will completely impede sediment transport. Second, temporary impacts to sediment transport are expected to occur during construction activities, third the presence of these structures will lead to changes in water flow which could alter depositional patterns and sediment delivery. Finally, by reducing the tidal amplitude for the system the measure could impact sediment delivery to the upper reaches of the marshes that line the Galveston Bay System.

All the gate systems in this plan have the potential to restrict sediment transport when they are in the closed position. These gate systems are being designed so that they would be open most of the time, would close in advance of a storm surge event, and would be opened as soon as the surge subsides. In addition to storm surges, closure would be needed occasionally for testing and maintenance activities. To minimize indirect environmental impacts, including impacts to sediment transport, the gates are being designed to allow the structures to be kept in the fully open position as much as possible. Further analysis will be performed and disclosed in the Tier Two studies.

The construction activities required to build the Bolivar Roads Surge Barrier System will have impacts on sediment transport. The estimated construction timeframe for the measure is 15 years. Construction is expected to include dredging, dewatering, and the installation of temporary structures, which all have the potential to impact sediment transport. These impacts will be analyzed in the Tier Two Study for the measure. Best Management Practices will be implemented to minimize the impacts from these construction activities. Also, the team is coordinating with the resource agencies to ensure that any compatible dredge material is beneficially used to restore marshes, beaches, or bird islands.

An impact identified by the interagency team is the potential for the Bolivar Roads Surge Barrier System to alter sediment transport to the Piping plover Critical Habitat at Big Reef. Big Reef is an accretionary zone adjacent to and north of the Galveston South Jetty and would be on the Gulf side of the Gate System. Once the gate designs are further developed, sediment transport modeling will provide critical understanding of the gate structures potential impact on sediment transport to Big Reef. If the system impacts sediment delivery to Big Reef, several possible solutions have been discussed and include the possibility of installing groin structures or breakwaters to protect Big Reef and encourage continued sediment deposition. Sediment transport modeling for the final gate designs and consultation with the U.S. Fish and Wildlife Service on the impacts and the effects to Big Reef will be conducted in the Tier Two Study.

The updated 3D Adaptive Hydraulics (ADH) Model for the Bolivar Roads Surge Barrier System, shows that a reduction in tidal amplitude of 1-inch (-0.5-inch from the high tide and +0.5-inch to the low tide), could have an impact on sediment transport to salt marsh habitat in Galveston Bay. Several investigations have shown that maximum sediment delivery to salt marshes occurs when strong winds mobilize sediments and increase flooding (Reed 1989). If the project results in a half inch reduction in the high tide, sediment delivered to the distal marsh perimeter could be reduced. This reduction in sediment delivery could make this distal portion of the marsh more susceptible to subsidence and RSLR. Impacts from such a small change in tidal amplitude were challenging to quantify due to lidar and GIS resolution (usually 0.5-foot resolution). To compensate for the lack of precision, the larger impacts forecast for the 2018 gate design were proportionally, reduced. HEP modeling was performed to assess the impact and to quantify the amount of mitigation required. The HEP modeling for these impacts resulted in a deficit of 789.9 average annual habitat units (AAHUs). To offset these losses, the mitigation plan includes the restoration of 1,148.0 acres of degraded marsh that is currently open water. Updated hydrologic modeling and impact analysis will be performed on the final gate designs and those results will be included in the Tier Two Study for the measure.

The Galveston Ring Barrier System, the Galveston Seawall improvements, the Clear Lake Gate, and the Dickinson Bayou Gate all have the potential to impact sediment transport. The impacts of the Offatts Bayou Gate, the Clear Lake Gate, and the Dickinson Bayou Gate were analyzed using the ADH modeling for the complete system. Sampling stations were near the structures. The ADH modeling results were very similar for the with and without project conditions when considering these structures. The results did show episodic differences which usually had a duration of less than a few days. Updated hydrologic modeling and impact analysis will be performed on the final designs for these measures and those results will be included in the Tier Two Studies.

The Bolivar and West Galveston Beach and Dune System would restore sediment volumes within these barrier resources. The measure includes the restoration of 43 miles of beaches and dunes along the west end of Galveston Island and the Bolivar Peninsula. The jetty structures at Sabine Pass and the Galveston entrance channel interrupt longshore sediment transport and have caused the development of fillets and sediment starved sections of beaches near the central portions of these barrier resources. The jetty structures and navigation channels also transport some sediment beyond the depth of closure. This measure would place sediment back into these systems which will then allow the coastal process to distribute the material and shape the beaches. Restoring the sand lens on the beaches also reduces the vulnerability to breaching and provides habitat for resident and migratory organisms like shorebirds and nesting sea turtles. A Kemp's ridley sea turtles nesting model has been developed to help guide the design of the beach nourishment features to maximize the benefits that would result from restoring the morphological traits of the beaches and dunes.

4.3.1.1.3 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The Upper Bay Barrier measure consists of navigation and environmental gates near the Fred Hartman Bridge, Clear Lake, Dickinson Bay, levee/floodwall that would follow the bay rim, and improvements to the Texas City Hurricane Flood Protection Levee. The navigation and environmental gates included in this alternative would reduce hydrologic flow conditions which would impact sediment transport into the Galveston Bay System.

During storm events, Galveston Bay would receive the same volume of surge water and associated sediment overwash into the bay as with the No-Action Alternative. The overwash of sediments could be deposited within the GIWW increasing shoals within the waterway, which would increase maintenance dredging needs.

An increase in scouring along the bay rim would be expected from storm surges and waves. When compared to the No-Action Alternative, the erosion on the non-protected rim shorelines is expected to increase from the surge build-up against the barrier and the sloshing of the water mass within the bay, causing larger impacts to the shoreline erosion and sediment transport.

4.3.1.1.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The beach and dune restoration at Follets Island would allow coastal processes to deliver sediment to the larger beach area south of the project site. Over an extended period of analysis, increases in shoaling through longshore transport can be expected at tidal inlets downdrift of ER beach. The shoreline at the Surfside Village beach may temporarily benefit from the downdrift transport of sediments from the Follets Island Gulf Beach and Dune Restoration (B-2) feature. However, wave amplification at Port Freeport's north jetty would mobilize the sediments transported to Surfside Beach carrying the sediments along the jetty and into Port Freeport's navigation entrance channel (Watson, 2007). An anticipated impact from Follets Island Gulf Beach and Dune Restoration (B-2) feature is an increase in shoaling within the entrance channel at Port Freeport although this would be a slow and gradual process.

Coastal engineers expect that large storms will induce sediment transport from the nourished beach and move sand offshore. When this happens, waves begin to break farther from the shoreline, thus weakening their force before they reach the shoreline itself. In this way, beach nourishment projects help protect dunes and property from further erosion, decrease flooding, and limit how far ashore storm surge will go.

4.3.1.2 Shoreline Change

4.3.1.2.1 No Action Alternative

Under the no action alternative, the ongoing shoreline retreat will continue due to erosion, subsidence, coastal storms, and RSLR. The wind and waves associated with Coastal Storms causes episodic erosion, the effects of which can take years to equilibrate (Paine et al. 2017). Rising sea level inundates low-relief coastal lands causing shoreline retreat by submergence and elevates dynamic coastal processes (currents and waves) that can accelerate shoreline retreat by physical erosion (Paine et al. 2017). Generally, as shorelines retreat, they are usually replaced with less environmentally productive shallow open water habitat. The continuing loss of estuarine wetlands, sea grass meadows, and palustrine wetlands will continue to be an issue for the region. Furthermore, as barrier resources erode, they can become more vulnerable to breaching which would completely disrupt the dynamics in effected estuaries.

Texas has a variety of shoreline types along its Gulf of Mexico coast and coastal bays that are constantly shifting and mostly retreating landward. This retreat results in loss of public and private property and important natural habitats such as beaches, dunes, and marshes. The Bureau of Economic Geology recently analyzed the results from several LIDAR surveys and determined that all major geomorphic features (beaches, Holocene barrier islands, strandplains, fluvial and deltaic headlands, and marshes) of the Texas Gulf Coast shoreline are retreating at a coastwide average rate of about 1.3 meters per year (Paine et al. 2017).

4.3.1.2.2 Alternative A

Coastal Barrier Alternative

The Coastal Barrier would have direct and indirect impacts to shoreline resources. Since these dynamic resources are expected to change between the end of the Feasibility Study and the start of the construction, the Tier Two Study will provide an opportunity to characterize the affected environment closer to the start of construction. Current trends in shoreline change, information on the footprints of the measures, and the results from the ADH modeling were used to identify impacts to shorelines.

The tie-in feature that would connect the Bolivar Roads Gate System to the Bolivar Beach and Dune System would directly and indirectly impact several shoreline resources. A portion of this area, known as Bolivar Flats is federally designated Critical Habitat for Piping plover. Bolivar Flats includes a dynamic series of sandbars, mudflats, oyster reef, salt marsh, dunes, and dune swale wetlands within a tight area. The configuration of the tie-in feature was designed to avoid and minimize impacts to these resources by following the southern and eastern boundary of the neighborhood near Port Bolivar and then by following as closely to State Highway 87 as possible. The current design for the tie-in feature would directly impact 11 acres of palustrine wetlands (freshwater wetlands) and another 78 acres of estuarine wetlands (salt marsh). It has also been pointed out that when storm surges interact with the tie-in structure that there will likely be erosion and impacts to adjacent habitat that is beyond the immediate footprint of the feature. The entire real estate right-of-way footprint (more than the construction footprint) was used to estimate the impacts above to incorporate a conservative estimate of those environmental impacts. The designs for the tie-in feature and the alignments will be further investigated in the Tier Two NEPA analysis and consultation with the Service on the effects to protected resources will be continued in the subsequent study.

The proximity of the Horseshoe Lake marsh (estuarine wetland) to Bolivar Flats and the documented use of the area by Piping Plover and Red knots was a consideration in selecting the mitigation areas. The mitigation work at Horseshoe Lake would include studying and if necessary replacing several road culverts to improve hydrology connectivity and using dredge material to restore some of the historic marsh boundaries. Additional analysis on the viability of the proposed mitigation activities at Horseshoe Lake and consultation with the Service will be required in the Tier Two studies.

The Bolivar Roads Surge Barrier would have indirect impacts to shorelines due to the change in water circulation. The ADH modeling shows that these changes to water circulation would be small, however they would not be expected to increase the average rate of shoreline erosion for the Galveston Bay System, although it could possibly change the locations of some of the hotspots.

The Bolivar Peninsula and West Galveston Island Beach and Dune System includes 43 miles of dune and berm segments on Bolivar Peninsula and West Galveston Island that would restore sediment to depleted areas. The current design for the measure is an excellent example of engineering with nature, other than a few drainage structures, it would be comprised entirely of sand from an offshore borrow source. The presence of these measures has the potential to restore critical parameters that work to balance several important processes, including, sea-level rise, land subsidence, sediment influx, littoral drift, and storm frequency, intensity, and recovery (Paine et al. 2017). The Kemp's ridley nesting model was used to guide the design on the measure to maximize the ecological benefits.

The Galveston Ring Barrier System would have direct impacts to palustrine wetlands and estuarine wetlands. The same ecological evaluation procedure discussed above for identifying direct impacts to habitat was used and it was determined that the measure would impact 44 acres of estuarine wetlands and 50 acres of palustrine wetlands. The mitigation plan includes estuarine wetland restoration near Sievers Cove and Greens Lake, special emphasis was given to restoring coastal barrier habitats on the coastal barriers. However, there are numerous on going and planned restoration activities in the marshes that line the south shoreline of West Galveston Bay. It is anticipated that mitigation options will be re-evaluated in the Tier Two Studies. The mitigation plan also includes the restoration of palustrine wetlands between Stewart Road and State Highway 3005 on Galveston Island to offset these impacts. **Table 4-3** includes the mitigation acreages determined using the geospatial analysis and the ecological modeling.

The Galveston Ring Barrier System will likely have indirect impacts to adjacent shorelines. As water from storm surges and daily tides interact with the structure, they are likely to increase erosion to adjacent areas resulting in increased shoreline erosion. The current design for this measure includes scour protection to minimize these impacts

The Galveston Ring Barrier System also includes breakwaters north of Harborside Drive to reduce the residual risk to industrial facilities that would be on the unprotected side of the Galveston Ring Barrier System. These breakwaters would reduce erosion along the adjacent shorelines and have the potential of providing hard substrate for encrusting organisms including oysters and barnacles. Currently, these breakwaters are conceptually designed using concrete riprap, however, the use of more natural (e.g., reef balls, archipelago) materials will be evaluated in the PED phase.

The Galveston Seawall Improvements measure is not expected to impact shorelines. This measure would raise the elevation of the existing structure by approximately 4 feet. The proposed improvements would not impact the beaches or shorelines because the gulfward footprint is not expected to change. If changes do occur or if other impacts are identified, they will be included in the Tier Two study for the measure.

The Clear Lake Gate and Dickinson Bayou Gate would have direct and indirect adverse impacts to shorelines. The footprints for these measures were used to estimate the direct impacts that would occur to wetlands and oyster reef habitats. The same ecological evaluation procedures discussed above to identify direct impacts to habitat were used and it was determined that the Clear Lake Gate would impact 4 acres of estuarine wetlands and 3.7 acres of oyster reef habitat and the Dickinson Bayou Gate would impact 7 acres of estuarine wetlands and 2 acres of oyster reef. Impacts to oyster habitat were modeled using the Swannack et al. (2014) oyster HSI. Mitigation sites for these gate systems were identified and are shown in the Mitigation Plan Appendix. Any additional impact analysis for these measures will be included in the Tier Two studies.

4.3.1.2.3 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The Bay Rim Alternative would directly impact several shoreline habitats including 227.1 acres of palustrine wetlands and 172.0 acres of estuarine wetlands. These shoreline habitats would be changed through the construction activities and would be replaced levees, structures, and mowed rights-of-way. The closure at the Fred Hartman Bridge, would also likely have direct and indirect impacts to the wetlands near the mouth of Cedar Bayou and near Black Duck Bay.

During Tropical Storms the Bay Rim Alternative would increase water elevations within Galveston Bay which would increase erosion during these events, when compared to the No-Action Alternative or Alternative A.

4.3.1.2.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The B-2 measure would have numerous beneficial impacts. The measure would restore beach and dune habitats which are important for many species including nesting sea turtles and shore birds. Additionally, ER measure B-2 would reduce the chance of a breaching event at Follets Island. These processes would improve sediment availability for longshore transport possibly benefiting down drift shorelines. Specifically, the shoreline at the Surfside Village beach may temporarily benefit from the down drift transport of sediments from the Follets Island Gulf Beach and Dune Restoration (B-2) feature.

4.3.1.3 Storm Surge Effects

Massey et al. (2018) performed coastal storm model simulations of waves and water levels, reporting on storm surge modeling scenarios, and comparing without-project versus with-project alternative CSRM project plans. Under the without-project conditions, 660 synthetic tropical storms along with the three starting water levels were used to compute storm surge and nearshore wave conditions. Nearly 2,000 model simulations were performed for without-project conditions. For more detailed information on the storm modeling see the Engineering Appendix (Appendix D to the Main Report)

An initial screening level comparison of the with-project alternative CSRM measures was modeled using 20 representative synthetic storm samples selected from a full suite of 660 storms. These representative storms were selected since they mimic water level responses that correlate with the return period analysis curves in the Galveston Bay area.

The effectiveness of each alternative CSRM measure was evaluated based on individual storms that produced the maximum storm surge results from the modeled simulations and based on probabilistic storm surge results for a 100-year return period.

4.3.1.3.1 No Action Alternative

Under the no action alternative, no additional CSRM structures or ER measures would be constructed and coastal storm surges would continue to impact the study area. The modeling discussed above used the without project results to establish a baseline. These without project results are synonymous with the No Action Alternative and demonstrate probabilistic impacts to Region 1.

4.3.1.3.2 Alternative A

Coastal Barrier Alternative

The Coastal Barrier CSRM component includes a system of structures and complementary ER measures that will reduce storm surge impacts to Region 1. With almost 2,000 model simulations performed for without and with the Coastal Barrier conditions, it is impossible to demonstrate the probabilistic results in a single model run. However, to demonstrate the effectiveness of the system, the engineering team identified an example storm with maximum wind speeds that reached 109 mph, and as such, it is classified as a category 2 hurricane on the Saffir-Simpson hurricane wind scale. Landfall for this simulated storm would have been near Freeport, Texas, with a roughly 60° angle of attack to the coastline. **Figure 4-1** shows a map of maximum surge elevation with current sea level rise scenario. Notice that surge in the bay is above 18 feet with the exception of Texas City, which is protected by the existing Texas City Levee system. **Figure 4-2** shows a map of maximum surge elevation for the with-project scenario which shows significant reduction (> 50%) of surge within the Bay while compared with the base condition. The with project scenario includes the Galveston Island Ring Barrier, which protects the island from inundation. These figures demonstrate the effectiveness of the Coastal Barrier at reducing surge levels from extreme storms. Examples of other storms are included in Melby 2020.

Along with response from individual storms, the performance of the alternatives was considered probabilistically. The probability mass surfaces were computed for without- and with-project alternatives for each RSLR scenario. The probabilistic storm surge for 100-year return period with a 90% Confidence Interval using the intermediate RSLR condition for year 2035 resulted in the with-project condition significantly reducing water levels inside the system by an average of 6 to 10 feet. This means that when storm surge is evaluated probabilistically with a 100-return period, reduction in storm surge elevation throughout Galveston Bay is observed with the proposed Coastal Barrier CSRM Alternative.

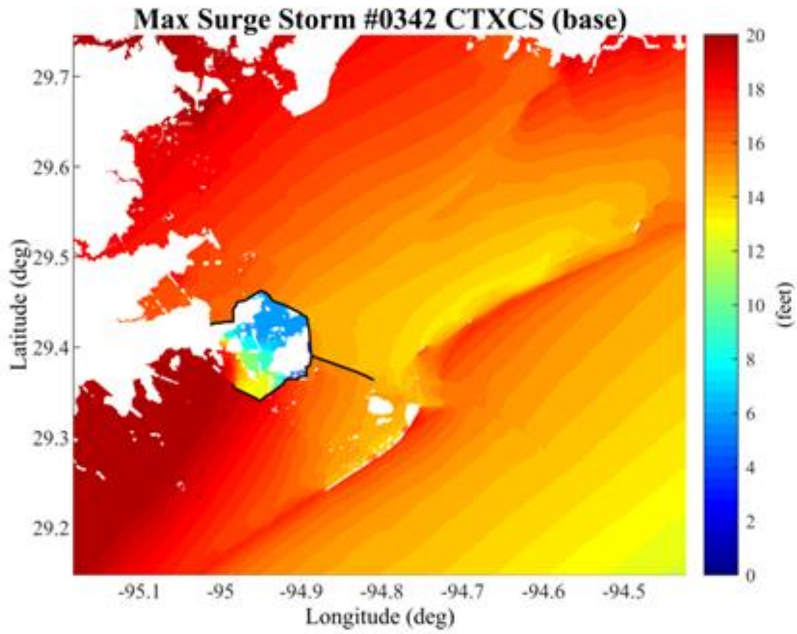

Figure 4-2 Maximum Surge (Without Project Condition)

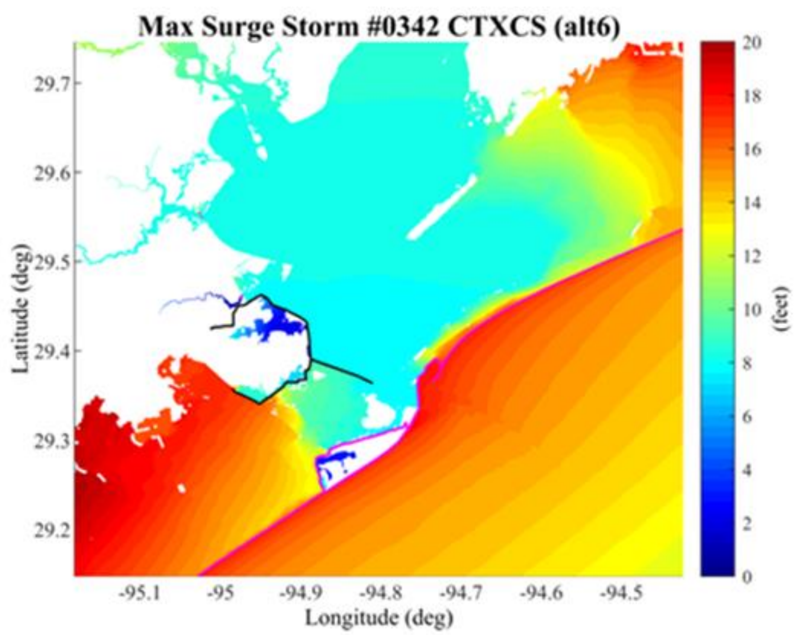

Figure 4-1 Maximum Surge with the Coastal Barrier Alternative

4.3.1.3.3 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

Surge or water surface elevation comparisons between without- and with (Upper Bay Barrier)-project conditions for Storm 154 (Category 3) and Storm 356 (Category 4) are displayed in **Figures 4-1** and **4-3**, respectively. For Storm 154 (Category 3), the Upper Bay Barrier provides no significant differences in maximum storm surge over the without-project condition for almost the entirety of Galveston Bay, with reduced surge values occurring only north and west of the structures (**Figure 4-3**). For Storm 356 (Category 4), the Upper Bay Barrier provides storm surge reductions landward on the southwestern portions of the bay, which are areas on the protected side of the levees (**Figure 4-4**). For both Storm 154 and Storm 356, the proposed Galveston Island ring levee does not appear to be overtopped by the surge.

For the 100-year return period probabilistic storm surge, the Upper Bay Barrier provides storm surge reductions landward on the southwestern portions of the bay, which are areas on the protected side of the levees**. Figure 4-5** displays the water surface elevation changes between the proposed Upper Bay Barrier measure and without-project condition.

When storm surge is evaluated by individual storms and probabilistically with a 100-return period, reduction in storm surge elevation landward on the southwestern portions of Galveston Bay throughout Galveston Bay is observed with the proposed Upper Bay Barrier CSRM measure.

4.3.1.3.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The restoration of the beach and dune system at the Follets Island Gulf Beach, enhances the barrier resources resiliency to storm surges from tropical cyclone storm events. Sand is efficient at dissipating wave energy. Also, the restored beach would protect the wetlands and mudflats located on the north side of Follets Island from the adverse effects of storm surge.

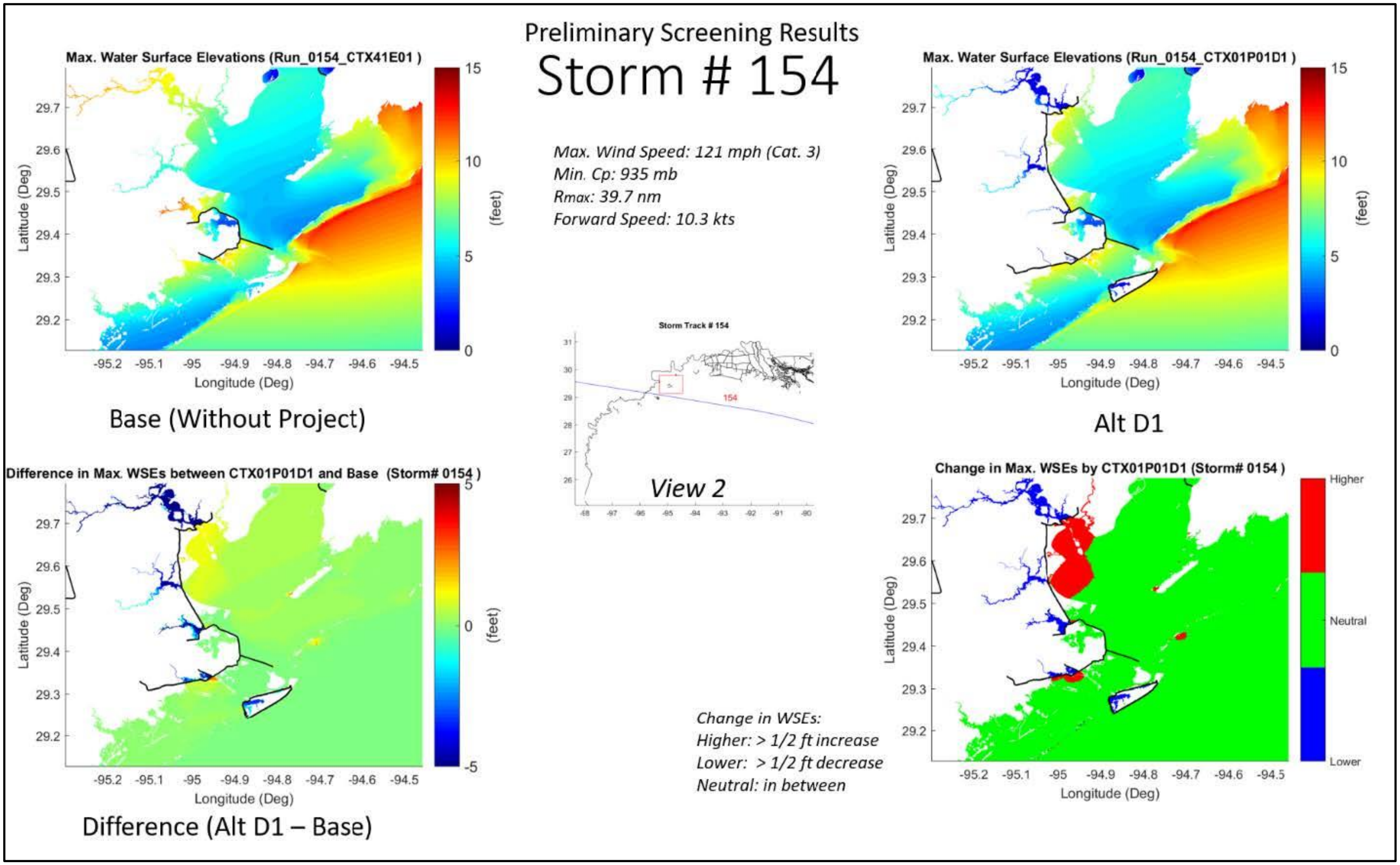

Figure 4-3 Storm Surge Results for Storm 154, Category 3 – Upper Bay Barrier (Massey et al., 2018)

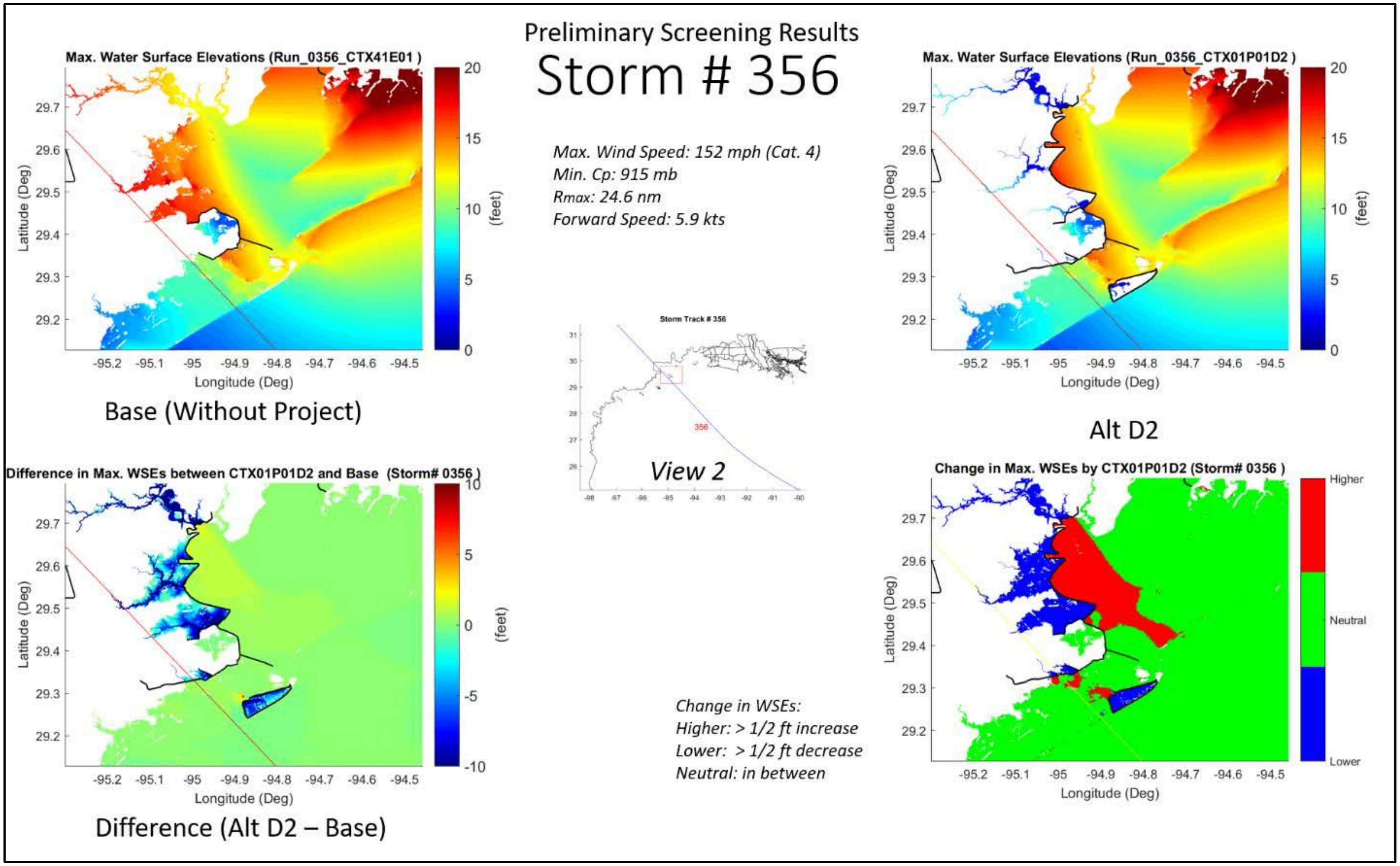

Figure 4-4 Storm Surge Results for Storm 356, Category 4 – Upper Bay Barrier (Massey et al., 2018)

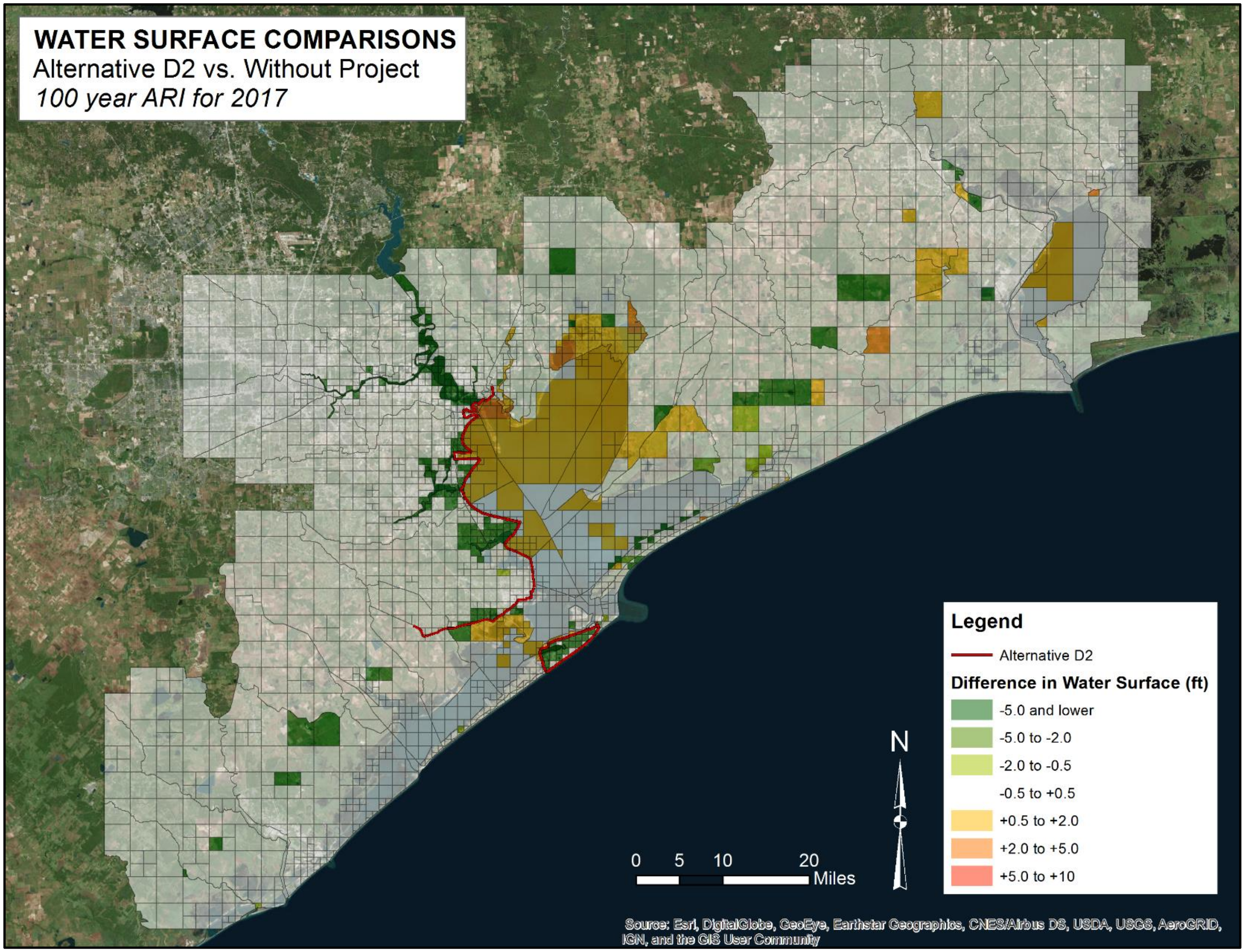

Figure 4-5 Storm Surge Elevation Changes Between the Upper Bay Barrier and FWOP (Massey et al., 2018)

4.3.2 Physical Oceanography

4.3.2.1 Tides, Currents, Circulation

These discussions specifically address effects that the alternatives would have to the day to day changes in water circulation assuming the gates included in the action alternatives would be in the open position.

4.3.2.1.1 No Action Alternative

ADH modeling was conducted to investigate the effect that the alternatives would have on tides, currents, and circulation. For this modeling, the without project conditions are synonymous with the no action alternative. With the no action alternative, RSLR and ongoing shoreline change will alter tidal fluctuations and current and circulation patterns within Region 1. RSLR will increase the tidal amplitude and tidal prism for the Galveston Bay system. The rates of RSLR will be assessed in the Tier Two studies to give a more accurate assessment of the without project condition.

Approximately 172 square miles of wetted area was added to account for 2085 projected sea level rise. Model simulations included freshwater inflows from Trinity River, San Jacinto River, and seven ungagged flow locations. Details of the ADH model results are available in McAlpin et al. (2018).

4.3.2.1.2 Alternative A Coastal Barrier Alternative

The structures included in the Coastal Barrier Alternative have the potential to impact water movement (tides, currents, and circulation). The design for the Bolivar Roads Surge Barrier System has been updated since the 2018 Draft Report. In 2019, USACE convened a team of surge barrier experts from around the world in Galveston to consider the design for this measure. Some notable design changes include the use of two 650-foot-wide sector gates instead of one larger sector gate, the inclusion of two 125-foot-wide sector gates to provide a navigation alternative to the main channel that doesn't have a mast restriction, 300-foot wide vertical lift gates instead of 100-foot-wide gates to reduce construction, the incorporation of 16-foot-wide monolith gates with sill depths of -5-foot to provide shallow water exchange, and ramped sills. The new design reduced the permanent channel constriction from 27.5% to less than 10% (~7.5%).

The ADH modeling conducted for the 2018 draft report was updated using the new gate system design (McAlpin et al. 2019 b.). All input conditions for this updated modeling match those for the present condition as referenced in McAlpin et al. 2019 b. The updated ADH modeling showed that the 2020 design for the System would have lower changes to tidal prism, water velocities, and salinities in the Galveston Bay System than the 2018 design. Using the present conditions (2019 water elevations/tides) with and without the 2020 Surge Barrier design, the model predicts changes in tidal amplitude between 2.4-5.7% across all the stations in Galveston Bay. Those changes are equivalent to a 0.01-0.02 meter (0.4-0.8 inch) change (Lackey and McAlpin 2020).

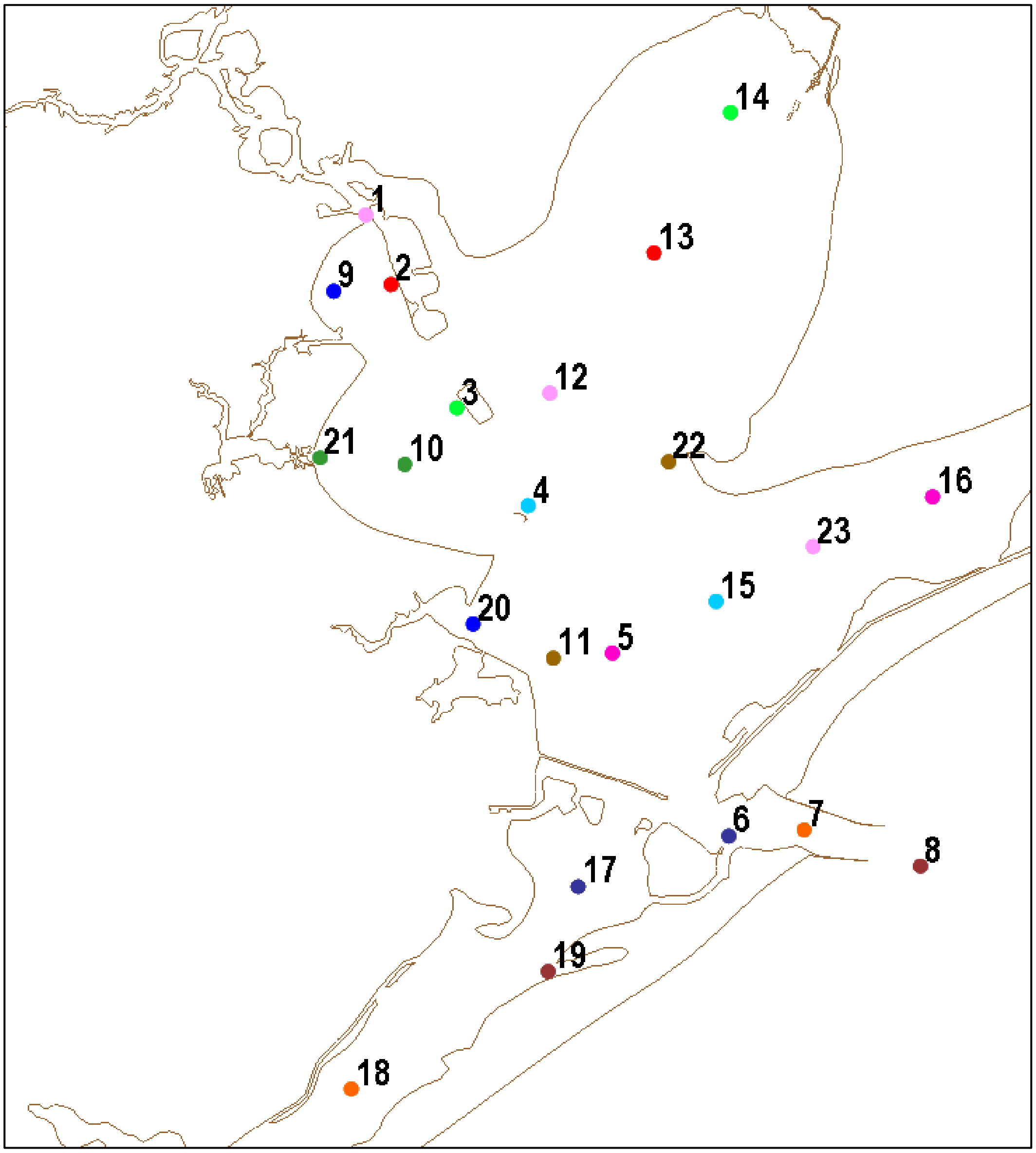

Figure 4-6 AdH Modeling Station Locations

The AdH modeling showed reduction in tidal prism stands between 3 and 7 percent, indicating that the updated design for the Barrier System would still have some restriction in flow in and out of Galveston Bay at Bolivar Roads. **Table 4-5** displays the model results for tidal prism.

Table 4-5 Average tidal prism comparison for analysis year

	2019PWP (m^3)	PWOP Re-Run (m^3)	2019 PWP % change from PWOP
Bolivar Roads	509,068,923	526,009,862	-3.22
Offatts Bayou	1,211,965	1,261,998	-4.00
Dickinson Bayou	535,201	572,211	-6.47
Clear Creek	3,411,910	3,541,595	-3.66

The water velocity magnitudes for Coastal Barrier Alternative do drop at most locations in comparison to the without project scenario. This was true for velocities at both the surface and the bottom of the water column, these reductions in the mean velocity were all less than 0.1 m/s and typically more on the order of 0.05 m/s or less. Locations in West Bay and on the western perimeter of Galveston Bay showed a slight increase in velocity magnitudes for both surface and bottom, again, the changes in these magnitudes are predicted to be less than 0.1 m/s. **Figures 4-6** and **4-7** show an example of the modeling results for water velocity from a station located in the lower reaches of Galveston Bay (Station 5 in **Figure 4-6**) and it shows that the anticipated change in surface water velocity between the with and without project scenario is very small.

The AdH modeling was also used to analyze the hydrodynamics for 2020 Surge Barrier design at the barrier location, to assess water currents and velocities in and around the structures. Instead of running the analysis for the full time series used in the 2018 analysis, the researchers chose the strongest tide cycle that was observed in the two-year period. The transition between low and high tide showed the greatest jump in predicted velocities (**Figure 4-8**) through the navigation gate which reached 2 m/s (6.6 ft/s) in places. This could result in the formation of eddies on the backside of the structures, which may have impacts on navigation and could adversely impact organisms that transit the area. The analysis does show that with this particularly strong tide cycle, once the transition period between low and high tide moves to the full incoming tide, the maximum velocities drop to 0.75 m/s (2.5 ft/s) which was less than the 1.3 m/s (4.3 ft/s) seen in the without project condition during the tide transition.

The gate structures and floodwalls at Clear Lake, Dickinson Bayou, and Offatts Bayou will impact tidal exchange, currents and water circulation. The hydraulic analysis provided in the AdH modeling shows minimal changes in the proposed vicinities of the structures. Future hydrologic analysis and any resultant impact assessments for these measures will be included in the Tier Two studies for these measures. If the future analysis identifies issues with water circulation, additional openings may be included in the project designs to reduce impacts to tidal exchange, salinity, and water circulation.

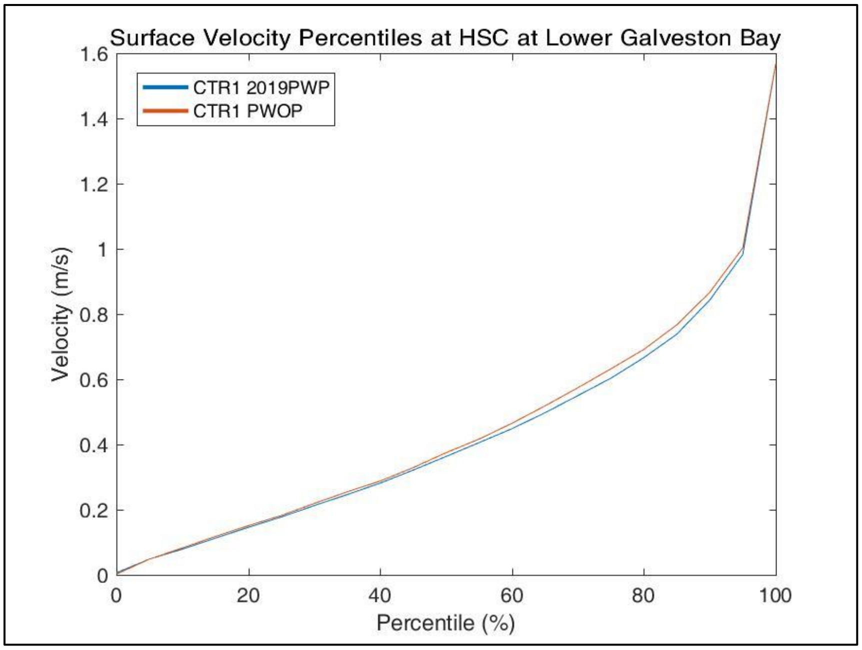

Figure 4-7 Modeled Surface Velocity for a station in the Lower portion of Galveston Bay

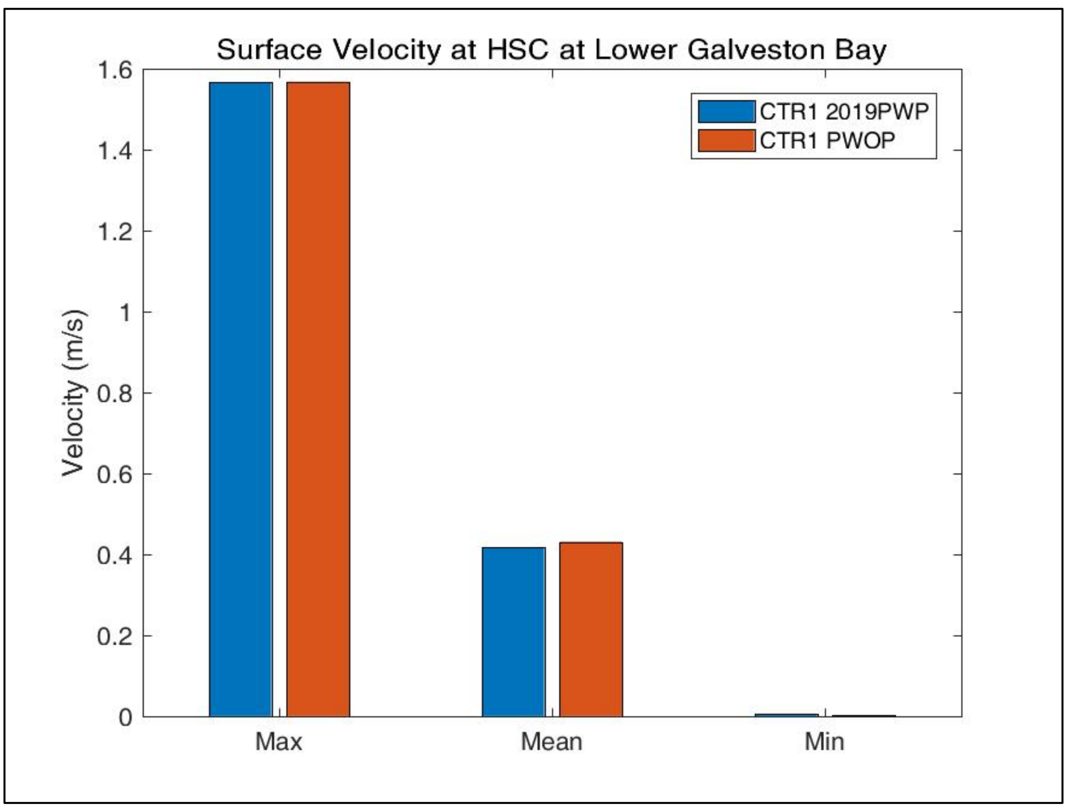

Figure 4-8 Surface velocity chart for the HSC at the Lower Galveston Bay

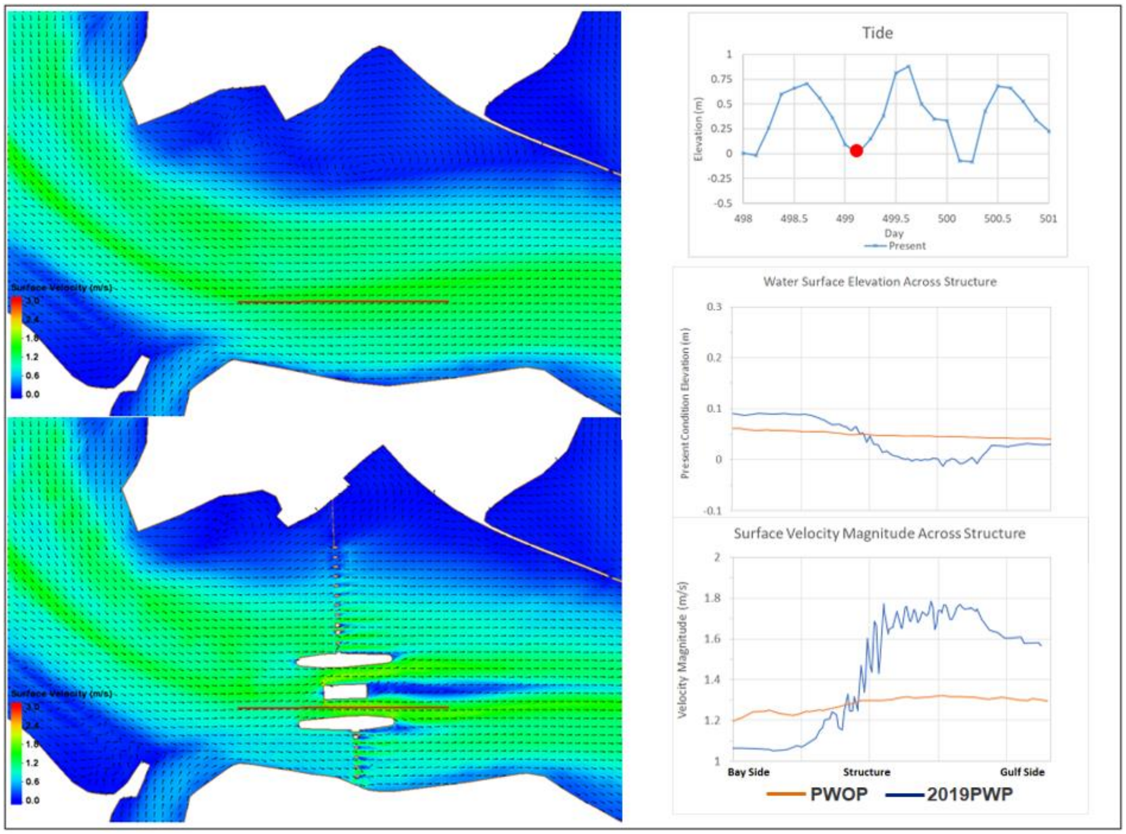

Figure 4-10 Hydrodynamics for the with and without project scenario for the largest tide cycle included in the two-year analysis (transition between low and high tide)

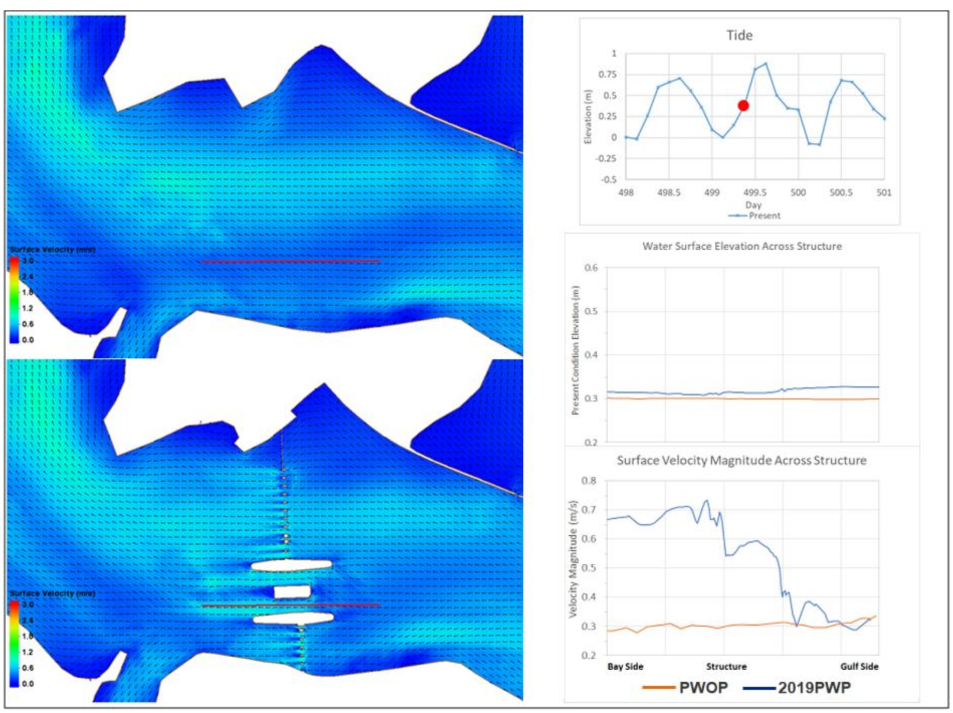

Figure 4-9 Hydrodynamics for the with and without project scenario for the largest tide cycle included in the two-year analysis (incoming high tide)

4.3.2.1.3 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The Upper Bay Barrier would include a closure on the Houston Ship Channel near the Fred Hartman Bridge and would cross Tabbs Bay to prevent storm surge from entering the upper reaches of the Houston Ship Channel. Additional flow control structures of the Upper Bay Barrier measure are proposed for Offatts Bayou, Dickinson Bayou, and Clear Creek, with geometries similar to the Coastal Barrier.

The closure structure system crosses Tabbs Bay to Hog Island, then to the Spillman Island Placement Area, a distance of 9,870 feet. The Tabbs Bay crossing consists of combi-wall and a series of 100-foot environmental gates to connect the north bank of the bay with Hog Island. A 3,070-foot crossing at the Houston Ship Channel would consist of combi-wall and a sector gate to accommodate the existing channel width of 530 feet.

Modifications to the Bolivar Roads are not proposed for the Upper Bay Barrier, therefore, the tidal prism and tidal amplitude is expected to remain relatively unchanged between without- and with-project conditions. The exception may be in the vicinity of Tabbs Bay near the Fred Hartman Bridge where a system of environmental and navigation gates is proposed for the Houston Ship Channel where tidal prism and amplitude will be nominally impacted. Further hydrodynamic modeling may be required to quantify potential impacts.

McAlpin et al. (2018) reported mean surface and bottom current velocities increased minimally from without- to with-project conditions at locations further upstream within Galveston Bay for the Coastal Barrier measure. It is anticipated that there would be increases in water velocities from the constriction caused by the structure adjacent to Tabbs Bay. Under this scenario, the velocity magnitudes for the rest of the Bay are expected to vary little between with- and without-project conditions.

Localized circulation changes are expected to be experienced near the vicinity of the Tabbs Bay environmental and navigation gates system and the other flow control structures. Further hydrodynamic modeling may be required to quantify potential impacts.

Tidal prism, tidal amplitudes, currents, and circulation within Galveston Bay are expected to remain unchanged under without- and with-project conditions, with the exception of the Tabbs Bay vicinity where a system of environmental and navigation gates for the Houston Ship Channel may impact tides and currents upstream of the gated system. Further hydrodynamic modeling may be required to quantify potential impacts.

4.3.2.1.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Appreciable impacts to tides, currents, and circulation are not expected to be induced by the beach and dune restoration features at Follets Island Gulf Beach.

4.3.2.2 Salinity

4.3.2.2.1 No Action Alternative

Salinity and currents were modeled in the 2018 analysis which includes the future without project scenario using the AdH model (McAlpin et al., 2019b). For this modeling the without project conditions are synonymous with the no action alternative. With the no action alternative, RSLR causes changes in salinity to the system.

4.3.2.2.2 Alternative A

Coastal Barrier Alternative

The 2020 AdH modeling update predicted changes in salinity using the present conditions with and without the 2020 Surge Barrier design. Most of the with and without project salinities were close to identical near Bolivar Roads Surge Barrier System and they begin to diverge further into the system. However, these predicted changes in the mean salinity are within 2 ppt and in most instances in the time series, the difference is less than 1 ppt for all the stations across the bay. The complete results for the salinity modeling are included in the Engineering Appendix (Appendix D to the Main Report).

The model assumed the Coastal Barrier would reduce the volume of water entering and leaving the bay with each tide (tidal prism) by 3 and 7 percent. If the final, constructed Coastal Barrier is designed with a smaller permanent cross-section at Bolivar Roads than the current design, salinity impacts would be expected to be lower. Likewise, if the Coastal Barrier blocks more of the tidal prism, impacts on salinity than those listed the Engineering Appendix are expected to be higher.

The AdH model predicts tidal circulation would be reduced when the tidal prism is reduced. The reduced circulation would increase residence time in the bay upstream of the Coastal Barrier and allow greater dilution by freshwater inflows. During periods of normal to relatively high freshwater inflow ("wet" periods), the model predicts salinity from surface to bottom would be lower and remain lower for a longer time.

During periods of severe drought, with low freshwater inflow and high evaporation or when storms push saline water into the bay upstream of the barrier, saline water would remain in the bay above the barrier for longer periods, and salinities would be higher than without the barrier in place.

Barriers at Clear Lake and Dickinson Bayou are also predicted to reduce the tidal prism entering these systems by 14 to 16 percent (McAlpin et al., 2019b). Although salinities were not modeled upstream of the barriers in these systems, the reduced tidal prism is expected to result in increased periods and extent of lower salinities than the condition without the barriers. The proposed barrier at Offatts Bayou is predicted to reduce the tidal prism about 16 percent. Since there is limited freshwater inflow into Offatts Bayou, salinities may be slightly higher at times upstream of the barrier than if the barrier were not in place.

4.3.2.2.3 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

Salinities were not modeled in portions of the system upstream from the Upper Bay Barrier, including the upper Houston Ship Channel, Buffalo Bayou and its tributaries, and the San Jacinto River tidal. Mean salinities are not expected to differ by more than 0.4 ppt in the bay system with this CSRM measure in place based on screening level analysis conducted by the USACE (pers. com H. Das [USACE], 2018). The small change in salinity is expected because the Houston Ship Channel is channelized and relatively narrow compared to the open bay, so the barrier would not block a substantial amount of the flow. Its position in the extreme upstream end of the bay would minimize any impact on the tidal prism. This CSRM measure, upstream of most of the bay system, is expected to have the least impact on bay salinities.

As with Alternative A, barriers are proposed for Clear Creek, Dickinson Bayou, and Offatts Bayou. Impacts on these systems are expected to be like those in Alternative A.

4.3.2.2.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The Follets Island Gulf Beach and Dune Restoration measure is not expected to impact salinities because they would be primarily constructed out of the water.

4.3.3 Water and Sediment Quality

4.3.3.1 Alternative A

Coastal Barrier Alternative

The Coastal Barrier is expected to impact water and sediment quality throughout the Galveston Bay system because it would reduce flushing and mixing of point and nonpoint source pollutants entering the bay. Gulf water contains fewer pollutants than the bay and tidal exchange dilutes pollutants entering the bay (Brock et al., 1996). Seventy-five percent of the tidal flow into and out of Galveston Bay occurs at Bolivar Roads (Matsumoto et al., 2005), and the barrier is estimated to reduce the volume of tidal flow between 3 and 7 percent (Lackey & McAlpin, 2020).

In addition to tidal exchange with the Gulf, water retention time in Galveston Bay is affected by freshwater inflow. Main sources of freshwater are the Trinity River, San Jacinto River, and Buffalo Bayou and its tributaries (Lester and Gonzalez, 2011). Retention time in Galveston Bay may be as low as 20 days during high inflows and up to 8 months during periods with low inflow (Rayson et al., 2016; Arcadis, 2017; Joye and An, 1999). Hydraulic modeling indicates the Coastal Barrier, along with barriers at Clear Lake, Dickinson Bay and Offatts Bayou, would increase retention time upstream of each barrier.

Reduced mixing and water exchange combined with pollution and episodic storms are considered major contributors to low dissolved oxygen levels in estuaries (Paerl, 2006;

Howarth et al., 2011). These conditions have occurred in Dickinson Bay and Dickinson Bayou in Galveston Bay (Quigg et al., 2009). Most fish die-offs in the Galveston Bay system have been attributed to low oxygen (Lowe et al., 1991; Thronson and Quigg, 2008). Galveston Bay has been considered a hot spot for fish kills with more fish reported killed in Galveston Bay than any other estuary in Texas from 1970 to 2006 (Thronson and Quigg, 2008). Many of those fish kills occurred in residential boat canals with limited water exchange.

Reduced mixing, combined with high phytoplankton production and vertical stratification of the water column, were specifically identified as causes of a fish kill in Offatts Bayou (McInnes and Quigg, 2010). The fish kill in Offatts Bayou and Lake Madeline was attributed to large amounts of organic matter from an algal bloom creating low oxygen in the bottom waters. Wind speeds and rainfall which contribute to mixing, were lower and algal concentrations higher in 2005, the year of the fish kill than they were in 2006 when a fish kill did not occur.

Estuaries are typically nitrogen-limited for all or much of the year (Howarth et al., 2011). Phosphorus is not usually a limiting nutrient because it is continually transported from Gulf waters (where phosphorus is usually present) into estuaries by tides. Nitrogen was found to be primarily removed from the bay system through outflow to the Gulf (Brock et al., 1996). Reducing tidal flushing by construction of barriers may alter nutrient balance by reducing phosphorus input into the bay and nitrogen transport out of the bay. Changes in ratios of nitrogen and phosphorus may change plankton communities in the bay with unknown consequences, particularly in areas where oysters rely on plankton as their primary food source.

Parts of the bay which are further from development and point sources of pollutants have lower nutrient concentrations and algal biomass than parts of the bay closer to urban and industrial development. Nitrogen, phosphorus, and chlorophyll α levels were considered good in West and East bay's where concentrations from 2000 to 2009 were less than TCEQ screening criteria in more than 85 percent of samples. Concentrations of these substances in Upper and Lower Galveston Bay exceeded TCEQ screening criteria in 16 to 30 percent of samples collected over the same period (Lester and Gonzalez, 2011). Increased retention time in these areas may allow effects of high algal productivity, low oxygen, and potentially harmful algal blooms to be expressed more widely and frequently in these areas of the bay.

Bolivar Peninsula and West Galveston Beach and Dune system would experience localized increases in turbidity at the sediment borrow location and at the beach placement locations. There may also be releases of low oxygen water and nutrients at the borrow source location as sediments are dredged. These conditions, like elevated turbidity, would be expected to be temporary and localized, ending when dredging was completed. The extent and frequency of these impacts depends on the renourishment approach used. The anticipated renourishment cycle is planned for every 10 years for the 50-year project.

4.3.3.2 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The intensity, frequency, and severity of possible impacts may be greater than with the Coastal Barrier since most of the waste load enters the bay upstream of the proposed Upper Bay Barrier, the area for mixing and volume for dilution is substantially reduced, and this area experiences the poorest water quality in the system. Most nutrients and potential pollutants enter the upper end of the bay, particularly the Houston Ship Channel and Upper Galveston Bay. The Upper Bay Barrier, which creates the smallest areas where flushing would be reduced, combined with the highest nutrient and pollutant loading may create more detrimental effects like hypoxic zones and harmful algal blooms than the Coastal Barrier.

Nearly three-fourths of permitted wastewater treatment plants in the five counties around Galveston Bay discharge treated wastewater into Harris County. Prior to 2009, there were 753 treated wastewater discharges in Harris County. It has the greatest land area, 1.1 million acres, of the five counties surrounding the bay and, of those counties, it has the highest percentage (43 percent) developed land, indicating its high potential contributions to nonpoint source pollution (Lester and Gonzalez, 2011). Lester and Gonzalez (2011) also identified the western, urbanized portion of the bay's watershed as the area with most of the water quality problems.

Sediment concentrations of nine heavy metals and chlorinated organic compounds were reviewed and concentrations above TCEQ screening criteria were identified only in the Houston Ship Channel (Lester and Gonzalez, 2011). Mixing with Gulf waters which might otherwise transport some of these materials out of the bay and allow some dilution of these potentially hazardous materials would be reduced. This reduction in mixing and dilution may increase sediment loading in areas where hazardous materials are above screening criteria. Increased concentrations of these materials in sediment may contribute to bioaccumulation and biomagnification of potential pathogens, heavy metals, and synthetic organic compounds in fish and shellfish in the area.

The TDSHS sampled fish tissues from Galveston Bay for metals, PCBs, dioxins, and pesticides (TDSHS, 2013c). Sampling from 1997 to 2000 showed "…little evidence of contamination…." with substances which could pose a risk to human health in East, West, Lower Galveston, and Trinity bays. The same sampling indicated potentially hazardous concentrations of PCBs and dioxins in upper portions of Upper Galveston Bay, the upper Houston Ship Channel, and the lower San Jacinto River. Sampling for PCBs in the Houston Ship Channel, its tributaries, and the San Jacinto River tidal revealed concentrations in water and fish tissue high enough to pose a concern to human health (Rifai et al., 2005).

The Upper Bay Barrier would be upstream of Trinity Bay, Upper Galveston Bay, Lower Galveston Bay, West Bay, and East Bay. Fewer nutrients, pollutants, and potential pathogens may be transported past this barrier than in the past and Upper Galveston

Bay, Trinity Bay, Lower Galveston Bay, Bolivar Roads, West Bay, and East Bay may experience improved water and sediment quality since they would be downstream of the barrier. If low oxygen conditions or harmful algal blooms develop upstream of the barrier, they would be expected to impact some portion of the bay downstream as they move through the barrier. Water and sediment quality impacts may be minimal and possibly improve relative to recent conditions.

4.3.3.3 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The Follets Island Gulf Beach and Dune Restoration measure would create localized increases in turbidity at the sediment borrow and beach placement locations. There may also be release of low oxygen water and nutrients at the borrow source location as sediments are dredged. These conditions, like elevated turbidity, would be expected to be temporary and localized, ending when dredging was completed. Since there are no renourishment cycles proposed for this measure, these impacts would only be expected to last until the dredging is complete. Water and sediment quality impacts resulting from the ER measures are expected to be temporary and associated with actual periods of construction.

4.3.4 Hydrology

4.3.4.1 No Action Alternative

It is anticipated that with the no action alternative the hydrologic regimes would remain largely unchanged. RSLR would increase tidal exchange within the Galveston Bay system.

4.3.4.2 Alternative A

Coastal Barrier Alternative

The Coastal Barrier and proposed barriers at Clear Lake, Dickinson Bayou, and Offatts Bayou (Galveston ring levee/floodwall) may impact the following watersheds in the Upper Coast River and Coastal Basins which are connected to the Galveston Bay system:

- Neches-Trinity Coastal Basin
- Trinity River Basin
- Trinity-San Jacinto River Basin
- San Jacinto River Basin
- San Jacinto-Brazos River Basin

The barrier at Bolivar Roads is not expected to affect watershed hydrology except for very localized impacts where the barrier connects to the shore. The structures and support systems for the barrier which are constructed on, or adjacent to land, may influence the direction and rate of rainfall runoff from the land and it may influence bay or Gulf water levels where the barrier meets the land. The barriers at Offatts Bayou, Dickinson Bayou, and Clear Lake, and pump stations associated with these structures will be appropriately sized to ensure that the measures do not induce localized flooding upstream and downstream of the barriers during extreme rainfall runoff events or water level fluctuations in the bay (extreme high tides or storm-generated waves).

Based on the estuarine modeling conducted by the USACE, the tidal amplitude in the bay would be reduced, meaning a relatively narrow edge along the shore around the bay would be less frequently exposed to tides (McAlpin et al., 2019b). This narrow edge which would be inundated less frequently would be very difficult to discern on shorelines with marsh or bulkhead.

The proposed ring levee around urbanized areas of Galveston would block some rainfall runoff from drainage channels and sheet flow from the watershed into the bay. Stormwater would be routed to pump stations and drainage gates, requiring some hydrological modification of watershed drainage. The extent of the hydrological modifications which are expected to be permanent is unknown.

No impacts to the Gulf Coast Aquifer are anticipated from this alternative.

4.3.4.3 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The Upper Bay Barrier along with barriers at Clear Lake, Dickinson Bayou, the Bay Rim levee/floodwall, and the Texas City Hurricane Flood Protection Improvements would impact the following water basins in the Upper Coast River Basins Region:

- Trinity-San Jacinto River Basin
- San Jacinto River Basin
- San Jacinto-Brazos River Basin

Trinity and Galveston Bays. The proposed barriers may increase localized flooding upstream and downstream of the barriers during extreme rainfall runoff events or water level fluctuations in the bay (extreme high tides or storm-generated waves). The extent of flooding would be affected by the extent the barriers reduce the existing cross-sectional area of the channels where the barriers are proposed for construction.

Because of the extensive nature of the levees and barriers proposed for this alternative, rainfall runoff in drainage channels and sheet flow is expected to be intercepted by the levees and forced into areas not typically inundated or into different channels for additional storm water runoff. Channel designs would need to ensure drainage features to pumps have adequate capacity to transport flood flows. Pump stations would be installed upstream of the levees and hydrological modifications would be required to channel flood flows to the pump stations. The extent of the hydrological modifications which are expected to be permanent is unknown.

Galveston Island. The proposed ring levee around urbanized areas of Galveston would block some rainfall runoff from drainage channels and sheet flow from the watershed into the bay. Stormwater would be routed to pump stations and drainage gates, requiring some hydrological modification of watershed drainage. The extent of the hydrological modifications which are expected to be permanent is unknown.

Gulf Coast Aquifer. No impacts to the Gulf Coast Aquifer are anticipated from this alternative.

4.3.4.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The placement of sediments on the beach may have very localized effects on the direction rainfall runoff flows in but would not block or interfere with any existing stream channels or other permanent inland waterbodies. No long-term impacts to watershed hydrology are anticipated as a result of these ER features. The ER measures are designed to provide an overall positive benefit to the ecosystem in a variety of ways. These benefits work together to contribute to the multiple lines of defense strategy that was developed by the Coastal Texas Study. When comparing the ER measures to the No-Action Alternative, the benefits resulting from the ER measures far outweigh the localized impacts that would be expected, especially when incorporating hydrologic connectivity as a design criterion when considering installing protective structural features.

4.3.5 Soils (Prime and Other Important Unique Farmland)

Prime and unique farmlands were mapped using the NRCS Web Soil Survey website (NRCS, 2018). The NRCS database was used to calculate prime farmland impacts of CSRM alternative construction right-of-way.

4.3.5.1 No Action Alternative

The No Action Alternative would not impact Soils.

4.3.5.2 Alternative A

Coastal Barrier Alternative

No prime or otherwise important farmlands were identified on Galveston Island or Bolivar Roads (NRCS, 2018). Upon completion, the coastal barrier is expected to benefit prime farmlands by providing a buffer and protective barrier against rising sea level and erosive wind/wave action that could potentially wash out prime farmland soils. No long-term significant impacts are expected as a result of the Coastal Barrier.

4.3.5.3 Alternative D2

Upper Bay Barrier- Bay Rim CSRM Measure (Upper Bay Barrier)

Potential impacts from the Upper Bay Barrier would be similar to those described for the Coastal Barrier, with the exception of the differences in the acres of impact to prime farmlands. The Upper Bay Barrier would impact approximately 332 acres of prime and unique farmlands. Most impacts to prime farmlands are located on the West Extension of the Texas City Hurricane Flood Protection System and along the West Galveston Bay rim. This CSRM measure would have the most impact to prime and unique farmlands. Impacted prime farmlands are currently used for residential, commercial, and agricultural practices.

Upon completion, the coastal barrier is expected to benefit prime farmlands by providing a buffer and protective barrier against rising sea level and erosive wind and wave action that could potentially wash out prime farmland soils. No long-term impacts are anticipated to prime farmlands as a result of the Upper Bay Barrier.

4.3.5.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

There are no proposed dune or beach improvements on designated prime farmlands. Prime farmlands are expected to benefit from the ER measures due to the characteristics of dunes and beaches at blocking erosive coastal winds and wave action from washing out prime soils located further inland.

4.3.6 Energy and Mineral Resources

The Gulf Coast Basin is an oilfield along the Texas Gulf coast. The counties of Chambers, Harris, Galveston, Brazoria, Matagorda, Calhoun, Nueces, Kenedy, Willacy, and Cameron are located within this oil field and depict a high concentration of oil and gas activities (Texas Oil and Gas, 2015).

Harris, Galveston, Chambers, Brazoria, and Matagorda counties are in an area that is home to one of the world’s largest hubs for petroleum refining and drilling and is ranked first in the United States in foreign waterborne tonnage, imports, and export tonnage (Port of Houston, 2018). Additionally, Houston, the energy capital of the world, is the leading domestic and international center for every segment of the energy industry. Approximately 4,800 energy-related firms are located within the Houston metro area, which include 700 exploration and production firms, 800 oilfield services companies, and 80 pipeline transportation firms (Greater Houston Partnership, 2017). These companies and the product are serviced by the Houston Ship Channel to the north of Galveston Island.

Furthermore, Calhoun, San Patricio, and Nueces counties contain a high concentration of oil and gas activities (Railroad Commission of Texas [RRC], 2018). High regional concentrations of petroleum industry are located in San Patricio and Nueces counties (Petroleum Product Manufacturing, 2015). Oil and gas activities are present within Kenedy, Willacy, and Cameron counties; however, the concentration of the activity is not as dense (RRC, 2018).

All in all, the Texas Coast is home to an enormous system of oil and gas pipeline and well network that stretches from the Texas-Louisiana border to Mexico. This analysis is being conducted to provide a broad overview of the potential impacts and proximity of energy and mineral resources within one mile of each measure limit along the Texas Gulf Coast.

4.3.6.1 Data Used and Method of Analysis

ArcMap 10.4.1 was utilized to conduct a search of oil and gas pipelines and well locations within a 1-mile radius of each CSRM and ER measure limit. The oil and gas pipeline and well shapefile data were purchased from the RRC in 2018 and utilized for the Coastal Texas Study. For each measure limit, a 1-mile radius was created using the “buffer” geoprocessing tool. For each RRC shapefile, the “clip” geoprocessing tool was used to identify the sites within 1-mile buffer of each measure limit. Following this process, an additional step was taken to identify the sites that intersect each measure limit.

Numerous oil and gas pipelines and wells are evident along each measure. Due to the lack of attribute data, the types of oil and gas wells could not be determined; however, locations and number of wells were identified during each analysis of the measure limits. Different types of oil and gas pipelines were identified within the attribute data. The following sections provide more detailed information on these findings.

4.3.6.2 No Action Alternative

The no action alternative is not anticipated to impact energy and mineral resources.

4.3.6.3 Alternative A

Coastal Barrier Alternative

Table 4-6 breaks down the number of oil and gas wells and pipelines within one mile of and that intersect the Coastal Barrier. These sites are also shown in Attachment 1, Figures 1A-1C.

The highest concentration of oil and gas wells is along the Galveston and Chambers County line, Galveston, Brazoria, and Matagorda counties. A total of 1,267 oil and gas wells are located within 1 mile of the Coastal Barrier, with 57 oil and gas wells intersecting the Coastal Barrier limits.

Pipeline intersections of the Coastal Barrier appear to be dispersed along the entirety of the measure. An increase in concentration of pipelines is visible within the one-mile radius of the gates at the mouth of the Clear Lake and Dickinson Bayou. A total of 49 pipelines are located within 1 mile of the Coastal Barrier, with 36 oil and gas pipelines intersecting the Coastal Barrier limits.

4.3.6.4 Alternative D2

Upper Bay Barrier – Bay Rim CSRM Measure (Upper Bay Barrier)

Table 4-7 breaks down the number of oil and gas wells and pipelines within one mile of and that intersect the Upper Bay Barrier. These sites are also shown in Attachment 1, Figures 2B-2C.

Table 4-6 Coastal Barrier – Analysis of Oil and Gas Pipelines and Wells

Feature Type	1-mile Radius	Intersect
Butane Pipeline	1	1
Carbon Dioxide Pipeline	1	0
Chemical Grade Propylene Pipeline	1	0
Crude Oil Pipeline	6	3
Diesel Fuel Pipeline	1	1
Ethylene Pipeline	2	2
Ethylene Gas Pipeline	1	1
Hydrogen Gas Pipeline	2	1
Isobutane Pipeline	1	1
Liquified Petroleum Gas Pipeline	3	3
Natural Gas Pipeline	17	11
Natural Gas Liquids Pipeline	1	1
Nitrogen Pipeline	2	1
Propane Pipeline	1	1
Propylene Pipeline	4	4
Propylene Chemical Pipeline	1	1
Propylene Dilute Pipeline	1	1
Refined Products Pipeline	3	3
Total Pipelines	49	36
Total Oil and Gas Wells	1,267	57

Table 4-7 Upper Bay Barrier – Analysis of Oil and Gas Pipelines and Wells

Feature Type	1-Mile Radius	Intersect
Acetic Acid Pipeline	2	2
Acrylic Acid Pipeline	1	1
Ammonia Pipeline	1	0
Anhydrous Ammonia Pipeline	2	1
Anhydrous HCL Pipeline	1	1
Benzene Pipeline	4	2
Butane Pipeline	2	1
Butane/Isobutane Pipeline	1	0
Butane/Isobutane/Isobutylene Pipeline	1	1
Butane/Isobutane/Natural Gas Pipeline	2	0
Butanol Pipeline	3	3
Butene Pipeline	1	1
Butyl Acrylate Pipeline	2	2
Butylene Pipeline	1	0

Feature Type	1-Mile Radius	Intersect
Carbon Dioxide Pipeline	1	1
Carbon Monoxide Pipeline	1	1
Chemical Grade Propylene Pipeline	1	1
Condensate Pipeline	1	0
Crude Oil Pipeline	19	8
Crude Oil FWS Pipeline	2	2
Cumene Pipeline	1	0
Cyclohexane Pipeline	1	1
Diesel Fuel Pipeline	1	1
Dripoline Pipeline	1	1
Empty Pipeline	4	2
EP Mix Pipeline	2	1
Ethane Pipeline	2	1
Ethane/Propane Pipeline	1	1
Ethane/Propane/Butane/Y-Grade Pipeline	1	0
Ethyl Acrylate Pipeline	1	1
Ethylene Pipeline	10	5
Ethylene Gas Pipeline	1	0
Ethylene Glycol Pipeline	3	3
Fuel Oil Pipeline	2	0
Gas/Diesel/Fuel Oil/Kerosene Pipeline	3	1
Gas/Jet Fuel/Diesel Pipeline	1	0
Hexene Pipeline	1	0
Hydrogen Gas Pipeline	10	5
Isobutane Pipeline	2	1
Isobutane/Natural Gas Pipeline	1	0
Isobutylene Pipeline	1	1
Kerosene Pipeline	2	0
Liquid Petroleum Gas Pipeline	4	1
Methanol Pipeline	2	1
Methyl Acetate Pipeline	1	0
Naphtha Pipeline	2	0
Natural Gas Pipeline	45	22
Natural Gas FWS Pipeline	3	2
Natural Gas Liquids Pipeline	4	2
Nitrogen Pipeline	6	2
Octene Pipeline	1	0
Petroleum Pipeline	3	0
Polymer Grade Propylene Pipeline	1	1
Propane Pipeline	7	3
Propane/Propylene Pipeline	1	1
Propylene Pipeline	14	8
Propylene Chemical Pipeline	1	0
Propylene Dilute Pipeline	1	0

Feature Type	1-Mile Radius	Intersect
Propylene Oxide Pipeline	2	1
Pyrolysis Gasoline Pipeline	1	1
Raffinate Pipeline	1	0
Refined Products Pipeline	5	1
Styrene Pipeline	1	1
Tertiary Butyl Alcohol Pipeline	1	1
Toluene Pipeline	1	0
Toluene Ethyl Benzene Pipeline	1	1
Vinyl Acetate Pipeline	2	1
Xylene Pipeline	1	0
Y Grade Products Pipeline	1	1
Total Pipelines	206	103
Total Oil and Gas Wells	3,813	89

The highest concentration of wells is along the Galveston and Chambers County line, Galveston, Brazoria, and Matagorda County. A total of 3,813 oil and gas wells are located within one mile of the Upper Bay Barrier, with 89 oil and gas wells intersecting the Upper Bay Barrier limits.

Pipeline intersections of the Upper Bay Barrier appear to be dispersed along the entirety of the Upper Bay Barrier limits, with a higher concentration concentrated in western Galveston County, near the Port of Texas City, and in Harris County, near La Porte, Texas. A total of 206 oil and gas pipelines are located within one mile of the Upper Bay Barrier, with 103 pipelines intersecting the Upper Bay Barrier limits.

4.3.6.5 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The pipelines that intersect ER measure B-2 are included in the similar section in Chapter 5.

4.3.6.6 Conclusions

This Energy and Mineral Resource analysis is preliminary. A historical use and regulatory records search review was not used to formulate these preliminary conclusions. Digital data from the RRC were used to determine the location and density of oil and gas activities; however, these conclusions are very broad. Therefore, significant conclusions should not be gathered from this information. This analysis is to be utilized to inform and guide decision making. However, some general conclusions can be gathered (**Table 4-8**):

- Oil and gas activities are generally concentrated within the Galveston Bay, Matagorda Bay, and Nueces Bay areas.
- The Coastal Barrier identifies the least oil and gas wells and pipelines within 1 mile of the Coastal Barrier and within the Coastal Barrier limits.

- Approximately 5 percent of the oil and gas wells and 74 percent of the oil and gas pipelines within 1 mile of the Coastal Barrier are located within the Coastal Barrier limits.
- The Upper Bay Barrier identifies the most oil and gas wells and pipelines within 1 mile of the Upper Bay Barrier and within the Upper Bay Barrier limits.
- Approximately 2 percent of oil and gas wells and 50 percent of the oil and gas pipelines located within 1 mile of the Upper Bay Barrier are within the Upper Bay Barrier limits.
- The ER Measures identify more oil and gas activities than the Coastal Barrier, but less oil and gas activities than the Upper Bay Barrier. A total of 1,223 oil and gas wells intersect the ER Measures. This is the largest number of oil and gas wells to intersect either of the measure limits.
- Approximately 43 percent of the oil and gas wells and 40 percent of the oil and gas pipelines located within 1 mile of the ER Measures are located within the ER Measure limits.
- Oil and gas activities are not visible within 1 mile of the South Padre Island limits.

Table 4-8 Summary of Energy and Mineral Resource Sites

Measure	Pipelines Within 1-Mile mile	Pipeline Intersection	Oil/Gas Wells Within 1-Mile	Oil/Gas Well Intersections
Coastal Barrier	49	36	1,267	57
Upper Bay Barrier	206	103	3,813	89
ER Measures	164	65	2,826	1,223
South Padre Island	0	0	0	0

Potential HTRW concerns are currently being identified for the RP. A desktop HTRW Assessment was conducted to identify the existence of, and potential for, HTRW contamination, which could impact or be impacted by the RP. This assessment followed guidance provided by Engineer Regulation 1165-2-132 and consists of a review of recent and historic aerial photographs and a review of Federal, State, and local regulatory agency database information. Additionally, a more detailed oil and gas activity record will be included in this HTRW Assessment. Once completed, the HTRW Assessment will be included as Appendix L.

4.3.7 HTRW

Harris, Galveston, Chambers, Brazoria, and Matagorda counties are in an area that is home to one of the world’s largest hubs for petroleum refining and drilling and is ranked first in the United States in foreign waterborne tonnage, imports, and export tonnage (Port of Houston, 2018). Additionally, in 2016, a total of 6,367 manufacturing establishments called the greater Houston area home (Greater Houston Partnership, 2017). The city of Houston alone accounts for 42 percent of the Nation's base petrochemical capacity and is home to approximately 5,000 energy-related firms (Petroleum Refining and Chemical Products, 2015). One of the most densely concentrated areas of industrial, manufacturing, petroleum refining, and commercial facilities in the greater Houston area appears along the western shoreline of Galveston Bay (TCEQ, 2018b; EPA, 2018a; U.S. Energy Information Administration [EIA], 2018). These industrial, manufacturing, petroleum refining, and commercial facilities are serviced by the Houston Ship Channel to the north of Galveston Island.

Furthermore, the Calhoun County coastline, adjacent to Lavaca and Matagorda bays, is home to Port Lavaca, Port O'Connor, Formosa Plastics Corporation Texas, and Alcoa World Alumina LLC. Industrial and commercial activities also appear to be present in the vicinity of Aransas Pass, Ingleside, Corpus Christi, and South Padre Island (TCEQ, 2018b; EPA, 2018a; EIA, 2018). This area contains a high concentration of basic chemical manufacturing; for example, petrochemicals, chlorine, and industrial gases are all produced in this area of the Texas Gulf Coast (Basic Chemicals Manufacturing, 2015).

This analysis is being conducted to provide a broad overview of the potential impacts and proximity of HTRW within one mile of each measure along the Texas Gulf Coast.

4.3.7.1 Data Used and Method of Analysis

The following GIS geospatial data was used:

- EIA (2018): Power Plant Sites
- EPA (2018) Facility Registry Service – Major/Special interest:
- AFS Majors – Sources of Toxic Air Pollutants
- ACRES – Brownfield Program Sites
- NPDES Majors – Major National Pollutant Discharge Elimination System outfalls
- RCRA Info – Resource Conservation and Recovery Act hazardous waste handlers
- TSDs and LQGs – Treatment, Storage, and Disposal and Large Quantity Generators of RCRA hazardous waste
- RMP – Facilities that require a Risk Management Plan under Sec. 112(r) of the CAA, due to the presence of a certain amount of regulated substances at the facility
- SEMS NPL – CECLA Superfund Enterprise Management System (SEMS) National Priorities List (NPL) Sites

- SSTS – Section Seven Tracking System (SSTS) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Section 7
- TRI – Toxic Release Inventory (TRI) Program Sites
- TCEQ GIS data (2018):
- Municipal Solid Waste (MSW) Sites/Landfills
- Superfund Sites
- Radioactive Waste Sites
- Petroleum Storage Tank Sites
- Active Air Monitoring Sites

ArcMap 10.4.1 was used to analyze this data and the proximity to each CSRM and ER measure. Each of the above data sources has a shapefile associated with it. For each CSRM and ER measure, a 1-mile radius was created using the “buffer” geoprocessing tool. For each shapefile, the “clip” geoprocessing tool was used to identify the sites within one-mile buffer of each measure limits. Following this process, an additional step was taken to identify the sites that intersect the limits of each measure. The following sections provide more detailed information on these findings.

4.3.7.2 Alternative A

Coastal Barrier Alternative

A total of 28 regulated facilities or environmental records were identified within the study area in the vicinity of Bolivar Peninsula, including PST and LPST sites, hazardous waste generators and handlers, RCRA corrective action sites, VCP sites, and SWLFs. The record or facility locations are shown in the HTRW Appendix. A detailed summary of the identified facilities is provided in Attachment 2. Six sites of interest were determined to be located within the project area or immediately adjacent to the proposed projects. The majority of which are due to the possible presence of residual petroleum hydrocarbons in the soil as well as one active solid waste facility.

Over 450 regulated facilities or environmental records were identified within the study area in the vicinity of Galveston, Texas, including drycleaners, PST and LPST sites, hazardous waste generators and handlers, RCRA corrective action sites, VCP sites, institutional control sites, and SWLFs. A total of 50 sites were found that pose a REC, potential REC or controlled REC. The record or facility locations can be found in the HTRW Appendix. A detailed summary of the identified facilities is provided in Attachment 2.

Fifty-six regulated facilities or environmental records were identified within the Clear Creek Gate Study Area, including PST and LPST sites, hazardous waste generators and handlers, EPA corrective action sites, and VCP sites. The record or facility locations can be found in the detailed summary of the identified facilities provided in Attachment 2 of the HTRW Appendix. Two sites of interest were determined to be located within the project area and immediately adjacent to the proposed projects in this area.

Twenty-two regulated facilities or environmental records were identified within the Dickinson Bayou Gate Study Area including EPA corrective action sites, PST and LPST sites, hazardous waste generators and handlers, RCRA corrective action sites, and SWLFs. The record or facility locations are shown in Attachment 3 of the HTRW Appendix. A detailed summary of the identified facilities is provided in Table Attachment 2. Two TCEQ PST facilities were identified immediately adjacent to the Dickinson Bayou Gate Project Area. Neither of the identified sites were determined to pose a REC, potential REC, or controlled REC to projects occurring in the Dickinson Bayou Gate Project Area.

4.3.7.3 Alternative D2

Upper Bay Barrier – Bay Rim CSRM Measure (Upper Bay Barrier)

The highest concentration of HTRW sites are located in Galveston, La Marque, Texas City, and in between Seabrook and Deer Park. Many of the HTRW sites identified within 1 mile of the Upper Bay Barrier are EPA registered facilities and TCEQ PST sites.

Table 4-9 HTRW sites Alternative D2

Feature Type	1-mile Radius	Intersect
EPA National FRS Major Sites	44	5
TCEQ Petroleum Storage Tank Sites	83	1
TCEQ Active Air Monitoring Sites	7	1
TCEQ Superfund Sites	2	0
TCEQ Radioactive Sites	1	0
TCEQ MSW Sites	7	1
Power Plants	3	0
Total	147	8

4.3.7.4 South Padre Island CSRM Measure

Table 4-10 summarizes the number of HTRW sites within one mile of and the number of HTRW sites intersecting the South Padre Island limits. These sites are included in Attachment 2, Figures 1H and 2H.

The highest concentration of HTRW sites are located to the west of the South Padre Island limits. A total of eight HTRW sites are located within 1 mile of the South Padre Island limits; however, no HTRW are visible within the South Padre Island limits. The majority of HTRW sites identified within 1 mile are TCEQ PST sites.

Impacts to the HTRW as a result of construction of the South Padre Island CSRM Measure would be the same as those described for Alternative 1. A total of 21 environmental records and regulated facilities were identified during the HTRW Assessment within or immediately adjacent to the South Padre Island CSRM Project Area; however, no RECs, potential RECs, or controlled RECs were identified within 0.1 mile of the South Padre Island CSRM Project Area footprint.

Table 4-10 SPI HTRW Sites

Feature Type	1-mile Radius	Intersect
EPA National FRS Major Sites	1	0
TCEQ Petroleum Storage Tank Sites	7	0
TCEQ Active Air Monitoring Sites	0	0
TCEQ Superfund Sites	0	0
TCEQ Radioactive Sites	0	0
TCEQ MSW Sites	0	0
Total	8	0

4.3.7.5 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Follets Island is adjacent to or listed on the FUDS site database. In particular the Follets Island and Surfside Beach area were utilized as the Galveston Army Airfield Bombing and Strafing Range. The potential to encounter unexploded ordnance and/or its constituents is possible. The former Galveston Army Airfield Bombing Range is located on Follets Island, approximately 5.5 miles southwest of the San Luis Pass, and approximately 7 miles southwest of Galveston Island, in Brazoria County, Texas. The area is publicly and privately owned and is used for gas and oil exploration, pipeline development, residential purposes as well as an open beach area. Because explosive hazards associated with military munitions from past military training may remain, precautions will be required when disturbing these areas.

South Padre Island CSRM Measure

Impacts to the HTRW as a result of construction of the South Padre Island CSRM Measure would be the same as those described for Alternative A.

ER Measures

Impacts to the HTRW associated with the proposed ER measures would be the same as those described for Alternative A.

4.3.7.6 Conclusions

This HTRW site analysis is preliminary.

- The Upper Bay Barrier identifies the largest number of HTRW sites within a one mile of the Upper Bay Barrier limits.
- The Coastal Barrier identifies the most HTRW site intersections of the Coastal Barrier limits.
- South Padre Island identifies the least HTRW sites within a one mile of the South Padre Island limits.
- The EPA FRS sites and TCEQ PST sites make up 92 percent of the HTRW sites within one mile of Alternative A (Coastal Barrier, ER Measures, and South Padre Island).
- The EPA FRS sites and TCEQ PST sites make up 88 percent of the HTRW sites within one mile of Alternative D2 (Upper Bay Barrier, ER Measures, and South Padre Island).

4.3.8 Air Quality

Air emissions during the construction of the Coastal Texas Study would consist primarily of tailpipe emissions (due to fossil fuel combustion from dredging equipment and land-side vehicles) and fugitive dust (ground surface disturbance). Air quality impacts would include an increase in PM with particle diameters of 10 micrometers or less (PM10) and particle diameters of 2.5 micrometers or less (PM2.5), SO2, CO, NO2, VOC, and carbon dioxide (CO2). Construction of this alternative is anticipated to begin in 2025 and is expected to continue for 15 years. Construction would be considered a one-time activity, i.e., the construction activities would not continue past the projected date of completion. Therefore, potential air emissions would be temporary and may vary in intensity and composition over the 15-year period of construction.

The details necessary to estimate the air contaminant emission rates for the Coastal Texas Study alternatives are not available at the time of this report. Therefore, the following is a qualitative description of the methods that will be used to estimate air emissions and a preliminary discussion of potential impacts to air quality in the study area. It is anticipated that additional information will be provided as the USACE progresses with more detailed engineering of the RP.

4.3.8.1 Alternative A

Alternative A would include the Coastal Barrier CRSM measure, South Padre Island CSRM measure, and eight ER measures. The CRSM features, when combined, would establish multiple lines of defense against storm surge. The features include levees, floodwalls, barrier walls, seawall, and gate structures for navigation channels, roadways, and railroads and pump stations and would affect approximately 4,525 acres along the Texas coastline.

The Coastal Barrier would include the construction of navigation and environmental gates at Bolivar Roads, GIWW, Clear Lake, Dickinson Bayou, and Offatts Bayou (Galveston ring levee/floodwall). Dredged material from the construction of the Coastal Barrier would either be used beneficially to construct ER measures or put in approved placement areas. The navigation and environmental gates at Bolivar Roads would also include construction of a bypass channel which would be dredged to accommodate vessel traffic from the Houston Ship Channel. Dredged material would be stockpiled in an upland or in-bay placement location, and then used to fill the bypass channel once construction is completed.

The South Padre Island CSRM would include beach fill with a re-nourishment interval of 10 years affecting approximately 153 acres of shoreline. A hopper dredge and gravity pipe would dredge and redirect the sediment from the borrow area to the shoreline.

ER measures would include construction of rock revetment/breakwaters features, island restoration, wetlands and marsh restoration behind each of the constructed revetment/breakwater features, oyster reef creation, and dune/beach restoration. These restoration measures would affect approximately 114,600 acres along the Texas coast and inlets.

Construction Emissions

Temporary increases in air pollution would result from the equipment associated with the construction of Alternative A. These air contaminant emissions would result from the use of marine vessel and land-based mobile sources that would be used during construction activities, including:

- Dredge and Support Equipment – dredging vessels and supporting vessels such as tugboats, crew boats, works boats;
- Non-Road Construction Equipment – land-based equipment such as bulldozers and graders;
- On-Road and Employee Vehicles – land-based equipment such as cars and trucks;
- Maintenance Dredging – dredging vessels and support vessels; and
- Landside Maintenance – land-based equipment such as bulldozers and graders.

The marine vessel emission sources would be primarily diesel-powered engines. The off-road and on-road equipment may be assumed to be a mix of gasoline and diesel-powered vehicles.

The rate of emissions from the project construction equipment is directly related to the horsepower (hp) rating of each engine, load factor, duration of use, and the projected amount of dredged material and surface area disturbed. The rate of emissions from employee commuter vehicles is directly related to the type of vehicle and total miles traveled for each vehicle. The combustion of diesel fuel in internal combustion engines during the construction operations would result in air emissions of particulate matter (PM10 and PM2.5), SO2, CO, NO2, VOC, and CO2. Air contaminant emissions will be estimated using emission factors currently approved or recommended by the EPA and TCEQ. These emission factors, in combination with the equipment lists, engine load rate levels, and scheduling information as prepared by the USACE in support of the Coastal Texas Study, will serve as the basis for calculating annual and total emissions for the Project.

Nonroad Construction Equipment

Air contaminant emissions from nonroad construction equipment used for on-shore excavation and construction will be estimated based on the anticipated type of equipment, activity, horsepower, and anticipated hours of operation. Onshore construction equipment would include cranes, trucks, dozers, front-end loaders, backhoes, compactors, graders, dump trucks, etc. The operation of construction vehicles would generate air emissions typical of vehicles powered by diesel-fueled internal combustion engines. The estimate of emissions for this equipment will be based on emission factors derived from EPA's Motor Vehicle Emissions Simulator model, version 2014a (hereafter, MOVES2014a), using the NONROAD modeling function. This computer model may be used to calculate emissions for many nonroad equipment types, categorizing them by hp rating and fuel type available for specific years, for a specific geographic area, state, or county.

Marine Vessels and Support Equipment

Marine vessel emissions would include those that would be expected to result from the use of dredging vessels, tugboats, and miscellaneous support vessels used in support of dredging activities. Air emissions directly related with the dredging equipment will be calculated on an annual basis based on the anticipated type of engine, activity, hp, and anticipated hours of operation. Air contaminant emissions from marine vessels will be estimated using emission factors from the EPA published study, Current Methodologies for Preparing Mobile Source Port-Related Emission Inventories (EPA, 2009).

Tugboat Assisted Barge Equipment

Tugboat assisted barges may also be used to transport construction materials and equipment to the construction sites. For example, if the navigation and environmental gates are fabricated in Louisiana, they may be shipped by barge via the GIWW to the construction site. If appropriate, tugboat assisted barge equipment emissions will be estimated to account for barge travel within the Coastal Texas study area. For purposes of General Conformity, the emissions may also be broken out by area, e.g., those that would occur in the Houston-Galveston-Brazoria (HGB) Nonattainment Area, the Beaumont-Port Arthur Maintenance Area, and the Baton Rouge, Louisiana Nonattainment Area traversed by the tug-assisted barges enroute to the construction delivery docks.

On-Road Mobile Sources

Mobile source emissions associated with the project construction would be generated from on-road construction vehicles, employee commuter vehicles, buses, and supply vehicles. Commuter vehicles may also be used to transport the crew and staff from the shore to land-side locations and back to the shore. Mobile on-road emissions associated with employee vehicles will be calculated using EPA's MOVES2014a.

Operating Emissions

Under Alternative A, operating emissions are anticipated to be minor. It is anticipated the proposed navigation and environmental gates across Galveston Bay and other navigational and environmental gates would be electrically powered; therefore, there would be no direct emissions from routine gate operation. These gates would be operated periodically for maintenance and testing for operational readiness. However, for the most part, they would remain in their static open position.

It is anticipated that diesel-fueled emergency generators would also be installed to provide emergency power during an emergency event, such as during a hurricane, which would require operation of the gate. In case of an emergency event that would result in an electrical power failure, the emergency generator would activate to provide emergency power for movement of the gate. It is anticipated this event would normally last until the emergency event is gone and power is restored. Each emergency generator would require testing on a monthly basis, but usually no more than 100 hours per year of routine operation for purposes of maintenance and testing for operation readiness. A summary of the estimated emissions in tpy resulting from the operation of the emergency generator engine(s) for purposes of maintenance and testing in support of gate operation for Alternative A will be presented in the Final IFR-EIS.

Maintenance Activities

Annual maintenance activities for Alternative A may result in higher air contaminant emissions in the localized area of activity compared to the maintenance activities required under the No-Action Alternative. Air emissions would result from the combustion of fuel used in dredging and support equipment and for land-side equipment necessary to support maintenance operations.

Summary

Air emissions associated with construction of Alternative A would impact the air quality of the study area compared to the No-Action Alternative. It is expected that air contaminant emissions from construction activities would result in temporary and localized impacts on air quality in the immediate vicinity of the project site as they are considered one-time activities (i.e., the construction activities would not continue past the date of completion).

After construction, temporary impacts to air quality would continue due to maintenance and renourishment activities, e.g., routine dredging would be required to maintain the

Galveston and Bolivar Peninsula Beach and Dune measure. It is anticipated these maintenance activities would be intermittent and of relatively short-term duration for each segment being maintained.

VOC and NOX emissions from these activities can combine under the right conditions to form O3, possibly increasing the concentration of O3 in the region. However, these reactions take place over a period of several hours, with maximum concentrations of O3 often far downwind of the precursor sources.

It is anticipated that air contaminant emissions from the operation of the navigation and environmental gates under Alternative A would result in a relatively minor increase in air contaminant emissions above those for existing emissions sources in Galveston County. Essentially, these operating emissions would be from products of combustion of diesel fuel in the proposed emergency generators, which would be operated periodically for maintenance and testing and during an emergency event.

4.3.8.2 Alternative D2

Alternative D2 would consist of the construction of levees, floodwalls, highway gates, drainage closure structures, and railroad gates. Additionally, there would be navigation gates, environmental gates, and combi-wall at the Houston Ship Channel, Clear Creek Channel, Dickinson Bayou, Offatts Bayou, and Highway Bayou Diversion Channel. The CRSM features would affect approximately 2,334 acres along the Texas Gulf coast. This alternative would also include the South Padre Island CSRM measure and nine ER measures as described for Alternative A. Impacts to air quality from the construction of Alternative D2 are anticipated to be similar to those described for Alternative A.

Construction Emissions

Temporary increases in air pollution would result from the equipment associated with construction of Alternative D2. These air contaminant emissions would result from the use of marine vessel and land-based mobile sources that would be used during the construction activities, including:

- Dredge and Support Equipment – dredging vessels and support vessels such as tugboats and workboats;
- Non-Road Construction Equipment – land-based equipment such as bulldozers and graders;
- On-Road and Employee Vehicles – land-based equipment such as cars and trucks;
- Maintenance Dredging – dredging vessels and support vessels; and
- Landside Maintenance – land-based equipment such as bulldozers and graders.

Air contaminant emissions associated with the construction activities would be primarily combustion products from fuel burned in equipment used for project dredging, support vessels, and dredged material placement equipment. Equipment such as excavators, backhoes, and front-end loaders would also be required. The marine vessel emission sources would be primarily diesel-powered engines. The off-road and on-road equipment may be assumed to be a mix of gasoline and diesel-powered vehicles.

Air contaminant emissions will be estimated in tpy for each vehicle or piece of equipment based on the equipment hp, fuel type, and expected operating hours during the year of construction activity. These construction activities would be considered one-time activities, i.e., the construction activities would not continue past the date of completion. The construction is anticipated to occur from 2025 through 2034.

Operating Emissions

Under Alternative D2, operating emissions are anticipated to be minor. It is anticipated that the proposed navigation gate across the Kemah-Seabrook Channel would be electrically powered; therefore, there would be no direct emissions from routine gate operation. These gates would be operated periodically for maintenance and testing for operational readiness. However, for the most part, they would remain in their static open position.

It is anticipated diesel-fueled emergency generators would also be installed to provide emergency power during an emergency event, such as during a hurricane, which would require operation of the navigation gate. In case of an emergency event that would result in an electrical power failure, the emergency generator would activate to provide emergency power for movement of the gate. It is anticipated this event would normally last until the emergency event is gone and power is restored. The emergency generators would require testing on a monthly basis, but usually no more than 100 hours per year of operation for purposes of maintenance and testing for operation readiness.

Maintenance Activities

Annual maintenance activities for Alternative D2 would result in higher air contaminant emissions compared to the maintenance activities required under the No-Action Alternative. Air emissions would result from the combustion of fuel used in dredging and support equipment and for land-side equipment such as bull dozers.

Summary

It is anticipated that air contaminant emissions from the construction activities associated with this alternative would also result in an increase in emissions above those from the existing inventory of emissions sources in the affected counties. As a result, the estimated increase in emissions may also result in corresponding impacts on air quality in the immediate vicinity of the project area. Due to the limited duration of these activities, emissions from these construction activities are not expected to adversely impact the long-term air quality in the area after construction has ceased. It is anticipated the impact to air quality in the study area resulting from this alternative would be less than those resulting from the construction of Alternative A due to the need for construction of a larger navigation gate and the larger area affected by construction activities under Alternative A compared to the smaller navigation and environmental gates and affected area proposed for Alternative D2.

As discussed for Alternative A, temporary impacts to air quality would continue after construction due to maintenance and re-nourishment activities, e.g., routine dredging would be required to maintain the ER activities. It is anticipated these maintenance activities would be intermittent and of relatively short-term duration for each segment being maintained.

It is anticipated that air contaminant emissions from the operation of the Kemah-Seabrook Channel under Alternative D2 would result in a relatively minor increase in air contaminant emissions above those for existing emissions sources in Galveston County. Essentially, these operating emissions would be from products of combustion of diesel fuel in the proposed emergency generator, which would be operated periodically for maintenance and testing and during an emergency event.

4.3.8.3 Conformity of General Federal Actions – General Conformity Determination

The Coastal Texas Study, as a Federal action, is subject to the General Conformity Rule promulgated by the EPA pursuant to the CAA, Section 176(c)(1). The rule mandates that the Federal government does not engage in, support, or provide financial assistance for licensing or permitting, or approving any activity not conforming to an approved SIP. In Texas, the applicable plan is the SIP, an EPA-approved plan for the regulation and enforcement of the NAAQS in each air quality region within the state.

General Conformity is applicable only to nonattainment or maintenance areas and refers to the process of evaluating plans, programs, and projects to determine and demonstrate they meet the requirements of the CAA and the SIP. The General Conformity Rule establishes conformity in coordination with and as part of the NEPA process.

The purpose of this General Conformity requirement is to ensure Federal agencies consult with State and local air quality districts, so they become aware of the project and its expected air emissions and would consider these expected emissions in their SIP. The General Conformity Rule is codified at Title 40 CFR Part 93, "Determining Conformity of Federal Actions to State or Federal Implementation Plans."

The CAA defines conformity to an implementation plan as the upholding of "an implementation plan's purpose of eliminating or reducing the severity and number of violations of the NAAQS and achieving expeditious attainment of such standards" (40 USC, Title 42, §7506). Conforming activities or actions should not, through additional air pollutant emissions, result in the following:

- Cause or contribute to new violation of any NAAQS in any area

- Increase the frequency or severity of any existing violation of any NAAQS in any area
- Delay timely attainment of any NAAQS or interim emission reductions or other milestones in any area

Alternatives 1 and 2 will include components located within Chambers, Galveston, Harris, and Brazoria Counties. These counties are part of the eight-county HGB O3 nonattainment area that is currently classified as "marginal" in terms of its degree of compliance with the current 8-hour O3 standard (TCEQ, 2007b). Therefore, the General Conformity Rules would apply to facilities in the project area that generate O3 precursors (NOX and VOC). A General Conformity Determination will be required if project emissions are greater than 100 tpy of either NOX or VOC; the de minimis thresholds set by the General Conformity Rules for a moderate nonattainment area such as the HGB O3 nonattainment area. Only those air emissions of NOX and VOC related to the Project that are within a nonattainment area, should be considered in this General Conformity Determination. General Conformity is not applicable to activities at locations in attainment areas or operating emissions covered by an air quality permit.

A recent court decision has provided the possibility that the HGB may be reverted to a "serious" ozone nonattainment area under the 1997 8-hour ozone standard. If this is the case, the applicability thresholds requiring a General Conformity analysis will be lowered to 25 tpy of either NOX or of VOC (South Coast Air Quality Management District v. EPA, No. 15-1115 [D.C. Cir. 2018]).

The General Conformity rules specifically exclude from applicability maintenance dredging where no new depths are required, applicable permits are secured, and disposal will be at an approved disposal site. In addition, routine maintenance and repair activities, including repair and maintenance of administrative sites, roads, trails, and facilities are also exempt under the General Conformity Rule. Therefore, a General Conformity Determination for this project would not include emissions from the anticipated maintenance activities of this type that are exempted under this rule.

Because of the project scale and duration, it is anticipated that air contaminant emissions resulting from the project construction activities would be more than 100 tpy of VOC and NOX for each year during the anticipated duration of the construction period. Therefore, it will be necessary to prepare a General Conformity Determination for estimated emissions of NOX and VOC emissions for these activities under the current attainment status for the HGB.

To demonstrate conformity with the SIP, General Conformity may be demonstrated as follows:

- Offsetting the emissions of NOX and VOC from construction and operation with the purchase and retirement of Emission Reduction Credits from the HGB nonattainment area

- Obtaining a specific commitment from the TCEQ to account for emissions of NOX and VOC in the next revision of the SIP
- Otherwise making a demonstration that the project would conform with the HGB SIP based on the criterion provided in 40 CFR Part 93.158(a)(5)(i)(A) whereby the TCEQ determines that the total of direct and indirect emissions from the action will result in a level of emissions which, together with all other emissions in the nonattainment (or maintenance) area, would not exceed the emissions budgets specified in the applicable SIP

For the General Conformity Determination, an inventory of annual NOX and VOC emissions will be prepared for each year of project-related activities within the HGB nonattainment area based on the schedule and other assumptions as developed by the USACE. Air emissions estimates will be calculated using techniques appropriate for a specific emissions-generating activity or source.

If the project will result in emissions originating in more than one nonattainment or maintenance area, conformity must be evaluated for each area separately (40 CFR Part 93). For example, if the navigation gates are fabricated in Louisiana, they may be shipped by barge via the GIWW through the Beaumont-Port Arthur and Baton Rouge maintenance areas and attainment areas to the project's construction site. For consideration of conformity with these nonattainment areas, a summary of estimated NOX and VOC emissions from the use of tugboat-assisted barges traversing areas other than the HGA nonattainment area should be provided, as applicable, and if data for these activities are available.

The Beaumont-Port Arthur area is designated as a "maintenance" area for the 1997 8-hour O3 standard and in attainment with the 2008 8-hour O3 standard (EPA, 2018b). As such, a General Conformity Determination would be required if the barge/tugboat escort emissions of NOX or of VOC in the Beaumont-Port Arthur Maintenance Area will be estimated to be greater than 100 tpy.

The Baton Rouge Nonattainment Area is designated as a "maintenance" area for the 1997 and 2008 8-hour O3 standard (EPA, 2018c). As such, a General Conformity Determination would be required if the barge/tugboat escort emissions of NOX or of VOC in the Baton Rouge nonattainment area will be estimated to be greater than 100 tpy.

SIP Emissions Budgets

Section §93.158(a)(5)(i)(A) of the General Conformity Rule applies to an O3 nonattainment area, where the EPA has approved a revision to an area's attainment demonstration after 1990, and the state makes a determination that "the total of direct and indirect emissions from the action, or portion thereof, is determined and documented by the State agency primarily responsible for the applicable SIP to result in a level of emissions which, together with all other emissions in the nonattainment (or maintenance) area, would not exceed the emissions budgets specified in the SIP."

The emissions budget for General Conformity purposes is defined in 40 CFR §93.152. In summary, the emissions budgets are those portions of the applicable SIP's projected emission inventories that describe the levels of emissions (mobile, stationary, area, etc.) for any criteria pollutant or its precursors.

For the HGB nonattainment area, the most recently approved SIP revision that provides applicable emissions budgets is the HGB 1997 Eight-Hour Ozone Attainment Demonstration, adopted by the TCEQ on March 10, 2010, and approved by the EPA on January 2, 2014. In this SIP, the emissions budgets for NOX and VOC are based on emissions inventories for the year 2006 baseline projected to the year 2018 (TCEQ, 2010).

However, a more recent SIP revision is pending review by the EPA that will likely be approved in the near future that provides applicable emissions budgets; the HGB Reasonable Further Progress (RFP) SIP Revision for the 2008 Eight-Hour Ozone Standard Nonattainment Area, adopted by the TCEQ on December 15, 2016, and pending EPA approval. In this SIP, the emissions budgets for NOX and VOC are based on emissions inventories for the year 2011 baseline projected to the year 2017 attainment year.

RFP SIP Non-Road Mobile Emissions Source Emissions Budget

The nonroad mobile emissions budget in the SIP is a very broad category that generally includes engines mounted on construction equipment and includes emissions from commercial marine equipment. The nonroad mobile emissions budget includes emissions from equipment associated with agricultural, aircraft, commercial, ground support (airport), industrial, lawn and garden, railroad maintenance, logging, locomotives, oil and gas exploration, recreational, and recreational marine equipment. The nonroad mobile emissions weekday budget in the RFP SIP is 86.97 tpd of NOX and 33.58 tpd of VOC.

RFP SIP On-Road Mobile Emissions Budget

The on-road mobile emissions budget in the SIP consists of automobiles, trucks, motorcycles, and other motor vehicles traveling on public roadways. The on-road mobile emissions weekday budget in the RFP SIP is 98.15 tpd of NOX and 56.37 tpd of VOC.

Discussions with the TCEQ and EPA – Methods for Demonstration of Conformity

The USACE and GLO participated in a conference call with the TCEQ on June 11, 2018 to discuss the methods that may be used to demonstration conformity of project emissions with the SIP. During this discussion, the USACE presented a brief overview of the project, including the breadth of new construction, environmental restoration and mitigation features, and anticipated schedule for document preparation, approvals, design, engineering, and construction. Based on this presentation, the following issues were discussed:

- Because of the project scale and duration, it is anticipated by the TCEQ that emissions of NOx and VOC would exceed the level of emissions anticipated and allotted for growth in the most recently approved SIP emissions inventory for construction emissions. Therefore, making a demonstration that the project emissions would conform with the HGB SIP based on the criterion provided in 40 CFR Part 93.158(a)(5)(i)(A) may be difficult.

- It is unclear what the impacts of the recent court case will have on the attainment status for the HGB nonattainment area and the de minimus thresholds which would trigger a general conformity determination. For example, if the HGB is redesignated to a "serious" nonattainment area, a SIP revision with more current emissions budgets would be required for approval by the EPA.

- Because of the project scale and duration, inclusion of the project emissions in a future SIP revision may be the more appropriate method for demonstration of conformity. This method has not been used by the TCEQ for previous conformity determinations but appears to be a method available under the General Conformity rules. The process would require coordination with the USACE, the TCEQ, and the EPA in the development of a detailed emissions inventory for NOX and VOC emissions from the Project, identification of mitigation measures to reduce NOX and VOC emissions, and the development and approval of a SIP revision that would include a future inventory and attainment date that would be representative of the anticipated schedule for construction (years 2025 – 2034) for the project.

The TCEQ has suggested that follow-on coordination with the USACE and GLO would be appropriate so that the Project emissions may be properly documented in a future SIP revision.

4.3.8.4 Potential Air Quality Mitigation Measures

Measures that could be used to reduce emissions for the project would consider the equipment used for the project over the expected life of the project and the feasibility and practicality of such measures. Alternatives considered for their ability to reduce or mitigate emissions are those that may provide for enhanced energy efficiency, lower NOX-emitting technology, repowering, etc., as appropriate, for the construction and operating equipment and vehicles to be used. Efforts to reduce emissions from the construction and operation of the project could include the following.

Dredging Mitigation Options

- Contracting with dredging companies with energy efficient equipment

- Design of the dredging operation and schedule to reduce overall fuel use and hours of operation

- Repowering/refitting with cleaner diesel engines; i.e., those that would emit less air contaminant emissions

- Selection of newer dredges with more efficient engines, if possible
- Selection of dredges equipped with emissions control equipment; e.g., selective catalytic reduction, etc., if available
- Provision of electric power to dredging equipment

Land-side Mitigation Options

Use of vehicles fueled by compressed natural gas (CNG) or liquefied petroleum gas (LPG) – CNG could provide about a 24 percent reduction in CO2 emissions compared to gasoline, and LPG could provide about a 12 percent reduction (40 CFR Part 98, Table C-1)

Repowering/refitting with cleaner, more fuel efficient, diesel engines

Use of newer vehicles with more fuel-efficient engines, if possible

Use of nonroad ultra-low sulfur diesel fuel

PM contaminants may be reduced by dust reduction techniques such as enforcing speed limits of construction vehicles within work zones, watering or misting work areas, and applying mulch or vegetation to disturbed areas (Wisconsin Department of Natural Resources, 2018).

4.3.8.5 Agency Coordination

The USACE and the GLO participated in an initial meeting with the TCEQ and the EPA on April 16, 2018. The purpose of this meeting was to introduce these agencies to the project, provide a brief overview, and to discuss potential General Conformity issues relating to the project. This was an introductory meeting with the intent of participating in future meetings as the project progresses.

On July 11, 2018 the USACE and the GLO participated in a follow-on meeting with the staff of the TCEQ and EPA to discuss potential methods for demonstration of conformity for the Project emissions. As a result of this meeting, it was determined that follow-on coordination would be appropriate.

4.3.8.6 Greenhouse Gas Impacts

Air emissions from the operation of internal combustion engines that result in GHG emissions that could contribute to global climate change. Climate change impacts are, by nature, cumulative and long term. Therefore, consideration of a proposed action’s impact to climate change is essentially an analysis of a project’s contribution to a cumulatively significant global impact through its emission of GHGs. In addition, GHG emissions persist in the atmosphere for decades or longer, impacting the climate over the long term.

Because the GHG emissions from the construction phase of the project alternatives are relatively short-term in nature, the associated adverse impacts on global climate change would be anticipated to be minor. The long-term effects of the proposed alternatives would be a consequence of their operational GHG emissions, which, assuming the use of electric powered barrier gates, would also be anticipated to be minor.

4.3.9 Noise

4.3.9.1 Alternative A

Coastal Barrier Alternative

Direct noise impacts to noise-sensitive receivers such as residential, recreational, and worship areas are expected during initial construction of the levee/floodwall and during periodic maintenance activities along the levees/floodwall. Construction and maintenance activities would be temporary, and therefore, noise generated by those activities would be temporary. Except for isolated areas and under rare circumstances, the levee/floodwalls have no noise generating components. Typical construction-related noise sources would be construction machinery (e.g., excavators, front end loaders) and movement of heavy trucks hauling construction spoils and materials within the construction right-of-way. Noise levels related to construction would be based upon the actual number and type of equipment operating in one location at a specific time. Typical temporary noise levels that could be associated with construction include 73 dBA for large front-end loaders from a distance of 100 feet and 86 dBA for off-road haul trucks at 50 feet (Epsilon Associates, Inc., 2006). Due to the existing high volume of traffic within the region, the potential increase in heavy trucks traveling throughout the region to transport materials related to the proposed project would be insignificant. General areas near the proposed levee/floodwall with noise-sensitive receivers would be primarily limited to the residential areas on Galveston Island and Bolivar Peninsula. Noise impacts associated with construction would be temporary and would typically take place during normal working hours (daytime), and therefore, are considered minor. In addition, many of these homes are likely weekend homes that may not be continuously occupied during peak times of construction (weekdays) or during winter months.

Construction of the navigation and environmental gates within Bolivar Roads are not expected to result in noise impacts to noise-sensitive receivers, like residential and recreational areas, due to the distance from the proposed gates to these areas. Similarly, the operation of the gates is not expected to result in noise impacts. Initial construction, long-term maintenance, and intermittent operation of proposed gates at Clear Lake, Dickinson Bayou, and Offatts Bayou would likely result in temporary and/or short-term noise impacts to a small number of residences near these proposed facilities. These areas have a low concentration of potential noise-sensitive receivers, and as such, noise impacts related to the construction and operation of navigation and environmental gates for the Coastal Barrier are expected to be minor.

Initial construction of proposed pump stations along the Coastal Barrier to drain the protected systems during storms would likely result in temporary noise impacts to a small number of residential areas during the operation of heavy construction equipment. Long-term maintenance and operation of the pump stations would likely not result in noise impacts because the proposed pump stations would be enclosed, and thereby, would not generate significant off-site noise during operation. Noise impacts related to the construction and operation of the pump stations along the Coastal Barrier are expected to be minor.

A long-term beneficial effect on noise (i.e., a reduction in noise near noise-sensitive receivers) is expected in residential areas protected from storm surges. The long-term reduction in noise would be from the expected decrease in infrastructure damage and subsequent construction/rehabilitation activities near receivers following storm surges. This would be an indirect noise effect, and due to the infrequency of potentially damaging storm surges, the benefit is considered minor.

4.3.9.2 Alternative D2

Upper Bay Barrier-Bay Rim CSRM Measure (Upper Bay Barrier)

As described for Alternative A, temporary and minor noise impacts related to construction noise along the proposed levee/floodway are expected. Typical construction-related noise sources would be heavy construction machinery (e.g., excavators, front end loaders) and movement of heavy trucks hauling construction spoils and materials within the construction right-of-way. Due to the existing high volume of traffic within the region, the potential increase in heavy trucks traveling throughout the region to transport materials related to the proposed project would be insignificant. The expected temporary noise impacts from the Upper Bay Barrier would be in the developed, urban areas with high concentrations of residences in the cities of Galveston, Hitchcock, Texas City, San Leon, Bacliff, Kemah, Seabrook, and La Porte. This CSRM measure is expected to have greater noise impacts from construction of the levee/floodway than the Coastal Barrier due to the greater lengths of proposed levee/floodway in proximity to residential areas.

Construction of the navigation and environmental gates within Hartman Bridge is not expected to result in noise impacts to noise-sensitive receivers, like residential and recreational areas, due to the distance from the proposed gate to this area. Similarly, the operation of the gates in these two areas are not expected to result in noise impacts. Construction, long-term maintenance, and intermittent operation of proposed gates at Clear Lake, Dickinson Bayou, the bay rim levee/floodwall, and the Texas City Hurricane Flood Protection Improvements would likely result in temporary and/or short-term noise impacts to a small number of residences near these proposed facilities. These areas have a low concentration of potential noise-sensitive receivers, and as such, noise impacts related to the construction and operation of navigation and environmental gates for the Upper Bay Barrier are expected to be minor.

Construction of proposed pump stations along the Upper Bay Barrier to drain the protected systems during storms would likely result in temporary noise impacts to noise sensitive receivers during construction. Long-term maintenance and operation of the pump stations would likely not result in noise impacts because the proposed pump stations would typically be enclosed, and thereby, would not generate significant offsite noise during operation. Noise impacts related to the construction and operation of the pump stations along the Upper Bay Barrier are expected to be minor.

Noise-sensitive areas protected from storm surges by the Upper Bay Barrier are expected to benefit from a minor long-term reduction in construction noise.

4.3.9.3 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Construction activities related to the operation of heavy equipment during dune and beach restoration could result in temporary noise impacts at beach-front recreational areas and residences. During construction, access for recreational uses may be limited at the areas of construction which would reduce the potential of noise impacts. In addition, many of the beach-front residences are likely weekend homes that may not be continuously occupied during peak times of construction (week days) or during winter months. Potential noise impacts from dune and beach restoration are expected to be temporary and minor.

4.4 ECOLOGICAL AND BIOLOGICAL RESOURCES

4.4.1 Wetlands

Coastal wetland and marsh habitats are important features in the landscape that have environmental and economic importance and provide numerous beneficial services for people and for fish and wildlife. These ecosystem services include protection of upland areas from flooding caused by RSLR and storm surge, coastline stabilization due to their ability to absorb energy from ocean currents and vessel wakes, and habitat for many Federally threatened and endangered species and state species of concern (Carter, 1997; Costanza et al., 2008; EPA, 2018d; USFWS, 2018i).

The Texas coast contains thousands of coastal wetlands and marshes that are situated between the open Gulf and the coastal plains (NOAA, 2018b). Galveston Bay is one of the largest estuaries on the Gulf Coast and the CSRM measures considered for the upper Texas coast are expected to have direct and indirect impacts on those habitats. Likewise, estuarine habitats of the Lower Laguna Madre, which is bordered by South Padre Island, are expected to be indirectly affected by the CSRM measure proposed for the lower Texas coast.

Strategic planning initiatives were inaugurated during the development of the CSRM measures to minimize the amount of wetland loss and to mitigate impacts associated with the structures. Preliminary studies have shown that levees and navigation gate structures, both of which are proposed as features of the CSRM measures, may affect wetland functions by constricting tidal exchange and altering hydrosalinity gradients (McAplin et al., 2018). Conversely, material dredged from the construction of the CSRM measures in open water may be used beneficially to restore degraded marsh habitats or to provide beach nourishment in the Galveston Bay region.

4.4.1.1 Alternative A Coastal Barrier Alternative

The proposed Coastal Barrier, including the levee, floodwall, barrier wall, seawall, and navigational and environmental gate structures, are expected to have direct and indirect impacts to wetland and marsh habitats in the Galveston Bay region. Approximately 122 acres of estuarine wetlands and 128 acres of palustrine wetlands are expected to be altered or potentially destroyed due to the construction of this action alternative. Construction of the tie in levee on Bolivar Peninsula and Ring Levee system on Galveston Island would require clearing, grubbing, levelling, and filling of wetland and marsh habitats. The potential for erosion and increased sedimentation during construction could affect the water quality and bury or damage adjacent vegetation in marshes. Hydrological barriers, such as levees, can lead to a loss of sheet flow, degradation of the wetland and marsh vegetation, and fragmentation of the coastal ecosystem (Harvey et al., 2011). Specifically, the wetland and marsh habitats located south of the proposed levee footprint could potentially be exposed to higher salinity from the Gulf for longer periods of times during storm events.

Proper best management practices, including implementation of a Storm Water Pollution Prevention Plan and general avoidance and minimization measures, can be utilized to contain and prevent sediments from entering wetlands adjacent to proposed construction areas. Silt fencing, silt curtains, rock berms, and mulch socks may be used to prevent sediment and contaminant transport to wetlands.

Diurnal tides account for 50 percent of the water level variance in Galveston Bay; the remainder of the variability is due to wind-driven coastal setup along the Texas-Louisiana shelf (Rayson et al., 2015). The hydrology of wetland and marsh habitats, and more specifically, the duration and seasonality of flooding, has a strong influence on the number, type, and distribution of plants and plant communities within these ecosystems (Carter, 1997). This affects resources that are critical to the survival of Gulf coast fisheries, which are almost entirely dependent on wetland and marsh habitats (Barbier, 2013; Texas A&M Agrilife Extension, 2018). The gate structures associated with the Coastal Barrier would likely alter the hydrology of Galveston Bay and potentially impact the ecology of the estuary by decreasing the available habitat that can serve as nurseries, food, and refuge for various fish and shellfish species (Minello et al., 2012; Minello et al., 2015) (see Section 5.2.2 for more details). This in turn would negatively impact birds and wildlife species which depend on the resources provided by the marshes (see sections 5.3.3 and 5.3.4.2 for more details).

Following completion of the navigational and environmental gate structures across Bolivar Roads, the cross-sectional entrance into Galveston Bay would be constricted by 9.5 percent causing a reduction in tidal amplitude. This reduction would likely lead to an estimated ½-inch lower high tides and ½-inch higher low tides and slightly less marsh habitat regularly or seasonally flooded. The constriction is also predicted slight decreases in bay salinities and water and sediment exchange between the Gulf and the bay (McAplin *et al.*, 2020). Potential changes to the characteristics and abundance of wetland and marsh vegetation could occur as a result of inadequate drainage, reduced tidal exchange, and decreased bay salinities relative to existing conditions. Section 4.3.4 discusses how the constriction would likely increase residence time in the bay upstream of the Coastal Barrier and allow greater dilution by freshwater inflows. This could potentially result in a conversion of plant communities and an expansion of freshwater wetlands on the bayside of the structure due to reduced salinity within the bay for longer periods of time.

An analysis was conducted using the NOAA C-CAP 2010 landcover dataset for estuarine wetlands to estimate the potential area of affected wetland and marsh habitats within Galveston Bay as a result of the reduction in tidal amplitude. Approximately 1148 acres of wetlands along the interior of the bay are expected to be indirectly impacted as a result of altered hydrology leading to eventual deterioration of those habitats.

Compared to the No-Action Alternative, the Coastal Barrier would most likely result in significant impacts to the wetland and marsh habitats within the Galveston Bay region. Construction activities associated with the levee/floodwall features on Bolivar Peninsula and Galveston Island and the reduced flow and reduced tidal amplitude resulting from the navigational and environmental gates would have long-term effects on the estuarine habitats.

The Bolivar Peninsula and West Galveston Beach and Dune System would restore 43 miles of Gulf facing shoreline which would indirectly benefit wetlands through additional sediment availability and reduction in the intensity of the effects from coastal storms.

4.4.1.2 Alternative D2 Upper Bay Barrier-Bay Rim CSRM Measure (Upper Bay Barrier)

The proposed Upper Bay Barrier, including the navigational and environmental gates at the Fred Hartman Bridge, Clear Lake, and Dickinson Bayou, the bay rim levee/floodwall, and the Texas City Hurricane Flood Protection improvements are expected to have direct and indirect wetland and marsh impacts in the Galveston Bay region. The level of impact would partially depend on the location of the wetlands and marsh, whereas some areas are expected to benefit from construction of the Upper Bay Barrier.

Construction of the Upper Bay Barrier could directly impact approximately 365 acres of wetland and marsh habitat. The majority of these impacts would occur on private land. Construction of the levee/floodwall features along the bay rim are proposed to start near the intersection of SH 99 and 146B in Baytown, Texas, and end northwest of the intersection of FM 2004 and SH 646 south of Santa Fe, Texas. Construction activities would include clearing, grubbing, levelling, and filling of wetland and marsh habitats. The potential for erosion and increased sedimentation during construction could affect the water quality, bury, and damage adjacent vegetation in marshes. However, proper best management practices, including implementation of a Storm Water Pollution Prevention Plan, and general avoidance and minimization measures can contain and prevent sediments from entering wetlands. Silt fencing, silt curtains, rock berms, and mulch socks may be used to prevent sediment and contaminant transport to wetlands.

Direct and indirect impacts associated with constructing the navigational and environmental gates would be similar to those described for the Coastal Barrier (Section 5.3.1.1). Freshwater and tidal wetland and marsh habitats in Tabbs Bay and the Upper San Jacinto Bay would likely be impacted from construction of the crossing south of the Fred Hartman Bridge due to decreased tidal exchange. Once construction is complete, the Upper Bay Barrier would likely benefit freshwater wetlands situated inland of the structure, such as wetlands within Clear Creek, Dickinson Bayou, and Moses Bayou watersheds, by providing a physical barrier against erosion during storm surges and high winds.

4.4.1.3 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

One of the most cost-effective and successful shoreline protection alternatives is beach nourishment, which usually involves borrowing of source material from inshore or offshore locations and transporting it by truck, hopped dredge, or hydraulic pipeline to the eroding beach. These operations have the potential to adversely affect sensitive habitats due to massive displacement of the substrate, changes in topography or bathymetry from where source material was borrowed, and destruction of benthic communities (USACE, 2015d).

ER measure B-2 is intended to restore and protect dune and beach complexes along gulf shorelines from breaches and erosion caused by storm surge and RSLR. Direct impacts as a result of construction activities would likely not affect the wetland and marsh habitats where dune and beach restoration features are proposed. The features would protect valuable wetland and marsh habitats from further erosion and would provide resiliency against coastal storms and RSLR.

The ER features are designed to provide a variety of services that are expected to have positive ecosystems benefits at the local, regional, and landscape levels across the Texas coast. The benefits gained as a result of the implementation of these features are expected to outweigh the short-term construction impacts. Additionally, the features would enhance the resiliency of coastal communities and ecosystems throughout the Texas coast by conserving, protecting, and enhancing fisheries, wildlife, and their habitats.

4.4.2 Aquatic Communities

4.4.2.1 Freshwater Habitats and Fauna

Fluctuations between prolonged low salinity/freshwater-dominated conditions and higher salinity/drought-dominated conditions depend on rainfall patterns, reservoir releases, and discharges of treated municipal wastewater. As these changes occur, suitable conditions in the bay for freshwater organisms would expand and contract. Freshwater fish, macroinvertebrates, and plants are more likely to be present when salinities are below 5 to 10 ppt. Concentrations of freshwater organisms may be higher near the mouths of tidal streams receiving freshwater inflow where salinities may be more favorable. When near the mouths of tidal streams or shorelines, fish may be closer to instream cover (large woody debris, undercut banks, submerged/emergent vegetation, etc.) like that in freshwater habitats which they rely on for protection. These habitat characteristics are less likely to occur in the open bay.

When salinities remain sufficiently low through a growing season, freshwater plants may colonize parts of the bay that experience higher, unfavorable, salinities in other years. Wild celery (Vallisneria americana) is a submerged aquatic plant that can grow in the Trinity River Delta in Trinity Bay when salinities are below 10 ppt (Adair et al., 1994). It was not observed in this area in 2011 during drought and high salinity (above 12 ppt) for over a year but was found during multiple surveys in 2016 when salinity in the area was below 3 ppt (Quigg et al., 2013; Guillen et al., 2016).

Tolan (2008) found salinity influenced nekton community structure in bag seine samples from Texas tidal streams. Tolan and Nelson (n.d.) found salinity to be the main factor affecting biological community structure in the tidal reaches of the Mission and Aransas rivers. Zimmerman et al. (1990) found white crappie (Pomoxis annularis) and channel catfish (Ictalurus punctatus) in the Trinity River delta marsh where salinities were below 5 ppt. Gelwick et al. (2001) found sunfish (Lepomis), white crappie, and gizzard shad (Dorosoma cepedianum) in the channelized zones in estuarine marsh in Matagorda Bay where salinity was below 5 ppt.

Nordlie (2003) identified freshwater fish known to utilize estuarine marsh in Texas, including alligator gar (Atractosteus spatula), gizzard shad, threadfin shad (D. petenense), and inland silverside (Menidia beryllina). Freshwater fish with identified salinity tolerances, which could utilize expanded and prolonged areas of lower salinity, might include the following species. Indicated salinities are those which the species can tolerate for extended periods of time:

- Largemouth bass (Micropterus salmoides): 8 ppt (Meador and Kelso, 1990);
- Channel catfish: 12 ppt (Allen and Avault, 1971);
- Blue catfish (Ictalurus furcatus): 8 ppt (Graham, 1999);
- Gizzard shad: 41 ppt (Nordlie, 2003);
- Flathead catfish (Pylodictis olivaris): 8-11 ppt (Bringolf et al., 2005); and
- Threadfin shad: 32 ppt (Froese and Pauly, 2017).

In addition to salinity changes affecting freshwater communities, movement and distribution of some freshwater species may be impeded by the physical barriers. Three species which may have their movements impacted are the American eel (Anguilla rostrata), alligator gar, and freshwater prawn, Macrobrachium ohione.

Adult American eel migrate out of streams and estuaries to the Atlantic Ocean to spawn (Hendrickson and Cohen, 2015). Larval and juvenile eel move from the ocean to estuaries and rivers where they live up to 30 years before returning to the sea to reproduce.

American eel have been reported from tributaries to Galveston Bay including Spindletop Ditch, Dickinson Bayou, Halls Bayou and White Rock Creek (Trinity River tributary). Although American eel have been found in tributaries to Galveston Bay, studies of American eel movement through Galveston Bay or other estuaries along the Gulf coast were not found (Hendrickson and Cohen, 2015). It is not known if their migratory movements would be impacted by water movement around the barriers or if the structures would be placed in portions of the bay where they may block eel migration. The species is recognized in Texas as a “Species of Greatest Conservation Need” by TPWD (2011).

Alligator gar is also recognized as a “Species of Greatest Conservation Need” by TPWD (2011). It spawns over shallow flooded plants when freshwater streams flow over their banks (Hendrickson and Cohen, 2015; Buckmeier, 2008). Successful spawning may occur where salinities are below 7 ppt and the optimal salinity range for juveniles is up to 8 ppt (Suchy, 2009). Alligator gar have been collected in Texas bays at salinities up to 40 ppt. Over the period from 1975 to 2012, 2,597 alligator gar were collected in gillnets in Galveston Bay. This is considered a conservative number since large specimens typically break free and are not retained by gillnets. In general, this species was collected more frequently after freshwater inflow had increased and when salinities were lower (Daugherty et al., 2017). Alligator gar can move long distances and have been tracked moving over 62 miles in the lower Trinity River (Buckmeier et al., 2013). It is not known if Alligator gar movement around the proposed structures for each measure would be affected.

The freshwater prawn migrates from freshwater streams to estuaries to spawn. Freshwater prawn preparing to spawn were collected around the mouths of Dickinson Bayou in Upper Galveston Bay and Cedar Bayou in Trinity Bay (Reimer et al., 1974). This species spawns in estuaries or enters estuaries as drifting larvae while juveniles migrate upstream into streams where they mature into adults (Benson, 2017). Information was not readily available describing the estuarine habitat occupied by larval and juvenile prawns before they begin migrating upstream. They may concentrate in marsh which provides protection from predators and ready access to detrital food sources. Rozas and Minello (2006) reported collecting Ohio shrimp (Macrobrachium ohione) in wild celery (Vallisneria americana) beds in Barataria Bay, Louisiana with highest concentrations in the interior of the plant bed rather than along its edge.

4.4.2.1.1 Alternative A

Coastal Barrier Alternative

Salinity modeling (McAlpin, et al., 2019b and Lackey and McAlpin, 2020) indicates portions of Galveston Bay upstream of the barrier would have lower salinities for longer periods when freshwater inflows are normal to high. Conversely, these areas would maintain higher salinities for longer periods when freshwater inflows are below normal for extended periods and evaporation is high or when a storm from the Gulf pushes large volumes of more saline water upstream of the barrier. Areas upstream of the barrier, which are fresher for longer periods, may allow temporary expansion of freshwater fish, invertebrate, and plant communities into some of those areas. These areas with salinities most favorable to freshwater organisms are expected to be near freshwater inflows entering the bay.

The design and positioning of the Coastal Barrier and environmental gates along with barriers at Dickinson Bay, Clear Lake, and Offatts Bayou has not been decided at the time of this writing. These barriers may be designed and operated in ways that avoid or minimize impacts on movements of freshwater organisms. The Coastal Barrier might have the greatest impact on American eel because it may reduce access to the entire bay system and its tributaries which provide habitat for maturing eel. The Coastal Barrier may have less impact on Alligator gar because the barrier is at the mouth of the bay and would not appear to inhibit movement of the fish between spawning tributaries and the bay. Since alligator gar occur in the bay they may occasionally move into the Gulf through Bolivar Roads; however, this movement is not necessary for completion of their life cycle and not expected to be frequent. Since other freshwater organisms are not known to move between the bay and Gulf under ordinary conditions, the Coastal Barrier is not expected to impact movement of other freshwater organisms through the gate systems.

When low salinities occur in the bay, the barriers at Dickinson Bay, Clear Lake, and Offatts Bayou may inhibit movement freshwater fish and shellfish past the barriers.

4.4.2.1.2 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The CSRM measure with the least impact on American eel might be the Upper Bay Barrier because it would reduce access only to the upper Houston Ship Channel, San Jacinto River tidal, and Buffalo Bayou watersheds and there are no data indicating those watersheds are utilized by American eel. The Upper Bay Barrier is also the only measure which would allow unobstructed eel access to the Trinity River and its watershed below Lake Livingston. The Trinity River watershed below Lake Livingston is a fourth of the potential habitat for eel in the Galveston Bay system downstream of Lake Livingston. Lack of information about alligator gar abundance in the bay’s tributaries and the bay and its movements around the bay prevent distinguishing the potential effects of Upper Bay Barrier on this species.

The Upper Bay Barrier should create the most beneficial conditions for freshwater organisms since it would be expected to experience the largest and most prolonged reductions in salinity since the barrier captures about 3 percent of the area of the bay but receives about 38 percent of the average combined inflow to the estuary (TWDB, 2018).

Effects of the barriers at Dickinson Bay, Clear Lake, and Offatts Bayou on freshwater organisms would be similar to the effects in Alternative A.

4.4.2.2 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Since the Follets Island Gulf Beach and Dune Restoration ER measure would be constructed on the beach, sediment placement is not expected to affect freshwater organisms. American eel migrates through the Gulf and it may be possible they migrate near the sediment source areas in the Gulf. There are no data on American eel occurrence in this part of the Gulf however monitoring data suggest there is a relatively low probability of American eel occurring near the sediment source area. If American eel do move near the sediment source area, they may be mobile enough to avoid entrainment by the dredge.

4.4.2.3 Estuarine Habitats and Fauna

AdH Model conducted by the USACE (Lackey & McAlpin, 2020 and McAlpin et al., 2019b) has shown that once the navigation/environmental gate structures are constructed, there would be reduced flow into and out of the bay, velocities along the openings of the gates would increase, and water retention times in the bay would increase resulting in indirect long-term impacts to the aquatic community. The navigation and environmental gates across Bolivar Roads would reduce the cross-section area of flow by 9.5 percent. The modeling predicts a 3 percent reduction in tidal prism at Bolivar Roads which would reduce tidal exchange. The modeling also shows a potential tidal amplitude reduction between 3 to 6 percent which indicates that the structures are restricting the flow and limiting the volume of water moving in and out of the bay at Bolivar Roads. It predicted lower high tides and higher low tides. Reduced flow and high velocities through Bolivar Roads could impede the migrations and movements of various life stages of fish into and out of the Galveston Bay complex.

4.4.2.3.1 Alternative A

Coastal Barrier Alternative

The predicted reduced flow and high velocities through Bolivar Roads could impede the migrations and movements of various life stages of fish into and out of the Galveston Bay complex. Eggs and larval stages of aquatic organisms are transported by currents, moving into the bay on the incoming tides. Larval forms of some species drop near the bottom on outgoing tides, particularly in the shallow areas nearshore to reduce transport out of the bay. An environmental gate along the shore of Bolivar Roads is expected to help alleviate some of the potential impacts to aquatic organisms that utilize shallow edge habitats. The important commercial/recreational and forage fish target species that are most vulnerable to flow constriction and velocity increases were identified by Rusty Swafford at NMFS (**Table 4-11**) (pers. com. Rusty Swafford [NMFS], 2017). **Table 4-11** describes the life stage relative abundance of these species in Galveston Bay and their migrations and movements. Adult fish passage modeling would provide additional information that would help assess these potential impacts.

The Engineer Research and Development Center, Coastal and Hydraulics Laboratory performed particle tracking modeling (PTM) to assess impacts on the recruitment of larval species from the proposed Bolivar Roads Gate System. The complete results of these investigations can be found in the Galveston Bay Larval Transport Study report (Lackey & McAlpin, 2020) The AdH Model provided circulation, salinity, current, and water surface elevation information for the with and without project conditions. Six larval marine species characteristic behaviors were modeled in this work. These behaviors correspond to the suspected dominant transport characteristic behavior of a variety of marine species native to the area. These behaviors were derived from the field data provided in Hartman et al. (1987) for the Keith Lake Fish Pass Larval Transport study

1. Tidal Lateral (move to center of channel during incoming tide)
2. Diel Vertical (move up during day)
3. Tidal Vertical (move up during incoming tide)
4. Bottom movers (particles remain 1 m from bottom)
5. Surface movers (particles remain 1 m from top)
6. Passive (neutrally buoyant particles)

The particles were initiated at a location upstream on the gulf-side of the planned gate structure. Approximately 7400 particles were re-leased over a five-week simulation which used actual water movement data from Spring 2018. The particles in the simulation were successfully recruited if they reached one of three target areas which corresponded to the entrances to West Galveston Bay, Trinity Bay, and East Bay (**Figure 4-10**).

Figure 4-10 Particle Track modeling. Different color particles represent different behaviors. The White polygons are the recruitment areas.

A series of 12 simulations were run (six without project and six with project). The slope of the time series, which can be thought of as a rate of particle recruitment was used to compare the simulations. Overall, the simulated recruitment was very similar between the with and without project hydrodynamic conditions. Although there is a restriction on the volume of water exchanging through the structures, the particle recruitment is essentially unchanged. It appears that the increased velocity at the structures is making up for the reduced tidal prism exchange, giving a near zero net change on the particle transport.

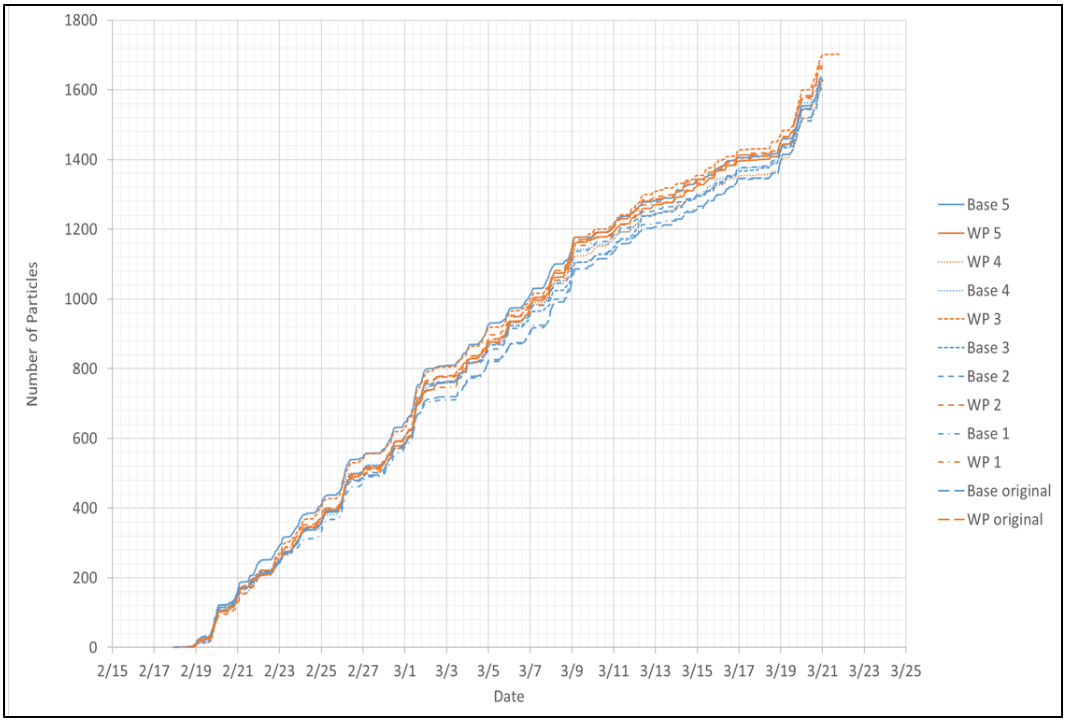

Figure 4-11 Outcomes of the PTM Simulations

It is important to note that this method for understanding larval fish transport is simplistic in the fact that it focuses on modeling "characteristic" transport. That is, the particle transport method included in this work does not suggest that it contains all the intricate behaviors of an alive biological larvae. Extrapolation of the impact of the structures to the population of a specific species was not within the scope of work of this project. That said, the results of this analysis are encouraging in that no significant impacts were identified for the 2020 design for the Bolivar Roads Gate structure. Further analysis on larval transport will be required if the gate designs are modified or updated.

Table 4-11 Key Species Most Vulnerable to Flow Constriction

Species	Life Stage*	Galveston Bay Abundance	Migrations and Movements
Commercial/Recreationally Targeted Species:			
Brown shrimp	E, A	Not present	Adults move offshore to spawn from May through August, eggs offshore
	L, J	Abundant	Larvae move into estuaries from February to April with incoming tides and migrate to shallow, vegetated areas
			Juveniles move into open bays
White shrimp	E	Not present	Adults spawn offshore from spring through fall
	L, J	Abundant	Larvae move into estuaries from May to November
	A	Common	Juveniles migrate farther up the estuary into less saline water
			As they grow and mature, they leave the marsh for deeper, higher salinity areas of the estuary
			Juveniles and sub-adults move from estuaries to offshore in late August and September
Blue crab	L, J, A	Abundant	Eggs hatch near the mouths of estuaries and zoeal larvae are carried offshore to grow for up to one month
			Re-entry to estuarine waters occurs during the megalopal stage
Gray snapper	E, L	Not present	Pre-juveniles move into estuarine habitats, juveniles occupy inshore grassy areas
	J, A	Rare	Adults migrate offshore in summer to spawn
Red drum	E	Not present	Adults spawn offshore.
	L, J, A	Common	Larvae and early juveniles are carried by tides and currents in the late fall into estuaries and bays and move to quieter back bay areas to grow
			Young move into primary bays
			Older fish move into the Gulf in the fall and winter
Spotted seatrout	E, L, J, A	Common	Estuarine dependent, completing entire life cycle in inshore waters

Species	Life Stage*	Galveston Bay Abundance	Migrations and Movements
			Eggs associated with grass beds at or near barrier islands, larvae in deep channels
			Juveniles and adults found in seagrass, deep basins, tidal river mouths, channels and canals
			Adults can be found in nearshore Gulf waters (surf zones) during the fall and winter
Sand seatrout (*Cynoscion arenarius*)	E, L	Not present	Spawning occurs offshore
	J	Abundant	Larvae migrate to estuaries in April to early fall, preferring small bayous, shallow marshes, channels
	A	Common	Migration from bay to offshore occurs late fall or winter, after spawning adults move back into higher salinity areas of the bay
Southern flounder	E, L	Not present	Adults move from estuaries during the fall and winter to spawn offshore
	J	Common	Post larvae and juveniles immigrate into bays and estuaries from later winter to spring
	A	Abundant	Adults migrate back into the estuary during spring and summer
Atlantic croaker	E, L	Not present	Seasonal inshore and offshore migrations
	J	Abundant	Adults move into bays and estuaries in the spring and offshore in the fall
	A	Common	Larvae are carried by tides into the estuaries October to May
			Juveniles move into headwater areas where they remain 6 to 8 months and begin migrating offshore in March-April
Black drum	E, L, J, A	Common	Larvae and small young move into upper estuary and tidal creeks to low salinity nursery areas during flood tides
			Juveniles move into bays, passes, and nearshore Gulf
			Spawn near passes, bays, channels, and nearshore Gulf
			Adults occupy bays and nearshore Gulf

Species	Life Stage*	Galveston Bay Abundance	Migrations and Movements
Sheepshead	E, L	Not present	Adults move offshore in the spring to spawn, returning to bays after spawning
	J, A	Common	Larvae move from offshore into estuaries
			Adults occur in nearshore waters during warm seasons and move out of the estuaries during periods of low temperatures
Gafftopsail catfish	E L, J, A	Present	Spawn in bays
			Adults migrate offshore in winter and return inshore in the spring
Gulf whiting	E	Not present	Adults spawn offshore
	L, J, A	Present	Eggs are offshore, larvae move to estuarine nursery areas
			Adults generally inhabit offshore waters and near barrier islands
			Juveniles are found mainly offshore, less common in estuaries
Forage Fish of Importance:			
Striped mullet	E, L	Not present	Adults move offshore in the fall and winter to spawn, adults return to estuary after spawning
	J	Abundant	Pre-juveniles migrate to estuary in the spring, migrating to nursery areas (secondary and tertiary bays)
	A	Common	
Gulf menhaden	E, L	Not present	Adults migrate from estuaries to the Gulf late summer to winter to spawn
	J, A	Abundant	Larvae migrate to estuaries October to May
			During flood tides larva can be dense in tidal passes
Bay anchovy	E, L, J, A	Abundant	Bays, estuaries, and shallow waters of the Gulf
			Spawning occurs near barrier islands, bays, estuaries, tidal passes, harbors, and in the Gulf

Source: Pattillo et al. (1997)
*E = eggs; L = larva; J = juvenile; A = adult

Fisheries productivity is dependent upon environmental conditions and habitats that are present in marshes. Generally, spawning occurs offshore in coastal waters and larvae move into the estuaries which serve as nursery habitat, protection from predators, and provide food for growth. Sub-adults migrate back to the Gulf to mature following a certain growth period (Minello et al., 2017). Marshes form a transition between aquatic and terrestrial ecosystems consisting of vegetation interspersed with shallow open water (Minello et al., 2008). The vegetation/edge of the marsh is important in providing access to the marsh surface, which is used by aquatic organisms when it is flooded. The less the marsh surface is flooded the less surface area is available for these species to utilize as nursery habitat (Minello et al., 2012; Minello et al., 2015). Tidal inundation is very important in determining marsh value and use. Studies have shown high densities of fish, crabs, and penaeid shrimp utilize about the first 10 feet of vegetation adjacent to open water. In Texas, juvenile red drum, spotted seatrout, penaeid shrimp, and blue crab densities are high in marsh edge habitat; these high densities could be associated with high flooding durations of these marshes (Minello et al., 2012). The wetland mitigation described in Section 4.4.1.1 is expected to offset the losses to salt marsh habitat to reduce any potential long-term impacts that would occur from these potential losses.

Estuarine modeling is predicting a reduction in tidal amplitude, and lower high tides and higher low tides (Lackey & McAlpin, 2020 and McAlpin et al., 2019b). Lower water levels mean less of the marsh would be flooded, resulting in a loss of marsh surface area available for aquatic organisms to use as nursery habitat. Reduced access to marsh due to the tidal amplitude change was estimated for the Coastal Barrier. A tidal amplitude reduction of 0.5-inch, which is lower than the reduced tidal amplitude predicted by the AdH model, was used to calculate this area of reduced marsh access. This could result in a reduction of fish and shellfish densities thus reducing the overall populations in the bay. There are many variables affecting ecology of the Galveston Bay complex, exactly what impacts the structure could have on fisheries in the Galveston Bay complex is uncertain.

The Bolivar Road Gate System would result in a permanent loss of 128.5 acres of open water and bay bottom habitat (**Table 4-3**). This measure includes two 650-foot-wide sector gates each with a 60-foot deep sill and two 125-foot-wide sector gates with 40-foot sill depths. Additional gates in the system include eight Shallow Water Vertical Lift Gates (300-foot-wide opening; 20-foot-deep sill), seven Deep Water Vertical Lift Gates (300-foot-wide opening; 40-foot-deep sill), 16 monolith gates (16-foot-wide opening, 5-foot-deep sill), and three manmade islands to hold the sector gates which would total 110.0 acres. The Galveston Bay complex contains approximately 378,063 acres of open-bay habitat (Pulich, 2002). The 128 acres loss is a small fraction (0.0003 percent) of the total available habitat within the entire system.

During construction of the Coastal Barrier, temporary disturbances and impacts to benthic organisms, plankton, and nekton assemblages would occur. Turbidity in estuarine and coastal waters is generally cited as having a complex set of impacts on a wide array of organisms (Hirsch et al., 1978; Stern and Stickle, 1978; Wright, 1978; Wilber et al., 2005). During construction of the Coastal Barrier, water column turbidity is expected to increase. The release of sediment during dredging increases turbidity in the water column, which creates a sediment plume, the extent of which is determined by the direction and strength of the currents, and the sizes of particles (Wilber and Clarke, 2001).

Turbidity from TSS tends to reduce light penetration and thus reduce photosynthetic activity by phytoplankton, algae, and seagrass (Wilber and Clarke, 2001). Such reductions in primary productivity would be localized around the immediate area of the dredging and placement operations. This reduced productivity may be offset by an increase in nutrients released into the water column during dredging activities that can increase productivity in the area surrounding the dredging activities (Newell et al., 1998; Wilber and Clarke, 2001). In past studies of impacts of dredged material placement from turbidity and nutrient release, the effects are both localized and temporary (May 1973). Due to the capacity and natural variation in phytoplankton and algal populations, the impacts to phytoplankton and algae from project construction, dredging within the project area, and dredged material placement of material would be temporary.

Increased concentrations of suspended sediment can temporarily impact benthic macroinvertebrates and juvenile and adult finfish and shellfish by disrupting foraging patterns, reducing feeding rates and effectiveness, burying habitat for feeding and reproduction, and reducing respiration rates by coating gills with sediment (Newcombe and Jensen, 1996; Clarke and Wilber, 2000; Wilber and Clarke, 2001). Finfish and shellfish can avoid highly turbid areas and under most conditions are only exposed to localized suspended-sediment plumes for short durations (minutes to hours) (Clarke and Wilber, 2000; Wilber and Clarke, 2001; Newcombe and Jensen, 1996). Shrimp and crabs are less impacted by elevated suspended sediments since these organisms reside on or near the bottom where sedimentation naturally occurs (Wilber and Clark, 2001; Wilber et al., 2005). Furthermore, turbid waters may actually provide a refuge for these species from predation (Wilber and Clarke, 2001). Research has shown that more-sensitive species and life stages (i.e., eggs, larvae, and fry) are more negatively impacted by longer exposure to suspended sediments than less sensitive species and older life stages (Germano and Cary, 2005; Wilber and Clark, 2001; Wilber et al., 2005; Newcombe and Jensen, 1996).

Effects of elevated suspended solids on the adult stages of various filter-feeding organisms such as oysters, copepods, zooplankton and other species include reduced filtering rates, and clogging of filtering mechanisms interfering with ingestion, respiration, and abrasion (Armstrong et al., 1987; Newcombe and Jensen, 1996; Wilber and Clarke, 2001; Stern and Stickle, 1978). These effects tend to be more pronounced when TSS concentrations are greater than 100 mg/L but are apparently reversible once turbidities return to ambient levels (Newcombe and Jensen, 1996). These impacts would be localized around the immediate area of dredging and placement operations.

Turbidities can be expected to return to near ambient conditions within a few hours after dredging ceases in a given area, thus, no long-term effects are anticipated. Modeling of dredged material discharge in the Laguna Madre, Texas, determined that turbidity caused by dredging was short lived and therefore impacts to the estuarine and offshore water column would be minimal (Teeter et al., 2003). No long-term impacts of elevated turbidities to finfish or shellfish populations are anticipated from construction, dredging, and placement activities associated with construction of the Coastal Barrier compared with the No-Action Alternative.

There would be direct impacts to benthic organisms which would be buried or removed during construction of the Coastal Barrier. Excavation of sediments removes and buries benthic organisms, whereas placement of dredged material and structures smothers or buries benthic communities. Dredging and placement activities may cause ecological damage to benthic organisms due to ecosystem physical disturbance, mobilization of sediment contaminants making them more bio-available, and increasing concentrations of suspended sediments (Montagna et al., 1998). Dredging can result in a reduction of species diversity by 30 to 70 percent, the number of individuals by 40 to 95 percent, and a similar reduction in the biomass of benthic fauna existing within the boundaries of dredged areas (Newell et al., 1998). Recolonization of areas impacted by dredging and dredged material placement occurs through vertical migration of buried organisms through the dredged material, immigration of postlarval organisms from the surrounding area, larval recruitment from the water column, and/or sediments slumping from the side of the dredged area (Bolam and Rees, 2003; Newell et al., 1998). The response and recovery of the benthic community from dredged material placement is affected by many factors, including environmental (e.g., water quality, water stratification), sediment type and frequency, and timing of disposal. Communities in these dynamic ecosystems are dominated by opportunistic species tolerant of a wide range of conditions (Bolam et al., 2010; Bolam and Rees; 2003, Newell et al., 2004; Newell et al., 1998). Although changes in community structure, composition, and function may occur, these impacts would be temporary in some dredging and disposal areas (Bolam and Rees, 2003). Shallower, higher energy estuarine habitats can recover as fast as 1 to 10 months from perturbation, while deeper, more stable habitats can take up to 8 years to recover (Bolam et al., 2010; Bolam and Rees, 2003; Newell et al., 1998; Sheridan, 1999; Sheridan, 2004; Wilber et al., 2006; VanDerWal et al., 2011).

Maurer et al. (1986) demonstrated that many benthic organisms were able to migrate vertically through 35 inches of dredged material; however, the species present in early successional stages of recovery are not the same as those buried by the dredged material. Although vertical migration is possible, most organisms at the center of the disturbance do not survive and survival was shown to increase as distance from the disturbance increased (Bolam and Rees, 2003; Maurer et al., 1986). The release of nutrients during dredging may also enhance species diversity and population densities of benthic organisms outside the immediate dredge placement area as long as the dredged material is not contaminated (Newell et al., 1998).

Dredged material for construction of the Coastal Barrier would either be used beneficially for construction of ER measures or put in approved placement areas.

A slight decrease in average salinity of about 2 ppt could be expected based on the estuarine modeling conducted by the USACE (McAlpin et al., 2019b). During normal flow conditions, average salinities range from less than 10 ppt in upper Trinity Bay to 30 ppt at Bolivar Roads (Lester and Gonzalez, 2011). Most organisms occupying these environments are ubiquitous along the Texas coast and can tolerate a wide range of salinities (Pattillo et al., 1997). The modeling also shows that RSLR could increase the average salinity for the Galveston Bay System. These opposing trends create a dynamic situation. Additional modeling on the further developed designs will be necessary to quantify these potential impacts to estuarine species.

The footprint for the Clear Lake Gate would impact 3.7 acres of oyster reef and the Dickinson Bayou Gate footprint covers 2 acres of oyster reef. Impacts to oyster habitat were modeled using the Swannack et al. (2014) oyster HSI and mitigation to offset the modeled losses is proposed. The interagency team noted that oysters do occur in locations that do not occur on the GLO mapped layer, specifically in Offatts Bayou where the proposed Galveston ring levee/floodwall would cross. A more detailed impact assessment, including additional oyster information from the interagency team, will be conducted in the Tier Two analysis for these measures.

Water column turbidity would increase during project construction that could affect survival or growth of oysters nearby. Temporary impacts to oysters include reduced filtering rates and clogging of filtering mechanisms causing abrasion and interfering with ingestion and respiration (Newcombe and Jensen, 1996; Wilber and Clarke, 2001; Stern and Stickle, 1978). Adult oysters are more capable of withstanding such conditions than spat, and during periods of high turbidity can close up tightly for a week or more until normal conditions return (Cake, 1983). Turbidity increases from the Coastal Barrier should be temporary and local.

Indirect effects to oyster reef habitat may result from a lower salinity regime due to the reduced flow of water into and out of the bay and the longer retention times. An overall decrease in salinity of about 2 ppt could be expected based on the estuarine modeling conducted by the USACE (McAlpin et al., 2019b). A benefit of a slight decrease in salinity is a potential reduction in exposure to oyster predators and pathogens, drills and Dermo which may occur more frequently with higher salinities (Cake, 1983; Soniat and Kortright, 1998). Based on the current design and available modeling, it is not anticipated that this potential salinity decrease would cause any long-term impacts to oyster reefs in the Galveston Bay complex.

Increased nutrients could cause algal blooms that could impact oysters. Freshwater inflow during rain events would bring in additional nutrients into the system and could cause algal blooms. The freshwater on top of the saltwater could stratify the water and reduce oxygen causing anoxic conditions in bottom waters thus impacting oysters.

When compared with the No-Action Alternative, the Coastal Barrier could result in a reduction in overall estuarine fauna productivity. Dredging and construction activities associated with construction of the Coastal Barrier would cause temporary and localized impacts resulting from increased turbidity, suspended sediments, and bottom impacts. In-bay construction durations are not known at this time; however, construction lasting for extended time periods could take estuarine habitats and fauna in those areas longer to recover to pre-construction conditions. Reduced flow, reduced tidal amplitude, and periodic high velocities around the gates would have long term effects on estuarine habitats and fauna in Galveston Bay. Potential long-term direct impacts to fish and shellfish with larval and juvenile life stages that depend largely on passive transport could result from the cumulative impacts of the Coastal Barrier. These impacts would include losses resulting from 1) reduced numbers entering the bay proportional to the reduced volume flowing into the bay, 2) loss of individuals trapped in eddies that could form on the backside of the gate structures; 3) increased exposure to predation while migrating across the open bay to the marshes due to reduced velocities and increased transport times; and 4) reduced area of accessible marsh caused by reduced tidal amplitude. Many of these species are important forage species for other species of fish, birds, and dolphins. These other species could experience indirect impacts resulting from reduced access to forage. It is difficult to predict what those impacts could be because few gate structures have been constructed in the world and no studies have been conducted on the ecological impacts these gate structures could cause. Therefore, the exact long-term impacts to the Galveston Bay complex are uncertain and additional studies would be required to best predict the impacts the structure may cause.

4.4.2.3.2 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

With the Upper Bay Barrier, the navigation and environmental gates at Hartman Bridge, Clear Lake, Dickinson Bayou, the bay rim levee/floodwall, and the Texas City Hurricane Flood Protection Improvements would result in a permanent loss of 564.0 acres of open water and bay bottom habitat (see Table 5-3). About half of that loss would occur at Hartman Bridge, which would also permanently convert to deeper-water habitat as a result of the underwater footprint needed to construct the navigation and environmental gates. The 564.0 acres loss is a small fraction (0.15 percent) of the total available habitat within the entire system.

Direct impacts associated with constructing the Upper Bay Barrier would be similar to those described for the Coastal Barrier (Section 5.3.2.1), with the exception of the smaller open water impacts. The Upper Bay Barrier has much less open water impacts compared to the Coastal Barrier. Minimal indirect impacts are anticipated with this alternative.

Open bay and bay bottom habitat would be disturbed during construction of the Upper Bay Barrier. The same types of temporary disturbances to water column turbidity and construction impacts would occur as those described for the Coastal Barrier (Section 5.3.2.1) Turbidity and bottom conditions would be expected to return to normal once construction is completed. Effects on salinity and velocity have not been modeled for the Upper Bay Barrier. Similar effects to those caused by the Coastal Barrier may be expected with reduced flow through the barrier, reduced tidal amplitude upstream of the barrier and periodically measurably higher velocities around the navigation and environmental gates. Aquatic organism exchange between upper Galveston Bay and Tabbs/Upper San Jacinto/Burnet bays and Buffalo Bayou could be impeded with construction of Upper Bay Barrier. However, due to this measure being located in the upper portions of Galveston Bay impacts would not be as great as those seen with the Coastal Barrier which reduces flow to the entire bay complex.

A total of 0.03 acres of oyster reef falls in the direct footprint of the Upper Bay Barrier and would be lost as a result of this measure. Impacts to nearby oysters during project construction would be the same as those described in the previous Section. A more detailed impact assessment, including additional oyster information from the interagency team, will be conducted on the TSP for the final report.

The Upper Bay Barrier would result in less impacts to estuarine fauna productivity when compared to the Coastal Barrier. Although no hydrologic modeling was conducted for the Upper Bay Barrier, it is expected that the effects of flow constriction and reduced tidal amplitude would impact less of Galveston Bay than the Coastal Barrier would. A greater proportion of the area above the Upper Bay Barrier has less marsh and is more developed/industrialized than Galveston Bay as a whole and there may be less impacts to recreational and commercial fisheries associated with this measure when compared to the Coastal Barrier.

4.4.2.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Impacts to the aquatic community could occur in the Gulf portions of the project area due to increased water column turbidity that can be expected during construction of the dune/beach restoration feature. Impacts associated with bay bottom habitat loss and temporary disturbances to water column turbidity on estuarine habitat and fauna would be the same as those described above for the Coastal Barrier open bay and bay bottom and would be expected to return to normal once construction is completed. Placement of the sand would cause benthic organisms to be smothered and water column turbidity impacts as described above for the Coastal Barrier. However, no long-term impacts to the aquatic community are anticipated as a result of dune/beach restoration features.

The ER measures are designed to provide an overall positive benefit to the ecosystem in a variety of ways. These benefits work together to contribute to the multiple lines of defense strategy that was developed by the Coastal Texas Study that relates to protection of coastal ecosystems and human infrastructure from storm damage caused by hurricanes and tropical storms coming ashore from the Gulf. The lines of defense provided first by the barrier islands, then by living shorelines, and finally coastal marshes, can reduce the physical impacts of storm surges and winds which enter the bays. This combination of lines of defense and ER is intended to provide redundant and resilient levels of protection and restoration for both humans and Texas coastal ecosystems. When comparing the ER measures to the No-Action Alternative, the benefits as a result of the lines of defense strategy far outweigh the short-term construction impacts that would be expected.

4.4.3 Wildlife Resources

Compared to the thousands of undeveloped wetlands, uplands and other wildlife habitats a small fraction would be directly or indirectly impacted by the CSRM measures. Direct impacts to wildlife habitats would be temporary. During construction, wildlife would be able to move out of construction corridors and staging areas into adjacent habitats to avoid disturbance and harm. Species competition in the remaining undisturbed habitat may temporarily lower reproductive rates. Clearing and grubbing associated with construction would be conducted during the fall or winter, when practicable, to minimize impacts to nesting migratory birds. Wildlife are also at risk of possible oil, chemical, or other hazardous material spills during the construction phase of the project. These risks would be reduced with adequate best management practices and spill response actions outlined by the USFWS (2003). Construction activities near the water may disturb feeding behaviors of wading birds inhabiting the project area due to increased noise and turbidity; however, suitable feeding and loafing areas can be found in the project vicinity (Greene, 2002). Wetlands, forested areas, and shorelines would be surveyed prior to construction to avoid or minimize sensitive wildlife such as bald eagles. Impacts to bald eagle nests would be avoided in accordance to the National Bald Eagle Management Guidelines (USFWS, 2007b) and impacts to migratory bird nests should be avoided in accordance to the MBTA (USFWS, 2017b). Construction of the levee barrier might interfere with existing wildlife corridors due to increased difficulty crossing over the levees or roadways.

After construction is completed, terrestrial wildlife would be able to traverse, burrow, and access earthen levees to adjacent habitats (Bayoumi and Meguid, 2011). If the CSRM barrier utilizes levee borrow pits, the pits could provide year-round water containment for wildlife, such as waterfowl, amphibians, and mammals. The navigational and environmental gate may influence the movements of local fisheries in the Galveston Bay which, in turn, could change foraging areas for shorebirds and other wildlife. Changes in hydrology, nutrients, and organic matter from the presence of the navigational gates may also have an indirect impact to wildlife in the bay by altering or changing fish distribution, movement, or production (see Section 5.3.2).

4.4.3.1 Alternative A

Coastal Barrier Alternative

Due to the proximity of construction along the Gulf coast, it is expected that shorebirds and coastal wildlife would be most impacted by the Coastal Barrier. Construction activity and noise can potentially disrupt and disturb wildlife behavior and their ability to hear (Dufour, 1980). Clearing and grubbing vegetation would remove potential habitat for wildlife species. Wildlife can avoid the area and potentially relocate away from the project area to adjacent habitat.

Once construction is completed, terrestrial wildlife displaced from construction activity would be able to recolonize the adjacent habitat. It is assumed that the tie in structure for the Bolivar Roads Surge Barrier System would be routinely maintained, regularly mowed, and vegetation prevented from growing on the structure (Bayoumi and Meguid, 2011).

4.4.3.2 Alternative D2

Upper Bay Barrier- Bay Rim CSRM Measure (Upper Bay Barrier)

A majority of the levee associated with the Upper Bay Barrier (bay rim) would be placed on developed property and along the highway. Since most of the CSRM measure would be in developed areas, species affected would urban wildlife, such as raccoons, rodents, and coyotes. Most of affected wildlife would be habitat generalists that traverse between urban areas to the Galveston or West Bay uplands and marsh habitats. Urban wildlife are usually more adaptive to changes in the environment (Adams, 2005). The Upper Bay Barrier would have less of an impact on wetland and upland habitats than the Coastal Barrier. The majority of the Upper Bay Barrier would be constructed along previously constructed breakwater, levees, and floodwalls. Construction along the Texas City West Levee Extension would be located close to roadways, railroads, and existing levee structures. These areas have been previously disturbed and fragmented. Nevertheless, construction activity and noise around the project area could potentially interfere with wildlife behavior and their use of corridors (Dufour, 1980). Grubbing and removal of vegetation along the levee footprint would decrease available woodland wildlife habitat. The levee barrier can potentially fragment the north-south migration corridor of wildlife from West Bay to developed areas north near Hitchcock and FM 2004.

After construction, the earthen levee system would continue to allow wildlife to traverse and move through to adjacent habitat. The levee barrier would be routinely maintained, regularly mowed, and trees prevented from growing on the structure. It is not known whether the levee barrier would be fenced or gated. Fences or gates would inhibit wildlife from using the earthen levee has a corridor between habitats. No long-term impacts to wildlife resources are anticipated from the Upper Bay Barrier.

4.4.3.3 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

A wide range of wildlife utilize coastal Texas dunes and beaches, including pocket gophers, raccoons, aplomado falcons, and sea turtles (TPWD, 2018). During the period of construction, noise from machinery may disturb some wildlife and cause turbidity, potentially reducing bird foraging efficiency (Greene, 2002; Notice Nature, 2007). Disturbances to wildlife are expected to be a short-term and wildlife with recolonization of beaches and dunes once construction is completed. Studies have documented that invertebrate fauna and prey species such as amphipods, polychaetes, and coquina clams recovered to pre-construction abundance following beach disturbance (Greene, 2002).

Upon completion, the restored beaches and dunes are expected to enhance wildlife habitat. Sand dunes and beaches would provide a natural barrier to erosive wind and wave action (United Nations Environment Programme, 2018). Significant impacts to wildlife resources are not anticipated from dune/beach restoration. The ER measures are expected to have a net positive effect on wildlife resources. In addition to improved coastal stability, the measures are expected to improve available wildlife habitats and increase productivity. Relative to the No-Action Alternative, the benefits of as a barrier against RSLR and improved habitat are expected to outweigh short-term construction impacts.

4.4.4 Protected Resources

4.4.4.1 Protected Lands

Protected areas are locations which receive legal protection because of their recognized natural, ecological, or cultural values. The International Union for Conservation of Nature (IUCN) (2018) has provided a definition of protected areas that has been widely accepted across regional and global frameworks: "A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."

The Texas coast contains many important natural, historical, and cultural resources that are managed by Federal, State, and local governments or are privately owned. These protected resources hold ecological, cultural, and economic value for individuals and communities throughout the state. The CSRM and ER measures considered for the upper, mid, and lower Texas coast would have direct and indirect impacts on managed or protected lands.

4.4.4.1.1 Alternative A

Coastal Barrier Alternative

The proposed Coastal Barrier levee system is expected to impact State-owned and Federally owned protected lands directly and indirectly. The impacts discussed below describe the sections of Anahuac NWR and Galveston Island State Park that are anticipated to be adversely affected, in addition to areas that are expected to benefit from construction of the Coastal Barrier.

Anahuac NWR is located on the upper Texas coast in Chambers County and borders the north shore of East Galveston Bay, within the Chenier Plain region of southwestern Louisiana and southeast Texas. The southern boundary consists of nearly 7 miles of bay shoreline and is comprised of over 37,000 acres of brackish and saline marshes, coastal prairie, and coastal woodlands (USFWS, 2018i). The refuge is part of the National Wildlife Refuge System and the USFWS protects and manages the area for waterfowl, shorebirds, and water birds. Approximately 300 acres within the Anahuac NWR are expected to be directly impacted by construction operations from the Coastal Barrier, including potential grubbing and clearing, levelling, and piling of fill material. The impacts would be limited to a section of the proposed levee system that will parallel the east side of SH 124 adjacent to the refuge north and west of High Island. Direct impacts from the proposed levee system are expected to result in permanent loss of approximately 100 acres of potential wetlands and marshes along the eastern and southern border of the refuge within the structure footprint and temporary impacts to wetlands and marshes due to construction of access roads and staging sites. The indirect impacts to the refuge are expected to result in changes to wildlife migration patterns and natural hydrography and drainage patterns of the area.

Galveston Island State Park is located on the west end of Galveston Island in Galveston County, Texas and covers about 2,000 acres of beach, bay, and freshwater habitats. The park protects both natural and cultural resources within the area, and provides recreational opportunities for anglers, boaters, and bird watchers. Approximately 64 acres of Gulf Shoreline within the State Park would be restored as part of the Bolivar Peninsula and West Galveston Beach and Dune Measure.

Collectively, the Coastal Barrier is expected to directly impact approximately 364 acres of protected lands from construction operations within the Galveston Bay region. Conversely, upon completion of the Coastal Barrier, several Federal, State, and privately-owned protected lands within the Galveston Bay region would indirectly benefit from the coastal levee protection measures by gaining protection from storm surges and RSLR. These areas include the Atkinson Island WMA owned by TPWD, Candy Abshire WMA owned by TPWD, Moody NWR owned by USFWS, North Deer Island owned by the Audubon Society, and Scenic Galveston Preserve owned by Scenic Galveston.

4.4.4.1.2 Alternative D2

Upper Bay Barrier-Bay Rim CSRM Measure (Upper Bay Barrier)

The proposed levee system and navigation gate structure of the Upper Bay Barrier is expected to indirectly impact State and Federally-owned lands. No protected lands are within the footprint of the measure, and therefore, no direct impacts are expected. Other protected lands outside of the Upper Bay Barrier would most likely not be affected by the proposed levee system or navigation gate structures.

Upon completion of the Upper Bay Barrier, water velocities could potentially increase near the structures and decrease exchange into and out of Galveston Bay. Atkinson Island WMA, which is located in the very northern tip of Galveston Bay on the edge of Harris and Chambers counties, could be indirectly impacted as a result of the erosional effects from increased velocity against the northern portion of the island.

Protected lands upstream of the proposed levee system and gate structure, such as the San Jacinto Battleground and Battleship Texas State Historic site, may experience inundation and drainage issues when the gates are closed during storm surge events. Additionally, the proposed levee system planned to intersect the Moses Bayou inlet could indirectly affect the tidal wetlands and coastal prairie of the Texas City Prairie Preserve (owned by TNC) by altering the tidal flow and salinity into the bayou.

4.4.4.2 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The features are intended to protect dune and beach complexes along gulf shorelines from breaches and erosion caused by storm surge and RSLR. Almost the entirety (1102.5 acres) of this measure is located in CBRS unit T04.

The ER features are designed to provide a variety of services that are expected to have positive ecosystems benefits at the local, regional, and landscape levels across the Texas coast. The benefits gained as a result of the implementation of these features would outweigh the short-term construction impacts. Additionally, the features support the missions of the parks, preserves, and refuges by conserving, protecting, and enhancing fisheries, wildlife, plants, and their habitats and further enhance the resiliency of coastal communities and ecosystems throughout the Texas coast.

4.4.4.3 Threatened and Endangered Species

There are 20 Federally-listed threatened or endangered species with potential to occur within the proposed project areas (**Tables 4-14** and **4-15**) for the alternatives. The species life history, habitat preference, and potential effects of the project on Federally-protected species are considered in more detail in the Biological Assessment provided in Appendix B-1. Since the measures discussed in this Chapter will have Tier Two NEPA studies, those Studies will also include documentation of compliance with the Endangered Species Act. Therefore, effect determinations are not being made for these proposed actions at this time. This section includes the identification several potential impacts that would likely occur if construction occurred today and if the current project design was adopted. For the Tier One measures further refinement to the features that comprise the measures is anticipated and with the potential 15-year window before the start of construction, the baseline condition may have changed. USACE is committed to reinitiate Section 7 consultation once the Tier Two Studies begin.

Table 4-12 Federally listed threatened or Endangered Species list provided by USFWS for the Tier One Measures

		Mammal	Birds							Reptiles					Plants
Measure	Location	West Indian Manatee *Trichechus mantus*	Eastern Black Rail *Laterallus jamaicensis jamaicensis*	Least Tern *Sterna antillarum*	Attwater's Greater Prairie-Chicken *Tympanuchus cupido attwateri*	Piping Plover *Charadrius melodus*	Piping Plover Critical Habitat Within Project Area	Red Knot *Calidris canutus rufa*	Whooping Crane *Grus americana*	Green Sea Turtle *Chelonia mydas*	Hawksbill Sea Turtle *Eretmochelys imbricata*	Kemps Ridley Sea Turtle *Lepidochelys kempii*	Leatherback Sea Turtle *Dermochelys coriacea*	Loggerhead Sea Tutle *Caretta caretta*	Texas Prairie Dawn-flower *Hymenoxys texana*
Bolivar Roads Surge Barrier	Galveston County, Texas	T	T		E	T	Yes	T		T	E	E	E	T	
Bolivar Peninsula and Galveston Island Beach and Dune	Chambers and Galveston Counties, Texas	T			E	T	Yes	T		T	E	E	E	T	
Galveston Island Ring Levee	Galveston County, Texas	T	T		E	T	No	T		T	E	E	E	T	
Clear Creek & Dickinson Bayou Surge Gates and non-structural	Chambers, Galveston, and Harris Counties, Texas	T	T	E	E	T	No	T		T	E	E	E	T	E
B-2	Brazoria County, Texas	T				T	No	T	E	E	E	E	E	T	E

Table 4-13 Federally listed threatened or Endangered Species list provided by NMFS for the Tier One Measures

		Reptiles					Fishes		Mammals			
Measure Type	Measure	Green Sea Turtle Chelonia mydas	Hawksbill Sea Turtle Eretmochelys imbricata	Kemps Ridley Sea Turtle Lepidochelys kempii	Leatherback Sea Turtle Dermochelys coriacea	Loggerhead Sea Turtle Caretta caretta	Oceanic whitetip Shark Carcharhinus longimanus	Giant Manta ray Manta birostris	Fin Whale Balaenoptera physalus	Sperm whale Physeter macrocephalus	Sei whale Balaenoptera borealis	Gulf of Mexico Brydes whale Balaenoptera edeni (GoM subspecies)
ER	B-2	T	E	E	E	T						
Coastal Storm Risk Management (CSRM)	Bolivar Roads Surge Barrier	T	E	E	E	T	T	T	E	E	E	E
	Bolivar Peninsula and Galveston Island Beach and Dune	T	E	E	E	T	T	T	E	E	E	E
	Galveston Island Ring Levee	T	E	E	E	T						
	Clear Lake & Dickinson Bayou Surge Gates	T	E	E	E	T						
	South Padre Island Beach Nourishment	T	E	E	E	T	T	T	E	E	E	E

4.4.4.3.1 Alternative A

Coastal Barrier Alternative

The proposed Coastal Barrier would consist of floodwalls, levees, navigation and environmental gate structures, and seawalls, which are expected to impact threatened and endangered species that are found around the Galveston Bay region. The impacts discussed below describe the Federally-listed species that might be impacted by the Coastal Barrier measure, in addition to benefits of the project.

During the construction phase, dredging and other marine construction activities in Galveston Bay and along the Houston Ship Channel could potentially impact sea turtles and manatees around the bay. The construction of the navigational and environmental gates across the bay could impair and prevent manatee and sea turtle migration, feeding, and reproductive behavior between the Gulf and Galveston Bay. Construction can produce underwater vibrations and noise at many different low and high frequencies, which could disrupt marine mammal communication (Peng et al., 2015). The gates would create a constriction between Galveston Bay and the Gulf, increasing traffic between construction vehicles, ships, and barges through the Houston Ship Channel and increasing the likelihood of collision with slower-moving species such as sea turtles and manatees (Department of Environmental Resources Management, 1995; NOAA, 2017k). The dredging of fill material for levees can injure or kill sea turtles, and increased turbidity can impede foraging ability of visual predators like sea turtles, piping plovers, red knots, and least terns (Greene, 2002). Precautionary measures, such as limiting dredging activity to winter, biological monitoring, and using sea turtle deflecting devices could reduce incidental take of sea turtles and manatees from construction activities (Michel et al., 2013; NMFS, 2018). The levee barrier would be placed adjacent to existing roadways, which would help avoid further habitat fragmentation on the Bolivar Peninsula and Galveston Island. Construction activity near tidal flats and sand dunes may affect the behavior of overwintering piping plovers and red knots. Construction activities on the beach and tidal areas within the critical habitat may also cause an increase in noise and light, which may disturb individuals, decrease nesting success, and impact foraging for species such as piping plovers, red knots, and sea turtles. Increased artificial lighting on the construction beachfront may potentially disorient nesting and hatching sea turtles. Sea turtles lured towards parking lots, streets, and other developed areas risk dehydration, vehicle collision, and depredation (NOAA, 2014b).

Once the project is complete, the operation of navigational gates will have to be contemplated to consider potential impacts to sea turtles and shorebirds within the area by changing the hydrology and salinity characteristics of the bay (see Sections 4.2.2.2 and 4.2.4). The gate structures may impede movement or crush manatees, marine mammals, and sea turtles travelling between the Galveston Bay and the Gulf (Department of Environmental Resources Management, 1995; NOAA, 2017k). Upon completion, the levee is expected to shield a small amount of light from the bay side of the levee. This may benefit some threatened and endangered species sensitive to light pollution. Piping plover and sand red knots could benefit from the CSRM since the project would help protect their habitats from coastal storms and RSLR. The Coastal Barrier is expected to benefit Federally listed species along the Galveston bay complex by protecting critical wetland and coastal shoreline habitat from RSLR and erosive wind and wave forces.

The current alignment of the tie-in feature on Bolivar Peninsula includes direct impacts to critical habitat for Piping plover at Bolivar Flats. Piping plover critical habitat is found within the Coastal Barrier measure (USFWS, 2017). Physical alterations to piping plover critical habitat include grubbing, levelling, and discharge of fill on loafing and foraging areas. Although there is no Federally designated rufa red knot critical habitat within the Coastal Barrier project area, red knots are commonly found on tidal flats, salt marshes, and coastal dunes during the winter months on Galveston Island and Bolivar Peninsula (USFWS, 2017). They occupy similar habitat to piping plovers and potential impacts may be similar (eBird, 2018a). Alternative A would directly impact 35 acres of designated piping plover critical habitat near Bolivar Roads on Bolivar Peninsula, Unit TX-36: Bolivar Flats during construction of the tie in structure (USFWS, 2017). Portions of critical habitat would be permanently impacted from the footprint of the combi-wall and levee that comprise the feature. Adjacent critical habitat would be temporarily impacted by earth moving activity, placement of fill material, and burial of resources.

The tie in structure that directly impacts 35 acres of critical habitat was necessary in order to avoid hundreds of acres of impact to the critical habitat if the project extended the dual-purpose beach and dune system across the critical habitat.

There are also potential indirect impacts to Piping plover critical habitat from the Bolivar Roads Surge Barrier System. Big Reef, Unit TX-35 is an accretionary zone adjacent to and north of the Galveston South Jetty and would be on the Gulf side of the Gate System. Once the gate designs are further developed, sediment transport modeling will be key to understanding how the gate structures could impact sediment transport to Big Reef. If the system impacts sediment delivery to Big Reef, several possible solutions have been preliminarily discussed and those include groin structures or breakwaters to protect Big Reef and encourage continued sediment deposition. Sediment transport modeling for the final designs will be conducted and the analysis on the impacts to sediment transport and the effects to Big Reef will be included in the Tier Two Study.

Direct and indirect impacts to coastal marsh have the potential to affect eastern black rail. Work in these areas and the potential impacts to this habitat will have to be monitored and mitigated to minimize potential impacts to the species.

4.4.4.3.2 Alternative D2

Upper Bay Barrier- Bay Rim CSRM Measure (Upper Bay Barrier)

The Upper Bay Barrier would consist of navigational and environmental gates, levee/floodwalls along the bay rim, improvements to the Texas City Hurricane Protection System, and the West Extension of the Texas City Hurricane Flood Protection System. The Upper Bay Barrier would result in the loss of 1,371 acres of developed/upland, 399 acres of emergent wetlands, and 564 of open water. The Upper Bay Barrier along the West Galveston Bay would primarily be constructed along previously developed roadways, levees, railroad ROW, and hard structure shorelines along Texas City and La Porte.

Sea turtles and manatees may be disturbed by construction activities related to the Upper Bay Barrier. Construction noise and turbidity from construction of navigational gates between Hog and Spillmans Islands can disturb individuals and limit visibility, potentially affecting foraging and migrating sea turtles and marine mammals within the Galveston Bay. It is unknown how the changes to hydrology and salinity from the environmental gates along the Houston Ship Channel would affect sea turtles within the Galveston Bay; however, it is hypothesized that a significant salinity difference between the Gulf and the bay may create a barrier to migration (Plataforma, 2008). Nesting habitat for sea turtles would not be impacted since there are no sandy beaches or suitable habitat found along the West Galveston Bay (Turtle Island Restoration Network, 2018). According to eBird (2018a), a northern aplomado falcon was sighted at the Texas City Prairie Preserve in 2017 for a few days. Construction noise and activity around the Texas City Prairie Preserve could potentially disturb aplomado falcons and other migratory birds within the area (Bottalico et al., 2015). Construction activity is also expected to disturb populations of Federally listed shorebirds such as piping plovers, rufa red knots, and least terns that have been observed foraging and loafing along the Texas City Dike, Tarpey Park, and Pine Gully Park. Construction noise and turbidity associated with the placement of fill near the bay can inhibit communication between the birds and decrease foraging rates (Bottalico et al., 2015; Greene, 2002). The effects are expected to be localized and temporary (Michel et al., 2013).

After construction, the operation of the navigational gate can potentially impede or harm migrating sea turtles attempting to traverse upstream to the San Jacinto River. There are no anticipated impacts to Federally listed birds, mollusks, fish, amphibians, cetaceans, or mammals after the completion of the Upper Bay Barrier. A greater portion of the Upper Bay Barrier is developed and would impact less wetland and beach habitat.

The Upper Bay Barrier would result in less impact to threatened and endangered species and their critical habitat when compared to the Coastal Barrier since much of the area is developed. There are no anticipated impacts to any Federally designated critical habitat for whooping cranes or piping plovers (USFWS, 2017).

4.4.4.4 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

The ER feature would include the construction of dunes that would be the same general height and shape of the natural dunes within the vicinity. Beach profile and sand composition (grain size, grain shape, and compaction, etc.) are important for sea turtle nesting preferences on nourished beaches. Piping plovers, red knots, and other shorebirds may be temporarily disturbed by construction activities during the placement of sediment material and beach shaping. Sediment composition and shell content of the fill material can also affect foraging efficiency for plovers (Greene, 2002). Disturbances to listed species are expected to be short term; the species are expected to return and recolonize beaches and dunes once construction is completed. Restored dunes and beaches are also expected to indirectly benefit threatened and endangered species by protecting coastal habitat and providing a barrier to erosive wave action and RSLR.

The ER measures are expected to have a net positive effect on threatened and endangered species. Beach nourishment, island restoration, oyster reef creation, and marsh restoration features would enhance and improve habitat for Federally listed species. Compared to the No-Action Alternative, the benefits from the ER measures would outweigh potential impacts to sea turtles.

4.4.4.5 Migratory Birds

The Migratory Bird Treaty Act (MBTA) of 1918 (as amended) extends Federal protections to migratory bird species. Among other activities, nonregulated "take" of migratory birds is prohibited under this Act in a manner similar to the ESA prohibition of "take" of threatened and endangered species. Additionally, Executive Order 13186 "Responsibilities to Federal Agencies to Protect Migratory Birds" requires Federal agencies to assess and consider potential effects of their actions on migratory bird species (including but not limited to, ducks, cranes, geese, shorebirds, hawks, and songbirds) (USFWS, 2017b).

The Galveston Bay complex provides many different habitat types such as mud flats, marshes, forested wetlands, and grasslands for migratory birds and 75 percent of the Nation's migratory waterfowl depend on these habitats at some point in their life cycle. The study area has one of the greatest concentrations of colonial water birds in the world and provides critical in transit habitat for migrating shorebirds and for most neotropical migrant forest birds of eastern North America. The region is also one of the most important waterfowl areas in North America with both wintering and migration habitat for significant numbers of continental duck and goose populations using the Central and Mississippi Flyways. The most important waterfowl habitats in the area are coastal marsh, shallow estuarine bays and lagoons, and wetlands on agricultural lands on rice prairies. Federal wildlife refuges, state parks and WMAs, and private sanctuaries are destinations for migrating birds and bird watchers. According to eBird data (2018b), more than 330 bird species have been sighted in Galveston County.

4.4.4.5.1 Alternative A

Coastal Barrier Alternative

Construction of the storm surge barrier systems at Bolivar Roads, the Clear Lake gate system, the Dickinson Bay gate system, and the Offats Bayou navigation gate (Galveston ring barrier system) can temporarily and indirectly affect migratory birds. The Galveston ring barrier system can directly harm migratory species and reduce available habitat for roosting and nesting due to clearing and grubbing vegetation prior to levee construction. When practicable, construction clearing activities should be conducted during the fall or winter to minimize impacts to nesting migratory birds (USFWS, 2017b). Activity, lighting, and noise during the construction of the levee, gates, and floodwalls can disturb, disorient, and harm migratory birds. Construction noise can mask bird calls and reduce their abilities to communicate. Construction activity near tidal flats and beach areas can displace shorebirds and gulls (Bottalico et al., 2015). Turbidity from dredging activities and sediment placement in the water column can decrease foraging rates and cause birds to relocate to adjacent habitats (Greene, 2002). Migratory birds relocating to adjacent, undisturbed habitats may be forced to compete for resources with other local wildlife. Construction contracts would include instruction to avoid impacts on migratory birds and their nests from construction-related activities. The completed levees and navigational gates are not expected to directly impact migratory birds, the height of the levees would not interfere with the flight pattern of birds.

The changes to the hydrology and salinity of Galveston Bay when the storm surge barrier system is closed may indirectly affect fisheries and the foraging habits of shorebirds (see Section 5.3.2). Migratory birds may benefit from the storm surge barrier system due to the system providing long-term habitat protection from coastal storms. The Bolivar and West Galveston beach and dune system would maintain historical coastal dune habitat characteristics and provide nesting habitat for migratory plovers and sandpipers (TPWD, 2018). This would also be the case for the South Padre Island Beach Nourishment and Sediment Management CSRM measures.

Overall, the effects of the storm surge barrier system on migratory birds are expected to be temporary and limited to migratory bird species near the Galveston Bay Storm Surge Barrier System.

4.4.4.5.2 Alternative D2

Upper Bay Barrier- Bay Rim CSRM Measure (Upper Bay Barrier)

The section of levees and floodwalls constructed near along the East Galveston Bay Rim of the Upper Bay Barrier is not likely to affect many migratory bird species. The area is largely developed with residential, commercial, and industrial property and is not likely to provide suitable habitat for migratory shorebirds, warblers, and other species. Revetments and bulkheads currently along the bay rim are unlikely to provide suitable habitat for many migratory birds. Navigational gates across Dickinson Bayou and the Houston Ship Channel to Spillman Island could change the hydrology and fisheries communities in the Galveston Bay and indirectly affect migratory birds (see Sections 5.2.4 and 5.3.2). Most of the impacts to migratory birds would occur along the West Extension of the Texas City Hurricane Flood Protection Plan. Most of the Texas City West Extension protection measures would be located close to existing roadway, railroads, and levee structures. These areas have been previously fragmented. Construction activity and noise could potentially interfere with migratory birds (Dufour, 1980; Bottalico et al., 2015). Grubbing and clearing vegetation along the levee footprint would remove habitat used by migratory birds for nesting and roosting. Construction contractor should use careful consideration and planning to avoid incidental take of any migratory bird species (USFWS, 2017b).

The Upper Bay Barrier would have less of an impact on wetland and upland habitats than the Coastal Barrier. After the construction of the Upper Bay Barrier is completed, migratory birds would continue to traverse across the levee barrier. The levee barrier would be routinely maintained: mowed and trees prevented from growing on the structure. This would reduce the amount of habitat available for bird species that prefer trees. Migratory shorebirds and grassland birds would be unaffected from routine maintenance of the levee barrier. No long-term impacts are anticipated from the Upper Bay Barrier.

4.4.4.5.3 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Shorebirds such as plovers, sandpipers, and terns use beach and dunes as breeding grounds or overwintering habitat for nesting, foraging, and roosting habitat (TPWD, 2018). Noise associated with construction can disturb waterfowl and other migratory birds (Bottalico at al., 2015). Sand dunes are also natural barriers for wave and wind action that could potentially erode the shoreline and fragile habitats (United Nations Environment Programme, 2018). Disturbances to wildlife are expected to be a short-term and wildlife species are expected to return and recolonize beaches and dunes once construction is completed. Benthic macroinvertebrates provide important forage for shorebirds. Dredging impacts to benthic macroinvertebrates can be minimized by using similar grain-sized fill materials and avoiding the placement of fill during peak periods of larval recruitment (Wilber et al., 2010). No significant impacts to wildlife resources are anticipated from dune/beach restoration.

4.4.4.6 Essential Fish Habitat

Table 2-27 lists the species that NMFS and the GMFMC identify in the study area as EFH. The categories of EFH that occur within the study area include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, seagrasses, and mangroves. Additionally, portions of the study area are in marine waters and include the marine water column, unconsolidated marine water bottoms, and natural structural features. EFH and all impacts associated with the project are described in detail in Appendix C-5. The following sections provide a brief summary of the impacts described in EFH Assessment (see Appendix C-5).

4.4.4.6.1 Alternative A

Coastal Barrier Alternative

Impacts from the Storm Surge Barrier System on Federally managed species would be the same as those described in section 5.2.2.1 and Section 4.2.1 of Appendix C-5.

The reduction of the cross-section area at Bolivar Roads could impede the migrations and movements of various life stages of Fish into and out of the Galveston Bay complex. Tidal amplitude reduction mean less of the marsh would be flooded, resulting in a loss of marsh surface area available for aquatic organisms to use as nursery habitat that could impact Federally managed species and their prey. Turbidity during construction would cause temporary disturbances but is generally localized and short lived. No impacts to the slight decrease in average salinity is expected. Benthic organisms would be buried or removed during construction of the barrier system and for dredging the bypass channel but would be expected to recover over time.

However, oyster surveys will be conducted during PED in areas that may have oysters, such as at Offatt's Bayou gate system, Dickinson Bayou gate system, and the Tie-ins on Bolivar near Bolivar Flats. Water column turbidity increases that are expected during construction could temporarily affect survival or growth of oysters nearby. Lower salinity regime due to the reduced flow of water into and out of the bay and longer retention times could indirectly affect oyster reef habitat. No long-term impacts to oyster reefs in the Galveston Bay complex are expected

4.4.4.6.2 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

Impacts to Federally managed species as a result of construction of the Upper Bay Barrier would be similar to those described for Alternative A, but on a smaller scale.

Direct impacts associated with constructing the Upper Bay Barrier would be similar to those described for the Coastal Barrier (see Section 5.2.2.1), with the exception of the smaller open water impacts. The Upper Bay Barrier has much less open water impacts compared to the Coastal Barrier. Minimal indirect impacts are anticipated with this alternative. Temporary disturbances to water column turbidity and construction impacts would occur but expected to return to normal once construction is completed. Although no modeling was conducted for the Upper Bay Barrier similar effects to salinity and velocities caused by the Coastal Barrier may be expected. Aquatic organism exchange between upper Galveston Bay and Tabbs/Upper San Jacinto/Burnet bays and Buffalo Bayou could be impeded with construction of Upper Bay Barrier. However, due to this measure being located in the upper portions of Galveston Bay impacts would not be as great as those seen with the Coastal Barrier which reduces flow to the entire bay complex. A total of 0.03 acre of oyster reef falls in the direct footprint of the Upper Bay Barrier and would be lost as a result of this measure and impacts would be the same as those described for Alternative A.

4.4.4.6.3 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Impacts to Federally managed species would be the same as those described in Section 5.2.2.1 and Section 4.2 Appendix C-5. Bay bottom habitat and open bay habitat would be permanently lost, temporary disturbances to water column turbidity would occur, but no long-term impacts to Federally managed species are anticipated. Although open bay and bay bottom habitat would be lost as a result of constructing ER features, the habitats created would benefit Federally managed species by attracting fish and invertebrate communities, and structures would protect valuable EFH habitats such as marsh, SAV, and oyster reef habitat from eroding, in turn protecting valuable nursery grounds for the many fish and shellfish species that live within these estuaries. The overall benefits from construction of the ER measures outweigh any short-term construction impacts and work together in the lines of defense strategy to help protect the Texas coast.

4.4.4.7 Marine Mammals

West Indian Manatee. While the number of manatees migrating into Texas is small, construction activities or the presence of a physical barrier may discourage migrant or stray individuals from taking refuge in Galveston Bay due to similar disturbance concerns outlined below for bottlenose dolphin.

Bottlenose Dolphin. Direct threats to bottlenose dolphins from construction and operational activities may include damage caused by noise exposure (permanent or temporary threshold shifts) and collisions with increased vessel traffic and equipment. Additional consequences may initially appear less severe but occur more frequently and are often more important over the long term on a population level. These may include temporary or permanent changes to habitat availability, behavioral changes affecting energy budgets, changes to physical properties of waters (i.e., decreased salinity), and indirect temporary (e.g., construction) or long-term loss of aquatic habitat, and indirect effects on aquatic prey organisms.

Potential construction and operational impacts vary based on geographical project location, seasonality, and activity type. Impacts of highest concern to marine mammals from construction and operational project activities are categorized below.

Noise. Sound plays a critical role in the life of most marine mammals, and the impacts of noise are of increasing concern in the aquatic environment. Potential impacts on bottlenose dolphin populations utilizing Texas waters, include 1) the physiological effects of high-intensity sound exposure; 2) masking of biologically important sounds; and 3) behavioral disruptions that may result in a decline in vital rates.

High-intensity sound exposure from pile driving can cause direct physical injury to marine mammals in the form of permanent or temporary threshold shifts (Clark et al., 2009; Jensen et al., 2009; Nowacek et al., 2007). Dolphins rely heavily on sound for communication, navigation, predator avoidance, and foraging, using both active echolocation and passive listening for detection of prey (Allen et al., 2001; Nowacek et al., 2007; Tyack, 2008). Therefore, increased noise pollution in an important habitat could cause disruption to dolphin activities.

Noise reduction measures are necessary where unmitigated sound levels exceed desired thresholds. The effectiveness of noise mitigation measures are highly site specific and must be chosen carefully and validated based on real time conditions. Mitigation measures that may be used, but are not limited to, include bubble curtains, double-walled piles, Hydro Sound Dampers, noise mitigation screens, cofferdams, “soft-start” operational procedures, and dolphin exclusion zones (Elmer and Savery, 2014; Reinhall et al., 2015; Stokes et al., 2010; Würsig, Green, et al., 2000).

Dredging. Noise, vessel activity, sediment suspension, and habitat modification are all concerns surrounding dredging activities with the potential to cause negative consequences to dolphin populations. Pirotta et al. (2013) found that higher intensities of dredging, even in an area of high baseline industrial activity, caused bottlenose dolphins to spend less time in the important foraging sites. While few studies have focused on the effects of dredging on marine mammals, Todd et al. (2015) provide a review of available data and conclude that effects are likely to vary by location and equipment type.

Increased Vessel Traffic. Vessel traffic is expected to increase temporarily during construction due to vessel-based construction activities. Dolphins are known to change their behavior in response to vessel traffic (Bejder et al., 2006; Nowacek et al., 2001; Piwetz and Würsig, 2015; Allen and Read, 2000). While there are many factors that play into how vessels may affect behavior, a common trend implies that smaller vessels quickly changing speed and direction have more of an immediate behavioral effect than larger vessels on a steady path such as cargo ships. Short-term responses to vessels can range from attraction (bow riding) to changes in behavioral state, dive patterns, and orientation. Reactions to vessel traffic appear to be highly related to the environment and dolphin behavior, necessitating site-specific observations to validate assumptions made from other studies.

Physical Barrier. The operational presence of the surge barrier gates have the potential to act as a hindrance to dolphin movements. Operational closing of the gates for emergency hurricane preparations would entirely close off the pass. These closures have a potential for injury, noise disturbance, separation of social groups, effects on prey items, and disruption of foraging.

Prey Source. Dredging, changes in tidal prism, water quality, and the effects of physical barriers can all impact recruitment through passes by fish and shellfish, which are important prey sources for Texas bottlenose dolphin bay, sound, and estuary stocks. These factors have the potential to impact the availability of prey sources for Texas bottlenose dolphin BSE stocks

4.4.4.8 Alternative A

Coastal Barrier Alternative

The location and size of the Bolivar Roads Surge Barrier makes it the most likely structure in this alternative to impact known bottlenose dolphin populations. NOAA Fisheries identified three bottlenose dolphin stocks that could be affected by the project (Western GoM coastal, Galveston Bay/East Bay/ Trinity Bay, and West Bay). NOAA Fisheries identified several potential construction related stressors including noise (from pile driving, vessels, and dredging), entrapment (in cofferdams or dredge booms), or passage restriction which could be blocked by construction equipment. NOAA Fisheries also identified several potential post-construction related stressors including perceived physical barriers (could restrict movements into and out of the Bay) changes to water quality, salinities, and water velocities.

A recent study (Fazioli *et al.* 2018) described a number of data gaps for the dolphins observed in the Bolivar Roads area. These data gaps included abundance, habitat use, baseline environmental conditions (noise, salinity, and water quality), and cumulative stressors. In the absence of data, NOAA Fisheries errs on the conservative side of the species and stock.

The PDT has worked with the interagency agency team to adopt design changes that would reduce the adverse environmental impacts from the Bolivar Roads Surge Barrier. Reduction of the permanent constriction of the structure from 27.5% to less than 10% has reduced the anticipated effects on salinity, water quality, and velocities. The reduction in constriction was partially achieved by increasing the size of some of the gate openings (100-foot-wide vertical lift gates to 300-foot-wide vertical lift gates) which may reduce the risk of perceived barriers. Best management practices including bubble screens and timeframe requirements on pile driving have been incorporated in the plan. The specific construction activities will be coordinated during the Tier Two environmental studies.

4.4.4.9 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The Bay Rim Alternative includes construction of surge barrier gates at inlets to Offatts Bayou, Clear Creek, Dickinson Bayou, and Tabbs Bay (Houston Ship Channel and San Jacinto River). The importance of these habitats to dolphins is not currently known, but they are likely to utilize them on occasion and impacts to travel in and out of these areas should be evaluated.

4.4.4.10 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

ER measure impacts to marine mammals are expected to vary based on geographical location, seasonality, and activity type. ER measures have direct benefits to marine mammals by providing improved water quality and enhanced production of prey organisms such as finfish, squid, and shrimp.

4.4.5 Hazardous Wildlife Attractants on or Near Airports

Due to the increasing concern about aircraft-wildlife strikes, the FAA has implemented standards, practices, and recommendations for holders of Airport Operating Certificates issued under Title 14, CFR Part 139, Certification of Airports, Subpart D (Part 139), to comply with the wildlife hazard management requirements of Part 139. Airports that have received Federal grant-in-aid assistance must use these standards.

When considering proposed dredged spoil, BU features, and mitigation areas, developers must take into account whether the proposed action will increase wildlife hazards. The FAA recommends minimum separation criteria for land use practices that attract hazardous wildlife to the vicinity of airports. These criteria include land uses that cause movement of hazardous wildlife onto, into, or across the airport's approach or departure airspace or air operations area (AOA).

These separation criteria include:

- Perimeter A: For airports serving piston-powered aircraft, hazardous wildlife attractants must be 5,000 feet from the nearest AOA (includes one airport within the study area);
- Perimeter B: For airports serving turbine-powered aircraft, hazardous wildlife attractants must be 10,000 feet from the nearest AOA (includes two airports within the study area); and
- Perimeter C: 5-mile range to protect approach, departure, and circling airspace (includes four airports within the study area).

Table 4-14 lists the public use airports that fall within the study area that must comply with these standards Proposed land uses for the Preferred Alternative were evaluated to determine if they could increase wildlife aviation hazards in the study area. The airports in the study area include Baytown, La Porte Municipal, Scholes International, Mustang Beach, McCampbell-Porter, and the Charles R. Johnson (**Figures 4-11** through **4-14**). All six airports sell Jet-A fuel and it was assumed that a separation distance of 10,000 feet for any of the hazardous wildlife attractants would apply in addition to the 5-mile range to protect approach, departure, and circling airspace. Certain land use practices, such as waste disposal facilities, water management facilities, golf courses, agricultural cropland, and dredged material placement areas can act as attractants to wildlife that pose a strike hazard. Some natural areas, such as wetlands, may attract wildlife associated with aircraft strikes.

Figure 4-11. Hazardous Wildlife Attractants on or Near Airports – LaPorte Municipal Airport and Baytown Airport

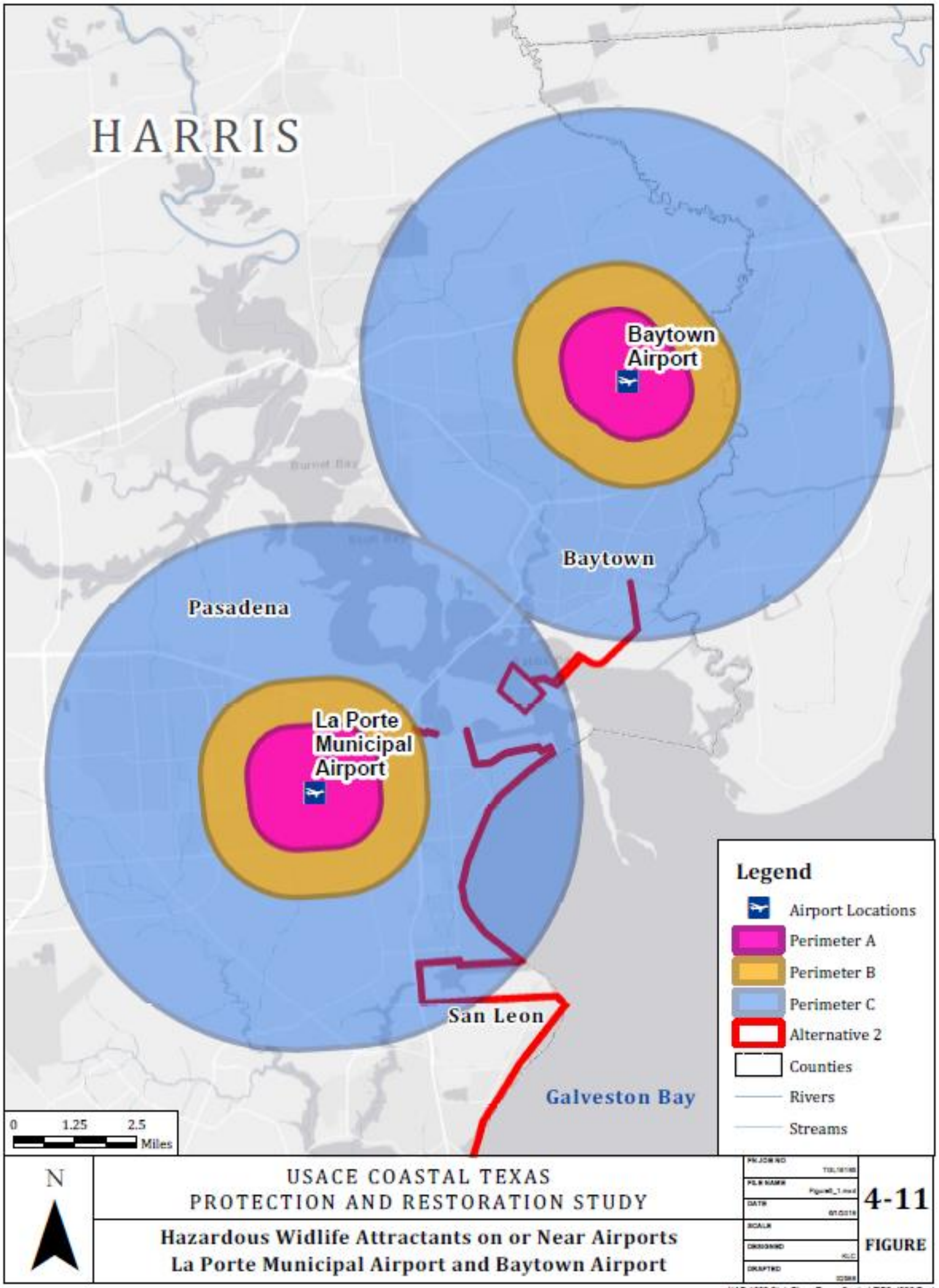

Figure 4-12. Hazardous Wildlife Attractants on or Near Airports – Scholes International Airport at Galveston

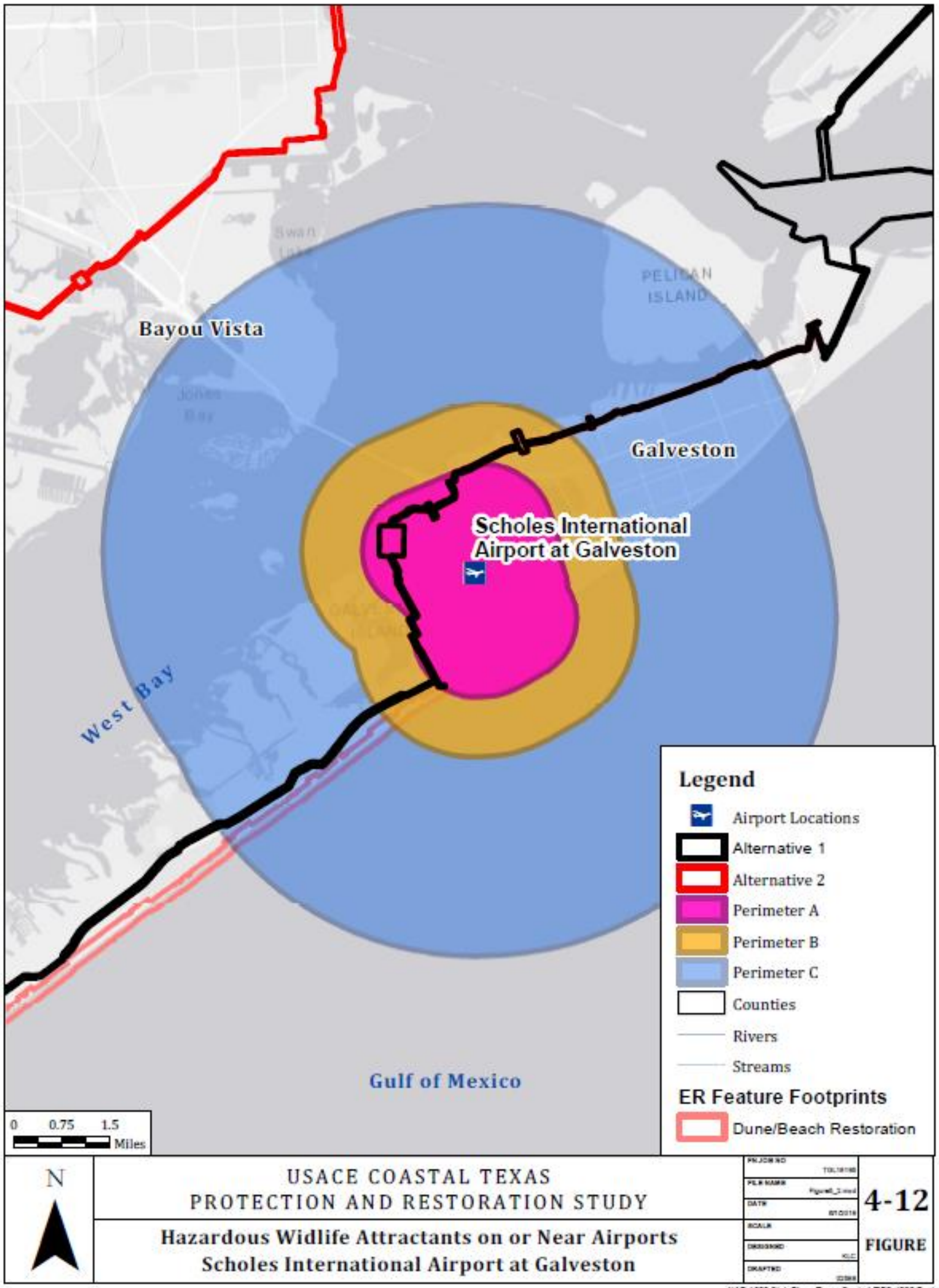

Figure 4-13. Hazardous Wildlife Attractants on or Near Airports – McCampbell-Porter Airport and Mustang Beach Airport

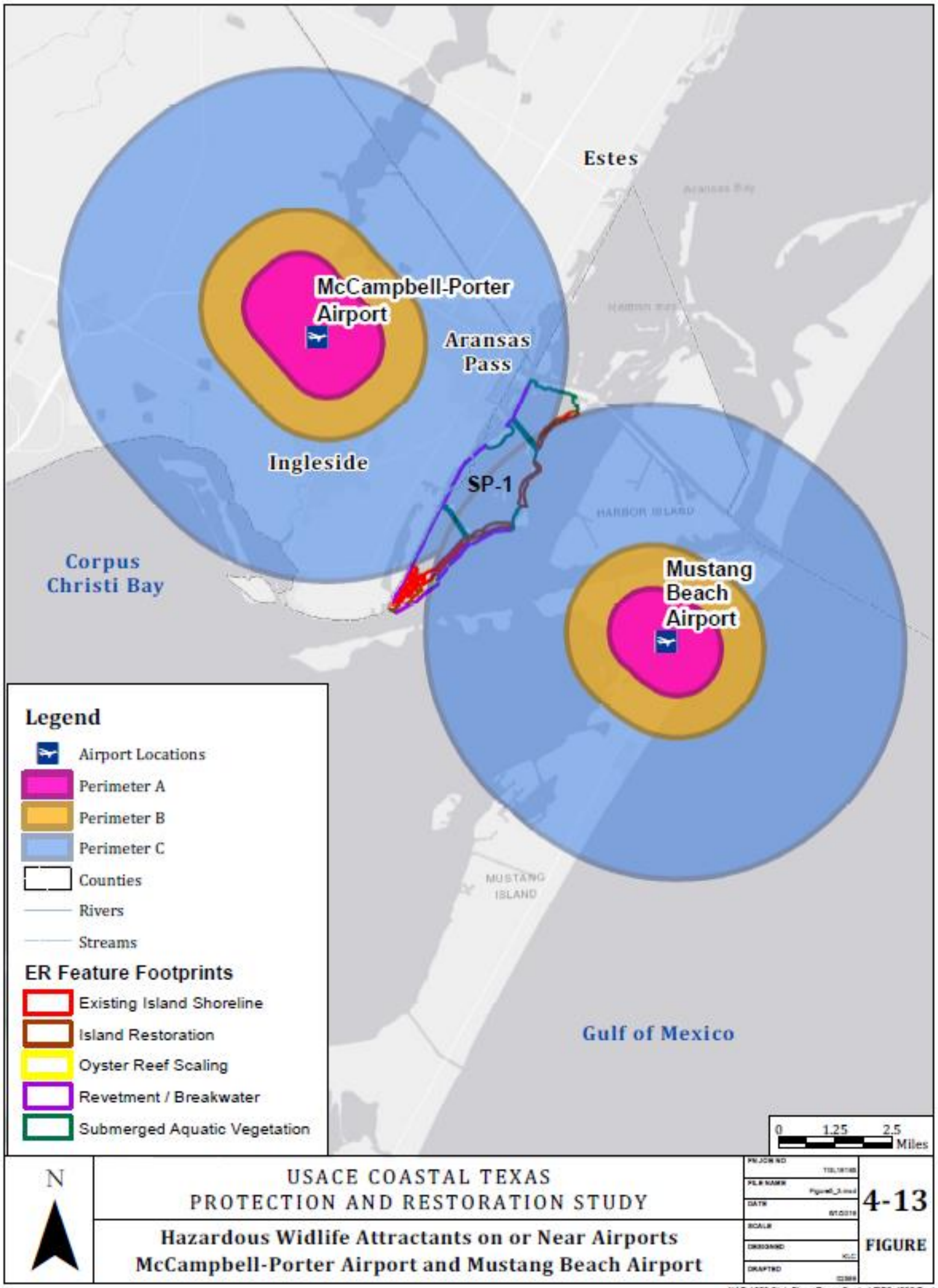

Figure 4-14. Hazardous Wildlife Attractants on or Near Airports – Charles R. Johnson Airport

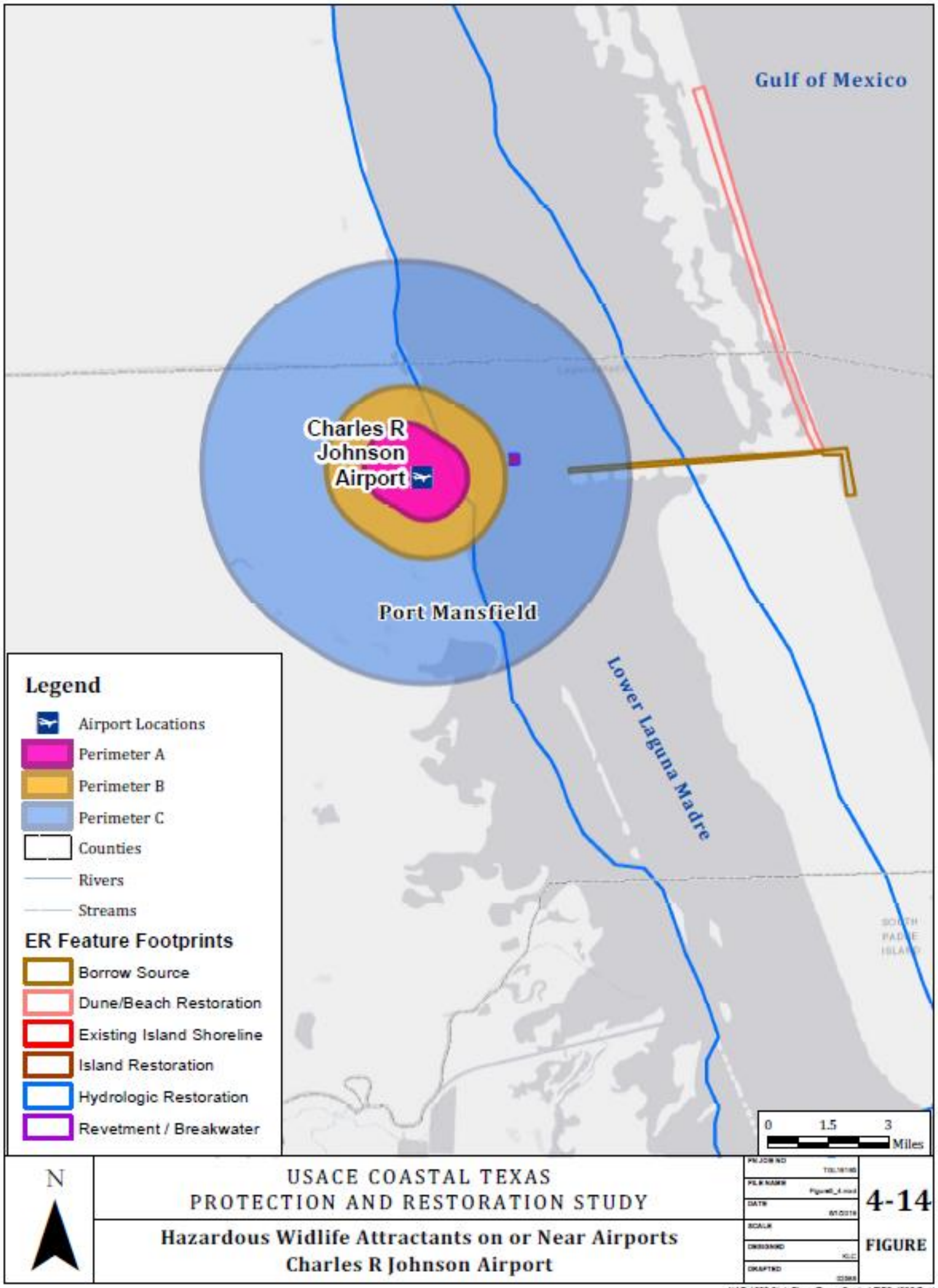

Table 4-14 Public Use Airports in the Study Area

Name	Site Number	City	County	Perimeter	Nearby Action	Distance (miles)
Baytown Airport	23412.1*A	Baytown	Harris	C	Alt 2	3.9
La Porte Municipal	24190.*A	La Porte	Harris	C	Alt 2	1.9
Scholes International	23915.*A	Galveston	Galveston	A, B	Alt 1&2, ER Gav beach/dune	0.9, 1.1
Mustang Beach	24528.2*A	Port Aransas	Nueces	C	ER Redfish Bay	3.8
McCampbell-Porter	24096.62*A	Ingleside	San Patricio	C	ER Redfish Bay	3.9
Charles R. Johnson	24543.*A	Port Mansfield	Willacy	B, C	ER Port Mansfield, Island Rookery	0.7, 2.1

Project features of alternatives 1 and 2 and the ER measures that could serve as attractants are bird islands, placement areas, and beneficial use marsh restoration areas. There are several project features that could serve as attractants within the separation perimeters of nearby airports. The Redfish Bay Protection and Enhancement (SP-1) ER measure is located within the 10,000-foot and 5-mile perimeter of Mustang Beach and McCampbell-Porter airports. In addition, the Port Mansfield bird island restoration (W-3), which goal is to improve bird nesting, is located approximately 2.1 miles from Charles R. Johnson Airport, which is between the 10,000-foot and 5-mile perimeters. This project would likely increase the number and species of birds associated with aircraft strikes. Project features for alternatives 1 and 2 and the Galveston beach/dune restoration (G-5) ER measure are within the separation buffers of Baytown, Scholes International, and La Porte Municipal airports; however, the infrastructure or action is not expected to serve as an attractant for wildlife species. Further analysis is needed once we learn about the locations of potential placement areas associated with the alternatives.

4.5 CULTURAL RESOURCES

There are over 5,200 recorded prehistoric and historic cultural resources located within the study area. A preliminary assessment of the cultural resources within a broad regional study area over 18,000 square miles of the Texas Coast was conducted using a desktop review of the databases maintained by the Texas Historical Commission and the Texas Archeological Research Laboratory for terrestrial and marine cultural resources as well as the shipwreck and obstruction databases of the NOAA and the BOEM. This search was then narrowed to an area within 1,000 feet of each CSRM measure (Coastal Barrier and Upper Bay Barrier; including the South Padre Island CSRM) and within the direct footprint of each ER measure, and is considered the project area for the cultural resources discussion below. This assessment identified 245 previously recorded cultural resources including 75 archeological sites, 10 cemeteries, and approximately 140 possible submerged archeological resources. There are also 20 recorded National Register properties within the project area. These resources are summarized by alternative or measure in **Tables 56** to **58**.

Table 4-15 Archeological Resources within the CSRM Measures

Bolivar Roads Gate System	41GV119, 41GV151, 41GV165, 41GV178
Bolivar and West Galveston Beach and Dune System	41GV73, 41GV74
Galveston Ring Barrier System	41GV5, 41GV48, 41GV66, 41GV69, 41GV70, 41GV71, 41GV95, 41GV112, 41GV119, 41GV133, 41GV140, 41GV148, 41GV162, 41GV163, 41GV164, 41GV167, 41GV169, 41GV170, 41GV174, 41GV175, 41GV176
Gates at Clear Creek and Dickinson	41GV18, 41GV20, 41GV75, 41GV83, 41GV84, 41GV85, 41GV86, 41HR91
West Galveston Bay Non-structural	41GV2, 41GV18, 41GV87, 41GV141, 41HR74, 41HR91, 41HR418, 41HR420, 41HR421, 41HR422, 41HR831, 41HR832
South Padre Island Beach Nourishment and Sediment Management	None
Ecosystem Restoration	41BO79, 41BO85, 41BO86, 41BO135, 41BO170, 41BO176, 41BO199, 41BO205, 41CH354, 41CH355, 41CH360, 41CH362, 41CH363, 41CL14, 41CL40, 41CL41, 41CL53, 41CL54, 41GV1, 41GV6, 41GV128, 41GV172, 41KN11, 41MG82, 41MG111, 41NU210, 41NU290, 41SP64, 41SP62, 41WY23
Ecological Mitigation	41GV93

Table 4-16 NRHP Properties within the CSRM Measures

Bolivar Roads Gate System	USS *Stewart*, USS *Cavalla*, Fort Travis
Bolivar and West Galveston Beach and Dune System	None
Galveston Ring Barrier System	The Strand Historic District (NHL), *Elissa* (NHL), Denver Court Historic District, Galveston Seawall, Silk Stocking Residential Historic District, Galvez Hotel, Ashbel Smith Building, Marschner Building, Truehart-Alliance Building, Falstaff Brewery, Galveston Causeway, House at 2528 Post Office Street
Gates at Clear Creek and Dickinson	None
West Galveston Bay Non-structural	Walker House, Sylvan Beach Pavilion, S. Ross Sterling House, Morgan's Point Historic District
South Padre Island Beach Nourishment and Sediment Management	None
Ecosystem Restoration	La Salle Monument
Ecological Mitigation	None

Table 4-17 Cemeteries within the CSRM Measures

Bolivar Roads Gate System	None
Bolivar and West Galveston Beach and Dune System	None
Galveston Ring Barrier System	Rosewood Cemetery, Lakeview Cemetery
Gates at Clear Creek and Dickinson	None

West Galveston Bay Non-structural	Beasley Cemetery, Cedarhurst Cemetery, La Porte Cemetery, Morgan’s Point Cemetery, San Leon Cemetery, Seureau-Kellett Cemetery, Twilight Cemetery
South Padre Island Beach Nourishment and Sediment Management	None
Ecosystem Restoration	Ducroz Cemetery (41BO170)
Ecological Mitigation	None

4.5.1 No action alternative.

There are 250 previously recorded cultural resources located within 1,000 feet of the CSRM Alternatives and the eight Ecosystem Restoration Measures. The formation processes that currently affect these sites will continue into a future without the project. Submerged cultural resources could be at risk from future dredging activities, shifting bars, and wave damage for shallow sites. Submerged resources are also at risk from high energy storms that can dislodge wrecks from the seafloor or impact wrecks on beaches or in shallow water. Upland historic and prehistoric sites will continue to be at risk from shoreline erosion and commercial, industrial, and residential development. Shoreline sites are also at risk from sea level rise and storm surge. These formation processes may result in partial or total loss of historic properties

4.5.2 Alternative A

Coastal Barrier Alternative

The primary consideration concerning cultural resources is the threat to archeological and historic sites from construction of CSRM and ER features and the associated staging and borrow areas. Additionally, there is a potential for direct impacts to submerged resources from dredging, the erosion of sites due to landscape modification, and visual impacts to historic buildings, structures or districts from above ground construction. The upland areas along Galveston Island and the Bolivar Peninsula, outside of the city of Galveston, as well as upland areas at South Padre Island, that have not been developed have a moderate to high probability for encountering intact prehistoric and historic archeological sites. Impacts from earth moving, dune/floodwall construction, and staging areas have a potential to impact historic properties in these upland areas. The material used to construct dunes will be dredged from offshore in the Gulf of Mexico, which poses a risk to submerged archeological resources. Within the city of Galveston, the construction of the ring levee and improvements to the Galveston seawall have a potential to impact both the physical aspects of adjacent historic properties and the historic setting, or view shed, of historic buildings, structures, and districts. Additionally, there is a moderate to high probability for encountering historic archeological sites within the city of Galveston.

The western rim of Galveston Bay has seen extensive development for residential, industrial, and commercial use. The potential for encountering intact prehistoric archeological sites is low to moderate. However, there is a moderate to high probability for encountering historic age buildings, structures, and archeological sites. Finally, the entrance to Galveston Bay at Bolivar Roads and the entire bay system have been used extensively throughout the 19th and 20th Centuries for navigation. The construction of the storm surge barrier, including flow control structures and temporary bypass channels, across submerged lands at Bolivar Roads and portions of Galveston Bay have a moderate to high probability to impact submerged archeological resources. Submerged resources are also likely to be encountered at offshore dredge locations.

4.5.3 Bolivar Roads Gate System

There have been 25 previous cultural resources investigations conducted between 1979 and 2012 within 1,000 feet of the proposed footprint for this feature. Only three of these investigations were terrestrial surveys and the remaining 22 investigations were marine investigations. There are four previously recorded archeological sites in the project area that have a potential to be directly affected by the project, 41GV119 (Fort San Jacinto), 41GV151 (USS Westfield), 41GV165 (unknown shipwreck), and 41GV178 (USACE hopper dredge Galveston). Fort Travis, on the Bolivar Peninsula is also within 1,000 feet of the project and is listed on the NRHP. There is a potential for construction of the navigation gates and tie-in structures to have an indirect impact on Fort Travis. Two more NRHP properties, museum ships USS Stewart and USS Cavalla, are located within 1,000 feet of proposed dredging activities in the Galveston Harbor Channel and will not be impacted. Additionally, the Texas Archeological Sites Atlas lists approximately 40 shipwrecks within the project area and previous research has indicated that over 100 ships may have wrecked in this area (Arnold 1987; Borgens et al. 2007; Borgens et al. 2008; Gearhart et al. 2006; Hoyt 1992 and 1993; Hoyt et al. 1998; Miller et al. 2012).

Due to the dynamic nature of the seafloor at Bolivar Roads, the USACE recommends an intensive marine archeological investigation within the areas of this feature's direct impact to identify any historic properties. The USACE also recommends a cultural resources evaluation of direct and indirect impacts to Fort San Jacinto (41GV119) and indirect impacts to Fort Travis. Finally, the USACE recommends a cultural resources investigation for all terrestrial portions impacted by this proposed feature.

4.5.4 Bolivar and West Galveston Beach and Dune System

There have been 11 previous cultural resources investigations across this feature, three on West Galveston Island and eight on the Bolivar Peninsula. As a result, only two cultural resources, archeological sites 41GV73 and 74, have been identified. Both of these sites are prehistoric sites with ceramics, lithics, and shell eroding out of dunes on the Bolivar Peninsula. Neither site has been evaluated for eligibility for inclusion in the NRHP. There are no cultural resources within 1000 feet of the West Galveston Island Dune feature. The previous investigations that intersect with these proposed features are not a sufficient sample of the proposed area of impact. Therefore, the USACE recommends a cultural resources investigation for these areas.

4.5.5 Galveston Ring Barrier System

There have been 13 previous cultural resources investigations conducted within 1,000 feet of the Galveston Ring Barrier and 34 previous investigations within the area designated for non-structural measures. As a result, seven archeological sites have been identified within the study area for the Galveston Ring Barrier and fourteen archeological sites have been identified within the West Galveston Island Non-Structural feature. Two National Historic Landmarks, The Strand Historic District and Elissa, are also located within the study area as well as ten NRHP properties (Denver Court Historic District, Galveston Seawall, Silk Stocking Residential Historic District, Galvez Hotel, Ashbel Smith Building, Marchscner Building, Truehart-Alliance Building, Falstaff Brewery, Galveston Causeway, and the House at 2528 Post Office Street). Additionally, there are two cemeteries, Rosewood and Lakeview Cemeteries, within the study area.

There is a potential for direct impacts to archeological sites within the proposed project area. Additionally, there is a potential for indirect impacts to historic buildings or structures, including the two NHLs and ten NRHP listed properties. Except for the Galveston Seawall, there are no proposed direct impacts to any of these historic properties. Proposed impacts to the Galveston Seawall include elevating the feature with a floodwall within the existing 200-foot-wide structure. Due to the potential for impacts to historic properties, the USACE recommends and intensive cultural resources investigation of the entire feature area to include archeological investigations in all areas within the feature that may contain intact archeological deposits, an evaluation of indirect impacts to historic buildings and structures, and an evaluation of direct and indirect impacts to the Galveston Seawall.

4.5.6 Gates at Clear Lake and Dickinson

There have been five previous cultural resources investigations within the feature at Clear Lake and three previous investigations within the feature at Dickinson Bayou. All these projects have been for terrestrial archeology. There are four archeological sites within 1,000 feet of the gates at Clear Lake, 41GV18, 20, 75, and 41HR91. Four sites are also located within 1,000 feet of the gates at Dickinson Bay, 41GV83, 84, 85, and 86. All of these sites are poorly defined prehistoric sites that have not been evaluated for NRHP eligibility. There are also 17 submerged anomalies within the project area, but no identified shipwrecks. Based on the potential for impacts to historic properties, the USACE recommends both terrestrial and marine cultural resources investigations within the proposed feature area.

4.5.7 West Galveston Bay Non Structural

This expansive area has had 36 previous cultural resources investigations. As a result of these investigations, 12 archeological sites, four NRHP properties, and seven cemeteries have been identified within the project area. Since this area is intended for focused non-structural measures rather than impacts across the whole mapped feature, any direct or indirect impacts will be limited to affected areas. The USACE recommends cultural resources investigations for any areas that may be impacted either directly or indirectly in areas that have a potential to affect historic properties.

4.5.8 Cultural Resources Mitigation

The mitigation of historic properties may be necessary following an evaluation of impacts to determine if any historic properties will be indirectly impacted. Any unevaluated archeological sites (marine or terrestrial) within the study area will need to be delineated as to their horizontal and vertical extent and evaluated for their eligibility for inclusion in the NRHP. Cemeteries within the study may be directly or indirectly impacted and will need to be delineated and evaluated. There is also the potential for identifying cultural resources during survey investigations of high probability areas. Based on the current level of data, the mitigation of impacted historic properties might involve the construction of measures to reduce impacts to the setting of historic buildings, structures, or districts as well as Historic American Building Survey/Historic American Engineering Record (HABS/HAER) documentation of historic properties. Archeological historic properties would require data recovery excavations or avoidance and cemeteries would need disinterment and interment of burials to a new location. The relocation of burials from impacted cemeteries might also involve purchasing land if other arrangements cannot be made.

4.6 SOCIOECONOMICS

4.6.1 Alternative A

Coastal Barrier Alternative

- It is anticipated that local building codes would be in place, requiring the elevation of future construction in the area to address impacts from RSLR. The Coastal Barrier Alternative would also include nonstructural measures along the westside of Galveston Bay to address residual damages from wind-driven bay surges. Raising structure elevation is an approach presently employed and may be addressed further in future planning and design phases. The ability of lower income groups to participate in these programs could be impacted by out-of-pocket expenses, including temporary relocation costs during structure elevation and any additional costs possibly required to meet the eligibility criteria. This could potentially offset the risk reduction in overall social vulnerability in lower income communities. As nonstructural measures are further developed in future planning and design phases, additional considerations related to community cohesion and environmental justice concerns along the west side of the Galveston Bay will be reviewed.

- It is not expected that the CSRM measures directly impact public facilities or services; however, public facilities could have temporarily interrupted services until the project is completed. Indirect impacts would include the reduced risk of damage from hurricane storm surge for public facilities and services.
- There would be minor, temporary transportation impacts resulting from increased vehicular congestion along roads, highways, and streets during construction. There would also be a degradation of local roads and highways resulting from transporting construction materials. Indirect impacts would include a lower risk of storm-related damages to the transportation infrastructure protected by the proposed barrier, South Padre Island CSRM, and ER dune/beach nourishment.
- The Ecosystem Restoration measures would reduce the adverse impacts to socioeconomic resources that are resulting from continued land loss and habitat fragmentation and degradation. The proposed action would increase marsh-related leisure activities and recreational and commercial fishing opportunities, resulting in positive, regional economic impact and improved sustainability.

4.6.1.1 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

- The socioeconomic resource impacts associated with the South Padre Island CSRM and ER measures would be the same as the Coastal Barrier Alternative. However, the location of the Bay Rim would have socioeconomic impacts in the upper coast region.
- There is potential for induced flooding in the communities of Baytown and Santa Fe. Rural areas on the east side of Galveston Bay and structures along the barriers (West Galveston Island and Bolivar Peninsula) would still receive damages from hurricane surges. Overtopping of the levee by storm surge during extreme events would immediately inundate vulnerable populated areas and key emergency service routes. This risk is a key concern for communities such as La Porte, Santa Fe, and La Marque, where the Social Vulnerability Index is high and includes a large number of households with low-income, elderly, or minority populations.
- The Bay Rim Alternative leaves many of the region’s critical roadways at risk. The alignment near the bay rim would have direct impacts to the area’s transportation infrastructure. Facilities along the bay rim since roadway and railway gates would have to be built to maintain water access. The bay rim construction would increase vehicular congestion along roads, highways, and streets during construction while also degrading transportation infrastructure due to the transport of construction materials.

4.7 NAVIGATION

4.7.1 Commercial and Waterborne Commerce

4.7.1.1 Alternative A

Coastal Barrier Alternative

The Coastal Barrier alignment would maintain the existing geomorphic features with the Bolivar Peninsula and West Galveston Beach and Dune System, which would allow for continued protection of the GIWW against storm-induced wave and surge effects. The Coastal Barrier is further enhanced with improvements to the Galveston seawall and navigation and environmental gates at the Bolivar Roads to prevent storm surge from entering Galveston Bay. Additional flow control structures of the Coastal Barrier measure are proposed for Offatts Bayou, Dickinson Bayou, and Clear Lake.

The Bolivar Road Gate System would result in a permanent loss of 128.5 acres of open water and bay bottom habitat (Table 4-3). This measure includes two 650-foot-wide sector gates each with a 60-foot deep sill and two 125-foot-wide sector gates with 40-foot sill depths. Additional gates in the system include eight Shallow Water Vertical Lift Gates (300-foot-wide opening; 20-foot-deep sill), seven Deep Water Vertical Lift Gates (300-foot-wide opening; 40-foot-deep sill), 16 monolith gates (16-foot-wide opening, 5-foot-deep sill), and three manmade islands to hold the sector gates which would total 110.0 acres. The Galveston Bay complex contains approximately 378,063 acres of open-bay habitat (Pulich, 2002). The 128 acres loss is a small fraction (0.0003 percent) of the total available habitat within the entire system.

At Bolivar Roads, the structural elements of the gates system would reduce the cross-sectional area of the inlet by 9.5 percent, constricting inlet tidal flows, and increasing current velocities. Per McAplin et al. (2019b), it is expected that within the inlet the maximum velocities through the navigation structure could be as high as 2 m/s (6.6 ft/s) in places. This could result in the formation of eddies on the backside of the structures, which may have impacts on navigation. The magnitudes of expected increases in mean bottom and surface velocities between with- and without-project conditions are significantly smaller than the reported maximum velocity changes. Ship simulations will be required to determine if FWOP/FWP changes to the inlet's maximum and mean velocities would impact deep-draft vessels transits through the ship channel.

For the rest of Galveston Bay, the velocity magnitudes do drop at most locations for both surface and bottom but this reduction in the mean velocity magnitude is less than 0.1 m/s and typically more on the order 0f 0.05 m/s or less. Locations in West Bay and on the western perimeter of Galveston Bay show a slight increase in velocity magnitude for surface or bottom but, again, the change in the mean velocity magnitude is less than 0.1 m/s. Therefore, current velocity changes within Galveston Bay induced by the Coastal Barrier measure should not impact commercial and recreational navigation.

The USACE (2017) reported that in 2015 the Houston Ship Channel, consisting of the Inner Bar Channel, served 8,325 oceangoing vessels' arrival including break bulk, bulk carrier, containers, roll-on/roll-off, tankers, tug tow, and vehicle carriers. It is expected inbound transit of a similar number and mix of vessels would continue during and after construction of the navigation and environmental gates. Risks to navigation safety are expected to increase due to a reduction in vessel operating margin of error associated with the temporary bypass channel constrictions, outbound recreational and commercial vessel traffic, and mobilized construction platforms and permanent constrictions associated with the constructed navigation gates and outbound recreational and commercial vessel traffic.

Summary. Overall, the potential impacts to deep-draft vessel operation caused by changes to tidal velocities and constricted channel geometries located at Bolivar Roads is offset by a reduction in risk to navigation infrastructure from storm surges. The Coastal Barrier would reduce the probability of overwash sediments being transported into the GIWW, therefore, potentially reducing storm-event driven maintenance dredging requirements.

4.7.1.2 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

The Upper Bay Barrier alignment would maintain the existing geomorphic features with levee/floodwall systems at the Bolivar Peninsula and the west end of Galveston Island, which would allow for continued protection of the GIWW against storm-induced wave and surge effects. With the Upper Bay Barrier in place, overwash and other storm-related sediment deposition in Galveston Bay would be significantly reduced, potentially reducing future storm-event driven maintenance dredging requirements of the GIWW. The Upper Bay Barrier is further enhanced with improvements to the Galveston seawall and closure gates further in-bay at Tabbs Bay to prevent storm surge from entering into the upper reaches of the Houston Ship Channel. Additional flow control structures of the Upper Bay Barrier measure are proposed for Offatts Bayou, Dickinson Bayou, and Clear Lake, with geometries similar to the Coastal Barrier measure.

The closure structures system for Tabbs Bay crosses Tabbs Bay to Hog Island then to the Spillman Island Placement Area, a distance of 9,870 feet. The Tabbs Bay crossing consists of combi-wall and a series of 100-foot environmental gates to connect the north bank of the bay with Hog Island. A 3,070-foot crossing at the Houston Ship Channel would consist of combi-wall and a sector gate to accommodate the existing channel width of 530 feet.

McAlpin et al. (2018) reported mean surface and bottom current velocities increased minimally from without- to with-project conditions at locations further upstream within Galveston Bay for the Coastal Barrier measure. Although not modeled, it is anticipated based on the Coastal Barrier measure hydrodynamic analysis findings, that there may be slight increases in current velocities induced by FWP Upper Bay Barrier measure by partially constricting tidal flows within Tabbs Bay with the closure structures system. Ship simulations would be required to determine if FWOP/FWP changes to the Tabbs Bay current velocities would impact deep-draft vessels transits through the inlet's ship channel.

Throughout the rest of Galveston Bay, the velocity magnitudes are expected to vary little between with- and without-project conditions. Therefore, current velocity changes within Galveston Bay induced by the Upper Bay Barrier measure should not impact commercial and recreational navigation.

The Upper Bay Barrier would have impacts on interactions between deep draft ships and shallow draft tugs and barges. Under the FWOP conditions, the navigation channel at Tabbs Bay includes a deep draft channel with a north- and southbound shallow draft channel adjacent to the deep draft channel. If a gate is built at this location, the shallow draft traffic would likely be forced to use the deep draft channel to transition through the gate.

To construct the navigation closure gate structures across the Houston Ship Channel at Tabbs Bay, a temporary bypass channel would first be constructed between the north bank and Hog Island. At Tabbs Bay, risks to navigation safety are expected to increase due to a reduction in vessel operating margin of error associated with the temporary bypass channel constrictions, outbound recreational and commercial vessel traffic, and mobilized construction platforms, and permanent constrictions associated with the constructed navigation gates and outbound recreational and commercial vessel traffic.

The Upper Bay Barrier would expose navigation infrastructure at risk from storm surges, since many of the ports and channels would be outside of the protection system. Storm surge can move large amounts of sediment into the deep-draft navigation channel during an event, adding to the annual cost of maintenance dredging.

Summary. Overall, the potential impacts of deep-draft vessel operation caused by constricted channel geometries located at the Houston Ship Channel in Tabbs Bay is offset by a reduction in risk to navigation infrastructure from storm surges. The Upper Bay Barrier would reduce the probability of overwash sediments being transported into the shallow-draft GIWW, therefore, potentially reducing storm-event driven maintenance dredging requirements. However, hurricane storm surges would move large quantities of sediments into the deep-draft navigation channel potentially increasing storm-event driven maintenance dredging requirements.

ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Additional sediments would become available in the natural system and allow natural processes such as reworking, erosion, and deposition to take place and enhance sediment availability for longshore transport. Increase in shoaling through longshore transport can be expected at navigation entrance channels downdrift of ER beach and dune features. Locations of anticipated shoaling increases due to proposed ER beach and dune restoration features include Galveston Bay Entrance Channel (Bolivar Roads) and San Luis Pass. An anticipated impact from Follets Island Gulf Beach and Dune Restoration (B-2) feature is an increase in shoaling within the entrance channel at Port Freeport as a result of longshore transport. An increase in shoaling within the GIWW, from these expected overwash events, would induce an increase in maintenance dredging requirements of the waterway.

The impacts due to the ER implementation would result in protected, created, and/or restored Gulf and bay island shorelines and marsh fringes. Long-term effects of sediment placement on Gulf shorelines may include increase in shoaling at the Galveston Bay Entrance Channel (Bolivar Pass), San Luis Pass, and Port Freeport Entrance Channel. Temporary impacts to navigation traffic may be experienced during construction of ER measure features, particularly within the GIWW when floating construction platforms are mobilized and operated during construction activities. When compared with the No-Action Alternative, the implementation of the ER measures would have a net positive impact by providing added protection to the GIWW and its barge traffic against wind-induced wave energy.

4.7.2 Recreational

4.7.2.1 Alternative A

Coastal Barrier Alternative

Impacts to recreational navigation would be similar to commercial navigation impacts (Section 5.6.1). Additional temporary impacts to recreational navigation traffic would be induced by construction of the flow control structures at Clear Lake, Dickinson Bayou, and Offatts Bayou, which are proposed to each consist of a single opening.

4.7.2.2 Alternative D2

Upper Bay Barrier–Bay Rim CSRM Measure (Upper Bay Barrier)

Impacts to recreational navigation will be similar to commercial navigation impacts. Additional temporary impacts to recreational navigation traffic will be induced by construction of the flow control structures at Clear Creek, Dickinson Bayou, and Offatts Bayou, which are proposed to each consist of a single opening.

4.7.2.3 ER Measure B-2 Follets Island Gulf Beach and Dune Restoration

Impacts to recreational navigation as a result of construction of the ER measures would be the same as those described for commercial navigation (Section 4.6.1).

4.8 FLOOD CONTROL

4.8.1 Texas City Hurricane Flood Protection Project

Intersection with Alternative A or 2. Texas City HFPP is part of the Upper Bay Barrier-Bay Rim (Alternative D2) with the line of protection being extended on either end of the current project. There will be no alterations to the Texas City alignment under Alternative A.

4.8.2 Lynchburg Pump Station

Intersection with Alternative A or 2. No changes or impacts are anticipated to the Lynchburg Pump Station with the construction of alternatives 1 or 2.

4.8.3 Colorado River Flood Protection at Matagorda

Intersection with Alternative A or 2. No changes or impacts are anticipated to the Colorado River Flood Protection at Matagorda with the construction of Alternative A or D2.

4.9 CUMULATIVE IMPACTS

NEPA regulations require that cumulative impacts of a proposed action be assessed and disclosed in an EIS or Environmental Assessment (EA). The Council on Environmental Quality (CEQ) regulations define cumulative impacts as:

> "…the impacts on the environment which result from the incremental impact of the action (project) when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7).

For purposes of this analysis, cumulative impacts are evaluated if the indirect and direct impacts of the federal action have substantial temporary adverse or positive impacts to the resource, when considering past, present, and reasonably foreseeable future actions. Potential impacts of the past, present, and reasonably foreseeable future actions include both potential direct effects (caused by the actions and occurring at the same time and place as the Preferred Alternative), and indirect effects (caused by the action but removed in distance and later in time, and reasonably foreseeable).

The cumulative effects analysis considers the magnitude of the cumulative effect on the resource health. Health refers to the general overall condition, stability, or vitality of the resource and the trend of that condition. Laws, regulations, policies, or other factors that may change or sustain the resource trend were considered to determine if stress on the resource is likely in the foreseeable future. Cumulative impacts may also occur when the occurrence of disturbances is so close that the effects of one are not dissipated before the next occurs, or when the timings of disturbances are so close that their effects overlap. The general approach provided in the CEQ's Considering Cumulative Effects Under the NEPA was used to conduct the analysis (CEQ, 1997).

This cumulative impact analysis was scoped with a temporal boundary of approximately 100 years in the past (1918), from the beginning of the study, and approximately 50 years into the future (2085), from construction completion. This timeframe accounts for the period of time when significant hydrologic modifications occurred within the focused study area. This period of analysis also captures the period of time when a significant number of environmental laws were enacted in which resource protection became a priority. The future timeframe aligns with the planning and economic period of analysis, and the HEP modeling.

For a spatial boundary to scope this cumulative impact analysis, projects or actions considered were mostly bounded by Galveston Bay to the Rio Grande. Some projects or actions within Jefferson County and Sabine Lake region were included as they have the potential to contribute beneficial effects to nearby ER measures in Chambers and Galveston counties. In addition, some inland projects were also considered as they have potential to affect the Recommended Plan and contribute to cumulative impacts (*e.g.*, Harris County and Houston-area flood damage reduction projects)

4.9.1 Past or Present Actions

4.9.1.1 Upper Texas Coast

GIWW Maintenance. The USACE Galveston District published "Maintenance Dredging, Gulf Intracoastal Waterway, Texas Section – Main Channel and Tributary Channels" (an EIS) in October 1975. This document identified and evaluated the environmental impacts of continued maintenance dredging of the GIWW Texas Section and tributary channels. The proposed action was continued maintenance by periodic dredging of shoal deposits. The main channel was authorized at a 12-foot depth and a 125-foot bottom width. The typical means of dredging is by hydraulic pipeline dredge, except for the Port Mansfield Channel that can be maintained by either pipeline or hopper dredge. At the time of the 1975 EIS, the environmental impact and adverse environmental effects of the proposed action were addressed based on the best available information (USACE, 1975).

Sabine-Neches Waterway Channel Improvement Project. The Sabine-Neches Waterway is a 64-mile-long Federally-constructed deep-draft navigation project serving Jefferson and Orange counties in Texas and Cameron and Calcasieu parishes in Louisiana. The Sabine-Neches Waterway is home to 2 of our Nation's 17 Department of Defense's Strategic Seaports. The Port of Beaumont at the upstream end of the channel and the Port of Port Arthur closer to the downstream end of the channel. The existing waterway consists of a jettied entrance channel, 42 feet deep and 500 to 800 feet wide from the Gulf; a channel 40 feet deep and 400 feet wide to Beaumont via the Neches River; and a channel 30 feet deep and 200 feet wide to Orange via the Sabine River. The USACE's recommended plan includes modifying the existing waterway by deepening the channel to 48 feet to avoid congestion and delays, increase safety, and improve efficiency and throughput capacity. The Sabine-Neches Waterway Channel Improvement Project was authorized for construction in Section 7002 of Water Resources Reform and Development Act 2014. However, the project economics excluded the latest investments that were under construction along the waterway at the time with more than $30 billion in improvements to the Sabine-Neches Waterway's refining and petrochemical industries. In April 2013, the Sabine-Neches Navigation District requested and was granted a modified design agreement that allowed for a reevaluation of the economics during preconstruction, engineering, and design. The Limited Reevaluation Report for the Sabine-Neches Waterway was completed in October 2016 and confirms the increased national economic significance of the Sabine-Neches Waterway. This economic analysis resulted in a benefit-cost ratio of 2.28 (using the FY 16 Federal interest rate of 3.125 percent), demonstrating that improvements to the Sabine-Neches Waterway will increase navigational efficiency while maintaining the ecological value of coastal and estuarine resources within the project area (USACE, 2018a).

McFaddin NWR Beach Dune Restoration. Jefferson County is acting to restore 104,150 linear feet of dune ridge and beach face along the 20 miles of beach along McFaddin NWR. Offshore 1.5 miles from the beach, a 241-acre borrow site will serve as the source for sand. The beach nourishment and dune creation would involve the discharge of approximately 4.1 mcy of sandy material into 1,004.16 acres of tidally influenced beach and open water. The proposed beach widths would range from 20 to 300 feet and the dune crest heights would be approximately +6 to +9 feet NAVD 88. The design criterion for dune elevation and beach height and width is intended to reduce inundation events into the NWR marshes, reduce shoreline erosion rates, and return sandy sediment to the littoral system. As of June 2017, approximately 3 miles of beach and dune restoration have been completed (SWG-2015-00444).

Smith Oaks Bird Sanctuary Rookery Island Restoration and Enhancement. The Texas Audubon Society has proposed bird sanctuary improvements to the Smith Oaks Bird Sanctuary on High Island. Excavation and fill activities will impact 3.2 acres of wetland habitat, and 6,791 cy will be discharged into wetlands during the process. Material will be used to create two bird rookery island sites, one in each pond, and to form emergent and shrub-scrub fringe wetland habitat (SWG-2017-00277).

East Bay and GIWW Shoreline Protection and Restoration. The Galveston Bay Foundation joined the USFWS along with other partners to protect the Anahuac NWR bay shorelines from continued erosion. The work began in 2006 and was completed through three phases in 2011. Rock breakwaters, reef dome breakwaters, and ReefBLK breakwaters were utilized to achieve the desired shoreline protection goals. The combined project phases had the effect of protecting 56,770 feet of refuge shoreline, and thousands of acres of marsh habitat. In addition, 5.5 acres of intertidal marsh was created through the planting of smooth cordgrass by volunteers.

Bolivar Peninsula Beach/Dune Restoration. Galveston County has ongoing efforts to improve the beaches and dunes on the Gulf side of Bolivar Peninsula primarily through nourishment activities on the beach front. Early efforts included the use of dredged sand from Rollover Bay for use in geo-tubes, while recent permit updates include sourcing sand from upland borrow sites on Bolivar Peninsula. The county plans to dredge approximately

300,000 cy of material for use in beach nourishment from Rollover Pass to beyond High Island (SWG-2007- 00391).

Burnet Bay Marsh Mound Creation. Aerial imagery dating back to the early 1900s shows extensive marsh loss due to an estimated 5–8 feet of subsidence in Burnet Bay, west of Baytown. In response, the Galveston Bay Foundation discharged approximately 34,000 cy of material to construct an additional 15 marsh mounds within a43.9-acre area on the northwest side of Burnet Bay. The mounds were constructed by hydraulically pumping sediment from nearby borrow areas, one previously authorized borrow area, and another newly proposed. The mounds add to an existing mound complex and provide additional habitat and ecological benefits (SWG-2008- 00127). Upon completion of the project, volunteers planted wetland vegetation on the newly created mounds.

Houston Ship Channel Dredging and Bulkhead Construction. Kinder Morgan Terminals performed dredging, filled 3.25 acres of open water, and constructed 2,400 linear feet of bulkhead in the process of expanding operations at an existing liquid bulk cargo facility. Approximately 250,000 cy of material was dredged, 80,000 cy of which was placed into 3.25 acres of open water for the construction of two additional storage tanks. The remaining dredged material was placed in authorized privately owned placement areas (SWG-2014-00023).

Barbours Cut Ethane Terminal Improvements. Enterprise Products Operating LLC created a new vessel terminal, mooring locations, and bulkhead, and performed dredging to accommodate discharging and loading vessels. Terminal construction involved dredging to a depth of –45 feet mean low tide, and impacted 12.6 acres of open water, including 0.48 acre of estuarine intertidal emergent wetlands, and 0.84 acre of oyster reef. Approximately 421,000 cy of material was placed in approved placement areas. A new bulkhead was also constructed along the shoreline of Spillman’s Island to maintain stability from dredging activities (SWG-2014-00905).

Bayport Ship Channel Container Terminal Dredging. The Port of Houston Authority dredged 7,000 linear feet of ship berths adjacent the Bayport Ship Channel Container Terminal in an area totaling 36.2 acres. The previously authorized depth of –40 feet was increased to –45 feet mean low tide, plus 2 feet of advanced maintenance and 2 feet of allowable overdepth, for a maximum of –47 feet. Approximately 1,231,000 cy of material was removed and placed in nearby placement areas adjacent the ship channel (SWG-1998-01818).

Dickinson Bayou Wetland Restoration and Protection. The TPWD teamed with numerous partners to accomplish a wetland restoration, creation, and protection project along the shoreline of Dickinson Bayou, which protected 17.7 acres of wetlands, and created approximately 12.3 acres of intertidal wetland complex. Marsh creation was achieved through the beneficial use of dredge material from three borrow areas in the Dickinson Bayou Channel. Earthen berms totaling 3,000 linear feet were placed around the created wetlands, and riprap was placed along the bayou-facing sides for erosion protection. The new wetlands were planted and seeded with smooth cordgrass (SWG-2013-00148).

Moses Lake Shoreline Protection. The Galveston Bay Foundation has proposed the construction of 7,500 linear feet of limestone breakwaters along the western shoreline of Moses Lake. The breakwaters will be placed from 25 to 250 feet from the shoreline along the –2.0 feet NAVD 88 contour. The designed width of the breakwaters is 27 feet, and the crest elevation will be +2.0 feet NAVD 88. The project would utilize 16,670 cy of riprap, and three bird nesting pads would also be incorporated into the structures (SWG-2015-00687).

Swan Lake Restoration. In response to significant marsh loss over the past 50 years, a rock breakwater was constructed in 2003, and in 2007, 77 acres of marsh were restored in Swan Lake. Up to 200,000 cy of beneficial use dredge material was used for the marsh restoration effort. The material was pumped from a nearby source into habitat restoration cells and placed at a suitable elevation to support marsh planting. In response to ongoing habitat degradation, the TPWD and the GLO are planning to restore an additional 250 acres of intertidal marsh complex in Swan Lake.

Greens Lake Shoreline Erosion Protection. Ducks Unlimited Inc. has proposed the construction of a breakwater along the northern bank of the GIWW from the mouth of Carancahua Lake and extending 3.3 miles northeast to the Flamingo Isles development. Approximately 25,848 cy of graded riprap would be utilized for breakwater construction. The breakwaters would be 20 feet wide, have a 3-foot crest height, and be placed 10 to 150 feet from the existing bank. To accommodate tidal flushing and boat traffic, there would be two separate breakwaters, forming an opening at Greens Lake (SWG-2015-00415).

North Deer Island Protection and Restoration. North Deer Island, one of the few remaining natural islands in Galveston Bay, has undergone several attempts to protect the vital bird rookery habitat. Under Phase I a breakwater protecting 5,750 feet of shoreline was constructed in 2003 around the southwest portion of the island and benefiting 57 acres of marsh. Phase II of the effort was completed in 2008 and included an additional 3,600 feet of breakwater protection on the south end, groins along the northern shoreline near the GIWW, and a 900- foot breakwater on the northwest shoreline. Phase II improvements were expected to protect 49 acres of marsh and 25 acres of upland habitat. Approximately 8 acres of marsh were restored through beneficial use of sediments dredged from barge access channels and planted with marsh cordgrass.

Galveston Bay Oyster Reef Restoration. The TPWD completed oyster restoration efforts at four sites in Galveston Bay in 2017. The sites included Todd’s Dump Reef, South Redfish Reef, and two locations on the north side of the Texas City Dike. Oyster cultch was distributed into 10-foot diameter mounds, with 10 to 15 feet of space between mounds. Maximum crown height of the reef mounds did not exceed 3 feet below MLLW elevation of 5 feet. Approximately 9,670 cy of oyster cultch was placed between the sites, at about 4 cy per mound (SWG-2016- 00252, 00270).

Galveston Island Beach Nourishment. The Galveston Park Board and partners teamed to address ongoing erosion by placing over 1 mcy of sand hydraulically dredged from the Bolivar Roads south jetty along nearly 4 miles of beachfront. The beach was renourished between 12th and 61st streets and was completed in the spring of 2017, adding between 100 and 150 feet of beachfront after settling. This most recent project, combined with previous nourishment projects west of 61st Street, accounts for over 5 miles of beach nourishment on Galveston Island (SWG-2000-02888).

Pierce Marsh Restoration. The Galveston Bay Foundation has begun the process of using hydraulically dredged material from GIWW maintenance for placement in Basford Lake in West Bay, southwest of Bayou Vista, in an area known for marsh loss. In total, 1,464,000 cy of hydraulically dredged material will be placed into 364 acres of submerged bay bottom to support the restoration of marsh habitat. In addition, 50,000 cy of mechanically dredged material will be placed into 10.8 acres of submerged bay bottom for the creation of perimeter berms at +2.7 NAVD 88. The berms will be planted and constructed to protect the interior hydraulically dredged material (SWG-2015-00313)

Galveston Island State Park Marsh Restoration and Protection. The TPWD is constructing 12,900 linear feet of rock breakwater in the Carancahua Cove, Butterrowe Bayou, Oak Bayou, and Dana Cove areas. In addition, 400,000 cy of sandy material from a nearby borrow in West Bay was used to restore intertidal elevations in the marsh behind the breakwaters. The dredged material was used to create marsh mounds with a maximum elevation of +2.7 NAVD 88 (SWG-2009-00148).

Sweetwater Preserve Shoreline Protection and Oyster Habitat Enhancement. The Galveston Bay Foundation has constructed 1,900 linear feet of oyster hash breakwater and planted 1.75 acres of smooth cordgrass along the eastern shoreline of Sweetwater Lake. The breakwaters occupy approximately 0.35 acre of former open water (SWG-2014-00258).

Snake Island Restoration. Snake Island Cove is a 900-acre, shallow, marsh-lined cove located in Galveston Bay. Seagrass degradation and loss were cause for concern in the area, and in 2007 and 2011, 4,900 linear feet of geotextile tube breakwater was installed to protect 200 acres of estuarine intertidal marsh complex. The result was also the creation of over 75 acres of protected calm shallow water habitat, which has led to the reestablishment of seagrasses within the project area.

Gang’s Bayou Marsh Restoration and Protection. The TPWD completed a marsh restoration and protection project in West Bay at Gang’s Bayou, west of Sportsman Road. The 45,000 cy of sediment from an 88.4-acre borrow site and access channel was hydraulically dredged and placed as marsh mounds with a height of +2.5 feet NAVD 88. A 3,800-linear foot breakwater using 13,000 cy of riprap was also constructed to protect 17.4 acres of saltmarsh and the constructed marsh mounds (SWG-2015-00652).

Oyster Lake Habitat Protection and Marsh Restoration. The USFWS completed a multi-phased project addressing erosion protection between a narrow strip of shoreline and marsh between Oyster Bay and West Bay in the Brazoria NWR. Initial stages included the installation of 500 feet of reef ball breakwaters on either side of the shoreline in 2012. In 2015, 2,500 linear feet of riprap breakwater was constructed to the north and south of the existing reef balls. The long breakwater segments displaced approximately 2.6 acres of bay bottom with approximately 7,000 cy of material (SWG-2012-00679). Ultimately, the project resulted in the construction of a 4,786-foot riprap breakwater that protects 5,150 feet of shoreline. The breakwater also protects upwards of 60 acres of coastal habitat that are part of the Brazoria NWR. Behind the shoreline protection features, the project now has the potential to restore intertidal wetlands in a 14-acre calm-water protected area. As of 2016, approximately 1.5 acres of this area has been planted with smooth cordgrass (Galveston Bay Estuary Program, 2016).

Surfside Beach Groins and Nourishment. The Village of Surfside Beach previously completed a beach nourishment project in March 2015 that placed 118,000 cy of sand from three upland sand pits along the beachfront, stretching 4,800 feet north from the Freeport jetties. The construction of two rock groins has been proposed, along with approximately 2,000 feet of beach nourishment on the northeast end. The rock groin footprint totals 1.7 acres and includes 1,650 cy of material (SWG-1998-02508).

Bryan Beach Renourishment. Using GLO Coastal Erosion Planning and Response Act funds, the Town of Quintana has renourished approximately 0.37 mile of beachfront in an area called Bryan Beach. An upland sand pit near the Colorado River and south of Bay City was used to source 99,600 cy of sand for the 16-acre dune reconstruction and beach nourishment project (SWG-2013-00640).

GIWW Barge Facility Expansion and Maintenance. Texas Barge and Boat performed maintenance and expansion of their facilities located off the GIWW, northeast of the Brazos River floodgates. Work was performed without a permit, and the company filed for an after-the-fact permit to retain impacts to waters of the U.S. Approximately 100,602 cy of material was dredged from uplands, resulting in the creation of 6 acres of open water, and approximately 2,288 cy of dredge material was placed into wetlands and open water. The applicant also constructed approximately 856 linear feet of steel bulkhead and placed approximately 305 cy of riprap below the high tide line for erosion protection. Pipe piling mooring structure was also installed for 1,682 linear feet within the project area (SWG-2001-01994).

4.9.1.2 Mid to Upper Coast

Mad Island WMA Shoreline Protection. The TPWD has completed 1.8 miles of breakwater to protect the Mad Island WMA shoreline along the GIWW from erosion. The TPWD is proposing to construct an additional 0.57 mile east of the previously constructed breakwater to Culver Cut. The final length of the breakwater will be approximately 2.37 miles. Approximately 4,900 cy of graded riprap will be used for the remaining segment of the project; upon completion, 20,400 cy will have been used. The final segment of the breakwater has not been completed (SWG-2009-00124).

Half Moon Reef Restoration. The TNC and USACE Galveston District teamed to restore a large historic subtidal reef in Matagorda Bay. In 2014, construction was completed on the 60-acre restoration project of one of the largest oyster reefs in the Gulf. Recycled concrete in various sizes was placed in a specific pattern to encourage the reef to grow vertically and to create niches and passageways for all kinds of marine organisms.

Formosa Plastics Plant. Formosa currently operates eight plants and support facilities at a 2,500-acre complex in Point Comfort. The plant started operations in 1983 and was further expanded in 1994, 1998, and 2002. The facility has added several new plastics production units, a wastewater treatment facility, and power co-generation. The facility manufactures plastic resins and petrochemical products. The Formosa Plastics Receiving Water Monitoring Program was established in 1993 and continues to monitor the discharge of treated wastewater into Lavaca Bay from the facility (Formosa Plastics Corporation USA, 2017).

Alcoa Alumina Plant. Alcoa operates one plant and support facilities at a 3,500-acre complex in Point Comfort. The plant has been in operation since 1948 and produces alumina and alumina chemicals. As of 2017, due to high imports of aluminum and high cost of power, the Point Comfort plant has been idled. The area around the plant was designated as a superfund site by the EPA in 1994 for its wastewater release of mercury. Portions of Lavaca Bay remain closed to finfish and crab harvest due to unsafe levels of mercury (EPA, 2017b).

GIWW. The GIWW is a shallow-draft, inland waterway used to transport cargo and goods throughout the Gulf coast. The channel stretches from St. Marks, Florida, to Brownsville, Texas, and was designed to be 12 feet deep by 125 feet wide. The GIWW West Matagorda Bay section (channel mile 454 to 473) is proposed to be rerouted from its original course to one farther north for safety and maneuverability. Dredging activities for the Matagorda Bay reroute have not started and are pending Federal funding (USACE, 2012b).

The Sanctuary at Costa Grande Mitigation Plan. D.H. Texas Development LP is proposing modifications to their mitigation plans for the Sanctuary at Costa Grande housing development. The development firm is amending the original permit and proposing to create 16 acres of freshwater wetlands instead of tidal wetlands and to relocate the planned 1.8-acre seagrass mitigation site to a site on the northeast point of Dewberry Island. The project is not yet completed (SWG-2005-00181).

4.9.1.3 Mid to Lower Coast

Park Road 13 Seawall Improvements. The TPWD is proposing to elevate approximately a 300-foot-long section of Park Road 13 (Trout Street) approximately 12 to 24 inches. The TPWD is also planning on constructing a 624- foot-long concrete seawall to tie in with the existing seawall on each side of the project site. The footprint of the design would require filling 0.261 acre below the annual high tide line and 0.0081 acre below the mean high water. The project has been approved but not yet completed (SWG-2003-01546).

Rockport Beach Nourishment Project. The project provided beach nourishment along Rockport Beach in Aransas County. The beach area experienced approximately 4,800 feet of shoreline erosion. Approximately 9,154 cy of sand was placed to repair the beach. Approximately 1.6 acres of sand was placed below the mean high water line, and 2.6 acres was placed below the annual high tide line. The project was completed in 2016 (SWG-1991-01789).

Rockport Harbor Maintenance Dredging. Aransas County Navigational District conducted maintenance dredging of Rockport Harbor. An estimated 109,876 cy was dredged from the harbor. Dredged materials were placed in an adjacent upland area. The project was completed in 2017 (SWG-2016-00194).

Ingleside Ethylene Cracking Plant. Occidental Chemical Corporation and Mexichem have completed construction on and have started up an ethylene cracking facility with the capacity to produce 1.2 billion pounds of ethylene per year. The ethylene will be used to manufacture vinyl chloride monomer and polyvinyl chloride. The plant was completed and started production in February 2017 (Chemical-Technology, 2017).

OXY Ingleside Energy Center. The OXY Ingleside Energy Center terminal has a total storage capacity of 2.1 million barrels and throughput capacity of 300,000 barrels per day. The facility can accommodate Aframax- and Suezmax-sized vessels. The crude oil storage and export terminal was completed and began operations in 2016 (Port of Corpus Christi, 2017a).

Corpus Christi Liquefaction Project. Cheniere Energy, through its affiliate, Corpus Christi Liquefaction LLC, is proposing the construction and operation of an LNG exporting facility on the La Quinta Ship Channel. The 1,000- acre site will include five liquefaction trains, marine tanker loading facilities, and 23 miles of pipeline. The marine loading berths will require dredging to create a turning basin and deepening of the La Quinta Channel. Project construction has begun and is in progress (Cheniere Energy, 2017).

Corpus Christi Ship Channel Improvements. The Port of Corpus Christi Authority is proposing to increase the capabilities of the existing ship channels. The Port of Corpus Christi Authority has already extended the channel 1.4 miles and deepened the La Quinta extension to –47 feet mean sea level (MSL). The second phase is to widen the Corpus Christi Ship Channel to 530 feet and deepen the channel from –47 to –54 feet MSL. The first phase of the project has been completed. The second phase of the project is pending (SWG-2005-01290).

Corpus Christi New Harbor Bridge. The city of Corpus Christi and TxDOT are currently in the construction phase of the new Harbor Bridge design. The new Harbor Bridge will have a main span of 3,285 feet and a vertical clearance of 205 feet. The new bridge will allow larger ships to enter the Corpus Christi Ship Channel. Construction on the bridge began in 2017 and is expected to be completed in 2020 (Flatiron Dragados USA, 2017).

Lake Padres Subdivision Canal. Gulf Shores Joint Venture is proposing to construct a canal-type connection between Lake Padre and the existing canal at Cruiser Street. The canal will extend under Park Road 22, along Padre Isles Golf Course. The project, as proposed, would impact a total of 122.6 acres of waters of the U.S., including 90.8 acres of wetlands, 20.1 acres of sand flats, and 11.8 acres of tidal open water (Lake Padre). Dredging of the wetlands and placement of fill for the project has started. The project is not yet complete (SWG2000-02743).

4.9.1.4 Lower Coast

South Padre Island Beach Nourishment. South Padre Island beach has been nourished multiple times since the first nourishment in 1997, facilitated by Coastal Erosion Planning and Response Act funding and through collaboration among the Texas GLO, USACE, and the Town of South Padre Island. Coastal Erosion Planning and Response Act Cycle 1 funded the first nourishment and continues to support the long-term nourishment of South Padre Island beach. Beneficial use of dredged material from Brazos-Santiago Pass was utilized during routine maintenance dredging of the Brownsville Ship Channel. During Cycle 2, a total of 348,000 cy of sand was placed on 3,780 feet of shoreline using beneficial use of dredged material. An additional Cycle 2 project utilized 120,000 cy of sand harvested from Park Road 100 by TxDOT on 2,000 linear feet of beach. A Cycle 4 nourishment project saw another 7,100 cy taken from Park Road 100 and placed on the beach, and wind-blown sand from the road continues to be used for nourishment and to rebuild dunes. In 2016, a USACE nourishment project moved 651,000 cy of beneficial use of dredged material from the Brownsville Harbor navigation channel to renourish approximately 0.75 mile of South Padre Island beach.

Adolph Thomae Jr. County Park Improvements. Cameron County has begun the process of improving facilities at the Adolph Thomae County Park, located near the mouth of the Arroyo Colorado River within the Laguna Atascosa NWR. The heavily used park has improved facilities and has begun shoreline repairs and stabilization efforts along the 2-mile stretch on the south bank of the river. The project will include 870 linear feet of precast concrete block wall with gravel backfill, 3,200 linear feet of habitat bench including riprap stone, 315 linear feet of articulated concrete block mattress, 200 linear feet of riprap breakwater, and riprap transitional sections between structures. Habitat bench installation will involve the discharge of approximately 6,100 cy of riprap, 3,415 cy of gravel backfill, and 3,200 cy of base stone below the high tide level elevation. An additional 0.156 acre of wetlands would be filled with base stone (SWG-2015-00602).

4.9.2 Reasonably Foreseeable Actions

4.9.2.1 Upper Coast

Texas Coastal Resiliency Master Plan. The GLO developed a master plan that identified critical coastal issues and potential projects to address those issues. Some of the common issues identified include altered or degraded habitats, Gulf beach erosion and dune degradation, bay shoreline erosion, coastal storm surge damages, coastal flood damages, water quality and quality degradation, impacts of other coastal resources, and abandoned derelict vessels, structures, and debris. To address these issues, the GLO identified several strategies including restoration of beaches and dunes, bay shoreline stabilization and estuarine wetland restoration, GIWW stabilization, freshwater wetlands and coastal uplands conservation, delta and lagoon restoration, oyster reef creation and restoration, and implementation of plans, policies, and programs. The Master Plan effort considered numerous projects to address coastal issues and ultimately identified a total of 59 coastal resiliency projects (during this iteration of the Master Plan), including 25 in the upper Texas coast, 12 in the mid to upper Texas coast, 16 in the mid to lower Texas coast, and 6 in the lower Texas coast. Future iterations of the Master Plan will reflect a greater depth and breadth of analysis as the planning process matures, and as additional data and analytical techniques are developed. Subsequent planning is also expected to include additional emphasis on life cycle and phasing aspects of recommended projects, an enhanced focus on storm surge defense and flood risk reduction, restoration of water quality, and community development and revitalization to achieve a more robust and resilient coast (GLO, 2017).

Texas GLO Coastal Erosion Planning and Response Act (CEPRA) Program. The GLO administers the CEPRA Program and it is intended to implement coastal erosion response projects and related studies to reduce the effects of and to understand the processes of coastal erosion as it continues to threaten public beaches, natural resources, coastal development, public infrastructure, and public and private property. CEPRA projects ultimately yield positive or beneficial effects to coastal resources. Some of the CEPRA Program reasonably foreseeable actions include the following beneficial coastal projects:

- Jamaica Beach Dune Restoration
- Rollover Pass Closure • Rollover Recreational Amenities Plan
- Follets Island Nearshore Beach Nourishment
- Virginia Point Wetland Restoration and Protection
- West Galveston Island Bayside Marsh Restoration
- Beach Monitoring and Maintenance Plan Monitoring
- Bolivar Beach Restoration

- Dellanera Park Beach Nourishment
- GIWW-Rollover Bay Reach Beneficial Use Beach Nourishment
- Babes Beach Nourishment
- Texas Coastwide Erosion Response Plan Update 2018
- Indian Point East Shoreline Protection

Sabine Pass to Galveston Bay Coastal Storm Risk Management and Ecosystem Restoration. The USACE proposed to reduce the risks of tropical storm surge impacts by constructing the Orange 3 CSRM system in Orange County, and improving flood protection in Port Arthur, Freeport, and Hurricane Flood Protection systems in Jefferson and Brazoria counties. The Orange 3 project would consist of a 26.7-mile-long levee/floodwall system along the edge of the Sabine and Neches river floodplains from Orange to Orangefield, Texas. The Port Arthur and Freeport projects would raise or reconstruct 11.6 and 18.2 miles of existing levees/floodwalls, replace vehicular closures, construct navigable surge gates, and increase resiliency through erosion protection. The hydrologic condition of the area is not anticipated to be affected by the features of the TSP. The Orange 3 project would result in the loss of 69.5 acres of forested wetlands and 203 acres of estuarine marsh, as well as functional impacts to 2,137.2 acres of estuarine marsh. The impacts would result in the loss of 43 average annual habitat units for forested wetlands and 143 average annual habitat units for estuarine marsh. Mitigation would restore 453 acres of estuarine marsh and preserve 559.5 acres of forested wetlands to compensate for the impacts from the project (USACE, 2017a).

Jefferson County Ecosystem Restoration. The USACE, in partnership with Jefferson County and the Sabine Neches Navigation District, prepared an Integrated Feasibility Report and EA for the Jefferson County Ecosystem Restoration Study in Jefferson County, Texas (USACE, 2018b). In addition to the “no-action” alternative, four alternatives with varying levels of ER were evaluated, including the recommended plan. Implementation of the recommended plan would include restoration of 8,421 acres of marsh and construction of 6,592 linear feet (1.25 miles) of offset breakwaters that would be placed along the south bank of the GIWW. Dredged material used in the recommend plan would be provided during implementation of normal dredging operations or through the Sabine-Neches Waterway Channel Improvement Project. Marsh restoration would beneficially use material dredged from the Sabine-Neches Waterway to increase the marsh elevation in five restoration units. Renourishment would occur at approximately year 30 to increase the target elevation to provide resiliency and sustainability in anticipation of projected RSLC (USACE, 2018c). The USFWS concurred that the recommended plan would not adversely affect any listed species. The NMFS issued biological opinions for normal dredging operations and the Sabine-Neches Waterway Channel Improvement Project in 2003 and 2007, respectively. Both Biological Opinions determined that the recommended plan will not jeopardize the continued existence of Federally listed species or adversely modify designated critical habitat. All terms and conditions resulting from previous consultations shall be implemented to minimize take of endangered species during dredging operations

Cedar Bayou Navigation Improvements. The USACE has evaluated improvements to Cedar Bayou. Cedar Bayou is a coastal stream that originates in Liberty County, Texas, east of Houston. It becomes navigable on the north end and meanders south along the urbanized eastern portion of the city of Baytown before entering Galveston Bay and the Houston Ship Channel. The project is supported by the Port of Houston Authority, the busiest barge channel in the United States; Kirby Corporation, the largest barge company in the United States; and the community and the companies who rely on the channel for their business. Companies that utilize the channel now and plan to use it in the future include Bayer Material Science LLC, Koppel Steel, Walmart, Home Depot, Dorsett Brothers Concrete, Reliant Energy, and Angel Brothers Cemex, to name a few. The channel primarily serves chemical, aggregate, steel, and asphalt. The waterway currently carries more than 1.5 million tons per year. Recent economic updates project a significant increase in the future; increases that depend on a normalized channel with a depth of 11 feet and a width of 100 feet. Constructing the Locally Preferred Plan would extend the barge transport benefits up to Mile 11, reduce environmental impacts, create a safer channel for the increased future traffic, and serve anticipated heavy development along the channel. The additional channel depth will accommodate barge traffic using the **Houston Ship Channel and the GIWW without light loading.** In addition, the wider channel and the cutoff of the bend at Devil's Elbow will result in much safer transport of materials and an area for barge tie up. The previously authorized and improved portion of the navigation project extends from its junction with the Houston Ship Channel near Barbours Cut container terminal at Mile 25, eastward across Galveston Bay to the mouth of Cedar Bayou to a point 3 miles upstream. The project dimensions are 11 feet by 100 feet. The proposed and newly authorized project extends the channel by 8 miles to SH 146 (USACE, 2018c).

Trinity Bay Living Shoreline and Erosion Protection. Chambers County is proposing to install 1,571 linear feet of living shoreline at Fort Anahuac Park on the eastern shore of Trinity Bay. The living shoreline would be constructed of concrete or limestone riprap, and smooth cordgrass would be planted on the protected shoreward side. A total discharge of 0.54 acre of fill material is expected (SWG-2016-00260).

Trinity Bay Discovery Center Shoreline Protection and Habitat Creation. The Galveston Bay Foundation has proposed the installation of a 1,200-linear-foot breakwater on the eastern shoreline of Trinity Bay. The breakwater would be composed of riprap and recycled oyster shells and occupy 0.5 acre of bay bottom. The action would also result in 2,070 cy of fill material. To facilitate marsh creation, smooth cordgrass would be planted between the existing shoreline and the proposed breakwater (SWG-2017-00589).

Buffalo Bayou and Tributaries Flood Risk Management. The Addicks and Barker Dam and Reservoirs are part of the Buffalo Bayou and Tributaries flood risk management system located within the west side of the city of Houston. The Addicks and Barker Dams

Dam Safety Modification Study by the USACE was the first (Phase 1) of a two-phase effort to fully address all dam safety issues associated with the Addicks and Barker Dams/Reservoirs. The Phase 1 of the study was initiated in 2009 and completed to primarily to address the issues near the conduits. A follow-on the Phase 2 study is proposed to assess risks associated with flows around and over the auxiliary spillways at the ends of the dams and flood risk in the pool areas upstream of the Addicks and Barker reservoirs and downstream along Buffalo Bayou. The purpose of this Section 216 study will be to investigate flood risk management problems in the Buffalo Bayou watershed that are not part of the Addicks and BarkerDams Dam Safety Modification Study Phase 1 or 2, including non-breach risk from spillway flow, residual risk in the upstream pool areas and downstream of the dams, water drainage from Cypress Creek watershed, and the potential need for a third reservoir in the Cypress Creek watershed (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Houston Regional Watershed Assessment. The USACE study area would include 22 primary watersheds within Harris County, 1,756 square miles encompassing Houston metropolitan region, each having unique flooding problems. These include Spring Creek, Little Cypress Creek, Willow Creek, Cypress Creek, Addicks, Barker, Buffalo Bayou, Clear Creek, Sims Bayou, Brays Bayou, White Oak, Greens Bayou, Hunting Bayou, Vince Bayou, Armand Bayou, Carpenters Bayou, San Jacinto River, Jackson Bayou, Luce Bayou, Cedar Bayou, Spring Gully and Goose Creek, and San Jacinto and Galveston Bay estuaries. Flooding problems in the watershed are frequent, widespread, and severe. Recent historical flooding in the region was documented in 1979, 1980, 1983, 1989, 1993, 1994, 1997, 2001, 2006, 2007, 2008, 2015, April 2016 with the loss of 8 lives, widespread damages to 5,400 homes and about $3 billion worth of damages to businesses, and most recently August 2017 with the loss of over 60 lives and billions in damages that are yet to be quantified. The principle purpose of the study is to develop a watershed management plan that would provide a system wide approach to water resources management. There is a significant opportunity to integrate and improve the operations of existing flood risk management systems and activities in Houston, Texas, the 4th largest metropolitan region in the Nation, while seeking opportunities to restore degraded ecosystems (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Brays Bayou Flood Risk Management Project. The USACE authorized project consists of 4 detention basins (Sam Houston, Old Westheimer Road, Eldridge Road, and Willow Waterhole), enlargement or modification of 21.1 miles of earthen channel, replacement and/or lengthening of 27 bridges. The project is being implemented under the authority of Section 211(f) of WRDA of 1996 where the work is accomplished by the NFS and following approval, the sponsor is reimbursed by the Federal Government for the Federal share. Direct benefits provided by the project are reduction of the 100-year return period floodplain by 97 percent. The project is about 80 percent complete and just beginning to reach critical life safety and health infrastructure in the community. This project will reduce the risk of flooding to the Texas Medical Center, which is the largest medical patient care, teaching, and research center in the world and includes patient's life and health in the 14 Texas Medical Center hospitals during major flood events due to staff and physicians not being able to travel through high water. The project will also reduce the risk of flooding along major traffic commuter routes such as SH 288, which is below ground level for much of its length crossing the Brays Bayou watershed. In addition, the project will reduce the risk of high-water causing life safety concerns on feeder roads and adjacent roadways along I-45, a hurricane evacuation route through Houston and Harris counties (USACE, 2018a).

White Oak Bayou Flood Risk Management Project. The USACE evaluated flood risk management on White Oak Bayou. White Oak Bayou is a tributary of Buffalo Bayou which originates northwest of FM 1960 and flows generally toward the southeast. The watershed covers about 110 square miles and includes three primary streams: White Oak Bayou, Little White Oak Bayou, and Cole Creek. The existing Federal channel in the lower reach of White Oak Bayou was completed in the mid-1970s under the authorization of the Flood Control Acts of 1954 and 1965 for Buffalo Bayou and tributaries. In 1986 the project was reauthorized under Buffalo Bayou and tributaries (Upper White Oak Bayou) in the WRDA of 1986 Section 401(a) based on the Chief of Engineers report dated June 13, 1978. In 1990 the Upper White Oak project was included in WRDA 1990 Section 101(a)(21) for the authorization of Buffalo Bayou Tributaries, which included six separate flood damage reduction plans for the tributary streams of Carpenters, Greens, Halls, Hunting, Little White Oak, and Brays bayous. When the study was initiated in 1999, it began as a feasibility study of 9.2 miles of channel modifications on the upper reach of White Oak Bayou including nonstructural flood plain management of future suburban development. The sponsor, HCFCD completed the General Reevaluation Report under Section 211(f) of WRDA 96 and received the Assistant Secretary of the Army (Civil Works) approval on August 28, 2014. The recommended plan includes earthen channel modification from Cole Creek to FM 1960; four detention basins of approximately 2,940 acre-feet of storm water storage; 4.99 acres of compensatory wetland credits in the Greens Bayou Wetlands Mitigation Bank; and approximately 12 miles of a linear bikeway. The proposed project reduces the extent of the 10 percent and 1 percent floodplain areas so that 1,285 and 1,511 structures, respectively, would now be located outside of the two reduced floodplain areas, leaving 48 and 4,563, structures, respectively, within the floodplains (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Hunting Bayou Flood Risk Management Project. The USACE evaluated flood risk management on Hunting Bayou. The Hunting Bayou watershed is located in central Harris County, Texas, northeast of downtown Houston, and is about 30 square miles. Hunting Bayou runs approximately 15 miles from its headwaters west of U.S. Highway 59 to its confluence with Buffalo Bayou near the Houston Ship Channel. Flooding problems on Hunting Bayou are primarily the result of flat topography and channel inadequacy to discharge increased runoff from urban development that occurred prior to local watershed management policies. The existing flood risk impacts life, health and safety of many who live in Harris County. The infrastructure within the Hunting Bayou 0.2 percent floodplain includes Lyndon B. Johnson General Hospital, the State's busiest Level III trauma center, which serves some of the 4.1 million people living in and beyond the Hunting Bayou watershed. Infrastructure impacted within the Hunting Bayou watershed: public schools, water treatment plant, hospitals, clinics, police and fire stations, daycare centers, and elder care facilities. Regionally significant infrastructure: electrical transmission and oil and gas product pipelines and two major railroad yards traverse the Hunting Bayou and broader watershed. Access to freeways, major transportation routes, and connections to hurricane evacuation corridors such as I-610, U.S. Highway 59, and I-10, and emergency response for medical transportation, police and fire officials have been, and likely will be, significantly hindered during a major flood event. Sections of these facilities are in the Hunting Bayou watershed. Consequently, the interregional transportation system is compromised during intense rainfall that accompanies tropical weather systems; freeway access flooding which precedes hurricane evacuation and can be a significant detriment to coastal residents fleeing low-lying areas for higher ground. The Hunting Bayou 1990 Authorized Plan is part of the Buffalo Bayou Tributaries, Texas, authorization found in Section 101(a)(21) of WRDA 1990. The approved General Reevaluation Report of December 2014 defines a Locally Preferred Planof 3.8 miles of grass lined channel, 75 acres of detention basin, 14 bridge modifications, three railroad bridge replacements, and 5.16 acres of wetland credits at Greens Bayou Wetland Mitigation Bank. The EA demonstrates that the Selected Plan falls within the 1990 authorized footprint and intent for flood prevention along Hunting Bayou (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

Bolivar Peninsula Debris Removal. The GLO has proposed to remove debris, pilings, and abandoned oil and gas infrastructure along the Gulf-facing beaches of Bolivar Peninsula. A barge mounted crane and material barge, in addition to smaller craft, would be utilized to retrieve and transport debris for disposal. The GLO plans to use RESTORE Act funds for the project (SWG-2016-00338)

Houston Ship Channel Expansion and Channel Improvement Project. The Chief's Report for the IFR-EIS for the project to deepen and widen the Houston Ship Channel and several ancillary navigation channels was signed on April 23, 2020. The project has begun the preconstruction engineering and design phase and a supplemental EA is expected to begin Public Review before the end of 2020. Several impacts were identified in the EIS. The proposed deepening project may result in a minor increase in bottom salinities farther up the channel. The project may also result in unavoidable temporary impacts to unvegetated estuarine bay and river bottom and permanent impacts to between 469 and 538 acres of oyster reef. Temporary avoidance and disturbance would occur during construction and maintenance dredging. The project may affect, but is not likely adversely affect, endangered sea turtles; a Biological Assessment is being coordinated with the NMFS and USFWS for concurrence. No specific cultural resource impacts have been identified; cultural resource investigations will be performed in the next planning phases. The USACE has determined that the Recommended Plan has the potential to cause effects on historic properties and will execute a Programmatic Agreement in coordination with the State Historic Preservation Officer (SHPO) to address the identification and discovery of cultural resources that may occur during the construction and maintenance of the project (USACE, 2017b).

Houston Ship Channel Barge Fleeting Expansion. The Port of Houston has proposed the expansion of a barge fleeting facility located near the confluence of the Houston Ship Channel and Old River. The expansion would include the dredging of approximately 550,000 cy of material from a 28.5-acre area, and the installation of 9 monopiles and 70 mooring structures. While the majority of dredged material would be moved to approved placement areas, 85,000 cy would be used to raise the grade at a site adjacent to the dredge area (SWG-2016- 00441)

Buffalo Bayou Petroleum Storage and Marine Terminal. Magellan Terminal Holdings LP has proposed the construction of a 188-acre petroleum bulk storage marine facility to receive, store, and transport petroleum hydrocarbons. The terminal would be located on a former dredge material placement area and include up to 86 storage tanks and associated infrastructure, as well as ship and barge births and bulkheads. A total of 5,457,700 cy of material would be excavated, 1,200,700 on land, and 4,257,000 by dredging. One million cy of material would be used on site to increase base elevation, and the remaining material would be placed in approved placement areas (SWG-2016-00635).

Bayport Turning Basin. The USACE will investigate the feasibility of assumption of maintenance for the Bayport Turning Basin. The Bayport Turning Basin was constructed in 2008 by the Port of Houston to accommodate the Post-Panamax and large container vessels. Current conditions require vessels to travel to the end of the Bayport Ship Channel in order to turnaround and exit to the Houston Ship Channel. The importance of this investigation is to identify an efficient option to reduce congestion delays and safety concerns with other vessels at the container, bulk, and petrochemical terminals. The study area includes the Bayport Turning Basin located on the south side of the Bayport Ship Channel. The Bayport Ship Channel is located along the west side of the Houston Ship Channel, southeast of the City of Houston along Texas State Highway 146 north of the City of Seabrook. The study will review the feasibility of assuming the operation and maintenance of the channel constructed by the Port of Houston Authority. The study will use existing economic, environmental, and dredging cost data to complete a rapid assessment of viability. The study will determine if the constructed channel and turning basin is economically justified, environmentally acceptable, and that they were constructed in accordance with applicable permits and appropriate engineering standards. The Port of Houston Authority has requested the USACE Galveston District to assess the scope of the required studies and work towards an expedited path to complete the study. Funds provided in fiscal year 2018 will be used to initiate and complete the feasibility study. The general scope of the study includes calculation of economic benefits associated with the facility, determination of environmental acceptability, estimation of future maintenance cost, and evaluation of facility design and construction (USACE, 2018a).

Galveston Channel Extension. WRDA of 1996 authorized the USACE to deepening and widening of the Galveston Harbor Channel from 40 feet deep to 45 feet. This deepening was completed in January of 2011; however, the deepening effort stopped at Station 20+000 of the Galveston Harbor exclusive of the last 2,571 feet at the most westward end to the Galveston Channel. At the time of the 1996 WRDA authorization, the remaining 2,571 feet had been evaluated for deepening to 45 feet but was determined to not be economically justified since there were no portside services facilities in place. In the intervening years, conditions changed and beginning in 2006 portside service facilities began operation and utilizing the 40-foot channel. A feasibility study is currently being conducted to investigate the feasibility of extending the 45-foot-deep Galveston Harbor Channel the additional 2,571 feet to reach the end of the limits of the existing 40-foot channel (USACE, 2018a).

Clear Creek Flood Risk Management. The USACE project provides flood risk management for an extensively developed urban area. There are 17 cities at least partially within the Clear Creek watershed including Houston, Pasadena, Pearland, Friendswood, Webster, and League City, some of the fastest growing cities in the Houston area. Flooding in 1973, 1976, twice in 1979, 1989, 1994, 2001, 2006, 2009, and 2017 (Harvey) caused extensive property damage. The authorized project consists of approximately 15.3 miles of channel enlargement and bend easing, more stringent regulations restricting development of the 100-year floodplain, and a second outlet channel with a gated structure between Clear Lake and Galveston Bay. In June 1986 a Local Cooperation Agreement was signed to execute the construction of the project. Under the Local Cooperation Agreement, the second outlet work structure and channel were constructed; however, environmental concerns were raised on the plan of construction for the upstream reaches due to potential of induced flooding on the downstream reaches. Construction was placed on hold pending reformulation of the project under a General Reevaluation Report. The report was approved on February 11, 2013. The recommended plan includes conveyance improvements in high flood damaged reaches on Clear Creek, Mud Gully, Turkey Creek, and Mary's Creek and linear detention within the Clear Creek conveyance improvements. The local sponsors are the HCFCD and Galveston County (USACE, 2018a). The hydrologic changes from the flood risk management features could be greater than the nominal salinity changes from the TSP features which restrict the flow of water between the bay and the Gulf.

GIWW Coastal Resilience Study. The study area includes the section of the GIWW located in Brazoria and Matagorda counties, which experiences excessive shoaling following floods and hurricanes. Erosion of the barrier islands along this section of the GIWW allows sediment from Caney Creek and the Gulf inlet flow directly into the GIWW causing draft restrictions and traffic delays. The USACE would evaluate potential solutions to alleviate the excessive shoaling that could include training structures or jetties, replacing erosion of the barrier islands, increase advance maintenance to increase the dredging interval, locks to prevent high shoaling during heavy flows, and many others. These proposals are expected to greatly increase waterborne transit efficiency. The general scope of the study includes analyzing alternatives to reduce the channel sedimentation and protecting the inland waterway from the waves and currents from the Gulf. Replacement of these land losses will decrease the vulnerability of continued safe and reliable barge tow transit on the GIWW to disruption. Decreased vulnerability includes less exposure of the GIWW to the forces of the Gulf open sea conditions to shallow draft navigation. It also would reduce exposure of sedimentation from the Gulf, diminishing the frequency and volume of channel shoaling and associated maintenance dredge requirements. This would result in cost savings to the USACE GIWW channel maintenance program (USACE, 2018a).

Dickinson Bay Waterbird Rookery. The Galveston Bay Foundation has proposed the construction of an 8.9-acre bird rookery island to provide 4.5 acres of upland habitat and 1 acre of oyster reef habitat. The U-shaped island would be composed of material from either beneficial use of dredged material in the mid-bay reach of the Houston Ship Channel or fill from an unnamed borrow site. The base material would be surrounded by a rock breakwater on three sides to protect and stabilize the island. An opening on the northwestern side of the island would make room for a shallow-water beach and a submerged oyster reef to attenuate wave action (SWG-2015-00810).

Dollar Bay and Moses Lake Marsh Terraces. The Galveston Bay Foundation has proposed the placement of fill material into two sites for the creation of planted marsh terraces. Site 1 is 12.9 acres in Dollar Bay, and Site 2 is 4.53 acres in Moses Lake. The 46,900 cy of material would be placed into Site 1, and 14,400 cy would be placed into Site 2. Rock breakwaters would be installed at both sites to protect from wave erosion. The breakwaters would have a crest width of 3 feet and an elevation of +2 feet NAVD 88. Geotextile fabric would be used under the breakwater to limit scouring and settling (SWG-2017-00032, 00033).

Texas City Turning Basin Improvements. The Texas City Terminal Railway Company has proposed dredging, dock removal, and other shoreline improvements to the inner Port of Texas City. Extensive dredging would be performed in a 9.2-acre berthing area, and 2.2 acres of upland would be converted to open water, creating a total of 431,000 cy of material for placement. Other work includes the demolition of a 320-foot dock, three dry docks, and 920 feet of existing bulkhead. A new 1,193-foot dock would be constructed, along with 840 feet of steel bulkhead, and 45,000 square feet of articulated concrete mat in front of the new bulkhead for erosion protection (SWG-2013-00042).

Spoonbill Bay Mixed Use Development. A mixed-use development is planned for a 115.37-acre tract in West Bay, 3 miles northeast of San Luis Pass. The proposed development will consist of a single marina, water front homes, access roads, and two channels. Approximately 10.76 acres of jurisdictional waters would be impacted; 6.08 acres of non-tidal wetlands, 1.53 acres of tidal wetlands, and 0.40 acre of sandflats. An additional 2.75 acres would be impacted through the dredging of the navigable channels, where 44,333 cy of material would be used to build up the site. The applicant has proposed on-site mitigation through the creation of 2.23 acres of non-tidal wetlands, 0.83 acre of living shoreline, and 6.52 acres of tidal wetlands (SWG-2007-01475).

San Luis Pass Dredge and Follets Island Nourishment. Brazoria County has proposed to dredge approximately 376,200 cy of sand material from West Bay and San Luis Pass for beach nourishment on the north end of Follets Island. The 160-foot-wide by 12,000-foot-long dredge area would improve vessel access through San Luis Pass and would be excavated to –9 NAVD 88. Sand would be placed nearshore, within the submerged portion of beach to reduce wave action and allow for onshore movement of material (SWG-2015-00306).

San Bernard River Mouth Restoration. Brazoria County has proposed to hydraulically dredge approximately 400,000 cy of material from the existing San Bernard River channel to restore consistent flow through the river mouth. A total of 30.1 acres is expected for the dredge footprint, with 21.6 acres of channel bottom, and 8.5 acres of side slope. Suitable dredge material would be beneficially used to restore marsh habitat along the GIWW, and sandy material would be placed in a 17.6-acre surf zone placement area. The two primary restoration areas are located in Cedar Lakes within the San Bernard NWR, and total 133.32 acres. Restored areas would also be planted with smooth cordgrass about 60 days after dredge material placement. A third 69.86-acre restoration area would be used after completion of areas 1 and 2 and involves shoreline protection with levees along the GIWW (SWG2015-00603).

4.9.2.2 Mid to Upper Coast

Harbor of Refuge Bulkhead. The City of Port Lavaca is proposing to construct approximately 4,500 feet of bulkhead and remove and replace approximately 2,000 feet of existing bulkhead around the Harbor of Refuge. The construction will impact 1.82 acres of bay bottom and 0.17 acre of wetland. The 4 acres of saltmarsh has been constructed to mitigate the impacts. The project has not been completed (SWG-1995-02218).

Mid-Coast Bird Rookery Island. The TNC is proposing the construction of an 803-foot-long by 445-foot-wide bird rookery in San Antonio Bay. The plan calls for placing 239,500 cy of fill material and rock riprap shoreline armoring. The rookery island will provide 4 acres of bird habitat and 1 acre of submerged reef habitat. The project has not started (SWG-2017-00516).

Port of Port Lavaca-Point Comfort and Matagorda Ship Channel Expansion. The Calhoun Port Authority is proposing to construct an additional turning basin and deepen the existing berthing facilities to accommodate larger ships at the port of Port Lavaca-Point Comfort from 36 to 44 feet. The Calhoun Port Authority is also proposing to deepen the channel from 36 to 44 feet and widen from 200 to 400 feet for the entire 26 miles of the ship channel. The project has not started (SWG-2006-00092).

Palacios Channel Maintenance Dredging. The Port of Palacios is proposing to maintain the Palacios Ship Channel. The channel will be dredged from a depth of 11 to 14 feet, and the bottom with be widened to 125 feet. Approximately 731,904 cy of material will be removed. Dredged material will be placed at a beneficial use of dredged material site near Sartwelle Lakes to restore hydrological function to the low-lying marsh. The project has not started (SWG-2014-00782).

4.9.2.3 Mid to Lower Coast

Port Bay Harbor Dredging. Landowners and developers plan to excavate a 3.973-acre harbor canal from an upland site. Approximately 58,000 cy of material will be removed and spread over the remaining upland areas. The 10-foot-deep harbor will be connected to an existing canal in Port Bay. The perimeter of the harbor will be capped-concrete bulkhead, and the created canal will be routinely dredged. The project has not been completed (SWG-2008-00997).

Aransas County Oyster Reef Restoration. The Harte Research Institute at Texas A&M University-Corpus Christi is proposing to construct a 1-acre educational oyster reef and 10 acres of restored oyster reef on State Tracts 67 and 68 in St. Charles and Aransas bays. The project will use reclaimed oyster shells from seafood wholesalers and restaurants, cleaned crushed concrete, limestone, river rocks, and other clean hard surfaces. The materials will be placed in 24-inch mesh bags containing approximately 3 gallons of oyster shells. The reef mounds will be 12 inches high by 10 yards wide by 60 yards long (SWG-2011-00365).

Fulton Beach Road Shoreline Stabilization Project. Aransas County is proposing the construction of 3,220 feet of breakwater to protect the shoreline and coastal wetlands from erosion. Each breakwater will measure 70 feet long, 26 feet wide at the base, a 4-foot-wide crest, 2:1 side slopes, and a total height of 4.5 feet. There will be 46 overlapping breakwaters covering an area of 1.3 acres. The area along the shoreline behind the breakwaters will be planted with smooth cordgrass and saltmeadow cordgrass. No work on the project has been completed, and a request to extend the time limit of the standard permit by 5 years has been submitted (SWG-2011-01237).

La Quinta-Ingleside Dredging. OXY Ingleside Energy Center is planning to use Berry Island, an existing confined area, as a dredged material placement area. The area will be used to place 1,200,000 cy of initially dredged material and 200,000 cy of maintenance material (every 3 to 5 years) afterwards from the La Quinta Ship Channel (SWG-1995-02221).

La Quinta Ship Channel Crude Condensate Storage and Marine Terminal. Cheniere Liquids Terminal, LLC is proposing a duAl vessel berthing area, two docks, an onsite dredged material placement area, and various supporting infrastructure (such as storage tanks, roads, parking areas, and administrative buildings). Approximately 2.6 mcy of stiff clay will be mechanically or hydraulically dredged including a 40-acre berthing basin and two marine docking structures. Work on the project has not yet started (SWG-2014-00848).

OXY Ingleside Energy Pier Dredging Activities. OXY Ingleside Energy Center, LLC is proposing the deepening of approximately 67 acres of channel depth adjacent to their east and west docking slips. Approximately 478,498 cy of dredged materials will be removed and placed in a dredged material placement area. Seagrasses are present in the west slip areas but are not expected to be disturbed. Work on the project has not yet started (SWG1995-02221).

North Beach Sand Placement. The city of Corpus Christi is proposing beach nourishment activities on a 3,900- foot stretch of North Beach. The proposal calls for placing 130,000 cy of imported inland sand and 20,000 cy of excavated and redistributed sand from the accretional end of the existing beach. Beach nourishment activities for the project have not yet started (SWG-1998-00131).

McGee Beach Sand Placement. The city of Corpus Christi is proposing beach nourishment activities on a 1,700- foot stretch of McGee Beach. The proposal calls for placing 14,000 cy of beach quality sand over approximately 4.18 acres. Sand placement has not yet begun (SWG-2002-01934).

Nueces Bay Rookery Island Shoreline Armoring. Coastal Bay Bend and Estuaries Program is proposing to install shoreline protection measures for several bird island rookeries in Nueces Bay. The islands will be armored with articulated concrete blocks or rock riprap. Approximately 4,200 cy of fill materials will be used to protect the islands. The project has not begun (SWG-2013-01068).

Nueces Bay Shoreline Protection Measures. Coastal Bay Bend and Estuaries Program is proposing to construct 3,901 linear feet of concrete breakwater to provide shoreline protection to the Nueces Bay Delta. The breakwater system will consist of 12 structures and utilize approximately 1,008 cy of porous concrete (SWG-2014-00725).

Corpus Christi Channel Marine Terminal Expansion. Plains All-American Pipeline LP is proposing the construction of an import/export liquid terminal and storage facility along the Corpus Christi Channel large enough to support Aframax ships and oceangoing barges. The proposal calls for dredging 514,557 cy of material over 12.7 acres of water (SWG-2014-00260).

Magellan Crude and Hydrocarbon Bulk Storage Terminal. Magellan Terminal Holdings LP is proposing to construct a 95-acre bulk storage holding terminal and docking facility along the Corpus Christi Ship Channel. The facility will include 27 bulk storage tanks, 4 docking platforms, bulkheading, and shoreline protection (SWG2016-00285).

Dagger Island Breakwater and Containment Area. TPWD is proposing to construct rock breakwaters parallel to the existing shoreline of Dagger Island. TPWD is also planning to construct a 28-acre containment area around a historic island footprint to accept dredged materials for beneficial use. The project has been proposed but construction has not started (SWG-2017-00295).

Pipelines. There are several pipeline projects that are reasonably foreseeable along the Corpus Christi Ship Channel. These include the 8.6-mile-long Oxy Viola station pipeline (SWG-2014-01002), 2-mile-long M&G Polymers plant pipeline (SWG-2015-00136), 3 parallel 16-mile-long Magellan pipelines across the Corpus Christi Ship Channel (SWG-2014-00518), 70-mile-long Flint Hills Refinery pipeline (SWG-2016-00657), and 8.2-mile-long Gravity Midstream pipeline (SWG-2016-00032).

4.9.2.4 Lower Coast

Brownsville Resacas Ecosystem Restoration. The USACE has evaluated ER actions with Brownsville Resacas. The project is located along the Resaca Boulevard near the Rio Grande in the southern half of Cameron County, Texas. The Resaca consists of former channels of the Rio Grande that have been cut off from the river, having no inlet or outlet because of siltation of the oxbow channels, and loss of critical native aquatic and riparian habitat. The unique thorn scrub riparian vegetation associations of the resacas are found exclusively in Resaca and riparian corridors of the Lower Rio Grande Valley, and they have been designated by the TPWD as habitats critically imperiled with extinction or elimination. The Resaca and its associated thorn-scrub riparian habitat are listed in the draft USFWS Ocelot Recovery Plan as critical transportation corridors for dispersing ocelots. The USFWS has determined that close to 99 percent of this habitat has been degraded on the Lower Rio Grande Basin within the United States and Mexico. Before land development and water control, floodwaters from the Rio Grande drained into resacas from the surrounding terrain. The primary hydrologic function of the resacas was diversion and dissipation of floodwater from the river. Measures that would be implemented per the NER plan include dredging accumulated sediment (completed by sponsor at no cost to the project), restoring wetland habitats, and restoration of the imperiled riparian vegetation associations. Restoration of the resacas would potentially provide habitat benefits for the Federally endangered species ocelot, a Federally endangered cat, jaguarondi, a Federally endangered cat, black-spotted newt (amphibian), and Rio Grande Cooter (turtle). The NER Plan would provide a total of 5.4 average annual habitat units over the current 0.03 average annual habitat units of the degraded ecosystem (USACE, 2018a).

Brazos Island Harbor Improvement Project. The Port of Brownsville has proposed to deepen Brazos Island Harbor, thereby expanding local industry and opening the harbor to larger ships now utilizing the improved Panama Canal. The project has been approved by the USACE, but congressional authorization remains for Federal funding. The Brazos Island Harbor entrance channel and jetty channel are proposed to be deepened to −54 MLLW from a current depth of –42 MLLW. No channel widening is proposed; however, where necessary, the channel may be extended or varied to maintain the channel side slopes. Dredged material is to be placed into upland dredge material placement areas and placed for beneficial use onto a feeder berm offshore of South Padre Island (SWG-2016-00038).

Port of Brownsville LNG Terminal #1. Texas LNG Brownsville LLC has proposed construction of an LNG storage and export facility adjacent to the Brownsville Ship Channel. The 625-acre site is between the north side of the channel and SH 48, approximately 19 miles northeast of the city of Brownsville, in Port Isabel, Cameron County. The facilities would be composed of a terminal to liquefy and store natural gas and marine facilities to export LNG and serve as port for vessels during construction. Included in the project is the removal of an abandoned pipeline that runs parallel to the Brownsville Ship Channel (SWG-2015-00175).

Port of Brownsville LNG Terminal #2. Rio Grande LNG has proposed construction of an additional LNG export facility on Port of Brownsville land south of SH 48, bounded to the west by the Bahia Grande Channel. The 984- acre terminal site would have up to six liquefaction trains, natural gas pretreatment facilities, four LNG storage tanks, operational infrastructure, and truck-loading facilities. The LNG facility would also include marine loading berths for LNG vessels, and require dredging to create a turning basin adjacent to the loading berth. Rio Grande LNG is also proposing onsite restoration and enhancement for mitigation of unavoidable impacts to waters of the U.S. The primary objective is to fund and restore the widening of the Bahia Grande Channel, to improve the tidal connection with the Brownsville Ship Channel (SWG-2015-00114).

Port of Brownsville LNG Terminal #3. Annova LNG has proposed the construction of an LNG terminal on the south side of the Brownsville Ship Channel, across the channel from the Bahia Grande. The proposed 731-acre facility would include LNG and marine transfer facilities, in addition to an access road. The project would permanently impact 37.1 acres of wetlands, 0.1 acre of estuarine emergent marsh, 36 acres of palustrine emergent ponds, 0.5 acre of estuarine open water, and 1.2 acres of tidal flat. Temporary impacts would include 19.2 acres of wetlands for initial clearing and fencing construction. The applicant is developing a final mitigation plan that should consist of aquatic resource preservation onsite, enhancement, creation, and/or restoration (SWG-2015- 00110).

Port of Brownsville Subsea 7 Spool Base Facility. The Brownsville Navigation District has proposed the construction of a 60-acre spool base facility on the south side of the Brownsville Ship Channel to load, store, and transport piping for pipe lay projects. The waterfront features of the project would include construction of a three-sided vessel slip with bulkhead, slope revetment, and installation of a mooring and a breasting structure. Other planned structures include buildings, a piperack for joining pipe units, drainage corridors, and an access road to SH 4. The 13-acre vessel slip would have dimensions of 1,000 feet long by 900 feet wide and accommodate 525- foot pipelay vessels. The vessel slip would be dredged to –35 feet mean low tide, and approximately 654,000 cy of dredge material would be removed and placed in approved placement areas. Project impacts include 7.6 acres of permanent impact from vessel slip dredging, and 3.03 acres of impact to jurisdictional features from onshore facilities (SWG-2017-00250).

Arroyo Colorado Aeration Structures. The Port of Harlingen has proposed the installation of three aeration water control structures in the main stem of the Arroyo Colorado River. Each structure is essentially a riprap weir meant to create a riffle, adding dissolved oxygen and improving water quality. Each structure would be 0.03 acre of impact to jurisdictional river bottom totaling 0.09 acre of permanent impacts (SWG-2016-00303).

East Wye Channel Widening. The Port Isabel-San Benito Navigation District has proposed to widen the East Wye Channel from 200 feet to approximately 350 feet in width. Additionally, the channel would be deepened to –38 NAVD 88 with 2 feet of overdepth. Approximately 195,630 cy of material is to be removed by hydraulic dredge from the 10.48-acre area and placed in the existing Dredge Disposal Area 3 Brazos Island Project. A 10-year maintenance dredge permit was also requested, which would result in an additional 20,000 cy of material removed over that time span. The applicant proposed the use of silt control measures, and to avoid all seagrass areas and oyster beds (SWG-2014-00849).

Bahia Grande Main Channel Project. The Brownsville Navigation District has proposed to widen and deepen the existing pilot channel between the Bahia Grande and the Brownsville Ship Channel. Approximately 200,000 cy of material would be excavated from the existing pilot channel and adjacent land and moved into adjacent placement areas. Permanent impacts include the conversion of 8.06 acres of jurisdictional area to open water, and 22.32 acres of jurisdictional area converted to upland, for a total of 30.38 acres. Affected jurisdictional features include tidal flats, open water, and palustrine emergent and palustrine scrub-shrub wetlands (SWG-2003-01954).

Long Island Village Residential Development. The estate of John Freeland has proposed to excavate 11.99 acres and place fill in 99.04 acres of jurisdictional waters to construct a residential canal subdivision in the Port Isabel area. The applicant proposed mitigation for the project, consisting of the onsite construction of a 22-acre mangrove and seagrass habitat area, and the preservation of 108.4 acres east of the project site. The protected area includes 89.6 areas of submerged seagrass habitat and 18.8 acres of mangrove wetlands (SWG-1999-02327).

South Padre Island Second Access. An additional access route to and from South Padre Island was proposed through a partnership among the Cameron County Regional Mobility Authority, TxDOT, and the Federal Highway Administration. The project consists of South Padre Island and mainland road improvements, and a bridge spanning the Laguna Madre. Approximately 139.14 acres of wetlands would be affected by the preferred Alternative 6, primarily due to bridge supports impacting Laguna Madre bay bottom. SAV in the form of seagrasses would also be affected. Construction is expected to begin in 2020.

4.9.3 Cumulative Impacts analysis for the Tier One Measures

The impact analysis for the Tier One Measures will be further refined in the Tier Two NEPA studies. This cumulative effects discussion is intended to provide the foundation for the Tier Two impact analyses. The Tier One Measures included in the Recommended Plan would continue the trend of projects designed to make the region more resilient to coastal storms and to protect navigation and infrastructure. After the 1900 storm sent a 15-foot storm surge careening towards Galveston Island, a number of modifications were made to the Island to make it more resilient to tropical storms. Those modifications included the construction of the seawall, the grade raising, and the construction of the groin system. Similarly, numerous modifications to the Galveston Bay System were made to improve the resiliency of the navigation systems. Some of those modifications include the construction of the Galveston Jetties, the Texas City Dike, the GIWW, and the ongoing improvements to the Houston Ship Channel. The construction of dredge material placement areas has shaped many of the dynamics in the bay system today. Several examples of the placement areas include Pelican Island, Redfish Island, the Midbay placement areas, and the placement areas north of the GIWW near Sievers Cove. Additionally, numerous Flood Risk Management projects have altered the delivery dynamics of water into the Bay system. Reservoirs regulate releases, detention basins slow the release of water, and channelization increases the delivery rates. Also wastewater treatment facility ensure that tributaries have some water inflow year round. These modifications are examples of how development has shaped the region and the scale of those modifications is very large.

Currently, the Port of Houston is working on designs for improvements to the Houston Ship Channel, the Harris County Flood Control District is constructing and designing several Flood Risk Management Projects in the Houston Area. Development in the Houston Metro Area is expanding and developers are required to get permits for impacts to Waters of the U.S. and for water quality.

In the foreseeable future it is likely that many of these projects will be constructed which would increase the tonnage handled by the Ports located in the Galveston Bay System, there would likely also be an expansion of industrial facilities, and urban development in the region will continue to grow.

The number of ecosystem restoration projects along the Texas Coast is expanding as the number of funding sources increases. These projects range in size from smaller neighborhood rain gardens to large federal projects like the Jefferson County Ecosystem Restoration project. This type of work is expected to increase and as technologies improve and restoration strategies are refined, the effectiveness and life of the projects is expected to increase. These activities also include the protection of valuable habitats that help to maintain the ecosystems in the Galveston Bay System. State and federal agencies and NGOs are working to acquire and to protect these important habitats.

4.9.3.1 Conclusion

The ER measures included in the Recommended Plan include beach and dune restoration, marsh restoration, shoreline protection, bird island restoration, and oyster reef creation. Many past, present, and reasonably foreseeable projects address restoration of coastal resources (which have the capacity to alter geomorphology and coastal processes). Some of these projects reduce erosion, provide habitat, function as storm buffers, promote recreational and commercial fisheries, improve water quality, for example; the recommended plan ER measures would result in the same benefits. The ER measures would result in positive environmental impacts. ER measure construction is anticipated to temporarily increase turbidity, dissolved oxygen, and contaminants in the water column that would occur during dredging activities and placement of rock breakwater and sediments. Long-term direct and indirect impacts of the ER measures on wetlands and marshes in the region will be positive and will mitigate marsh loss from shoreline erosion and sea level rise. Revetments and breakwaters will diffuse erosional forces approaching the shoreline and protect sediments from disturbances. Marsh nourishment efforts would complement current and future marsh restoration efforts by State, Federal, non-government organizations, and private entities. With regards to ER measures, the cumulative effects of the recommended plan would be beneficial when combined with other past, present, and reasonably foreseeable restoration actions around Galveston Bay.

The CSRM measures located in Region 1 are likely to alter the dynamics in the Galveston Bay System. The largest potential change anticipated for the Recommend Plan would result from the Bolivar Roads Gate System, which would alter tidal dynamics by creating a constriction through Bolivar Roads. With the measure across Bolivar Roads resulting in a less than 10 percent constriction, analysis shows an overall tidal prism reduction between 3 and 7 percent, and a tidal amplitude reduction between 2.4-5.7 percent. With the Coastal Barrier CSRM measure in place, freshwater would stay in Galveston Bay longer, resulting in an average reduction in salinity between 0 to 2 ppt. In general, a slight reduction in bay velocity would likely occur, with an average reduction of 0.8 to 3.9 inches per second. An increase in velocity at the Bolivar Roads inlet would also be expected, with maximum velocity increasing from 3.9 to 5.9 feet per second. These alterations to the tidal system may result in impacts to some aquatic species, wetlands, and EFH, for example. Despite modeling efforts to identify potential changes from the recommended plan, actual changes are hard to predict. Climate variability (e.g., drought and flood events) and RSLR also contribute to the uncertainties regarding the magnitude of the impacts, both positive and negative. To offset these penitential impacts and the other potential impacts discussed in this Chapter, a mitigation plan has been developed that used ecological modeling and expert information from resource agencies. While the characterization of the impacts and the development of the mitigation plan has been advanced as much as possible, the Tier Two environmental studies will add new information from public the resource agencies, and the additional analysis that will be available at that time.

While the measures included in the Recommended Plan are most certainly going to alter the dynamics of the system, the PTD has worked diligently to assess the potential impacts of those changes and to avoid, minimize, and develop mitigation for the unavoidable impacts. The Galveston Bay System has been heavily altered however, the system still contains numerous ecological resources that need protection and/or restoration. The ER measures included in the Recommended Plan are consistent with those efforts and would result in benefits to the environment.

5.0 ENVIRONMENTAL CONSEQUENCES ACTIONABLE MEASURES

This chapter evaluates the potential impacts of the actionable measures of the Coastal Texas Study. Actionable measures have sufficient site-specific information to complete a Tier Two environmental analysis within the larger EIS document. When combined with other relevant chapters in this EIS, the analyses here provide sufficient information on the potential adverse and beneficial environmental effects to allow the District Engineer to make an informed decision on whether or not to implement these actionable items through signing of the ROD and subsequent authorization and appropriation of funds to construct by Congress. The analysis meets the requirements of NEPA, CEQ Regulations (40 CFR 1500—1508) and USACE ER 200-2-2 (33 CFR 230). It is also compliant with the Endangered Species Act (ESA), National Historic Preservation Act (NHPA), Clean Water Act (CWA), and other laws and regulations listed in Chapter 6 – Compliance with Laws and Regulations.

5.1 ANALYSIS APPROACH

Similar to the Tier One approach to the analysis impacts are considered in this section and are described as either beneficial or adverse. Throughout this document, the terms “impacts”; “effects”; or “consequences” are synonymous.

Beneficial impacts result in a positive change in the condition of the resource when compared to the No Action alternative. Adverse impacts result in a negative change in the condition of the resource when compared to the No Action alternative. Impacts are also described in terms of duration. Temporary impacts would not persist long after implementation of the management action. Long-term impacts would be permanent or continuous over the period of analysis.

Finally, impacts are also described in relation to their significance. The CEQ regulations[4] require consideration of both context and intensity when determining the significance of an impact on a resource. Context means considering the extent of the impact such as in a national, regional, or local setting. Intensity refers to the severity of the impacts and follows the same descriptions as provided for the Tier One Environmental Consequences Analysis including: No or Negligible Impact, Less than Significant, Significant and Unavoidable, and Too Speculative for Meaningful Consideration.

The main difference between the analysis for the Tier One Measures and Actionable Measures is that the analyses for the Actionable Measures are more site-specific and not

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[4] The updated CEQ regulations (40 CFR 1500-1508, 1515, 1516,1517, and 1518) effective on September 14, 2020 give that agencies have one year to update their regulations to be consistent with the updates. The USACE is allowing NEPA documents that were underway to continue using the previous format. The updated regulations replace the term context with “potentially affected environment” and intensity with “degree.”

broad overviews of the impacts. With that, there should be minimal to no potential impacts that warrant future investigations to fully understand the context or intensity of the impact within the analysis for the Actionable Measures.

This analysis for the Actionable Measures describes the adverse and beneficial impacts of the No Action (baseline condition) and the final array of ER Alternative Plans, which includes Alternative D2 and Alternative A. The two actiona alternatives include implementation of the same Actionable Measures. Therefore, for comparative purposes, Alternative D2 and Alternative A would have the same actionable measure impacts and are not further differentiated.

The actionable items being assessed include all of the ER features, except B-2. B-2 is not included as an actionable item because the precise location of the sand source(s) has not been identified. **Table 5-1** shows the actionable measures and the anticipated construction duration and potential footprint of each.

Like Chapter 3 and 4, this chapter is organized by resource topic with the impacts of each individual component (e.g. breakwaters, island restoration, wetland and marsh restoration, oyster reef, dune/beach restoration, and new work dredging) of the actionable measures (e.g. G-28, B-12, CA-5, CA-6, M-8, SP-1, and W-3) described. The impacts described would be anticipated for any actionable measure at any of the locations which include that component. Where impacts vary across locations, actionable measure specific impacts are described only when additional impacts are anticipated to be greater than the general impacts.

5.1.1 Assumptions

For the purposes of this analysis and the "worst case scenario", the construction duration assumes that only one restoration area is worked on at a time and that when one area is complete the next would commence without extended breaks between contracts. The reality is that contracts will most likely overlap and concurrent work will be implemented.

When considering impacts, it was assumed that, at a minimum, best management practices (BMPs) identified throughout this chapter would apply during project construction. Assumed BMPs are based primarily on widely accepted industry, State and Federal standards for construction activities.

Specifically related to the dredging component, the impacts of dredging activities (e.g. excavation and scraping of the sea bed and transport and placement of sediments) are only described for the new work dredging associated with W-3. All sediment needs for implementation of the five actionable measures requiring dredged material would come from the GIWW or nearby channels during routine O&M cycles or by mining material from existing Upland Placement Areas (PAs) (O&M Column in **Table 5-1**). The impacts of the O&M dredging (e.g. excavation and scraping of the sea bed) would occur in the future with or without implementation of the actionable measures and are considered part of the No Action. As well, the impacts of a number of the dredging projects have been previously described in NEPA documentation associated with that specific project and location. Analysis of the five actionable measures that require dredged material will focus only on the transportation and placement of dredged material because that part would be different than what would be expected in the absence of the actionable items being implemented.

5.2 LANDS WITH SPECIAL MANAGEMENT

5.2.1 No Action

Under the No Action Alternative, land management would remain the same. Each of the special management areas would continue to be managed according the reasoning that the area was established.

5.2.2 Alternative D2 and Alternative A

5.2.2.1 Coastal Zone

Under the Coastal Zone Management Act, the Texas General Land Office (GLO) is responsible for implementing the Texas Coastal Management Plan (TCMP) that was developed for Texas. Within this plan there are 20 enforceable policies (**Table 5.2**) and 16 critical natural resource areas (CNRAs). Any Federal undertaking within the CZMA boundary must be consistent with the enforceable policies and must not adversely affect CNRAs. Adverse effect for the purposes of the TCMP are “Effects that result in the physical destruction or detrimental alteration of a CNRA.” Due to the nature of ecosystem restoration measures incorporated into each of the four plans, no adverse effects to any of the CNRAs are anticipated.

Direct or indirect adverse impacts would be localized and temporary and not result in any long-term physical destruction or detrimental alternations of a CNRA. Anticipated impacts to CNRAs from implementation of the TSP have been analyzed in the consistency determination in Appendix F: Coastal Zone Management Act.

The 20 policies were reviewed, and it was determined that eight policies are applicable to some or all of the actionable measures. Each actionable measure is compliant with the enforceable policies. TCMP compliance documentation has been completed for the TSP and transmitted to GLO for a consistency determination (Appendix F: Coastal Zone Management Act).

Table 5-1 Actionable Measures

Actionable Measures	Construction Duration (months)	Breakwaters (miles)	Island Restoration (acres)	Wetland and Marsh Restoration (acres)	Oyster Reef (miles)	Dune/ Beach Restoration (miles)	O&M Dredging (cy)	New Work Dredging (cy)	New Work Dredging (miles)
Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection (G-28)	120	36	362	664	5	--	6,537,964	--	--
West Bay and Brazoria GIWW Shoreline Protection (B-12)	120	43	--	551	0.7	--	399,863	--	--
Keller Bay Restoration (CA-5)	24	3.8	--	--	2.3	--		--	--
Powderhorn Shoreline Protection and Wetland Restoration (CA-6)	36	5	--	531		--	385,760	--	--
East Matagorda Bay Shoreline Protection (M-8)	84	9.0	92.7	239	3.7	--	1,443,077	--	--
Redfish Bay Protection and Enhancement (SP-1)	120	7.4	391	--	0.64	--	6,685,556	--	--
Port Mansfield Channel Island Rookery and Hydrologic Restoration (W-3)	24	0.66	22.3	--	--	9.5	--	?	6.9

Table 5-2 Enforceable Policies of the Texas CMP (31 TAC 501, Subchapter B)

Policy	Applicability
§ 501.15 Policy for Major Actions	Yes
§ 501.16 Policies for Construction of Electric Generating and Transmission Facilities	N/A
§ 501.17 Policies for Construction, Operation, and Maintenance of Oil and Gas Exploration and Production Facilities	N/A
§ 501.18 Policies for discharges of Wastewater and Disposal of Waste from Oil and Gas Exploration and Production Activities	N/A
§ 501.19 Policies for Construction and Operation of Solid Waste Treatment, Storage, and Disposal Facilities	N/A
§ 501.20 Policies for Prevention, Response and Remediation of Oil Spills	N/A
§ 501.21 Policies for Discharge of Municipal and Industrial Wastewater to Coastal Waters	N/A
§ 501.22 Policies for Nonpoint Source (NPS) Water Pollution	N/A
§ 501.23 Policies for Development in Critical Areas	Yes
§ 501.24 Policies for Construction of Waterfront Facilities and Other Structures on Submerged Lands	N/A
§ 501.25 Policies for Dredging and Dredged Material Disposal and Placement	Yes
§ 501.26 Policies for Construction in the Beach/Dune System	Yes
§ 501.27 Policies for Development in Coastal Hazard Areas	Yes
§ 501.28 Policies for Development Within Coastal Barrier Resource System Units and Otherwise Protected Areas on Coastal Barriers	Yes
§ 501.29 Policies for Development in State Parks, Wildlife Management Areas or Preserves	Yes
§ 501.30 Policies for Alteration of Coastal Historic Areas	Yes
§ 501.31 Policies for Transportation Projects	N/A
§ 501.32 Policies for Emission of Air Pollutants	Yes
§ 501.33 Policies for Appropriations of Water	N/A
§ 501.34 Policies for Levee and Flood Control Projects	N/A

5.2.2.2 Coastal Barrier Resources

G-28, B-12, and W-3 would be implemented in CBRA managed area, while CA-5, CA-6, M-8, and SP-1 do not have any components that would be within a CBRA managed area. **Table 5-3** shows the extent of each actionable component that would be implemented in a System Unit or OPA.

The stated purpose of Coastal Barrier Resources Act (CBRA) is to “minimize the loss of human life, wasteful expenditure of Federal revenues, and the damage to fish, wildlife, and other natural resources associated with the coastal barriers…by restricting future Federal expenditures and financial assistance which have the effect of encouraging development of coastal barriers…” (16 U.S.C. § 3501(b)). CBRA prohibits new federal projects that encourage development or modifications to costal barrier units unless the project qualifies for a specific exception under 16 USC §3505.

Table 5-3 Extent of Coastal Barrier Resource System Affected by the Actionable Measures

Actionable Measure	System Unit	Otherwise Protected Area	Not in a CBRS Area
G-28			
Breakwaters	10.4 mi	--	25.6 mi
Island Restoration	--	--	362 ac
Marsh Restoration	221 ac	--	443 ac
Oyster Reef	--	--	5 mi
B-12			
Breakwaters	11.1 mi	20.7 mi	11.2 mi
Marsh Restoration	155 ac	221 ac	175 ac
Oyster Reef	26 ac	2 ac	
W-3			
Breakwaters	--	--	0.66 mi
Island Restoration	--	--	22.3 ac
Beach/Dune Restoration	--	1,398 ac (9.5 miles)	--
Hydrologic Restoration	TBD*	TBD*	--

* Port Mansfield, where dredging operations would be completed, is the boundary of the OPA and System Unit. Additional coordination with USFWS will be required to determine how to allocate the area of disturbance to either the OPA or the System Unit.

The CBRA contains two categories of exceptions to the general prohibition found in 16 U.S.C. §3504. The first category allows federal expenditures if the requirements of the specific exception are met (16 U.S.C. §3505(a)(1-5). The §3505(a)(1-5) exceptions refer to Federal involvement in projects related to energy resources, existing Federal navigation channels, existing public roads and transportation, national security, and Coast Guard facilities. The second category of exceptions allow federal expenditures if they meet the requirements of the specific exception and also meet the three purposes of CBRA as stated herein (16 U.S.C. §3505 (a)(6)(A-G). The §3505(a)(6)(A-G) exceptions include projects to benefit fish and wildlife habitats, air, and water navigation projects under the Land And Water Conservation Fund Act of 1965 and the Coastal Zone Management Act of 1972. Scientific research, emergency actions under Federal major disaster assistance programs (42 U.S.C.S. §5170, and 42 U.S.C.S §5192), road maintenance, and nonstructural projects for shoreline stabilization are also considered to be a §3505(a)(6)(A-G) exception.

Amendments to CBRA in 1992 created Otherwise Protected Areas (OPAs), which are areas such as parks, sanctuaries and preserves that are not typically threatened with development that may still receive federal assistance.

The portions of the actionable measures that are within the OPAs would be permissible because they do not include expenditures for Federal flood insurance. However, for the actionable measures in the system units to be permissible and compliant with CBRA several criteria must be met including: meeting one of the General Exceptions (16

U.S.C. 3505(a)(1)-(5)) or meeting one of the Specific Exceptions (16 U.S.C. 3505(a)(6)(A)-(G)) AND be consistent with all three purposes of the CBRA, which are to minimize (1) the loss of human life; (2) wasteful expenditure of Federal revenues; and (3) damage to fish, wildlife, and other natural resources.

General Exceptions § 3505(a)(2) applies to G-28 and B-12 of the actionable measures but would not apply to W-3. Specific Exception 16 U.S.C. 3505(a)(6)(A) applies to all actionable measures, which states "Projects for the study, management, protection, and enhancement of fish and wildlife resources and habitat, including acquisition of fish and wildlife habitats, and related lands, stabilization projects for fish and wildlife habitats, and recreational projects." **Table 5.4** shows which exceptions are applicable to which measures.

Implementation of any of the actionable measures would also comply with the three purposes of the CBRA by minimizing:

1. Loss of human life: Although the project does not specifically reduce loss of human life, the barrier beach, dune, and wetlands have been shown to reduce wind and wave energies from significant weather events on coastal communities. It is anticipated that the restoration efforts would reduce some level of storm surge on coastal communities, although this has not been specifically modeled or calculated because the study purpose is not for coastal storm risk management.

2. Wasteful expenditure of Federal revenues: Ecological benefits have been monetized and each of the alternatives have been identified as being cost-effective and "worth it" to invest federal resources into the project.

3. Damage to fish, wildlife, and other natural resources associated with the coastal barriers: The study purpose is to improve the ecological conditions of the focused study area through restoration actions. Through implementation the form and function of the coastal system would be improved over the existing and future-without project condition in which there would be a net gain in wetland and barrier beach habitat benefiting fish and wildlife species. Implementation of either alternative would result in temporary impacts to fish, wildlife, and other resources during construction, but would for most resources result in improved conditions over the long-term, realizing net benefits.

Figure 5-1 CBRA managed areas in relation to G-28 components on Bolivar Island

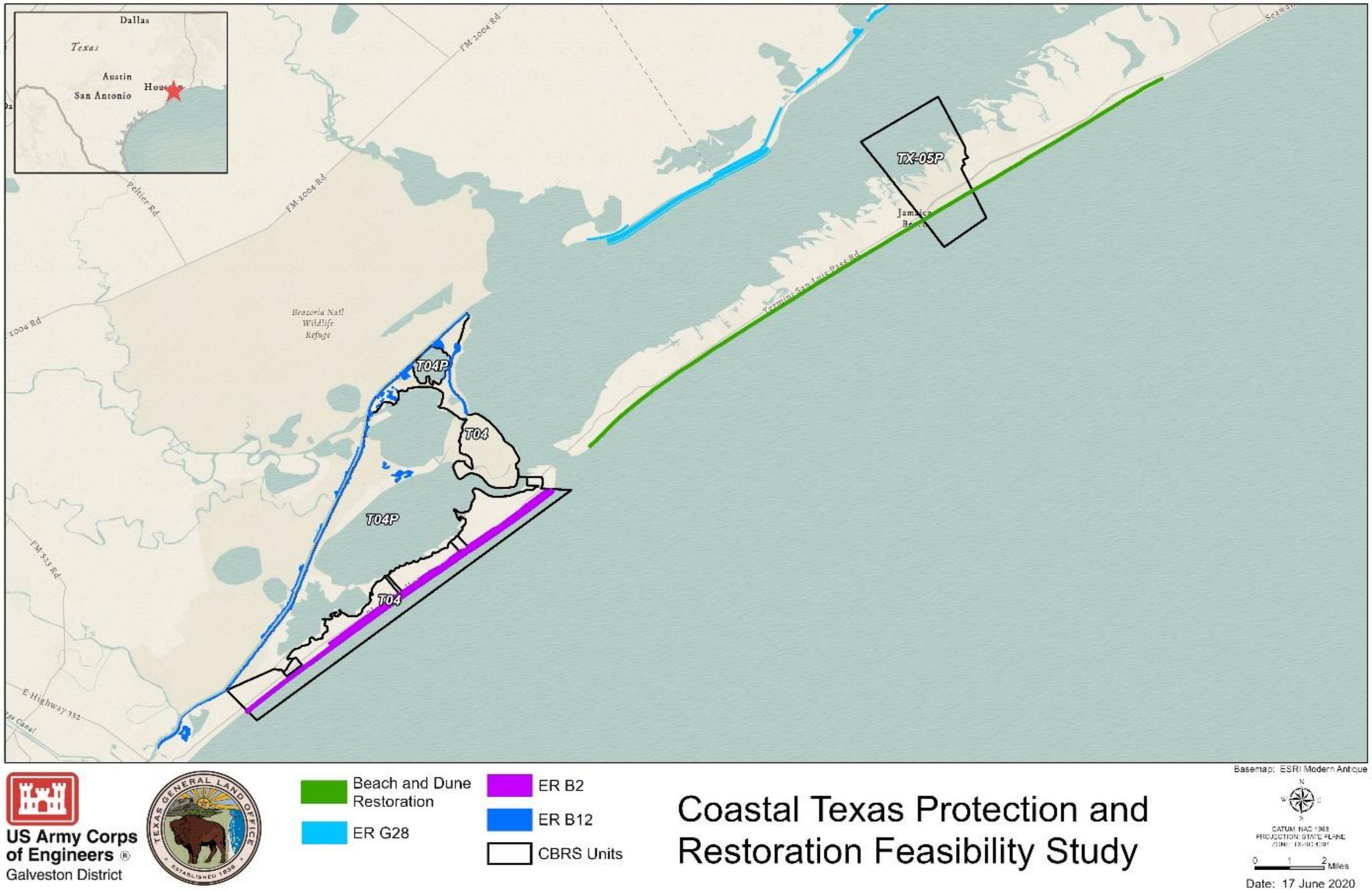

Figure 5-2 CBRA managed areas in relation to G-28 and B-12 components near Follets Island

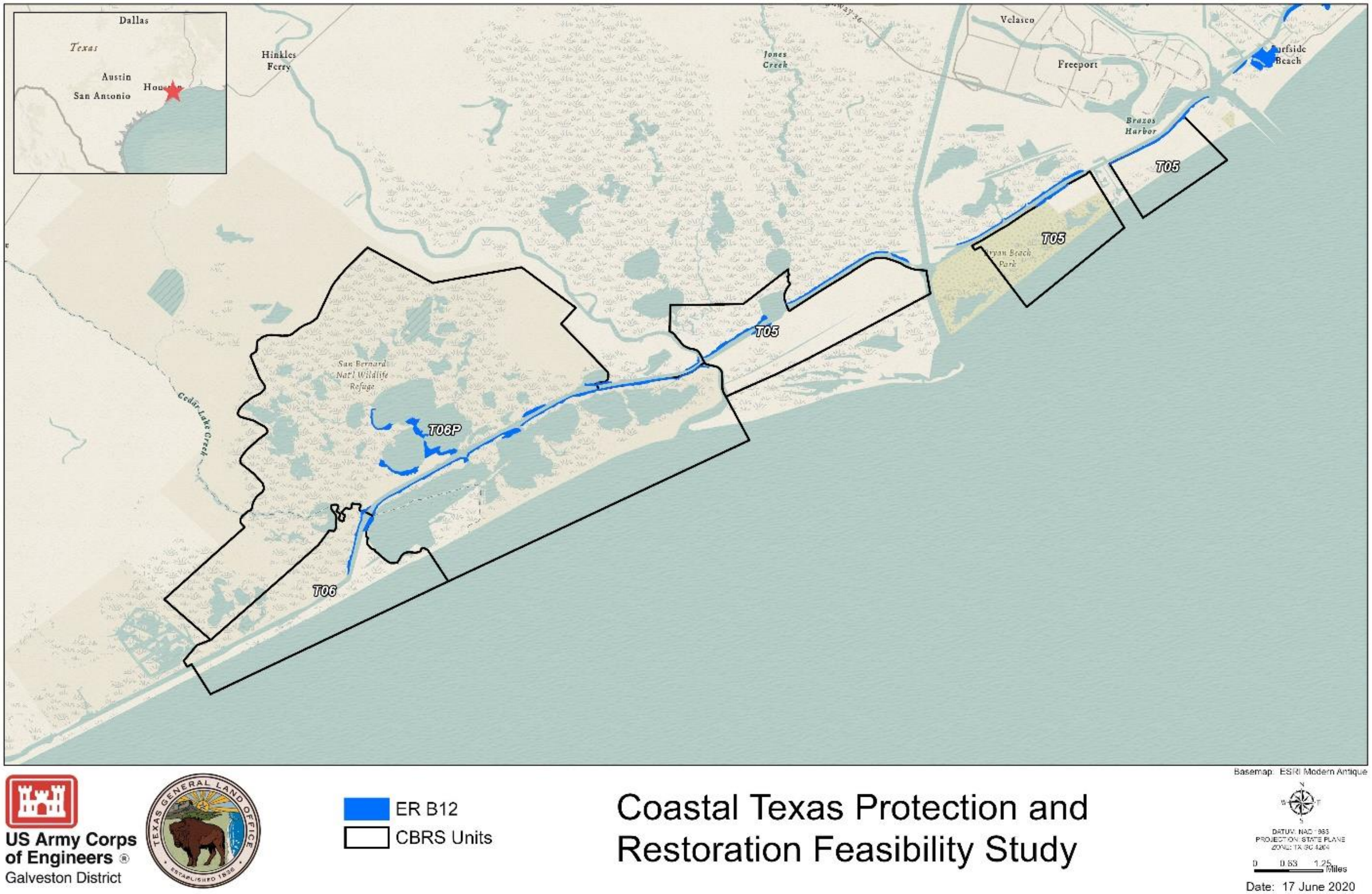

Figure 5-3 CBRA managed areas in relation to G-28 and B-12 components near Cedar Lakes

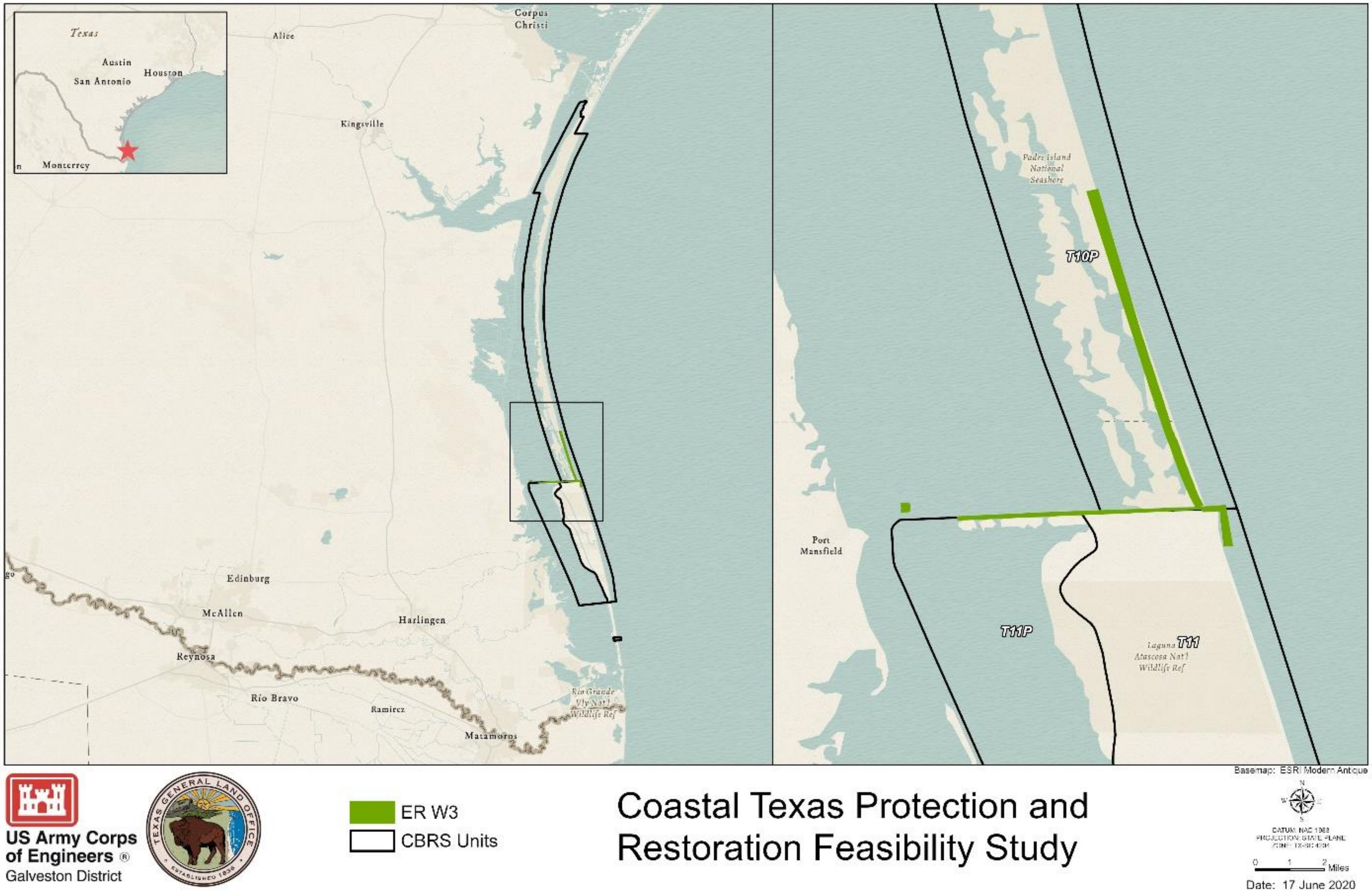

Figure 5-4 CBRA managed areas in relation to W-3 components

Table 5-4 CBRA Exceptions Applicable to Actionable Measures found within System Units

Measure	General Exceptions	Specific Exceptions	
	§ 3505(a)(2)	§ 3505(a)(6)(A)	§ 3505(a)(6)(G)
G-28: Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	X	X	
B-12: West Bay and Brazoria GIWW Shoreline Protection	X	X	
W-3: Port Mansfield Channel, Island Rookery, and Hydrologic Restoration		X	

5.2.2.3 Floodplains

EO 11988 requires federal agencies to avoid, to the extent possible, the short- and long-term adverse impacts associated with occupancy and modification of floodplains. Federal agencies are to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities."

The objective of the actionable measures is to restore coastal ecological functions. Each of the measures are expected to exclusively have beneficial impacts to natural floodplain values. No losses of natural and beneficial floodplain values are anticipated. The nature and extent of flooding within the base floodplain is unaffected by any of the proposed measures.

The risk of inducement of development within the floodplain is normally associated with structural projects such as levees and floodwalls where vacant parcels are no longer subject to frequent flooding, lowering the cost of potential development and providing economic incentive for the addition of inventory to the floodplain. None of the actionable measures include features that would induce development. Implementation of any of the actionable measures may ease the impacts of flooding under RSLR, but it would not otherwise lower the cost of developing in the floodplain as a prerequisite to providing economic incentive that could induce development.

5.2.2.4 Fish and Wildlife Management Areas

Temporary impacts during construction may affect when and where visitors to the land may be able to go or how management is conducted within the project area, but access and management would return to normal once construction is complete. As well, some measures, such as breakwaters, would result in a loss of existing land use at the immediate site of the measure footprint. It is expected that any adverse temporary or long-term impacts would be outweighed by the benefit of protecting and restoring important habitats.

Implementation of any of the alternatives would not interfere with long-term management of USFWS, TPWD, TNC, and HAC lands. All ER measures are consistent with existing agency management actions. Significant coordination was conducted with each agency during alternative development to ensure their concerns were addressed and that they could support action on their land.

Table 5.5 shows the footprint of disturbance for each ER measure within each land ownership.

Table 5-5. Footprint of Ecosystem Restoration Measures within the Various Land Ownerships (acres)

Land Owner	Breakwaters (acres)	Island Restoration (acres)	Marsh Restoration (acres)	Oyster Reef Creation (acres)	Dune/ Beach Restoration (acres)
USFWS—Anahuac NWR	35	0	31	0	30
USFWS—Brazoria NWR	113	0	320	2	0
USFWS—San Bernard NWR	68	0	130	0	0
USFWS – Big Boggy NWR	9	0	5	0	0
USFWS—McFaddin NWR	0	0	0	0	70
USFWS—Padre Island National Seashore	0	0	0	0	1,400
TPWD – Justin Hurst WMA	13	0	15	0	0
TPWD—Galveston Island State Park	0	0	0	0	130
TNC—Muddy Marsh Bird Sanctuary	0	0	2	0	0
TNC—McFarlane Marsh	0	0	0	0	0
HAS—Bolivar Flats Shorebird Sanctuary	0	0	0	0	20

5.3 AIR QUALITY

5.3.1 No Action

Because there would be no action under this alternative, project work would not contribute to future emission increases in the study area.

Air quality has improved markedly in the HGB NAA, as a result of SIP action and improved national emissions standards. The 2015 NAAQS for Ozone continues the trend of improvement in standards and will begin taking effect in the near future. Considering this, it is expected that improvements to air emissions controls implemented as a result of these SIP requirements and improving national emission standards for on-road and non-road sources will continue resulting in gradual air quality improvements, despite the projected population increase and subsequent increase in traffic volumes. The planning and implementation of the SIP incorporates the effects of population and industrial growth, technology changes, and national or statewide control measures.

Outside of regulated pollutants, other regional trends are also contributing to reduced emissions. Power generation (e.g. electric utilities), which is a major part of the point source category, is increasingly coming from renewable or non-fossil fuel sources (e.g. wind, nuclear, solar). The increasing percentage of non-combustion power reflects the significant increase in renewable energy, most notably, wind power in Texas, with nearly one-fifth of the net electricity produced by renewable sources. The HGB region's power grid is interconnected and managed at the state-level by the Electric Reliability Council of Texas power management region, and therefore local power demands would also increasingly use State-wide additions of wind turbine and other renewable generation. This trend would also be expected to contribute to gradual air quality improvements.

For all areas outside the HGB NAA, air quality conditions are expected to continue to meet NAAQS and be in attainment for all criteria pollutants in the future.

5.3.2 Alternative D2 and Alternative A

Air quality impacts from implementation of any of the actionable measures and the individual components would be similar in scope but varying in scale and duration. In general, each actionable component would have direct impacts to ambient air quality from construction activities. Air emissions would be mobile in nature, temporary, and localized to the restoration unit(s) being worked at that time. Operation of heavy equipment, booster pumps, support vehicles and vessels, and other motorized machinery for construction would result in combustion of fossil fuels and the release of volatile organic compounds (VOCs), nitrogen oxides (NOx), carbon monoxide (CO), ozone (O3), sulfur dioxide (SO2), and particulates(PM10 and PM2.5). Additionally, fugitive dust emitted to the atmosphere by heavy equipment and support vehicles moving across unpaved, non-vegetated roadways or staging areas and wind blowing dust from disturbed areas and storage piles into the atmosphere could create a haze over the project area and increase ambient concentrations of particulate matter.

Construction emissions, including fugitive dust, would be short-term lasting only as long as it takes to complete each measure within each restoration unit. Implementation of the following BMPs would further reduce air quality impacts and should be incorporated when developing contract specifications.

Dredging Mitigation Options

- Contracting with dredging companies that have energy efficient equipment

- Design of the dredging operation and schedule to reduce overall fuel use and hours of operation
- Repowering/refitting with cleaner diesel engines; i.e., those that would emit less air contaminant emissions
- Selection of newer dredges with more efficient engines, if possible
- Selection of dredges equipped with emissions control equipment; e.g., selective catalytic reduction, etc., if available
- Provision of electric power to dredging equipment

Land-side Mitigation Options

- Use of vehicles fueled by compressed natural gas or liquefied petroleum gas – compressed natural gas and liquefied petroleum gas could provide a reduction in CO2 emissions compared to the use of gasoline fuel
- Repowering/refitting with cleaner, more-fuel-efficient, diesel engines
- Use of newer vehicles with more-fuel-efficient engines, if possible
- Use of non-road ultra-low sulfur diesel fuel
- The use of heavy machinery should be fitted with approved muffling devices that reduce emissions;
- Plan construction scheduling to minimize vehicle/watercraft trips;
- Limit idling of heavy equipment;
- Maintain and tune engines per manufacture's specifications to perform at EPA certification levels, prevent tampering, and conduct inspections to ensure these measures are followed; and
- Consider alternative fuel and energy sources (e.g. natural gas, electricity, etc.) when and where appropriate.
- Stabilize open storage piles and disturbed areas by covering and/or applying water or chemical/organic dust palliative where appropriate at active and inactive sites; and
- Install wind fencing and phase grading operations where appropriate and operate water trucks for stabilization of surfaces under windy conditions.

G-28 and B-12 are the only two actionable measures that would occur within a non-attainment area. Air emissions calculations indicate that G-28 would exceed the 50 tpy threshold for NOx in all years of construction, with annual emissions being 129 tpy NOx. B-2 is would not exceed the 50 tpy threshold at any time during construction and would at most emit 19.2 tpy NOx. G-28 and B-2 are would have VOC emissions far below the 50 tpy threshold in all years of construction. G-28 is expected to have about 2.2 tpy and B-12 is expected to emit about 0.6 tpy NOx annually.

Coordination with TCEQ is ongoing to ensure compliance with the CAA and secure a General Conformity Statement.

5.4 CLIMATE

5.4.1 No Action

Future projections of freshwater inflows for the study area are highly uncertain. These flows would be influenced by changes in the timing and amount of precipitation, temperature, water demand, and water supply strategies. The Texas State Climatologist concluded that it is impossible to predict with confidence what precipitation trends will be in Texas over the next half century (Nielsen-Gammon 2009). Unlike precipitation, there is more consensus for a predicted temperature increase in Texas of close to 4 degrees Fahrenheit (°F) by 2060. Patterns of precipitation change are affecting coastal areas in complex ways. The Texas coast saw a 10-15% percent increase in annual precipitation for 1991-2012 compared to the 1901-1960 average. Texas coastal areas are expected to see heavier runoff from inland areas, with the already observed trend toward more intense rainfall events continuing to increase the risk of extreme runoff and flooding.

Texas' entire Gulf Coast historically averages three tropical storms or hurricanes every four years, generating coastal storm surges and sometimes bringing heavy rainfall and damaging winds hundreds of miles inland. The expected rise in sea level is anticipated to result in the potential for greater damage from storm surge along the Gulf Coast. Tropical storms have increased in intensity in the last few decades. Future projections suggest increases in hurricane rainfall and intensity, with a greater number of the strongest hurricanes (Categories 4 and 5) (Melillo et al. 2014).

5.4.1.1 Relative Sea-Level Change (RSLR)

Scientific research indicates that the Global Mean Sea Level has been increasing since the 1990s, which has seen a sea level rise (SLR) rate of around 3 millimeters (0.14 inches) per year, roughly twice the rate seen during the past 100 years. Rise in sea levels is linked to several primary climate-related factors, all induced by the ongoing global change including water thermal expansion and melting of glaciers and polar ice caps. Another factor which is not directly climate related but intensifies sea-level change is the subsidence of coastal lands. Land subsidence, which is the sinking of a land mass, when combined with SLR can have significant impacts on land loss.

Most RSLR models generated for the study area were run using scenario A1B from the 2000 Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios (SRES)—mean and maximum estimates, which are based on global SLR. The A1 family of scenarios assumes that the future world includes rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. In particular, the A1B scenario assumes energy sources will be balanced across all sources. Under the A1B scenario, the 2007 IPCC WGI Fourth Assessment Report suggests a likely range of 0.21 to 0.48 meters of SLR by 2090-2099 "excluding future rapid dynamical changes in ice flow."

Although the global SLR predictions are valuable, USACE policy requires incorporation of projected changes to Local Mean Sea Level (LMSL) into the design of Civil Works projects. To attain these values, the USACE Sea Level Change Curve Calculator (http://corpsclimate.us/ccaceslcurves.cfm) was used to attain these values and compare the USACE scenarios to the NOAA 2012 Technical Report OAR CPO-1, "Global Sea Level Rise Scenarios for the United States National Climate Assessment." The calculator provides three rates of RSLR including the "low," "intermediate," and "high." The "low" rate of RSLR in based on an extrapolation of historical tide gauge readings. The "intermediate" and "high" rates represent a future acceleration in sea-level change with trajectories based on modified National Resource Council curves (NRC 1987) I and III respectively and adjusted for local vertical land movement.

The output of the calculator is dependent on using adequate historical water level data. The NOAA tide gage assigned to Region 1 is Galveston Pier 21 (8771450), which has a published RSLR rate of +0.02096 feet per year (+0.25 inches/year). For Region 2 and 3, the tide gage assigned to these two regions is Rockport, which has a published RSLR rate of +0.01693 feet per year (+0.2 inches/year). The tide gage assigned to Region 4 is Port Isabel, which has a published RSLR rate of +0.01194 feet per year (+0.14 inches/year). **Table 5-6** uses the published rates to project the anticipated rise in sea level from the base year (2017) through 2135, which is 100 years after construction is complete and benefits are expected to be realized. The intermediate curve is the accepted rate of RSLR for purposes of this study.

5.4.2 Alternative D2 and Alternative A

Climate impacts are analyzed from two perspectives: impact of implementing any of the actionable measures on climate and climate change, and the impact of climate change on the performance of any of the action alternatives.

5.4.2.1 Construction Activity Impacts Common to All Actionable Measures

Construction activities associated with each of the actionable measures would generate GHG emissions as a result of combustion of fossil fuels while operating on- and off-road mobile sources. After construction is complete, all GHG emissions would cease and the area would return to baseline conditions. There are no apparent carbon sequestration impacts that would result from implementation; thus, the total direct and indirect impacts would be constrained to very small increases in GHG emissions to the atmosphere from the construction activities. These small increases would be far below the 25,000-metric ton per year threshold for discussion of GHG impacts (CEQ 2014). In years in which construction activities are implemented, emissions would incrementally contribute to global emissions, but would not be of such magnitude as to make any direct correlation with climate change.

Table 5-6.Relative Sea Level Rise (feet) at the Gages Assigned for Each Region

Year	Galveston Pier 21 (Region 1)			Rockport (Region 2 and 3)			Port Isabel (Region 4)		
	Low	Int*	High	Low	Int*	High	Low	Int*	High
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.5
2020	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.6
2025	0.2	0.2	0.3	0.1	0.2	0.3	0.4	0.5	0.8
2030	0.3	0.4	0.6	0.2	0.3	0.5	0.4	0.5	1.0
2035	0.4	0.5	0.8	0.3	0.4	0.8	0.5	0.6	1.2
2040	0.5	0.6	1.1	0.4	0.5	1.0	0.5	0.7	1.4
2045	0.6	0.8	1.4	0.5	0.7	1.3	0.6	0.8	1.6
2050	0.7	0.9	1.7	0.6	0.8	1.6	0.7	1.0	1.9
2055	0.8	1.1	2.0	0.6	0.9	1.9	0.7	1.1	2.2
2060	0.9	1.3	2.4	0.7	1.1	2.2	0.8	1.2	2.5
2065	1.0	1.4	2.8	0.8	1.2	2.6	0.8	1.3	2.8
2070	1.1	1.6	3.1	0.9	1.4	2.9	0.9	1.4	3.2
2075	1.2	1.8	3.5	1.0	1.5	3.3	1.0	1.6	3.5
2080	1.3	2.0	4.0	1.1	1.7	3.7	1.0	1.7	3.9
2085	1.4	2.1	4.4	1.2	1.9	4.1	1.1	1.8	4.3
2090	1.5	2.3	4.9	1.2	2.0	4.6	1.1	2.0	4.7
2095	1.6	2.5	5.3	1.3	2.2	5.0	1.2	2.1	5.1
2100	1.7	2.7	5.8	1.4	2.4	5.5	1.3	2.3	5.6
2105	1.9	2.9	6.4	1.5	2.6	6.0	1.3	2.4	6.0
2110	2.0	3.1	6.9	1.6	2.8	6.5	1.4	2.6	6.5
2115	2.1	3.3	7.4	1.7	3.0	7.0	1.4	2.8	7.0
2120	2.2	3.6	8.0	1.7	3.2	7.6	1.5	3.0	7.6
2125	2.3	3.8	8.6	1.8	3.4	8.2	1.6	3.1	8.1
2130	2.4	4.0	9.2	1.9	3.6	8.7	1.6	3.3	8.7
2135	2.5	4.2	9.8	2.0	3.8	9.4	1.7	3.5	9.3

* Int = Intermediate

5.4.2.2 Alternative Performance

Each actionable measure has been designed to be effective and sustainable under future climate conditions. ER measures were developed using the intermediate rate of sea level change and incorporate future nourishment cycles to ensure that each measure is sustainable under rising sea level conditions for the full 50 year planning horizon. An assessment of RSLR was included in the design of each of the actionable measure. The evaluation of RSLR is documented in the Engineering Appendix of the Feasibility Main Report.

However, there is uncertainty about how much sea level change would occur in the project area. RSLR could impact the benefits achieved by any of the action alternatives. If future sea level change is less than the intermediate rate of change, each action alternative would provide more benefits than anticipated for longer. If higher rates of sea level change are experienced, each alternative would provide less benefits than anticipated. With a higher rate of change, marsh and shoreline restoration features would be less effective because they could be overwhelmed by water levels which would increase their vulnerability. This is a risk to the effectiveness of any of the actionable measures but this situation would also imply that landscape-level inundation would be so great that engineered or designed features could no longer control how, when, or where water moves throughout the restoration unit(s). This could ultimately lead to a shift in project strategy from maintaining elevations to relocations if future sea levels are higher than anticipated. Such a shift in strategy would only be considered after the adaptive management strategies have been considered and/or implemented.

Additional uncertainties relate to possible extreme weather events. Uncertainty about the size and frequency of storms and climate events, such as El Niño, cannot be predicted over a set period of time. Storm events can cause significant damage to the shoreline and marsh areas. Intact habitats are more resilient against the effects of hurricane storm surge and associated flooding, salinity spikes, and tidal scour, though some hurricane storm surge damage may be unavoidable.

During PED, prior to initial construction (if conditions changed since PED), local conditions will be assessed. If the rate of change is higher than expected under the intermediate scenario, the target elevations for marsh and construction elevations and widths for the beach berm and dune would be modified to increase effectiveness, resiliency, and sustainability in the face of climate change. If the observed rate of change is more aggressive, approaching or exceeding the high rate, reevaluation of the NER may be required.

After construction, monitoring would help evaluate the progress toward meeting project goals, objectives, and desired outcomes for each ER measure and restoration units. If minimal success or obvious failure is occurring, adaptive management techniques would be employed to increase the likelihood of achieving desired project outcomes given the uncertainties with ecosystem restoration. For example, the timing of renourishment cycles may need to be adjusted either sooner or later based on actual loss rates after construction. Also, the dune height or berm width may need to be increased to keep up with RSLR or to combat higher wave and wind energies associated with more significant weather events.

Specially related to oyster reefs and long-term performance, oysters are less susceptible to the impacts of RSLR and are capable of keeping pace with sea level changes. However, USACE will manage the risk of RSLR and climate change by constructing reefs only at sites with the most favorable conditions for the growth of oysters. Areas on the fringe of optimal range for oysters that would be the most likely to be negatively impacted would be avoided. For example, cultch and reef balls would be constructed within a limited depth range (six to 12 feet). So even as sea levels increase, oyster will still be able to grow because oysters have been documented to live at a depth greater than 30 feet. During PED, suitable cultch material will be identified, which will include substrates that provide a reef base resilient to the risks posed from higher salinities.

5.5 GEOLOGIC RESOURCES

5.5.1 No Action

Under the No Action, no Federal action would be taken. Over the short term of this alternative, topographic features, geologic formations, and soils in the study area would remain essentially in their present condition, except for where residential development is projected to expand and where dredging of navigation channels would occur. At development sites, surface grades would be leveled or built up to facilitate drainage and development of sites and soils would be converted to impervious surface and rendered unusable. At dredging sites alterations to bathymetry from maintenance and new work dredging, in addition to topographic changes from the placement of dredged material at PAs and in restoration units would continue in the future within the study area.

Under the No Action, current sedimentation and erosion patterns are expected to continue throughout the 50-year period of analysis. Existing hydrologic alterations would continue to affect water levels and salinities and continue influencing land loss at similar or increased rates. RSLR would expose additional shoreline areas to erosive forces into the foreseeable future.

5.5.1.1 Sediment Transport

There are two main types of sediment transport in the system—sediment carried into the channels by heavy rains in the watershed and conveyed through the navigation channels, and sediment transport along the coast.

Under the No Action, deeper and wider navigation channels will require more dredging than under the existing condition. The low velocities near the bottom of the navigation channel offer conditions favorable for sediment deposition, despite no change in the amount of sediment-laden runoff. As well, deeper channels will have a larger volume below the existing seabed, making it function as a larger sediment trap. As a result of potential higher sedimentation rates in the navigation channels, it is assumed that under the No Action there would be less sediment entering the Gulf and contributing to longshore sediment transport than under the existing condition. At navigation channels where a deeper and longer entrance channel would be constructed, the change would be expected to have some effect on waves moving from the Gulf to the shore, and that would in turn exert an effect on the rate of longshore sediment transport.

5.5.1.2 Shoreline Erosion

Under the No Action condition, shorelines will continue to retreat due to RSLR and interrupted longshore sediment transport along the Gulf coast. The Bureau of Economic Geology (BEG) has analyzed historical rates of change and projected shoreline retreat along the Texas Coast (BEG 2017). Erosion rates are predicted to continue following the historical trend and rate of erosion as described in the existing condition, where the upper Texas coast retreat was calculated at 5.5 feet per year, and the mid to lower coast retreated an average of 3.2 feet per year (Paine et al., 2014). The most impacted areas are expected to lose more than 30 feet per year. The FWOP shoreline consists of widespread erosion except for at two locations: 1) near Sea Rim State Park which is a location of longshore transport convergence and 2) at the fillet against the west side of the SNWW jetties which has historically accreted due to an interruption in the prevailing longshore sediment transport.

Along the GIWW, it was assumed that vessel- and wind-generated waves and surges would continue to erode the shoreline at the historical rate of approximately four feet per year, as determined by resource agencies and land managers affected by the loss, where breakwaters do not currently exist. Where GIWW armoring exists now, it is assumed that the structures would continue to function as designed and there would be no significant/measurable erosion to the shoreline behind the structure.

5.5.2 Alternative D2 and Alternative A

None of the actionable measures would be expected to modify regional or local geology. Also, there are no prime or unique farmlands in the focused study area; therefore, implementation of any of the actionable measures would have no impact on farmlands.

5.5.2.1 Breakwaters

Construction of GIWW armoring would convert soils/water bottoms under the structures to a hardened surface in which the productivity of those soils and water bottoms would be lost. The adverse impact of this conversion is far outweighed by the reduction in shoreline erosion. Existing structures on the GIWW have not resulted in alteration of sediment patterns and is therefore not expected if the structures proposed under this alternative were constructed.

The adverse impacts of construction are far outweighed by the beneficial impacts of the breakwater features. Construction of breakwaters would stabilize shorelines and reduce navigation and wind-induced wave energy to adjacent coastal habitats, resulting in overall reduced shoreline erosion along the banks of the GIWW. This reduction in erosion would decrease the rate of sedimentation into the bays and waterways. The construction of breakwaters would replace some habitat with hardened structures, and the structures would reduce or restore habitat lost to erosion.

Construction of offshore breakwaters would also result in the conversion of soil and water bottoms to a hardened surface but would also reduce the rate of shoreline erosion over time. However, this measure has the potential for unintended adverse consequences, such as alteration of sedimentation patterns or creation of erosional problems outside the breakwater benefit area.

5.5.2.2 Marsh Restoration

Marsh restoration would reintroduce sediments into the system through placement of dredged material. This increase in sediment is expected to result in long-term beneficial impacts by increasing the amount of hydric soils in the system and creating stability. For marsh sites, the increase in sediment is expected to increase productivity, support wetland building functions, and reintroduce and distribute sediment and nutrients throughout the ecosystem, not just within the restoration unit. As well, restored/nourished marsh units would contribute to trapping sediments and prevent them from migrating or eroding into nearby waterways.

Introduction of the dredged materials would change the topography and bathymetry of the restoration units. Marsh units would be increased to +1.2 feet MSL at year 0. For these surface changes, the existing elevations are at or below -1.0 MSL, which does not benefit the system. With the increase in elevation and change in topography, the system will be able to more closely function as nature designed allowing surface flows to enter and pass rather than being trapped, thereby creating a more resilient and sustainable system under RSLR conditions.

All soils in the marsh restoration units are hydric soils. During construction, hydric soils in the project area would be minimally compacted from heavy equipment moving and placing dredged material within the restoration unit. Compaction would be temporary and would be expected to have a compaction rate similar to other marsh areas near the restoration unit shortly after construction ceases and the marshes are under normal surface flow influence. Placed material would be of very similar quality as the existing soil, which would reduce any compositional or structural changes associated with placing an outside source into the marsh.

5.5.2.3 Island Restoration

Restoration of the rookery islands would affect substrates at the placement site through the placement of clean fill and hard, structural material. Adverse impacts would be minor and local. Long-term benefits would occur to the bottom substrates due to stabilization of sediments protections from erosion.

Fill for the island restoration would be contained and protected by rock structures and stabilized with vegetation; therefore, it is expected that sediment losses from the restored islands would be minimal. During construction, temporary impacts of increased sediment suspension and dispersion within the water columns adjacent to the constructed islands should be expected.

5.5.2.4 Oyster Reef

Cultch plant and reef ball construction could result in short- and long-term, minor adverse impacts from activities that disturb sediments and/or convert soft bottom substrate to hard bottom. In the short-term, the use of large equipment and in-water construction activities could temporarily disturb sediments suspending sediments in the water column. Construction BMPs would be implemented to minimize any adverse impacts from construction.

In the long-term, oyster reef restoration, either through cultch plant or reef ball placement, would replace a small amount of soft sedimentary substrates with hard substrates. The loss of soft bottom substrates would occur in small patchy areas of sediment that may result in several acres of sediment substrate being permanently converted to hard bottoms. During PED, site-specific surveys will inform the extent of soft bottom loss and, where possible and appropriate, relocate the cultch plant or reef ball placement to existing hard substrate to reduce the extent of soft bottoms impacted.

Long-term, beneficial impacts from creating or restoring oyster reefs include minimizing impacts to landward shorelines. Well-established oyster reefs (anticipated about 15 years after construction, assuming successful recruitment and establishment of an oyster population) attenuate wave energies minimizing erosion and land loss.

5.5.2.5 Dune/Beach Restoration

Sand fill placed in the restoration area would temporarily cover existing sediments, but not disturb them. Natural longshore and cross-shore sediment transport would be expected to mix fill sand with adjacent native sands relatively quickly. The fill sand would have similar characteristics as the beach sand and any differences would migrate to pre-projection conditions with the mixing.

Dune and Beach restoration would reintroduce sediments into the system through placement of dredged material and an increase in available sacrificial land. From the sacrificial land, additional sediment would be available in the natural system and allow natural processes, such as reworking, erosion, and deposition to take place and enhance sediment availability for longshore sediment transport. An increase in shoaling through longshore sediment transport would be expected at tidal inlets downdrift of the ER feature.

5.5.2.6 Hydrologic Restorations

Dredging of Port Mansfield Channel would remove existing sediments and place them into the island restoration site or along the beach north of Port Mansfield Channel.

Removing the sediments would result in bathymetric changes through the channel which would in turn support hydrologic reconnection between Laguna Madre and the Gulf of Mexico. With the hydrologic connection it is possible that sediment transport would be facilitated and could result in erosion and accretion in areas historically subjected to these changes when the channel was regularly maintained. It is anticipated that the channel would sediment back in and return to near baseline conditions near the end of the project life.

5.6 HYDROLOGY AND HYDRAULICS

5.6.1 No Action

Under the No Action, no hydrologic changes would occur. Overwash, storm surge, and RSLR would continue to impact coastal ecosystems by introducing marine waters into historically estuarine or fresh habitats. The introduction and repetitive influence of marine waters into these habitats is expected to degrade them over time and result in habitat conversion from fresh or intermediate marsh to more saline brackish or saline marshes and eventually into open water. As RSLR occurs, much of the area will be converted to open water and the unconsolidated shorelines and marshes are expected to migrate inland as the tidal amplitudes increase.

5.6.2 Alternative D2 and Alternative A

Implementation of any of the actionable measures would result in temporary, minor adverse impacts to water quality, but would realize long-term, direct and indirect benefits over the planning horizon once construction is complete and each of the measures are functioning as designed. Adverse impacts to tides, currents, and circulation are not expected, although localized current and circulation beneficial changes at the project sites are expected and intended by design to restore the function of the area and to promote long-term resilience of the feature. Implementation of the actionable measures would have no impact on groundwater quality or quantity.

5.6.2.1 Breakwaters

GIWW armoring (G-28, B-12, M-8, and SP-1) is not expected to alter flows into and out of the area nor would it alter water levels behind the structures. The structures would by design reduce velocities and protect marsh from wave induced erosion. The proposed design of the GIWW armoring are identical to those used throughout Texas along other parts of the GIWW. To date, no adverse hydrological influences have been identified. Rather, these structures have provided overall beneficial impacts by reducing erosion caused by waves, slowing land loss, and reducing saltwater intrusion into adjacent marshes.

Offshore breakwaters would be constructed in the Keller Bay (CA-5), Matagorda Bay (CA-6), and Port Mansfield (W-3). These structures would allow flows through the gaps between structures and slow flows over the structures thereby dissipating high energy

Gulf waters (i.e. reduce water velocities) and reducing overall wave heights. The structures would not be expected to change water levels or influence the tides. Construction of the breakwaters could induce currents or alter long-shore sediment transport.

Construction of breakwaters would result in temporary, adverse impacts to water quality. Anticipated water quality impacts are expected to be localized and occur only during placement of breakwater materials. Impacts may include an increase in turbidity and total suspended solids (TSS). Increases in turbidity and TSS would be due to fine material included in the construction materials, as well as the suspension of bottom sediment at the placement site. The placement of material on the sea floor and the moving of barge spuds are expected to suspend bottom sediments. Construction materials would be inspected, and fine material would be removed prior to construction to ensure that excess amounts of fine material would not be introduced into the water column. A ten-foot plume extending from the construction site is expected to impact water quality during construction at the placement site, but would be expected to dissipate within 24 hours of material placement. It is also anticipated that TSS and turbidity levels would return to baseline conditions once construction activities have been completed. Increased turbidity and TSS levels also have the potential to lower the dissolved oxygen (DO) concentration in the water column. Reduced DO levels within the water column can stress aquatic organisms if the levels are low enough.

5.6.2.2 Marsh Restoration

During marsh restoration, existing fragmented marsh and shallow open water areas would be restored to marsh habitat. Temporary earthen containment/exclusion dikes, if constructed, would temporarily prevent local flows from coming into and over the marsh restoration site during construction activities. However, the dikes would be expected to naturally degrade or would be mechanically breached to provide hydrologic exchange following dewatering and consolidation of dredge sediment slurry. The temporary change in hydrologic flows through the restoration units would not be expected to modify water levels in adjacent areas or permanently alter flows or water levels.

Post-construction, marsh platforms would be elevated from their existing condition to aid in the resiliency and sustainability under future conditions. The higher elevations may slightly reduce and modify local throughput (current patterns and flow) of water over the footprint immediately following construction and until the area compacts and sea levels rise. However, overall basin current patterns and flows would be similar to that which existed prior to the fragmentation, degradation and loss under the existing condition. Marsh elevation increases would also reduce the amount of ponding and allow flows to move throughout the area and drain to the lakes, bayous, and ocean, which under the existing condition aided in the conversion of marsh to open water. Marsh restoration would be expected to have an overall beneficial impact in the restoration units by inducing flow conditions more suited to functional wetlands.

Construction activities and placement of dredged material could result in the following localized and temporary impacts to water quality including: reduction in water clarity; change in color; reduction in the pH of receiving area waters toward more acidic conditions, emission of reduced Sulphur compounds including hydrogen sulfide often characterized as an objectionable rotten-egg smell; release of organic material with varying quantities of ammonia, nitrogen, and phosphorous, which could stimulate growth of algae and other aquatic plants. The factors responsible include increased turbidity, increased suspended sediments, and organic enrichment, chemical leaching, reduced dissolved oxygen, and elevated carbon dioxide levels, among others. Tidal currents present in the measure areas would serve to disperse and thereby dilute localized changes. Any such impacts would be minimized and controlled by the use of the best available practical techniques and BMPs. Following construction, degraded water quality conditions would be expected to return to baseline conditions prior to construction.

During dredge material placement, effluent from the dredge discharge pipe would be directed to the placement site for nourishment. Dredged material is expected to be free of contaminants and would be suitable for placement in the aquatic habitat in accordance with the CWA Section 404(b)(1) and is not expected to result in adverse effects to aquatic organisms. Dredging would occur during regularly scheduled maintenance events; therefore, water quality and salinity impacts during dredging would be the same as those described under the No Action.

5.6.2.3 Island Restoration

Island restoration would be expected to have similar construction as marsh restoration. From a long-term perspective, the new or restored island would be subjected to wave and tidal energies that either historically did not occur in that area (new islands) or that has not occurred in the recent past (restored areas). The construction of the features would result in circulation and flow patterns although the extent of change is not expected to be significant enough to cause long-term adverse impacts to adjacent habitats (e.g. erosion/accretion, increase in salinities, etc.).

5.6.2.4 Oyster Reef

Construction of new oyster reef habitats may result in minor changes in the movement of water in and around the reefs. Once constructed, new reefs would create a less active water column between the reef and shoreline, allowing sediment to fall out of suspension, and fostering sediment accretion. As well, oyster reefs would attenuate wave energies, which would directly reduce erosion and the subsequent increase in TSS and turbidity levels, while also minimizing the potential pathways for saltwater intrusion into adjacent wetlands.

Oyster reef creation can result in temporary, minor adverse impacts to water quality due to the disturbance associated with placement of materials. The short-term impacts associated with construction of the breakwaters would also be applicable here.

Long-term, beneficial impacts on water quality would be expected to last throughout the 50-year period of analysis. Oyster reefs provide attachment sites for sessile filter feeders such as mussels and oysters. These organisms can remove substantial quantities of suspended material from the water column as they feed. For example, a single oyster is reported as being able to filter up to 60 gallons of water per day. These animals would remove suspended solids from the water column, decreasing turbidity, reducing TSS levels, and increasing water clarity.

5.6.2.5 Dune/Beach Restoration

Dune/Beach Restoration measures would alter the hydrologic flow from the existing condition. Under the existing condition, storm surge and wave energies regularly run up and over the beach and dune causing tidal influences on habitat that was not historically tidally influenced, except during extreme weather events. By design, this measure would reduce tidal influence on habitats landward of the dune. A wider beach would reduce wave energies and slow erosion rates of the beach and dune, while increasing the dune height would prevent storm surge from flowing into marshes behind the dune causing erosion, subsidence, and marsh conversions from less saline habitat to more saline habitat or open water. Storm surge over the dune would still occur during extreme weather events, such as tropical storms and hurricanes, as would have occurred historically.

5.6.2.6 Hydrologic Restorations

ER measure W-3 (Port Mansfield Channel, Island Rookery and Hydrologic Restoration) is in the Nueces-Rio Grande Basin and the only ER measure specifically designed to achieve hydrologic improvements in the Lower Laguna Madre. Dredging the channel would enhance flow and tidal exchange between the Gulf and the Lower Laguna Madre, which will also influence salinities within the estuary.

The shape and orientation, combined with prevailing winds from the southeast and a microtidal environment, result in the flow at Port Mansfield Channel flowing out of the estuary into the Gulf much of the time (King et al., 2016). This wind-driven hydrodynamic force commonly overwhelms the tidal prism on incoming tides in this microtidal environment. This flow out of Port Mansfield Channel functions more like a river mouth with outgoing currents occurring most of the time rather than a tidally influenced estuary opening. Maintaining Port Mansfield Channel open with dredging is likely to help reduce the frequency and magnitude of high salinity conditions in the Lower Laguna Madre.

The Lower Laguna Madre is a hypersaline lagoon along the southern Texas coast offset from the Gulf of Mexico by Padre Island. The area is tidally connected to the Gulf of Mexico by the Brazos Santiago Inlet and Mansfield Pass. Limited freshwater inflow and evaporation conspire to generate hypersaline conditions. Saline inflow from the Gulf of Mexico acts to reduce the salinity in the lagoon. Shoaling in Mansfield Pass limits the inflows that help mitigate the hypersalinity. Since Mansfield Pass is a smaller inlet than Brazos Santiago Inlet it acts as a choke point in the Lower Laguna Madre system; dredging the pass would reduce the hydrodynamic restrictions and promote more favorable conditions in the lagoon. Restoring the connection would also be expected to have several ecological benefits including: reduction of salinity in the lagoon, additional flushing of pollutants from the lagoon, increased supply of fully oxygenated water to the lagoon, nutrient exchange between the two water bodies, and a mechanism for larval transport (King et al. 2018).

This actionable measure would affect salinity in the Lower Laguna Madre. Salinity in the Gulf near the Port Mansfield Channel is about 35 ppt, while salinities in the Lower Laguna Madre at the Port Mansfield Channel have ranged up to 40 to 50 ppt in the past (King et al., 2016). Measured salinities near Port Mansfield from 1995 through 2009 ranged from 7 to 45 ppt and averaged 31 ppt (Schoenbaechler and Guthrie, 2011e). Cited literature indicates salinity in the Lower Laguna Madre has averaged 32 ppt over the period from 1995 to 2002 (Rio Grande, Rio Grande Estuary, and Lower Laguna Madre Bays Basin and Bay Expert Science Team, 2012).

The ability of this ER measure to influence salinity in the Lower Laguna Madre is affected by flow patterns in the estuary. Effects of this ER measure on salinity have not been modeled for the Coastal Texas Study.

5.7 BIOLOGICAL RESOURCES

5.7.1 No Action

Effects of climate change on ecosystems are difficult to predict, due to both uncertainty in climate change scenarios (direction and magnitude of temperature and precipitation) and uncertainty in understanding how species will respond to those changes. Changes in extreme weather events, precipitation, temperature, and sea-level rise are expected to alter coastal habitats resulting in loss of habitats and their component wildlife species.

The repetition of tropical storm events, hurricanes, and human modification of hydrology and coastal features has increased ecosystem vulnerability throughout the Texas coast. Successive disturbance and salt stress from interference with freshwater flows has put in jeopardy the process by which marsh sediment accretion and land accumulation occurs. “Without a healthy plant community, sedimentary deposition decreases due to the loss of plants in the water column, biogenic accretion ceases due to the lack of plant detritus, and the substrate becomes exposed, leading to rapid erosion. As a result, a tipping point may have been reached, or is about to be reached, where these wetlands will be unable to keep pace with rising sea level.” (Williams et al. 2009) As a result, the extensive marshes along the upper Texas coast have reduced resiliency to storm surge impact, complicating their post-storm recovery. All of this is also occurring within the context of climate change, which is likely to result in an increase in the intensity of tropical storms, rising average annual temperatures, and an increase in the rate of relative sea level change.

5.7.1.1 Impacts on Habitat

Without action, marine influences and other natural and human factors, such as subsidence, sea level change, navigation channels, oil and gas development, industry growth, and population increases would result in continued coastal habitat loss in the study area. Without action, the coastal vegetation resources would continue to decline through bankline erosion, sloughing of the shoreline, and continued fragmentation and conversion of existing brackish and saline marsh to shallow open water habitats.

RSLR is the most likely factor to result in significant changes to biological communities. Future RSLR threatens existing vegetated marshes with submergence and conversion to open water. Increased saltwater intrusion and introduction of tidal energies to historically non-tidal or micro-tidal freshwater marshes is expected to continue causing plant mortality, peat collapse and erosional loss of organic marsh soils, leading to habitat switching and conversion of vegetated marshes to open water. It is likely that these impacts have been and will be the most severe in areas subject to saltwater intrusion from the navigation channels and seawater overwash and in areas with rapid subsidence.

Significant reductions of the brackish and saline marshes under the No Action is anticipated because of the accelerated rate of land loss and the narrowing of zones based on differing salinity regimes. Land loss, saltwater intrusion, and marine influences, conditions that would exacerbate the loss of barrier beach system, would result in the narrowing of the broadly delineated zones of coastal habitat types that exist today. As the zones narrow into smaller bands of coastal habitat types, the acreage associated with each coastal habitat type, particularly brackish marsh and saline marsh, would also diminish.

The barrier beach system, which includes the beach and dune, would continue to erode under normal conditions and would likely be breached during significant storm events. The only location where this would not be as catastrophic is at locations where beach nourishment restoration efforts are underway and renourishment is expected to continue into the future or where beach accretion is occurring. Without the protective buffer provided by the beach and dune system, interior wetlands would be at an increased risk to severe damage from tropical storm events.

It is possible there would be a long-term reduction in freshwater inflow to the estuaries since the population of the state is expected to double during the life of the project. The doubling of the population is expected to increase demand for water, which in turn is anticipated to lower freshwater inflows into marshes and inland freshwater habitats. As well, population growth is anticipated to reduce the acreage of coastal habitats as additional land is converted for development.

In marine and freshwater open water habitats, salinity changes from increased rainfall or tidal influences, increase in water temperatures, extreme weather events, and increased absorption of Carbon dioxide is contributing to a reduction or redistribution of habitat forming organisms. This is resulting in a decrease in nursery habitat for commercially significant fish species and a reduction in suitable habitat for rare or imperiled species. This trend is very likely to continue into the future.

Existing dredging, dredge placement, and offshore oil and gas development is expected to continue into the future similar to the existing conditions.

The NOAA Marsh Migration Viewer was used to project the future condition of marine and non-tidal communities in the study area. As sea levels rise, the ratio of existing communities (e.g. marsh, beach [unconsolidated shore], and islands] to open water changes with an increasing amount of open water and a decreasing amount of community. **Figure 5.5**, **Figure 5.6**, and **Figure 5.7** show the potential area of marsh under the low, intermediate, and high scenarios at year 2085, or approximately 50 years after construction is complete.

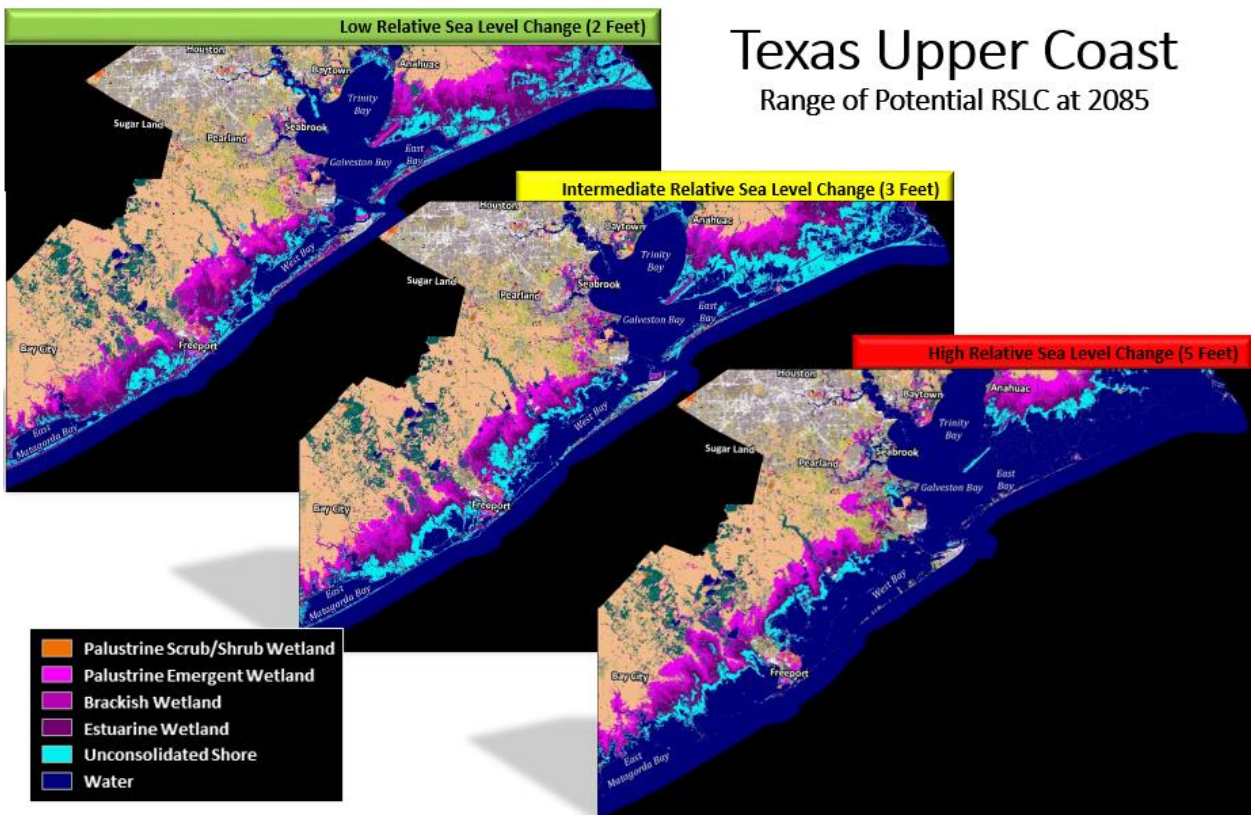

Figure 5-5 NOAA Marsh Migration Projections for Year 2085 in the Upper Region of the Study Area

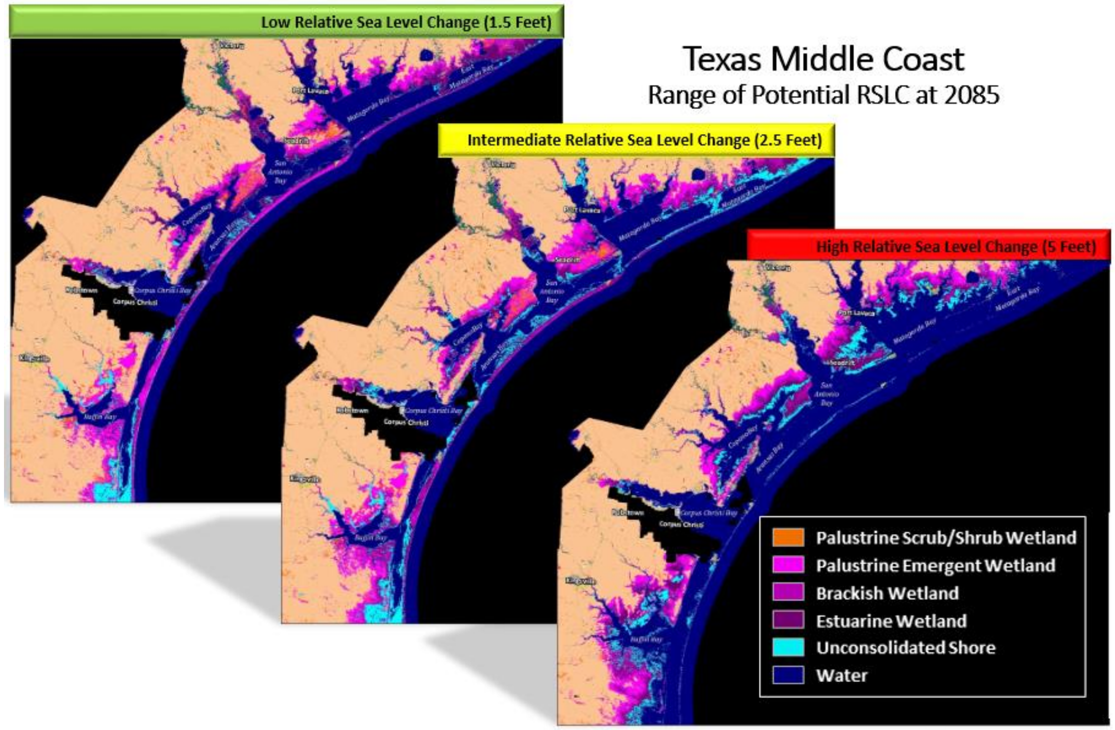

Figure 5-6 NOAA Marsh Migration Projections for Year 2085 in the Middle Region of the Study Area

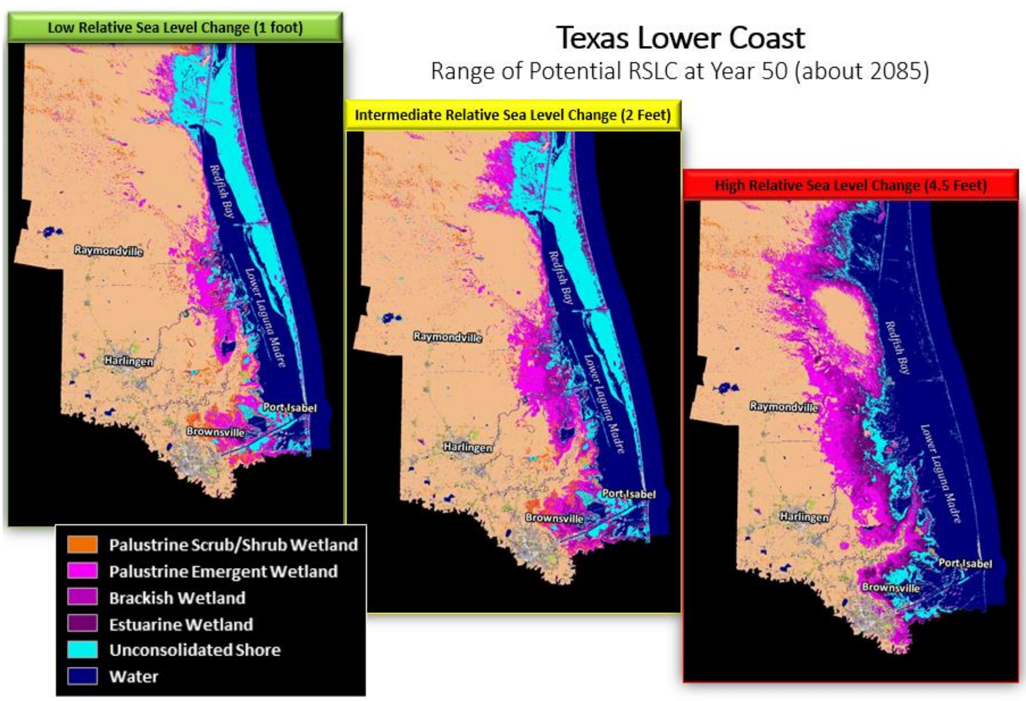

Figure 5-7 NOAA Marsh Migration Projections for Year 2085 in the Lower Region of the Study Area

5.7.1.2 Impacts on Individuals/Species

Impacts to coastal habitats found in the study area and the associated wildlife and fisheries are expected to vary both temporally and spatially and may be irreversible and severe, particularly for listed species, species of concern, and rare, unique, or imperiled communities. The added impacts of climate change on coastal habitats may greatly increase the threats to already vulnerable populations and species likely resulting in reduced biodiversity (Ohlemuller et al. 2008). It is likely that there will be an increase in species warranting conservation and protection and even extirpation from the area.

In the future, it is reasonable to expect some native marsh-dependent species will move out of their current distribution to seek habitat which meets their life requisites. Within the focused study area, conversion of fresh, intermediate, and brackish marsh to more saline conditions or open water will likely result in a decrease in abundance of existing species due to loss of suitable habitat. However, such range shifts are only feasible with adequate habitat, good dispersal and colonization ability, availability of food resources, and absence of physical barrier which might preclude movement. Displaced species may suffer from increased competition or predation, be susceptible to disease or be maladapted to their new environment. Range shifts would be expected in avian species and larger mammals; however, small mammals, herptofauna and species with limited range mobility are expected adapt to their new conditions or become extirpated in that portion of their range. During the adjustment period, wildlife demographic responses may include alterations in social groups, reproductive success, and age or sex ratios. Whether a species seeks new habitat or remains in place, all species will react independently and be affected at different rates according to their ecological and physiological constraints (Root and Schneider 2006).

With range shifts, it is probable that different species will move into the now ecologically free space and increase in abundance, which can lead to establishment of monocultures or invasive species. An increase in the extent, frequency, and severity of invasive species and a shift toward invasion in species that have not historically been invasive is also expected.

In marine habitats, altered habitat structure and quality affects species at the population level. As described for marsh-dependent species, changes in distribution, abundance and diversity of communities and species is anticipated. The reduction and/or modification in habitat may reduce overall yield from fisheries through a shrinking of the number, size, and distribution of species.

At the individual level, climate change can have a direct effect on growth and reproduction, changes in spawning periods and duration, lower recruitment, weakening of exoskeletons, and increased stress through changes in metabolism and oxygen consumptions. However, it is possible that some aquatic species may benefit from habitat shifts. For example, coral cover is being reduced due to increased sea temperatures and ocean acidity; however, macroalgal cover is increasing where coral was lost (Bell and

Coauthors 2013). Fish species that benefit from algal rich habitat may be able to exploit this change and thrive, while those that rely on coral habitats are expected to suffer (Pearson and Connolly 2016).

5.7.2 Alternative D2 and Alternative A

5.7.2.1 Breakwaters

Habitats

Breakwaters along bay and Gulf shorelines would act as protective barriers to prevent saltwater tides and wave energy from damaging wetland and marsh habitats and improve SAV growth (TPWD, 2018a). They are intended to protect intertidal and freshwater marsh complexes from erosion caused by RSLR and increased wave energy from vessel traffic and storms. Construction of breakwaters would protect SAV along the shoreline of Keller and Redfish bays. Breakwaters would protect coastlines, accumulate sediments, and provide stable habitat for marsh expansion.

A total of 48.1 acres of submerged bottomlands, inland open water habitat, and offshore habitat would be modified through construction of the GIWW armoring and the offshore breakwaters. Construction of both stone/rock structures would permanently convert a narrow (<40 feet) but long (length of the breakwater is dependent on the location) portion of the habitat in which it is being converted to a hard bottom. GIWW armoring is currently being used in other places along the GIWW and to date no unintended adverse consequences, such as alteration of sedimentation or hydrologic flow patterns have been realized and would therefore not be expected to indirectly impact adjacent habitats.

Long-term adverse impacts of offshore segmented breakwaters could include alteration of longshore sediment transport. Modeling during PED and site-specific tide and current surveys would aid in the final placement location of the breakwater to minimize adverse impacts. If longshore sediment transport changes are realized, the impacts would be expected to be minor and not result in any long-term changes to adjacent habitats.

Individuals/Populations

During placement of the material, minor adverse impacts to the benthic, fish, and marine fauna community are expected. Benthic invertebrates could be buried during the placement of material and the placement of barge spuds in the sediment, resulting in injury and mortality. Injury or mortality to slower moving fish and larval fish may result if the organisms are buried or if the organism cannot move away from the project site when heavy equipment is being operated. However, most fish are extremely motile and expected to move out of the area during construction. Natural behaviors of marine organisms such as foraging and hunting may be interrupted because of noise or changes in water quality while construction activities occur. Organisms that are able to leave the immediate area may be scared away from the activity, but behaviors should return to normal once construction is complete. The extent of temporary, adverse impacts would be dependent on the organisms' dependence on their ability to seek alternate habitat until construction is complete and baseline conditions return.

Long-term impacts on marine organism populations would be expected from the conversion of soft bottom habitat to hard substrate habitat. The transition would result in population increases of marine communities favoring hard substrate and a decline in populations that rely on soft bottoms. However, long-term presence of the component would not be expected to cause significant changes to the overall populations of species reliant on open bottoms because of the significant amount of similar habitat types in the bays, estuaries, and along the GIWW.

Once completed, breakwater structures can provide hard surface areas for oyster colonization and habitat for small fish, crustaceans, and mollusks, which provide food for wildlife such as raccoons, skunks, reptiles, and small mammals. Breakwater structures would also slow the rate of shoreline erosion of marshes, SAV, wetlands, and tidal flats, which are used by wildlife for foraging, nesting, and roosting (Swann, 2008). By reducing impacts from erosion, valuable nursery habitats used by many fish and shellfish species would also benefit. Overall, the long-term benefits from the breakwater structures as part of the actionable measures far outweigh the short-term construction impacts.

5.7.2.2 Marsh Restoration

Habitats

Within the marsh areas, placement and reworking of dredged material by construction equipment would cover and trample marsh vegetation throughout the construction footprint. Minimal emergent vegetation would be present immediately after construction as most of the project area would be unvegetated dredged material. Areas which were already marsh would likely revegetate more rapidly than large, open-water areas which are filled. Marsh vegetation nourished with 6 to 12 inches of material has been shown to respond favorably and revegetate quickly. Large, open-water areas which are filled with dredged material would likely revegetate at a slower rate than nourished marsh. Areas of significant concern for erosion or formation of a monoculture communities would be planted post-construction. Areas that are not planted would be expected to fully revegetate to densities, heights, and compositions similar to adjacent marshes within 1 to 2 years after construction.

Earthen retention dikes would be constructed from borrow taken from within each marsh creation site. The dike features would be mechanically breached or degraded within three years of construction if natural degradation has not sufficiently removed the earthen material. Impacts from the construction of retention dikes would be considered temporary and would be mitigated by natural or induced recruitment of native vegetation.

Floatation access channels may be excavated, as needed, in shallow water areas to allow construction equipment access to marsh restoration units. The materials would be temporarily stockpiled on water bottoms adjacent to the excavated channel. Floatation access channel material would be used to backfill floatation access channels following completion of the work. Increased turbidity would be the most immediate impact from the excavation and construction activities. Once the activities have been completed and the dredged material is returned to the previously excavated areas, natural recruitment and rehabilitation of the disturbed areas should occur.

Post-construction, marsh restoration activities would restore shallow open water habitat to brackish marsh. Once the marsh is functioning, the overall benefits outweigh the initial impacts.

Individuals/Populations

Short-term impacts to wildlife from marsh restoration and nourishment can include disturbance from construction activities, noise, and turbidity in the water column from dredging and sediment placement (Dufour, 1980; Greene, 2002; Michel et al., 2013). Impacts to water quality from turbidity are expected to be localized and temporary (Greene, 2002). Wildlife may relocate during the construction phase of the ER measures but would be expected to return to the area once the wetlands are restored (Greene, 2002; Rewa, 2007). Wildlife are expected to benefit from marsh restoration measures (Swann, 2008). The improved marsh habitat would include circulation channels and tidal access for marine life and provide shelter, forage, roost, and nursery habitat for wildlife.

5.7.2.3 Island Restoration

Habitats

As a result of island restoration features, bay bottom habitat and open bay habitat would be permanently lost. Impacts associated with bay bottom habitat loss

However, as a result of restoration, an increase in more productive marsh and SAV habitats is expected. Islands would be designed so the material (from dedicated dredging of the GIWW or another adjacent navigation channel) would form a natural slope and would create elevations suitable for marsh growth, wading birds, and SAV colonization. Marsh vegetation would be planted in the intertidal range on the backslope of the island. Nesting habitat on the crest of the islands would be improved with nesting platforms and native shrub planting, which would cover approximately half of the island. The island crest would be at least +8.0 feet in order prevent inundation of ground nests. No long-term impacts are anticipated from construction, dredging, or placement activities associated with the island restoration features. Impacts to existing wetlands and SAV, such as sedimentation from placement of fill material, increased turbidity, installation of containment levees, or disturbances due to channel maintenance operations, would be temporary and localized. Care would be taken to avoid existing SAV and oyster reef to the greatest extent practicable. Silt curtains would be deployed during construction to prevent movement of sediments into nearby SAV beds and oyster reef habitats.

Individuals/Populations

Short-term disturbance of island wildlife is possible during the construction and placement phase of the project. Most of the impacts described for marsh restoration would also be applicable to inhabitants of existing marsh sites in the action area. As well, impacts to individuals from breakwater construction would also be applicable to any areas that are currently bay bottom and is expected to be converted to another habitat.

Concrete blocks placed on the GIWW side of the island, used for erosion control, can impair nesting and foraging habitat. Island restoration is expected to increase vegetation coverage and increase available nesting habitats. Wildlife is expected to recolonize the island as soon as construction is completed with migratory birds, insects, rodents, and reptiles. Native and nesting platforms would provide additional habitat for bird species such as brown pelicans, double-crested cormorants, and great egrets (Schreiber and Schreiber, 1978). As the island matures, habitat for greater species diversity is expected to increase. Trees, shrubs, and groundcover would increase cover for nesting and roosting habitats and attract different species of wildlife (Michel et al., 2013; Schreiber and Schreiber, 1978). Long-term negative impacts are not expected with island restoration.

5.7.2.4 Oyster Reef

Short- and long-term adverse and beneficial impacts to biological resources as described for breakwaters would be applicable to the construction and long-term presence of oyster reefs. However, construction of a reef site rather than a hardened structure would be expected to be far more productive than the breakwaters. Oyster reefs have a positive benefit to the estuaries by providing ecosystem services such as water filtration and nutrient removal, fisheries habitat, benthic invertebrate habitat, and stabilization of adjacent habitats and shorelines (Baggett et al., 2014; LaPeyre et al., 2014; Schuster and Doerr, 2015).

Oyster reef establishment is expected to have long-term, beneficial impacts through the increase in reef habitat and population of reef-dependent species. The reefs provide hard structure used by a diversity of macroinvertebrates (e.g. crustaceans and epifauna [organisms that attach to hard bottoms]) and fish, resulting in a higher level of benthic primary and secondary production than is produced in most other benthic substrates. Reef creation and restoration is expected to result in enhanced recruitment, settlement, and growth of oysters and, over time, could increase the size of reef structures. It is expected that it will take approximately three years for a mature community to become established on the reef habitat (Burke 2010).

Placement of cultch material or reef balls will form elevated reef structure with greatly increased surface area providing attachment surfaces for sessile organisms (e.g. algae, barnacles, sponges, etc.) and benthic egg masses produced by mollusks and fish. While, the reef structure would provide shelter, cover, and foraging habitat for fish and mobile invertebrates. With the reefs in place and increase in oyster production, there could be an increase in recreationally and commercially valuable finish and shellfish communities.

The expansion of oyster reef into shallow waters is expected to have a direct benefit on avian piscivore species (e.g. raptors), benthic-feeding species (e.g. black ducks), and those such as oystercatchers that feed directly on oysters by providing additional foraging habitat.

The overall benefits from oyster reef creation outweigh any short-term construction impacts.

5.7.2.5 Dune/Beach Restoration

5.7.2.5.1 Swash Zone (Intertidal/Supratidal Zone)

Habitat

Beach fill placement would increase the width of the swash zone which would provide additional habitat.

Individuals

Beach fill placement would eliminate the majority of the intertidal benthic invertebrate infauna through direct burial. The direct impacts of beach construction activities would include the disturbance and displacement of shorebirds from intertidal beach foraging habitats in the vicinity of the active construction zone. Although the duration of disturbance along any given segment of the nourishment beach would be short term, the indirect effects of benthic infaunal prey removal (described below) would likely preclude the immediate return of shorebirds. The principal project-related factors that influence benthic community recovery rates are the compatibility of the beach fill sediments with those of the native beach and the timing of nourishment projects relative to spring benthic invertebrate larval recruitment periods (Wilber et al. 2009). Most benthic recovery studies have reported rapid recovery within seven months of the initial impact when highly compatible beach fill sediments were used and larval recruitment periods were avoided (Jutte et al. 1999a, Burlas et al. 2001, Van Dolah et al. 1994, Van Dolah et al. 1992, Gorzelany and Nelson 1987, Salomon and Naughton 1984, Parr et al. 1978, Hayden and Dolan 1974). Conversely, longer recovery periods of up to 15 months (Rakocinski et al. 1996) have generally been associated with the use of incompatible beach fill sediments containing excessively large quantities of fine silt and clay material.

Direct losses of intertidal benthic infauna within the beach fill footprint would constitute a temporary reduction in the availability of potential prey for shorebirds and predatory surf zone fishes. A two-year investigation of the effects of beach nourishment on shorebird and waterbird communities at Holden Beach and Oak Island detected no significant effects on shorebird or waterbird abundances (Grippo et al. 2007). However, the authors noted the possibility that abundances on nourished beaches could have been maintained by a continuous flux of arriving and departing migratory birds as opposed to extended residency by the same individuals. In terms of behavioral effects, Grippo et al. (2007) detected a significant reduction in waterbird feeding activity on nourished beaches; however, the feeding activities of shorebirds that are heavily dependent on intertidal beach foraging habitats (e.g., willet and sanderling) were not affected. Peterson et al. (2006) reported a 70 to 90 percent decline in shorebird feeding activity on a nourished beach at Bogue Banks. The decline in shorebird activity was attributed primarily to depressed infaunal communities; however, the use of incompatible fill containing large quantities of shell hash may have contributed to the decline by impeding shorebird foraging. Following the winter nourishment event, feeding activity remained severely depressed through July, but increased substantially between July and September and returned to normal between September and November.

According to Wilber et al. (2003), the effects of a beach nourishment project in NJ on surf zone fishes were limited to short-term, localized decreases (bluefish) and increases (northern kingfish) in abundance. Analyses of the stomach contents of kingfishes and silversides showed no evidence of reduced foraging efficiency or dietary changes along nourished beaches. Potential indirect prey-loss effects on shorebirds and surf zone fishes could include a temporary reduction in foraging efficiency in the action area and/or temporary displacement to adjacent undisturbed intertidal foraging habitats. However, based on the anticipated rapid rates of benthic community recovery, the minimal intertidal habitat impacts, and the availability of adjacent undisturbed intertidal foraging habitat, it is anticipated that indirect impacts on shorebirds and surf zone fishes would be localized and short term.

5.7.2.5.2 Beach Face (Dry Beach)/Dune

Habitats

Beach nourishment has the potential for both beneficial and detrimental indirect effects on dry beach communities. In the case of the nourishment area, which is characterized by severely eroded beaches, the restoration of a wider and higher dry beach can improve the quality of potential nesting habitats for sea turtles (Davis et al. 1999, Byrd 2004) and potential loafing, roosting, and nesting habitats for shorebirds and waterbirds (Melvin et al. 1991).

Potential detrimental effects on the quality of dry beach and dune habitats are primarily related to changes in sediment composition and the modification of other physical substrate characteristics and/or changes in beach profile morphology. Port Mansfield Channel has shoaled with sediments that would have been transported onto the beaches through longshore sediment transport so it is assumed that dredged sediments would be compatible but will be confirmed prior to placement. Available sediment data from the borrow sites indicate the presence of beach-compatible sand in sufficient volumes for nourishment.

Individuals

The placement of beach fill on the upper dry beach would impact ghost crabs and other burrowing invertebrate macrofauna through direct burial. The reported effects of beach nourishment and beach scraping on ghost crabs range from no significant response (Bergquist et al. 2008) to significant long-term effects lasting >1 year (Dixon 2007). The results of ghost crab recovery studies indicate that influential project-related factors are similar to those associated with intertidal benthic infaunal recovery rates; including sediment compatibility, the timing of operations relative to recruitment periods, and the frequency of repeated impacts. Bergquist et al. (2008) attributed the absence of any clear response to a nourishment project at Folly Beach, SC, to the use of highly compatible beach fill; however, Lindquist and Manning (2001) and Peterson et al. (2000) attributed significant reductions in ghost crab abundances lasting six to eight months to changes in sediment composition on newly constructed dune faces at Bogue Banks. In contrast to the minimal effects of (winter) nourishment reported by Bergquist et al. (2008), a separate investigation of a summer nourishment project at Folly Beach reported significant long-term (>1 year) effects on local population structure, including the loss of entire cohorts (Dixon 2007). Lindquist and Manning (2001) detected no response to an initial beach nourishment project at Topsail Beach; however, repeated annual nourishment projects resulted in significant reductions in ghost crab abundances. Based on the results of these studies, it is anticipated that the use of compatible sediments for beach fill and avoidance of recruitment periods, when possible, would minimize the potential for significant long-term effects on ghost crabs and other beach-dwelling invertebrate macrofauna.

Use of the dry beach by shorebirds/waterbirds and sea turtles for nesting is possible although unlikely due to the current poor quality of the beach. However, biological surveys would be completed prior to placing any sediment on the beach to determine presence and absence of nesting if construction would occur during the nesting season. If nesting is determined, an environmental window would be applied to the area and no work would be completed until the nesting season is over. However, if no nesting is found, work could commence, and a biological monitor would continue to assess nesting status. Because of the lack of suitable habitat and if necessitate avoidance of sea turtle and shorebird/waterbird nesting seasons, no direct impacts on nesting activity or success would be expected. Construction activities would result in short-term displacement of shorebirds and waterbirds from upper beach loafing and/or roosting habitats; however, the spatial extent of displacement at any given time would amount to a relatively small segment of the beach in the immediate vicinity of the active construction zone.

The use of heavy machinery to redistribute and establish the design beach profile can result in compaction of the newly deposited beach sediments, which in turn can impede sea turtle nest excavation. Sediment compaction and changes in sediment composition can also affect the suitability of the nest incubation environment and the ability of hatchlings to emerge from the nest (Nelson and Dickerson 1988, Crain et al. 1995). The initial post-construction dry beach (aka berm) profile is generally flatter than the natural beach profile, and consequently, is subject to a period of adjustment during which sediments are sorted and redistributed by wave and wind driven transport processes. This adjustment process often results in the formation of escarpments that can prevent sea turtles from accessing upper dry beach nesting habitats. The potential effects of beach nourishment and other project-related activities on sea turtles and sea turtle nesting habitat are evaluated in detail along with other threatened and endangered species in Section 5.8.2.6.1.

5.7.2.5.3 Dune

Impacts similar to dry beach zone would be expected at the dune, except that the impacts would be applicable to dune dependent species. Existing dune vegetation would be smothered but would be expected to reestablish through natural recruitment and facilitated plantings.

5.7.2.6 Hydrologic Restorations

Habitats

No terrestrial habitats would be impacted by dredging operations. Placement of fill material on the beach is assessed in section 5.7.2.5.

Dredging operations have the potential to adversely affect aquatic habitats and associated species in a variety of ways. These include actions of the dredging equipment (e.g. cutting, suction, sediment removal, hydraulic pumping of water and sediment); physical contact with dredging equipment and vessels; and physical barriers imposed by the presence of dredging equipment, such as from pipelines and booster pumps. Potential impacts vary according to the time period in relation to life cycles of organisms that could be affected, and the nature of the interaction of a particular species with the dredging activities.

The channel was previously dredged and since the channel opening hasn’t been maintained the aquatic habitats are generally featureless and lack any variability in habitat types. Aquatic habitats within the action area primarily consist of soft-bottom benthic habitats. Existing habitats would be expected to follow the historical trend after dredging and the existing habitats would be expected to reappear in the future. There are no special aquatic sites, such as sanctuaries and refuges, coral reefs, mudflats, vegetated shallows, or riffle and pool complexes present within the project footprint.

Individuals/Populations

Dredging involves the complete removal of sediment, which leads to direct mortality to the benthic infauna, such as polychaetes and amphipods that live in the substrate. It can be assumed that dredging would result in high mortality to benthic infauna present in the dredging footprint, but the community would be expected to recolonize after dredging ceases. The resultant turbidity and settling from dredging have the potential for smothering sessile benthic organisms and/or inhibiting filtration functions required by some organisms for respiration and nutrition. The temporary lower DO concentrations that could result from temporary suspension of organic material during dredging could cause a temporary displacement of mobile organisms and may stress or cause mortality to sessile organisms. The effects would be expected to be temporary and minor given the nature of hydraulic dredging, as suspended sediments would return to background levels within a short time and would be similar to what has occurred during maintenance dredging in the past.

Temporary disturbances to finfish such as from noise and light during dredging would be expected; however, given their high mobility, finfish juveniles and adults would be expected to be able to readily avoid impacts of the dredging activity. Injury or mortality to slower moving fish and larval fish may result if the organism cannot move away from the action area when heavy equipment is being operated.

As with other actionable components, natural behaviors of marine organisms may be interrupted because of noise or changes in water quality while dredging is occurring. Organisms that are able to leave the immediate area may be scared away from the activity, but behaviors should return to normal once construction is complete. The extent of temporary, adverse impacts would be dependent on the organisms' dependence on their ability to seek alternate habitat until construction is complete and baseline conditions return.

Long-term impacts on marine organism populations would be expected from the hydrologic reconnection of Laguna Madre. The transition would result in population increases of marine communities favoring hard substrate and a decline in populations that rely on soft bottoms. However, long-term presence of the component would not be expected to cause significant changes to the overall populations of species reliant on open bottoms because of the significant amount of similar habitat types in the bays, estuaries, and along the GIWW.

5.7.3 Modeling

The USACE and its stakeholders used Habitat Evaluation Procedures (HEP) to evaluate the ecological impacts of proposed ER measures. HEP evaluated potential changes to the complex ecosystem processes and patterns operating at the local, regional, and landscape levels across the Texas coast. To summarize the overall HEP analyses, the following steps were completed in the assessment of the study's proposed ER:

1. Build a multidisciplinary evaluation team.
2. Define the proposed ER measures.
3. Set goals and objectives and defining a project life and target years.
4. Select species-based Habitat Suitability Index (HSI) models and a community-based Wetland Value Assessment (WVA) model (a modification of HEP) to evaluate ecological impacts.
5. Calculate baseline conditions and forecasting Future-without Project (FWOP) and Future-with Project (FWP) conditions.

6. Reporting the results of the analyses.

5.7.3.1 Modeling Methodologies

In response to the growing need to evaluate ecological impacts associated with Federal projects, in the 1970s and 1980s, the USFWS and other Federal agencies developed a standard habitat evaluation system, known as HEP, to integrate ecological principals into the planning process. HEP employs a species-based approach to assess ecosystems and provides a tool for planners, resource managers, and biologists to evaluate changes in habitat quality and quantity over time under proposed alternative scenarios (USFWS, 1980). Habitat Suitability Indices (HSI) calculators have been developed to conduct HEP and allows the user to establish habitat units (HUs), the common form of currency when assessing project impacts and benefits, and to determine Average Annual Habitat Units (AAHUs) to capture future project changes for specific project timescales.

HEP models are supported by computed-based programming modules that accept the input of mathematical details and data comprising the specified index model (either species-based or community-based), and through their applications in HEP, calculate identifiable outputs in response to proposed alternative scenarios. These models allow for rapid assessment of changing habitat conditions and the implications of those changes on species, communities, and ecosystems (USFWS, 1980). USACE Civil Works policy requires that only standard habitat models previously certified by the USACE Ecosystem Planning Center of Excellence be used to determine ecological benefits and/or impacts and mitigation (USACE, 2005). In a memo dated July 11, 2017, the use of HEP was approved by the USACE Headquarters Model Certification Panel to be used in support of the Coastal Texas Study. Additional certification is required for the Kemp's Ridley Sea Turtle model.

Five HEP models were approved or will be approved by the USACE to conduct the FWOP and FWP project analyses to determine HSI values, HUs, and AAHUs (**Table 5.7**).

For a complete description of each of the species and community models used, assumptions applied to project future conditions, and the full suite of results see Appendix I.

Table 5-7 Models used to conduct FWOP and FWP analyses

Model	Model Type	Cover Type	Measure Location Where Model Applied
Brown Shrimp Farfantepenaeus aztecus (Tuner and Brody, 1983)	HEP	Estuarine Wetland and Marsh	G-28, B-12, M-8, CA-5, CA-6
Spotted Seatrout Cynoscion nebulosus (Kostecki, 1984)	HEP	SAV	CA-5, SP-1, W-3
Brown Pelican Pelecanus occidentalis (Hingtgen et al., 1985)	HEP	Bird Rookery Islands	G-28, M-8, SP-1, W-3
American Oyster Crassostrea virginica (Swannack et al., 2014)	HEP	Oyster Reefs	G-28, B-12, M-8, CA-5, SP-1, W-3
Kemp's Ridley sea turtle (Pinsky et al., 2020)	HEP	Beach/Dune	W-3

5.7.3.2 Modeling Results

Table 5.8 shows the net AAHUs for each of the actionable measures by model used.

Table 5-8 Summary of Net Habitat Units of Actionable Measures

Model Species by Target Year (TY)	TY 0 (2017)	TY 1 (2035)	TY 31 (2065)	TY 51 (2085)	Net AAHUs*	TY 51 Acres
G-28 Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection						
American Oyster	0	10	8	7	9	18
Brown Pelican	0	185	186	182	184	280
Brown Shrimp	0	1,250	820	60	890	850
B-12 Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection Port-Owned Land Tracts Removed**						
American Oyster	0	1	1	1	1	2
Brown Shrimp	0	930	1,480	150	1,260	1,990
M-8 East Matagorda Bay Shoreline Protection						
American Oyster	0	8	7	5	7	15
Brown Pelican	0	68	62	56	62	79
Brown Shrimp	0	110	190	90	150	2,430
CA-5 Keller Bay Restoration						
American Oyster	0	2	2	2	2	4
Brown Shrimp	0	-30	-30	10	-20	880
Spotted Seatrout	0	240	240	240	238	296
CA-6 Powderhorn Shoreline Protection and Wetland Restoration						
Brown Shrimp	0	60	0	0	20	620
SP-1 Redfish Bay Protection and Enhancement						
American Oyster	0	1	1	0	1	2
Brown Pelican	0	268	266	265	265	419
Spotted Seatrout	0	3,258	3,258	3,258	3,236	3,258
W-3 Port Mansfield Channel, Island Rookery, and Hydrologic Restoration						
Brown Pelican	0	18	18	18	18	23
Kemp's Ridley Sea Turtle					884	
Spotted Seatrout	0	13,010	38,380	38,380	30,420	46,810

Table 5-9 presents the net AAHU outputs and acres for all HSI and/or WVA models within each ER measure.

Table 5-9. Measure Net AAHU Outputs

ER Measure Description	Net AAHUs	Acres
G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	1,083	1,148
B-12 – West Bay and Brazoria GIWW Shoreline Protection	1,261	1,992
CA-5 – Keller Bay Restoration	220	1,179
CA-6 – Powderhorn Shoreline Protection and Wetland Restoration	20	620
M-8 – East Matagorda Bay Shoreline Protection	219	2,524
SP-1 – Redfish Bay Protection and Enhancement	3,501	3,679
W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	30,535	47,812
FWP Scale 1 Total	36,839	58,954

5.8 SPECIAL STATUS SPECIES AND HABITATS

5.8.1 No Action

Under the No Action, special status species and their habitats would be expected to continue degrading over time as a result of storm surge, saltwater intrusion and RSLR. It is possible that in the future, additional species and habitat will be identified as warranting protection under the various environmental laws protecting fish and wildlife.

5.8.2 Alternative D2 and Alternative A

5.8.2.1 Common to All Actionable Measures

5.8.2.1.1 Federally-Listed Species

Table 5-10 provides a summary of which species are listed for each measure and their potential for occurrence in the action area of the applicable measure. A total of 10 species have the potential to occur in at least one of the action area locations, while 15 were identified as not likely to occur in the action area due to lack of suitable habitat.

CH for piping plover overlaps four measures (G-28, South Padre Island [SPI] Beach and Dune Improvements, Bolivar Roads Surge Gates, and Bolivar Peninsula and Galveston Island Beach and Dune Improvements). Designated CH for the remaining six species does not overlap any of the action areas.

Table 5-10 Species listed by USFWS or NMFS as potentially occurring in the action area

Species	Actionable							
	G-28	B-12	CA-5	CA-6	M-8	SP-1	W-3	SPI
Birds								
Piping plover	✓	M	NSH	M	M	M	✓	✓
Red knot	✓	M	NSH	M	M	M	✓	✓
Whooping crane	✓	✓	✓	✓	✓	✓	✓	--
Northern aplomado falcon	--	NSH	NSH	NSH	NSH	NSH	NSH	NSH
Eastern black rail[+]	M	M	NSH	M	M	NSH	NSH	NSH
Attwater's greater prairie-chicken	NSH	--	--	--	--	--	--	--
Clams								
Texas fawnsfoot	--	NSH	--	--	--	--	--	--
Fish								
Oceanic whitetip shark	NSH	NSH	NSH	NSH	NSH	NSH	NSH	NSH
Giant manta ray	NSH	NSH	NSH	NSH	NSH	NSH	NSH	NSH
Mammals								
Sei whale	NSH	NSH	NSH	NSH	NSH	NSH	NSH	NSH
Bryde's Whale	NSH	NSH	NSH	NSH	NSH	NSH	NSH	NSH
Fin whale	NSH	NSH	NSH	NSH	NSH	NSH	NSH	NSH
Gulf Coast jaguarundi	--	--	NSH	NSH	--	NSH	NSH	NSH
Ocelot	--	--	--	--	--	NSH	NSH	NSH
Sperm whale	NSH	NSH	NSH	NSH	NSH	NSH	NSH	NSH
West Indian manatee	✓	✓	✓	✓	✓	✓	✓	✓
Plants								
Texas ayenia	--	--	--	--	--	--	NSH	NSH
South Texas ambrosia	--	--	--	--	--	NSH	--	NSH

Species	Actionable							
	G-28	B-12	CA-5	CA-6	M-8	SP-1	W-3	SPI
Slender rush-pea	--	--	--	--	--	NSH	--	--
Texas prairie dawn-flower	--	--	--	--	--	--	--	--
Reptiles								
Loggerhead sea turtle	✓	✓	✓	✓	✓	✓	✓	✓
Green sea turtle	✓	✓	✓	✓	✓	✓	✓	✓
Leatherback sea turtle	M	M	M	M	M	M	M	M
Hawksbill sea turtle	✓	✓	✓	✓	✓	✓	✓	✓
Kemp's Ridley sea turtle	✓	✓	✓	✓	✓	✓	✓	✓

-- : Not Listed ✓: Quality Habitat, High Potential to Occur in the Action Area

M: Marginal Habitat, Low Potential to Occur in the Action Area

X: No Suitable Habitat, no potential to occur in the action area

+: Species is not listed on the IPaC reports as occurring in the project areas; however, the Service strongly encouraged USACE to consider the species

West Indian Manatee

None of the proposed actionable measures would alter marine habitats or food sources, such as seagrass or other aquatic food plants, in any of the action area. In the rare instance that a manatee could occur in the action area, in-water work during placement of pipelines, operation of watercraft to move material or equipment, etc. could impact manatees. Impacts could include temporary habitat avoidance, exposure to underwater sound, and visual disturbances, which would all cease after construction is complete. The most extreme impact could include entrapment and/or collision with pipes, silt barriers, pumps, placement equipment, support watercraft or other in-water construction equipment. Although this is unlikely due to the extremely rare occurrence of West Indian manatee in the action area, conservations measures, such as utilizing biological monitors with stop work authority and utilizing buffer zones to indicate when to stop work, would be incorporated into the plan to avoid harassment and take of manatee.

Due to the rarity of the manatee in the action area and the conservation measures that would be implemented, implementation of the action may affect, but not adversely affect the West Indian manatee.

5.8.2.1.2 Marine Mammals

Impacts to marine mammals from implementation of any of the actionable measures could occur during in-water activities such as set-up/take-down of dredged material transport pipes, operations of watercraft and heavy equipment, placement of fill material, etc. Actionable measures occurring in nearshore, deeper water (e.g. breakwaters, island restoration, oyster reefs, and hydrologic connections) would have a higher potential for impacting marine mammals during construction than measures which predominantly have construction activities occurring on land with in-water work limited to transport of dredged material (e.g. island restoration, marsh restoration, dune/beach restoration). Impacts could include temporary habitat avoidance, exposure to underwater sound, and visual disturbances, which would all cease after construction is complete. The most extreme impact could include entrapment and/or collision with pipes, silt barriers, pumps, placement equipment, or other construction equipment. Although this is unlikely due to the relatively low occurrence rate of bottlenose dolphins and extremely rare occurrence of West Indian manatee in the project area, additional measures are being incorporated into the plan to avoid potential incidental harassment and "take" of marine mammals. The following mitigation measures would be implemented:

- Qualified biologists would monitor the presence of marine mammals during phases which involve open water areas capable of supporting marine mammals.
- Before activities occur in open water areas, a 50-foot radius of the work area should be delineated. If any marine mammal is observed within the 50-foot radius, the biological monitor shall halt construction activities, including shutting down any running equipment until the animal has moved beyond the radius, either through sighting or by waiting until enough time has elapsed (approximately 15 minutes) to assume that the animal has moved beyond the buffer.
- If siltation barriers are used, they will be made of material in which marine mammals cannot become entangled, should be properly secured, and regularly monitored to avoid mammal entrapment.

Implementation of any of the actionable measures could have minor, temporary adverse impacts on marine mammals, but impacts are not anticipated to result in take. None of the action alternatives would result in long-term adverse impacts to marine mammals through a reduction in their food base, blocking or limiting passage to or from biologically important areas, or permanently destroying habitat.

The anticipated impacts are not expected to rise to the level of significant or result in the need for NOAA to issue an Incidental Take Authorization, especially with the incorporation of the mitigation measures listed above. Typical actions which require permits from NOAA include actions that involve: military sonar and training exercise; oil and gas development, exploration, and production activities; geophysical surveys for renewable energy and scientific research; and pile driving associated with construction projects. None of these activities are proposed under any of the actionable measures.

5.8.2.2 Breakwaters

5.8.2.2.1 Federally-Listed Species

Movement of construction vehicles and barges with riprap along the GIWW could potentially increase the risk of a collision with an animal (NOAA, 2017d). Navigational lighting on breakwaters may also disorient sea turtles (NOAA, 2014). There are no known sea turtle nesting sites along the GIWW due to lack of suitable habitats; therefore, impacts to sea turtles from these ER features are not expected (Turtle Island Restoration Network, 2018). Breakwaters are expected to benefit Federally-listed shorebirds such as piping plovers, red knots, and least terns. Breakwater structures would provide a hard surface for oysters and clams to colonize. Colonized hard structures such as breakwaters can provide habitat for fish, crabs, and invertebrates, which would attract red knots and whooping cranes (see Section 5.4.2.2; Cornell Lab of Ornithology, 2018). Accretion of sand and sediments behind the breakwater structure would increase tidal flat areas for foraging and loafing shorebirds such as piping plovers (USFWS, 1996). Breakwater ER features would also indirectly benefit Federally listed shorebirds and inland species by providing coastal shoreline protection from erosive wave action from barge traffic or rising sea levels.

Approximately 4 acres of piping plover critical habitat would be impacted (USFWS, 2017c). The impacts to Unit TX-37: Rollover Pass are expected to be permanent with riprap structures and placement. However, the breakwater would stabilize the shoreline and prevent further erosion from storms and ship wake. The ER measure is expected to provide a net benefit to critical habitat and undesignated piping plover and rufa red knot habitat by protecting vulnerable habitat from erosion.

5.8.2.2.2 Migratory Birds

Construction of breakwaters can disturb migratory birds roosting or loafing within the vicinity (Dufour, 1980). Turbidity within the water column can decrease foraging efficiency of birds (Greene, 2002). Once completed, breakwater structures can provide hard structures for oyster colonization and habitat for fish, crustaceans, and mollusks, which would provide food for migratory birds such as oystercatchers, sandpipers, and plovers. The structures would indirectly benefit migratory birds by protecting vulnerable beaches, wetlands, and tidal flats from wave action and erosion. The structures would protect marsh, SAV, and oyster reef habitat from eroding, which in turn would protect marsh, beaches, and other valuable nursing grounds, loafing, and foraging habitat for migratory birds (Swann, 2008). There are no long-term impacts to migratory birds expected from the construction of breakwaters.

5.8.2.2.3 Essential Fish Habitat

Construction of breakwaters would permanently convert open water (combination of estuarine mud bottoms, Gulf waters, marsh edge, offshore, beach, coastal, and sand EFH) to rock which is not considered EFH. However, the loss of EFH would be offset by the long-term protection of valuable EFH habitats such as marsh, SAV, and oyster reef habitat from erosion, which then also maintains valuable nursery grounds for the many fish and shellfish species that live within the estuaries. As well, the quality of EFH in the immediate vicinity would increase due to a decrease in long-term turbidity and suspended sediments from continual erosion and land loss.

Finfish could be directly affected by construction of the breakwaters. Particular species that could be effected include the Red Drum (*Sciaenops ocellatus*), Gray (mangrove) snapper (*Lutjanus griseus*), Brown Shrimp (*Penaues aztecus*), White Shrimp (*Penaues setiferus*), and the Pink Shrimp (*Penaues duorarum*). Other Highly Migratory Species (HMS) could be impacted as well. Those HMS species include the great hammerhead (*Sphyrna mokarran*), bull shark (*Carcharhinus leucas*), lemon shark (*Negaprion brevirostris*), spinner shark (*Carcharhinus brevipinna*), Bonnethead Shark (*Sphyrna tiburo*), and the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*). Individuals could be injured or killed through contact with the construction equipment or could be smothered under the breakwater material. In addition, construction activities, may change EFH species' normal behaviors, such as foraging and hunting, as a result of noise and/or temporary, minor changes to water quality. The disturbance of sediment and placement of reef material is expected to result in increased turbidity and decreased DO during placement of material. Increased turbidity could cause gill clogging and reduce the foraging success of sight hunters. Reduced DO levels within the water column can stress aquatic organisms if the levels are low enough. Impairments to water quality are expected to be minor and temporary only lasting until all material is placed. Fish usage is expected to return to baseline conditions once construction is complete.

As well, the placement of material may reduce the population of prey species used by EFH. Relatively non-motile benthos, such as polychaetes and mollusks would be lost during placement of the material; this may cause fish to move out of the project area until benthic communities recover. Recovery time of the benthos within the project area is expected to be between several months to several years.

The significance of direct effects resulting from construction of the breakwaters on EFH species will depend on life stage and the usage of the project area. For example, it is more likely that eggs and larval fish will be affected to a greater extent than adults and juveniles, because the older life stages have greater swimming abilities and will be able to move away from construction activities. However, eggs and larvae of many species are widely distributed over the continental shelf, so the destruction of these life stages is not expected to cause significant impact to fish populations.

USACE has determined that construction of the ER feature may have minor adverse effects on EFH for federally managed species, but the adverse effects on EFH species will largely be temporary and localized within the footprints of the constructed breakwater. Long-term operation of the breakwater is not expected to impact "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" to any appreciable extent over a significantly large area or over any significant period of time. Although construction of the project may impact individual fish, no adverse effects to the populations of EFH species that inhabit any of the project areas are expected. Also, conversion of EFH habitat to non-EFH habitat is conserved a long-term adverse impact to EFH habitat; however, the long-term benefit of protection of a significantly larger area of EFH habitat outweighs the minor loss. Because no significant adverse impacts are anticipated, no mitigation has been proposed.

5.8.2.2.4 Invasive Species

There are no known invasive species issues known to be associated with the construction of breakwaters.

5.8.2.3 Island Restoration

5.8.2.3.1 Threatened and Endangered Species

Due to lack of suitable habitat, there are no known sea turtle nesting locations along the GIWW (Turtle Island Restoration Network, 2018). Impacts to sea turtles are not expected to result from island restoration measures. Prey species, such as marine worms, small crustaceans, and small mollusks that piping plovers and red knots rely on may become buried with sediment placement on islands, but these impacts would be temporary (Michel et al., 2013). Turbidity is expected to be localized to the placement area and would quickly disperse or settle down (Greene, 2002). In the long term, piping plovers, red knots, and northern aplomado falcons would benefit from the ER features due to increased island size and stability for foraging, nesting, roosting, and hunting (Greene, 2002; Schreiber and Schreiber, 1978). No long-term effects are anticipated from island restoration ER features.

5.8.2.3.2 Migratory Birds

Possible short-term impacts to island reconstruction can include increased turbidity from sediment placement and bird disturbance from construction activity. Overall, island restoration is expected to benefit to migratory bird species. The expansion and restoration of functionality to islands along the Texas coast can increase available habitat for nesting, foraging, and roosting for migratory birds. The construction of nesting platforms and native shrub plantings can attract birds to establish rookeries on the islands (Schreiber and Schreiber, 1978). There are no long-term impacts expected with the restoration of islands.

5.8.2.3.3 Essential Fish Habitat

The Island Restoration would convert approximately 868 acres of tidally influenced open water habitat classified as EFH to upland habitat designed to support bird nesting and foraging. The majority of the Island Restoration would occur along the GIWW which were eroded over time and have converted to shallow soft substrate habitat. Once restored, these islands would benefit the surrounding EFH by reducing wind energy which reduces turbidity and increases the suitability for sea grasses. Additionally, the designs for many of the islands would include oyster reef construction on the bay side of the features to protect against future erosion, increase the diversity of habitat, and increase the water quality through the filter feeding activities. Finally, these islands would further protect the bay systems from ship wakes that are common along the GIWW.

The same species and potential effects from the previous section on marsh restoration also apply to island restoration (Section 5.8.2.2.3) because the activities both involve placing dredge material in eroded soft habitat.

5.8.2.3.4 Invasive Species

Following the suggestions of the interagency team, the restored islands will be planted with native scrub species and some areas would be covered with shell hash or similar material to support birds that nest in open areas. The final plant species list and densities will be determined with help from the interagency team in PED. Invasive and noxious plant species like Saltcedar (*Tamarix L.*) and Chinese tallow (*Triadica sebifera*) are of particular concern. The planting regimen and monitoring and management for these species is included in the Monitoring and Adaptive Management Plan (Appendix K).

5.8.2.4 Marsh Restoration

5.8.2.4.1 Federally-Listed Species

Piping Plover and Rufa Red Knot

Marsh restoration activities would occur at least 0.5 miles from any beach/dune ecosystems. It is unlikely that at this distance any construction activities would affect piping plover or red knot from a noise disturbance or habitat avoidance standpoint. No dredged disposal placement areas, which are sometimes used by both species, would be affected by restoration measures. None of the landscape features attractive to plovers are present in or adjacent to where restoration activities would occur; therefore, implementation of the proposed action would have no effect on the piping plover or rufa red knot.

Eastern black rail

Marsh restoration activities would occur in degraded open water habitat, but it would be in close proximity to stands of smooth cordgrass. If present, it is likely that Eastern black rail would be displaced by construction noise and activity. It is highly unlikely that mortality of any individuals would occur during construction due to their ability to avoid the construction area. However, additional voluntary conservation measures have been incorporated into the plan to reduce the potential impacts. The conservation measures include preconstruction surveys to ensure individuals are not present. From a long-term perspective, the restoration of the tidal salt marshes will be beneficial for the species because that is one of the preferred habitats of eastern black rail.

USACE has determined the proposed action may affect, but is not likely to adversely affect the eastern black rail because the temporary adverse impacts are anticipated to be insignificant and discountable, especially since conservation measures have been incorporated into the plan, and the overall beneficial impacts would far outweigh any negative impacts.

Whooping Crane

Attempts would be made to avoid construction from October 1 through April 15 when birds are most likely to be present. If construction must be completed during this time in order to take advantage of the dredging windows, potential impacts to whooping cranes include noise disturbance during foraging activities or habitat avoidance while construction equipment is operating. Impacts to the species would cease after construction is complete. It is highly unlikely that mortality of any individuals would occur during construction due to their ability to avoid the construction area. However, additional voluntary conservation measures have been incorporated into the plan to reduce the potential impacts.

Implementation of this actionable component will indirectly contribute to recovery of the species through marsh restoration and protection from future development. The International Recovery Plan lists several recovery actions including protecting wintering habitat to accommodate expanding crane populations (CWS and US Fish and Wildlife Service 2007), which is already evidenced by the presence of NEP birds near the study area. By restoring marsh habitat at least two identified recovery actions have been addressed (1.5.3.6—Better manage deposition of dredge material, 1.5.5—Create wetland habitat). In general, marsh restoration actions would be beneficial to the whooping crane through an increase in quality foraging habitat and at some point in the future could serve as a wintering site.

USACE has determined the proposed action may affect, but is not likely to adversely affect the whooping crane because the temporary adverse impacts are anticipated to be insignificant and discountable, especially since conservation measures have been incorporated into the plan, and the overall beneficial impacts would far outweigh any negative impacts.

5.8.2.4.2 Migratory Birds

During construction, migratory birds may be disturbed by human activity and relocate to adjacent habitats (Bottalico et al., 2015). After construction is completed, wetland restoration measures would benefit migratory birds by providing forage, roosting, and nesting habitat (Schreiber and Schreiber, 1978; Stewart, 2016). Marsh nourishment construction of containment levees and pumps, placement of fill within the levees, and creating sinuous circulation channels and pond with marsh buggies are expected to disturb and disrupt migratory birds (Bottalico et al., 2015; Michel et al., 2013). The restored marsh would provide shelter, forage, roost, and nursery and stopover habitat for migratory bird species (Stewart, 2016).

Many important habitats in the focused study area provide migratory bird shelter, nesting, feeding, and roosting habitat. All adverse impacts to migratory birds would occur during construction and cease post-construction. Significant beneficial impacts to migratory birds would be expected from ecosystem restoration measures. Restoration of marsh, beach, and dunes would result in an overall net increase in functional value and ultimately support larger populations of species and potentially increase species diversity.

During construction, there is a potential for harm and/or harassment of nesting migratory birds. Attempts would be made to conduct all restoration activities outside of the nesting season; however, this may not be possible, due to the timing of dredge availability and the extended length of the nesting season for some species. Prior to construction commencing, if during the nesting season, nest surveys should be completed. If nests are identified, all construction activities should observe a 1,000-foot buffer of any colonial-nesting waterbird colonies (e.g. egrets, herons, ibis, pelicans, etc.); a 1,300-foot buffer for any shorebird nesting colonies (e.g. terns, gulls, plovers, skimmers, etc.); and a 2,000-foot buffer for any brown pelican nesting colonies near the restoration measure implementation locations. Coordination with USFWS should be completed prior to construction if nesting has been identified and USFWS guidelines should be followed to avoid adverse impacts to these species. By implementing these conservation measures, there should be no adverse effects to migratory birds.

Implementation of any of the action alternatives would be in compliance with the Migratory Bird Treaty Act and Executive Order 13186, Responsibility of Federal Agencies to Protect Migratory Birds.

5.8.2.4.3 Essential Fish Habitat

Any of the action alternatives would convert open water and degraded marsh (combination of estuarine marsh and estuarine mud bottoms EFH) to estuarine marsh (marsh edge, submerged aquatic vegetation, marsh ponds, and inner marsh EFHs). Construction activities using earthen materials to create marsh would elevate substrates and temporarily change environmental conditions, including increased turbidity, total suspended sediments, and water temperatures and lower dissolved oxygen levels in the water column. However, the effects would be short-term and localized, and the area would be expected to return to baseline conditions following completion of dredging and construction activities, except for in the marsh restoration units, in which a different EFH type would form.

Estuarine emergent wetland would be the primary type of EFH that would increase significantly at any of the restoration sites. This type of habitat would be created in shallow-open water areas and deteriorated marsh. Depending on the actionable measure, anywhere from 236.5 to 664 acres, for a total 1,980.5 acres of emergent marsh habitat would be restored. Estuarine emergent wetlands are highly productive in comparison to subtidal open bay bottom habitat. Additionally, estuarine emergent marsh provides nursery habitat for numerous marine species including the Red Drum, Brown Shrimp, White Shrimp, and Pink Shrimp. These larval, juvenile, and young adult crustaceans, finfish, and mollusks are important prey species for other marine organisms including all of the species listed in Section 5.8.2.2.3.

The discharge of dredge material into open bay bottom to create estuarine emergent wetlands would result in some minor impacts during construction and very large long term ecological benefits.

5.8.2.4.4 Invasive Species

There are no current invasive species concerns with salt marsh restoration in the region. Plants will be sourced locally to ensure that regional variants of the species are not introduced.

5.8.2.5 Oyster Reef

5.8.2.5.1 Federally-Listed Species

Oyster cultch placement via boat or barge would produce localized turbidity, boat traffic, and construction noise. These actions could temporarily affect Federally-listed species but would be limited to the period of construction only (Greene, 2002; Peng et al., 2015). Oyster reefs provide habitat and attract a variety of fish, crustaceans, and invertebrates. Piping plovers, red knots, whooping cranes, and sea turtles would directly benefit from additional food resources and improved water quality from oysters (NOAA, 2018c). The overall benefit from oyster reefs are expected to outweigh short-term construction impacts. In addition, oyster reefs also provide shoreline protection from waves, floods, and tides.

5.8.2.5.2 Migratory Birds

Placement of oyster reef balls may disturb the bay bottom and create localized turbidity. Turbidity would be temporary, and conditions are expected to normalize after reef construction is complete (Greene, 2002). Oyster reefs can indirectly benefit migratory birds similarly to breakwaters, by providing fisheries, crustacean, and benthic macroinvertebrate habitats, and stabilizing shoreline. Oyster reefs can provide food for migratory species, such as oystercatchers, godwits, and plovers. In addition, oyster reefs and living shorelines can reduce erosive wave action and protect bird habitat such as rookery islands and marsh (Swann, 2008). There are no anticipated long-term impacts to migratory birds from oyster reef creation.

5.8.2.5.3 Essential Fish Habitat

The short- and long-term impacts of constructing oyster reefs would be similar to those described for the breakwaters, except that more productive EFH habitat would replace existing EFH habitats.

The conversion of shallow, muddy or sandy bottom habitat to hard reef habitat will be permanent in nature. However, the amount of muddy or sandy bottom that will be altered is relatively minor in comparison to the large areas of sandy seafloor that would remain available once construction is complete. As well, increasing habitat heterogeneity would have a long-term beneficial effect to EFH species and will far outweigh the effects that would result from the loss of sandy bottom habitat. The reef would increase productivity of the system and provide habitat for prey species, such as crustaceans, mollusks, worms, and fish. The hard reef structures would also increase shelter, cover, and foraging opportunities for EFH species, as well as attachment surfaces for benthic egg masses.

5.8.2.5.4 Invasive Species

The development of oyster reef habitat is not anticipated to spread or support invasive species.

5.8.2.6 Dune/Beach Restoration

Construction of sand dunes would add additional hunting and nesting habitat available for aplomado falcons which are typically found in sand ridges in coastal prairies along the barrier islands (USFWS, 1990). Sea turtles are known to nest on South and North Padre islands and therefore would be temporarily impacted by the ER feature. The beach on the north and south side of the Port Mansfield Channel is an important nesting site for Kemp's ridley sea turtles and is a designated critical habitat for piping plovers. Piping plovers, red knots, and other shorebirds may be temporarily disturbed by pipelines, bulldozers, and other construction activities during the placement of sediment material and beach shaping. Disturbances to listed species are expected to be short term; the species are expected to return and recolonize beaches and dunes once construction is completed. Restored dunes and beaches are also expected to indirectly benefit threatened and endangered species by protecting coastal habitat and providing a barrier to erosive wave action and RSLR.

There are approximately 388 acres of piping plover critical habitat from Unit TX-36: Bolivar Flats to Unit TX-34: San Luis Pass (USFWS, 2017c). Impacts to critical habitat would be temporary and would include construction activities associated with beach nourishment and environmental restoration (e.g., placement of dredge material, contouring using bulldozers, and planting of dunes with native species). There are no anticipated permanent impacts to critical habitat associated with the project. Tidal areas and beach habitat would be enhanced and continue to provide foraging, nesting, and loafing habitat for piping plovers.

5.8.2.6.1 Federally-Listed Species

Sea Turtles

W-3 and the South Padre Island beach and dune nourishment are the only actionable measures in which dredged material would be beneficially used to nourish 9.5 miles of beach for W-3 and 2.2 miles of dune and beach restoration for South padre Island; which could impact sea turtle nesting; therefore, additional consultation with USFWS is required because sea turtles on land fall under the purview of that agency. The dredged material would come from the Hydrologic Reconnection component of W-3 and the Brazos Island Harbor or the extra sand source identified for South Padre Island. The impacts of dredging on turtles and other Federally-listed species is addressed in section 5.8.2.7.1.

Sea turtle nesting has not been documented in the action area in the recent past. The project area has been described as unsuitable due to the narrow existing beach width. With implementation of this actionable measure, beach nourishment and dune construction is expected to increase the suitability of the action area's beaches for sea turtle nesting. Because nest-site selection by female turtles is poorly understood, it is difficult to predict any effect that changes induced by nourishment could have on selection of a nest site (Crain et al 1995). If nesting were to occur it would most likely be by Kemp's ridley, however, any of the five species of listed turtles could nest in the project area. All five species are known to nest at Padre Island National Seashore, in which the project area is located.

Placement of dredged material on the beach is not expected to impact nesting turtles due to the anticipated lack of presence in the action area and the anticipated timing of the action occurring outside the nesting season. Biological monitors would be present throughout the operation and all work would cease if turtles or nests are discovered.

Drift fences, also commonly called sand fences, may be erected to help build and stabilize the newly constructed dune. Improperly placed, broken, or abandoned drift fences can impede nesting attempts and/or trap emergent hatchlings and nesting females. If sand fences are erected, monitoring of the site would occur to ensure that the sand fence is maintained and functions properly. If turtle nesting is observed within the project areas, the sand fence would be reassessed to determine if its presence could hinder nesting at the site. At that time, removal, modification, or no action would be taken to ensure the sand fence does not present a threat to potential nesting in the area.

Construction activities from setting pipelines, movement of personnel and equipment, and heavy equipment operation associated with shoreline or marsh restoration measures could create activity, noise and vibrations that the species finds undesirable. Sea turtles are highly mobile and will likely avoid the area due to any project activity and noise. Likewise, there is sufficient nearshore habitat that temporary avoidance of the area would not be expected to affect foraging ability. Normal behavior patterns of sea turtles are not likely to be significantly disrupted because of the short-term localized nature of the action and the ability of sea turtles to avoid the immediate area.

Overall, implementation of the proposed action may affect, but is not likely to adversely affect the loggerhead, green, hawksbill, and Kemp's ridley sea turtles, and may ultimately be beneficial through creation of suitable nesting habitat. Mitigation measures such as seasonal-timing restrictions if nesting is identified and reassessment of sand fences would eliminate the potential for take of the species.

Piping Plover and Rufa Red Knot

Because both of the species share very similar foraging and roosting behaviors and share similar coastal habitats within the action area, the effects of the action on the two species is expected to be very similar and will, therefore, be discussed together.

Implementation of the proposed actionable measure would occur within habitat that is documented as being used by wintering piping plover and red knot. Since piping plover spends a significant portion of the year in or near the action area and red knots would be present during the prime dredging window, construction is likely to occur while the species are utilizing or could utilize the beaches and associated habitats. Short-term and temporary impacts could result from project work occurring on the beach that flush birds from roosting or foraging habitat. Additionally, construction activities could result in harassment caused by human presence, vehicular traffic, operation of heavy equipment, increased noise, loss of benthic prey, and unavailability of wintering foraging and roosting habitat during construction and until the benthic fauna recovers after the project is complete. Although in other similar nourishment projects, it has been noted that birds are seen feeding at the sediment discharge site due to the increase in potential food supply. Because these species are opportunistic and could utilize other suitable adjacent habitats for feeding, roosting, and shelters, the impacts are expected to be relatively minor and insignificant and would not be expected to cause a long-term decrease in the birds ability to recover from migratory flights from their breeding grounds, survive while on the wintering grounds, or hinder the ability to prepare for migration back to the breeding grounds.

Physical changes to the existing shoreline are expected to have an overall long-term benefit. Beach nourishment would increase the currently narrow beach, which should support a more productive wrack line, thereby improving foraging habitat. Increasing the sediment in the sediment budget may also increase the likelihood of developing washover fans and emergent nearshore sand bars which are valued by piping plovers in particular. Once restoration is complete, the overall project would benefit piping plover and red knots by providing approximately 9.5 miles of higher quality foraging and roosting habitat.

Beach nourishment would occur near, but not within piping plover critical habitat. Dune construction and beach restoration would not affect the characteristics of the critical habitat located on the backside of the action area.

Despite temporary habitat unavailability for wintering birds during the construction period and a temporary reduction of habitat quality, the benefits of the restoration far outweigh any potential temporary adverse impacts to the species and wintering habitat. Therefore, implementation of the proposed action may affect but is not likely to adversely affect the piping plover or rufa red knot.

5.8.2.6.2 Migratory Birds

Noise associated with construction can disturb waterfowl and other migratory birds (Bottalico at al., 2015). Sand dunes are also natural barriers for wave and wind action that could potentially erode the shoreline and fragile habitats (United Nations Environment Programme, 2018). Disturbances to wildlife are expected to be short term, and wildlife species are expected to return and recolonize beaches and dunes once construction is completed. Benthic macroinvertebrates provide important forage for shorebirds. Dredging impacts to benthic macroinvertebrates can be minimized by using similar grain-sized fill materials and avoiding the placement of fill during peak periods of larval recruitment (Wilber et al., 2010).

5.8.2.6.3 Essential Fish Habitat

The Beach and Dune restoration activities for the Actionable Measures would convert 9.5 acres of open water to EFH to beach and dune habitat. The proposed restoration area on the Padre Island National Seashore is highly erosive, the annual rate of beach retreat for the mid to lower coast is estimated an average of 3.2 feet per year and can be as high as 30 feet per year (Paine et al., 2014). The Mansfield Jetty structures also interrupt the longshore transport in that area. Restoring the beach habitat would benefit adjacent EFH because the sand veneer protects the underlining fine sediments from being disturbed which would increase turbidity. Also, interstitial species that transit into the wash zone and are prey items for marine species rely on the beach environment.

5.8.2.6.4 Invasive Species

Following the suggestions of the interagency team, the restored dunes will be planted with native species. The final plant species list and densities will be determined with help from the interagency team in PED. Monitoring for invasive and noxious plant species is included in the Monitoring and Adaptive Management Plan (Appendix K). Saltcedar is again a species of concern.

5.8.2.7 Hydrologic Restorations

5.8.2.7.1 Federally-Listed Species

The federal action for the hydrologic restoration is dredging the Mansfield Channel. The potential effects of the construction activities to federally listed species are the same as those discussed for dredging associated with Island Restoration and for the Beach and Dune Restoration (Sections 5.8.2.6.1 and 5.8.2.3.1). The hydrologic restoration is anticipated to improve salinities and water quality in the Laguna Madre by allowing tidal exchange with the Gulf of Mexico through the Mansfield Channel. These conditions would support sea grasses which would increase the productivity of the system and would increase the availability of the prey items of several federally listed species including the Least Tern, the Northern Aplomado Falcon, the Piping Plover, the rufa Red Knot and the Piping Plover.

5.8.2.7.2 Migratory Birds

The hydrologic restoration is anticipated to improve salinities and water quality in the Laguna Madre by allowing tidal exchange with the Gulf of Mexico through the Mansfield Channel. These conditions would support sea grasses which would increase the productivity of the system and would increase the availability of the prey items migratory bird species including the bald eagle. The sea grasses in the Laguna Madre are important forage material for migratory waterfowl.

5.8.2.7.3 Essential Fish Habitat

The hydrologic restoration is anticipated to improve salinities and water quality in the Laguna Madre by allowing tidal exchange with the Gulf of Mexico through the Mansfield Channel. These conditions would benefit EFH in the Lagoon. Specifically, Red Drum and the three shrimp species listed above (especially the Pink Shrimp) would benefit from the measure.

5.8.2.7.4 Invasive Species

There are no invasive species issues thought to be associated with the hydrologic restoration.

5.9 CULTURAL RESOURCES

5.9.1 No Action

There are 250 previously recorded cultural resources located within 1,000 feet of the CSRM Alternatives and the eight Ecosystem Restoration Measures. The formation processes that currently affect these sites will continue into a future without the project. Submerged cultural resources could be at risk from future dredging activities, shifting bars, and wave damage for shallow sites. Submerged resources are also at risk from high energy storms that can dislodge wrecks from the seafloor or impact wrecks on beaches or in shallow water. Upland historic and prehistoric sites will continue to be at risk from shoreline erosion and commercial, industrial, and residential development. Shoreline sites are also at risk from sea level rise and storm surge. These formation processes may result in partial or total loss of historic properties.

5.9.2 Alternative D2 and Alternative A

There are seven actionable ER measures proposed along the Texas Coast. Although a majority of these areas have not been previously investigated for cultural resources, there are previously recorded cultural resources within the project area (**Table 5.11**). The probability for encountering intact archeological resources in the upland portions of these ER measures is moderate to high. The archeological resources may consist of prehistoric or historic terrestrial sites that may be exposed on shorelines or shallowly submerged. Activities in these upland areas such as nourishment of marshes and beaches (G-28, B-12, M-8 and W-3) are expected to have minimal impact on the integrity of intact resources. However, beach nourishment material will be obtained by dredging material from offshore and there is a moderate to high potential for impacting submerged archeological sites in those areas. Earth moving activities in the uplands that involve dune building and modifications to existing islands and landforms (G-28, CA-6, M-8 and SP-1) have a potential to adversely affect historic properties. Additionally, some measures include impacts to submerged lands including breakwaters and oyster reefs (G-28, B-12, M-8, CA-5, CA-6 and SP-1), as well as dredging in the Laguna Madre (W-3).

Table 5-11 Cultural Resources within Ecosystem Restoration Measures

ER Measure	Archeological Sites	National Register Historic Properties
G-28	41GV1, 41GV6, 41GV128, 41GV172, 41CH354, 41CH355, 41CH360, 41CH362, 41CH363	None
B-12	41BO79, 41BO85, 41BO86, 41BO135, 41BO170 (Ducroz Cemetery), 41BO176, 41BO199, 41BO205	None
CA-5	41CL40, 41CL41	None
CA-6	41CL14, 41CL53, 41CL54	La Salle Monument
M-8	41MG82, 41MG111	None
SP-1	41SP64, 41SP72, 41NU290, 41NU210	None
W-3	41KN11, 41WY23	None

The Area of Potential Effect (APE) for the proposed undertaking includes the footprint of all areas of direct impacts and a 1,000-foot buffer for indirect impacts to standing structures or buildings, as a result of new construction, construction of staging and access areas, ecosystem restoration features, offshore dredging, and project maintenance activities. Based on the current information, there is a potential to affect historic properties. These affects consist of direct impacts to upland and submerged areas, both inshore and offshore, from construction and maintenance of storm and flood risk management features, the construction and maintenance of ecosystem restoration features, and offshore dredging for beach nourishment. The USACE recommends intensive cultural resources investigations to identify and evaluate any historic properties within proposed areas of direct and indirect impacts. The scope of these investigations will be determined in concert with the Texas State Historic Preservation Officer (SHPO) and Tribal Nations and in accordance with the Draft Programmatic Agreement for this project. The Programmatic Agreement is currently being coordinated with the SHPO, Tribal Nations, and the Advisory Council on Historic Preservation. Once executed, it will be included in future phases of the project.

5.9.3 Mitigation

The mitigation of historic properties may be necessary following an evaluation of impacts to determine if any historic properties will be indirectly impacted. Any unevaluated archeological sites (marine or terrestrial) within the study area will need to be delineated as to their horizontal and vertical extent and evaluated for their eligibility for inclusion in the NRHP. Cemeteries within the study may be directly or indirectly impacted and will need to be delineated and evaluated. There is also the potential for identifying cultural resources during survey investigations of high probability areas. Archeological historic properties would require data recovery excavations or avoidance and cemeteries would need disinterment and interment of burials to a new location. The relocation of burials from impacted cemeteries might also involve purchasing land if other arrangements cannot be made.

5.10 SOCIOECONOMICS

5.10.1 No Action

The Galveston Bay region is surrounded by intensive urban and industrial development that is expected to continue changing in response to the demands of projected economic growth. Resources in the Bay watershed have been utilized for construction, transportation, oil, gas and petrochemical production, water supply, fisheries, agricultural and recreational uses. Projected growth in population and economic activity would result in increasing use of bay resources. Major expansions and managed changes are in progress or proposed for the ports and navigation channels. More people would place more demands on water supply, roads and highways, and land for development. Under the No Action Alternative, the action areas in and near G-28 and B-12 may experience encroachment in the future in which more people would seek to utilize the areas.

All other action areas are considered to be rural and development is unlikely to encroach on these areas; therefore, under the No Action alternative, the socioeconomics of these areas is not expected to change.

5.10.2 Alternative D2 and Alternative A

5.10.2.1 Socioeconomics

Socioeconomic impacts are assessed in terms of direct effects on the local economy and population, and related indirect effects on other socioeconomic resources within the study area or adjacent to the study area. Socioeconomic impacts would be considered significant if the alternative resulted in a substantial shift in population trends or notably affected regional employment, earnings, or community resources such as schools.

Implementation of the actionable measures would not affect the area’s population distribution, community cohesion, the demand for local public services, or land use. Construction activities would be expected to directly beneficially affect the local economy through a temporary increase in economic activity in the construction sector. Temporary increases in employment, income, business activity, and local tax revenues would be anticipated in years in which construction would occur.

Many in the local community’s value recreation and depend on recreation activities as a source of income. No negative impacts associated with reduced recreation, in particular hunting and fishing opportunities, are anticipated as public access to public lands would be maintained. Private land owners affected by recreation decreases would be appropriately compensated when lands are purchased to implement the action. The restoration nature of the actionable measures is expected to increase the overall diversity and productivity of each site, which could encourage additional recreational use within and in the vicinity of the restoration units thereby benefiting local economies.

Implementation of any of the actionable measures would not result in any long-term or permanent, significant adverse or beneficial impacts to socioeconomics. All impacts would be temporary in duration and localized resulting in beneficial non-significant impacts.

5.10.2.1.1 Oyster Reef

The oyster cultch and reef sites would not be open to oyster leasing and would therefore not provide any direct increase to local watermen. However, the increase in production of oyster larvae at the new sanctuary sites could be transported to areas open to harvest, which would beneficially impact local watermen. The extent of benefit has not been quantified and is not expected to be significant.

5.10.2.2 Environmental Justice

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, addresses concerns over disproportionate environmental and human health impacts on minority and low-income populations. The impetus behind environmental justice is to ensure that all communities, including minority, low-income or federally recognized tribes, live in a safe and healthful environment and that no group of people including racial, ethnic, or socioeconomic, should bear a disproportionate share of the negative consequences resulting from the execution of federal, state, local, and tribal programs and policies. The goal of fair treatment is not to shift risks among populations, but to identify potential disproportionately high and adverse effects and identify alternatives that may mitigate these effects.

None of the actionable measures would be expected to contribute to the status of any of the environmental justice indicators. Short-term, minor adverse impacts on recreation during implementation of any of the actionable measures is expected. However, these impacts would not disproportionally affect minority or low-income populations.

5.11 TRANSPORTATION

5.11.1 No Action

Under the No Action alternative, transportation infrastructure would be to continue to operate and be maintained in a similar manner over the planning horizon. For the most part, minimal to no roads or railways are found in or near the actionable measures. In the future, transportation infrastructure would be more susceptible to damages resulting from hurricane storm surge events due to expected RSLR. There would also be reduced access to infrastructure during and following the events until any damages are remediated.

Maintained navigation channels are assumed to be dredged following established O&M schedules. For both maintained and natural navigation channels, there would be an expected increase in vessel use of the channels over the planning horizon as a result of increased shipping needs and additional recreational use in the future.

5.11.2 Alternative D2 and Alternative A

Implementation of any of the action alternatives would have no direct impact on transportation or transportation corridors. Local use of roadways and highways would be minimal since most access to the restoration site would be via waterways. Insignificant indirect impacts on local roadways and Highway 87 could include the additional wear and tear, caused by support vehicles entering the restoration units. The level of indirect impacts would be expected to be minimal and not cause a noticeable increase or hardship on local maintenance programs.

5.11.2.1 Navigation

During project construction, various small recreational type vessels and larger commercial vessels, including barges and tugs, may be moving near the action areas. The target location of any of the actionable measures would be sufficiently offset from any navigation channels, so that during construction there would be sufficient space for recreational and larger commercial vessels to avoid construction equipment and vessels. Multiple actionable components occurring in the same area would be completed in phases (e.g. breakwaters would be constructed first, then marsh restoration would be completed at a later date) to ensure there would be no disturbance to navigation traffic as a result of having multiple construction activities going on at the same time.

Post-construction, marshes, island, and beach/dune restoration would have no long-term impact on navigation traffic or operations as these actions would be completed outside of the navigation channel. GIWW breakwaters would be built within the GIWW; however, the structures would be placed outside of the right-of-way where possible and when placed within the right-of-way would be placed so as to not interfere with navigation or cause navigational hazards. Navigational lighting would be placed on the breakwaters to signal to watercraft of teir presence. For oyster reef restoration, all constructed reefs would be well below mean low water and signage would be installed, as recommended by the Coast Guard, to inform local boaters of the boundaries of the reefs are so that they can be avoided. Required signage will not be located within any local navigation channel, either maintained or natural.

No significant adverse impacts to commercial or recreational navigation are expected, either during or post-construction.

5.11.2.2 Airports

Only one actionable measure (SP-1) is within five miles of an FAA regulated airport. All other actionable measures are significantly further (>10 miles) from any FAA airport and would not be expected to increase the chance of wildlife strikes during takeoff/landing or while on approach.

SP-1 is between four and six miles from Mustang Beach Airport (RAS) in Port Aransas, TX. The runway has a northwest/southeast heading, which would place the flight path directly over the proposed rookery island location. According to the area navigation

(NRAV) map for the airport (**Figure 5.8**), aircraft are recommended to be at an altitude of about 1,500 feet at about four miles out (3.4 nautical miles [NM]). This altitude would be within the common flight altitudes of shorebirds that could be using the rookery. Implementing SP-1 could result in an increase in bird strike; however, the extent of potential increase has not been determined at this time and will be identified during additional coordination with FAA. Additional coordination will also involve address any concerns associated with bird strikes. The results and recommendations will be incorporated into the final report.

Implementation of G-28, B-12, CA-5, CA-6, M-8 and W-3 would have no impact on airports or air traffic; however, SP-1 may have adverse impacts to air traffic by increasing the chances of bird strikes. For purposes of this analysis, the potential increase in bird strikes is considered a significant safety concern and is considered a significant adverse impact. Whether or not this is considered a significant impact will be determined after further coordination with FAA.

5.12 AESTHETICS/NOISE

5.12.1 No Action

5.12.1.1 Aesthetics

The visual complexity surrounding the action areas of each of the actionable measure locations is related to its geomorphic features including barrier island, marsh, beach/dune, and open water. All of these elements are critical systems and together provide pleasing aesthetic scenery to the public from certain points of view, especially those areas closest to the national seashore, national refuges, and wildlife management areas. As well each provide a unique experience for viewers to observe wildlife in their natural environments and contribute to a dynamic, scenic and memorable viewshed.

As RSLR occurs, the diversity of these geomorphic features will convert from islands, marshlands and dunes/beaches into open water. Whether this conversion is considered adverse or beneficial is subjective and dependent on the viewer’s value to each geomorphic feature.

5.12.1.2 Noise

Under the No Action alternative, existing noise levels would continue into the future. Most of the action areas are remote and uninhabited areas with low ambient noise levels, except for the occasional commercial or recreational vessel traveling the GIWW or in the open water areas.

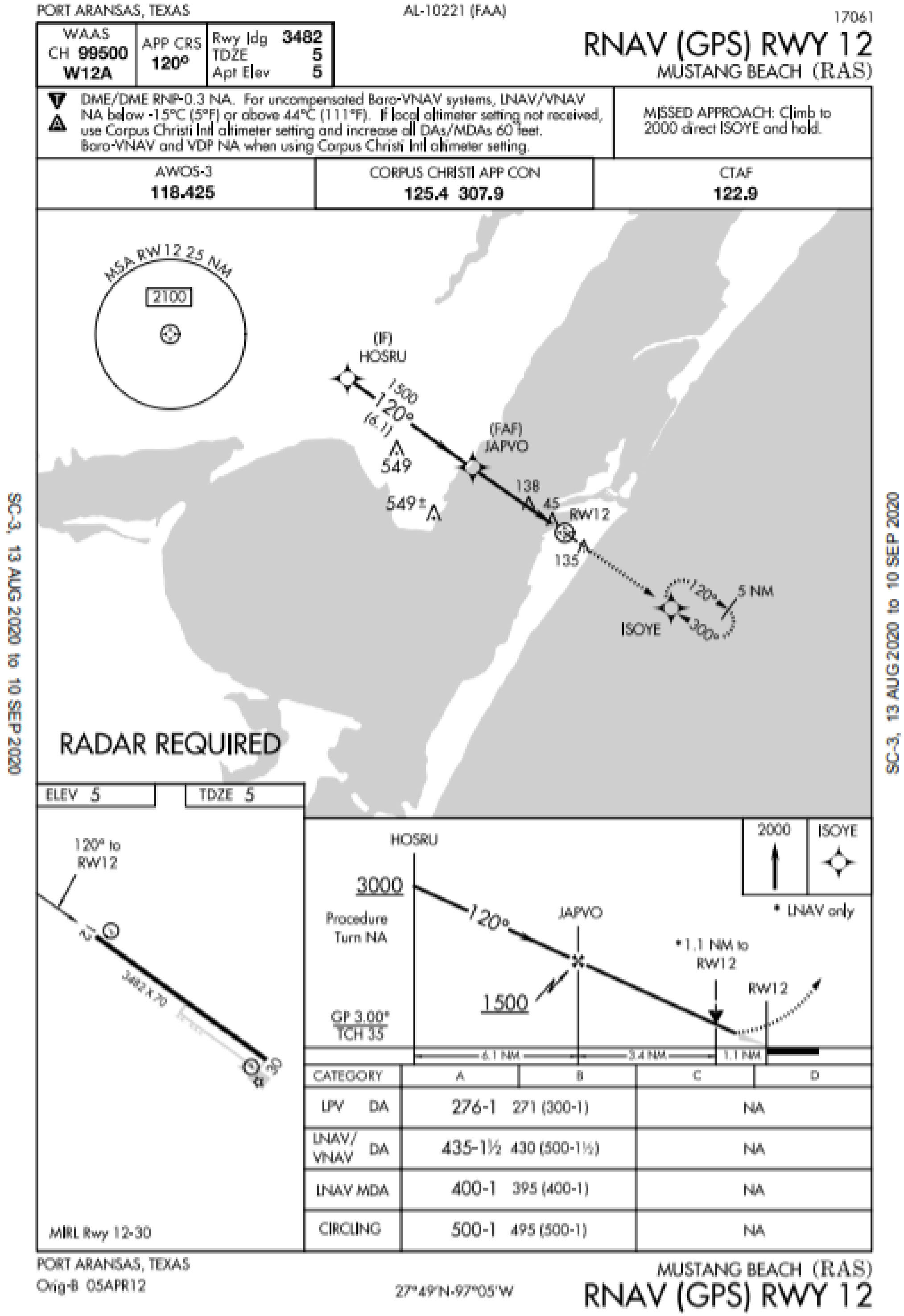

Figure 5-8 Area navigation (RNAV) map for Mustang Beach Airport

5.12.2 Alternative D2 and Alternative A

5.12.2.1 Common to all Measures

5.12.2.1.1 Aesthetics

The aesthetic value of the area suffers each time there is any intrusion in the natural environment by man. The primary issue associated with visual resources is the degree of visible change that may occur in characteristic landscapes, viewsheds, and areas with high scenic value. Construction activities can introduce differing elements of form, line, color, and texture into the landscape through construction or placement of constructed features such as roads, structures, equipment, or manipulation of vegetation. Effects can also result when actions change scenic integrity or result in conditions that produce unattractive landscapes.

Impacts associated with any of the action alternatives on aesthetics include visibility of construction disturbances, constructed structures, and temporary roads. Vegetation clearing and/or placement of dredged material over existing vegetation would present an obvious contrast in color with the surrounding vegetation. As well constructed features such as the dune, breakwaters and GIWW shoreline armoring may be visually prominent at foreground and middleground distance zones. Constructed structures and placement areas would be most obvious immediately after construction.

Short-term impacts may occur where construction-related equipment, activities, and dust could be visible to observers. Impacts would be anticipated in years in which construction is implemented. Alternatives that do not include construction of structures, would realize only temporary aesthetic degradation until the disturbed area blends in with the surrounding environment, at which time, it would be anticipated that the aesthetic value of the area would be improved over the existing condition.

Temporary adverse impacts on the aesthetic value of the area from construction and ground disturbance is certain under each of the action alternatives; however, the level of impact, by nature, is subjective and difficult to quantify.

5.12.2.1.2 Noise

The sound levels and noise characteristics would vary based on location. Ambient sounds at the sites are typically dominated by waves, wind, and birds. Watercraft traffic and recreational activities of people may influence noise levels in and near the action areas.

The noise generated from operation of marine vessels and other heavy equipment (e.g. front-end loaders, cranes, bulldozers, marsh buggies, booster pumps, etc.) would attract attention and contribute to the soundscape in local areas. However, the sensitivity of impacts would depend to a large degree on the project site, distance to sensitive receptions (e.g. recreational users or wildlife), and the level of ambient noise. For this analysis, adverse impacts would be expected within the zone of relatively high construction noise levels which typically extends to distances of 400 to 800 feet from the site of major equipment operations. Sensitive-noise receptors more than 800 feet from construction sites seldom experience appreciable levels of construction noise (EPA 1974) and would be considered negligible. In all cases, noise impacts would cease once equipment use is complete.

No long-term noise producing features are included as a component of any of the actionable measures; therefore, there would be no long-term impacts to sensitive noise receptors.

5.12.2.2 Breakwaters

5.12.2.2.1 Aesthetics

Breakwaters and GIWW armoring would have the greatest potential to permanently alter visual conditions due to use of stone material and placement in open waters. The structures would only be visible while they are being passed in vessels using the GIWW or in the nearshore. The structures would be approximately seven feet above the water surface elevation during low tide and would not be expected to affect the overall aesthetics of the environment or decrease the value of the area to the viewer.

5.12.2.2.2 Noise

Local noise levels would increase while construction activities are taking place. The increase would be due to the use of diesel engines of the various equipment needed to construct the breakwaters including a crane positioned on a barge, a tow boat to move the barge, and a small vessel powered with outboard motors. Decibel levels produced by the crane are approximately 80 to 90dBA, while a tugboat will produce approximately 80 dBA, and an outboard motor will create between 70 and 90dBA. These noise projections describe the noise level at the source and do not take into account the factors that affect the noise levels experienced by the sensitive noise receptor. Noise levels decrease as one moves further away from the source. It is anticipated that ambient noise levels would increase while construction in ongoing and may be noticeable by residents living less than 800 feet from the placement sites or by workers in the commercial areas. In these areas, sensitive noise receptors (residences, industrial areas, recreational areas, etc.) are accustomed to vessel noise generated along the GIWW, which is not expected to be substantially different in decibel levels than they currently experience.

In general, most of the placement sites are in rural areas with sensitive noise receptors being greater than 800 feet from the action area. The increase in noise would not be considered disruptive. Construction would only take place during daylight hours to further reduce any disruption to sensitive noise receptors near the project sites.

Local, motile marine life would likely be temporarily impacted by construction noise. Marine life and terrestrial species would likely avoid the area where placement occurs, due to the combination of water quality and noise impacts but are expected to return upon completion of construction activities.

No long-term adverse impacts are anticipated, and short-term adverse impacts are expected to be negligible.

5.12.2.3 Marsh Restoration

5.12.2.3.1 Aesthetics

Nature-based features such as marsh restoration bring a unique design to the landscape and typically adhere to the basic design elements of form, line, texture, color, and repetition. Marsh restoration would work to reclaim former land masses that have been converted to a more open water setting. The restoration would present the possibility of creating vertical features (derived from future landscape and vegetation growth) that, along with ground features, could work to frame the large open water areas beyond. This creates an aesthetic setting that is much more desirable and contains the basic design elements.

Obvious aesthetic changes from the surrounding environment would remain until vegetation has established and the system has begun to function as designed. Temporary placement of staging areas, access roads and floating docks would be visually obvious until use of these is discontinued and the area naturally restores, or the structure is removed. Natural restoration would be expected to occur over a period of a couple of years. As restoration, as a measure or naturally from access roads, takes over, aesthetic degradation would decrease as the disturbed surface begins to blend in color, form, and texture. In general, restoration measures would be beneficial to the aesthetic value of the area and pleasing to recreationists.

Marsh nourishment and restoration would maintain the diversity of geomorphic features of the action area and enhance the marshlands. The enhancement would include an increase in habitat for wildlife, which would be expected to increase wildlife populations thereby further increasing the viewshed dynamics.

5.12.2.3.2 Noise

Construction activities associated with implementing marsh restoration would temporarily increase noise levels in the action area. Most noise associated with construction would be highly localized in the immediate vicinity of the equipment being operated. All sensitive noise receptors are more than one mile from any of the action areas, except for G-28, where sensitive noise receptors are within 1,000 feet of the action area but greater than 800 feet away. Any increase in construction generated noise would not have a substantial impact or generate noise levels that would become injurious. At the G-28 site, any work that is within 1,000 feet of a residential area would be limited to daytime hours (7:00 am to 6:00 pm) to avoid significant impacts from temporary increases in ambient noise during construction.

Wildlife and aquatic species would likely temporarily leave the action area during construction activities due to noise impacts, if capable. However, tolerance of unnatural disturbance varies among species. If project work occurs during the breeding season, localized noise could interfere with bird communications.

5.12.2.4 Island Restoration

Island restoration is expected to have nearly identical impacts to visual resources and sensitive noise receptors as marsh restoration. Impacts to visual resources are expected to diversify the overall viewshed of the environment and improve the quality of the scenic landscape for viewers. Noise generated during construction would be expected to be negligible to sensitive noise receptors, considering the action areas are over one mile to the nearest sensitive noise receptor. Noise impacts to wildlife and aquatic species is expected to be non-injurious and relatively minor considering most species would be able to move away from the disturbance until construction is complete.

5.12.2.5 Oyster Reef

No significant adverse impacts to the aesthetic resource would be caused by the action. During construction, some may consider that visual and aesthetic resources are impacted due to the presence of heavy construction equipment. These impairments would be temporary, as conditions would return to normal once construction is complete.

Impacts from noise would be very similar to the breakwaters; however, all locations would be further removed from sensitive noise receptors. Impacts caused by noise would be negligible.

5.12.2.6 Dune/Beach Restoration

5.12.2.6.1 Aesthetics

During beach nourishment and dune construction activities, the presence of pipelines and construction equipment on the beach would temporarily diminish the aesthetic quality of the action area and in Port Mansfield but would not be expected to impact aesthetic values in Redfish Bay. There are no structures in or near the action area so visual impacts would be limited to recreationists using the area. Construction impacts on visual resources would be further limited because construction activities would be completed during the colder months when recreational use of the area would be at its lowest. When work activities are completed, the aesthetic value of the area is anticipated to be restored or enhanced as construction equipment moves offsite. Immediately following placement and working of material there would be an obvious difference in color in the action area compared to beaches further north. Relatively quickly, natural longshore and cross-shore sediment transport would be expected to mix fill sand with adjacent native sands blending the color difference.

For at approximately 10 years, the beach width would be noticeably wider and the dune height noticeable higher than adjacent beaches and dunes. Whether this is an adverse or beneficial impact would be dependent on the viewer. As RSLR and erosion narrow the beach and as wind erodes and waves run-up on the dune, the structures are expected to be reverted to baseline conditions.

5.12.2.6.2 Noise

Sensitive noise receptors in the action area would be limited to recreationists in the immediate vicinity of the action area. Impacts of construction would be very similar to those described for marsh restoration. No long-term adverse or beneficial impacts are expected.

5.12.2.7 Hydrologic Restorations

5.12.2.7.1 Aesthetics

Minor visual changes to the overall landscape would result from dredging the channel. During dredging, barges and other equipment would be visible from both the land and the bay. However, none of the sites are within areas of high scenic value or visible from scenic highways. Visual impacts would be temporary, limited to the time that the dredges are operating. Dredge areas would look the same after construction as they did before.

5.12.2.7.2 Noise

Short-term impacts would primarily involve construction sounds during dredging. To dredge the channel, a hydraulic cutterhead suction dredge, tugboats, and a survey/crew boat would be required. Noise generated by a cutterhead suction dredge is continuous and muted and results from the cutterhead rotating within the bottom sediment and from the pumps used to transport the effluent to the placement area. The majority of the sound generated peaks at the 100 to 110 dBs range. Although attenuation calculations were not completed, reported field observations indicate that this type of dredge becomes almost inaudible at about 1,640 feet (500 meters) (Clarke et al. 2002). It is anticipated that the maximum sound levels would only minimally exceed normal ambient noise in the action area as noised would be attenuated by background sounds from wind and surf. As well, sensitive noise receptors within 1,650 feet of the action area are limited to recreationists at Padre Island National Seashore, which is typically very minimal considering that access to the area is limited to those traveling the 60 miles of four-wheel drive along the beach from park headquarters or by watercraft.

In-water noise would be expected in association with dredging activities and produce similar impacts to in-water noise generated during breakwater construction. The impact of underwater sound during dredging would also be temporary and limited to the vicinity of the dredge. Current literature indicates that sound generated from conventional cutterhead suction dredging is low frequency and would not likely cause physical injury to fish species (Popper et al. 2006, Southall et al. 2007, Reine and Dickerson 2014). Temporary effects on hearing could occur if fishes remain in the immediate vicinity of the dredge for lengthy durations, although this is unlikely due to avoidance behavioral response of fish to the sound.

Over the long-term, there may be a temporary increase in small vessel traffic through the channel which would increase the noise levels from vessel engines that does not occur under the existing condition. However, this is a one-time dredging event, so the channel is expected to silt in over-time reducing the ability of vessels to use the pass and reverting to the baseline condition. The temporary increase in vessel traffic would not induce landside changes; therefore, no long-term noise sources from port or industry source emitters or terminal activity is expected.

No injurious effects would be expected because the noise generated by the dredging equipment and support vessels is relatively low and would dissipate with an increasing distance from the source. As well, the noise levels generated, and duration of impacts expected would be similar to those that occurred during previous maintenance dredging activities within the channel and along the GIWW. Because the noise impacts would be temporary and similar in nature to past actions, the impacts are considered adverse but minor.

5.13 RECREATION

5.13.1 No Action

Under the No Action alternative, recreation resources at each of the actionable areas would not be modified as a result of construction actions. Over the planning horizon, existing recreational resources and opportunities within each of the actionable areas are expected to diminish in quality and quantity as land loss continues from erosion and RSLR. As a result, there may be an economic loss felt by local marinas and other shops and tourism services that specialize in a particular recreation opportunity as a result of changes in recreation opportunities.

The continued loss of marshes and habitat diversity affects recreational opportunities. Storm surge and saltwater intrusion would influence less saline habitats (e.g. freshwater, intermediate, and brackish marshes) and could reduce recreational opportunities such as fishing, hunting, wildlife watching, and other outdoor activities. In general, further degradation of area marshes would continue and its associated negative effects on recreation activities would increase. As existing freshwater marsh areas convert to saltwater marsh, then to open water, the recreational opportunities would change accordingly. For example, freshwater fishing opportunities may be expected to become saltwater opportunities. If the expected peak and then decline of fishery production occurs in these open waters, then the associated marine-fishery recreational opportunities would also decline. As populations of migratory birds and other animals dependent on marsh decrease, again associated recreational opportunities would also decrease.

Along the beach areas, beaches are expected to narrow which will limit the area for beach going activities

5.13.2 Alternative D2 and Alternative A

With implementation of any of the action alternatives, recreation opportunities would be temporarily lost in the immediate vicinity of the construction footprint while construction-related activities are underway. During this period of construction, recreationists may experience an increase in noise from operation of equipment that could impact their ability to seek solitude or may reduce the success of wildlife-dependent recreation activities. During the temporary reduction, similar recreation opportunities would remain available on adjacent lands. Public access to public lands would be maintained during construction. Recreation would resume in a manner similar to the existing condition after construction is complete.

5.13.2.1 Breakwaters

Recreation resources may experience temporary, adverse impacts. During construction, private boats would not be allowed to enter the immediate placement areas due to public safety considerations. These restrictions would temporarily reduce recreational opportunities during the construction phase. Recreational resources near the project's areas, such as boat landings, private marinas, etc. would continue their operations during project construction.

Long-term, recreation opportunities in and near the immediate vicinity of the breakwaters are not expected to change. By constructing the breakwaters, marsh loss would be limited which would allow for existing recreational opportunities, such as wildlife watching, hunting, and fishing, would be sustained at the baseline condition or improved if marsh areas are restored or recover from historic loss.

5.13.2.2 Marsh Restoration

Any direct impacts to recreational opportunities would be temporary and occur during construction. Recreationists may have to circumvent the action area when traveling to a destination due to construction limiting or delaying access. During delivery of sediment to the restoration units, increased levels of turbidity and disturbance from construction equipment may deter fish and wildlife from the action area and neighboring areas and may result in a temporary degradation of recreational opportunities outside the action area.

In general, marsh restoration would benefit recreation opportunities by providing additional habitat for waterfowl and other birds, which would enhance opportunities for wildlife watching and hunting. Enhanced marsh habitat would also benefit fishing in the area as marshes are very productive nursery habitat for fish. There is a possibility that marsh creation could impact boating access if newly created marshes impede familiar and direct access routes to recreation spots.

5.13.2.3 Island Restoration

Recreational use would be temporarily, adversely impacted during construction and would be similar to the impacts described for breakwater construction and marsh restoration, as some of the proposed action areas are predominantly in open water, while others are in or near historic marshes areas.

Long-term beneficial impacts would include enhancement of waterbird populations locally, regionally, and Gulf-wide, which would in turn be expected to increase the opportunity for bird watching and related tourism. Birds are an important component that supports nature-based tourism and play a significant role in generating revenue for local recreational supply retailers, restaurants, and hospitality providers.

5.13.2.4 Oyster Reef

Temporary impacts are nearly identical to those anticipated for construction of breakwaters.

Most long-term impacts on recreation resources are anticipated to be beneficial. For example, recreational fishermen may find an increase in finfish numbers and species on and in the vicinity of the reefs. Additionally, water-related recreation will benefit from the increase in water quality resulting from the filtering ability of oysters. Construction would result in shallower depths over the new reefs, which may require that vessels with deeper drafts navigate around the project areas. Signs will be placed to warn boaters of the location of the new reefs.

5.13.2.5 Dune/Beach Restoration

The beach restoration area is located within the Padre Island National Seashore, which is well known for recreation activities along its 70 miles of beach and sea turtle viewing opportunities. Other recreation opportunities include primitive camping, beachcombing, fishing, and surfing. Recreationists wishing to access the restoration area by land must travel by four-wheel drive nearly 60 miles along the beach. Access by watercraft is also possible but this mode of access is typically to access fishing sites. Therefore, recreation within the beach restoration unit is typically low compared to other beaches in the area.

Temporary construction safety zones would restrict public beach access within an approximately 500- to 1,000-foot zone on either side of the beach fill discharge point, thus potentially impacting recreational activities. Construction activities would be completed during the colder months (November to April) when recreational beach use is at its lowest point.

Once construction is complete, beach and dune restoration would maintain a wider beach, thus resulting in beneficial impacts for approximately 10 years or until erosion has reduced the beach width to the existing width. Compared to the No Action, this extends the length of recreational beach available in the action area over the planning horizon, even if beneficial impacts wouldn't be realized for the full 50-year period.

Considering the short-term nature of the adverse impacts and the low level of public exposure to these impacts, the long-term beneficial impacts would be expected to outweigh any adverse effects.

5.13.2.6 Hydrologic Restorations

Opening of Port Mansfield channel would have minor, temporary adverse impacts to recreational opportunities during construction. During construction, safety zones may limit small recreational vessels from access to recreational spots within the channel or for use as a direct access route to/from Redfish Bay or Laguna Madre and the Gulf of Mexico. As well, temporary disturbances from decreased water quality and noise, would cause wildlife and fish to leave the area thereby reducing the fishing and wildlife viewing opportunities near the action area.

Over the long-term, changing the hydrologic flows into and out of Redfish Bay and Laguna Madre would improve the estuarine habitat of the bays. This would increase the fishing and wildlife viewing opportunities through an increase in diversity and higher quality habitat. As well, the increase in depth through the channel would allow larger recreational vessels to access recreation spots that were previously limited by water depth. At some point these benefits would diminish back to baseline conditions but would be an overall long-term net benefit over the No Action Alternative.

5.14 HAZARDOUS, TOXIC AND RADIOACTIVE WASTES

5.14.1 No Action

The No-Action Alternative would result in no direct impacts on hazardous materials associated with regulated facilities and shipping traffic. As industrial activity continues to increase to accommodate future anticipated demands for petroleum products, additional indirect impacts would occur. Continued RSLR and hurricane storm surges would increase degradation of natural and man-made seawalls, levees, and barrier islands leaving industrial facilities more susceptible to damage, increasing the potential for the release of waste materials into the environment. Due to climate change, storm intensity could increase, potentially causing increased damage to industrial facilities.

5.14.2 Alternative D2 and Alternative A

There are seven actionable ER measures proposed along the Texas Coast. Although a majority of the surrounding areas have not been specifically investigated, there are previously recorded HTRW occurrences located in various locations within the project area (**Table 5.12**). The probability for encountering abandoned munitions in the upland portions of these ER measures is moderate to high. This is because the islands and beaches were historically used as bombing or shooting ranges by U.S. Armed Forces.

These sites may consist of historic munitions and explosives of concern that may become exposed on shorelines or shallowly submerged. Activities in these areas such as nourishment of marshes and beaches (G-28, B-12, M-8 and W-3) could potentially cause a threat to health and safety concerns. However, beach nourishment material will be obtained by dredging material from offshore and there is a moderate to low potential for impacting submerged munitions in those areas. Earth moving activities in the uplands that involve dune building and modifications to existing islands and landforms (G-28, CA-6, M-8 and SP-1) have a potential to come into contact with MEC or other HTRW in those locations with known or suspected contamination. Caution has been taken to avoid these locations to prevent disturbing the ground near any of these sites.

Table 5-12 HTRW Locations within Actionable Measure Locations

ER Measure	Formerly Used Defense Sites (FUDS)	Superfund	Toxic Release Inventory	RCRA Corrective Action	LPST	PST	Voluntary Cleanup Program.	Solid Waste Landfill	Institutional Control Sites	Dry Cleaners	Response Site	Hazardous Waste Generator/ Handler
G-28 - Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	✔			✔	✔	✔	✔	✔	✔	✔		✔
B-12 - West Bay and Brazoria GIWW Shoreline Protection	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
CA-5 - Keller Bay Restoration			✔									
CA-6 - Powderhorn Shoreline Protection and Wetland Restoration			✔									
M-8 - East Matagorda Bay Shoreline Protection	✔											
SP-1 - Redfish Bay Protection and Enhancement	✔			✔	✔	✔	✔	✔				✔
W-3 - Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	✔				✔	✔	✔				✔	

5.15 CUMULATIVE IMPACTS

The cumulative effect analysis for the Tier One Measures is located in Section 4.9 of this DEIS. Section 4.9 includes the list of past, present, and reasonably foreseeable future actions for the entire project area and is incorporated in this section by reference. Additionally, the Cumulative Effects analysis included in the 2018 IFR-DEIS (Section 5.10 of the 2018 report) is also incorporated by reference.

For purposes of this analysis, cumulative impacts are evaluated if the indirect and direct impacts of the federal action have substantial temporary adverse or positive impacts to the resource, when considering past, present, and reasonably foreseeable future actions. Potential impacts of the past, present, and reasonably foreseeable future actions include both potential direct effects (caused by the actions and occurring at the same time and place as the Preferred Alternative), and indirect effects (caused by the action but removed in distance and later in time, and reasonably foreseeable).

The cumulative effects analysis considers the magnitude of the cumulative effect on the resource health. Health refers to the general overall condition, stability, or vitality of the resource and the trend of that condition. Laws, regulations, policies, or other factors that may change or sustain the resource trend were considered to determine if stress on the resource is likely in the foreseeable future. Cumulative impacts may also occur when the occurrence of disturbances is so close that the effects of one are not dissipated before the next occurs, or when the timings of disturbances are so close that their effects overlap. The general approach provided in the CEQ's Considering Cumulative Effects Under the NEPA was used to conduct the analysis (CEQ, 1997).[5]

All of the Actionable Measures are anticipated to have long term benefits to the ecosystems that they are sited within. All of these measures involve restoration of degraded habitat and they would not have adverse impacts to high quality habitats. The discussions above document that temporary impacts are anticipated during construction and include temporary turbidity, noise disturbances, physical impacts from construction equipment, and the potential to bury organisms. All of these temporary impacts would end as soon as the construction phase is over and would not contribute to an adverse cumulative effect. These Actionable Measures would help contribute to beneficial cumulative effects that are anticipated from increasing amounts of ER projects that are occurring in Texas' Coastal Zone.

5.16 ANY ADVERSE ENVIRONMENTAL IMPACTS THAT CANNOT BE AVOIDED SHOULD THE RECOMMENDED PLAN BE IMPLEMENTED

The only adverse impacts associated with the Actionable Measures are temporary impacts that are anticipated during construction and include temporary turbidity, noise disturbances, physical impacts from construction equipment, and the potential injury or harassment of organisms by construction activities. All of these temporary impacts would end soon after the construction phase is over. Additionally, best management practices would be used to minimize these temporary impacts. There are no anticipated long-term adverse impacts associated with the Actionable Measures.

Sensitive habitats in close proximity to these measures were identified by the interagency team and were avoided. For example, all of the construction activities for the beach and dune restoration measures would be Gulfward of the existing line of vegetation to ensure that the project doesn't impact existing vegetation or dune habitat.

[5] This DEIS was substantially complete before the updated CEQ regulations were effective, therefore this document is proceeding under the 1978 regulations and their existing agency NEPA procedures. Please note that in Section 1508.1(3)(g) Cumulative impact, defined in 40 CFR 1508.7 (1978) is repealed.

5.17 ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES INVOLVED IN THE IMPLEMENTATION OF THE TSP

NEPA 40 CFR 1502.16 requires that environmental analysis include identification of "any irreversible and irretrievable commitments of resources which would be involved in the TSP should it be implemented." Irreversible and irretrievable resource commitments are related to the use of nonrenewable resources and the effects that the use of these resources have on future generations. Irreversible effects primarily result from use or destruction of a specific resource (e.g. energy and minerals) that cannot be replaced within a reasonable time frame. Irretrievable resource commitments involve the loss in value of an affected resource that cannot be restored as a result of the action (e.g. extinction of a threatened or endangered species).

Implementation of the actionable measures would result in the direct and indirect commitments of resources. These would be related mainly to construction components. Energy typically associated with construction activities would be expended and irretrievably lost under all of the alternatives except for the no action alternative. Fuels used during the construction and operation of dredging equipment, barges, placement equipment (e.g. bulldozers, backhoes, marsh buggies, etc.) and support vehicles would constitute an irretrievable commitment of fuel resources. Capital and labor resources, as well as, stone material would also be considered an irretrievable and irreversible commitment of resources. The use of such resources would not adversely impact the availability of such resources for other project both now and in the future.

Most resource commitments are neither irreversible nor irretrievable. The dredging of borrow material is considered reversible although it is anticipated that the natural infilling of the borrow pits may take several years. Benthic communities would be removed and lost along with sediment during dredging and placement operations. Benthic communities would also take several years to recover. Slow moving or non-motile fish, wildlife, invertebrates, and plant (aquatic and terrestrial) species would be entrained in the dredge during the dredging of borrow material or smothered during placement of dredged material, oyster cultch, reef balls or the breakwater structures. These losses would be irretrievable as well. However, most impacts to the species' population as a whole would be insignificant. As well, these impacts would only occur during construction.

No other impacts, such as water resources, existing land uses, or visual resources, have been identified which could result in irreversible or irretrievable commitments of resources which would preclude implementation of any of the action alternatives.

5.18 RELATIONSHIP BETWEEN SHORT-TERM USES OF ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

NEPA Section 102(2)(c)(iv) and 40 CFR 1502.16 require that an EIS include a discussion of the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity. This section describes how the actionable measures would affect the short-term use and the long-term productivity of the environment.

For this analysis, “short-term” refers to the temporary phase of construction of the proposed project while “long-term” refers to the operational life of the proposed project and beyond. The preceding sections in this chapter evaluate the short- and long-term impacts of implementing the actionable measures in more detail for each resource.

Construction of the actionable measures would result in short-term construction related impacts within parts of the action areas and would include minor limited air emissions, increases in ambient noise, disturbances of fisheries and wildlife, increased turbidity levels, lover DO, and disturbance of recreational opportunities. These impacts would be temporary and would occur only during construction and are not expected to alter the long-term productivity of the natural environment.

Each of the actionable measures would assist in the long-term productivity of the coastal ecological communities by reestablishing hydrologic connections and introducing sediments and features that would facilitate protection, growth and productivity of emergent marsh, beaches, rookery islands, and oyster communities and the invertebrates, fish and wildlife that utilize these habitats. An increase in the diversity of fish and wildlife, as well as fish and wildlife population increase, would be expected resulting in beneficial long-term impacts for biological communities, recreational opportunities, and socioeconomics. The long-term beneficial effects of the actionable measures would outweigh the impacts to the environment resulting from temporary construction activities.

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6.0 CONSISTENCY WITH OTHER STATE AND FEDERAL PLANS AND REGULATIONS

This DEIS has been prepared to satisfy the requirements of all applicable environmental laws and regulations and has been prepared using the Council on Environmental Quality (CEQ) NEPA regulations (40 CFR Part 1500–1508)[6] and the USACE's regulation ER 200-2-2 – Environmental Quality: Policy and Procedures for Implementing NEPA, 33 CFR 230. In implementing the Recommended Plan, the USACE would follow provisions of all applicable laws, regulations, and policies related to the proposed actions. The following sections present brief summaries of Federal environmental laws, regulations, and coordination requirements applicable to this DEIS.

6.1 NATIONAL ENVIRONMENTAL POLICY ACT

NEPA requires that all Federal agencies use a systematic, interdisciplinary approach to protect the human environment. This approach promotes the integrated use of natural and social sciences in planning and decision-making that could have an impact on the environment.

NEPA requires the preparation of an EIS for any major Federal action that could have a significant impact on the environment (42 United States Code [USC] 4321–4347). The EIS must address any adverse environmental effects that cannot be avoided or mitigated, alternatives to the proposed action, the relationship between short-term resources and long-term productivity, and irreversible and irretrievable commitments of resources. According to 40 CFR 1502.9, a supplement to either a DEIS or FEIS must be prepared if an agency makes substantial changes in the proposed action that are relevant to environmental concerns, or there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

The NEPA regulations provide for the use of the NEPA process to identify and assess reasonable alternatives to proposed actions that avoid or minimize adverse effects of these actions upon the quality of the human environment. "Scoping" is used to identify the range and significance of environmental issues associated with a proposed Federal action through coordination with Federal, State, and local agencies; the general public; and any interested individuals and organizations prior to the development of an EIS. The process also identifies and eliminates, from further detailed study, issues that are not significant or have been addressed by prior environmental review.

This DEIS has been prepared in accordance with NEPA regulations and fully discloses the environmental impacts associated with the alternatives as best known with the level of detail available and best available science. This NEPA document employs a tiered

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[6] This DEIS was substantially complete before the updated CEQ regulations were effective, therefore this document is proceeding under the 1978 regulations and their existing agency NEPA procedures.

NEPA approach as described in Chapter 1.0 to document the overall broad review of the complete project. Subsequent, NEPA documents will be prepared for the measures which have significant uncertainty in their design or in the potential impacts. The broad understanding of impacts of measures requiring additional NEPA are described in Chapter 4.0. For measures that are actionable, full disclosure of impacts are described in Chapter 5.0.

6.2 CLEAN WATER ACT

The Federal Water Pollution Control Act of 1972, as amended in 1977 via the Clean Water Act (CWA), authorizes the EPA to regulate activities resulting in a discharge to navigable waters. Section 404 of the CWA normally requires an USACE permit for the discharge or deposition of dredged or fill material and for the building of structures in all waters of the United States, other than incidental fallback (a term that generally refers to material falling back into waters incidentally during an activity designed to remove material, but if in doubt should be clarified during the preparation or review of a permit application). Section 404(r) of the CWA exempts from Section 404 permitting requirements the discharge of dredge or fill material as part of the construction of a Federal project specifically authorized by Congress if information on the effects of such discharge is included in an EIS pursuant to NEPA. Pursuant to the provisions of Section 404(r), the process used for completion of this project would be consistent with the guidelines described in Section 404(b)(1) of the CWA. Criteria to be considered in evaluating the alternatives include cost, technology, environmental effects, and logistics. Guidelines prepared for the evaluation of dredge and fill material also indicate that actions subject to NEPA would, in all probability, meet the requirements of the analysis of alternatives specified by Section 404(b)(1) guidelines.

The USACE is requesting a §401 State Water Quality certification from Texas for the recommended plan. A draft CWA §404(b)(1) evaluation of the recommended plan is provided in Appendix D and describes the effects of the proposed discharges to Jurisdictional Waters of the US.

6.3 CLEAN AIR ACT OF 1970

The CAA is the comprehensive Federal law that regulates air emissions from area, stationary, and mobile sources. Air emissions associated with construction of the TSP would impact the air quality of the study area. It is expected that air contaminant emissions from construction activities would result in temporary and localized impacts on air quality in the immediate vicinity of the project site as they are considered one-time activities (i.e., the construction activities would not continue past the date of completion). After construction, temporary impacts to air quality would continue due to maintenance and renourishment activities, e.g., routine dredging would be required to maintain the ER activities. It is anticipated these maintenance activities would be intermittent and of relatively short-term duration for each segment being maintained. It is anticipated that air contaminant emissions from the operation of the navigation and environmental gates would result in a relatively minor increase in air contaminant emissions above those for existing emissions sources in Galveston County. Essentially, these operating emissions would be from products of combustion of diesel fuel in the proposed emergency generators, which would be operated periodically for maintenance and testing and during an emergency event.

Pursuant to Section 176 of the CAA Amendments of 1990, the USACE must prepare a General Conformity Determination for the Coastal Texas Study. This document will be prepared for only the recommended plan actionable measures. This document will be submitted by the USACE, as the lead Federal agency, to the TCEQ and EPA along with a request for concurrence that the project emissions are conformant with the SIP. Appendix G is reserved for the Draft General Conformity Determination.

6.4 NATIONAL HISTORIC PRESERVATION ACT OF 1966

Compliance with the National Historic Preservation Act of 1966, as amended (54 USC § 306108), requires the consideration of effects of the undertaking on all historic properties in the project area and development of mitigation measures for those adversely affected properties in coordination with the SHPO, Native American Tribes, and the Advisory Council on Historic Preservation. It has been determined that there is a potential for new construction, improvements to existing facilities, and maintenance of existing facilities to cause effects to historic properties. Therefore, in accordance with 36 CFR 800.14, the USACE will execute a Programmatic Agreement among the USACE, the Texas SHPO, and any NFS to address the identification and discovery of cultural resources that may occur during the construction and maintenance of proposed or existing facilities. The USACE will also invite the Advisory Council on Historic Preservation and Native American tribes to participate as signatories to the Programmatic Agreement. The Draft Programmatic Agreement is currently being coordinated with applicable agencies and is included in Appendix H.

6.5 ENDANGERED SPECIES ACT

The Endangered Species Act (ESA), as amended, establishes a national policy designed to protect and conserve threatened and endangered species and the ecosystems upon which they depend (16 USC 1531–1543). The ESA is administered by the Department of the Interior, through the USFWS, and by the U.S. Department of Commerce, through the NMFS. Section 7 of the ESA specifies that any agency that proposes a Federal action that could jeopardize the “continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species” (16 USC 1536 Section 7(a)(2)) must participate in the interagency cooperation and consultation process.

The biological assessment (BA) prepared for this study is the first of several anticipated ESA compliance documents that will be required to show the proposed action is compliant with ESA. The BA documents USACE’s conclusions and the rationale to support the conclusions regarding the effects of the actionable measures (measures that could be constructed within a standard design and construction timeframe) of the proposed action.

It also demonstrates the proposed action is in compliance with Section 7, which assures that, through consultation with the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), Federal actions do not jeopardize the continued existence of any threatened, endangered or proposed species, or result in the destruction or adverse modification of CH.

A second component of this document includes a broad level documentation of Tier 1 actions (actions that have longer than usual design and construction timeframes). Since construction of most of these actions is not likely to begin for at least 10 years, a Tiered NEPA strategy has been employed for these measures, meaning that subsequent NEPA reviews and ESA consultation would be required for these measures. The Tier 1 actions are described to seek technical assistance from USFWS and NMFS on potential impacts to listed species, recommendations to avoid or minimize potential impacts, and to document what questions remain that need to be answered prior to initiating official Section 7 consultation on these actions in the future. Effects determinations on these actions have not been made and official Section 7 consultation is not being requested at this time.

Based upon the findings of the BA, the USACE has made the following effects determinations for species that were identified as occurring or potentially occurring in the action area of the actionable measures:

Species	Scientific Name	Jurisdiction	Conclusion
Birds			
Piping Plover	*Charadrius melodus*	USFWS	NLAA
Rufa Red Knot	*Calidris canutus rufa*	USFWS	NLAA
Whooping Crane	*Grus americana*	USFWS	NLAA
Northern Aplomado Falcon	*Falco femoralis septentrionalis*	USFWS	No effect
Eastern black rail	*Laterallus jamaicensis jamaicensis*	USFWS	NLAA
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	USFWS	No effect
Clams			
Texas Fawnsfoot	*Truncilla macrodon*	USFWS	No effect
Fish			
Oceanic Whitetip Shark	*Carcharhinus longimanus*	NMFS	No effect
Giant manta ray	*Manta birostris*	NMFS	No effect
Mammals			
Sei whale	*Balaenoptera borealis*	NMFS	No effect
Bryde's Whale	*B. edeni*	NFMS	No effect

Species	Scientific Name	Jurisdiction	Conclusion
Fin whale	*B. physalus*	NMFS	No effect
Gulf Coast Jaguarundi	*Herpailurus (=Felis) yagouaroundi cacomitli*	USFWS	No effect
Ocelot	*Leopardus (=Felis) pardalis*	USFWS	No effect
Sperm whale	*Physeter macrocephalus*	NMFS	No effect
West Indian Manatee	*Trichechus manatus*	UFWS/ NMFS	NLAA
Texas Ayenia	*Ayenia limitaris*	USFWS	No effect
South Texas Ambrosia	*Ambrosia cheiranthifolia*	USFWS	No effect
Slender Rush-pea	*Hoffmannseggia tenella*	USFWS	No effect
Texas prairie dawn-flower	*Hymenoxys texana*	USFWS	No effect
Reptiles			
Loggerhead sea turtle	*Caretta caretta*	USFWS/ NMFS	**On land:** No effect **In water:** LAA*
Green sea turtle	*Chelonia mydas*	USFWS/ NMFS	**On land:** No effect **In water:** LAA*
Leatherback sea turtle	*Dermochelys coriacea*	USFWS/ NMFS	**On land:** No effect **In water:** LAA*
Hawksbill sea turtle	*Eretmochelys imbricata*	USFWS/ NMFS	**On land:** No effect **In water:** LAA*
Kemp's Ridley sea turtle	*Lepidochelys kempii*	USFWS/ NMFS	**On land:** No effect **In water:** LAA*

NLAA= Not likely to adversely affect **LAA***= Likely to adversely affect, covered by GRBO

Conservation measures have been incorporated into the design of the actionable measures that would be adhered to during construction to further minimize the potential impacts to listed species. Conservation measures include: biological monitors on site with stop-work authority if a listed species should be found in or near the active construction zone, surveys to determine presence/absence in the action area, seasonal timing restrictions, and additional restrictions if seasonal timing restrictions cannot be avoided, etc.

6.6 MIGRATORY BIRD TREATY ACT AND MIGRATORY BIRD CONSERVATION ACT AND EXECUTIVE ORDER 13186

The MBTA of 1918 (as amended) extends Federal protection to migratory bird species; among other activities non-regulated "take" of migratory birds is prohibited under this MBTA in a manner similar to the ESA prohibition of "take" of threatened and endangered species. Additionally, EO 13186 "Responsibility of Federal Agencies to Protect Migratory Birds" requires Federal activities to assess and consider potential effects of their actions on migratory birds (including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds). The effect of the TSP on migratory bird species has been assessed. Impacts to migratory birds as a result of the TSP are expected to be temporary and limited to migratory bird species near the CSRM measures. Migratory birds would benefit from the ER measures by protecting and creating foraging, nesting, and roosting habitat. Improved coastal resiliency is expected to improve bird habitat and increase productivity in the project area. The MBTA (16 USC 715–715d, 715e, 715f–715r; 45 Stat. 1222) establishes a Migratory Bird Conservation Commission to approve areas of land or water for acquisition as reservations for migratory birds which is not applicable to the project. Coordination with the USFWS is ongoing.

6.7 FISH AND WILDLIFE COORDINATION ACT OF 1958

The Fish and Wildlife Coordination Act provides for consultation with the USFWS and, in Texas, with TPWD whenever the waters or channel of a body of water are modified by a department or agency of the United States. The intent of this consultation is to help prevent the loss of and damage to wildlife resources from water development projects.

Pursuant to Fish and Wildlife Coordination Act, the USFWS provided a Planning Aid Letter (PAL), dated November 20, 2017, to assist with the planning of the proposed project by providing comments and recommendations related to impacts on fish and wildlife resources. A copy of the PAL is provided at Appendix C-6, Attachment 1. The PAL provided a list of high action coastal Texas priorities based in the USFWS vision. The PAL only covered the Coastal Texas Study's ER measures.

The USFWS is preparing a Coordination Act Report and will be included in the Final EIS as Appendix A. The recommended plan has been coordinated with the USFWS and other State and Federal resource agencies through the interagency team coordination, all of which had input to the potential impact assessment, mitigation, and BU areas.

6.8 MARINE MAMMAL PROTECTION ACT OF 1972

The Marine Mammal Protection Act of 1972 (16 USC 1361 et seq.) established a national policy to prevent marine mammal species and population stocks from declining beyond the point where they ceased to be significant functioning elements of the ecosystems of which they are a part. The Marine Mammal Protection Act prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the

United States. In the Marine Mammal Protection Act, "take" is defined "as harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect." The Department of Commerce, through the NMFS, is charged with protecting species that are known to occur in the Texas Gulf region such as whales, dolphins, and porpoises. Manatees are protected by the Department of the Interior through the USFWS. The Animal and Plant Health Inspection Service, a part of the Department of Agriculture, is responsible for regulations managing marine mammals in captivity.

It is expected that construction and operational activities related to the implementation of the measures related to CSRM features may result in the incidental take of marine mammals, as defined under the Marine Mammal Protection Act. Responsible parties conducting any activities under the selected project alternative that would result in the incidental take of marine mammals will require an Incidental Take Authorization issued by the NMFS. Incidental Take Authorization applications must include detailed information regarding each discreet project activity, projected environmental impact, potentially effected marine mammal populations, mitigation of negative impacts, and a comprehensive monitoring and reporting plan.

The requirements of the Marine Mammal Protection Act apply to this study. Potential impacts to marine mammals are anticipated for Tier One (not actionable measures), but not anticipated for the Tier Two (actionable measures). The impacts to "not actionable measures" have been broadly disclosed in Chapter 4.0 and would be further described in future NEPA documents. At that time, coordination with NMFS would be begin and an Incidental Take Authorization would be pursued.

For the actionable measures, none of the actions would be expected to result in the need for an Incidental Take Authorization and conservation measures have been incorporated into the plan to reduce impacts to marine mammals; therefore, disclosure of the impacts in Chapter 5.0 is deemed sufficient for full compliance with the MMPA and no additional coordination with NMFS is necessary.

6.9 MAGNUSON STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

The MSFCMA (PL 94-265), as amended, provides for the conservation and management of the Nation's fishery resources through the preparation and implementation of Fishery Management Plans (FMPs) (16 USC 1801 et seq.). The MSFCMA calls for NOAA fisheries to work with regional Fishery Management Councils to develop FMPs for each fishery under their jurisdiction.

One of the required provisions of FMP specifies that EFH be identified and described for the fishery, adverse fishing impacts on EFH be minimized to the extent practicable, and other actions to conserve and enhance EFH be identified. The MSFCMA also mandates that NMFS coordinate with and provide information to Federal agencies to further the conservation and enhancement of EFH. Federal agencies must consult with NMFS on any action that may adversely affect EFH. When NMFS finds that a Federal or State action would adversely affect EFH, it is required to provide conservation recommendations.

EFH is designated for the project area in which the recommended plan is located. Consultation with NMFS will be initiated with the release of the Draft Feasibility Report and Draft EIS. An EFH Assessment has been prepared for this project and is being coordinated with NMFS (Appendix C). NMFS recommendations during consultation will be incorporated into the Final EIS and included in the Appendix.

6.10 FEDERAL WATER PROJECT RECREATION ACT

The Federal Water Project Recreation Act, as amended, declares the intent of Congress that recreation and fish and wildlife enhancement be given full consideration as purposes of Federal water development projects if non-Federal public bodies agree to (1) bear not less than one-half the separable costs allocated for recreational purposes or 25 percent of the cost for fish and wildlife enhancement; (2) administer project land and water areas devoted to these purposes; and (3) bear all costs of operation, maintenance, and replacement (16 USC 460(L)(12)–460(L)(21)). Cost-sharing is not required where Federal lands or authorized Federal programs for fish and wildlife conservation are involved. This Act also authorizes the use of Federal water project funds for land acquisition in order to establish refuges for migratory waterfowl when recommended by the Secretary of the Interior, and authorizes the Secretary to provide facilities for outdoor recreation and fish and wildlife at all reservoirs under his control, except those within NWRs.

The provisions of the Federal Water Recreation Act apply to this study. One of the goals of the TSP is to protect and enhance outdoor recreation opportunities. However, the potential impacts of the CSRM gate structures could alter recreational opportunities, which would need to be further considered by the agencies.

6.11 COASTAL ZONE MANAGEMENT ACT

Under the Texas Coastal Management Program (TCMP), enacted under the Coastal Zone Management Act in 1972, the GLO reviews Federal activities to determine whether they are consistent with the policies of the TCMP. USACE has prepared a Consistency Determination that evaluates the TSP for consistency with the TCMP and has concluded that it is fully consistent to the maximum extent practicable with the enforceable policies of the Texas program (Appendix F).

6.12 COASTAL BARRIER RESOURCES ACT OF 1982 AND COASTAL BARRIER IMPROVEMENT ACT OF 1990

The Coastal Barrier Resources Act (16 USC 3501 et seq.) and the Coastal Barrier Improvement Act of 1990 (PL 101-591) are Federal laws that were enacted on October 18, 1982, and November 16, 1990, respectively (FEMA, 2015). The legislation was implemented as part of a Department of Interior initiative to minimize loss of human life by discouraging development in high-risk areas, reduce wasteful expenditures of Federal resources, and to preserve the ecological integrity of areas Congress designates as a Coastal Barrier Resources System and Otherwise Protected Areas. This Law encourages the conservation of hurricane prone, biologically rich coastal barriers by restricting federal expenditures that encourage development, such as federal flood insurance. Statutory exceptions for federal expenditures are included for specified activities. Also, areas within the Coastal Barrier Resources System Units can be developed provided that private developers or other non-federal parties bear the full cost.

Coastal Barrier Resources System designated units are located in a number of proposed project areas of the recommended plan. The USACE, Galveston District consulted with the USFWS to ensure that the recommended plan is in compliance with Coastal Barrier Resources Act policies. On October 21, 2020, USFWS responded to USACE request for consultation under CBRA indicating that the project is located within a System Unit and meets General Exception 16 USC 3505(a)(2) (maintenance or construction of improvements of existing Federal navigation channels), and specific exceptions 16 USC 3505(a)(6)(A) (Projects for the study, management, protection, and enhancement of fish and wildlife resources and habitats) and 16 USC 3505(a)(6)(G) (Nonstructural projects for shoreline stabilization) of the CBRA. The response notes that the Service recognizes that it is not the intention of the project to promote development and that development is limited by the inability of property owners to receive federally backed insurance or construct in areas protected by the CWA. However, they note that there are instances in CBRA system where neither of those restrictions has been a deterrent to development; therefore, the Service recommends the project proponents consider means to provide protection or conservation easements within these CBRS units to deter such development in the future that could arise due to the flood control objectives of the project.

The USACE intends to formally respond acknowledging the request to consider incorporation of conservation easements or other means of protection to prevent development in CBRA units. USACE will evaluate the feasibility of incorporating protection measures and report the findings in the Final Feasibility Report.

The complete consultation package can be found in Appendix E. Consultation required under CBRA is considered complete and the project is compliant with the law.

6.13 FARMLAND PROTECTION POLICY ACT OF 1981 AND THE CEQ MEMORANDUM PRIME AND UNIQUE FARMLANDS

In 1980, the CEQ issued an Environmental Statement Memorandum “Prime and Unique Agricultural Lands” as a supplement to the NEPA procedures. Additionally, the Farmland Protection Policy Act, passed in 1981, requires Federal agencies to evaluate the impacts of federally funded projects that may convert farmlands to nonagricultural uses and to consider alternative actions that would reduce adverse effects of the conversion.

Further investigation is needed to determine the potential for impacts to prime farmlands as a result of implementing the Galveston Bay Storm Surge Barrier System because prime farmlands exists near existing proposed alignments, but may or may not be impacted in the future depending on future designs and alignments. When Tier Two NEPA documents are prepared, FPPA compliance will be considered and if necessary, consultation with the Natural Resource Conservation Service (NRCS) will occur.

The South Padre Island CSRM and ER measures are not expected to impact prime farmlands as there are none located in or near the action areas; therefore, the FPPA is not applicable.

6.14 EXECUTIVE ORDER 11988, FLOODPLAIN MANAGEMENT

EO 11988 requires Federal agencies avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in USACE ER 1165-2-26, requires an eight-step process that agencies should carry out as part of their decision making on projects that have potential impacts to, or are within the floodplain. The eight steps and project-specific responses to them are summarized below.

1. Determine if a proposed action is in the base floodplain (that area which has a one percent of greater chance of flooding in any given year). The proposed action is within the base floodplain. However, the project is designed to reduce damages to existing infrastructure located landward of the proposed project.

2. If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain. Section 5 of this document presents an analysis of potential alternatives. Practicable measures and alternatives were formulated and evaluated against the Corps of Engineers guidance, including nonstructural measures such as retreat, demolition and land acquisition.

3. If the action must be in the flood plain, advise the general public in the affected area and obtain their views and comments. There has been extensive coordination with pertinent Federal, State and local agencies. Once the draft report is released, public meetings will be scheduled in the study area during the public review period.

4. Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base flood plain will affect the base flood plain, impacts resulting from these actions should also be identified. The anticipated impacts associated with

the Selected Plan are summarized in sections 5.0 and 6.0 of this report. The project would not alter or impact the natural or beneficial flood plain values.

5. If the action is likely to induce development in the base flood plain, determine if a practicable non-flood plain alternative for the development exists. The project provides benefits solely for existing and previously approved development and is not likely to induce development. Nonstructural components of the project, and real estate requirements required for construction of the project will reduce the level of development that is at risk.

6. As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no-action" alternative. There is no mitigation to be expected for the Selected Plan. The project would not induce development in the flood plain and the project will not impact the natural or beneficial flood plain values. Section 6.0 of this report summarizes the alternative identification, screening and selection process. The "no action" alternative was included in the plan formulation phase.

7. If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings. The Draft Interim Feasibility Report and Environmental Impact Statement will be provided for public review and a public hearing will be scheduled during the public review period. Each comment received will be addressed and, if appropriate, incorporated into the Final Report. A record of all comments received will also be included in the Pertinent Correspondence Appendix.

8. Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the EO. The Recommended Plan is the most responsive to all of the study objectives and the most consistent with the EO.

6.15 EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS

The purpose of EO 11990 is to "minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands." To meet these objectives, this EO requires Federal agencies, in planning their actions, to consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. The EO applies to:

- Acquisition, management, and disposition of Federal lands and facilities construction and improvement projects which are undertaken, financed or assisted by Federal agencies; and

- Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities.

EO 11990 applies to this study. All practicable measures have been taken to minimize the loss of wetlands. For Tier One measures, alternatives to avoid the loss of wetlands will be evaluated, and future alignments of structures and features will be sited to minimize wetland loss to the greatest extent practicable. Wetland losses will be fully mitigated for to result in no net loss of wetlands. Mitigation need has been broadly reviewed and is available in Appendix J; however, the mitigation need and anticipated method and location of mitigation will be reviewed and revised as necessary once more site-specific designs are available and further investigation into the impacts on wetlands are completed.

For Tier Two Measures (ER measures), wetland loss would be temporary during construction but would be restored and/or protected to result in a net increase in wetlands in the action areas. Without these actions, it is likely that wetlands losses would otherwise be lost to anthropogenic and natural processes. These measures are considered in compliance with the EO as they are seeking to restore and preserve existing wetlands and not cause further degradation and loss.

6.16 EXECUTIVE ORDER 13112, INVASIVE SPECIES

EO 13112 addresses the prevention of the introduction of invasive species and provides for their control and minimization of the economic, ecological, and human health impacts the invasive species causes. It establishes the Invasive Species Council, which is responsible for the preparation and issuance of the National Invasive Species Management Plan, which details and recommends performance-oriented goals and objectives and specific measures of success for Federal agencies. BMPs would be employed during construction activities to prevent the spread and introduction of invasive and non-native species. ER features of the recommended plan would help offset some habitat loss as a result of invasive species by restoring native habitats. The recommended plan is in compliance with EO 13112.

6.17 EXECUTIVE ORDER 12898, ENVIRONMENTAL JUSTICE

Environmental justice requires agencies to incorporate into NEPA documents an analysis of the environmental effects of their proposed programs on minorities and low-income populations and communities. Environmental justice is defined by EPA as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of Federal, state, local, and tribal programs and policies.”

EO 12898 applies to the study and the potential impacts to minority and low-income groups are described in Chapters 4.0 and 5.0 of this EIS. Based on a demographic analysis of the study area and findings of an environmental justice review, the recommended plan would not have a disproportionately high and adverse impact on any low-income or minority populations.

6.18 EXECUTIVE ORDER 13045, PROTECTION OF CHILDREN

EO 13045 directs Federal agencies to ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks. Examples of risks to children include increased traffic volumes and industrial or production-oriented activities that would generate substances or pollutants that children may come into contact with or ingest. This report has evaluated the potential for the recommended plan to increase these risks to children, and it has been determined that children in the project areas would not likely experience any adverse effects from the proposed project.

6.19 FEDERAL AVIATION ADMINISTRATION – HAZARDOUS WILDLIFE ATTRACTANTS ON OR NEAR AIRPORTS

In accordance with FAA AC 150/5200-33 and the Memorandum of Agreement among the FAA, the USACE, and other Federal agencies (July 2003), the recommended plan was evaluated to determine if proposed land uses could increase wildlife hazards to aircraft using public use airports in the study area. The infrastructure associated with the project is not expected to attract wildlife; however, the ER measures could have the potential to attract birds and increase the incidence of wildlife strikes. ER measures are within Perimeter C of the Charles R Johnson Airport near Port Mansfield and Campbell-Porter and Mustang Beach airports near Aransas Pass/Port

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7.0 PUBLIC INVOLVEMENT AND AGENCY COORDINATION

NEPA was enacted by Congress in 1969 to ensure that Federal agencies consider the potential environmental impacts of their proposed actions and alternatives prior to making decisions. NEPA requires the preparation of an EIS for major Federal actions that may significantly affect the quality of the environment.

NEPA established the Council on Environmental Quality (CEQ), which issues guidance and interprets regulations that implement NEPA's procedural requirements. Pursuant to CEQ Regulations for Implementing the NEPA (40 CFR §1501.7 and §1508.22), public involvement is an essential part of the Federal Feasibility study processes and requires an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action. It is integral to assessing the environmental consequences of the proposed action and improving the quality of the environmental and feasibility study decision making. The USACE planning regulations in ER 1105-2-100 also requires a public involvement, collaboration, and coordination process with the goal of opening and maintaining channels of communication with the public in order to give full consideration to public views and information in the planning process. The objectives of public involvement are 1) to provide information about proposed Corps activities to the public; 2) to make the public's desires, needs, and concerns known to decision-makers; 3) to provide for consultation with the public before decisions are reached; and, 4) to consider the public's views in reaching decisions.

Substantial supporting information is available in Appendix M of this EIS, including a scoping report, the Notice of Intent, public notifications, and a comment report from the 2018 Public Review of the Draft Integrated Feasibility Report and EIS.

7.1 PUBLIC INVOLVEMENT

The GLO created and maintains a Coastal Texas website that is periodically updated to keep an open line of communication with the public. This website contains a summary of the study, copies of all documents prepared and released to the public including public notices, newsletters, and presentations, and reports.

The website can be accessed at: https://coastalstudy.texas.gov/

7.1.1 Scoping

The best time to identify issues, determine points of contact, establish project schedules, and provide recommendations to the agency is during the scoping period. This period provides the most opportunity to alter existing alternatives, propose new alternatives, and refines the proposed action and is usually the best time to initiate collaborative processes.

Collaborative processes can improve communication, reduce conflict, and provide generally more acceptable and practical alternatives and solutions.

The scoping process presents citizens the opportunity to provide input on the range of issues to be addressed in the EIS. USACE planning regulations also require a scoping process to gain input on the initial planning steps required for a feasibility study. Step 1 of the six-step planning process is to identify problems and opportunities that a Federal project could address under the purpose of the feasibility study through agency and public stakeholder input on the specific problems and opportunities. Scoping is required for both NEPA and USACE planning purposes. USACE used this process to receive citizens' ideas on the significant issues and impacts to be addressed in the analysis of environmental impacts, to help define the scope of the study and the context of the issues that will be analyzed in depth in the EIS. The USACE also specifically sought the public's input on the problems, opportunities, and potential alternatives that navigation improvements can address.

In accordance with CEQ regulations, USACE is required to identify and invite the participation of interested persons or resource agencies and, therefore, should use communication methods best suited for the effective involvement of local, regional, and/or national communities, which are interested in the proposed action. The intent of the scoping process was to engage each affected interest as soon as the EIS process began to afford them the opportunity to provide input on the impacts and alternative solutions to potential issues, problems, and actions. Appendix I, Public Involvement, provides a summary of the public coordination conducted during the scoping process. The following subsections summarize the coordination conducted.

7.1.1.1 Early Scoping

Early scoping efforts began in 2012 for the study. The effort began when GLO developed an overview of issues affecting the Texas coast entitled "The Texas Coast: Shoring Up Our Future." The Document identified the issues of concern as wetland/habitat loss, water quality and quantity, impacts to fish and wildlife, impacts to marine resources, Gulf beach/dune erosion, bay shoreline erosion, flooding and storm surge, tourism/local economy, along with other less significant issues. This publication was used as a starting point in identifying the scope of issues, problems and opportunities, and alternatives to be examined in the Draft Integrated Feasibility Report and EIS.

A series of scoping meetings were held along the Upper Texas Coast as part of the Sabine Pass to Galveston Bay Feasibility Study. Meetings were held in Seabrook, Beaumont, Freeport, and Galveston, Texas in February and March 2012 to gather ideas for Coastal Storm Risk Management and Ecosystem Restoration opportunities in Region 1 of the study area. The information collected at these meetings was also used in the preparation of the Reconnaissance 905(b) Report (USACE 2015).

In August 2014, separate scoping meetings were held in Palacios, Corpus Christi and South Padre Island, Texas to collect similar information for the remainder of the Texas coast (**Table 7-1**). These meetings requested input from the counties in Regions 2, 3, and 4 in the study area. As well, an additional meeting was held in League City to update the public on the activities in Region 1.

Table 7-1 Early Scoping Meetings Held in 2014

Date	Area	Location
11-AUG-2014	Port of Palacios	Port Administration Building, 1602 Main Street, Palacios, TX 77465
12-AUG-2014	Texas A&M University Corpus Christi	Corpus Christi, Harte Research Institute Building, Room 127, 6300 Ocean Drive, Corpus Christi, TX 78412
13-AUG-2014	South Padre Island	Hilton Garden Inn – South Padre Island, Great White Room, 7010 Padre Blvd, South Padre Island, TX 78597
27-AUG-2014	Mainland Galveston	Johnnie Arolfo Civic Center, 400 West Walker St, League City, TX 77573

During the public scoping meetings, numerous individuals provided verbal comments at each meeting. A total of 20 people representing county, city, and state agencies, ports, non-governmental organizations (NGOs), and private and special interest groups provided a total of 54 comments during the first three meetings.

The following summarizes the concerns expressed during each of the scoping meetings:

August 11, 2014, Palacios, Texas – Public Meeting

<u>Matagorda Bay</u>

- The study should acknowledge the loss of fresh, intermediate, brackish, saline gradient due to low flow in Colorado River flows, changes to native fisheries, especially oysters.
- The study needs to include coastal S/L revetment and re-establish the Gulf Intracoastal Waterway (GIWW) land bridge with dredged sediments to include wetland restoration.
- The study should acknowledge the steadily increasing salinities in Matagorda Bay due to decreased freshwater inflows.
- The single best way to maintain the ecological productivity of the bay is to buy Colorado Rights for freshwater inflows and re-establish seasonal inflows.

- The study should acknowledge the erosion of beach front of East Matagorda Bay and erosion protection for Sargent Beach.
- The study should acknowledge the threat of breakthrough in the land barrier and how this would impact the habitat types currently in Keller Bay.
- The study should propose the improvement of the Matagorda Ship Channel.

Coast Wide

- The study needs to obtain a sediment budget for the Texas Coast to inform objectives in planning and should use current studies to inform future data collection strategically, where required.
- The study should identify potential sand sources from GLO designated sites.

August 12, 2014, Corpus Christi, Texas – Public Meeting:

Galveston Bay

- The study should identify areas where wintering piping plover habitat can be established, particularly on marsh along Bolivar Peninsula.

Matagorda and San Antonio Bays

- Concerned with lack of freshwater inflow into the system.
- Interested in preservation and restoration of habitats: oyster reef, Mad Island Wildlife Management Area, and bird rookery islands.

Corpus Christi Bay

- There is a need for industry to understand and realize the risks and residual risks in order to focus on non-structural solutions needed to perform flood proofing against storms.
- Within the Nueces Delta, the project should complete acquisition of all delta parcels, implement more hydrological restoration projects, protect the delta shoreline, and restore marsh in the delta using dredged material.
- The study should identify areas where wintering piping plover habitat can be established, particularly on Pelican Islands on Corpus Christi Ship Channel.
- Interested in local/regional coalition to support the project and build support.

Coast Wide

- The study should place monetary value on sediments to be dredged for non-Federal sponsor cost share accounting to offset the required funds.

- The study should coordinate plans across Federal and non-Federal organizations that may not be explicitly partnering to strive toward consistency and synergy in plan outcomes.
- The study should incorporate analyses of the effects of sea level rise.
- The study should seek out opportunities to increase whooping crane habitat coast wide.
- The study needs to consider observing each coastal region as independent of the surrounding regions.

August 13, 2014, South Padre Island, Texas – Public Meeting:

Laguna Madre

- The study needs to address the wind storm surge flooding in Port Isabel and consider adding a relief valve under Highway 100.
- The study should consider hydrological detention in regional valley floodways to modulate adverse freshwater impacts in Laguna Madre.
- The study should consider keeping the Port Mansfield Ship Channel open, as this is important in relieving bay surge.

Coast Wide

- There is a need to educate the local community on coastal vulnerability to stimulate engagement in the process.
- The study should to address the need to produce vegetation for use (mangroves, smooth cord grass, sea oats, sea grasses, etc.).
- The study needs to address relative sea level rise and establish a long-term strategy for relative sea level rise, setbacks, and anticipated adaption in near-term designs.

In addition, written scoping comments (letters and emails) were received from Federal, state, and local agencies, NGOs, private and special interest groups, and concerned members of the public. A total of 22 scoping comment letters and emails were received during the scoping comment period in August 2014 containing 57 comments. The following summarizes concerns brought forth during the NEPA scoping process that were not previously documented, including both written comment letters and emails that were received during the August 2014 scoping review period.

- The study needs to identify bird island beneficial use projects that could be incorporated into planned dredging events.

- The study needs to support and identify other beneficial use projects that could enhance foraging habitats for water birds, shorebirds, and neotropic migrants.
- Supports protection and restoration of wetlands, bird islands, oyster reefs, critical habitat, and other natural features along the coast and project features that will protect these resources.
- The study needs to focus on capturing dredged sediments along the Texas Coast to be used as beneficial use projects.
- The study should not support hard structures (seawalls, extensive rock groins, jetties, or similar projects) that destroy and interrupt beaches and dunes and the natural sand transport systems.
- The study should concentrate support and projects on developing East Galveston Island instead of West Galveston Island.
- Building the "Ike Dike" provides the best solution for the Gulf coast region, it protects the entire bay area and industries and eliminates the need for the other bay alternatives.

A total of 111 comments were received during the scoping comment period in August 2014. Comments were received from Federal, state, and local agencies, NGOs, private and special interest groups, and concerned members of the public.

7.1.1.2 Formal Scoping

When the agency determines that an EIS is required, they issue a Notice of Intent (NOI) in the Federal Register to inform the public that an EIS (or supplemental EIS) will be prepared and to formally announce the beginning of the scoping process.

The USACE, consistent with 40 CFR §1508.22, published a Notice of Intent (NOI) in the Federal Register (Volume 81, Number 62) on Thursday, March 31st, 2016, to prepare an EIS to evaluate a study that would identify and evaluate the feasibility of developing a comprehensive plan for flood risk management, hurricane and storm risk management, and ecosystem restoration for the coastal areas of the State of Texas. The NOI also notified the public that comments would be accepted through May 9, 2016, and that further coordination with the Federal, State, and local agencies would be completed.

Scoping comments were received from individuals, non-governmental organizations (NGOs) universities, cities/towns, state and Federal stakeholders. A total of 2,108 scoping comment letters and e-mails were received during the scoping comment period (**Table 7-2**). A total of 10,954 multi-part scoping comments were expressed. The majority of comments were submitted by NGOs, especially the Sierra Club, which accounted for 2,092 comments.

Table 7-2 Number and Source of Scoping Comments Received During Formal Scoping

Source of Comments	#	# Multi-part comments	Federal	State	City/ Town	University	NGO	Individual
Individual Comments from Various Sources	40	389	4	6	2	1	11	16
Sierra Club Mass E-mail with Same Comments	2,082	10,410	0	0	0	0	2,082	0
Sierra Club Mass E-mail Combination Sam and Individual Comments	61	155	0	0	0	0	61	0
Total	2,108	10,954	4	6	2	1	2,092	16

NEPA scoping comments were categorized, consistent with 40 CFR §1502.10, according to the standard format section of the EIS where the subject matter of the comment would likely be addressed. A scoping comment may have contained multi-part comments regarding multiple areas of concern and may be addressed in multiple sections of the EIS. **Table 7-3** displays the categorization and breakdown of the 20,357 specific comments by EIS format or subject matter.

Table 7-3 Categorization of Scoping Comments by EIS Subject Matter

	Individual Comments	Sierra Club Form Letter	Sierra Club with Form Letter and Individual Comments	Total
Purpose and Need	36	0	2	38
Alternatives	272	4,168	261	4,440
Affected Environment	163	6,246	216	6,409
Environmental Consequences	246	8,328	318	8,574
Consultation, Coordination, and Compliance with Regulations	93	0	4	93

The top five themes identified from the scoping comments included:

- Address impacts to human development and population growth.
- Significant natural resources that could be negatively impacted by a coastal barrier risk reduction system.
- Changes to natural resources should focus on nonstructural solutions and disclose biological effects.
- Solutions must protect the coastal environment and must disclose biological effects.
- Alternatives should include nature-based solutions that improve access to outdoor recreation and conserves Texas' diverse coastal ecosystems.

A summary of the comments received during scoping is available in the Scoping Report and the Addendum to Scoping Report found in Appendix M of this EIS. As well as a summary of comments received outside the scoping comment period that were received from the Sierra Club and private parties are available for review in Appendix M.

7.1.2 Public Review of the 2018 Draft Integrated Feasibility Report and EIS

The Draft Integrated Feasibility Report and EIS were released for public review in October 26, 2018. In compliance with the National Environmental Policy Act (NEPA) and Engineering Regulation (ER) 1105-2-100, public participation is an integral component of the feasibility study process. All Corps planning studies are required to incorporate public involvement, collaboration and coordination with the public.

7.1.2.1 Public Meetings

Seven public meetings for the study were held between November 27 and December 18, 2018, in a combined open house and town hall style (**Table 7-4**). Upon arrival, attendees were asked to complete an attendee card and were provided with meeting materials including a meeting agenda, a study summary handout, and a comment form for written comments. A total of 1,245 people completed attendee cards at the seven meetings, although it is likely more people attended but opted to not fill out an attendance card.

The public meetings began as an open house. Attendees were invited to view an informational video and informational displays and discuss the study with study team representatives available at each meeting. The informational video was produced to provide a point of consistent, targeted communication in a professional and easily distributed format. The informational video is approximately 20 minutes in length and informed the viewer about the TSP. Informational displays were arranged around the meeting space and provided information about the study, the study process, the TSP, the CSRM and ER measures, storm surge barriers, storm surge impacts, and environmental impacts and mitigation.

Table 7-4 Public Meetings for Release of Draft Integrated Feasibility Report and EIS in 2018

Date	Area	Location	Attendees
27-NOV-2018	Port Lavaca	Bower Community Center, 2300 TX-35, Port Lavaca, TX 77979	48
28-NOV-2018	Corpus Christi	Harte Research Institute, Texas A&M Corpus Christi, 6300 Ocean Dr, Corpus Christi, TX 78412	34
29-NOV-2018	Port Isabel	Port Isabel Event & Cultural Center, 309 Railroad Ave, Port Isabel, TX 78578	60
11-DEC-2018	Winnie	Winnie Community Building, 335 South Park Street, Winnie, TX 77665	71
12-DEC-2018	Galveston	Galveston Island Convention Center, 5600 Seawall Blvd, Galveston, TX 77551	406
15-DEC-2018	Bolivar	Crenshaw Elementary and Middle School, 416 SH 87, Crystal Beach, TX 77550	407
18-DEC-2018	Seabrook	Bay Area Community Center, 5002 E NASA Parkway, Seabrook, TX 77586	219

At the conclusion of the open house portion of the meetings, the town hall portion of the meeting was called to order by USACE representatives. Then, a study overview video was presented to attendees before representatives from the USACE and GLO provided opening remarks. Following the opening remarks, a formal presentation was given by the USACE. The presentation included information about the study focus, plan formulation, alternatives for consideration, study alternatives, the TSP, effects on environmental quality, and the study process. Following the formal presentation, attendees were invited to provide verbal comments.

Attendees wishing to provide verbal comments were required to sign up during registration and were called to speak in the order in which they registered. Each speaker was provided with one minute to speak and was asked to state their first and last name before speaking. Verbal comments were recorded by a court reporter present at each public meeting. Each meeting adjourned following the verbal commenting period. In addition to verbal comments, attendees were invited to submit written comments at the public meeting or at any time during the public review period via mail or email.

An attendee database, copies of the completed attendee cards, handouts in English, Spanish, and Vietnamese, display materials, and formal presentation, and photographs of the meetings are included in Appendix M of this EIS.

7.1.2.1.1 Public Notification

The public was notified about the public meetings and the Draft Integrated Feasibility Report and EIS via a published Notice of Availability (NOA) in the Federal Register, mailed notices, newspaper notices, a news release, and the study website.

The USACE published a Joint NOA in the Federal Register to notify the public of and announce the public review period for the Draft Integrated Feasibility Report and EIS on October 26, 2018. The Joint NOA also announced the public meetings in November and December 2018 and solicited written comments on the Draft Integrated Feasibility Report and EIS throughout the public review period.

A total of 1,832 notices to interested parties and local, state, and federal elected officials were sent via mail on October 17, 2018, announcing public meetings in November and December 2018. The notices also announced the public review period for the DIFR-EIS and solicited written comments throughout the public review period via mail or email.

A public notice was published in English as a legal advertisement in November 2018. The notice announced the availability of the Draft Integrated Feasibility Report and EIS, the date, time, and location of the public meetings, information about where to access the report for review and solicited written comments throughout the public review period via mail or email. A legal advertisement was published in the following publications:

- Anahuac Progress – The Vindicator – November 13, 2018
- Brownsville Herald – November 9, 2018
- Corpus Christi Caller Times – November 11, 2018
- Galveston County Daily News – November 8, 2018
- Houston Chronicle – November 9, 2018
- Port Isabel-South Padre Press – November 9, 2018
- Port Lavaca Wave – November 14, 2018
- Valley Morning Star – November 9, 2018
- Victoria Advocate – November 9, 2018

The USACE also published a press release on October 26, 2018, on the USACE, Galveston District website announcing the availability of the Draft Integrated Feasibility Report and EIS for the study and the public meetings in November and December 2018.

Lastly, a website for the study (coastalstudy.texas.gov) has been maintained by the GLO throughout the study process. The website provides overview information about the study and study schedule, outlines the alternatives evaluated in the study, and provided links to download the Draft Integrated Feasibility Report and EIS and study materials study, including the informational videos and exhibits presented during the November and

December 2018 public meetings. Additionally, the website provides contact information for the study team and information about other relevant studies.

A copy of the Joint NOA, mailed notices, the stakeholder mailing list, public notices, news release and screen shots of the study website are included in Appendix M.

7.1.2.2 Public Comments

The Draft Integrated Feasibility Report and EIS was made available for public review and comment from October 26th, 2018 until February 8th, 2019. The initial 75-day public review period was extended until February 8th, 2019 for a total of a 105-day comment period. The extension was in response to numerous requests by the public and agencies to provide additional time to review the documents. Transcripts of verbal comments and copies of all written comments received are provided in Appendix M of the EIS.

A total of 2,050 comments were received during the public comment period between October 26th, 2018 and February 8th, 2019. A total of 251 comments were received from written forms and during the verbal commenting period of the public meetings, while an additional 1,799 were received by mail or e-mail during the 105-day comment period (**Table 7.5**).

Table 7-5 Comments Received During the Public Review Period for the Draft Integrated Feasibility Report and EIS in 2018

Comment Method	Quantity
Verbal comment provided during the comment period	158
Written comment submitted during a public meeting	93
Written comment received by email or mail	1,799

The major themes of the comments included: requesting an extension of the public comment period, various concerns related to cost of project features, concern for the environment in relation to new construction, concern for restriction of nutrient flow and larval transport with a surge gate, concern for real estate loss due to construction of project features, and requests for additional analysis and consideration of other organization’s proposals.

The following section describes the most common themes identified across 14 different topics including:

- Overall Project Scope
- Surge Barrier
- Galveston Ring Levee
- Bolivar-Galveston Floodwall

- Nonstructural
- Clear Creek Surge Barrier
- ER Measures
- SSPEED Center
- TAMUG Plan
- General Opposition
- Tribal
- Policy Concerns
- South Padre Island
- Additional Measures

7.1.2.2.1 Overall Project Scope

1. **Public Comment Period needs to be extended.**
   The standard public comment period for a draft EIS is 45 calendar days. Prior to release of the 2018 report, and in response to written requests in advance of that report's release, the comment period was first extended an additional 30 days to a total of 75 days. Once the 2018 report was released, additional requests were made, and the period was extended 30 additional days – 105 days total.

2. **Will there be another comment period once the study is closer to being finalized?**
   Yes, in the current version of this report, a public comment period will be held for a length of 45 days beginning on the day the Notice of Availability was published in the Federal Register (October 30, 2020).

3. **Why were some stakeholders not notified about the study?**
   While stakeholders were not notified individually, the release and availability of the report was made public through NEPA compliant posting in the Federal Register. Additionally, notifications were made through social media, local newspapers, and news releases. To address this concern for the 2020 release, we have increased our public outreach efforts.

4. **Who will pay for maintenance on the project once finished?**
   Operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) of the project is the responsibility of the non-Federal construction sponsor, which has not yet been identified.

5. **How will this project affect the economy in regards to ecotourism?**
   Our economic analyses show a positive impact to the regional and local economies; however, ecotourism was outside the scope of this study.

6. **Will this project damage bay industries such as fishing, shrimping, tourism, etc.**
   Potential temporary impacts to fish and wildlife habitat have been characterized in the EIS. Long-term impacts to bay bottom resources, oyster reefs, and seagrasses have been assessed and unavoidable impacts would be fully mitigated as documented in our Mitigation Plan. In addition, the project includes restoration of ecosystems that will restore habitats contributing to the viability of these industries.

7. **What effect will this project have on tax rates?**
   The effects of this project on tax rates are outside of the purview of this study. Funding mechanisms have yet to be identified, but there are several different funding options being explored at the local, regional, state, and federal levels.

8. **How will this project directly or indirectly impact the National Historic Landmarks within the study area?**
   Compliance with the National Historic Preservation Act is documented in Chapter 6 of the 2020 draft EIS. We are working closely with the State Historic Preservation Office to identify and avoid, minimize, or mitigate for any potential impacts to historic resources. We took every opportunity to avoid and minimize impacts through design modification. During future Tier 2 assessments, the designs would be further refined and where possible additional avoidance and minimization would be taken. Implementation of the recommended plan features would also directly benefit some historical landmarks by reducing the flood risk to the site.

9. **Why will construction of the project take so long? Can it be shortened?**
   The construction duration has numerous factors that influence the amount of time needed to build the features. The ability to physically fit the construction equipment into the area where these features are being constructed -- while still maintaining navigation and tidal exchange -- limits the opportunity to shorten construction duration. An overall 15-year schedule for the proposed Bolivar Roads Gate System is necessary due to its complexity. Less complex features can be constructed in a shorter length of time.

10. **What would the indirect impacts be to the ecosystem? Tidal flow, nutrient transport, salinity, sedimentation patterns?**
    The direct and indirect impacts to the ecosystem from construction activities and long-term operation of the gates are described in Chapter 4 of the EIS. The USACE Engineer Research and Development Center (ERDC) conducted 3D Adaptive Hydraulics (AdH) modeling and particle tracking modeling for the Galveston Bay

Storm Surge Barrier System to model the potential indirect impacts of constructing the gates on tidal flow, salinity, and sediment and organism movement. The modeling showed the average difference between water levels at high and low tide (tidal amplitude) would increase or decrease by less than 1 inch (0.4-0.8" to be exact) with the gates in place and there would be a slight decrease in average salinity of between 1 and 2 ppt. The change in tidal amplitude would result in the loss of approximately -1,148 acres of habitat that would be fully mitigated as described in the Mitigation Appendix (Appendix J of the EIS). The changes in salinity, circulation, velocity and currents are well within the tolerable range of most organisms in the Bay and surrounding areas given the wide range of salinities and habitats they currently occupy and would therefore not be expected to have any measurable effects.

During future design refinements, the indirect impacts would be reassessed, and additional avoidance and minimization measures would be incorporated to the greatest extent practicable. Mitigation would be completed for all unavoidable indirect impacts, such as habitat loss.

11. **What does this plan do to address flooding from heavy rainfall events like Harvey?**
    This study does not independently authorize or study ways to address flood risks that are not associated with storm surge induced flooding and erosion, such as flooding caused by heavy rainfall, but it did consider how each of the measures would perform in the event of a heavy rainfall event. The proposed plan is designed to keep coastal storm surge in the Gulf, maintaining the storage capacity of the Bay, and avoids compounding the effects of heavy rainfall events by including drainage structures and pumping stations at critical locations throughout the system to reduce flooding during storms. Several separate Flood Risk Management (FRM) studies are authorized in the Houston region to evaluate flood risks that are associated with heavy rainfall among other causes of flooding not related to storm surge.

12. **Will there be access for emergency services during storm events? Will the project cut certain populations off?**
    The physical flood risk management structures (floodwalls, gates, etc.) will not prevent access for emergency services or cut any populations off from access; however, residents should still follow established evacuation procedures when ordered to do so by local officials.

13. **Will the beaches be accessible during construction?**
    Beaches will be constructed in segments and phased to try and maximize access. Access will be restricted to segments of beaches where active construction activities are occurring. The remaining and already-constructed beaches will be open to the public.

14. **The plan seems rushed and needs to be reevaluated. Has the Corps considered dune restoration?**

    In response to the public comments received on the first draft report in 2018, the plan was revised to drop the levee system on the barrier islands and proposes to replace it with a beach and dune system.

15. **What effects will this project have on our tidal marshes and wetlands?**

    The PDT performed numerous analyses in cooperation with local, state, and federal resource agencies to describe both the direct and indirect environmental impacts. The project includes several Ecosystem Restoration Measures (G-28, B-12, M-8, CA-5, and CA6) which would protect and restore hundreds of acres of tidal marshes and wetlands along the Texas Coast. The PDT also used hydrologic modeling combined with GIS and ecological models to quantify and mitigate for any adverse impacts identified in the study process. For more detailed discussions on these topics, see Chapters 4 and 5 in the EIS.

16. **How will this project affect the marine life in the surrounding bays and estuaries?**

    The PDT cooperated with local, state, and federal resource agencies to ensure that considerations for marine life were fully considered. Examples include the recommendation of 8 Ecosystem Restoration Measures and one dual-purpose measure (Galveston Island and Bolivar Beach and Dune measure) that would restore hundreds of acres of beach and dune habitat, marsh habitat, bird rookery islands, oyster reefs, and would protect sensitive sea grass meadows in Regions 3 and 4. The PDT also used hydrologic modeling combined with GIS and ecological models to quantify and develop mitigation for all adverse impacts described in the study from the CSRM measures in Region 1. For the CSRM measures in Region 1, this is a Tier One EIS, mean that Tier Two NEPA studies will be conducted for those measures. This Tier One EIS includes a description of the project affects to the marine life in bays and estuaries in Chapters 4 and 5 of the EIS.

17. **The project will displace wildlife and destroy critical habitat for endangered species.**

    Discussions of how the project would directly or indirect impact wildlife and endangered species and ways we are working toward avoiding, minimizing and mitigating impacts can be found in Chapter 4 and 5 of the EIS and Appendix B, C, I, and J of the EIS. The PDT, in collaboration with the resource agencies, identified direct and indirect adverse impacts that are anticipated if the project is implemented. The PDT used ecological modeling to evaluate these potential impacts to quantify the impacts and developed a mitigation plan to fully compensate for unavoidable adverse impacts. The PDT has identified two locations near Bolivar flats and Big Reef where piping plover Critical Habitat could be adversely impacted. We are coordinating closely with the US Fish and Wildlife Service to identify the specific impacts and how to avoid, minimize, and mitigate, if necessary for the impacts (Appendix B of the EIS).

18. **How will this project affect property values, taxes, or my house insurance?**
This report has feasibility level of detail. There are multiple variables that are considered when determining property values, taxes, or home insurance at present time. It would not be responsible or legal for the Government to predict future property values, taxes, or homeowners insurance for a project that has yet to be constructed.

19. **Will homeowners be compensated for property value or rental losses as a result of this project?**
Landowners whose land is required for this project will be compensated at fair market value at the time of purchase. Fair market value will be determined by the independent, non-USACE real estate appraiser in compliance with Uniform Standards of Professional Appraisal Practice standards.

20. **Will residents be forced to move out of their homes?**
Displaced persons will not be required to move without at least 90 days advance written notice. All persons displaced by this project will be offered decent, safe, and sanitary replacement housing.

7.1.2.2.2 Bolivar Roads Gate System

1. **Why is the public (taxpayer) paying to protect the oil/gas industries? Let them pay or they can build their own barrier.**
The purpose of the Coastal Texas Study is to identify coastal storm risk management (CSRM) and ecosystem restoration (ER) measures that would protect the health and safety of Texas coastal communities, reduce the risk of storm damage to industries and businesses critical to the Nation's economy, and address critical coastal ecosystems in need of restoration.

2. **Concern for the cost of maintaining the surge barrier and associated pumping and dredging.**
The need for and cost of long-term operation and maintenance of the surge barrier, and all features of the proposed plan, have been taken into consideration and included in the overall cost of the project. As design refinements occur, long-term operation and maintenance will be further considered.

3. **The surge barrier will affect tidal exchange and harm the environment and collapse the fishing and/or recreational industry.**
Potential temporary impacts to fish and wildlife habitat have been characterized in our Chapter 4 and 5 of the EIS. These temporary impacts will be fully mitigated as documented in our Mitigation Plan. In addition, the project includes restoration of ecosystems that will restore habitats contributing to the viability of these industries.

4. **What would happen in Galveston Bay if another storm like Harvey hit? Would the barrier keep surge water in?**
During extreme storm surge events, the proposed barrier will be operated under a multi-criteria threshold (to be determined) considering water level both inside and outside of the barrier and considering runoff from rainfall, including inducements adjacent to the barrier. When these proposed gates are closed, the pump stations will need to operate to remove water due to rainfall and/or wave overtopping from within the ring barrier system. While the pumps are initially designed to handle 25-year rainfall with surge tail water boundary conditions of 1% ACE, the compound interaction of rainfall and surge has not been fully explored in this phase of the study. The final design of the systems including proposed Pump Station capacity, interior storage and drainage features will be based on the latest information to address the authorized risk. Note that the Corps' project cannot cause an increase in damage to one area in order to reduce damage to a different area.

5. **The restriction caused by the barrier would negatively impact navigation for both commercial and recreational boaters and cause increased traffic.**
The current proposed plan has 2 large navigation gates (650-ft wide) for commercial ships and barges and two small (125-ft wide) sector gates for recreational boaters. Future navigation concern was given priority on the current barrier selection. During PED, the width of navigation gates will be optimized by doing additional ship simulations.

6. **How will the flow restriction caused by the barrier affect runoff? Will it affect nearby communities in the event of a heavy rainstorm?**
The current proposed barrier plan has less than 10% restriction of the Galveston inlet. Our modeling exercise on this restriction suggest minimal impacts on the day-to-day circulation in and around the Bay. During extreme storm surge events, the barrier will be operated under a multi-criteria threshold (to be determined) considering water levels both inside and outside of the barrier and considering runoff from rainfall, including inducements adjacent to the barrier. Note that the Corps' project cannot cause an increase in damage to one area without mitigation measures in order to reduce damage to a different area.

7. **The surge barrier will limit tidal exchange and this will reduce/impede larval spawning of local fish/invert species.**
The Corps, in coordination with the resource agencies, used a Particle Tracking Model (PTM) to show indirect impacts, and the extent of those impacts, from constructing the storm surge barrier system at Bolivar Roads on the larval stages of the marine life that travel in and out of Galveston Bay. The PTM simulates the transport of particles, or local marine larval species, using environmental inputs such as circulation, salinity, currents, and water surface elevation from the 3D Adaptive Hydraulics Model and local marine species' transportation characteristics (e.g. bottom dwellers, top dwellers etc.). The particle movements represent a multitude of

aquatic species including shrimp, blue crabs, and commercially and recreationally important finfish (e.g. spotted sea trout and flounder). Results showed that movement of larval species into the Bay were similar whether the proposed storm surge barrier system was in place or not.

8. The gates in the Netherlands do not apply to the geography of Texas and/or the Netherlands gates are environmental disasters.

The gate structures included in the proposed plan were all designed for the specific locations where they would be built. The PDT used examples from other projects and lessons learned from around the world to inform the design.

9. The effect of the surge barrier on salinity, tidal exchange, and velocity will harm the ecosystem.

The direct and indirect impacts to the ecosystem from construction activities and long-term operation of the gates are described in Chapter 4 of the EIS. The USACE Engineer Research and Development Center (ERDC) conducted 3D Adaptive Hydraulics (AdH) modeling and particle tracking modeling for the Galveston Bay Storm Surge Barrier System to model the potential indirect impacts of constructing the gates on tidal flow, salinity, and sediment and organism movement. The modeling showed the average difference between water levels at high and low tide (tidal amplitude) would increase or decrease by less than 1 inch (0.4-0.8" to be exact) with the gates in place and there would be a slight decrease in average salinity of between 1 and 2 ppt. The change in tidal amplitude would result in the loss of approximately -1,148 acres of habitat that would be fully mitigated as described in the Mitigation Appendix (Appendix J of the EIS). The changes in salinity, circulation, velocity and currents are well within the tolerable range of most organisms in the Bay and surrounding areas given the wide range of salinities and habitats they currently occupy and would therefore not be expected to have any measurable effects.

During future design refinements, the indirect impacts would be reassessed and additional avoidance and minimization measures would be incorporated to the greatest extent practicable. Mitigation would be completed for all unavoidable indirect impacts, such as habitat loss.

10. The surge barrier will harm wetlands by decreasing tidal exchange and increasing sedimentation.

Impacts to wetlands from reduction in tidal amplitude, loss of sediment, and erosion have been evaluated in this EIS. Mitigation to offset these impacts was developed. See the discussions in Chapter 4 of the EIS more information on this.

11. **The public wants to see quantified impacts to the environment and associated economy due to the ~30% restriction the surge barrier will cause.**
Direct and indirect impacts from constructing and operating the surge barrier are quantified in Chapter 4 of the EIS and in the Appendix I of the EIS. Through further refinement of the surge barrier, the restriction has been reduced to less than 10%. Indirect and direct impacts to the environment have been quantified and where unavoidable impacts are anticipated, mitigation has been developed to offset the function and value of the losses. During future refinements to the design, additional impact analyses would be taken and where possible additional avoidance and minimization measures would be implemented to further reduce the impact to the environment. Also, the Ecosystem Restoration measures will result in a net benefit above and beyond the mitigation for marsh, bird rookeries, and oyster reefs in the Galveston Bay Complex. Our economic analyses show a positive impact to the regional and local economies

12. **What will happen to homes outside of the dike when surge bounces off of the surge barrier? How will the govt. determine appropriate risk for these homes?**
Detailed analysis will be conducted in the PED phase to assure this project does not induce flooding and minimize property impacts. All real estate requirements will be identified in the PED phase, prior to undertaking any construction activities associated with this project.

7.1.2.2.3 Galveston Ring Levee

1. **The cost to construct and maintain the ring barrier is too high.**
The need for and cost of long-term operation and maintenance of the ring barrier, and all features of the proposed plan, have been taken into consideration and included in the overall cost of the project. As design refinements occur, long-term operation and maintenance will be further considered.

2. **Why are the taxpayers bearing the burden for the ring barrier?**
The effects of this project on tax rates are outside of the purview of this study. Funding mechanisms have yet to be identified, but there are several different funding options being explored at the local, regional, state, and federal levels.

3. **Concerned for possible cultural impacts if the pumps fail (listed the Elissa, East End historic district, etc.)**
Compliance with the National Historic Preservation Act is documented in Chapter 6 of the 2020 draft Environmental Impact Statement. We took every opportunity to avoid and minimize impacts to these landmarks with our current proposed designs. Consideration was given to reducing coastal storm risk damages that will preserve many areas of historical relevance within the system. Specific impacts will be minimized and avoided through modifications to alignments as designs mature in the next phase of the project. Redundancies have been included in the pumping systems,

and the drainage system has been designed to match the existing gravity drainage system operating during non-tropical events.

4. **The Ring Levee will make Galveston a "bathtub" and withhold water during rainstorms; this will increase flooding and destroy property. Cite New Orleans as an example**

   Any new features proposed by the study are not permitted to worsen any existing conditions (i.e. the risk of flooding from a rain event cannot be increased with the implementation of the proposed ring barrier). Pump stations would be implemented to address rainfall during storm events and storm surge is present. The City of Galveston currently has plans to address existing urban flooding problems in the city proper.

5. **The current placement of the ring levee severs UTMB, hospitals/ER's, parts of east end, and businesses from thorowfares and needs to be reconsidered.**

   The alignment of the Galveston Ring Barrier System through the UTMB and east end areas was sited to avoid, minimize, and reduce impacts. All UTMB facilities are included inside of the proposed Ring Barrier and only a handful of businesses that require water access remain outside the barrier.

6. **There needs to be an additional flood gate as San Luis Pass rather than constructing the Ring Levee.**

   The anticipated risk reduction benefits for protective features at San Luis Pass do not outweigh the potential negative environmental impacts of closing off the last remaining natural pass along the Texas coast. Many of the structures and assets that would be protected as a result of the closure are already elevated above surge heights or are at a ground elevation that limits surge impact. There is also limited surge risk when factoring in the full probability of potential storm directions. The pass and the adjoining West Bay are very shallow and constitute only to 3-to-5% of the water exchange between West Bay and the larger area of Galveston Bay. The shallow ridge across West Bay provides a natural barrier limiting circulation between West Bay and the larger water body of the Galveston Bay. This condition minimizes the risk of surge being transmitted to the large area of Galveston Bay where there is a greater number of structures and assets at risk from storm surge.

   Our modeling suggests that San Luis Pass left open, does allow more storm surge water to enter the overall bay system; however, the majority of that water is diffused along Chocolate and West Bays before it reaches significant levels into Galveston Bay. Forerunner water levels can also enter into the bay system, but again, the overall water level in Galveston Bay is not significantly increased. Our modeling showed that even with the San Luis Pass closed off, water levels in the bay could still cause flooding of Galveston Island. Thus, the ring barrier around Galveston Island would still be needed to provide protection, and as such, San Luis Pass closure should not be used as an alternative to the proposed Ring Barrier system around Galveston.

7. **The pump placement on Teichman Road will impact my property. Please move it elsewhere.**
The Offatts Bayou Pump Station is positioned adjacent to the Galveston Causeway as far away from the Teichman Road area as possible. This location was chosen to minimize the impact to the area while allowing continuous access to the pump station during an event and maintaining a functioning pump station. Alternate locations for the Offatts Bayou Pump Station will be reviewed during the PED phase.

8. **The ring levee will negatively affect Real Estate by displacing property, hurting aesthetics, and separating neighborhoods.**
Since the release of the 2018 report, and in response to comments received, we re-evaluated the Ring Barrier alignment, modifying the alignment to avoid and minimize impacts. Where impacts remain, we are proposing non-structural measures to mitigate those effects. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the Galveston Ring Barrier System.

7.1.2.2.4 Bolivar-Galveston Floodwall

1. **Please extend the public comment period by 30/90 days.**
The standard public comment period for an EIS is 45 calendar days. Prior to release of the report, and in response to written requests in advance of the report's release, the comment period was first extended an additional 30 days to a total of 75 days. Once the report was released, additional requests were made, and the period was extended 30 additional days – 105 days total.

2. **"The USACE has excluded the residents of High Island/Bolivar Peninsula from commenting by not including them in the notice, not scheduling big enough venues, not scheduling; additional public meetings when requested, etc."**
Upon receipt of comments from the High Island/Bolivar Peninsula community, an additional meeting was added (on a Saturday at the request of the community).

3. **The placement of the levees/barriers is currently undecided, and this makes it impossible for the public to adequately comment.**

In the 2020 Draft Main Report, maps of the conceptual location of each of the recommended plan features are included in the Engineering Appendix (Appendix D). The location and design of the features will continue to be refined in the future to improve performance and reduce impacts. Additional public involvement will occur when the refinements are made.

4. **Citizens are concerned about having taxpayers pay for the construction and long-term upkeep of the floodwall.**
The effects of this project on tax rates are outside of the purview of this study. Funding mechanisms have yet to be identified, but there are several different funding options being explored at the local, regional, state, and federal levels.

5. **The floodwall will cause insurances and taxes to increase, impacting the local community and making cost of living higher, as well as impacting the local economy overall.**
The effects of this project on insurance rates and taxes are outside of the purview of this study. Funding mechanisms have yet to be identified, but there are several different funding options being explored at the local, regional, state, and federal levels.

6. **Who will pay for the non-federal portion of the overall cost?**
Prior to the next phase of the project, a non-federal sponsor will be identified. Funding mechanisms have yet to be identified, but there are several different funding options being explored at the local, regional, state, and federal levels. The State of Texas is working with the State Legislature and local entities to formulate a plan.

7. **Tourism and businesses would be affected by an ugly floodwall.**
Since the release of the 2018 report, and in response to comments received, we re-evaluated the floodwalls on Bolivar Peninsula and West Galveston. The revised proposed plan has dropped the floodwall and moved toward a nature-based solution – beaches and dunes on the front of the barrier islands. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the revised proposed plan.

8. **The current placement does not account for impacts to cultural resources in Galveston and Bolivar.**
Compliance with the National Historic Preservation Act is documented in Chapter 6 of the 2020 draft Environmental Impact Statement. We took every opportunity to avoid and minimize impacts to these landmarks with our current proposed designs. Consideration was given to reducing coastal storm risk damages that will preserve many areas of historical relevance within the system. Specific impacts will be minimized and avoided through modifications to alignments as designs mature in the next phase of the project.

9. **My home is outside of the current placement for the floodwall; who will be responsible for the destruction of X amount of homes outside of the floodwall?**
The revised proposed plan no longer includes a levee/floodwall on the north side of Highway 87 or on the north side of FM 3005. A nature-based beach and dune system has been proposed for the fronts of both Bolivar Peninsula and West Galveston

Island. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the revised plan.

10. If a levee is built at FM 3005, what will happen to homes that are south of the levee during storm surge?

The revised proposed plan no longer includes a levee/floodwall on the north side of Highway 87 or on the north side of FM 3005. A nature-based beach and dune system has been proposed for the fronts of both Bolivar Peninsula and West Galveston Island. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the revised proposed plan.

11. Citizens prefer a dune system rather than a floodwall.

Since the release of the 2018 report, and in response to numerous concerns raised about the floodwall, we revised the proposed plan, dropping the floodwall and moved toward a nature-based solution. The 2020 plan now proposes beaches and dunes on the front of the barrier islands. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the revised plan.

12. The floodwall would not adequately protect the island and would cause more damage during storm surge events.

The proposed ring barrier system at Galveston is comprised of multiple lines of defense from storm surge. Each proposed structure will work together to provide the most flood protection possible. During Hurricane Ike, the most severe flooding came from the bayside. In order to protect this area, a ring barrier is suggested. The current proposal envisions a system of flood walls, highway and railroad gates, and a 2,400-foot crossing of Offatts Bayou with surge gates for navigation and environmental flow. The proposed ring barrier would encompass the Harborview Drive, or "Fish Village," neighborhood on the far east end of Galveston, consisting of a two-foot flood wall on top of the existing piers adjacent to the Strand Historical District on the north side of the island, continue west on Harborside Drive, wrap around Offatts Bayou to 103rd Street, and connect to high ground at the west end of the Seawall. The proposed ring barrier alignment extends to the west end of the Seawall to reduce risk to critical infrastructure (e.g. Scholes International Airport) and to avoid separating communities as much as possible. Near the west end of the seawall the ring barrier would tie into a gulf-side 19-mile beach and dune system that would extend west to a tie-in point at the San Luis Pass Bridge.

Because Galveston Island currently operates on a gravity drainage system, the plan would add a forced drainage system consisting of approximately six new pump stations to move water off the island. The pump stations would address storm surge flooding as well as rainfall related flooding.

13. **The floodwall does not account for rainfall events like Harvey.**
    The purpose of this study is to address coastal storm surge reduction and not precipitation events, however when possible and not increasing costs, features will be designed to provide surge and runoff improvements. The study has been authorized to identify plan for coastal storm surge reduction measure (CSRM). The proposed ring barrier system would include series of drainage outlet structures to allow water exchange and hydrologic connectivity. This hydrologic connectivity would be maintained to the extent practicable through water control structures, except during closure for hurricanes or tropical storms. When these gates are closed, the pump stations will need to operate to remove water due to rainfall and/or wave overtopping from within the ring barrier system. While the pumps are initially designed to handle 25-year rainfall with surge tail water boundary conditions of 1% ACE, the compound interaction of rainfall and surge has not been fully explored in this phase of the study. The final design of the systems including Pump Station capacity, interior storage and drainage features will be based on the latest information to address the authorized risk. Corps' projects cannot cause an increase in damage to one area without mitigation measures in order to reduce damage to a different area.

14. **The floodwall will reduce natural habitat for wildlife (in particular, birds); the floodwall will negatively affect important fishery/recreational species.**
    The current plan no longer promotes the use of a floodwall, but rather engineered dunes. It is worth noting that the project will result in an overall increase in bird rookeries, as well as the marshes and wetlands the birds inhabit. The same goes for fishery and recreational species. Any impacts to these species will be mitigated and are described in Chapters 4 and 5 and in the Ecological Modeling Appendix.

15. **The floodwall will cut through important wildlife sanctuaries, birding habitat, and T&E habitat.**
    Since the release of the 2018 report, and in response to numerous concerns raised about the floodwall, we revised the plan, dropping the floodwall and moved toward a nature-based solution. The 2020 plan now proposes beaches and dunes on the front of the barrier islands. This new solution avoids and minimizes impacts to fish and wildlife habitat on the barrier islands. For the remaining impacts, a mitigation plan has been developed to offset these losses. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the revised plan, and Appendix C-1 to review the Mitigation Plan.

16. **Impacts to the environment have not been adequately analyzed; the public needs to see an accurate inventory of environmental impacts.**
    Since the 2018 draft release, the PDT has worked to supplement and improve the analyses performed to quantify the environmental impacts of the proposed plan. The additional analyses include updates to the Advanced Hydraulic (AdH) modeling, particle transport modeling for the gated system at Bolivar Roads, and more detailed

impact analysis for direct and indirect impacts using Habitat Evaluation Procedures (HEP). Refer to Appendix L (Ecological Modeling) of the EIS for more details.

17. **The floodwall will impact property values and property taxes, how will the government take this into consideration? Will the public be compensated?**
The revised proposed plan no longer includes a levee/floodwall on the north side of Highway 87 or on the north side of FM 3005. A nature-based beach and dune system has been proposed for the fronts of both Bolivar Peninsula and West Galveston Island.

18. **Will there be a buyout of homes that will not be protected by the floodwall?**
The revised proposed plan was updated, modified, and improved by identifying non-structural measures in areas that would experience frequent residual damages (even with the proposed system in place).

19. **The decrease in property values/people losing their homes will disrupt the local tax base due to loss of tax income from these properties.**
The revised proposed plan no longer includes a levee/floodwall on the north side of Highway 87 or on the north side of FM 3005. A nature-based beach and dune system has been proposed for the fronts of both Bolivar Peninsula and West Galveston Island. However, the effects of this project on tax rates are outside of the purview of this study. Funding mechanisms have yet to be identified, but there are several different funding options being explored at the local, regional, state, and federal levels.

20. **The Pointe West community will be destroyed/devastated/disrupted.**

Since the release of the 2018 report, and in response to numerous concerns raised about the floodwall, we revised the proposed plan. In this area, the floodwall has been dropped, and the revised proposed plan now includes beaches and dunes on the front of the community.

7.1.2.2.5 Nonstructural

1. **What about using wetlands and sand dunes to protect the coastline instead of walls and levees?**
The floodwall on Bolivar and West Galveston has been dropped in response to numerous concerns raised during the first public comment period. The proposed plan has been updated, modified, and improved by identifying non-structural measures in areas that would experience frequent residual damages (even with the proposed system in place). In addition, more than 6,600 acres of ecosystem restoration has been included in the proposed plan to enhance coastal resilience.

2. **What about using buyouts as an option to reduce damages from storms?**

Buyouts are an option to reduce coastal storm risk and are a subcomponent of "Non-structural" approaches considered in the planning process. A plan comprised of buyouts only was found to be cost-prohibitive and non-responsive to many of the project goals and objectives for this region.

It is often considered to address residual risk with a structural solution in place, or to address those structures that are not included in a structural plan. Several areas are evaluated for elevation or buyouts in the second draft of the plan, once the structural features were identified and the areas with remaining flood risk were identified.

7.1.2.2.6 Clear Creek Surge Barrier

1. **Concerned that flood gates in Clear Lake will increase flooding, especially in the event of a Harvey-like storm.**
   Numerous comments regarding the proposed Clear Lake Barrier system warranted us to supplement the details provided on the designs for the structures at this location. The CSRM feature along Clear Lake consists of a gated closure structure, associated barrier walls, and a pump station to address the residual risk that persists for the Clear Lake area as a result of residual wind driven storm surges, due to the large fetch of Galveston bay. This measure is not a response to flooding induced by the barrier or other features of the draft proposal. The bay is large enough to generate secondary waves and elevated surge even though the Bolivar gate remains closed. This increased water surface elevations near Clear Lake area may result from wind and fetch within the bay under extreme conditions, even as the barrier significantly reduces the storm surge entering the bay. The design includes a 75' sector gate across the channel and a pump station with a design capacity of 20,000 cubic feet per second (cfs). While pumps are designed to handle 25-year rainfall with surge tail water boundary conditions of 1% ACE, the compound interaction of rainfall and surge have not fully explored in this phase of the study.

7.1.2.2.7 ER Measures

1. **ER measures should be the focus of the plan since they are cheaper, easier, and faster to construct with faster benefits.**
   We have provided additional details in Chapter 2 of the 2020 Main Report describing the benefits we gain from combining both coastal storm risk management features and ecosystem restoration solutions to comprehensively improve and enhance coastal resilience. While the majority of the ER measures are considered "actionable" based on the NEPA analysis, and therefore may not require additional environmental review to be constructed, many of the benefits projected by the ER measures could be realized as soon as possible.

2. **"Would like to see the expanded use of oyster reef creation/ restoration, beach/ dune nourishment, and where appropriate to expand use of wetland creation rather than the proposed ER measures."**

   We supplemented the information available on the screening and development of the ecosystem measures proposed in the 2020 draft EIS. Screening criteria including addressing the potential effects of sea level change, geomorphological impacts, etc. were used to select potential sites. For more details, refer to Appendix A of the 2020 Main Report for more details regarding the plan formulation process. The ER measures were formulated with input from subject matter experts from the resource agencies to maximize the site-specific ecological restoration that would increase diversity and restore ecological function. "

7.1.2.2.8 SSPEED Center

1. **The Rice University SSPEED Center plan is cheaper and faster to build, why has this not been accepted?**

   The Study Team compared the SSPEED Center's Bay Park Plan to the Alternatives carried forward for detailed analysis (Alternatives A and D2) in this EIS. The Bay Park Plan was screened out for several reasons: First, the resource agencies pointed out that the Bay Park Plan would have numerous environmental impacts, including direct impacts to many oyster reefs and a large area of open bay bottom habitat. In the Galveston Bay system, oyster reef is considered a highly productive habitat that supports a broad diversity of species, the permanent loss of so much reef would be considered extremely detrimental. Second, the team determined that placing a barrier structure in Galveston Bay, without a gulf front system in place, would induced flood risks to Galveston Island and Bolivar Peninsula. Third, the Bay Park Plan and Alternative D2 would both have a higher level of residual risk due to the proximity of the barriers to highly developed areas. The analysis performed in this study demonstrated that the gulf front alignment (Alternative A) provides a first line of defense that is key to a multiple lines of defense strategy. If SSPEED is able to obtain the environmental clearances and project funding to implement as a non-Federal action, we do believe it could be complementary to the recommended plan (Alternative A).

7.1.2.2.9 TAMUG Plan

1. **Citizens prefer the plan for fortified dunes as proposed by Dr. Bill Merrell**

   Since the release of the 2018 report, and in response to numerous concerns raised about the floodwall, we revised our proposed plan, dropping the floodwall and moved toward a nature-based solution. The 2020 draft plan now proposes beaches and dunes on the front of the barrier islands. The design of the dune has been enhanced to address coastal storm risk reduction through the use of natural components (sand, vegetation, etc). We supplemented the information by including an analysis of fortified dunes. These fortifications were not included in the current (2020) proposed plan due to potential environmental impacts. Additional analysis will be undertaken in the next phase of the project to enhance these designs. Refer to Appendix E of the Main Report to review the designs for the beach and dune systems in the revised 2020 proposed plan.

2. Need a levee at San Luis Pass as recommended by the TAMUG Plan

The anticipated risk reduction benefits for protective features at San Luis Pass do not outweigh the potential negative environmental impacts of closing off the last remaining natural pass along the Texas coast. Many of the structures and assets that would be protected as a result of the closure are already elevated above surge heights or are at a ground elevation that limits surge impact. There is also limited surge risk when factoring in the full probability of potential storm directions. The pass and the adjoining West Bay are very shallow and constitute only to 3-to-5% of the water exchange between West Bay and the larger area of Galveston Bay. The shallow ridge across West Bay provides a natural barrier limiting circulation between West Bay and the larger water body of the Galveston Bay. This condition minimizes the risk of surge being transmitted to the large area of Galveston Bay where there is a greater number of structures and assets at risk from storm surge.

Our modeling suggests that San Luis Pass left open, does allow more storm surge water to enter the overall bay system; however, the majority of that water is diffused along Chocolate and West Bays before it reaches significant levels into Galveston Bay. Forerunner water levels can also enter into the bay system, but again, the overall water level in Galveston Bay is not significantly increased. Our modeling showed that even with the San Luis Pass closed off, water levels in the bay could still cause flooding of Galveston Island. Thus, the proposed ring barrier around Galveston Island would still be needed to provide protection and as such, San Luis Pass closure should not be used as an alternative to the proposed Ring Barrier system around Galveston.

3. Citizens state the need for a gate at San Luis Pass.

To address this concern, additional analysis has been included in the 2020 Main Report's Engineering Appendix (Appendix D) to evaluate a closure at San Luis Pass. Based on these analyses, it has been determined that the anticipated risk reduction benefits for protective features at San Luis Pass do not outweigh the potential negative environmental impacts of closing off the last remaining natural pass along the Texas coast. Many of the structures and assets that would be protected as a result of the closure are already elevated above surge heights or are at a ground elevation that limits surge impact. There is also limited surge risk when factoring in the full probability of potential storm directions. The pass and the adjoining West Bay are very shallow and constitute only to 3-to-5% of the water exchange between West Bay and the larger area of Galveston Bay. The shallow ridge across West Bay provides a natural barrier limiting circulation between West Bay and the larger water body of the Galveston Bay. This condition minimizes the risk of surge being transmitted to the large area of Galveston Bay where there is a greater number of structures and assets at risk from storm surge.

Our modeling suggests that San Luis Pass left open, does allow more storm surge water to enter the overall bay system, however the majority of that water is diffused along Chocolate and West Bays before it reaches significant levels into Galveston Bay. Forerunner water levels can also enter into the bay system, but again, the overall water level in Galveston Bay is not significantly increased. Our modeling showed that even with the San Luis Pass closed off, water levels in the bay could still cause flooding of Galveston Island. Thus, the proposed ring barrier around Galveston Island would still be needed to provide protection and as such, San Luis Pass closure should not be used as an alternative to the proposed Ring Barrier system around Galveston.

7.1.2.2.10 General Opposition

1. **The walls and levees will destroy ocean views for homeowners and tourists.**
Since the release of the 2018 report, and in response to numerous concerns raised about the floodwall, the measures have been revised to move toward a nature-based solution. The 2020 plan now proposes alternatives such as beaches and dunes instead of floodwalls on the barrier islands. The study team acknowledges that the aesthetics of some of the features could degrade or impede the view from certain areas. We are working to minimize these effects, such as through changes in designs, consideration of more natural features, or best management practices for maintaining the scenic quality, as much as possible while also achieving the necessary performance of the features. Chapter 4 of the 2020 EIS describes the potential impacts to visual quality as a result of implementing the features.

2. **Not enough time has been given to comment on the project.**
The standard public comment period for an EIS is 45 calendar days. Prior to release of the report, and in response to written requests in advance of the report's release, the comment period was first extended an additional 30 days to a total of 75 days. Once the report was released, additional requests were made, and the period was extended 30 additional days – 105 days total.

3. **The cost is too high and will waste taxpayer money.**
We have supplemented the economic analysis to better reflect changes to the project which included some cost reductions attributed to changes in the revised proposed plan presented in the 2020 Main Report. Since this comment does not directly address a NEPA-related topic, further agency response is not required at this time.

4. **Why doesn't the petrochemical plants pay to protect themselves?**
Information on the study's authority has been supplemented in the plan formulation section of the 2020 Main Report (see Chapter 2). Note that the plan was authorized to provide coastal storm risk reduction on a regional scale to assure that the

communities in and around all industries in the region are afforded coastal surge protection.

5. **Not enough research has been conducted and the project is being rushed.**
USACE planning studies are conducted with a finite schedule for completion. Due to the complexity of this study, additional time was provided to complete the analysis and recommend a plan. Public input is sought early in the evaluation process to ensure that final design and refinements are not made to a plan until public input is received. The publication of the plan while some features were scoped to a conceptual level was consistent with this USACE process, which may result in a sense that the project was being rushed. Since the release of the 2018 report, the study team has continued to conduct additional research to assess potential impacts that have driven design changes. In the next phase of the project, we will continue to conduct research to support designs and decision-making.

6. **The project will cause an increase in damage to one area in order to reduce damage to a different area.**
Policy and guidance mandates that induced risks must be mitigated. Supplemental analysis conducted after the release of the 2018 report has informed the realignment of the features, reducing the impacts to more vulnerable communities. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the revised proposed plan.

7. **The project will cause beach erosion and sedimentation problems in the bays.**
Supplemental analysis conducted after the release of the 2018 report has informed the modification of the proposed plan. Potential erosion concerns have been addressed by incorporating the placement of sand dredged from offshore sources (or from nearby navigation channels) on degraded gulf shorelines to create or restore dune and beach habitat in the revised (2020) plan. Beach and dune systems would be maintained by replacing sand at regular intervals after storm events. These systems would provide habitat to many plant and animal species and protect habitat, homes, and infrastructure that may be washed away due to erosion and severe storms.

8. **Project will cause permanent damage to the local ecosystem and wildlife.**
Unavoidable impacts are likely, however we are mitigating for these impacts. The impacts to fish and wildlife are described in the revised 2020 draft Environmental Impact Statement (EIS). The proposed mitigation efforts are documented in our 2020 Mitigation Plan. As we continue into the next phase of the project, efforts will be taken to further avoid and minimize the impacts. In addition, the project includes restoration of ecosystems that will restore habitats contributing to the viability and resilience of the system.

7.1.2.2.11 Tribal and Cultural

1. **USFWS recommends inviting potentially affected tribes and the Bureau of Indian Affairs as part of section 7 (ESA) consultation. USFWS cites Secretarial Order 3206.**
   Consultation with affected tribes is ongoing, and their concerns are being addressed. Refer to Appendix H of the 2020 draft EIS for more details.

2. **Citizen wishes to make USACE aware of Caplen Mound, where archaeologists previously found human remains.**
   The USACE documented Caplen Mound as a potential site that could be impacted by project features. During future phases of the study, known cultural resources (including cemetaries and burial sites) will continue to be evaluated, and areas within the project scope not previously surveyed will be surveyed prior to construction per the requirements of our Programmatic Agreement (PA) with the State Historic Preservation Officer (SHPO) to confirm no additional unknown cultural resources are present. For sites with cultural resoures, intensive cultural resource surveys will be completed to delineate the boundaries of the site in comparison to the location of project features and the potential for direct or indirect impact. Modification of the project design will be considered first to avoid the site altogether to the greatest extent practicable. If the site cannot be avoided, USACE will coordinate with the TX SHPO and tribes to determine the method of mitigation.

3. **The identity of the tribal nations USACE coordinated with could not be found. Please identify in the Final EIS the tribal nations consulted.**
   Coordination efforts with tribes are documented in Appendix H of the 2020 draft EIS.

4. **Multiple State Antiquities Landmarks are included in the project study area. Additional maps indicating where work is projected are required.**
   Compliance with the National Historic Preservation Act is documented in Chapter 6 of the 2020 draft EIS. We took every opportunity to avoid and minimize impacts to these landmarks with our current proposed designs. Consideration was given to reducing coastal storm risk damages that will preserve many areas of historical relevance within the system. Specific impacts will be minimized and avoided through modifications to alignments as designs mature in the next phase of the project. Redundancies have been included in the pumping systems, and the drainage system has been designed to match the existing gravity drainage system operating during non-tropical events. Known cultural resources will continue to be evaluated, and areas within the project scope not previously surveyed will be surveyed prior to construction per the requirements of our Programmatic Agreement (PA) with the State Historic Preservation Officer (SHPO).

7.1.2.2.12 Policy Concerns

1. **What professional non-linked organization or body will review and conduct quality control for the study? An Independent External Peer Review (IEPR) process is required**

   In 2018, an IEPR was conducted, and a final report will be produced from that body to accompany the Final Report in 2021.

2. **Why were many organizations and conservation landowners not notified when the DIFR-EIS was released?**

   While stakeholders were not notified individually, the release and availability of the report was made public through NEPA-compliant posting in the Federal Register. Additionally, notifications were made through social media, local newspapers, and news releases. To address this concern for the 2020 release, we have increased our public outreach.

3. **Where can more detailed information about the study be found?**

   Please see our website for additional information: www.coastalstudy.texas.gov. If looking for detailed technical details of the proposed plan, they can be found in the associated technical appendices published with this 2020 draft report and EIS. Also refer to our project's StoryMaps for interactive maps detailing the plan.

4. **In regards to the many CBRA zones within the study area, how will these sections be funded since federal dollars are not permitted to be spent in these zones?**

   Coordination has been initiated with the USFWS and other appropriate authorities to determine the funding of features of the plan within CBRS units. The 2020 draft Report/EIS has been updated to reflect revisions to the project measures that occur within the CBRS units. Compliance documentation on these measures in relation to the law can be found in Appendix E of the DEIS. A final determination will be included in the final report.

5. **The TSP fails to adequately account for the loss of tax dollars for businesses**

   The revised 2020 plan has fewer residential and commercial acquisitions than those proposed in the 2018 version, which would reduce the potential for impacts to the tax base. Potential reductions to business incomes as a result of the draft proposal is too speculative to quantify.

6. **Description of potential project alternatives is not useful to fulfillment of the action agency's section 7 obligations.**

   The 2020 main report and EIS have improved upon the descriptions of the alternatives and completed a more thorough impact assessment. Compliance documents for various environmental laws can be found as technical appendices to the EIS.

7. **How do you address the Texas Open Beaches Law if you put the barrier on the beach?**
   The revised Proposed Draft Plan includes a beach & dune system in lieu of a barrier. Beach access will comply with the Texas Open Beaches Act.

8. **Violation of infrastructure criteria with the Problem of Highway 87 being the only TxDOT designated evacuation route**
   The revised proposed plan no longer includes a levee/floodwall on the north side of Highway 87 or on the north side of FM 3005. A nature-based beach and dune system has been proposed for the fronts of both Bolivar Peninsula and West Galveston Island. The evacuation routes on both barrier islands are not being impacted by the proposed plan.

9. **The DIFR-EIS does not quantify particulate matter emission for the construction of the TSP.**
   Quantification of air emission impacts have been completed for the revised (2020) plan and are available in Appendix G of the EIS.

10. **Open water impacts were not addressed in the mitigation calculations due to the majority of these being caused by dredging impacts.**
    Impacts from dredging to clay or sand substrate is mostly considered temporary in nature because the existing open water habitat is being converted to slightly deeper open water habitat. The 2020 DEIS has been updated to include an additional assessment of adverse impacts to open water, specifically, those where the open water habitat is lost due to the construction of a structure (e.g. the surge barrier islands). The information on the impact assessment and the mitigation can be found in the Chapter 4 of the EIS has a specific section that addresses temporary impacts attributed to dredging, the Ecological Modeling Appendix (Appendix I of the dEIS) quantifies impacts to open bay bottom, and the Mitigation Plan (Appendix C-1 of the Main Report) addresses compensatory mitigation for unavoidable impacts to open bay bottom.

11. **The TSP does not meet the definition of the LEDPA as it would cause much greater direct, indirect, and cumulative environmental impacts than the Bay Rim Alternative.**
    Additional details on the plan formulation procedures has been included in the revised 2020 Main Report and draft EIS. This effort led to the selection of the recommended plan based on costs, benefits and impacts following the USACE Civil Works planning process. Documentation of compliance with the Clean Water Act is presented in Appendix D of the draft EIS.

12. Direct and Indirect Environmental Impacts Not Fully Assessed

The impacts have been more thoroughly assessed in the revised draft EIS of 2020. Additional impact assessments will be necessary in the next phase of the study for some features as designs are refined. Those additional environmental reviews will be conducted in compliance with NEPA requirements and will include additional resource agency consultation and public involvement.

13. There has not been adequate analysis of the impacts on various Superfund or hazardous waste disposal locations.

The information on HTRW in the 2020 draft EIS has been updated. A Regulatory Database Report has been procured for the measures which document each of the areas of concern. A summary of these reports has been provided in Chapters 4 and 5 and Appendix L of the 2020 draft EIS.

14. Have environmental justice communities, residents, advocates, and organizations that work on environmental justice issues been contacted?

While stakeholders were not notified individually, the release and availability of the report was made public through NEPA compliant posting in the Federal Register. Additionally, notifications were made through social media, local newspapers, and news releases. To address this concern for the 2020 release, we have increased our public outreach. A primary study goal for the Upper Texas Coast is to provide coastal storm risk reduction for the entire region. Refer to Chapter 4 of the 2020 dEIS for a discussion of environmental justice.

15. The requirements of NEPA have not been met, in that a range of reasonable alternatives have not been considered, evaluated or offered to the public for comment.

The revised 2020 Main Report and EIS have improved the description of the plan formulation process to better discuss measures and alternatives formulated in this study. The Chapter 2 of the 2020 DEIS and the plan formulation appendix (Appendix B of the 2020 Main Report) describes the measures and alternatives considered, as well as the screening process used to select the plans carried forward for more detailed analysis. Project measures were developed using a wide range of input e.g., planning charrettes, public scoping meetings, public engagement meetings, resource agency meetings, and subject matter expertise within the confines of the scope of the study.

16. "It's not appropriate to comment on a project that's only 10% complete. Would it be possible to request a supplemental draft EIS."

In light of the response to public comments stemming from the release of the 2018 report/EIS, a decision was made to revise the plans and produce a second draft report and EIS. The 2020 report now includes additional details regarding the revised proposed plan as well as additional analyses. The approach to level of detail, data collection, and models is based on what is necessary to support decision to be made. The level of detail required to make planning decisions will grow progressively more detailed over the course of the study, as the study team moves from an array of alternatives to a single recommended alternative. Final feasibility studies will have an adequate level of detail required by law and regulation for a Chief's Report and recommendation to Congress for an authorized project but would not have sufficient detail to make the project ready for construction. The expense and time of collecting more data, developing a new model, or analyzing multiple alternatives to a high level of detail must be justified, rather than assumed.

7.1.2.2.13 South Padre Island

1. **The study should include more, if not all of Cameron County's beaches (state only 2 miles are being considered) as Cameron county is currently investing money into erosion control, beach restoration, etc**.

   To be included in the Recommended Plan, a measure must be shown to be economically justified by comparing the benefits of the measure with the costs. For the South Padre Island portion, benefits are measured as a reduction of expected annual damages and recreation benefits to users of the Padre Island beach.

   The economic analysis confirms that beach nourishment is cost effective based upon construction costs, benefits, and real estate costs based upon state law and policy considerations only for the portions where the estimated reduction in storm damages is larger than the cost of nourishment. In South Padre Island, the central portion is the area with the more vulnerable beach profile and warrants additional sediment.

   Following publication of the 2018 Draft Feasibility Report and EIS, the team continued to refine the data and run the model that estimates the benefits of the proposed action, and was able to include one more "reach" within the recommended plan.

7.1.2.2.14 Additional Measures

1. **USACE needs to use more public outreach to make more of the public aware of the project, so that they can comment.**

   While stakeholders were not notified individually, the release and availability of the report was made public through NEPA compliant posting in the Federal Register. Additionally, notifications were made through social media, local newspapers, and news releases. To address this concern for the 2020 release, we have increased our public outreach.

2. **Citizens state that they prefer natural barriers such as dunes in place of the floodwalls and surge barriers**

   Since the release of the 2018 report, and in response to comments received, we re-evaluated the floodwalls on Bolivar Peninsula and West Galveston. The revised proposed plan has dropped the floodwall and moved toward a nature-based solution – beaches and dunes on the front of the barrier islands. See Chapter 3 of the 2020 Main Report for more details on the revised alignment of the revised plan.

7.1.2.3 Revisions to the Recommended Plan in Response to Public Comment

Based on public and resource agency comments, and supported by continued engineering design and optimization efforts, multiple changes to the TSP were considered and evaluated to enhance the performance of the ER and CSRM measures and to further minimize environmental and social impacts. The following sections summarize some of the major changes to the TSP which occurred after publication of the 2018 Draft Integrated Feasibility Report and EIS in response to public concern.

Levee along West Galveston and Bolivar Levee

The levee proposed along West Galveston and Bolivar peninsula provided an engineered barrier to prevent storm surge from entering the Galveston Bay system over land. Public comment indicated that the roadway access issues were unfavorable, the real estate impacts were disruptive, and the views would be unacceptably changed. Many expressed dissatisfaction that the impacts would be borne by the residents and businesses on Galveston Island and Bolivar Peninsula, without reducing their storm surge risk. Many commenters also expressed that they are aware of the risks of development on a barrier island or peninsula and favored the risk of storm damage over the levee. In response, the study team found that the levee was unimplementable and it was removed from the recommendation.

Beach and Dune Restoration (G5)

The beach and dune restoration feature proposed along the Gulf on West Galveston and Bolivar Peninsula was justified for inclusion within the ER purpose. It restored the coastal habitat that had lost sediment to years of coastal forces on the Gulf side and hardened features, yards, structures and roadways. Once the levee was found to be unacceptable, the beach and dune restoration was refined to include taller dunes and wider berm to increase the risk reduction it provides. The beach feature does not provide a comparable scale of risk reduction as the levee, but is placed gulfward of all structures, and creates fewer community impacts. The larger beach feature also sustains the barrier features and supports the function of the Bolivar Roads Gate System.

Beach Nourishment – South Padre Island

Several refinements to the BeachFX model were made following public, agency and technical review. Technical comments requested further comparison of performance across berm widths, renourishment cycles, and all rates of sea level change. Public comment expressed concern that reach 5 was as erosive as reaches 3 and 4. The BeachFX model was reviewed to confirm the planform rates accurately compare the with- and without- project condition, and to confirm the appropriate scale and nourishment cycles were identified.

The model results indicated that erosion occurs over a longer extent, including Reach 5. The comparison of with- and without- project condition confirmed that the NED scale of the beach nourishment is 2.9 miles from Reach 3 through 5, with the same dune and berm dimensions as before, but on a 10-year periodic renourishment cycle for the authorized project life of 50 years. Although beach-fill typically includes construction of an initial profile and periodic renourishment, the recent practice of beneficial use of dredge material from the Brazos Island Harbor has offset erosion and established a fairly healthy starting condition. No initial construction is required, and nourishment is not proposed until the beach profile erodes in approximately year 10, to reestablish the beach width.

The economic analysis confirms that beach nourishment is cost effective when considering construction costs and benefits, and recreation benefits, but may be infeasible due to the real estate costs to acquire easements for privately owned portions of the dune and beach. The relatively modest volume of sediment required to restore the beach profile may offset erosion if placed on the beach or the near shore. This is notable because the real estate costs may be reduced or eliminated to achieve an NED scale placement on the beach or the near shore waters.

Bolivar Roads Gate System

The Bolivar Roads Gate System was refined to reduce the constriction of the flow in the channel. The refinement was undertaken in response to potential environmental impacts that were identified during the screening process. Operators of storm surge structures offered technical recommendations for design refinements to maintain function while reducing environmental impacts. Other refinement includes the replacement of a single larger gate with two smaller gates. Public comments addressing the storm surge gate are included in in the attached EIS.

Galveston Ring Barrier System

The Galveston Ring Barrier System was realigned to include additional areas and to avoid other impacts. Residents of Lindale Park opposed the partial enclosure of the neighborhood within the barrier, and the alignment that overlaid existing homes. Other alignment changes were made to reduce waterfront business and infrastructure impacts, and to reduce environmental impacts from crossing wetlands. Other comments opposed the disruption of traffic and access, the potential to exacerbate drainage problems, and the potential environmental impacts.

Galveston Seawall Improvements

The Seawall height increase was proposed as a future adaptation to address sea level change. Following publication of the initial draft report, the height increase was proposed for the north side of Seawall Boulevard to avoid view impacts and to avoid impacting the existing Seawall stability.

Ecosystem Restoration

The ER features initially included outyear nourishment for adjacent areas that would be subject to sea level change over the study period. Policy review clarified that those actions would not be considered continuing construction and would not be a cost shared action in the Recommended Plan. Those nourishments, which were reflected in the original draft as Scale 2 of several Alternatives, are now recommended adaptations, instead of plan components.

San Luis Pass

Public comments questioned the effectiveness of the structures at stopping storm surge without a closure at San Luis Pass. Engineering models were revisited to confirm the contribution of a closure at San Luis Pass. The study team conferred with the SSPEED Center to compare engineering models and confirm the areas most likely to see increased water surface elevations with surge entering through San Luis Pass. The evaluation confirmed that the relatively low development areas to the east of Galveston Bay would not justify the environmental impacts of constructing a barrier in the pass.

7.1.2.4 Distribution List

A total of 890 Federal, State, and local governments, landowners in or near the project area, special interest organizations, and interested individuals who requested to be on the mailing list received a copy of the NOA for the Draft Integrated Feasibility Report/Environmental Impact Statement. Appendix M contains a complete distribution list.

The document was also available for review on the USACE, Galveston District website (www.swg.usace.army.mil/), at local libraries and compact disc copies of the report were made available to interested individuals upon request.

News releases, paid ads, Facebook posts, and other sources of publication were utilized to notify the public of the availability of the report for review and comment.

7.2 INTERAGENCY COORDINATION

An interagency team of Federal, state, and local agencies and Tribal Nations met monthly to discuss study progress and formulation issues related to the Coastal Texas Study regarding environmental issues. Team members shared updates on pending decisions and sought comment and approval of methods to assess performance and impacts of features proposed to reduce risk and restore habitat and natural coastal processes.

Interagency workshops were held throughout the planning process to consider restoration measure performance metrics, to screen and refine restoration alternatives, and to develop habitat modeling assumptions.

All Federal and state agencies were invited to participate as a Cooperating Agency pursuant to Council on Environmental Quality Regulations for Implementing NEPA (40 CFR §1501.6 and §1508.5), and tribes under Executive Order 13175, NEPA, and Section 106 of the National Historic Preservation Act. The purpose of this request was to formalize, via designation as a Cooperating Agency, the continuing coordination and active participation by resource agencies in the Coastal Texas Study. Entities that agreed to serve as a Cooperating Agency included the EPA, NOAA/NMFS, and Bureau of Ocean and Energy Management.

Individual coordination meetings with resources agencies were held in addition to the monthly interagency team meetings. Informal consultation with NMFS regarding essential fish habitat and NMFS fatal flaw review of the Draft Feasibility Report and EIS sections occurred in June 2018 and September 2018. An in-person meeting with representatives from USFWS was held in October 2017, where USACE and GLO staff presented information including the Coastal Barrier Resources Act, critical habitat, beach nourishment, overall project impacts, mitigation needs, ESA concerns for sea turtles and manatees, and Biological Assessment delivery and Biological Opinion requirements. Additionally, multiple phone conversations were held with USFWS staff to discuss the Planning Aid Letter, Biological Assessment, and estuarine modeling. Further, multiple phone conversations were held with NOAA representatives from April 2018 through August 2018 to discuss estuarine modeling and marine mammal mitigation options, consultation timeline and assessment needs, and Incidental Take Authorizations and Marine Mammal Protection Act permitting. Further coordination will continue through the future phases of the project.

Tribal consultation efforts have been ongoing. Coordination efforts are documented in Appendix H.

7.3 COORDINATION WITH OTHERS

Coordination with stakeholders also included attendance at regular interagency meetings and over 60 formal presentations of study scope and status throughout the study process. Academic and governmental agencies have been advancing complementary or alternative studies to reduce coastal storm risk or habitat loss within the study area. Coordination and data sharing were emphasized early in the study to ensure transparency in the evaluation and screening decisions of the Coastal Texas Study. To expand awareness of the scope and objectives of the study and to review preliminary planning steps, the study team convened interested NGOs for an overview of the planning process, the measures under consideration, and to discuss concerns in January 2018.

As a result of the feedback received during the public review and comment period following the release of the DIFR-EIS in fall 2018, the GLO approached elected officials in four coastal Texas communities to request assistance in establishing the Coastal Texas Study Community Work Groups (CWG). Appointed by elected officials from each community, CWG members are regularly invited to meet with the GLO for up-to-date study information and topic-specific presentations. During presentations, CWG members are encouraged to ask questions, request clarity, and raise issues of concern that may impact their communities.

In addition, three additional Public Open Houses were held in February 2020 to update stakeholders on the progress of the study (**Table 7-9**).

Table 7-6 2020 Public Open House Meetings

Date	Location	Time
8-FEB-2020	High Island High School 2113 6th Street High Island, Texas 77623	1 pm to 3pm
12-FEB-2020	Galveston Island Convention Center 5600 Seawall Boulevard Galveston, Texas 77551	6pm to 8pm
13-FEB-2020	Bay Area Community Center 5002 E NASA Parkway Seabrook, Texas 77586	6pm to 8pm

During the meetings a total of 40 comments were received. The main concerns and suggestions are listed below:

Key concerns

- Cost of construction and maintenance for proposed features.
- Disruption of resident's daily activities.
- Beach access during construction activities.
- Changes to FEMA flood zones and insurance rates as a result of the proposed dune system on Bolivar Peninsula
- Possible replacement of the code-approved walkover if removed during construction.
- Filling in the data gaps if there is an absence of LIDAR-Bathymetric data for Bolivar Peninsula.
- Exclusion of rainfall analysis in the Study.
- Removal and compensation of private property impacted by proposed features.
- Lack of aerial impacts analysis, as opposed to aquatic impacts.

- Lack of proposed protection for La Porte, Shore Acres, Seabrook and San Leon.
- Environmental impacts to Galveston Bay.

Suggestions:

- Consider offshore breakwater barriers to minimize erosion.
- Prioritize surge gates followed by dune and beach restoration.
- Propose a ring barrier for Bayou Vista, Tiki Island, Omega Bay, and the Gulf Intracoastal Waterway.
- Consider drainage improvements for subdivisions.
- Increase Study Team engagement with groups working in the Galveston Bay area.
- Encourage smart development (coastal defenses) for Texas coastal subdivisions.
- Conduct further assessment of water flow from bayous feeding into Clear Lake.
- Place signs to help keep people and vehicles off dunes to facilitate vegetation growth.
- Update the Coastal Texas Study website with the information available at the public open houses.

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8.0 LIST OF PREPARERS

Name/Title	Experience	EIS Area of Responsibility
U.S. Army Corps of Engineers, Galveston District		
Sharon Tirpak, Deputy Chief of Project Management Branch	38 years, Programs and Project Management	Program Manager, DQC Level 2
Kelly Burks-Copes, PhD, Project Manager	27 years, Project Management, Landscape Ecology, Ecosystem Response Modeling	Senior Project Manager, HEP/HEAT, DQC Level 2
Eddie Irigoyen, Civil Engineer	14 years, Civil Engineering, Project Management	Project Manager
Tricia Campbell, CE, Operations Project Manager	13 years, Operations Management, Project Engineer	Dredging Placement, Beneficial Use Management, DQC Level 2
Robert Thomas, Chief, Engineering and Construction Division	19 years, Coastal Engineering, Levee Safety	Coastal Engineering and Design Oversight and Review
Joseph King, RA, Chief, Engineering Branch	23 years, Architecture	Coastal Engineering and Design Oversight and Review, DQC Level 2
Lori Thomas, PE, Chief, General Engineering Section	28 years, Civil and Structural Engineering	Coastal Engineering and Design Oversight and Review
Ismael J. De la Paz-Bonilla, Civil/ Geotechnical Engineer	4 years, Civil and Structural Engineering	Geotechnical Engineering Oversight and Review, DQC Level 2
Corraggio Maglio, PE, CFM, Chief, Hydrology and Hydraulics Branch	16 years, Hydrology and Hydraulics, Coastal Engineering	Hydrology and Hydraulics Engineering Oversight and Review, DQC Level 2
Himangshu S. Das, PhD, Civil Engineer	23 years, Hydrology and Hydraulics, Coastal Engineering	Coastal Engineering Lead, Hydraulics and Hydrology
Mike Diaz, PE, Civil Engineer	37 years, Civil Engineering	Coastal Engineering and Design – CSRM
Paul Hamilton, PhD, Civil Engineer	5 years, Hydrology and Hydraulics, Coastal Engineering, Sediment Transport, Geomorphology	Coastal Engineering and Design – ER
Ratnam Tharmendira, PE, GE, Civil/ Geotechnical Engineer	19 years, Geotechnical Engineering	Lead Geotechnical Engineer – CSRM and ER
Islam Mohammed, PE, Civil Engineer	12 years, Numerical and In-situ Modeling, GIS Data Analysis, Flood Risk Management	Geotechnical Engineering Oversight and Review
Willie Joe Honza, PE, Chief, Professional Services Section	32 years, Civil Engineering	Cost Engineering Oversight and Review
Jackie Lockhart, PE, CCE, Cost Engineer	41 years, Cost Engineering	Lead Cost Engineer – CSRM

Name/Title	Experience	EIS Area of Responsibility
Adam Tallman, EIT, Cost Engineer	7 years, Cost Engineering	Lead Cost Engineer – ER
Dale Williams, Cost Engineer	8 years, Cost Engineering	Cost Engineering
Kristen Shivers, Biologist	16 years, Biology, GIS Analysis	GIS Analyst
Joshua Hutchinson, EI, Civil Engineer	10 years, Geotechnical Engineering	Coastal Engineering and Design – CSRM (Matagorda)
Matthew Duke, GISP, Chief of the Hydrographic Survey Section, Galveston District Datum Coordinator	14 years, GIS Analysis	GIS Analyst, Geospatial Datums DQC Level 1
Timothy Nelson, Chief, Real Estate Division	10 years, Real Estate Planning, Management and Property Disposal	Real Estate Analysis Oversight and Review
Brian Murphy, Chief, Support Branch	22 years, Real Estate Planning, Management and Property Disposal	Real Estate Analysis Oversight and Review, DQC Level 2
Kenny Pablo, Realty Specialist	10 years, Real Estate Planning, Management and Property Disposal	Lead Real Estate Analyst – CSRM
Nichole Schlund, Realty Specialist	7 years, Real Estate Planning, Management and Property Disposal	GIS Mapping and Real Estate analysis for the Gross Appraisals
Kelsey Ciarrocca, Cartographer	6 years, GIS Analysis	GIS Mapping and Real Estate analysis for the Gross Appraisals
U.S. Army Corps of Engineers, New Orleans District – Regional Planning and Environmental Divisions, South		
Travis Creel, USACE Certified Planner, National Water Resources; Regional Technical Specialist, Plan Formulator	17 years, Plan Formulation and Coastal Storm Risk Reduction	Lead Planner – CSRM and ER
Louise Williams, PhD, Plan Formulation Specialist	27 years, Economics, Program Management, Plan Formulation	Planning Oversight and Review, DQC Level 1
Mark Haab, Chief, Navigation Section	34 years, Navigation	Economics Oversight and Review – CSRM
Ben Logan, Senior Economist	11 years, Flood Risk Management and Ecosystem Restoration	Economics QA/QC – CSRM
Brian Maestri, Regional Economist	35 years, Economics – CSRM	Lead Economist – CSRM
Warren Cashen, Computer Scientist	17 years, GIS Analysis	GIS Analyst for Economics – CSRM
Brittanie Corley, Economist Department of the Army (DA) Intern	3 years, Economics	Economics – CSRM

Name/Title	Experience	EIS Area of Responsibility
U.S. Army Corps of Engineers, New Orleans District		
Charlie Brandstetter, PE, Civil Engineer	24 years, Structural Engineering	Coastal Structural Engineering and Designs – CSRM
Rob Dauenhauer, PE, Supervisory Structural Engineer	24 years, Structural Engineering	Coastal Structural Engineering and Design Oversight and Review – CSRM, DQC Level 2
Dustin Smith, Engineering Technician	12 years, Structural Engineering	Coastal Structural Engineering and Designs – CSRM
Kenny Riggs, Engineering Intern	4 years, Structural Engineering	Coastal Engineering Equipment Lists – CSRM
Ben Barcelona, Civil Engineer	4 years, Structural Engineering	Structural Engineering – Navigation Gate Design – CSRM
Jabeen Pasha, Electrical Engineer	22 years, Power Engineering	Electrical Engineering Lead – CSRM
Stefan Miller, Mechanical Engineer	19 years, Structural Engineering	Mechanical Designs – CSRM
U.S. Army Corps of Engineers, Regional Planning and Environmental Center, Southwest Division		
Brian Harper, Chief, Civil Works	31 years, Economics, Civil Works Planning	Planning Oversight and Review
Andrea Catanzaro, Chief, Planning Section	24 years, Project Management, NEPA Compliance, Biology, Regulatory	Project Manager Houston Ship Channel ECIP Feasibility Study
Carrie McCabe, Plan Formulator	24 years, Economics, Civil Works Planning	Lead Planner – ER
Norm Lewis, Economist	25 years, Regional Economics, Socioeconomic Analysis, Flood Risk Management, Ecosystem Restoration	Lead Economist – ER
Amanda McGuire, Chief, Environmental Branch	17 years, Environmental Compliance	Environmental Oversight and Review
Janelle Stokes, Archaeologist, NEPA and Cultural Resource Specialist	36 years, Planning, Environmental Impact Assessment and Impact Analysis	Lead Environmentalist (Retired)
Jennifer Morgan, Biologist, NEPA Specialist	13 years, Planning, Environmental Impact Assessment and Impact Analysis	Lead Environmentalist
Melinda Fisher, Biologist, Regional Technical Specialist	15 years, Environmental Compliance	Environmental Impacts and Environmental Compliance
Jeff Pinsky, Biologist, NEPA Specialist	13 years, Regulatory, Fisheries and Marine Biology	Environmental Impacts and Environmental Compliance

Name/Title	Experience	EIS Area of Responsibility
Danny Allen, Certified Wildlife Biologist	22 years, Habitat Assessment, Ecosystem Restoration, Ecological Modeling	Environmental Oversight and Review, DQC Level 2
John Campbell, Archaeologist	25 years, Archaeology	Cultural Resources Impacts
David Clark, Environmental Protection Specialist	8 years, NEPA, HTRW, CERCLA	HTRW Impacts Oversight and Review, DQC Level 2
U.S. Army Corps of Engineers, Engineer Research and Development Center		
Thomas C. Massey, PhD, Research Mathematician	18 years, Numerical Hydrodynamic Modeling, Large-Scale Storm Surge & Wave Modeling	Coastal Storm Modeling Lead (ADCIRC)
Jennifer McAlpin, Research Hydraulic Engineer	19 years, Multi-Dimensional Modeling, Sediment and Particle Transport	Coastal Storm Modeling (AdH)
Dylan Sanderson, Research Hydraulic Engineer	2 years, Probabilistic Life-Cycle Analyses	Coastal Modeling (Beach-FX)
Noberto Nadal, PhD, Research Hydraulic Engineer	41 years, Wave Modeling, Wave Measurements, Meteorology, Climate Assessment	Coastal Storm Modeling (Statistical Analyses)
Julie Rosatti, PhD, PE, Technical Director, Flood & Coastal Systems	38 years, Coastal Engineering	Coastal Engineering DQC Level 1
Mary Bryant, Research Hydraulic Engineer	8 years, Nearshore Waves Physics and Processes	Coastal Storm Modeling (ADCIR)
Yan Ding, PhD, Research Civil Engineer (Hydraulics)	30 years, River & Coastal Engineering, Hydraulics & River Dynamics, Wave Dynamics, Numerical Analysis/Modeling	Coastal Storm Modeling (ADCIR)
Alan Cialone, Civil Engineering Technician	29 years, Wave Hindcasting	Coastal Storm Modeling (ADCIR)
Amanda Lewis, Research Physical Scientist	5 years, Climatology, Meteorology, Coastal Hazards, Statistics	Coastal Storm Modeling (ADCIR)
U.S. Army Corps of Engineers, Hydrologic Engineering Center		
Robert Carl, PE, Hydraulic Engineer	46 years, Civil Eflood Risk Management, Prescriptive Reservoir Modeling	Beach-FX Modeling DQC Level 1
U.S. Army Corps of Engineers, Southwest Division		
Mark Shafer, Environmental Engineer	29 years, Environmental Engineering, Hydrology	Habitat Evaluation, DQC Level 1
U.S. Army Corps of Engineers, Philadelphia District		
Preston Oakley, Economist	6 years, Economics	Beach-FX Modeling DQC Level 1

Name/Title	Experience	EIS Area of Responsibility
Texas General Land Office		
Ray Newby, P.G., Coastal Geologist	30 years, Geology	Project Coordination, QA/QC
Tony Williams, Environmental Review Coordinator	26 years, Coastal Resources	Project Manager and Coordination, QA/QC
Dianna Ramirez, Coastal Biologist	13 years, Environmental Assessment and Impact Analysis	Environmental Lead, Conceptual Mitigation, HEP/WVA, QA/QC
Savannal Horton, Coastal Biologist	5 years, Coastal Environmental Management, Marine and Freshwater Biology/Physiology	Coastal Field Operations Coastal Biologist
Lee Schroer, Coastal Biologist	8 years, Coastal Resources	
Carla Kartman, Environmental Scientist	24 years, Environmental Scientist, NEPA Compliance, Environmental Impact Assessment and Impact Analysis	Project Manager, Project Coordination, NEPA Specialist, QA/QC
Freese and Nichols, Inc.		
Tony Risko, P.E., Coastal Engineer	32 years, Coastal Engineering	Project Manager, Commercial and Recreational Navigation
Lisa Vitale, FP-C, Marine Biologist/Project Manager	21 years, Marine Biology, NEPA Compliance and Coordination	Project Manager, NEPA Document Manager, Marine Fisheries/EFH, Document Coordination, QA/QC
Tom Dixon, Senior Scientist/Project Manager	14 years, Wildlife and Protected Species	Section 404(b) and TCMP preparation, Wetlands and SAV, T&E, HEP/WVA, QA/QC
Dave Buzan, Aquatic Biologist	40 years, Aquatic Biology, Vegetation Analysis and Impacts	Water and Sediment Quality, Freshwater Inflow, Climate, SLR, Oyster Reef Restoration, HEP/WVA, QA/QC
Juan Moya, PhD, P.G., Geomorphologist	31 years, Geologist, Ports and Coastal Engineering	Coastal Geomorphology, GLO Technical Advisor
Andrew Labay, FP-C, Aquatic Biologist	24 years, Aquatic Biology, Freshwater Fisheries	HEP, QA/QC
Kelsey Calvez, Biologist	5 years, Biology and Geology	HEP/WVA, GIS Data
Aaron Petty, Aquatic Biologist	8 years, Environmental Assessment and Impact Analysis	T&E, Wildlife, Cumulative Impacts, Hazardous Wildlife Attractants
Tam Tran, Wildlife Biologist	7 years, Environmental Assessment and Impact Analysis	Wetlands, T&E, Wildlife, Soils, Hydrology, Migratory Birds, Cumulative Impacts

Name/Title	Experience	EIS Area of Responsibility
Ryan Deal,	6 years, HTRW	HTRW Analysis, Energy and Mineral Resources
Ben Hagood, Biologist	11 years, Biologist	Noise
Dan Gise, Biologist	38 years, Biologist	Noise, QA/QC
Kim Buckley, Geomorphologist	17 years, Environmental Geology	Geology, QA/QC
Sabrina Joplin, GIS Analyst	12 years, GIS	GIS Data/Figures
Brian King, GIS Analyst	17 years, GIS	GIS Data
Christine Vidrick, Word Processor	31 years, Word Processing	Word Processing, Document Formatting and Review
Linda Nance, Technical Editor	35 years, Editing	Technical Editing
Mott MacDonald		
Hugo Bermúdez, P.E., Country Manager	25 years, Coastal Engineering	Project Manager
Patrick McLaughlin, P.E., Coastal Engineer	4 years, Coastal Engineering	Assistant Project Manager
Josh Carter, P.E., Principal Engineer	18 years, Coastal Engineering	Project director
Atkins		
Ruben Velasquez, P.E., Senior Engineer	35 years, Air Quality	Air Quality, General Conformity
Environmental Institute of Houston		
George Guillen, Executive Director	7 years, Marine Mammals; 43 years, Estuarine Ecology	Marine Mammal Protection Act
Kristi Fazioli, Research Associate	23 years, Marine Mammals	Marine Mammal Protection Act
Jenny Oakley, Environmental Scientist	6 years, Marine Mammals, 12 years, Estuarine Ecology	Marine Mammal Protection Act
Hollaway Environmental + Communications		
Leslie Hollaway, President	15 years, Public Communications	Public Involvement
Greg Sevcik, Project Manager/Creative Director	14 years, Graphic Designer	Public Involvement
Conner Stokes, Editor/ Communications Specialist	6 years, Editor and Communications	Public Involvement

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