# COASTAL TEXAS PROTECTION AND RESTORATION FEASIBILITY STUDY

COASTAL **TEXAS** STUDY

# FINAL REPORT

AUGUST 2021

US Army Corps of Engineers®
Galveston District

TEXAS GENERAL LAND OFFICE
ESTABLISHED 1836

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This Final Report is a product of the
U.S. Army Corps of Engineers - Galveston District
and the Texas General Land Office.

**COVER PHOTOS:**
Top: Representational illustration of proposed multiple lines of defense for the upper Texas coast (not to scale)
Bottom: Hurricane Ike approaching the Texas Coast in 2008

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# ABBREVIATIONS

**AAHU:** average annual habitat unit

**ADCIRC:** Advanced Circulation Model

**AdH:** Adaptive Hydraulics Model

**AEP:** Annual Exceedance Probability

**AM&M:** adaptive management and monitoring

**ASTM:** American Society for Testing and Materials

**BCR:** Benefit-Cost Ratio

**BOEM:** Bureau of Ocean Energy Management

**CBRA:** Coastal Barrier Resources Act

**CBRS:** Coastal Barrier Resources System

**CDBG:** Community Development Block Grants

**CEICA:** Cost Effective, Incremental Cost Analysis

**CEPRA:** Coastal Erosion Planning and Response Act

**CEQ:** Council on Environmental Quality

**CERCLA:** Comprehensive Environmental Response, Compensation and Liability Act

**CFR:** Code of Federal Register

**cfs:** cubic feet per second

**CIAP:** Coastal Impact Assistance Program

**cm:** centimeter

**CMP:** Coastal Management Program

**CSRA:** Cost and Schedule Risk Analysis

**CSRM:** coastal storm risk management

**CSTORM:** Coastal Storm Modeling System

**CWG:** Community Work Groups

**cy:** cubic yards

**CZMA:** Coastal Zone Management Act

**DIFR-EIS:** Draft Integrated Feasibility Report and Environmental Impact Statement

**EA:** Environmental Assessment

**EAD:** Equivalent Annual Damages Reduced (Benefits)

**EIS:** Environmental Impact Statement

**EO:** Executive Order

**EPA:** Environmental Protection Agency

**ER:** ecosystem restoration

**ESA:** Endangered Species Act

**FEMA:** Federal Emergency Management Agency

**FIF:** Texas Flood Infrastructure Fund

**FIRM:** Flood Insurance Rate Map

**FRM:** Flood Risk Management

**FWOP:** Future Without Project

**FWP:** Future With Project

**GBF:** Galveston Bay Foundation

**GBPP:** Galveston Bay Park Plan

**GCCPRD:** Gulf Coast Community Protection and Recovery District

**GDP:** gross domestic product

**GIWW:** Gulf Intracoastal Waterway

**GLO:** State of Texas General Land Office

**GOMESA:** Gulf of Mexico Energy Security Act

**GRBS:** Galveston Ring Barrier System

**H:** horizontal

**ha/yr:** hectares per year (1 hectare = 2.47 acres)

**HEA:** Habitat Equivalency Analysis

**HEAT:** Habitat Evaluation and Assessment Tool

**HEC-FDA:** Hydrologic Engineering Center Flood Damage Analysis

**HEP:** Habitat Evaluation Procedure

**HSI:** Habitat Suitability Index

**HTRW:** Hazardous, Toxic, and Radioactive Waste

**HU:** Habitat units

**HUD:** Housing and Urban Development

**ICW:** Inspection of Completed Works

**IWR:** Institute for Water Resources

**LERRD:** Land, Easements, Rights-of-Way, Relocation, and Disposal Area

**MAMP:** Monitoring and Adapative Management Plan

**MCACES / MII:** MicroComputer Aided Cost Estimating System, Second Generation

**MCX:** Cost Engineering Center of Expertise

**MLLW:** mean lower low water

**MOUs:** Memoranda of Understanding

**NAVD88:** North American Vertical Datum, 1988

**NED:** National Economic Development

**NEPA:** National Environmental Policy Act

**NER:** National Ecosystem Restoration

**NGO:** non-governmental organization

**NMFS:** National Marine Fisheries Service

**NOAA:** National Oceanic and Atmospheric Administration

**NRDA:** Natural Resource Damage Assessment

**OBA:** Open Beaches Act

**OCS:** Outer Continental Shelf

**OCSLA:** Outer Continental Shelf Lands Act

**OMRR&R:** operation, maintenance, repair, replacement, and rehabilitation

**OPA:** Oil Pollution Act

**P&G:** 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies (Principals & Guidelines)

**PAL:** Planning Aid Letter

**PCP:** Primary Care Pavilion

**PCX's:** National Planning Centers of Expertise

**PED:** Preconstruction Engineering and Design

**PGN:** Planning Guidance Notebook

**PPA:** Project Partnership Agreements

**ppt:** parts per thousand

**REMI:** Regional Economic Models Inc

**RESTORE:** Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act

**ROD:** Record of Decision

**RSLC:** relative sea level change

**SAV:** submerged aquatic vegetation

**SMART:** Specific, Measurable, Attainable, Risk Informed, and Timely

**SPI:** South Padre Island

**SSPEED:** Severe Storm Prediction, Education, and Evacuations from Disasters

**SWEG:** Shallow Water Environmental Gates

**TCEQ:** Texas Commission on Environmental Quality

**TPWD:** Texas Parks and Wildlife Department

**TSP:** Tentatively Selected Plan

**TWL:** Total Water Level

**TxDOT:** Texas Department of Transportation

**USACE:** United States Army Corps of Engineers

**USFWS:** U.S. Fish and Wildlife Service

**USMC:** U.S. Marine Corps

**UTMB:** University of Texas Medical Branch

**V:** vertical

**VLG:** Vertical Lift Gate

**WIK:** work in kind

**WVA:** Wetland Value Assessment

# 1. Introduction

*A photo of Bolivar Peninsula at Rollover Pass following Hurricane Ike in 2008*

Along the Texas coast, vital resources critical to the social, economic, and environmental welfare of the nation are at risk. When tropical disturbances negatively impact the man-made and natural environments of the Texas coast, the immediate fallout and the continued aftermath affect not only the people who live in these coastal counties, but also the entire nation. Due to the importance of the Texas coast, the United States Army Corps of Engineers (USACE) has partnered with the State of Texas General Land Office (GLO) to identify and recommend feasible projects to reduce risks to public health and the economy, to restore critical ecosystems, and to advance coastal resiliency.

This effort, known as the Coastal Texas Protection and Restoration Feasibility Study (Coastal Texas Study), was initiated in 2014 to evaluate large-scale coastal storm risk management (CSRM) and ecosystem restoration (ER) actions aimed at providing the coastal communities of Texas with multiple lines of defense to reduce impacts from a wide array of coastal hazards. This study falls under the USACE's Civil Works Mission, which includes but is not limited to inland and coastal flood risk management and the restoration, protection, and management of aquatic ecosystems. This planning effort was conducted in full compliance with the National Environmental Policy Act (NEPA) and this report includes a companion Final Environmental Impact Statement (EIS).

This Final Feasibility Report presents the findings and recommendations of this years-long study effort by the USACE and GLO. This report supersedes the previously issued 2018 Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR-EIS) and the October 2020 Draft Feasibility Report and Draft EIS and represents the most current and complete findings of this study effort.

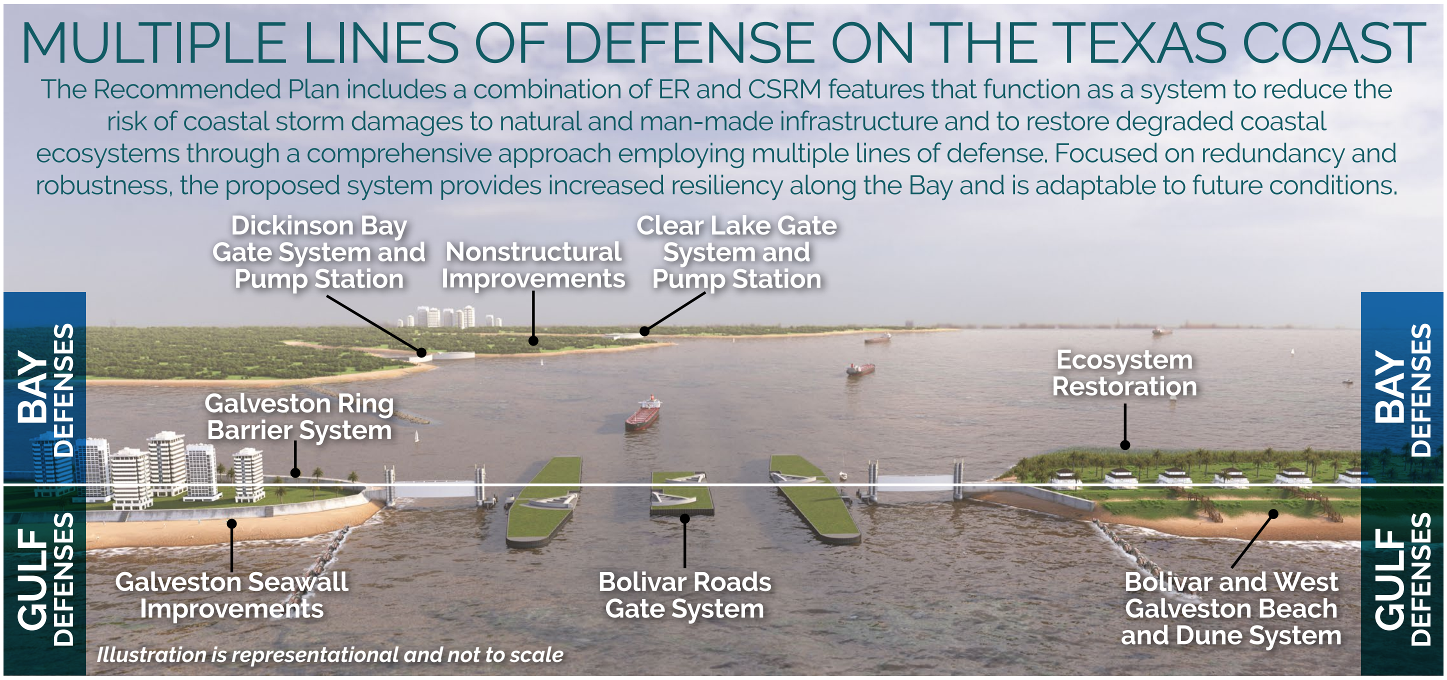



***Figure 1.1:*** *Examples of multiple lines of defense on the Texas coast*

The authors of this report recognize that the volume of information included within this report, and all attachments and appendices, is significant and can present a challenge to review and digest in total. As such, emphasis has been placed on scaling the presentation of information to allow for differing levels of review. This is achieved through the provision of an executive summary, main report, and associated technical appendices and attachments.

The **Executive Summary** presents a condensed summary of the complete Feasibility Report aimed at conveying key concepts, findings, and recommendations in the most efficient and easily understandable manner.

The **Main Report** presents an efficient but complete accounting of information needed to fully understand the scope, process, findings, and recommendations of the study. This report also complies with USACE requirements for Feasibility Report content.

The **Technical Appendices** provide extensive scientific and engineering supporting information covering Plan Formulation, Engineering, Economics, and Real Estate. These appendices provide a greater depth of technical information than that provided in the Main Report, covering all aspects of the planning process. Additional technical detail is also provided within various annexes included in these appendices.

Furthermore, the stand-alone **Final EIS** is included as an attachment to this report and provides a complete, NEPA compliant, record of public outreach, agency coordination, and environmental evaluation and documentation associated with the project.

*The authors of this report recognize that the volume of information included within this report is significant and can present a challenge to review and understand in total. As such, emphasis has been placed on scaling the presentation of information to allow for differing levels of review.*

Within the Main Report, information is presented as follows:

- **Chapter 1: Introduction.** This chapter introduces the reader to the study, its authors, its purpose, and its key considerations. This section also summarizes the structure of the report and details where to find critical information.
- **Chapter 2: Plan Development.** This chapter reviews the plan formulation process and discusses the different planning iterations conducted. The chapter concludes with the rationale for selecting the Recommended Plan.
- **Chapter 3: Recommended Plan.** This chapter provides a detailed review of the CSRM and ER features associated with the Recommended Plan and their benefits. The chapter also covers the risk and uncertainty associated with the plan.
- **Chapter 4: Environmental and Community Impacts.** This chapter provides a summary of the attached Final EIS and discusses compliance with an array of environmental laws.
- **Chapter 5: Consistency with Other Federal, State, and Local Plans.** This chapter focuses on the Recommended Plan's consistency and compatibility with other Federal, State, and local plans.
- **Chapter 6: Implementation Requirements and Strategy.** This chapter focuses on the implementation requirements associated with the Recommended Plan, including state and Federal partnership requirements and cost sharing considerations. The chapter also summarizes the potential phasing/funding requirements.
- **Chapter 7: Recommendations.** This chapter recaps key considerations associated with the study and the Recommended Plan and concludes with the official recommendation and signature of the USACE Galveston District Commander.

*A photo of Galveston Beach and the Galveston Seawall*

**Water Resources Development Act of 2007**
*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."

***Figure 1.2:*** *Water Resources Development Act (WRDA) of 2007, Sec. 4091*

## 1.1. Study Authority

The Coastal Texas Study is being performed under the standing authority of Section 4091, Water Resources Development Act (WRDA) 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." See Figure 1.2 for the full enabling language.

The study effort was initially funded by Congress in 2014, leading to a USACE led reconnaissance study. 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 Study and EIS.

The multi-year feasibility study process is governed by USACE policy, as discussed in Section 1.7, and follows an established process to ensure compliance with both USACE requirements and NEPA. Figure 1.3 highlights the key phases and milestones associated with the Coastal Texas Study. More in-depth information on the planning process can be found in Chapter 2.

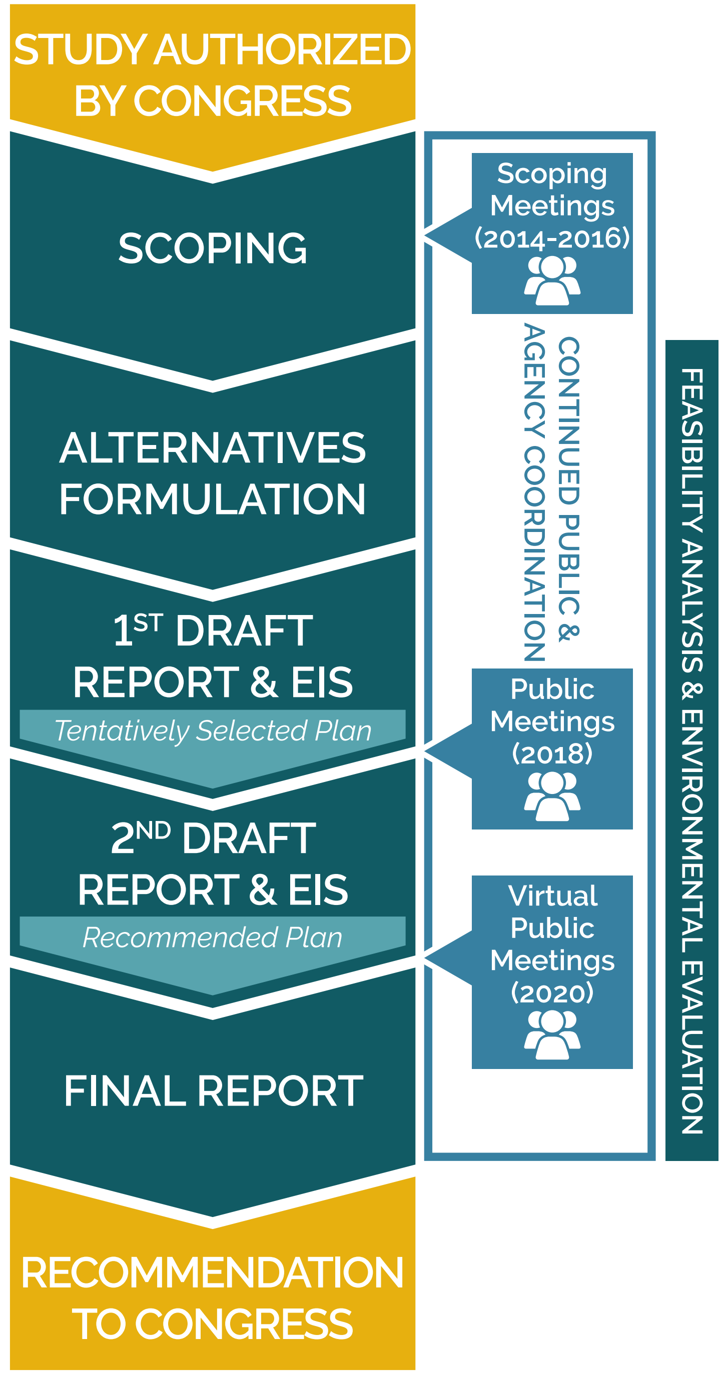



***Figure 1.3:*** *Coastal Texas Study key phases*

Subsequent legislation which has impacted the Coastal Texas Study includes:

- **Section 1205 of the Water Infrastructure Improvements for the Nation (WIIN) Act of 2016**, which further directed the USACE to consider and incorporate other past or concurrent efforts to identify similar coastal protection and restoration needs and projects, such as Gulf Coast Community Protection and Recovery District's Storm Surge Suppression Study, which was a state-funded locally led effort to identify schemes to protect the upper Texas coast from hurricane storm surge.
- **85th Texas Legislature, Regular Session, House Concurrent Resolution 106**, which stated the state's support for the "development and construction of a coastal barrier to protect the Gulf Coast Region of Texas from storm surges" and identified the role of the GLO moving forward and the need for an Operations and Maintenance sponsor.
- **Bipartisan Budget Act of 2018 (BBA 2018)**, which authorized additional funding, not-requiring local cost-share, to complete the Coastal Texas Feasibility Study and EIS.

At the completion of the study, and upon approval by the Chief of Engineers of the United States Army, a plan consisting of CSRM and ER features would be recommended to Congress for authorization and funding. If authorized and funded by Congress, subsequent phases of the project would include Preconstruction Engineering and Design (PED), Construction, and Operations and Maintenance. This project lifecycle, showing anticipated durations of each phase, is illustrated in Figure 1.4. It should be noted that all future phases of this project are reliant on authorization by Congress and subsequent appropriation of funds.

## 1.2. Study Partners

As stated above, this study is being conducted by the USACE in coordination with its non-Federal sponsor, the GLO. The following sections summarize each entity and their role in the study effort.

***U.S. Army Corps of Engineers:***

Since the American Revolution, the United States Army has established the Corps of Engineers as a separate, permanent branch with responsibility for responding to the changing defense requirements of the nation. In modern times, the USACE has significantly expanded its Civil Works activities and played an integral role in the development of the country's water resources infrastructure. Starting with the Flood Control Act of 1917, the USACE has served as the lead Federal flood control agency, tasked with studying and constructing water resources projects related to flood risk reduction. Two of the USACE's primary missions, both of which are reflected in the Coastal Texas Study, are CSRM and ER. To meet these missions, the Corps works in partnership with Federal, state, local and private entities. Since 1976, the USACE typically receives direction and funding from Congress through legislation commonly known as a Water Resources Development Act.

The Coastal Texas Study Team is led by the USACE Galveston District and supported by members of the USACE's Cost Engineering Center of Expertise (MCX) and National Planning Centers of Expertise (PCX's), including those for CSRM and ER.

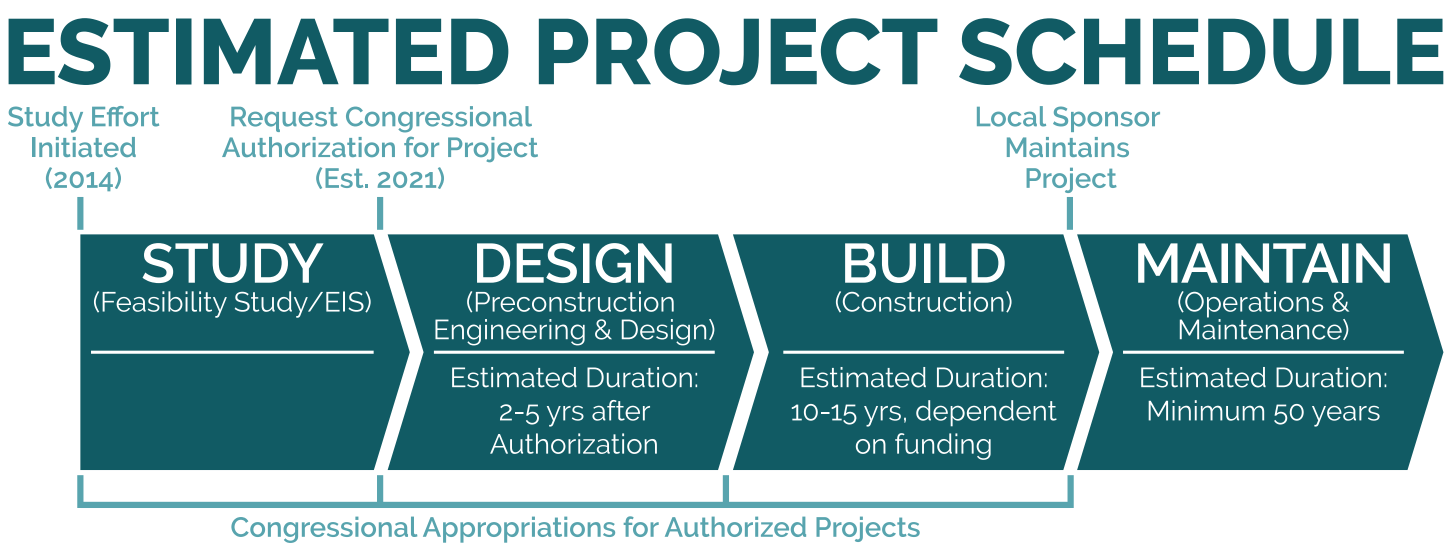



***Figure 1.4:** Coastal Texas Study project phases*

Photo of a recent GLO beach renourishment project at Indianola Beach Park

***Texas General Land Office:***

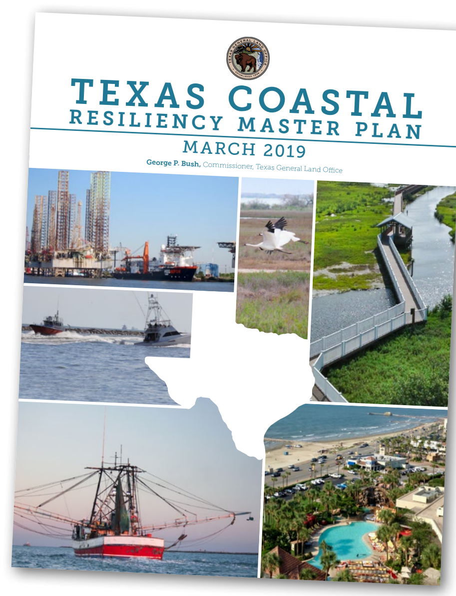
The GLO is the state agency responsible for the management of Coastal Public Lands and implementation of the Open Beaches Act, Dune Protection Act, the Coastal Erosion Planning and Response Act, and the Coastal Management Program. To accomplish this, the GLO operates various coastal programs, projects, and partnerships that work together to address erosion, loss of habitat, impacts on wildlife and fisheries, degradation of water quality and quantity, storm surge, public access to beaches, and the enhancement of coastal resiliency.

An example of the above referenced partnerships is the GLO's role as non-Federal sponsor to the USACE for this Coastal Texas Study. Under a Feasibility Cost Sharing Agreement with the USACE, the GLO contributes both funding and in-kind/contracted services to the USACE to support the development and completion of this study. This work is led by the GLO's Coastal Protection Division, whose mission is to restore, enhance and protect the state's coastal natural resources. Another similar activity led by the Coastal Protection Division is the creation of the state's 'Texas Coastal Resiliency Master Plan', which was developed in coordination with the Coastal Texas Study.

*The GLO served as the non-Federal sponsor for the feasibility study phase, which concludes with the approval of this Feasibility Report and its accompanying EIS*

It should be noted that USACE Civil Works projects require participation of a non-Federal sponsor through all phases of project development, including Feasibility, PED, Construction, and Operations and Maintenance. The GLO has agreed to serve as the non-Federal sponsor for the feasibility study phase only, which concludes with the approval of this Feasibility Report and its accompanying EIS.

Project Partnership Agreements will need to be executed for subsequent phases of this project. Various entities within the State of Texas, including the GLO and the Gulf Coast Protection District (GCPD), will serve as the non-Federal sponsors, with support from local entities, for future phases of the Coastal Texas Protection and Restoration Plan. Specifically, the GLO has issued a Letter-of-Intent stating its intent to serve as the non-Federal sponsor for the ER measures and the South Padre Island Beach Nourishment and Sediment Management measure, while the GCPD has issued a Letter-of-Intent stating its intent to serve as the non-Federal sponsor for the upper Texas coast CSRM features. In addition, 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 GLO, GCPD, and the USACE in the implementation of this project. These implementation considerations are discussed in greater detail in Chapter 6.




Cover of the 2019 GLO Coastal Resiliency Master Plan

## 1.3. Study Area

The enabling legislation for this study (see Figure 1.2) 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 eighteen of Texas' coastal counties, which for study purposes have been subdivided into four areas: the Upper Texas Coast, the Mid to Upper Texas Coast, the Mid Texas Coast, and the Lower Texas Coast (see Figure 1.5).

Texas has 367 miles of coastline 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, Padre, 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 of the Texas Gulf coast. Another key feature in the study area is the Gulf Intracoastal Waterway (GIWW), which parallels the Texas coast and can be found directly behind the barrier island system.

For the 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 the coastal waters". Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams, and adjacent developed lands are all included. In addition, potential sediment sources are located on the Outer Continental Shelf (OCS), which is under the jurisdiction of the Bureau of Ocean Energy Management (BOEM).

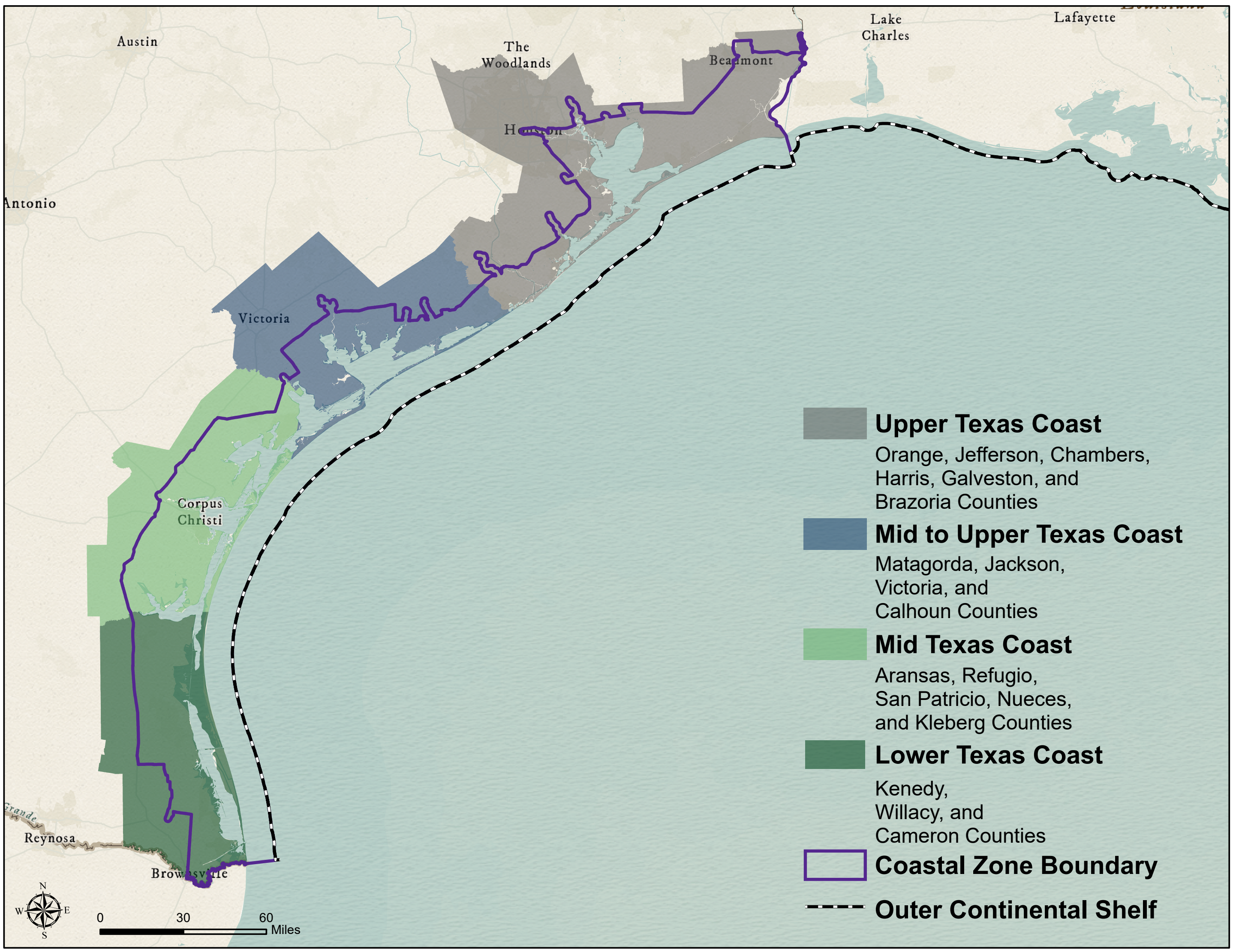



***Figure 1.5:*** *Coastal Texas Study area and regions*

## 1.4. Study 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. Some numbers that demonstrate both the value and the vulnerability of Texas and its coast are presented as follows:

**THE VALUABLE TEXAS COAST**
*BY THE NUMBERS...*

**3,300**
*MILES OF ESTUARINE SHORELINE*

**24%** *STATE'S POPULATION*

**15.8%** *U.S. PORT CARGO HANDLED*

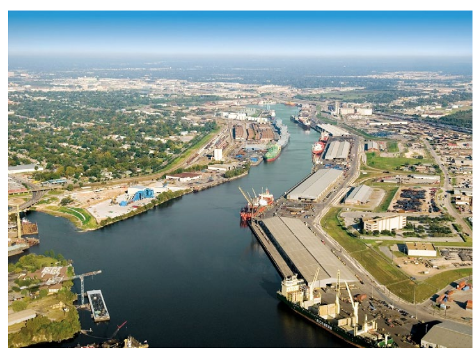
**30%** *OF US REFINING CAPACITY*

***Texas is one of the states with the most residential, commercial and industrial infrastructure vulnerable to coastal storm damage:***

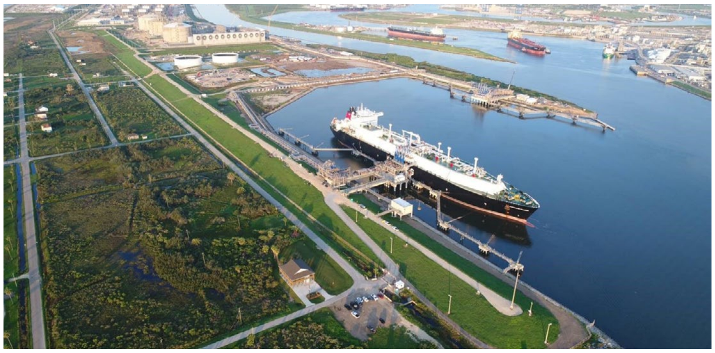
- Third ranked state by the National Oceanic and Atmospheric Administration (NOAA) as most vulnerable to hurricanes by property value ($1.17 trillion).
- Endured two of the 10 costliest U.S. hurricanes as of 2020: Hurricane Harvey (#2) in 2017 and Hurricane Ike (#7) in 2008 (calculation considers the combination of wind, rainfall, and surge damage).
- Navigation and maritime commerce has been a growth driver for the state's economy since its days as a Republic, which in turn has driven population and employment growth on the coast.
    - 18 coastal counties are less than 6 percent of state's land area but contain 24 percent of the population (6.1 million in 2010), including the nation's fourth largest metropolitan area, Houston.
    - Coastal population is expected to increase to 7 million in 2020, and to over 9 million by 2050.
- In recent decades, extreme weather events, such as floods and high tides, are occurring more frequently and with greater intensity, presenting greater challenges to at-risk communities, ecosystems, and infrastructure.

***Texas is one of the nation's top states for waterborne commerce, which is a critical gateway to international trade and provides Texas with a multitude of economic opportunities:***

- Home to seven deep-draft navigation channels and the GIWW which provide valuable transportation infrastructure for the energy industry, military deployments, and the movements of consumer products in and out of the state.
- Contributes over $82.8 billion in economic value to the region from its ports.
- Transports more than 500 million tons of cargo annually, including machinery, grain, seafood, oil, cars, retail merchandise, and military freight.
- Handled 15.8 percent of total U.S. cargo and 20.1 percent of the total export tonnage and 26 percent of total foreign imported tonnage in 2007-2011.
- The GIWW is the nation's third busiest inland waterway, transporting over $25 billion of cargo annually.
- Houston is the number one national port by volume; however, all of the Texas ports play an integral role in the movement of energy products to market.



*Houston Ship Channel*



*Freeport Liquefied Natural Gas facility*

- The GIWW and Texas ports offer critical links to other modes of transportation throughout the United States, such as major railroad lines and trucking routes. In 2010, 7.4 million tons of intermodal rail freight were shipped from Texas, the nation's third-highest total, contributing to domestic energy security.

***Texas is home to energy production and refining critical to the nation's consumer, commercial, and military supply of petroleum and related products:***

- Texas ports export the vast majority of the nation's crude oil, from 76% in 2016 when the export ban was lifted to 94% in 2020, more than 70% of its refined petroleum including gasoline, and more than 70% of its organic chemicals used in plastics, resins, pharmaceuticals, and other finished products.
- Home to over 4,000 energy-related companies and 14 of the 20 largest oil pipeline companies in the nation.
- Home to 29 refineries with 30 percent of the nation's refining capacity in 2017.
- The upper Texas coast has a distillation capacity of more than 8.6 million barrels of crude oil daily and exported more than $59.1 billion of petroleum and coal products in 2014, supporting more than 1.1 million jobs through exports.
- Texas refining capacity is about 5 million barrels per day with about 2.5 million of those barrels from Galveston Bay, the majority of which is exported to other regions of the country, primarily the East Coast.
- Home to three ports which are designated by the Department of Defense as "strategic military ports," providing maritime deployment and distribution for strategic military cargo worldwide.
- Home to three ports which serve in the U.S. Maritime Administration's National Port Readiness Network, supporting deployment of U.S. military forces during defense emergencies.
- Delivers a larger volume of energy products, such as jet and diesel fuel, to the U.S. military than any other State.
- Home to the majority of the nation's strategic petroleum reserves, much of which is located near Houston.

***Texas is home to natural environments which provide priceless ecosystem services, recreational opportunities, and natural buffers protecting communities and commerce from erosion and storm surges:***

- Home to an environment that, when healthy, supports a critical nursery for hundreds of species of birds, wildlife, fish, crabs, and shellfish.
- Home to 367 miles of Gulf shoreline and 3,300 miles of estuarine shoreline that host hundreds of thousands of acres of beach and dune systems, lagoons, seagrass beds, oyster reefs, and tidal marshes.
- Home to numerous resources of national significance, including the Central and Mississippi Flyways, which provide nesting, feeding, and overwintering areas for migratory species, the Laguna Madre, a rare hypersaline lagoon that accounts for 80% of all Texas' seagrass beds, and critical habitat for threatened and endangered species such as the Piping Plover, Red Knot, Whooping Crane, Attwater's Greater Prairie Chicken, West Indian Manatee, and sea turtles.
- These biological and geomorphic systems are the foundation for much of the coast's productivity, economy, and quality of life.
- More than 95 percent of commercially and recreationally important Gulf of Mexico finfish and shellfish species, and 75 percent of the nation's migratory waterfowl depend on these wetlands at some point in their life cycle.
- These coastal resources contribute significantly to the Texas and the region's economy through direct sales and nature tourism. For instance, in 2016, commercial fishing accounted for $195 million in landings revenue, with an additional $425 million spent on saltwater fishing trips.
- Texas barrier islands, beaches, and dunes are the first line of defense against the destructive impacts of hurricanes and tropical storms on inland communities and sensitive coastal environments, while the bays and lagoons serve as the backbone for critical nursery habitats.

*Whooping Cranes at Mustang Island State Park*

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. Among a wide array of risks, three primary risks were identified as drivers for investment in CSRM and ER on the Texas coast. These interdependent risks, hurricane storm surge, coastal erosion, and relative sea level change (RSLC), are summarized in the sections below.

The study recognizes that natural physical features and processes are interconnected with man-made features within the coastal Texas region. Population and industry grew in this region specifically because the natural features supported economic growth. However, erosion and storm surge impair physical landforms that are integral to maintaining a barrier between the Gulf of Mexico and the various bay systems along the coast. Furthermore, RSLC increases the vulnerability of these systems, and interventions to sustain natural features and reduce inundation and erosion risk can be achieved at lower cost when implemented before conditions deteriorate further.

### 1.4.1. Hurricane Storm Surge

As discussed in the previous section, Texas is one of the states most impacted by hurricanes and surge, ranking among the top states in at-risk property value, historical storm damages, and historical number of direct hurricane hits. Furthermore, from 1960 to 2010, Texas has added 3.7 million residents to its vulnerable coastal counties. When hurricanes and tropical storms hit the Texas coast, homes and infrastructure are devastated not only by storm surge, but also wind damage and rainfall induced flooding. This includes not only immediate destruction of property, but also longer-term disruptions to the regional and national economy and the life, health, and safety of coastal residents.

Over recent history, significant hurricane storm surge events have impacted every region of the Texas coast, including every major bay system. This is illustrated in Figure 1.6, which shows the tracks of all Gulf hurricanes from 2000-2019 which made landfall in Texas. In addition, Figure 1.7 shows modeled inundation extents along the Texas coast for storm surge associated with a Category 5 hurricane. This figure illustrates the extensive impact hurricane surge can have on the natural and man-made environments of the Texas coast.

The risk associated with hurricane storm surge is anticipated to increase over time for multiple reasons. This includes 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.


*Figure 1.6: Gulf hurricane tracks from 2000-2019 for storms making landfall in Texas (Source: NOAA)*

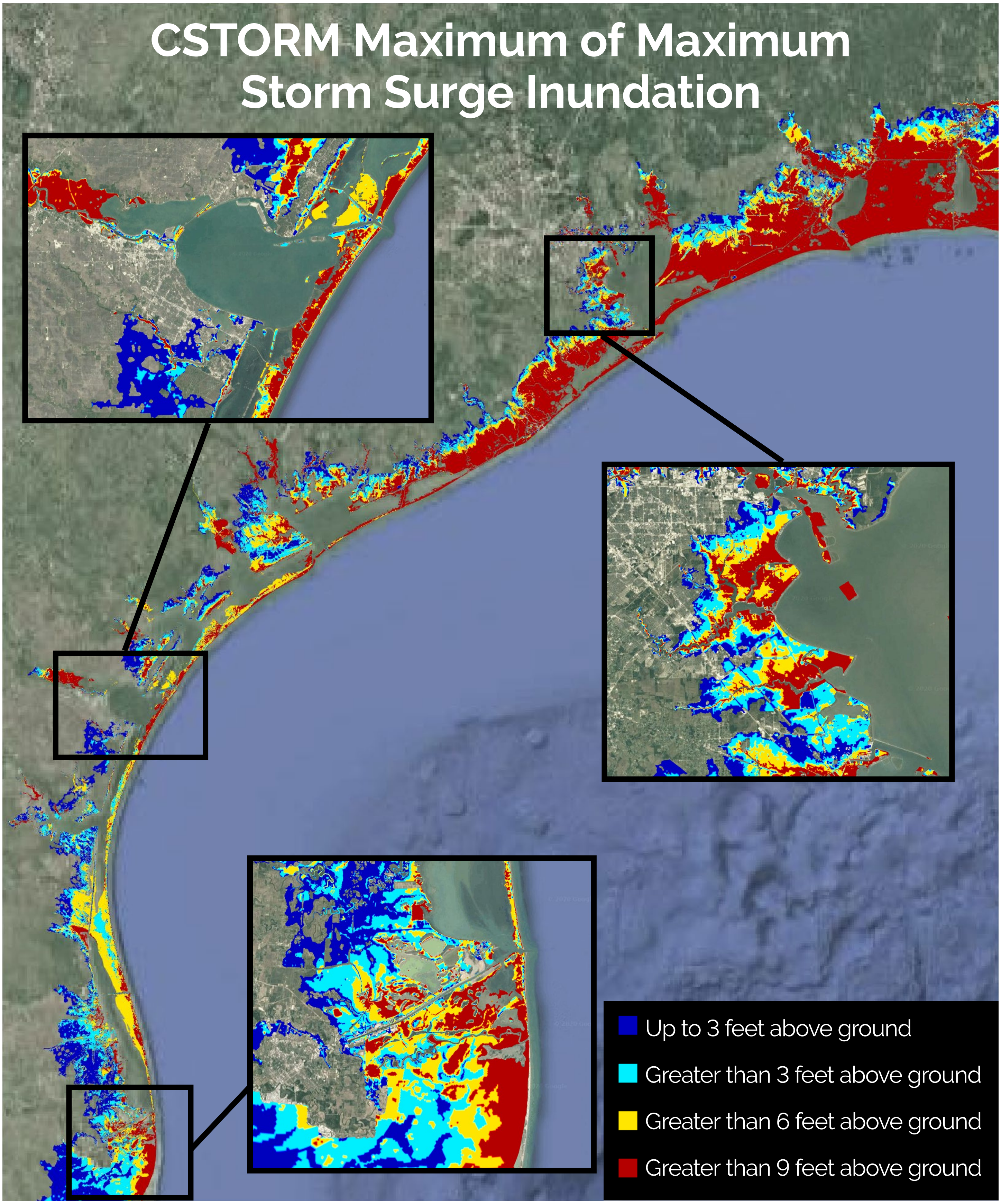



***Figure 1.7:*** *Coastal Storm (CSTORM) model results showing extreme surge levels from hurricanes (without project conditions)*

### 1.4.2. Erosion

Shoreline erosion threatens coastal habitats, recreational amenities, and residential, transportation, and industrial infrastructure. Furthermore, degradation or loss of coastal features such as dunes and marshes diminishes a critical natural line of defense against hurricane surge. The Texas coast is highly dependent on these natural features, along with man-made structural features (e.g. seawalls and levees) and nonstructural measures (e.g. structure elevation), together comprising multiple lines of defense, to protect the area and its economic resources from storm surge and flood damage. Furthermore, rapid shoreline erosion destroys ecosystems critical to the diversity and vitality of the region's aquatic resources and the economies they support.

Gulf shoreline change rates between the 1930s and 2012 averaged 4.1 feet per year of retreat (see www.beg.utexas.edu). As shown in Figures 1.8 and 1.9, rates of shoreline change are generally greater on the upper Texas coast (from the mouth of the Colorado River to Sabine Pass) than those in the mid to lower Gulf Coast. 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 (see www.beg.utexas.edu). The most impacted areas are losing more than 30 feet per year.

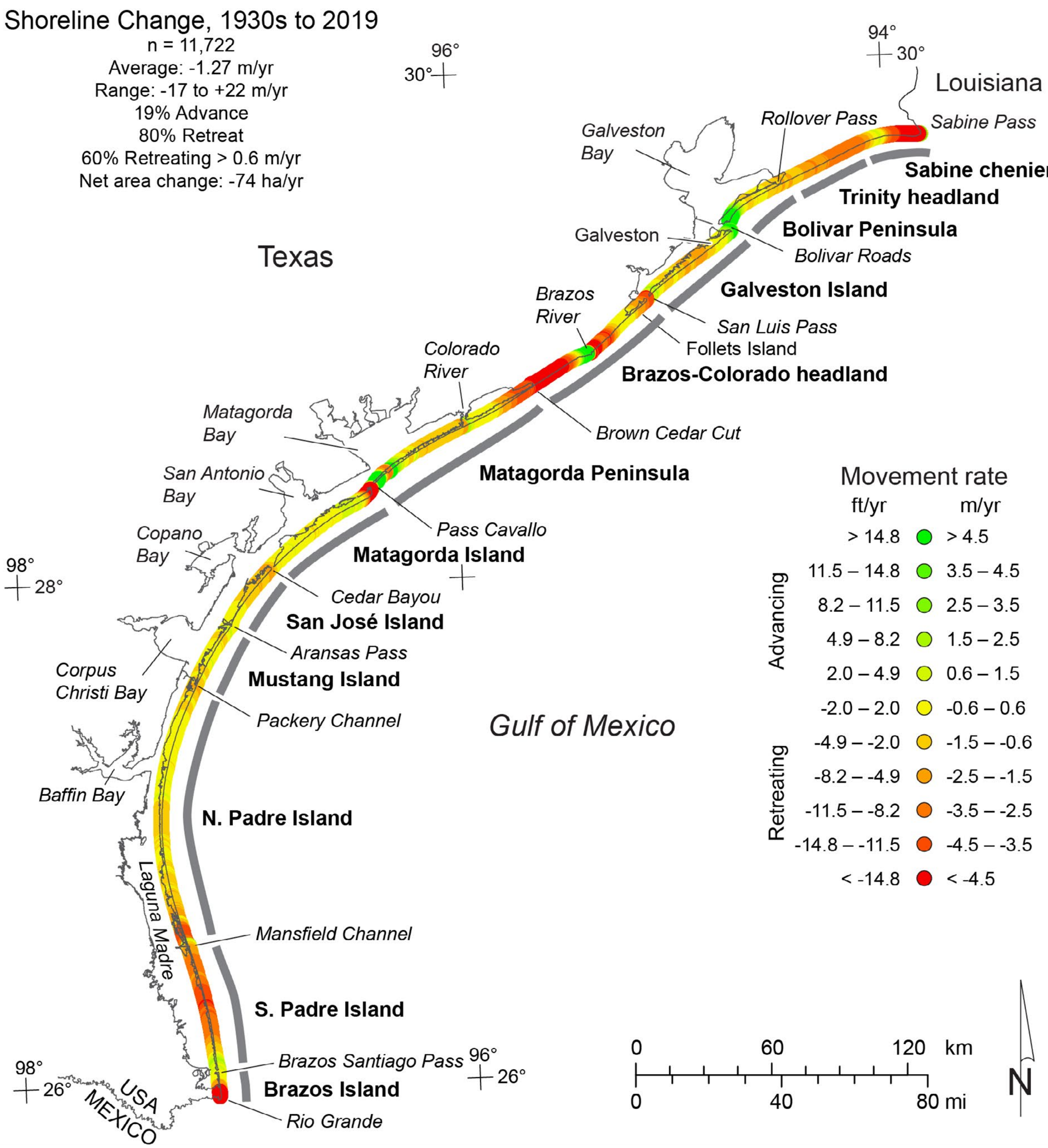



*Figure 1.8: Gulf shoreline erosion rates between the 1930s and 2019 (Source: Bureau of Economic Geology)*

The risks associated with coastal erosion are anticipated to increase over time. As the shoreline retreats, sensitive ecosystems are destroyed and the ability of the natural coastline to defend against hurricane surge is diminished. Furthermore, due to forecasted stronger hurricanes and rising sea levels, among other reasons, the rate of shoreline change is projected to increase, further stressing coastal ecosystems.

*Photo of shoreline erosion on the Texas coast*

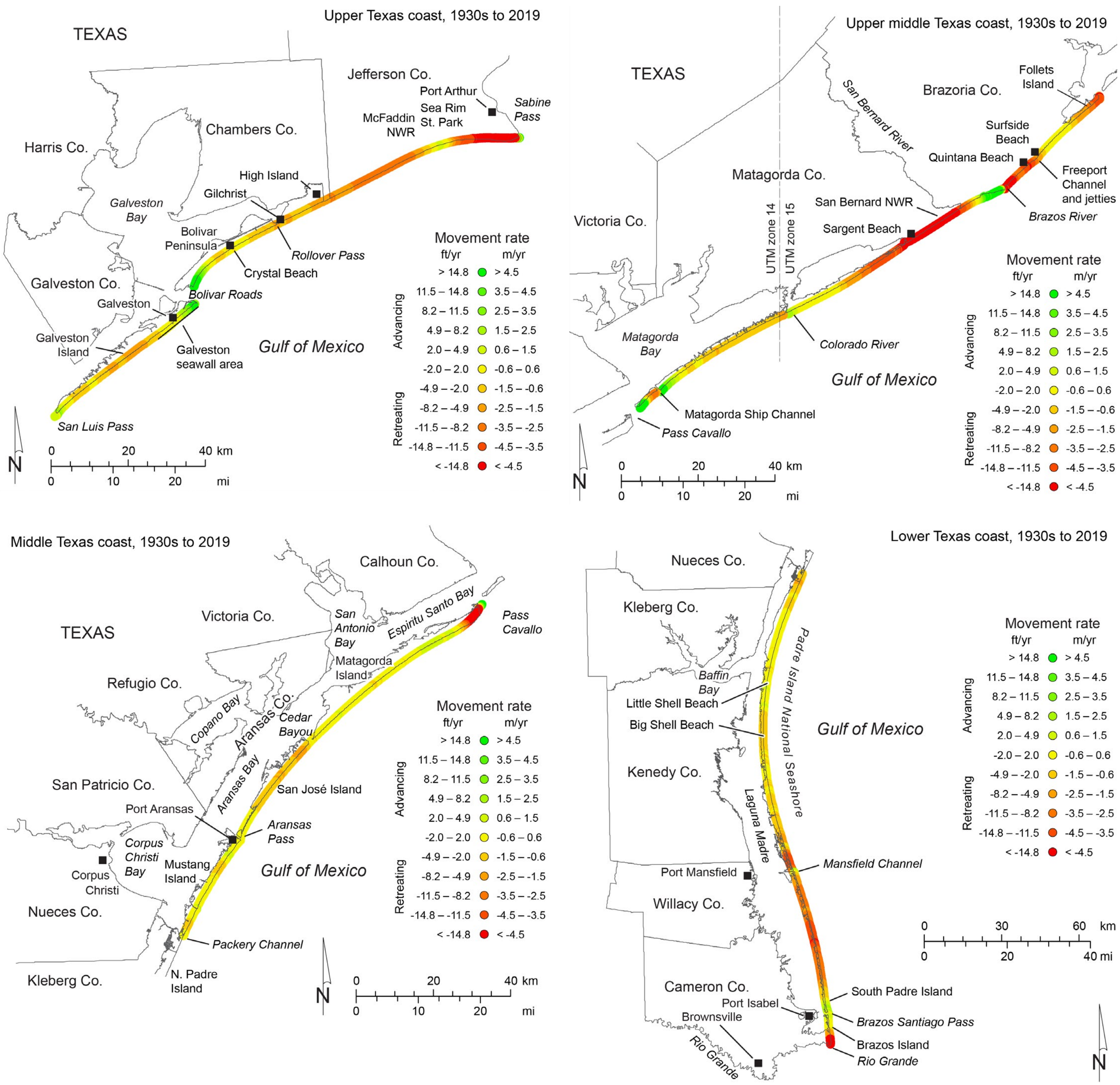
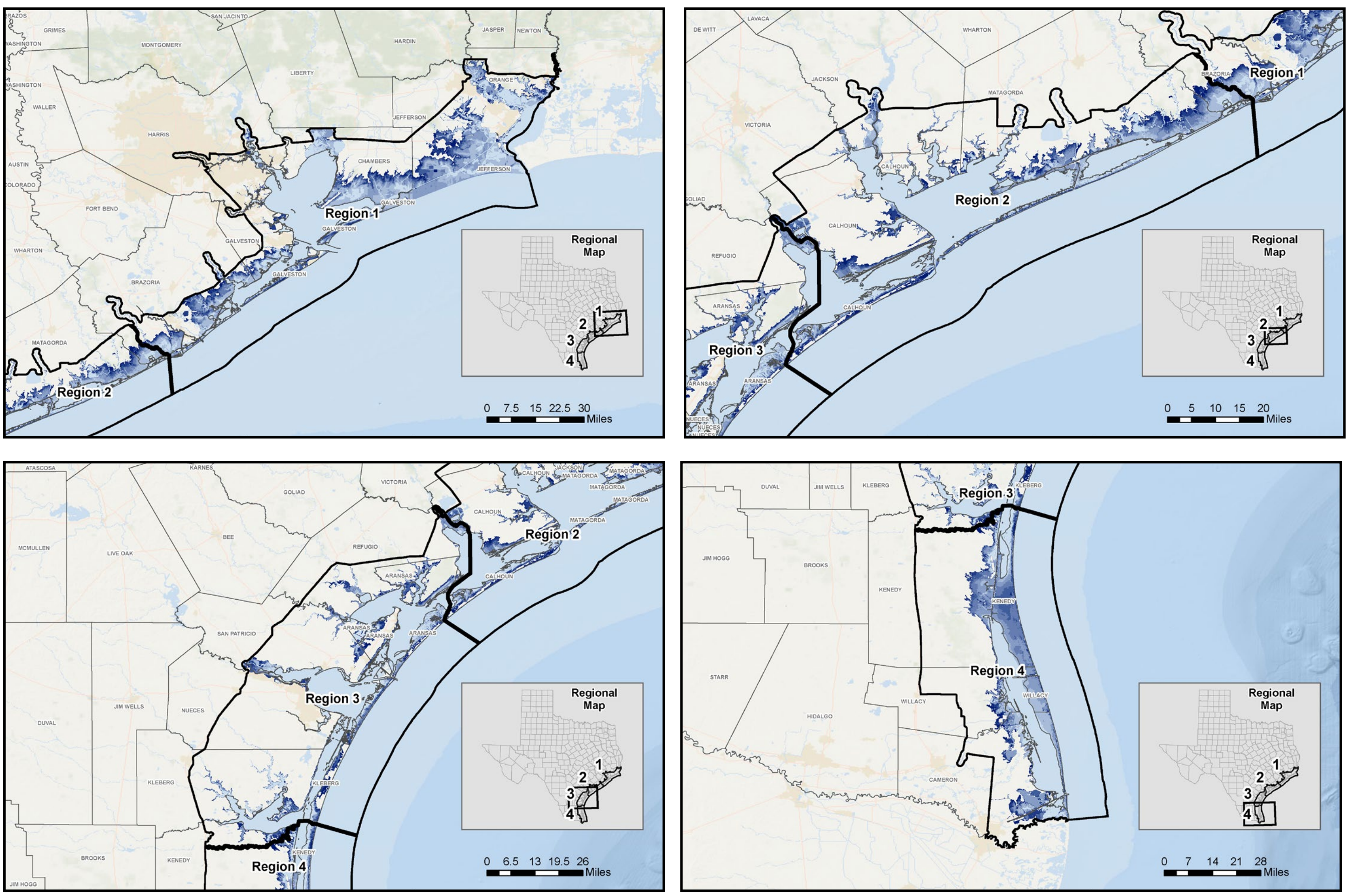



***Figure 1.9:** Gulf shoreline erosion rates between the 1930s and 2019 by region (Source: Bureau of Economic Geology)*

### 1.4.3. Relative Sea Level Change

RSLC, 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 coastal 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 (see Figure 1.10, which shows potential inundation associated with this range in forecasted sea level rise). Also, due to the same global phenomena driving sea level rise, major coastal storms could increase in intensity and the intensity of precipitation events is also likely to increase. Depending on the severity and rate of sea level change, there could be significant impacts to 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. Furthermore, rising sea level submerges wetlands and dry land, erodes beaches, and exacerbates coastal flooding. In accordance with USACE policy, this study evaluates three RSLC scenarios (low, intermediate, and high) when formulating alternative plans and assessing each alternative's performance. Figure 1.11 shows RSLC projections from 1992 to 2100 at the Galveston Pier 21 tide gauge, which is illustrative of the range of projected sea level change over time. However, it should be noted that different regions of the Texas coast have different projected curves for RSLC. Table 1.1 shows the specific relative sea level rise assumptions used in the Coastal Texas Study at 2017, 2035, 2085, and 2135 (representing existing conditions, the base year, 50-year period of analysis, and 100-year horizon, respectively) for the different regions of the coast, under the low, intermediate, and high scenarios.

**Sea Level Rise Vulnerability**




**LEGEND:** 0 ft 1 ft 2 ft 3 ft 4 ft 5 ft 6 ft

***Figure 1.10:*** *Potential inundation associated with forecasted sea level rise (Source: TxGLO)*

| | Pier 21 (Region 1) | | | Rockport (Regions 2 and 3) | | | Port Isabel (Region 4) | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Low | Intermediate | High | Low | Intermediate | High | Low | Intermediate | High |
| **2017** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2035** | 0.4 | 0.5 | 0.8 | 0.3 | 0.4 | 0.8 | 0.2 | 0.3 | 0.7 |
| **2085** | 1.4 | 2.1 | 4.4 | 1.2 | 1.9 | 4.1 | 0.8 | 1.5 | 3.8 |
| **2135** | 2.5 | 4.2 | 9.8 | 2.0 | 3.8 | 9.4 | 1.4 | 3.2 | 8.8 |

***Table 1.1:*** *Relative Sea Level Change Projections (feet)*

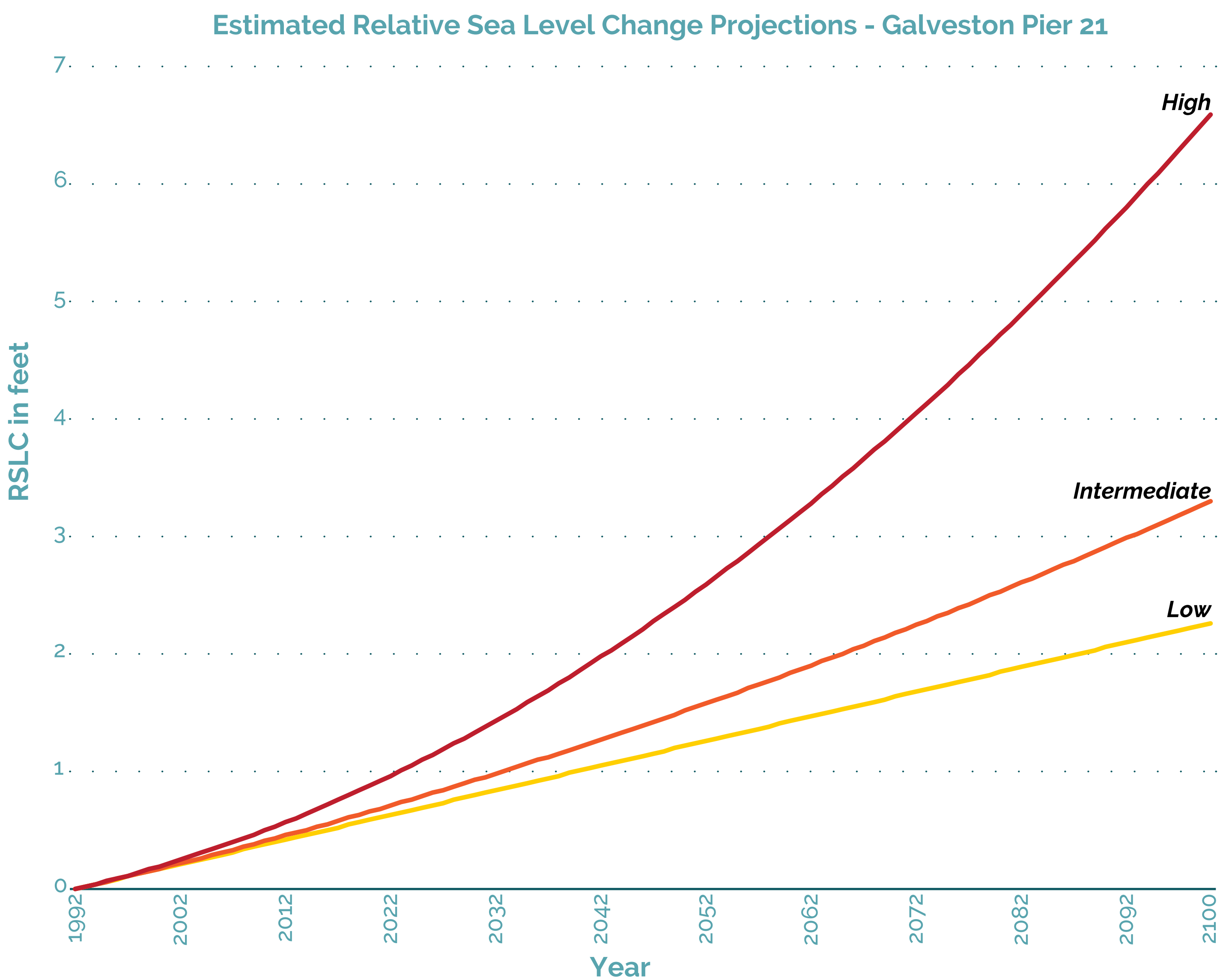



***Figure 1.11:*** *Relative Sea Level Change Projections, Pier 21 on Galveston Island*

## 1.5. History of CSRM and ER on the Texas Coast

Perhaps no event better illustrates the unique risks coastal communities face than the "Great Galveston Hurricane". Also known as the "Great Storm of 1900", this infamous hurricane devastated the City of Galveston, killed thousands, and spurred lasting changes to development patterns and approaches aimed at better protecting residents and economic resources from a variety of coastal risks and hazards. In the aftermath of this event, 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. For example, Federal navigation channels serve as economic engines for the region, while hurricane flood protection systems reduce risk to vulnerable coastal communities from storm surge. Figure 1.12 provides select examples of projects implemented by the USACE and their local partners.

In recent years, numerous USACE led or locally led studies have evaluated CSRM and ER needs along the Texas coast. These studies represent a wealth of information which was utilized heavily in the development of the 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, TX. 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 CSRM and ER along the 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 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 Evacuation from Disasters (SSPEED) Center have 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.

**Federal Coastal Storm Risk Management 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 (in design)
- Texas City Hurricane Flood Protection System

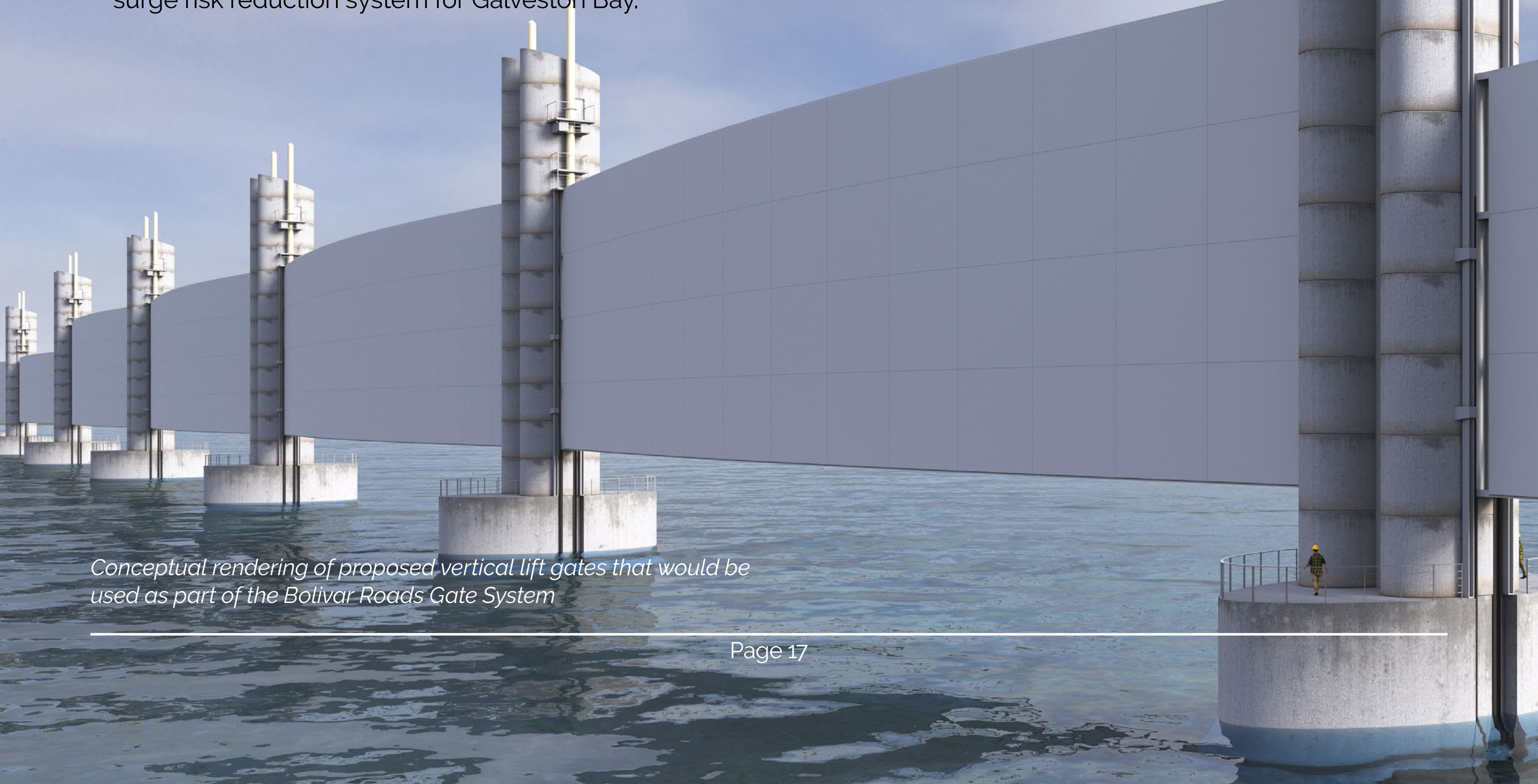
**Key Federal Navigation Channel Systems:**

- 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-Naches Waterway
- Texas City Ship Channel

***Figure 1.12:*** *Relevant projects implemented by the USACE and local partners*

*In recent years, numerous USACE led or locally led studies have evaluated CSRM and ER needs along the Texas Coast*

- **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 PED 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 GLO prepared 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 ER plan for Jefferson County would restore marsh and GIWW shoreline features that stabilize and sustain critical environmental resources.
- **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 risk reduction system for Galveston Bay.



*Conceptual rendering of proposed vertical lift gates that would be used as part of the Bolivar Roads Gate System*


*Example of beach renourishment in-progress*

Beyond large-scale studies, numerous Federal and state laws have been enacted and programs developed to safeguard coastal resources and provide funding for restoration projects. These programs serve as the foundation of coastal protection activities and support many of the day-to-day or year-to-year activities undertaken to address coastal issues. Examples of Federal laws or programs relevant to coastal protection and ecosystem restoration include:

- Coastal Zone Management Act (CZMA, 1972)
- Coastal Barrier Resources Act (CBRA, 1990)
- Outer Continental Shelf and Lands Act (OCSLA, 1953)
- WRDA Section 204/1135 Projects
- RESTORE Act (including National Fish and Wildlife Foundation)
- Natural Resource Damage Assessment (NDRA)
- Gulf of Mexico Energy Security Act (GOMESA)
- USACE Continuing Authorities Program (WRDA, Sec. 204, 1996)
- Coastal Impact Assistance Program (CIAP, 2001 and 2005)

As stewards of the Texas coast, the GLO is responsible for implementing many state and Federal laws related to coastal and environmental protection, including several of those referenced above. Furthermore, the GLO administers numerous funding programs aimed at addressing coastal environmental damage both proactivity and reactively. Examples of state-funded programs or federally directed grants relevant to the Coastal Texas Study, managed by GLO or other agencies, include:

- Texas Open Beaches Act (OBA)
- Texas Coastal Management Program (CMP)
- CIAP Program
- Coastal Erosion Planning and Response Act (CEPRA) Program
- NRDA Program
- Federal Emergency Management Agency (FEMA) Grant and Disaster Recovery Programs
- Housing and Urban Development (HUD) Community Development Block Grants (CDBG) Disaster Recovery / Mitigation Programs
- The Texas Infrastructure Resiliency Fund
- Texas Flood Infrastructure Fund (FIF)

The USACE acknowledges the numerous laws, programs, projects, and studies which support common efforts to improve coastal resiliency in Texas. The USACE also recognizes that large-scale improvements, like those proposed in this report, must integrate with other completed, ongoing, and planned efforts at the state and local level.

Further discussion of complimentary efforts at the Federal, state, and local levels is provided in Chapter 5.

## 1.6. Study Goals and Objectives

As a first step in the planning process, it was necessary to define a "problem statement" which encapsulated the challenges to be addressed by the study. This statement, provided in Figure 1.13, defines the core risks to be addressed in the study effort. In addition, a focused set of problems was developed to further inform and guide the plan formulation process. These specific coastwide problems identified for the Coastal Texas Study are detailed in Figure 1.14. Building on these, corresponding coastwide opportunities to address identified challenges were developed to lay out a range of actions which could potentially address the problems. Recognizing that there exist opportunities to improve these problems helps frame the way in which problems can be remedied. The specific coastwide opportunities identified for the Coastal Texas Study are also detailed in Figure 1.14. In total, identification of study specific problems and opportunities provided a foundation for a focused but comprehensive planning process, which is discussed further in Chapter 2.

**Problem Statement:**

Given the area's low elevation, flat terrain, and proximity to the Gulf, the people, economy, and unique environments are at risk due to tidal surge flooding and tropical storm waves. In addition, continued loss of natural surrounding ecosystems will contribute to the region's loss of biodiversity. Land subsidence, combined with rising sea level, is expected to increase the potential for coastal flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future.

***Figure 1.13:*** *Coastal Texas Study problem statement*

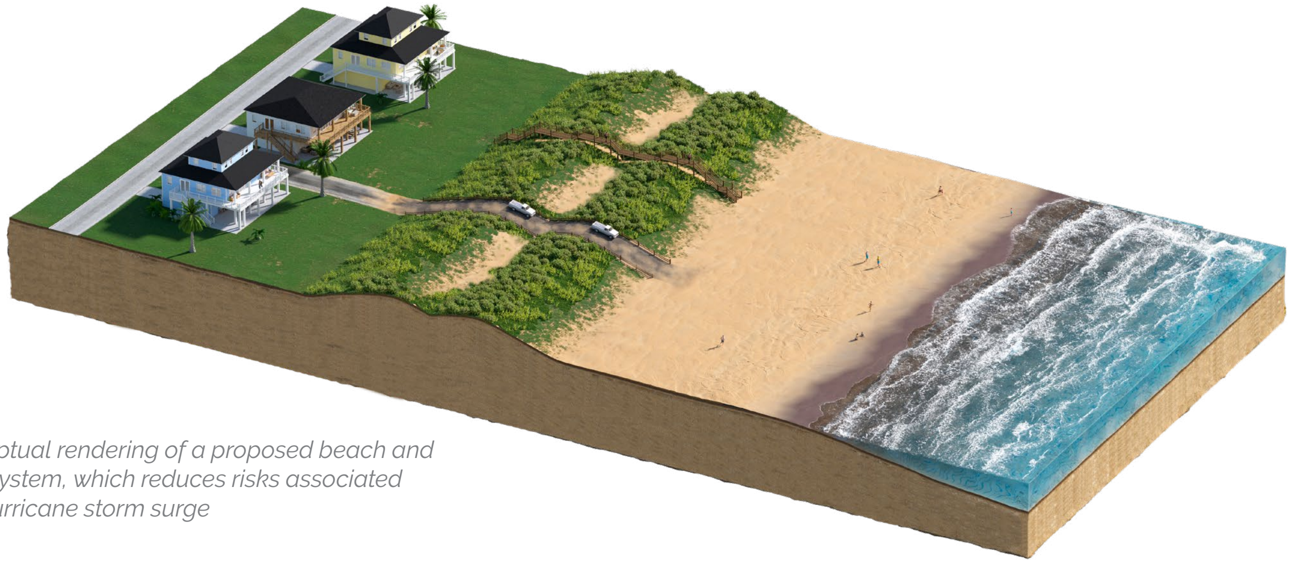
***Problems identified for this study include:***

- Coastal communities, including residential populations and the petrochemical industry, are 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 are becoming more at risk for damage from coastal storm events;
- Existing hurricane flood protection systems, including systems at Port Arthur, Texas City, and Freeport that do not meet current design standards for resiliency and redundancy will be increasingly at risk from storm damages due to relative sea level rise and climate change (note: Freeport and Port Arthur are being addressed through the separate Sabine Pass to Galveston Bay project);
- Degradation of nationally significant migratory waterfowl and fisheries habitats, oyster reefs, and bird rookery islands within the study area is occurring and increasing due to storm surge erosion; and
- Water supply shortages are due to increasing conflicts between municipal and industrial water demand and the ecological needs of coastal estuaries and ecosystems.

***Opportunities identified for this study include:***

- 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 resources 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; and
- Use available sediment within the system beneficially.

***Figure 1.14:*** *Coastwide problems and opportunities*



*Conceptual rendering of a proposed beach and dune system, which reduces risks associated with hurricane storm surge*

To help restrain and guide the planning process, numerous planning constraints were also identified early in the study effort. While not inclusive of all potential constraints, the following primary planning constraints generally pertain to preventing negative impacts to existing ecosystem resources or existing Federal projects while formulating remedies to the recognized problems.

1. Avoid or minimize negative impacts to threatened and endangered species and protected species;
2. Induce no impact to authorized navigation projects. Avoid actions that negatively affect the ability of authorized navigation projects to continue to fulfill their purpose;
3. Induce no loss of risk reduction from existing coastal storm damage risk reduction projects;
4. Avoid or minimize impacts to critical habitat, e.g., essential fish habitat;
5. Minimize impacts to commercial fisheries;
6. Avoid or minimize contributions to poor water quality;
7. Minimize impacts to local hydrology. Hydrology regimes in the study area are sensitive to changes in flows and drainage patterns. The measures and alternatives will consider local hydrology impacts. Careful consideration should also be given to actions that could induce flooding inside and outside of systems; and
8. Avoid induced development, to the maximum extent practicable, that contributes to increased life safety risk. As an example, public comments in scoping meetings reflected a concern that potential enclosed wetland areas would be opened in the future to urban development.

In accordance with the legislative authority and intent, and incorporating public and agency feedback from the scoping phase, the following high-level goals were established for the Coastal Texas Study effort. These goals are stated to organize and focus the work of problem-solvers and decision-makers.

- ***Increase the resilience of the economy, the communities, and the natural resources in the Coastal Texas region.***
- ***Promote a resilient and sustainable economy by reducing the risk of storm damage to residential structures, industries and businesses critical to the nation's economy.***
- ***Promote a resilient and sustainable coastal ecosystem by minimizing future land loss (erosion), enhancing wetland productivity, and providing and sustaining diverse fish and wildlife habitats.***

In accordance with these goals, 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.

The Coastal Texas Study planning process aimed to identify projects needed to support a comprehensive state-wide approach to CSRM and ER, recognizing the great differences in coastal storm risk and restoration needs across the full Texas coast, and considering the concurrent and complementary actions being advanced by local partners, such as the GLO. Accordingly, measures were not proposed in areas with low risk for coastal storm damage. And both CSRM and ER measures were coordinated closely with ongoing or proposed restoration projects included in the State's Coastal Resiliency Master Plan, in addition to the various adjacent USACE led projects such as Sabine Pass to Galveston Bay. By coordinating efforts across projects and between different entities, the study achieves its goal of identifying the specific projects necessary to fill in the gaps of a state-wide comprehensive CSRM and ER program.

| Goals | Objectives |
|---|---|
| ***COASTAL STORM RISK MANAGEMENT*** *Promote a resilient and sustainable economy by reducing the risk of storm damage to residential structures, industries, and businesses critical to the nation's economy* | 1. Reduce risk to human life from storm surge impacts along the Texas coast;<br>2. Reduce economic damage from coastal storm surge to business, residents, and infrastructure along the Texas coast;<br>3. Enhance energy security and reduce economic impacts of petrochemical supply-related interruption due to storm surge impacts;<br>4. Reduce risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.) from storm surge impact;<br>5. Manage regional sediment, including beneficial use of dredged material from navigation and other operations so it contributes to storm surge attenuation where feasible;<br>6. Increase the resilience of existing hurricane risk reduction systems from sea level rise and storm surge impacts; and<br>7. Enhance and restore coastal geomorphic landforms that contribute to storm surge attenuation where feasible. |
| ***ECOSYSTEM RESTORATION*** *Promote a resilient and sustainable coastal ecosystem by minimizing future land loss, enhancing wetland productivity, and providing and sustaining diverse fish and wildlife habitats* | 1. Restore size and quality of fish and wildlife habitats such as coastal wetlands, forested wetlands, rookery, oyster reefs, and beaches and dunes;<br>2. Improve hydrologic connectivity into sensitive estuarine systems;<br>3. Reduce erosion to barrier island, mainland, interior bay, and channel shorelines;<br>4. Create, restore, and nourish oyster reefs to benefit coastal and marine resources; and<br>5. Manage regional sediment so it contributes to improving and sustaining diverse fish and wildlife habitat. |

***Table 1.2:*** *Overall Coastal Texas Study goals and objectives*

It should be noted that the Study Team elected to not consider another core USACE mission, Flood Risk Management (FRM), as a component of this 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 projects/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 River and Harbor Flood Control Act of 1970 (PL 91-611), which the Buffalo Bayou and Tributaries Resiliency Study is being conducted under, for example. 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.

*CSRM measures and alternatives were formulated to achieve National Economic Development principles and objectives while ER measures and alternatives were formulated to achieve National Ecosystem Restoration principles and objectives*

In line with the goals established for this study, the objectives detailed in Table 1.2 were established for each primary goal. Objectives are means by which stated goals are achieved; when objectives are met, then goals have been accomplished. In accordance with USACE policies, CSRM measures and alternatives were formulated to achieve National Economic Development (NED) principles and objectives while ER measures and alternatives were formulated to achieve National Ecosystem Restoration (NER) principles and objectives.

## 1.7. USACE Civil Works Guidance and Initiatives

The USACE follows strict policies and procedures when conducting Civil Works planning studies. This unified planning framework ensures that all studies nationwide are conducted in a similar manner, include all components required by Federal law, and are evaluated under the same standardized criteria. This is vitally important as Civil Works projects must be independently authorized and funded by Congress through a WRDA or similar legislation. A key guiding principle for Federal interest in water resources is that projects must produce more benefits than they cost (a positive benefit-cost ratio).

The following two documents detail the core planning requirements and guidance which direct all USACE Civil Works feasibility studies, including the Coastal Texas Study.

- **1983 Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies (hereafter Principles and Guidelines [P&G]).** The Principles and Guidelines provides guidelines for the development, or "formulation", of reasonable plans responsive to national, state, and local concerns. Within this framework, the USACE seeks to balance economic development and environmental needs as it addresses water resources problems.
- **Planning Guidance Notebook (PGN).** Based on the broader guidelines of the P&G, the PGN provides overall direction to the USACE on how to formulate, evaluate, and select projects for implementation. This study was conducted in accordance with the PGN and under the USACE's Civil Works Planning Modernization process by utilizing Specific, Measurable, Attainable, Risk Informed, and Timely (SMART) planning to effectively execute and deliver the study in a timely manner. Chapter 2 of this report details the plan formulation process that the Coastal Texas Study followed.

The study also meets the USACE Campaign Plan goals and the USACE Environmental Operating Principles by undertaking a proactive public involvement campaign, including a project website and targeted stakeholder meetings. Active and responsive public involvement has informed the development of solutions to the problems this study seeks to address and has facilitated the sharing and distribution of data and knowledge.


*Representatives attend a Community Work Group meeting in May 2019*


*Members of the public attend a Public Meeting on Bolivar Peninsula held in December 2018.*

## 1.8. NEPA Compliance

To comply with NEPA, a Federal agency must prepare an EIS if it is proposing actions that may significantly affect the quality of the natural and human environment. The NEPA environmental review process seeks to facilitate better-informed decisions, focused on avoiding, minimizing, and/or mitigating potentially negative impacts of 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 aid in the reader's understanding of the environmental evaluation and review process employed for the Coastal Texas Study, an abbreviated introduction to the Final EIS is included in Chapter 4. In addition, as discussed in the following section, a summary of NEPA required public outreach and agency coordination is also provided within this report as part of Chapter 2. The full NEPA compliant Final EIS is included as an attachment to this report.

*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*

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 Code of Federal Regulations [CFR] 1500 – 1508, specifically 1502.20). Under this structure, rather than preparing a single definitive EIS as the basis for approving the entire project, the USACE will conduct two or more rounds – or "tiers" – of environmental review. In this phase associated with the Feasibility Report, the USACE has prepared a Final EIS that analyzes the project on a broad scale. In future phases, the USACE will prepare one or more additional NEPA documents (either supplemental EIS or Environmental Assessment) which build off the original EIS to examine individual features of the Recommended Plan in greater detail. 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, or Tier Two environmental reviews are able to present more thorough assessments of impacts and mitigation needed as the project components are refined and more information is available. This tiered approach also allows for additional public review of the updated project designs and Tier Two environmental analysis. Furthermore, a tiered approach to NEPA compliance provides for a timely response to issues that arise from specific proposed actions and supports forward progress toward completion of the overall study.

## 1.9. Public/Agency Involvement and Coordination

In accordance with USACE planning guidelines and NEPA requirements, a proactive approach was taken to engage the public, resource agencies, industry, local government, and other interested parties in the Coastal Texas Study planning process. 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 Virtual Public Meetings to review and finalize the Draft Feasibility Report and Draft EIS in 2020, as summarized in Figure 1.15. Each round of engagement activities included public meetings in the different regions which comprise the Texas coast. Highlights of this multi-year outreach program include:

- Eight (8) Scoping Meetings in 2014 to announce initiation of the reconnaissance/feasibility studies and to solicit input on storm risk reduction and habitat restoration.
- Issuance of Notice of Intent in 2016 and solicitation of scoping comments from Federal, state, local agencies, Tribal Nations, and other interested organizations.
- Regular updates to the study website; https://coastalstudy.texas.gov.
- Resource agency meetings were held monthly from 2016 to 2018 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 Procedure/Wetland Value Assessment, mitigation, etc.
- Seven (7) Public Meetings were held in 2018 to provide the public with updated information about the study scope and schedule and to solicit public comments for consideration on the DIFR-EIS and the proposed Tentatively Selected Plan (TSP).
- Twenty (20) community-based work group sessions, led by the GLO, in partnership with local leaders.
- Three (3) Public Open Houses in 2019/2020 to update stakeholders on study progress.
- Over sixty (60) presentations or briefing sessions at conferences, professional meetings, and other public or private events.
- An additional six (6) Virtual Public Meetings were held in the fall of 2020, along with three virtual question and answer sessions, to review the Draft Feasibility Report and Draft EIS and the proposed Recommended Plan.

Engagement activities exceeded that required by NEPA and proved integral to the planning process, as they 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 consideration of community impacts 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 included in Chapter 2 of this report and within the attached Final EIS.

**PUBLIC INVOLVEMENT ACTIVITIES**
*BY THE NUMBERS...*

**8** *SCOPING MEETINGS*

**7** *PUBLIC MEETINGS*

**20** *COMMUNITY-BASED WORK GROUP SESSIONS*

**3** *OPEN HOUSES*

**6** *VIRTUAL PUBLIC MEETINGS*

**60** *BRIEFING SESSIONS*

***PLUS:***
- *Monthly Resource Agency Meeting*
- *Project Website*
- *Published Notices*

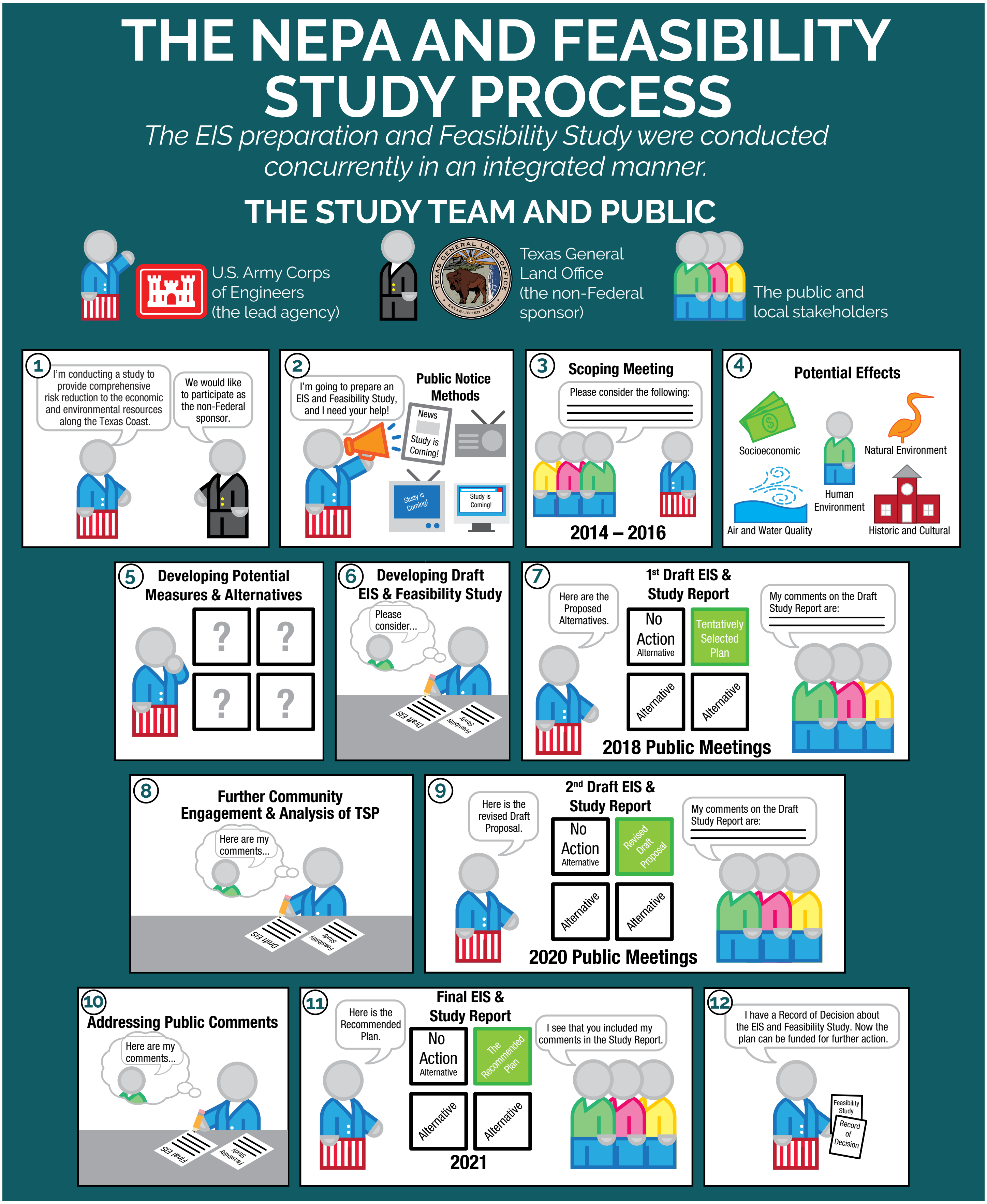



***Figure 1.15:*** *The NEPA and Feasibility Study process*


# 2. Plan Development

As discussed in Section 1.7, the USACE Civil Works planning process follows a consistent and standardized approach to identify and evaluate potential solutions to water resources problems and to ensure that investment decisions reflect important benefits and consequences and meet Federal investment requirements. The planning process includes six major steps, all of which were followed for the Coastal Texas Study:

*Example of beach renourishment in progress*

1. Specification of water and related land resources problems and opportunities;
2. Inventory, forecast and analysis of water and related land resources conditions within the study area;
3. Formulation of alternative plans;
4. Evaluation of the effects of the alternative plans;
5. Comparison of the alternative plans; and
6. Selection of the recommended plan based upon the comparison of the alternative plans.

As shown in Figure 2.1, if additional information is developed during the screening process, the Study Team may repeat steps to incorporate that information to balance the need for data and analysis with timely completion of the study. Detailed information regarding the plan development process can be found in Appendix A, the Plan Formulation Appendix. In an abbreviated manner, this process is described in the following sections.

**Problem Statement:**
Given the area's low elevation, flat terrain, and proximity to the Gulf, the people, economy, and unique environments are at risk due to tidal surge flooding and tropical storm waves. In addition, continued loss of natural surrounding ecosystems will contribute to the region's loss of biodiversity. Land subsidence, combined with rising sea level, is expected to increase the potential for coastal flooding, shoreline erosion, saltwater intrusion, and loss of wetland and barrier island habitats in the future.

*Coastal Texas Study problem statement*

## 2.1. Summary of Planning Considerations

The coastal problem statement presented in Section 1.6, and shown on the previous page, describes the damaging impacts of coastal storms and constant coastal processes on the physical features of the region. The study area's low elevation and flat terrain, combined with long term changes such as land subsidence and rising sea level, create potential risk for coastal flooding, storm surge, erosion, and habitat degradation. Erosive coastal forces impact both the natural and man-made habitats. As we lose shorelines and marshes retreat, natural protective features are lost. Degradation of these resources worsens the impact of storm events, as storm surge is able to push further past eroded shorelines and marshes. Defining these problems helps to identify engineering solutions to coastal risks. Assessing problems, opportunities, and constraints supports identification of comprehensive solutions for risk reduction across a long planning horizon and changing conditions.

The risks along the Texas coast are well documented through historical storms, available data, and previous USACE and academic studies. Beyond the dollar value of damages to structures, storm surge and other coastal forces have broader impacts on economic productivity and essential community services which maintain health and wellbeing. This study is an opportunity to prepare coastal systems to be resilient to storm and erosion damage.

***Resiliency*** is multifaceted and can best be defined as the ability of a specific system to withstand, recover, and adapt to disturbances. There are multiple systems of interest in the coastal region, including social systems, natural systems, and economic systems. Plans were formulated to be resilient against future storm and erosion damage. The Recommended Plan should reduce harm to neighborhoods and communities, helping them prepare for and withstand storm surge. The Recommended Plan should also support recovery efforts, such that communities and industry can return to normal as quickly as possible. Shortening the recovery time requires that households and businesses have access to basic needs. For households, that means shelter, food, utilities, schools, and hospitals, for example. For businesses and industry, that means employees, energy, supply chains, and transportation networks, for example.

This study also provides an opportunity to build ***redundancy*** into the alternatives. In engineering terms, redundancy is the layering of critical components or functions of a system with the intent of increasing the reliability of the system, either in the form of a backup feature, or to improve actual system performance. If a single point of failure is enough to produce catastrophic consequences, the benefits may not be achieved. Where redundancy can be built into feature design, less risk remains from failure of a front line of defense if the plan includes an interior line of defense to mitigate consequences. Redundancy is similar to the multiple lines of defense approach that was taken for formulation of plans. It is a common approach to solving problems, particularly those with low probability-high consequence outcomes. Economic benefits, which are measured in terms of damages avoided, may not capture the benefits of redundancy very effectively when comparing one alternative to another. For example, the benefits provided by redundant features are generally only realized in rare instances when a storm event exceeds the performance limit of one feature, requiring a second feature to provide additional risk reduction.

### RESILIENCY

***Resiliency*** is multifaceted and can best be defined as the ability of a specific system to withstand, recover, and adapt to disturbances.

### REDUNDANCY

***Redundancy*** is the layering of critical components or functions of a system with the intent of increasing the reliability of the system, either in the form of a backup feature, or to improve actual system performance.

### ROBUSTNESS

***Robustness*** is an opportunity to formulate measures within the alternatives that perform under various possible scenarios.

The Study Team considered redundancy in the design and comparison of measures and alternatives. The multiple lines of defense strategy achieves redundancy by designing risk reduction features in locations where they support the function of other features. For example, in the Galveston Bay area, a coastal barrier system can offer redundancy for the existing interior hurricane flood protection system at Texas City. The Texas City system has performed well for 50 years, but an additional line of defense will help increase the life of the Texas City system by reducing the loading frequency.

Another broad opportunity is to develop a plan that performs under a wide range of conditions, in this instance, under a wider range of storm severity, storm tracks, tide, forecast accuracy at the time of the event, and rates of relative sea level change (RSLC). If the plan design is too focused on optimizing a system on one set of assumptions, the optimal outcome only holds true if the storm meets those input assumptions. ***Robustness*** is an opportunity to formulate measures within the alternatives that perform under various possible scenarios. The Study Team considered robustness in the design and comparison of risk reduction systems. Alternative screening compares function in the "with" and "without project" conditions, and across multiple scenarios of RSLC, storm approach, wind driven surges in the bay, and rainfall volumes. Feature design and operation can enhance robustness of the system to ensure improved function of the system features under variable storm scenarios and long-term study area conditions.

### 2.1.1. Planning for Resilience

Resilience represents a comprehensive, systems-based approach to address acute hazards and chronic stressors over time. This study uses the concept of resilience to guide a broad-based, collaborative approach to finding integrated solutions to the erosion, storm, and sea level rise impacts summarized in Chapter 1.

Executive Order (EO) 13653, "Preparing the United States for the Impacts of Climate Change" (November 2013), describes resilience as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions." To help organize resilience activities and describe how resilience measures can be applied, the USACE has divided resilience into four key principles: prepare, absorb, recover, and adapt. These principles provide a lifecycle perspective for resilience-related actions in recognition of the fact that adverse events happen, and conditions change over time.

To incorporate resilience concepts into the study, the team first sought to align the concepts with the familiar 6-step planning framework described above. The planning framework is a


***Figure 2.1:*** *City Resilience Framework*

flexible problem-solving approach that adapts to all water resource studies. Application of the planning framework relies on a clear understanding of how successful outcomes are defined and achieved. Planning objectives were established in Chapter 1 to describe those successful outcomes. Under the Principles and Guidelines (P&G), introduced in Section 1.7, the USACE is required to formulate plans to contribute to the national economy and to identify the plan that maximizes net national economic development benefits. As such, this has traditionally served as the guide to success and the primary decision rule in USACE planning studies.

This study used resilience as a guiding strategy for plan development, while still being mindful of the need to measure national economic effects. To assist the integration of resilience concepts into the traditional National Economic Development (NED) focused process, the study team reviewed the City Resilience Framework (Rockefeller Foundation, 2015) developed to support the Rockefeller Foundation's 100 Resilient Cities program. Figure 2.1 displays the City Resilience Framework. The framework presents a broad, multi-dimensional perspective on the integrated conditions that support resilience within a community. The framework highlights four dimensions of resilience – Health & Wellbeing, Economy & Society; Infrastructure & Environment; and, Leadership & Strategy. These dimensions align well with the four accounts that USACE uses in its standard planning process – Other Social Effects, National Economic Development, Regional Economic Development, and Environmental Quality. Accordingly, the resilience framework offers an opportunity to consider how the effects of the alternative plans would support or hinder resilience in the study area, while still making use of many of the familiar metrics produced in USACE studies. The study team does not, however, claim that the framework was fully utilized as intended in the 100 Resilient Cities program.

### 2.1.2. Plan Formulation Considerations

Plan formulation follows the steps discussed above, which are graphically presented in Figure 2.2. Initially, planners and scientists review the study area, documenting problems and opportunities that will shape how to approach the study. Once identification of problems and opportunities is achieved, planning goals and objectives are developed to address those problems and opportunities. Objective criteria are established that can be applied to gauge how well the goals and objectives address the problems and opportunities identified. These problems, opportunities, goals, and objectives are detailed further in Section 1.6.

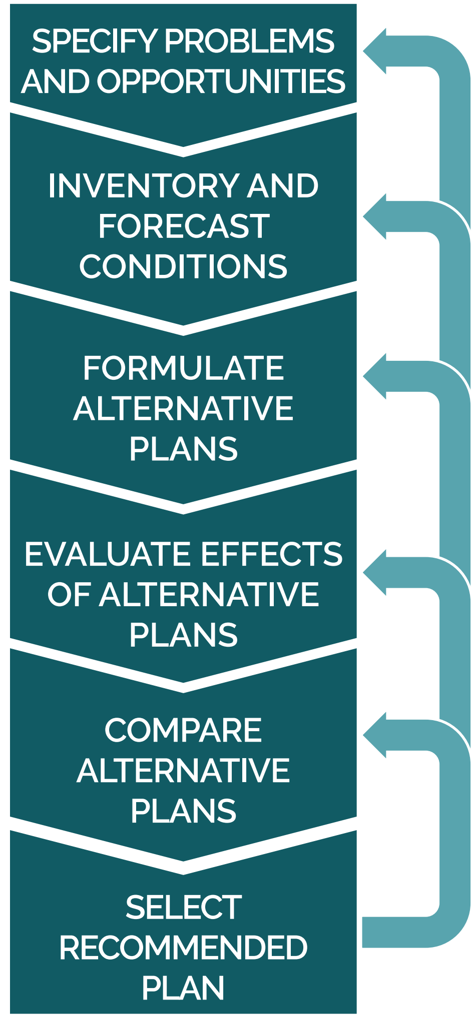



***Figure 2.2:*** *USACE Planning Process*

### 2.1.3. Planning Criteria

The P&G establishes four criteria for evaluation of water resources projects: effectiveness, efficiency, completeness, and acceptability. Benefits, costs, and social & environmental impacts are used to judge the degree to which an alternative plan meets these criteria

- ***Effectiveness*** is the extent to which the alternative plans achieve the planning objectives of the study. In other words, does the plan address the problem? This is reflected in the benefits and positive effects of the plans. Resilience implies that the effectiveness of a plan persists over time, but future adaptation maybe required.
- ***Efficiency*** is the extent to which an alternative is cost-effective while meeting the planning objectives. This is reflected in the comparison of costs to the beneficial outcomes. Efficiency should not come at the expense of flexibility, however. Resilience requires the flexibility to in-corporate future adaptations in complex risk situations.
- ***Completeness*** is the extent to which the alternative plans include all necessary actions and costs to achieve the planning objectives and the benefits that are claimed for each plan. Again, resilience adds a future aspect to the consideration of completeness. What future adaptations may be required to address changing conditions?
- ***Acceptability*** is the extent to which the alternative plans comply with applicable laws, regulations and public policies. Environmental and social impacts are assessed, with the intent to avoid or minimize to the extent practicable, then utilize appropriate mitigation actions.

The performance of measures and alternatives are compared to a baseline condition, called the "future without project" condition, to assess whether there are actions that can be taken to achieve the planning goals and objectives. Plan development starts as small increments, or "measures", proposed to address specific risks and localized problems and opportunities within subareas in the study area. The measures are defined and evaluated, and the ones that effectively address the problems in the most cost-effective manner are combined, forming alternative plans. Alternative plans are assembled according to engineering strategies and economic justification to create a thorough set of possible solutions. These alternative plans are compared for benefits to people, property, and natural habitats; engineering performance; project cost; and environmental impacts, until a comprehensive cost-effective solution is identified and labeled either the Tentatively Selected Plan (TSP) or the Recommended Plan.

Engineering and economic models are applied to characterize the performance of the alternative plans using consistent measurement units. As an example, engineering models estimate storm surge risk in terms of height of surge and extent of flooding, described as water surface elevations. When those data are combined with the location of people, property, and critical infrastructure vulnerable to flood risk, consequence models estimate potential threat to the population and damages to property across an array of different storm events.

The same models measure the relative performance of alternative plans by estimating the height of surge and extent of flooding as if the alternative plan were in place, and the risks reduced as a result. The difference between the consequences without and with an alternative plan are the plan's benefits. The primary economic benefit is the avoided damage to property, like homes, businesses, roads, utilities, and industry.

Other benefit metrics include the reduced safety risks to the population, and avoided damage to critical systems, such as roads, ports, hospitals , and other similar infrastructure, that impact regional support systems, economic productivity and growth, and ongoing community support systems that maintain health and wellbeing.

Engineering models can also be applied to estimate environmental impacts of the alternative plans. If alternative plans perform comparably, alternative plans that create fewer negative impacts are carried forward for further evaluation. If negative environmental impacts cannot be avoided, mitigation is required to compensate for negative impacts. The cost of mitigation also affects the cost effectiveness of alternative plans, since plans that require extensive mitigation increase the overall cost of that alternative plan.

Screening of ecosystem restoration (ER) alternatives compares measures to baseline conditions but is measured with different tools than those for coastal storm risk management (CSRM) projects. Federal policy for USACE projects does not allow for monetization of environmental impacts/benefits. Rather, biological models estimate plan performance in creation of "habitat units". Through a cost effectiveness/incremental cost analysis process, a plan's creation of habitat units can be optimized for cost-effectiveness and recommended for Federal interest.

Further detailed information on the economic analysis of CSRM features and the cost-effectiveness and incremental cost analysis of ER features can be found in Appendix E, the Economics Appendix.

## Measuring Benefits

Economic damages are expressed as average annual equivalent values that reflect the time value of money. Economic damages are discounted over the project life to a point in time, the base year (the first year of the project life), and then amortized over the 50-year project life. Damages and damages reduced (benefits) are correctly expressed as average annual equivalent values. Costs of the project are treated in the same way, with project costs amortized over the 50-year project life so that uniform comparisons can be made between costs and benefits of a project. The Federal discount rate and price levels current to the study period are applied for the calculation of average annual equivalent values for both costs and benefits.

Cost effectiveness is measured by comparing benefits to costs. For CSRM, the USACE screening process defines specific categories of damages avoided, measured in dollars, as NED benefits, or contributions to the national economy. When NED benefits are shown to be larger than the costs of construction and operation of the alternative, it is considered to be cost effective and eligible for consideration for Federal funding. The alternative plan that produces the greatest benefits when costs are subtracted is identified as the NED Plan.

### 2.1.4. Iterative Planning Considerations

Decisions about which alternative plans or measures to carry forward in the planning process are made in steps, incrementally. Initial comparisons can choose from conceptual descriptions based on professional judgment or available data about performance, comparisons of impacts, or relative costs. As project measures are refined, or as more detailed information about plan performance and area conditions and impacts become known, alternative plans may be screened from further consideration. When additional detail is needed to choose between alternative plans or measures, the Study Team will conduct additional analyses to generate information necessary to reduce uncertainties and to refine the decision-making process.

This iterative process supports reducing the duration and cost of studies by conducting the necessary technical analyses at each stage of the study. The risk informed decision making process is designed to speed the publication of the draft plan and to seek agency and public comment on the proposed plan as quickly as possible.

Throughout the plan formulation process, public input is encouraged. The public helps USACE planners and scientists to understand the problems and opportunities and to develop goals and objectives that guide the full process, leading to the development of both the TSP and the Recommended Plan. The Recommended Plan is what is presented to Congress for approval and funding.

## 2.2. Public Involvement and Consultation

Throughout the planning process, in accordance with USACE planning guidelines and National Environmental Policy Act (NEPA) requirements, a proactive approach was taken to solicit input from the public and other interested parties. As discussed in Section 1.9, these efforts started with formal scoping meetings in 2014, included multiple other opportunities for engagement over the years, and extended through the publication of the Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR-EIS) in 2018 and associated public meetings. In addition to this regular proactive coordination, the Study Team has met with various community and stakeholder groups upon request to provide study updates and address concerns. In addition to the public outreach summarized in Section 1.9, scoping activities and agency consultation activities related to the Coastal Texas Study are summarized in the following sections. Further information on revisions made to the Study based on public input are included in Section 2.10.

*Members of the public attend a Public Meeting on Bolivar Peninsula held in December 2018.*

### 2.2.1. Scoping

Two types of public engagement are required by the NEPA process. The Study Team must hold a NEPA Scoping Meeting to obtain public input on the scope of the study and to gather local expertise that can be applied to the study. Once a Draft Feasibility Report and Draft EIS are prepared, a public meeting is required during the public review period. The Scoping meetings generated public input that was used in the initial formulation of conceptual alternatives.

A Notice of Intent was published in the Federal Register at the beginning of the Reconnaissance Study and public meetings were held to capture the stakeholder input of all the problems and opportunities along the entire Texas coast. The Notice of Intent indicated that the same scoping meeting input would be used for the Feasibility Study.

To support this effort, the GLO developed an overview of issues affecting the Texas coast, entitled "The Texas Coast: Shoring Up Our Future." This document identified the issues of concern as wetland/habitat loss, water quality and quantity, impact to fish and wildlife, impact to marine resources, Gulf beach/dune erosion, bay shoreline erosion, flooding and storm surge, tourism/local economy, along with other 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 Feasibility Study and EIS.

A series of scoping meetings were initially held in February and March 2014 along the upper Texas coast, as a part of the Sabine Pass to Galveston Bay Feasibility Study. Meetings in Seabrook, Beaumont, Freeport, and Galveston, Texas, sought ideas for storm risk reduction and habitat restoration opportunities in the upper Texas coast region of the study area. In August 2014, additional scoping meetings were held in Palacios, Corpus Christi, and South Padre Island, Texas, to collect similar information for the remainder of the Texas coast. These meetings requested input from the counties identified in mid to lower Texas coast regions of the study area. An additional meeting was held in League City to update the public on the activities in the upper Texas coast.

Scoping input from Federal, state, and local agencies, Tribal Nations, and other interested private organizations and parties was solicited with publication of the Notice of Intent in the Federal Register on March 31, 2016 (see attached Final EIS, Chapter 7). In addition to the request for scoping comments on the Notice of Intent, a separate Scoping Notice announcing the USACE's request for scoping comments was also sent via email to affected and interested parties. Scoping comments were requested, consistent with the Notice of Intent, to be provided between March 31, 2016, and May 9, 2016. Scoping comments were requested to identify:

- Affected public and agency concerns;
- Scope of significant issues to be addressed in the Feasibility Report and EIS;
- Critical problems, needs, and significant resources that should be considered in the Feasibility Report and EIS; and
- Reasonable measures and alternatives that should be considered in the Feasibility Report and EIS.

A total of 2,108 scoping comments, letters, and emails were received during the comment period, with the vast majority of the comments submitted by non-governmental organizations (NGOs). The top five themes identified from the scoping comments included:

1. Address impacts due to human development and population growth.
2. Significant natural resources that could be negatively impacted by a coastal barrier risk reduction system.
3. Changes to natural resources should focus on nonstructural solutions and disclose biological effects.
4. Solutions must protect the coastal environment and must disclose biological effects.
5. Alternatives should include nature-based solutions that improve access to outdoor recreation and conserves Texas's diverse coastal ecosystems.

A summary of the comments received during scoping can be found in the Scoping Report and the Addendum to Scoping Report (see attached Final EIS). Additional comments were also received outside the scoping comment period from the Sierra Club and private parties and are included in attached Final EIS.

### 2.2.2. Agency Coordination

An interagency team of Federal, state, and local agencies and Tribal Nations met monthly to discuss study progress and environmental issues related to the Coastal Texas 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, 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 Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA) / National Marine Fisheries Service (NMFS), and the Bureau of Ocean and Energy Management (BOEM).

Individual coordination meetings with resource 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 Draft EIS sections occurred in June 2018 and September 2018. An in-person meeting with representatives from the U.S. Fish and Wildlife Service (USFWS) was held in October 2017, where USACE and GLO staff presented information including the Coastal Barrier Resources Act (CBRA), critical habitat, beach nourishment, overall project impacts, mitigation needs, Endangered Species Act (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 continued through the remaining phases of the study, as is detailed in the Final EIS.

Additional information on coordination with the resource agencies, and the environmental evaluation and documentation process in general, can be found in Chapter 4 of this report and in Chapter 7 of the attached Final EIS. Chapter 4 also discusses the multi-staged, or tiered, process employed to comply with NEPA requirements while efficiently advancing the study.

## 2.3. Future Without Project Condition

The future without project condition is the most-likely future conditions in the study area in the absence of a proposed project, over a 50-year time period. For planning and initial evaluation purposes, the base year for analysis was estimated as 2035, with the period of analysis running through 2085. The future without project condition serves as the base condition for the analyses of alternatives, including the engineering design, economic evaluation of alternatives, comparison of alternatives, as well as environmental, social and cultural impact assessment. The future without project condition is a forecast based upon what has actually occurred, is currently occurring, or is expected to occur in the study area if no actions are taken as a result of this study. As it is impossible to predict the future, the without project condition represents the most likely future scenario (not the only future scenario), based upon reasoned, documentable forecasting of what is most likely to occur, and based on historic practices and expected future trends.

The future without project condition was established based on the following primary assumptions (additional assumptions are listed in Appendix A):

1. Coastal storms will occur in a manner and frequency similar to those that have historically occurred.
2. Relative sea level rise will continue and the uncertainty of the timing of RSLC is captured by the range of RSLC over the project life.
3. Future development will be undertaken consistent with existing regulations.
4. No improvements are made to existing hurricane protection projects.
5. Maintenance of Federal navigation projects are expected to continue in the future.
6. Projects that have been completed (existing), are under construction, or have been authorized for construction are reflected in this analysis as if they existed.

The existing coastal barrier systems (barrier islands, shorelines, and headlands) and estuarine bay shorelines and marsh across the Texas coast, while still relatively intact, are critical geomorphic or key landscape features that are experiencing substantial land loss. According to the Bureau of Economic Geology, the Texas coast shoreline has averaged 4.1 feet per year of retreat from 1930 through 2012 with net shoreline retreat along 80 percent of the shoreline. The annual rate of land loss along the Texas Gulf shoreline (through 2007) is 178 acres per year. Average rates of retreat are higher (5.5 feet per year) along the upper Texas coast than on the mid and lower coast (3.2 feet per year).

The average annual equivalent damages that are likely in the future without project scenario are summarized in Table 2.1. This analysis was undertaken considering low, intermediate, and high rates of RSLC in the future, as discussed in Section 1.4.3. This analysis shows that there is a potential for significant damages along the Gulf shorefront and in and around Galveston Bay.

These dollar damages are estimated as a baseline for comparison of alternative plans and for measuring relative economic performance. Additional economic information on the future without project condition can be found in Appendix E, the Economics Appendix.

| Total Equivalent Annual Damages 2035-2085 (FY20 Price Level, 2.75% Discount Rate, Presented in $ millions) | | |
|---|---|---|
| | Damage Category | Equiv. Annual W/O Project Damages |
| **Low Sea-Level Rise Scenario** | Residential & Commercial - Structure/Content/Vehicles | $ 2,134 |
| | Transportation Infrastructure | $ 338 |
| | Aboveground Storage Tanks | $ 52 |
| | **Total Damages** | **$ 2,524** |
| **Intermediate Sea-Level Rise Scenario** | Residential & Commercial - Structure/Content/Vehicles | $ 2,854 |
| | Transportation Infrastructure | $ 441 |
| | Aboveground Storage Tanks | $ 60 |
| | **Total Damages** | **$ 3,354** |
| **High Sea-Level Rise Scenario** | Residential & Commercial - Structure/Content/Vehicles | $ 5,876 |
| | Transportation Infrastructure | $ 781 |
| | Aboveground Storage Tanks | $ 86 |
| | **Total Damages** | **$ 6,744** |

***Table 2.1:*** *Future Without Project Average Annual Equivalent Damages (Galveston Bay Area)*

| Formulation Strategy Developed | Methodology for Strategy |
|---|---|
| Multiple Lines of Defense | The strategy works on the well-founded premise that coastal Texas must be protected from hurricane surge by both man-made features, such as barriers, and by the natural dunes, beaches, and wetland coastal features along the Texas coast. Levees alone will not meet all objectives. Together, a healthy coastal estuary, beaches, and appropriately designed barrier system can sustain Texas's ecology and economy of the coast. |
| Resiliency | The strategy focuses on ER measures that would provide resiliency to existing CSRM features or proposed CSRM features. The strategy also focuses on including nonstructural measures that would increase the resiliency of coastal communities. |
| Focus on Significant Resources | The strategy focuses on ER measures where they would restore or protect key nationally significant migratory bird habitat, critical threatened and endangered species habitat, and critical essential fish habitat areas. |
| Navigation Impacts | The strategy focuses on ER measures which repair or prevent future damages to the coastal ecosystems from USACE navigation projects. |
| Limited Impacts to Navigation | The strategy focuses on CSRM measures that would have limited impacts to existing navigation features. |

***Table 2.2:*** *Key Considerations and Strategies for Achieving Goals and Objectives*

## 2.4. Approaches Considered

The study authorization directed the Study Team to evaluate ER and CSRM solutions. These two purposes recognize that the study area is vulnerable to both storm risk and gradual coastal processes that wear away natural coastal areas and habitats. Residents and visitors are familiar with the risk to life and damage to structures that occur when a coastal storm brings surge flooding to communities along the Gulf coast, in addition to the damage that high winds and rainfall flooding cause.

As communities grow larger and become more densely developed along the coast, natural features are altered. The natural coastal processes that allow barrier islands to roll over and replenish sediment over time are interrupted. The hardening of existing shorelines and roadway construction degrade coastal landforms and habitats. To address the problems and opportunities described in Section 1.6, the planning strategy taken reflects the conflict and complementarity of uses along the coast. Table 2.2 defines several of the key considerations or opportunities/strategies for the Study Team. A broader discussion of multiple lines of defense and comprehensive approaches is provided in the following sections.

### 2.4.1. Multiple Lines of Defense

The plan 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 of Mexico. The series of defenses 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 Texas' bays. This combination of lines of defense and ER is intended to provide redundant levels of protection for both humans and coastal ecosystems.

The restoration strategy employed recognizes the value of making a meaningful impact. Accordingly, large scale measures were considered necessary to address years of impairment to natural coastal features. The strategy sought to restore features that support significant resources and to maintain diversity of habitat along the coast.

# Evaluation of Managed Retreat

Considerations related to "managed retreat" were formulated as part of the multiple lines of defense evaluation, however it was determined not to be a practicable and standalone solution. A standalone managed retreat scenario, whereby development retreats inland away from coastal risks, rather than addressing storm surge, inundation, and erosion through structural alternatives, is a significant challenge along the Texas coastline.

Experiences with managed retreat in other locations have identified similar challenges to implementation. Social and livelihood losses, jurisdictional conflicts, and lack of political will inhibit the effectiveness of impactful retreat. Residents of all income levels can feel economic and social losses from relocation. Furthermore, regional governments often resist the loss of tax base from relocations, or support residents who recognize and accept the flood risk and resist relocation. The risk-prone areas are found in both broad and densely populated areas.

A review of managed retreat options was conducted as CSRM measures were developed. The effort focused on the upper Texas coast due to the area's risk and projected RSLC impacts in the future. A managed retreat project would require the acquisition of between 60,000 to 85,000 properties over a 50-year period, and could increase under different RSLC scenarios or with increased floodplain management restrictions. Currently, many of the urban areas around Galveston Bay are discussing ordinances requiring construction of new structures above either the 200-yr or 500-yr flood elevations. In 2018, for example, the City of Houston required all newly built homes to be elevated at least 2 feet above the 500-yr flood elevation. Extending managed retreat to areas outside the 100-yr floodplain, as certain municipalities are currently doing, has the potential to significantly increase the cost of managed retreat.

The efforts showed that under the existing conditions, a modeled 100-yr storm would impact over 60,000 structures. The evaluation showed that the impacted structures would have a depreciated replacement value of $20.8 billion. However, this value only represents a portion of the cost to implement a managed retreat plan. Homeowners would also have to be compensated for loss of the use, in addition to the replacement value. These land values could vary anywhere from 50% to 100% of the depreciated replacement value, placing the overall cost well over $30 billion. This cost also doesn't include future costs of managing the lands acquired, or removal of utilities.

Also, by focusing on structures impacted by 100-yr surges, and not by the area of the floodplain; a managed retreat plan would lead to a patchwork of structures and properties being acquired, since many structures have already been raised above the existing 100-yr flood elevations. This approach would have significant impacts on community cohesion and would leave local municipalities with a patchwork of utilities and services to manage.

An overall managed retreat plan would have to focus on not only structures impacted by more frequent storm stages, but on areas or properties included in a particular floodplain regardless of the elevation of the structure. This would support a complete retreat from high-risk areas and would ensure that as the surge levels change over time, due to changing RSLC, all structures would be included.

The team reviewed the 2085 100-yr floodplain and determined that an estimated 85,000 structures would be located within the floodplain. The evaluation showed these structures would have a depreciated replacement value of $28.3 billion, with a total retreat cost of over $50 billion. By extending relocation to all structures within the 100-yr floodplain, this approach would address the challenge of patchwork acquisitions and would allow local municipalities to focus exclusively on providing services and managing utilities in locations outside the current and future 100-yr floodplain. Implementing this method for storm events such as the 200-yr or 500-yr, would only increase these costs. This effort showed that the cost for a comprehensive managed retreat plan would significantly exceed the overall benefits. In addition, the acquisition strategy would likely face legal challenges, which would have cost and schedule implications that do not achieve the study goals and objectives to reduce risk to life and reduce flood damage in the period of analysis. In coastal areas, where residents and business are tied to the coastal landscape, there is historical evidence to show residents don't fully retreat from the coast, but rather retreat vertically, using methods such as home raising or rebuilding at a higher elevation.

Rather than completely removing the managed retreat options, the team determined that a managed retreat option could work in combination with a structural system to manage residual risk and address changes in future conditions. Accordingly, managed retreat could be considered as a future adaptation to help the region continue to adapt to changing risks, but is not explicitly included as part of the Recommended Plan for the reasons described above.

Restoration measures provide redundant and resilient levels of protection and restoration for both humans and coastal ecosystems. The interpretation of each of these multiple lines of defense themes is presented below:

- ***1st Line of Defense – Barrier Systems***: includes barrier shorelines, islands, and headlands as well as barrier beach, dune, and back marsh. Restoration of this line of defense includes consideration of barrier system ecological and geomorphic functions.
- ***2nd Line of Defense – Estuarine Bay System:*** includes geomorphic bay features and estuarine habitats including bay shorelines and estuarine marsh, bird rookery islands, oyster reefs, and seagrass beds. Restoration of this line of defense includes consideration of estuarine and bay ecological and geomorphic functions.
- ***3rd Line of Defense – Bayhead Deltas:*** includes bayhead deltaic features and associated habitats including adjacent bird rookery islands, reefs, subaquatic vegetation, and marsh. Restoration of this line of defense includes consideration of bayhead delta ecological and geomorphic functions.

### 2.4.2. Comprehensive Approach

The Coastal Texas Study planning process aimed to identify projects needed to support a comprehensive state-wide approach to CSRM and ER, recognizing the great differences in coastal storm risk and restoration needs across the full Texas coast, and considering the concurrent and complementary actions being advanced by local partners, such as the GLO. Accordingly, measures were not proposed in areas with low risk for coastal storm damage. And both CSRM and ER measures were coordinated closely with ongoing or proposed restoration projects included in the State's Coastal Resiliency Master Plan, in addition to the various adjacent USACE led projects such as Sabine Pass to Galveston Bay. By coordinating efforts across projects and between different entities, the study achieves its goal of identifying the specific projects necessary to fill in the gaps of a state-wide comprehensive CSRM and ER program.

In addition, the Coastal Texas Study presented an opportunity to address multiple problems and opportunities in a holistic way, combining ER and CSRM measures into a more resilient and comprehensive approach to protection and restoration. Accordingly, the CSRM alternatives were assembled with a systems approach to reduce risk. ER features that maintain and achieve diverse coastal habitats are critical to restoring coastal features and the species that thrive there. Marsh, beach, estuaries, and coastal prairie provide habitat to support varied plant species, which support diverse bird species. Critical components of the ER system include coastal prairie and hypersaline lagoons, both of which are addressed within an ER measure to restore sites in the study area that are recognized as unique examples of rare habitat. In addition, the Galveston Bay region required features that connected to existing systems and functioned together to impede storm surge and address residual risk. Features that are adaptable over time, under different sea level change scenarios, were included to ensure the alternatives were comprehensive. For example, beach-fill is highly adaptive in the short term, while Seawall elevation and interior gates are scoped as later adaptations.

The strategy also considered whether alternatives could address multiple objectives to reduce:

- Health and safety risks to the human population;
- Damage risks to assets and infrastructure;
- Interruption risks to business and navigation channels; and
- Degradation risks to ecosystems.

The alternatives are also multi-purpose, addressing the USACE's missions in CSRM, ER, and navigation, all of which are impacted by coastal storms and losses in the region.

## 2.5. Summary of the Planning Process

Three primary iterations occurred during the planning process, as follows:

- **Conceptual Plans:** Evaluates potential measures and assesses effectiveness. The section below provides an overview of the screening process to develop a comprehensive list of individual ER and CSRM measures and to refine a combination of ER and CSRM measures to achieve overall study objectives.
- **TSP Selection:** Quantifies and compares benefits and impacts to identify the TSP (NED and National Ecosystem Restoration [NER]), supporting publication of the 2018 DIFR-EIS (1st Draft Report).
- **Integration and Refinement:** Refining the TSP, considering public, agency, and technical comments, in addition to further technical refinement, to identify the Recommended Plan, which was presented in the 2020 Draft Feasibility Report (2nd Draft Report), and further refined in this Final Feasibility Report.

A summary of the planning process, then a more detailed look at both ER and then CSRM measures, is presented in the following sections. As discussed in the following sections, this concludes with the identification of the TSP and its ultimate refinement into the Recommended Plan. Further information on each of these plan formulation steps can be found in Appendix A, Plan Formulation.

## 2.6. Development of ER and CSRM Measures

In the Conceptual Plans phase; management measures, defined as features or activities that can be implemented at a specific geographic site to address one or more planning objectives, were developed for each of the four planning regions of the Texas Coast. Measures were developed to address problems and to capitalize upon opportunities. The objective of the ER measures was to restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition, while CSRM measures are proposed to reduce flood damage to property and infrastructure, and increase the resilience of coastal populations against storm surge damage. Measures were selected from a variety of sources including prior studies, the public scoping process, and professional judgment of the study team and the resource agencies.

The initial list of measures considered included ninety-two (92) different measures across all four of the planning regions. Evaluations also included measures that could potentially be constructed under other authorizations (e.g. CAP, CIAP, RESTORE, CEPRA, NRDA, etc.). These measures were included to inform a more comprehensive approach to the planning effort. For example, measures investigated under the Sabine Pass to Galveston Bay study were initially included in the measures list. An overview of the measure screening process planning process is shown and on Figure 2.3, with further discussion provided in Appendix A.

Following the planning process, an initial step was to determine if the management measures identified met the overall planning objectives discussed in Section 1.6, in addition to region-specific planning objectives discussed further in Appendix A.

Evaluations of the measures considered numerous planning constraints. For example, the initial screening of the CSRM management measures used the current 100-year and 500-year FEMA floodplains paired with the national structure inventory as a metric for screening based on the objective to "Reduce economic damage from coastal storm surge to business, residents, and infrastructure along the Texas coast." The evaluation showed that many of the structures in the middle regions of the Texas Coast were outside of the areas of high risk from surges or were elevated above these surge impacts. The evaluation also showed that more frequent surges impacted the upper and lower Texas coast. Locations such as Corpus Christi had less risk from coastal storm surges due to the area's location in the coastal

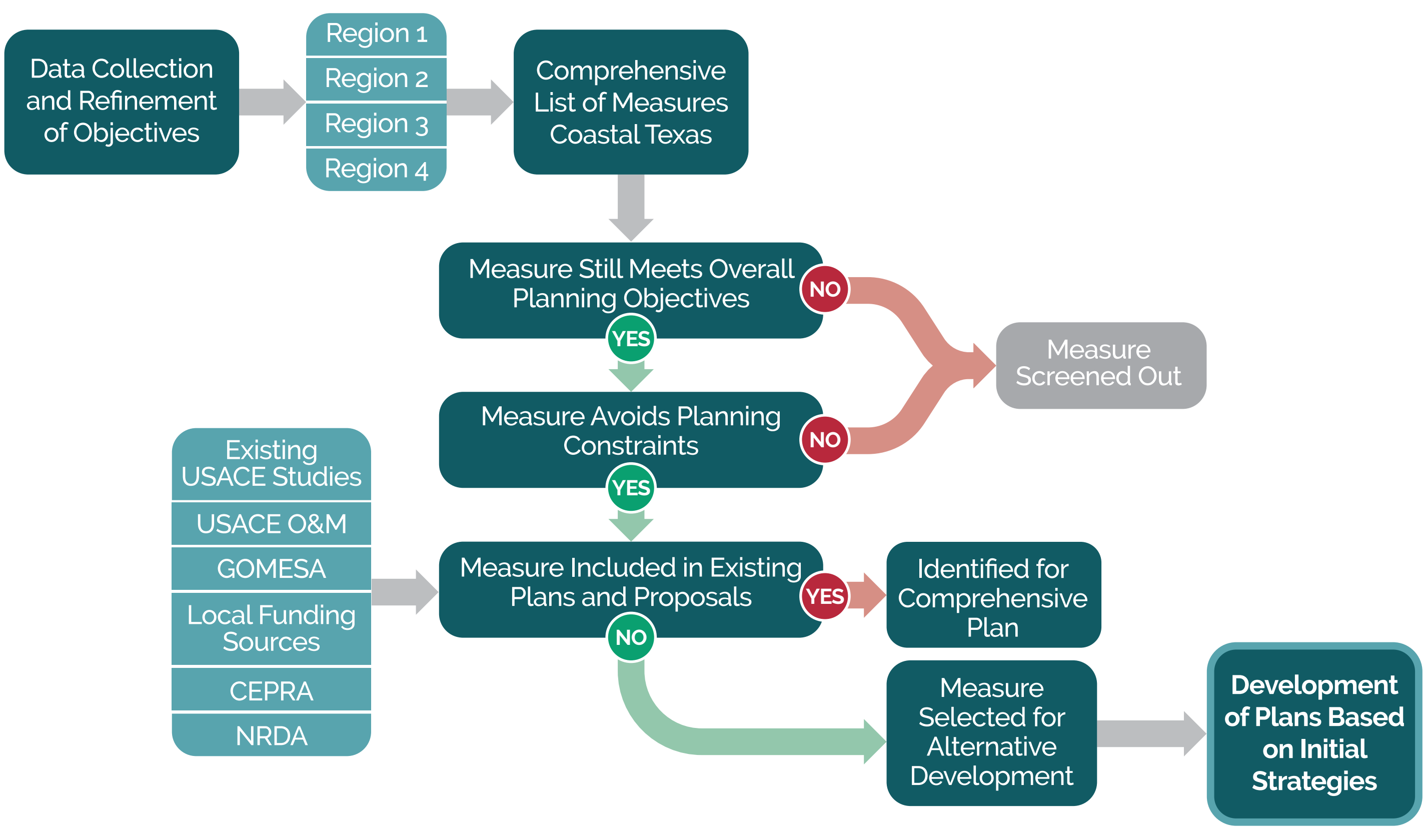



***Figure 2.3:*** *Measure screening process planning process*

landscape and previously elevated structures sitting above frequent surge elevations. Further, the evaluation showed that many of these areas could be supplemented with more natural and nature-based features, where nonstructural and structural measures could be used as part of an integrated approach to flood risk management, while delivering a broad array of ecosystem goods and services to local communities.

The initial screening of ER management measures used the historical shoreline and land loss rates to determine areas of significant concern. The Texas Coast Shoreline Change Rate was a key metric for screening measures along the gulf front, while the NOAA sea level rise viewer showing historical and potential future losses was a key tool in evaluating inland ER sites. The key metric at the time of screening was acres to be improved or created and resource significance.

The initial list of measures were also grouped by NER, NED, and measures that provided qualitative NER or NED benefits in addition to the primary quantitative benefits. Before measures were screened, the list was reviewed for measures that currently are being investigated under other study efforts to inform the comprehensive planning effort. Measures that were being implemented by others were still included in the list for evaluation of contributions to the goals and objectives, however they were not considered for the inclusion in the array of alternative plans developed after the screening process.

A matrix of measures in each region was developed and the Study Team scored each NER and NED measure by Exceeds, Meets, No Change, or Decreases the objectives of the study. The matrix of measures was also scored on the ability to avoid the study constraints. Measures were given a score of High, Medium, Low to no issue or not applicable, or Conflicts with the constraint. Using the matrix, the study team screened the measures based on those which best meet the planning objectives while avoiding the study constraints. Each included a final discussion for the inclusion or screening.

Although many of the remaining measures produce benefits that could be assigned to the four P&G accounts; National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), or Other Social Effects (OSE), the Coastal Texas Study presented an opportunity to address multiple problems and opportunities in a holistic way, by combining ER and CSRM measures into a comprehensive approach to protection and restoration. Accordingly, the CSRM measures were assembled with a systems approach to reduce risk. Many of the ER measures serve as natural and nature-based features critical to achieving diverse coastal habitats and restoring coastal features and the species that thrive there. Marsh, beach, estuaries, and coastal prairie provide habitat to support varied plant species, which support diverse bird species. Critical components of the ER system include coastal prairie and hypersaline lagoons, both of which are addressed within various ER measures which recognize the importance of these rare habitats. In addition, the Galveston Bay region included measures that connected to existing systems and functioned together to impede storm surge and address residual risk. The remaining measures were ones that were adaptable over time, under different sea level change scenarios, and could be combined into comprehensive alternatives. For example, beach-fill is highly adaptable in the short term, while Seawall elevation and interior gates are scoped as later adaptations.

As discussed in section 2.4.1, an approach emphasizing multiple lines of defense was considered in the development of the alternatives. By focusing on different alternatives spanning the 1st Line of Defense – Barrier Systems, the 2nd Line of Defense – Estuarine Bay Systems, or the 3rd Line of Defense – Bayhead Deltas, benefits could be achieved across the four P&G accounts. Varying these strategies helped to assess whether different alternatives could address multiple study goals and objectives (as detailed in Table 1.2). Table 2.3 details the established metrics associated with each objective.

Although ultimately no CSRM measures were proposed for the Mid to Upper Texas Coast and the Mid Texas Coast, due to either reduced risk to communities and infrastructure or the presence of existing coastal protection systems, the proposed ER measures represent critical features alongside the State's Coastal Resiliency Master Plan which fill in the gaps of a resilient and comprehensive approach to risk reduction and restoration along the Texas Coast.

| Goals | Objectives | Metrics |
|---|---|---|
| ***COASTAL STORM RISK MANAGEMENT*** *Promote a resilient and sustainable economy by reducing the risk of storm damage to residential structures, industries, and businesses critical to the nation's economy* | 1. Reduce risk to human life from storm surge impacts along the Texas coast; | Dollar damages reduced |
| | 2. Reduce economic damage from coastal storm surge to business, residents, and infrastructure along the Texas coast; | Population at Risk |
| | 3. Enhance energy security and reduce economic impacts of petrochemical supply-related interruption due to storm surge impacts; | REMI dollar denominated economic losses reduced |
| | 4. Reduce risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.) from storm surge impact; | Number/proportion of critical infrastructure removed from risk |
| | 5. Manage regional sediment, including beneficial use of dredged material from navigation and other operations so it contributes to storm surge attenuation where feasible; | Yes / No – Achieves RSM |
| | 6. Increase the resilience of existing hurricane risk reduction systems from sea level rise and storm surge impacts; and | Yes / No – Increases resilience of existing hurricane risk reduction systems |
| | 7. Enhance and restore coastal geomorphic landforms that contribute to storm surge attenuation where feasible. | Yes / No - Enhances & restores coastal geomorphic landforms |
| ***ECOSYSTEM RESTORATION*** *Promote a resilient and sustainable coastal ecosystem by minimizing future land loss, enhancing wetland productivity, and providing and sustaining diverse fish and wildlife habitats* | 1. Restore size and quality of fish and wildlife habitats such as coastal wetlands, forested wetlands, rookery, oyster reefs, and beaches and dunes; | Net Average Annual Habitat Units (AAHUs) |
| | 2. Improve hydrologic connectivity into sensitive estuarine systems; | Yes / No - Improves hydrologic connectivity |
| | 3. Reduce erosion to barrier island, mainland, interior bay, and channel shorelines; | Yes / No – Reduces erosion |
| | 4. Create, restore, and nourish oyster reefs to benefit coastal and marine resources; and | Net AAHUs |
| | 5. Manage regional sediment so it contributes to improving and sustaining diverse fish and wildlife habitat. | Yes / No – Achieves RSM |

***Table 2.3:*** *Metrics Associated with Study Goals and Objectives*

## 2.7. Ecosystem Restoration

Identified ER measures restore beach, island, oyster, or marsh habitat. Many of the restoration measures were drawn from the GLO's Coastal Resiliency Master Plan, past USACE studies, NEPA public scoping, and resource agency suggestions. Additional ideas were developed from professional judgment of future without project conditions of vulnerable habitats, and from GIS mapping. The complete list of measures evaluated during this process can be found in Appendix A. During the conceptual phase of screening, the restoration measures were evaluated and refined by an interagency team who screened them for performance, viability, and whether the measures would likely achieve the planning goals and objectives.

The conceptual screening of measures was completed in a series of inter-agency meetings to confirm current area conditions and to review and refine features. As discussed in Section 2.6, initial screening removed features that were found to be in development by others, that did not produce high environmental outputs, or which were too conceptual in nature and determined not to be feasible. Most ER features that were screened out were excluded because they were found to be in development by others. In several instances, similar actions in adjacent areas were combined into one larger measure. For example, Measure B5 (Bastrop Bay, Oyster Lake, and West Bay Shoreline Protection) was combined with Measure B6 (Brazoria County Gulf Intracoastal Waterway [GIWW] Shoreline Protection), because they were not considered separable elements, and were renamed to B12. G12 East and G12 West were combined with G13 East and G13 West to create measure G28. In addition, W1 and W2 were combined to create one measure, W3, when it was decided that the material dredged from the channel in W1 could be used beneficially for beach nourishment and for additional restoration of Mansfield Island proposed in W2. Section 4.2.3 of Appendix A, the Plan Formulation Appendix, provides more detail on the ER screening process.

A spatial analysis using the NOAA Marsh Migration Viewer, as shown in Figure 2.4, identified vulnerable ecosystems threatened by RSLC. The analysis confirmed that RSLC will impact critical ecosystem features and habitats along the Texas coast, as wetland and estuarine environments evolve into open water or unconsolidated shoreline.

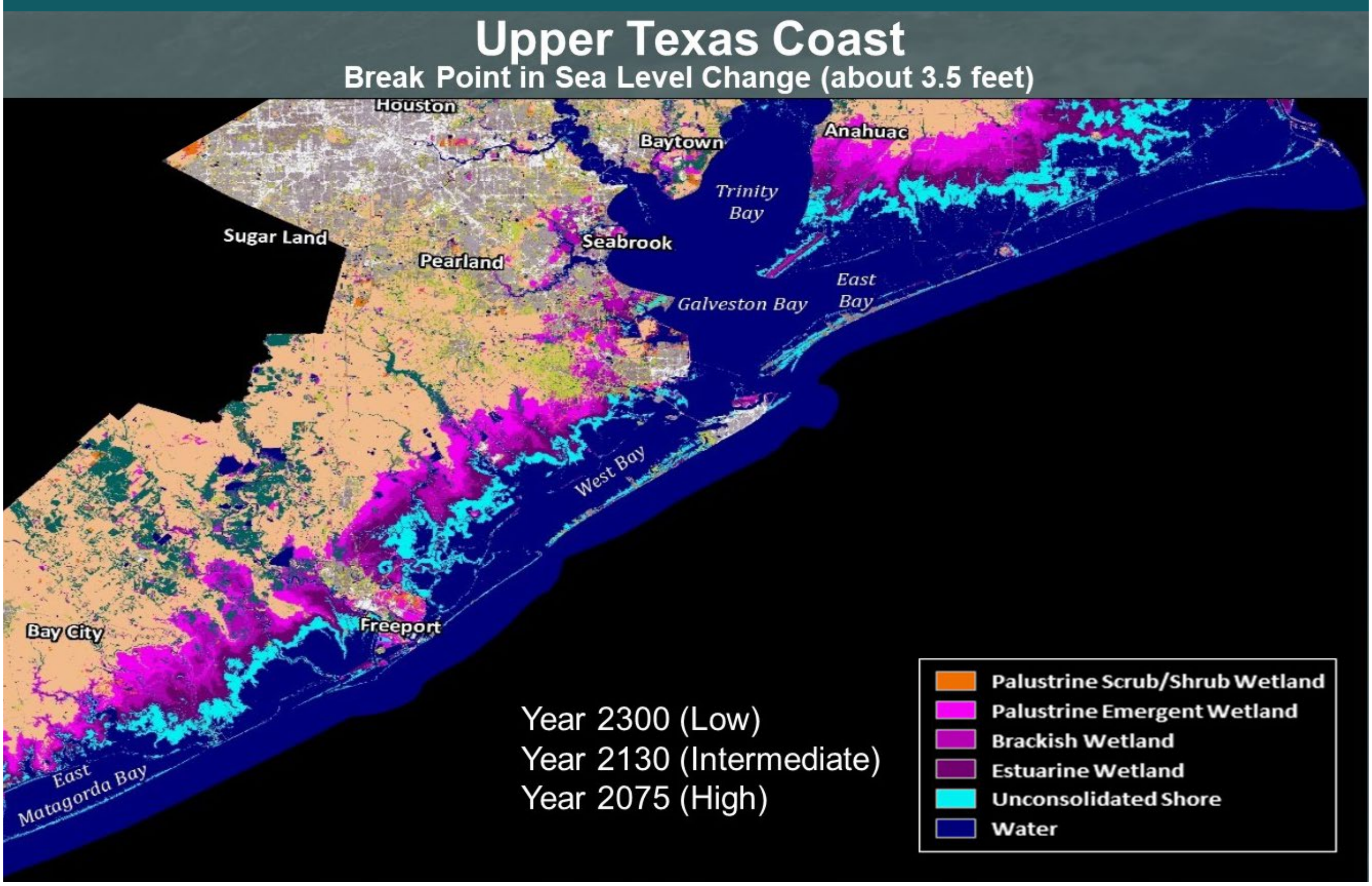



***Figure 2.4:*** *Projected Conversion of Landforms/Habitats due to Sea Level Change, Upper Texas Coast*

### 2.7.1. Performance and Costs of ER Measures

The benefits of an ER action are measured as the change in environmental outputs between future with project and future without project conditions. Habitat units (HUs) are derived by multiplying habitat suitability indices by the areas affected by the measure following standard Habitat Evaluation Procedures (HEP). The models for each type of measure were selected based on the most representative species to characterize the ecological change created by the restoration. The species selection and model application were conducted in coordination with an interagency group to ensure the estimated benefits were applicable. The Habitat Suitability Index (HSI), the Wetland Value Assessment (WVA), and turtle model were applied, and the specific species for each action are noted in the descriptions below. The habitat units are then averaged over the planning period to get AAHUs, which allows for comparison of performance across the measures. The AAHUs estimated for each of the measures and scales is presented in Figure 2.3. A more detailed discussion of the development of the AAHUs is found in Appendix I of the Final EIS, Ecological Modeling. Additional benefits to recreation, navigation, and regional economies are anticipated, but have not been explicitly quantified in this study.

The types of restoration actions included in the array of ER measures are:

- ***Marsh Restoration – Performance measured by Brown Shrimp HSI:*** These features improve degraded marsh habitat or restore habitat that has become open water due to erosion, RSLC, or other coastal forces. The added sediment increases the elevation of the land to restore or maintain fluctuating water levels as tides vary, and planting of native marsh vegetation provides habitat and traps sediment. Breakwaters will be placed along the boundary to reduce erosion in the adjacent GIWW.
- ***Island Restoration/Creation – Performance measured by Brown Pelican HSI:*** Restore and/or create coastal islands to prevent shoreline erosion, inundation of inland areas from RSLC, and maintain valuable ecosystem services and functions. Sediment will be placed to increase the elevation of degraded islands. The island shorelines along the GIWW will be stabilized to withstand erosion and provide bird nesting habitat and the bay side of the island will slope to a created marsh and oyster reef.
- ***Dune and Beach Restoration – Performance measured by WVA Headland (2018) and Kemps Ridley Sea Turtle HSI (2020):*** Restore and/or enhance beaches and dunes along the Gulf of Mexico shoreline to prevent breaches and erosion caused by storm surge and RSLC and to protect coastal wetlands.
- ***Oyster Reef Restoration/Creation – Performance measured by Swannack Oyster Model:*** Restore and/or create oyster reefs to prevent shoreline erosion, improve water quality, create estuarine habitat, and maintain valuable ecosystem services and functions.
- ***Hydrologic Restoration – Performance measured by Spotted Seatrout (Seagrass) HSI:*** Reestablish the connection between water bodies to achieve the salinity that sustains habitats.

ER measures were formulated as combinations of the types of restoration to address site specific needs along the Texas coast. Each of the nine (9) measures that survived the screening process include one or more of the restoration approaches to achieve diverse and sustainable habitat along the coast. The proposed measures would address years of erosional forces that removed sediment and impaired natural habitats. The nine measures carried forward are described below. Note, these descriptions represent the scope of the measure at this specific point in the planning process (2018 timeframe). Several measures have subsequently been refined further, as discussed in other sections of this report.

**Measure G5 – Bolivar Peninsula/Galveston Island Gulf Beach and Dune Restoration**

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

***Measure G28, Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection***

Install breakwaters and restore marsh habitat to protect 27 miles of marsh habitat along the GIWW on Bolivar Peninsula and 9 miles of shoreline along the north shore of West Bay. Use sediment to restore, create, and/or enhance islands adjacent to the GIWW to protect 5 miles of shoreline habitat along the north shore of West Bay.

***Measure B2 – Follets Island Gulf Beach and Dune Restoration***

Restore, protect, and/or enhance beach and dune complex on approximately 10 miles of Gulf shoreline on Follets Island in Brazoria County.

***Measure B12 – Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection***

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. Use breakwaters along the GIWW and along the land that separates Oyster Lake from West Bay. In Oyster Lake, add 0.7 mile of oyster cultch near the shoreline that is expected to breach into West Bay.

***Measure M8 – East Matagorda Bay Shoreline Protection***
Living shorelines and/or breakwaters would 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 would 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 would be restored.

***Measure CA5 – Keller Bay Restoration***
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. Add oyster reef balls to protect and enhance about 2.3 miles of western shoreline along Sand Point, which separates the two bays.

***Measure CA6 – Powderhorn Shoreline Protection and Wetland Restoration***
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. Powderhorn Lake Estuary is recognized as a rare, valuable coastal prairie, of which only 5% of the original coastal prairies in the country remain.

***Measure SP1 – Redfish Bay Protection and Enhancement***
Breakwaters and/or living shorelines, beneficial use material, and oyster reef balls would be placed to restore, create, and/or enhance the island complex of Dagger, Ransom, and Stedman islands in Redfish Bay. 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.

***Measure W3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration***
This feature 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 approximately 4,000 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.

The remaining ER measures from the conceptual planning efforts were combined into alternatives based upon specific planning objectives. The formulation strategy is based on the concept that natural landforms provide lines of defense against coastal storms, as discussed previously. 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 coastal ecosystems.

Six ER alternatives were formed from the measures, which include selected subsets of the measures in Alternatives 2 through 6, and all measures in Alternative 1. Each of these alternatives are defined in greater detail in Appendix A, the Plan Formulation appendix. Table 2.4 presents the list and title of the alternatives, and a summary of the specific measures in the alternatives. Figure 2.5 presents the initial AAHUs calculated for each measure. Note, the final AAHUs are presented in Chapter 3. These measures are also shown in Figure 2.6 and 2.7. Additional exhibits showing the details of each restoration measure can be found in Chapter 3. The ER measures were initially formulated to include out-year nourishment in response to changing physical conditions and RSLC. This additional nourishment was presented as "Scale 2" of each the ER measures but was later removed when it was determined that out-year nourishment could not be cost-shared.

| Measure | Without Project | With Project | Net AAHUs |
|---|---|---|---|
| G5 | 104 | 1,192 | 1,088 |
| G28 | 20,327 | 30,339 | 10,012 |
| B2 | 54 | 608 | 554 |
| B12 | 30,357 | 31,618 | 1,261 |
| CA5 | 1 | 266 | 265 |
| CA6 | 901 | 919 | 18 |
| M8 | 10,769 | 10,992 | 223 |
| SP1 | 11 | 2,201 | 2,190 |
| W3 | 14,911 | 22,307 | 7,396 |

***Figure 2.5:*** *Initial AAHUs for Evaluated ER Measures*

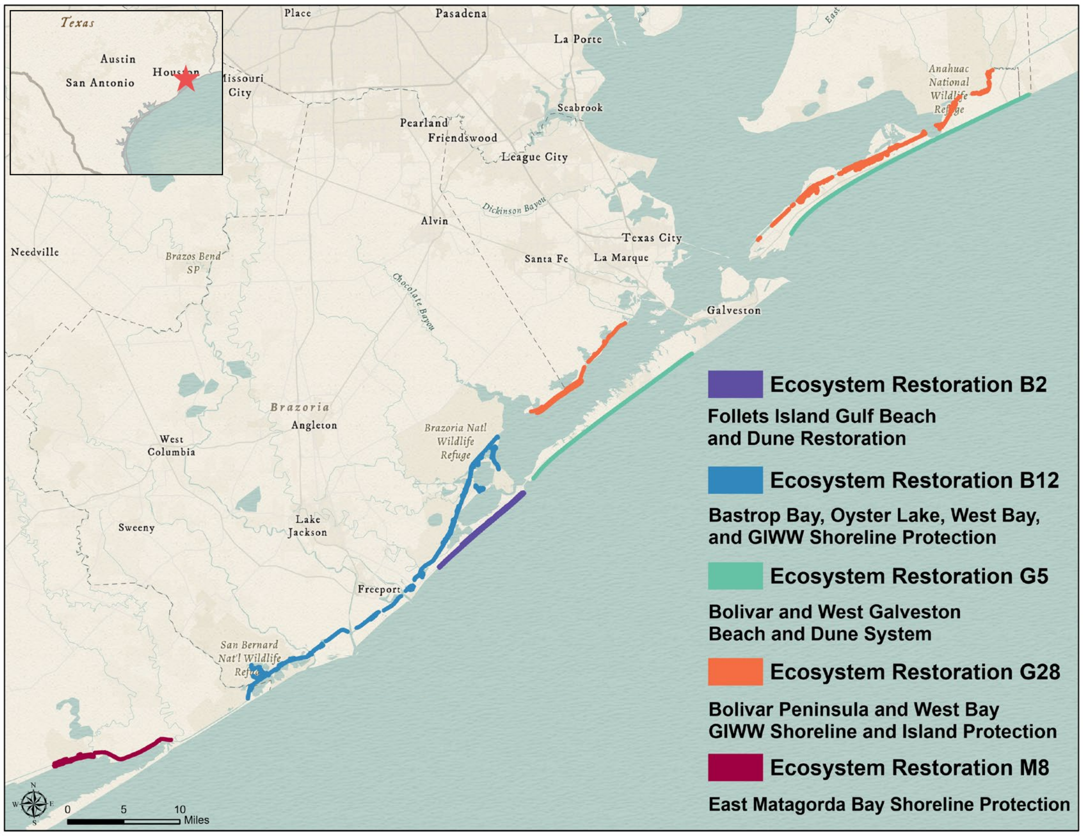



***Figure 2.6:*** *Upper Texas Coast ER Measures*

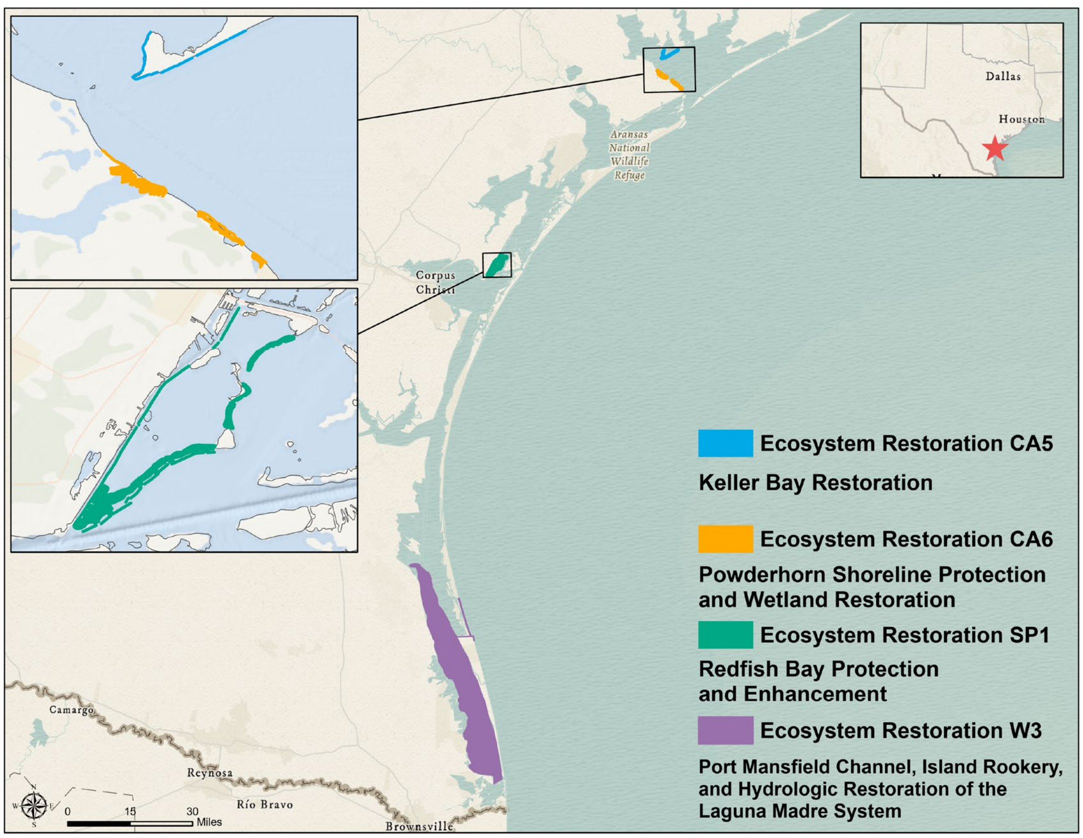



***Figure 2.7:*** *Lower Texas Coast ER Measures*

| | | Measures | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative** | **Name/Description** | **G5** | **G28** | **B2** | **B12** | **CA5** | **CA6** | **M8** | **SP1** | **W3** |
| **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 2.4:*** *Ecosystem Restoration Alternatives*

The removal of the "Scale 2" should not be viewed as ineffective or an unwise investment. The team identified scale 2 features as a potential future need in light of the uncertainties associated with long term RSLC trends. Many of the areas identified in Scale 2 include areas of existing critical habit that is expected to be lost under the intermediate RSLC trend, and is a critical component to focus on in comprehensive planning efforts in the future. Note, there is some uncertainty in the timing of this loss and the long-term impacts from this expected loss. In the future, if the RSLC trends continue and if additional habitat loss is seen in these areas, additional studies could be proposed under the existing Coastal Texas Study authorization to review these areas again. At this time, Scale 2 is not included in the final recommendation.

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 condition for each alternative in 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. A USACE specific model, the Institute for Water Resources (IWR) Planning Suite, completes this Cost Effective, Incremental Cost Analysis (CEICA).

A series of CEICA runs were made to assess and compare the habitat gained as each additional measure is added to an alternative. The initial runs compared the specific alternatives, and a separate run assessed potential alternatives that could result from any potential combination of all measures. Results from the cost-effectiveness analysis are shown in Section 4.3.8 of Appendix A in addition to Appendix E-3. The analysis identified the cost-effective plans to be No Action, Alternative 4, and Alternative 1.

From the cost-effective alternatives, Alternatives 1 and 4 were identified as "Best Buy" plans. Alternative 1: Coastwide All-Inclusive Restoration is the largest alternative and includes all ER measures (G5, G28, B2, B12, M8, CA5, CA6, SP1, W3). 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, and reviewing the study objectives, Alternative 1 was identified as the lowest cost comprehensive plan, and was recommended as the NER plan within the DIFR-EIS published in 2018.

There were several important considerations that supported selection of the largest alternative. The final array included only two measures that restored significant beach habitat. Beach habitat provides diversity of habitat for species along the coast and supports resiliency beyond the benefits measured with the WVA model. Sediment placement along West Galveston Island and Bolivar Peninsula restores sediment to a critical coastal feature and supports the function of complimentary CSRM measures. The larger array of measures supports further benefits to resources of national significance.

Furthermore, the benefits measured with the HSI model for CA6 reflect only a small addition to AAHUs, but the area proposed for restoration is regionally significant as a remaining coastal prairie and has broad community and agency support. The NER plan would achieve a comprehensive plan, constructed from an array of measures that evolved through multiagency screening and consensus.

Further discussion on the selection of Alternative 1 as the lowest cost comprehensive ER plan can be found in Section 4.2.3.8 of Appendix A, the Plan Formulation Appendix.

*Example of a beach access point over a dune*

## 2.8. Coastal Storm Risk Management

Plan formulation for CSRM was undertaken in a systems framework, to assemble and evaluate features using NED procedures into a comprehensive plan to reduce coastal storm risk damages and to enhance resiliency in the region. After assessing the general needs across the entire coast, efforts focused on providing risk reduction within the lower and upper Texas coast. The CSRM planning evaluation for these systems is described in the following sections.

### 2.8.1. South Padre Island

On the lower Texas coast, South Padre Island (SPI) is vulnerable to coastal storms and is included as a hydrologically separable CSRM feature. This region was included because of the City's dense concentration of structures and risk from coastal storms. The region experienced an overall 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.

A history of beneficial use placements since 1988, conducted in conjunction with the GLO and the 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 the Brazos Santiago Pass to nourish the City's Gulf-facing beach to counter ongoing erosion. However, when timing and funding are limited, the structures and population remain at risk along the study area. These periodic efforts require repeated coordination among multiple agencies to obtain funds and execute contracts, which are not guaranteed. The future without project condition, therefore, is that dredging will continue, but there is no certainty that beneficial use placements will be implemented, and the modeling does not include future beneficial use nourishments.

The initial planning evaluation focused only on beach and dune measures because revetments, seawalls, rock groins, or offshore breakwaters would have detrimental impacts to the longshore and cross-shore sediment transport processes. Nonstructural measures were initially considered but not carried forward since many nonstructural measures (flood proofing of structures, implementing flood warning systems, flood preparedness planning, establishment of land use regulations, development restrictions within the greatest flood hazard areas, and elevated development) are already being implemented.

To determine the value of the long-term construction and renourishment of beach and dune measures, life cycle costs

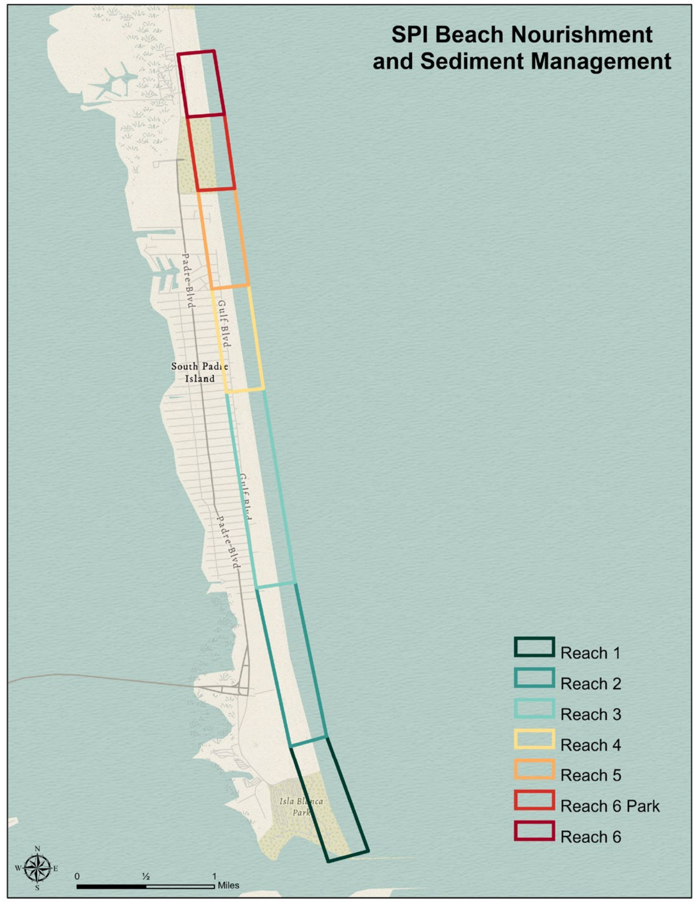



*Figure 2.8: SPI Reaches*

and benefits of varying scales of beach and dune features were estimated with the Beach-fx model. The area was divided into seven reaches to represent the different portions of the study area.

The initial model results showed that the average annual equivalent benefits exceeded the average annual equivalent project costs within Reaches 3 and 4 for all scales of beach-fill, since these reaches encompass 2 miles of the most erosive beachfront. Recreation opportunities improve due to the beach nourishment project, and recreation benefits are a recognized NED benefit. The in-depth computation of recreation benefits was deferred since the appropriate scale of the measure is based upon flood risk reduction in the area. Based on life cycle modeling of the nourishment volumes and intervals, the most cost-effective scale within these reaches at the publication of the 1st Draft Report in 2018 in 2018 was shown to be a 12.5-foot dune and 100-foot-wide beach with a 10-year renourishment cycle. Section 4.2.2 of Appendix A, the Plan Formulation Appendix, presents the analysis and range of potential benefits based on varying levels of cost estimate details. Note that subsequent refinement of this measure expanded renourishment efforts to include Reach 5, as is discussed further in this report.

### 2.8.2. Galveston Bay System

On the upper Texas Coast, the Galveston Bay system represents the most at-risk area not being presently addressed by other programs, such as the Sabine Pass to Galveston Bay project. In general, CSRM features were formulated in systems along two alignments, one along the Gulf, and one along the Bay. The outermost system (or Gulf Alignment) was formulated to reduce the penetration of Gulf surge across the gulfward land masses and into the Galveston Bay system. The alternative alignment (or Interior Alignment) reduces the penetration of storm surge generated within the Bay into the region's surrounding areas by placing the system around the Bay's landward perimeter.

As shown in Figure 2.9, three of the conceptual strategies focused on a Gulfward Alignment to prevent storm surge entry into Galveston Bay and the surrounding communities, considering alternate locations of the barrier and various tie-in features. Each alternative included a ring barrier around the City of Galveston and Seawall elevation to address sea level change from the Gulf of Mexico and wind driven surge and flooding from the Bay. Two of the Gulfward alternatives (A and B) added interior storm surge gates and pump stations to reduce flooding at Clear Lake and Dickinson Bay. Nonstructural measures along the bay rim, such as elevation or floodproofing, were also included. These alternatives are described further below.

**Conceptual Alternative A – Coastal Barrier:** This alternative prevents storm surge from entering Galveston Bay with a levee system across Bolivar Peninsula and west Galveston Island and a closure at Bolivar Roads.

**Conceptual Alternative B – Coastal Barrier:** This alternative is similar to Alternative A but avoided the barrier island and used existing landscape features such as the GIWW disposal dikes and the Texas City Dike as the tie-ins for the closure.

**Conceptual Alternative C – Mid Bay Barrier:** This alternative avoids some of the navigation impacts at Bolivar Roads by placing a surge barrier near the middle of Galveston Bay. The

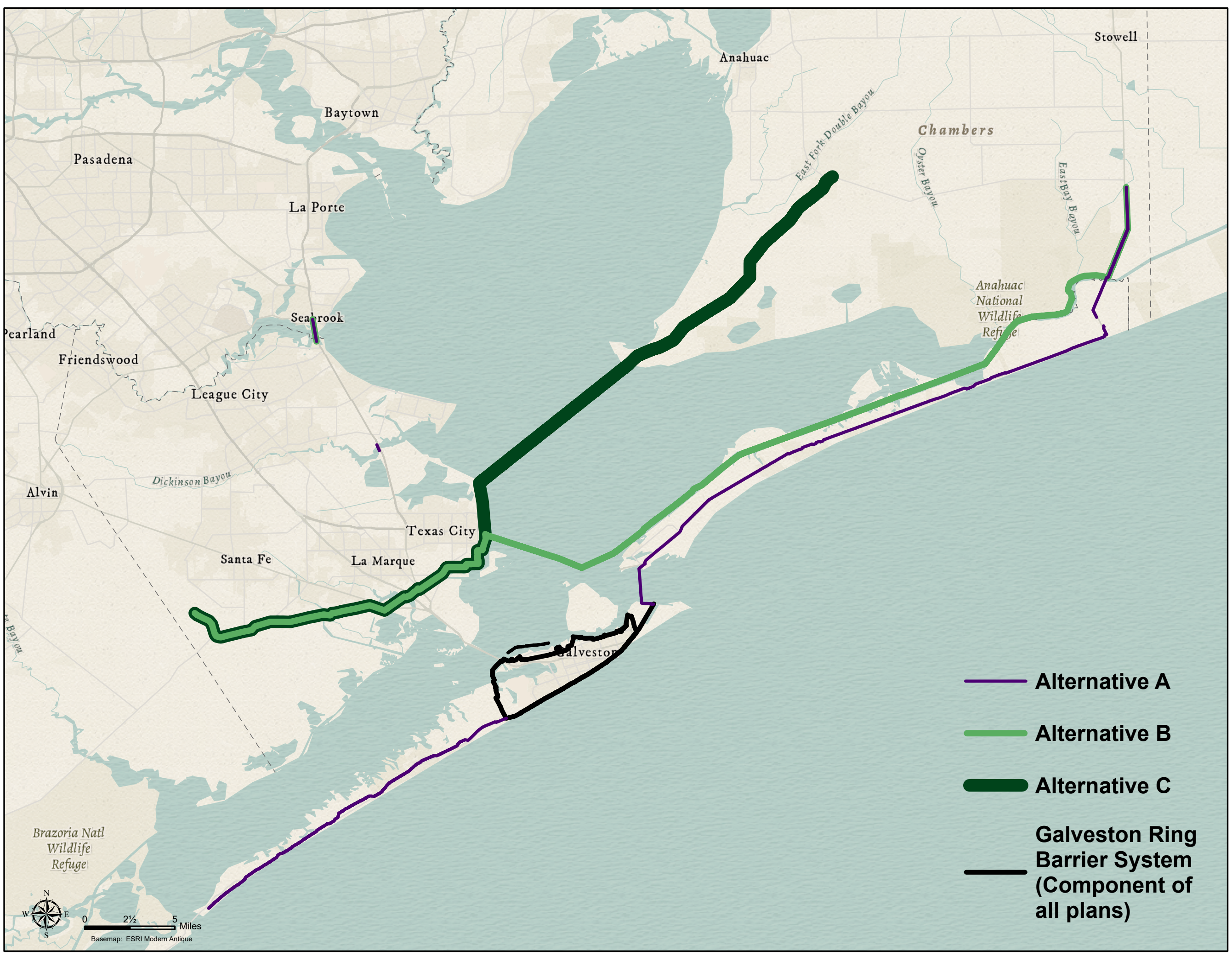



*Figure 2.9: Gulf Alignments*

system started on the east side of Galveston Bay near Smith Point, and continued across the bay, crossing the Houston Ship Channel, and tying into the existing Texas City Levee System.

As shown in Figure 2.10, two of the conceptual strategies proposed an Interior Alignment on the west side of Galveston Bay along State Highway 146, from Texas City to the Fred Hartman Bridge. These alternatives varied in the alignment of the levee, placing the barrier along the bay rim, or further inland along State Highway 146. These alignments avoided navigation impacts that a coastal barrier presented but provided limited risk reduction to portions of the Gulf shoreline. Both alternatives eventually tie into the existing Texas City Levee System and include improvements to that system. Additional improvements to that system further west into the communities of Hitchcock and Santa Fe would also be necessary. Each alternative also included a ring barrier around the City of Galveston and Seawall elevation to address sea level change from the Gulf of Mexico and wind driven surge and flooding from the Bay. In addition, surge gates and pump stations at Clear Lake and Dickinson Bay were also included for both alternatives, while Nonstructural measures along the Bay rim were proposed only for Alternative D1.

**Conceptual Alternative D1 – Upper Bay (State Highway 146)/Nonstructural System:** The proposed a levee system on the west side of Galveston Bay along State Highway 146 from Texas City to the Fred Hartman Bridge. Communities between State Highway 146 and the Bay are left out of the system and would require nonstructural treatment.

**Conceptual Alternative D2 – Upper Bay (Bay Rim)/ Nonstructural System:** This alternative proposed the levee system along the Bay rim from Texas City to the Fred Hartman Bridge, which enclosed the 10,000 structures that were left out of the system in Alternative D1.

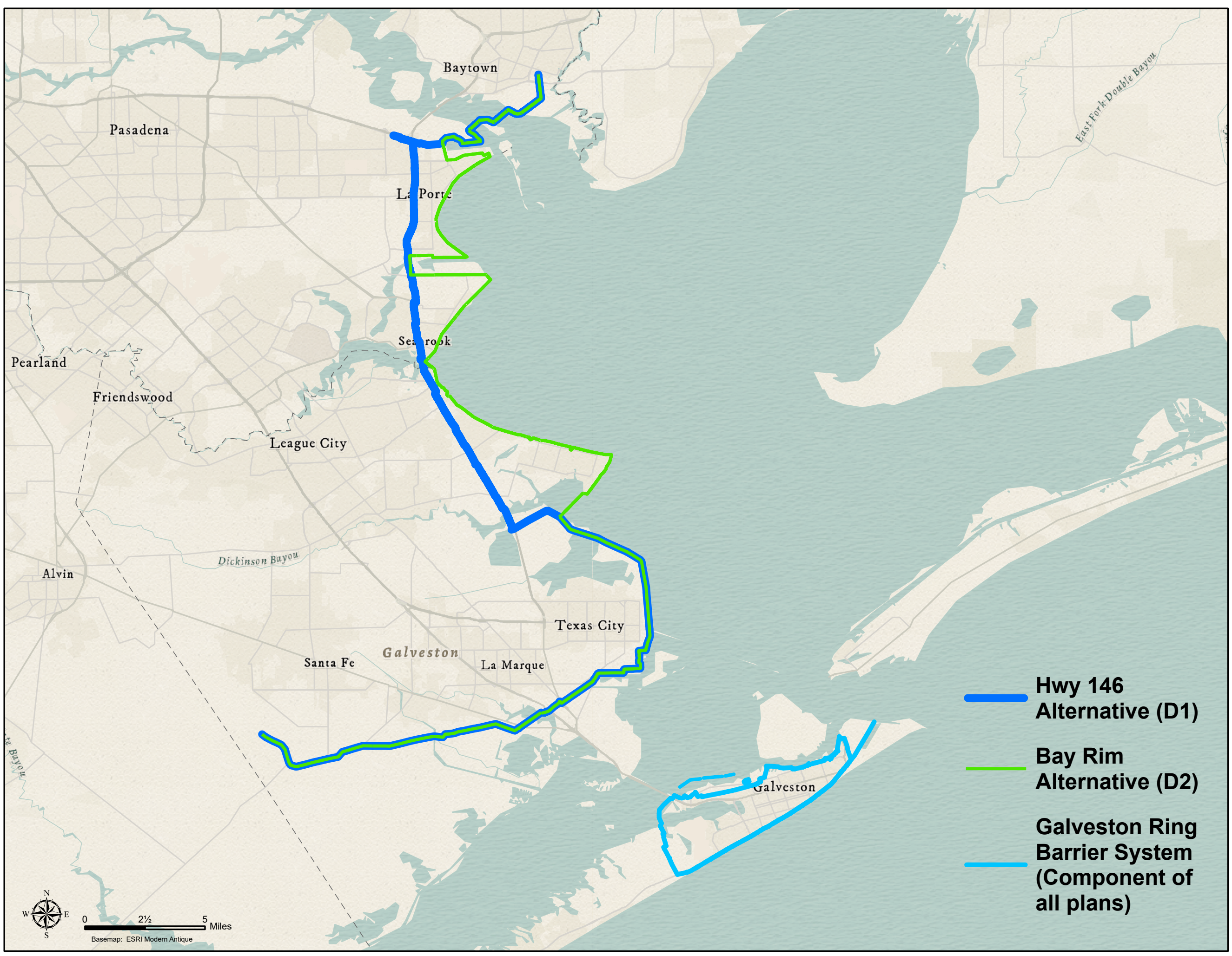



*Figure 2.10: Interior Alignments*

### *2.8.2.1. Conceptual Phase Evaluations*

The first assessment to be completed by the Study Team was to confirm the effectiveness of the five alternative risk reduction plans in the Galveston Bay region. Since the level of design of the alternatives was conceptual at this stage, the performance was measured by assessing high-level differences in performance, cost, and impacts.

As described above, the five alternatives included similar components that addressed storm surge and erosion through a slightly different alignment of features along either a gulfward alignment or interior alignment. The three gulfward alignments all include a structure across the Bay to prevent storm surge pushing into the inland areas of the Bay, but propose different features connecting the barrier to high ground. The two interior alignments primarily target the Bay perimeter with floodwalls and also include a ring barrier around the populated portion of Galveston Island.

As plans were developed, they were assumed to have similar levels of risk reduction as some of the existing risk reduction systems in the upper Texas coast. For example, plans which had a levee system tying into the Galveston Seawall were designed and evaluated based on similar heights of the existing seawall, an elevation of approximately 17 ft (NAVD88). The same assumption was used for plans tying into the Texas City hurricane flood protection system. The Study Team made these simplifying assumptions to ensure that the analysis focused on an initial comparison of distinctly different plans rather than different scales of plans. This was consistent with the conceptual formulation strategy, which explored different strategies (Gulf shoreline focus, back/mid bays focus, upper bay focus).

*The three gulfward alignments all include a structure across the Bay to prevent storm surge pushing into the inland areas of the Bay, but propose different features connecting the barrier to high ground*

#### 2.8.2.1.1. Differences across the Gulfward alignments

***Alternative A:***

Alternative A proposed the storm surge barrier across Bolivar Roads and tie-in features connected to the Galveston Seawall to the west and to a levee system to the east along Bolivar Peninsula. 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 Central Region Alternative (CR #1) – Coastal Spine or Texas A&M University at Galveston's "Ike Dike".

***Alternative B:***

Alternative B placed the storm surge barrier north of the GIWW and would tie into the existing Texas City Dike to the west and connect to some of the existing dredge disposal sites to avoid habitat along Bolivar Peninsula. The placement behind the GIWW would stop storm surge from the Gulf and reduce the barrier's exposure to high and intense surges compared to the location proposed in Alternative A.

***Alternative C:***

Alternative C avoided some of the navigation impacts at Bolivar Roads, by placing a surge barrier gate across the middle of Galveston Bay, in an alignment 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 continue across the bay, crossing the ship channel and tie into the existing Texas City levee system on the west side of the Bay.

When compared to the future without project conditions, the Study Team identified strengths and weaknesses that allowed them to screen the alternatives based on relative risk reduction performance, construction and life cycle cost, and potential environmental and navigational impacts.

#### 2.8.2.1.2. Navigation Concerns for the Gulfward Alignments

***Alternative A:***

Deep-draft ships would have to transition through the surge-barrier gates, and anchorage areas would require relocation.

***Alternative B:***

Shallow-draft tugs and barges and deep-draft ships would have to transition through the surge-barrier gates which raised concerns about navigation safety and efficiency.

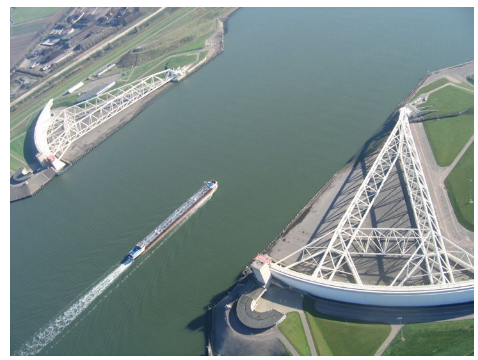
***Alternative C:***

Navigation safety for recreational vessels was a concern when deep-draft ships, shallow-draft tugs and barges, and large recreational vessels would all be forced to use one opening in the storm surge gate.

#### 2.8.2.1.3. Construction, Cost and Maintenance Concerns for the Gulfward Alignments

***Alternative A:***

The location in the center of the inlet would require environmental gates, or similar components, to maintain the natural water circulation into the Bay when the system is open. Initial modeling estimated that over 30 environmental gates would be needed to maintain existing circulation in the Bay. Initial construction and substantive operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs would be associated with these gates.



*Example of a ship transitioning through Maeslant storm surge barrier gate structures (Photo Credit: John McQuaid)*

***Alternative B:***

The storm surge gate in Alternative B would connect to the Texas City Dike. The dike was built to protect the Texas City navigation channel from cross currents and excessive silting, not to withstand storm surge. The foundation of the existing dike would have to be improved to increase its existing height to function effectively against storm surge. Aside from cost, this action would have major impacts on the current recreational use on the dike during construction or would require permanent relocation of the fishing and recreational features.

***Alternative C:***

The location in the center of the bay would require environmental gates, or similar components, to maintain the natural water circulation in the Bay when the system is open. Modeling estimated that over 100 environmental gates would be needed to maintain existing circulation in the Bay. Initial construction and substantive OMRR&R costs would be associated with these gates.

#### 2.8.2.1.4. Direct and Indirect Environmental Impacts

All three alignments would impact the natural flow within the Bay by constructing a barrier. The mid-bay location, and the large underwater footprint for Alternative C, is likely to have negative impacts on the historic "Redfish Oyster Reef" near the middle of Galveston Bay and the reefs along the Houston Ship Channel near the proposed surge barrier gates.

#### 2.8.2.1.5. Differences across the Interior alignment plans

Placing the levee system path along SH 146 reduced construction costs and environmental impacts by avoiding in-water construction but left approximately

10,000 structures east of the levee outside of the system. This created a concern related to the overall project objective to reduce risk to critical infrastructure, such as medical centers, government facilities, universities, and schools, from coastal storm surge flooding. An evaluation of the future without project 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 stages and damages in the area outside of the levee system. Economic modeling estimated that over $175 million in average annual equivalent damages would accrue to the area without addressing the induced damages.

#### 2.8.2.1.6. Conceptual Phase Conclusions

After comparing the relative performance of the alternatives and the potential cost or environmental impacts, Alternatives B and C were screened out since Alternative A provided comparable if not better performance in terms of reduced risk, with fewer negative impacts. Similarly, Alternative D1 was screened out since Alternative D2 provided better performance in terms of reduced risk, with fewer negative impacts.

### *2.8.2.2. Tentatively Selected Plan Phase Evaluations*

Alternative A and D2 were found to be the two most effective comprehensive alternatives to address coastal storm risk within the Galveston Bay system. Alternatives B, C and D1 were screened out because of impacts that were evident even with less detailed economic information. The initial analysis demonstrated that these two alternative plans offered distinct approaches that achieved the study goals without creating unnecessary environmental and community impacts. This second screening phase required more thorough refinement of the design and operation of the features within each alternative to conduct a meaningful comparison.

The engineering performance was evaluated with more detailed models to simulate performance of the features when faced with representative storm conditions over the 50-year period of analysis. Updated engineering models produced more refined water surface elevations to generate a more detailed economic estimate of the benefits.

The comparison of the gulfward Alternative A and interior Alternative D2 required standard NED benefit evaluation procedures for damage reduction be used to compare system-level alternatives and identify the TSP. The certified model applied to quantify NED benefits is HEC-FDA, a risk-based model that combines water surface elevation estimates for a representative storm suite and dollar damage assessments for resources within the study area. Additional NED benefits for recreation and extended Gross Domestic Product (GDP) impacts were then estimated as part of the selection of the Recommended Plan.

Both Alternative A and Alternative D2 include a ring barrier around the central portion of Galveston Island to protect against back-bay flooding. This barrier is illustrated in Figure 2.11. For Alternative D2, a much taller barrier would be necessary due to the additional volume of water in the bay, absent the Gulf defense system.

#### 2.8.2.2.1. Environmental Impacts

A major direct impact of the project is the loss of wetlands within the project right-of-way. Due to the limited enclosure of wetlands with Alternative D2, indirect impacts were assumed to be negligible.

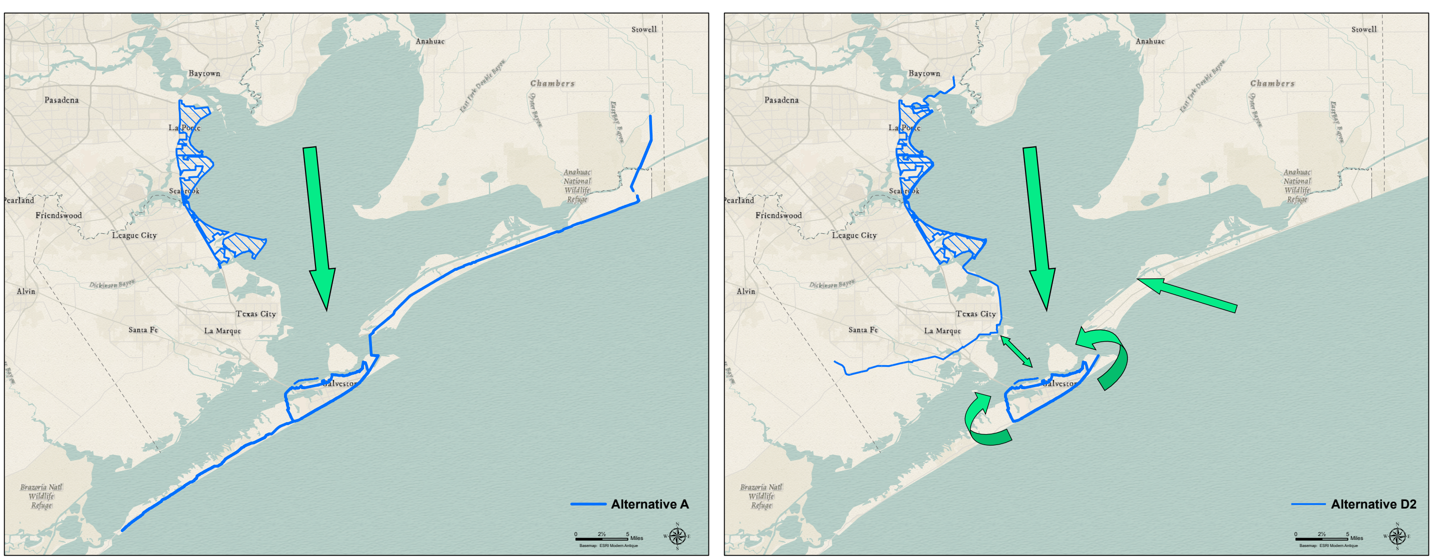



*Figure 2.11: Function of Galveston Ring Barrier System in Alternatives A and D2 (arrows indicate flow of water)*

The structural supports and the islands that house the Bolivar Roads sector gates in Alternative A create an obstruction in the channel. This may reduce tidal flow and a change in the tidal amplitude may occur (see Appendix D, the Engineering Appendix).

The Study Team developed a methodology to assess the potential impacts to estuarine marshes within the tidally influenced areas of Bolivar Roads. A 3D Adaptive Hydraulic (AdH) model was applied to assess hydrological impacts, changes in tidal prism (volume of water which leaves or enters the bay between mean low tide and mean high tide), and tidal amplitude (height difference between mean low tide and mean high tide) that may occur from the proposed gates.

During this phase of evaluation, the constriction of the opening at Bolivar Roads was limited to 27.5 percent closure with the barrier in the open position. Preliminary AdH modeling of the Galveston Bay system indicated that tidal amplitude could be reduced by up to 0.5 feet if the structure were placed across Bolivar Roads in a future with project tidal range of 0.0 to +1.5 foot.

Further detailed discussion of environmental impacts can be found in Chapter 4 of this report and Chapters 4 and 5 of the attached Final EIS.

#### 2.8.2.2.2. Comparison of Alternatives

Table 2.5 provides a detailed comparison of Alternative A and Alternative D2.

| Criteria | Alternative A | Alternative D2 |
|---|---|---|
| **Comparison of Design Details** | Complex design only focused on large navigation structure | Complex design due to multiple tie-ins |
| **Construction Schedule and Benefit Assumptions** | Lower acquisition risk | High acquisition risk |
| **Environmental Impacts** | High indirect environmental risk (Galveston Bay) | Localized direct and indirect risk (smaller waterbodies) |
| **Potential Induced Flooding** | Localized manageable risk | Localized to levee tie-in points |
| **Navigation Impacts** | Potential impacts to deep-draft operation but reduces risk to navigation infrastructure from storm surges | Potential impacts to both deep-draft and shallow-draft operations and navigation infrastructure still at risk from impacts from storm surges |
| **Critical Infrastructure** | Highway and navigation infrastructure included in the system | Critical highway and navigation infrastructure left out of the system |
| **RSLC Scenario** | Limited cost for adaptation (Galveston Bay storage) | Substantial cost for adaptation (floodwall modification) |
| **Project Cost** | Low cost range – high cost range<br><br>$14.2 – $19.9 billion | Low cost range – high cost range<br><br>$18.2 – $23.8 billion |
| **Net Benefits ($ millions) and Benefit-Cost Ratios** | <u>Range: High RSLC and Low Cost – Low RSLC and High Cost</u><br>(Without GDP Impacts)<br>$571 – ($294) and 1.8–0.6<br>(With GDP Impacts)<br>$1,192 – $14 and 2.7–1.0 | <u>Range: High RSLC and Low Cost – Low RSLC and High Cost</u><br>(Without GDP Impacts)<br>$255 – ($544) and 1.3–0.5<br>(With GDP Impacts)<br>$923 – ($237) and 2.0–0.8 |
| **Residual Risk** | Galveston Bay's storage capacity mitigates risk | Risk from exceedance surge events and rainfall events |

***Table 2.5:*** *Comparison of Alternative A and D2 (FY17 Price Level, 2.75% Discount Rate)*

#### 2.8.2.2.3. Net Benefits and Benefit-Cost Ratios

The majority of monetary benefits attributable to a risk reduction project result from the reduction of physical damages to structures, contents, vehicles and indirect losses to the national economy.

The study problems and objectives presented earlier introduced the broader problems that a community faces following a storm event. Disruptions to the area businesses, industry and support systems create impacts to the local and national economy. Businesses can be forced to curtail their normal operations because workers are displaced, facilities are inundated, and flooded roads limit access to the facilities. By implementing coastal storm risk reduction measures, the losses associated with indirect economic impacts can be reduced.

*By implementing coastal storm risk reduction measures, the losses associated with indirect economic impacts can be reduced*

A model developed by Regional Economic Models Inc. (REMI) was used to quantify the indirect impacts to the region, the remaining counties of Texas, and the rest of the U.S. economy. The model estimates the geographic redistribution of production and the net changes in national output associated with storm damage. The information is included in Table 2.4 (as GDP impacts) to investigate the possible range of benefits between the alternatives when including indirect economic impacts. Additional information on the REMI model assumptions can be found in Part 3 and Addendum C of Appendix E-1, CSRM Upper Coast Economics and Appendix E-4, Regional Economic Development Analysis.

Table 2.6 provides an overview of the results of these evaluations for both CSRM alternatives under the intermediate RSLC scenario and a variety of cost ranges, to address uncertainties.

| RSLC & Cost Scenario | w/o Project Damages | Alt A w/ Project Damages | Annual Damage Reductions | Annual Benefits (Damage Reduction plus GDP Impacts) | Annual Costs | Equivalent Annual Net Benefits (w/ GDP Impacts) | Equivalent Annual Net Benefits (w/o GDP Impacts) | BCR (w/GDP Impacts) | BCR (w/o GDP Impacts) |
|---|---|---|---|---|---|---|---|---|---|
| **Alternative A** | | | | | | | | | |
| Intermediate RSLC & Low Cost | $2,243 | $1,464 | $779 | $1,141 | $717 | $424 | $62 | 1.6 | 1.09 |
| Intermediate RSLC & High Cost | $2,243 | $1,464 | $779 | $1,141 | $956 | $185 | ($177) | 1.2 | 0.81 |
| **Alternative D2** | | | | | | | | | |
| Intermediate RSLC & Low Cost | $2,243 | $1,543 | $700 | $1,049 | $887 | $163 | ($193) | 1.2 | 0.78 |
| Intermediate RSLC & High Cost | $2,243 | $1,543 | $700 | $1,049 | $1,122 | ($73) | ($429) | 0.9 | 0.62 |
| *2017 Price Level, 2.75% interest rate, Price $ millions* | | | | | | | | | |

***Table 2.6:*** *Alternatives A and D2: Net Benefits and BCRs*

#### 2.8.2.2.4. Residual Risk

While Alternative D2 is predicted to have fewer environmental impacts than Alternative A, Alternative D2 comes with residual flood and life safety risk, such that it could be classified as a non-practicable alternative. An alternative can be defined as practicable if it is capable of being implemented. Using lessons learned from the Interagency Performance Evaluation Task Force post-event investigations of Hurricane Katrina and from other USACE Dam and Levee Safety studies, Alternative D2 is deemed to be an alternative that is not practicable, due to the long-term risk introduced when major flood infrastructure acting as a single line of defense is placed immediately adjacent to dense populations. The Interagency Performance Evaluation Task Force report illustrates an effective platform for developing better policy and planning decisions when recommending and designing hurricane risk reduction systems. One of the key lessons learned was to use a system approach when assessing risk to make practicable, rational, and defensible decisions.

If Alternative D2 were implemented, it would likely include a large number of different T-Wall sections for levee tie-in points due to alignment transitions from levee to floodwall to levee passing through highly developed residential areas along Galveston Bay and commercial port facilities. These additional floodwall sections and tie-in points add complexity, and potential vulnerability, to the system and increase maintenance costs.

Tie-in points for Alternative A are mainly limited to the large navigation structure across Bolivar Roads. Tie-in points, where one engineered feature transitions into another feature, create a vulnerability in the system. Any alternative that includes more tie-ins creates more residual risk. The Interagency Performance Evaluation Task Force found that there will always be residual risk with any system; however, it is imperative that flooding vulnerability from extreme events is factored into planning decisions. These decisions may require designing a system to allow for more-effective evacuations or emergency responses to extreme events (i.e., greater than the recommended 100-year level of risk reduction). In the case of Alternative D2, residual risk is high due to the proximity of the levee alignment to developed areas.

Alternative D2 has the greatest residual risk since 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 highly developed areas of the study area; therefore, it has a lower residual risk in the event of extreme overtopping events. Nonstructural measures in the developed area could also reduce this residual risk. Galveston Bay's storage capacity also plays a key role in reducing residual risk. It not only provides a storage basin for exceedance surge events, it also avoids inducing damage under extreme rainfall events. Alternative D2 includes multiple drainage and pump stations, which could be overwhelmed during an extreme rainfall event. Rainfall would stack up behind the levee system until it was pumped or drained out.

#### 2.8.2.2.5. Summary of CSRM Alternatives Comparison

As compared to the Alternative D2, Alternative A has:

- **Higher net benefits –** Under all RSLC Scenarios and cost ranges.
- **Lower residual risk –** A lower residual risk in the event of extreme overtopping events because the overtopping surge volume is captured in Galveston Bay before reaching the most densely populated areas.
- **Greater flexibility and greater focus on critical infrastructure –** Alternative A takes a systems approach when reviewing the regions larger system context. The Gulfward alignment encloses critical infrastructure within the risk reduction system and enhances resiliency in the region. Also, by establishing the first line of defense on an outermost alignment, greater adaptive options are possible to manage risk over time.

Furthermore, Alternative A was identified as the Least Environmentally Damaging Practicable Alternative (LEDPA). Specifically, residual engineering and design regulations, risk analysis regulations, encroachment regulations, cost analysis regulations, flood fighting and emergency operations regulations, and OMRR&R regulations would make Alternative D2 an impracticable alternative.

## 2.9. Selection of the TSP

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 SPI Beach Nourishment and Sediment Management measure, and the lowest-cost comprehensive ER measure, Alternative 1. Specifically, the Alternative A CSRM measure for Galveston Bay and the SPI 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. This determination considered impacts and benefits across all four of the P&G accounts, including national economic development, regional economic development, environmental quality, and other social effects. Furthermore, the combined Recommended Plan supports the desired comprehensive, systems-based, approach to enhancing resiliency across the Texas coast.

## 2.10. October 2018 Draft Integrated Feasibility Report and EIS

A first draft of the Coastal Texas Study's DIFR-EIS was released in October 2018. The DIFR-EIS was provided to all known Federal, state, and local agencies, and interested organizations and individuals were sent a notice of availability. In addition to the official public comment period, seven Public Meetings, covering the different regions which comprise the Texas coast, were held in 2018 to provide the public with updated information about the study scope and schedule and to solicit public comments for consideration on the DIFR-EIS and the proposed TSP. This public comment period occurred at the same time as USACE technical/policy review and resource agency review. A summary of comments received and USACE responses have been included in Chapter 7 of the attached Final EIS. All comments received are included in Appendix M to the Final EIS.

*Representatives attend a Community Work Group meeting in October 2019*

### 2.10.1. Additional Coordination

Coordination with stakeholders also included attendance at regular interagency meetings and over 60 formal presentations of study scope and status throughout the study process. Recognizing that 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 and again in October 2019.

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 local leaders and elected officials in four coastal communities to request assistance in establishing the Coastal Texas Study Community Work Groups (CWG). Appointed by local leaders and elected officials from each community, CWG members were regularly invited to meet with the GLO for up-to-date study information and topic-specific presentations. During presentations, CWG members were 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. These open houses were held in multiple locations along the upper coast to reach the affected communities.

## 2.10.2. Response to Comments and Revisions to the TSP

Based on public and resource agency comments, and supported by continued engineering design and refinement 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. This is the third phase of the plan formulation process, building on the conceptual and TSP phases, and integrating comments and refining alternatives to generate the Recommended Plan. The following sections summarize some of the major changes to the TSP which occurred after publication of the 2018 DIFR-EIS. Of critical importance, this includes further refinements to achieve a system of integrated risk reduction measures, a complete coastal barrier system, working together across multiple lines of defense to enhance resiliency, redundancy, and robustness, while addressing both public comments/concerns and policy considerations. Refinements to the TSP are discussed in the following order: Ecosystem restoration, the South Padre Island CSRM measure, and the Galveston Bay CSRM system, split between the Gulf defenses and the Bay defenses.

### *2.10.2.1. 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, that could be evaluated as a later study under the Coastal Texas authority, instead of plan components. The removal of outyear nourishment did not have a material impact on overall site selection, the identification of the Recommended Plan, nor the feasibility and cost-effectiveness of the measures (considering reduced benefits). Removing out-year nourishment reduces both the project first cost (i.e., the cost of design and construction) and the expected AAHUs.

### *2.10.2.2. South Padre Island - Beach Nourishment*

Several refinements to the Beach-fx 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 Beach-fx 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, specifically that smaller scales were not more cost effective. The modeling confirmed that the central reaches of the barrier island warrant nourishment over time, and that the efficiency of that action can be improved through continued beneficial use placement in the nearshore area to extend the time between required nourishment cycles.

The model results also 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 50-year period of analysis. 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 (nearby deep-draft navigation channel) 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 based upon construction costs, benefits, and real estate costs. Real estate considerations associated with SPI are discussed in more detail in Section 4.2 of Appendix F, the Real Estate Plan.

### *2.10.2.3. Galveston Bay – Gulf Defenses*

The Gulf line of defense separates Galveston Bay from the Gulf of Mexico to reduce storm surge volumes entering the Bay. Specific refinements associated with these features include:

#### 2.10.2.3.1. Bolivar Roads Gate System

The storm surge gate between Bolivar Peninsula and Galveston Island is the largest and most critical feature of the coastal barrier 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 summarized in Chapter 7 of the attached Final EIS. All comments received are included in Appendix M to the Final EIS. It is important to note that the other features included in the plan rely on the benefits of gate system, and were added to the plan to supplement the function of the gate or to address residual risk and community resiliency over the period of analysis.

The height of the gate system was refined and served as the basis for the design for all the connecting features. As discussed in Section 3.4.1.1, a design height of 21.5 ft (NAVD88) was selected while balancing future RSLC impacts, limits on the tie-in points, and due to the overall purpose of the gate. It is important to understand that the overall goal of the gate is to stop that large volumes of surges entering the Galveston Bay system well ahead of a storm making landfall. The system is somewhat limited by tie-in improvements needed along the Galveston Seawall. The gate system is designed to prevent a 100 year storm surge overtopping the gate system and includes additional heights to account for the intermediate RSLC scenario. Exceedance events (overtopping of the gate structure) would not add a significant amount of water to the bay system due to the small length of the gate system compared to the overall system (2 miles vs 64 miles.). Indicating the importance of the gate system, additional evaluations showed that incrementally the gate accounts for over 30% of the overall benefits.


*Conceptual rendering of the proposed sector gates at the Bolivar Roads Gate System*

#### 2.10.2.3.2. Galveston Seawall Improvements and Galveston Ring Barrier System

The Galveston Seawall height increase was proposed as a future adaptation to address sea level change. Following publication of the 2018 DIFR-EIS, a height increase was proposed for the north side of Seawall Boulevard to avoid view impacts and to avoid impacting the existing Seawall stability. Specific discussion of design criteria for the Seawall improvements is provided in Section 3.4.1.3, with further discussion of impacts of overtopping and interconnection with the Galveston Ring Barrier System included in Appendix D, the Engineering Appendix.

Moving out from the Bolivar Roads Gate System, existing seawall provides the first line of defense from gulf surges, however the design had to balance impacts to existing structures (e.g. views along the seawall), overtopping volumes into the interior of the City of Galveston and future adaptations to address sea level change.

#### 2.10.2.3.3. West Galveston and Bolivar Peninsula (Levee Feature and Beach and Dune Restoration G5)

Moving outward from the Bolivar Roads Gate System and the Galveston Seawall Improvements, the study team identified multiple technical, policy, and legal challenges. The levee proposed in the 2018 DIFR-EIS along West Galveston and Bolivar Peninsula provided an engineered barrier to prevent storm surge from entering the Galveston Bay system over land. However, the system placed a significant number of structures and properties between the levee and the gulf. This alignment increased storm damages on these properties and resulted in uncertainty on the sustainability and cost-effectiveness of the proposed G5 ER Beach and Dune Restoration feature. Specifically, the levee limits the ability of the sediment from the ER feature to contribute to the island and the peninsula's overall sustainability. The alignment also caused significant life safety concerns by placing the only west and east evacuation route outside of the levee system.

The originally proposed levee feature also ran into significant concerns when evaluating the plan Completeness and Acceptability under Federal P&G criteria. As discussed above, the levee would prevent surges from entering the bay and would have also significantly reduced damages to the existing structures along West Galveston and Bolivar Peninsula. Many of the existing structures on Bolivar are in existing CBRA Zones. In the 1970s and 1980s, Congress recognized that certain actions and programs of the Federal Government have historically subsidized and encouraged development on coastal barriers, resulting in the loss of natural resources; threats to human life, health, and property; and the expenditure of tax dollars. To remove the Federal incentive to develop these areas, CBRA designated relatively undeveloped coastal barriers along the Texas Coast as part of the John H. Chafee Coastal Barrier Resources System (CBRS) and made these areas ineligible for most new Federal expenditures and financial assistance.

Including a structural system in these areas would have likely encouraged development in the CBRA zones behind the levee, which would have limited the federal government ability to construct the feature. As such, issues arose with the acceptability and compatibility of including the proposed levee in the plan. It was discussed that the non-Federal sponsor could pay for the portions of the levee within CBRA zones. However, doing so would place a significant financial burden on the non-Federal sponsor and would have caused significant concerns related to the plan's completeness, specifically the "extent to which an alternative provides and accounts for all features, investments, and/or other actions necessary to realize the planned effects, including any necessary actions by others". In response to community and CBRA concerns, the study team removed a large portion of the levee from the recommendation; however, the study team still had to address the storm surge from entering the Galveston Bay system over land. Although the gate structure addresses over 60% of the surges in the Galveston Bay System, the existing barrier island are a significant weak point in the system when you factor in RSLC trends. Currently there are over 250 openings in the existing dune system which during storm events become areas for significant surge overwash areas. These areas are expected to enlarge under future storms as RSLC trends increase, and without a consistent line of defense we would likely see increases volumes of surge passing around the Bolivar Roads Gate System and the Galveston Seawall Improvements if these features are built alone.

In order to address this concern, and still comply with CBRA rules, the ER beach and dune restoration feature (G5, which was justified for ER purposes), was converted into a CSRM beach and dune restoration feature along the Gulf on West Galveston and Bolivar Peninsula. Except for a small area where a levee is needed to transition between the dune and the Bolivar Roads Gate System, the beach and dune restoration was adapted to include higher dunes and wider beaches to increase the risk reduction it provides. Further information on the design criteria for these features can be found in Section 3.4.1.2. It should be noted that the beach and dune feature does not provide a comparable scale of risk reduction as the levee, but it is placed gulfward of all structures, creates fewer community impacts, and also creates incidental ER benefits from the natural resiliency of sand systems. The larger beach feature also sustains the barrier features and supports the function of the Bolivar Roads Gate System. The feature would also meet one the CBRA exemptions for nonstructural projects for shoreline stabilization that are designed to mimic, enhance, or restore a natural stabilization system.

It should also be noted that the proposed improvements would not trigger a change in the regulatory FEMA flood elevation or Flood Insurance Rate Map, as surges would continue to overtop the dune feature in a 100-year event. The dune features are designed to work together with the large gate at Bolivar Roads to prevent pre-surge from entering the Galveston Bay system. Structures and property in these zones would still be subject to the hazard associated with storm waves, which give these zones the VE designation. Furthermore, the features would not meet FEMA's criteria for coastal flood protection structures, which would allow for or trigger a change to the regulatory base flood elevation. The dune features are not designed to serve as a non-overtopping features, such as levee or a engineered clay dune feature. The measures are designed to mimic, enhance, and restore a natural stabilization system and to ensure that the natural coastal processes such as littoral drift, overwash, and erosion is improved to prevent breaching of the coastal system. The dune heights are well below the base flood elevations at the Gulf front, and would be susceptible to over washing. Any subsequent FEMA flood mapping efforts would not show a discernable change in the regulatory flood elevation and floodplain.

The presence of the beach and dune feature is unlikely to change current development patterns as the availability of flood insurance is driving factor for developing non-CBRA lands over lands within a CBRA zone. Based on the current rate of development on Bolivar and Galveston, there is presently decades of available lands that are outside of the CBRA units that will be developed before lands inside the CBRA units would likely be developed. In addition, the cost of complying with building codes on the barriers in Coastal High Hazard Areas (FIRM maps zones V, VE, V1-30) would continue to make new housing development very expensive. Even with the proposed beach and dune system, there would still be a significant risk to structures that are not elevated on piers and the beach and dune system does not protect against flooding caused by high water from Galveston Bay.

#### 2.10.2.3.4. 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 Severe Storm Prediction, Education and Evacuation from Disasters (SSPEED) Center at Rice University 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 west of Galveston Bay would not justify the environmental impacts of constructing a barrier in the pass.

### *2.10.2.4. Galveston Bay – Bay Defenses*

The bay defenses enable the system to manage the residual risks not addressed by the Gulf defenses. Residual risks are driven by the water already in Galveston Bay, plus any additional surge that overtops the Gulf defenses. The interior features also provide resiliency against the variations in storm track and intensity. Specific refinements include:

#### 2.10.2.4.1. 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.

Critically, when considering the Galveston Ring Barrier System, it is very important to consider its function as part of a broader system of improvements. Specifically, the ring barrier is not scaled to completely address flood risk without the Bolivar Roads Gate System or the West Galveston and Bolivar Peninsula beach and dune systems in place. Delaying or not including construction of one of those components, either the beach and dune system or the gate system, would equate to significantly lower net benefits. This is key consideration when considering implementation of the system, specifically the construction phasing. Additional discussion on the construction sequencing is included in Chapter 6 of this report. Building the Galveston Ring Barrier System alone would not follow a systems-based approach to address acute hazards and chronic stressors over time. Furthermore, without the gulf line of defense, life safety risks would increase and flood damage reduction benefits would be reduced. Further information regarding the design criteria employed for the Galveston Ring Barrier System can be found in Section 3.4.2.1.

#### 2.10.2.4.2. Clear Lake Gate System and Pump Station

After publication of the 2018 DIFR-EIS, additional feasibility phase engineering design was completed for the Clear Lake Gate System and Pump Station. The surge gate at Clear Lake would reduce surge volumes that push into neighborhoods in the Clear Lake area. Further details, and specific discussion on design criteria, can be found in Section 3.4.2.2. Similar to the Galveston Bay Ring Barrier system, the Clear Lake Gate system is not scaled to completely address flood risk without the gulf defenses in place.

#### 2.10.2.4.3. Dickinson Bay Gate System and Pump Station

After publication of the 2018 DIFR-EIS, additional feasibility phase engineering design was completed for the Dickinson Bay Gate System and Pump Station. The surge gate at Dickinson Bay would reduce surge volumes that push into neighborhoods along Dickinson Bayou. Further details, and specific discussion on design criteria, can be found in Section 3.4.2.3. Similar to the Galveston Bay Ring Barrier system, the Dickinson Bay Gate system is not scaled to completely address flood risk without the gulf defenses in place.

#### 2.10.2.4.4. Nonstructural Improvements

After publication of the 2018 DIFR-EIS, additional planning was conducted to refine necessary nonstructural improvements for the west side of Galveston Bay. As discussed in the sections above, there is still significant water in Galveston Bay that can impact low lying structures along the bay shoreline. Elevation and floodproofing measures were formulated for floodplains on the west side of Galveston Bay, including the communities of San Leon Point and Kemah, to manage residual surge risk. Flooding could occur in these reaches if counter-clockwise winds from tropical events push water toward the west bank of the bay. Further information on the continued refinement of the proposed nonstructural measures can be found in Section 3.4.2.4. As discussed for the other bay defenses, the nonstructural improvements were not scaled to completely address flood risk without the gulf defenses in place.

## 2.11. Development and Assessment of the Recommended Plan

As discussed in the previous sections, various CSRM alignments and ER measures were evaluated to identify and assemble a Recommended Plan, as is presented in Chapter 3, that met the intent of the authority to develop a comprehensive plan to protect, restore and maintain a diverse coastal ecosystem and reduce the risks of storm surge damage to homes and businesses across Texas' coastal regions.

Specifically, the Recommended Plan includes:

- A Coastwide ER Plan, refined from ER Alternative 1 (the NER Plan)
- The refined South Padre Island Beach Nourishment and Sediment Management measure, as discussed previously (the NED Plan for the lower Texas coast)
- The Galveston Bay Storm Surge Barrier System, refined from CSRM Alternative A (the NED Plan for the upper Texas coast)

In total, the Recommended Plan represents a system-wide risk management strategy for the coastline of Texas integrating structural and non-structural coastal storm damage risk reduction actions with ecosystem restoration actions to enhance the resiliency of coastal communities and the living shoreline from coastal storms.

Standard damage reduction procedures for CSRM measures and habitat criteria (AAHU) for ER measures were used to compare and optimize alternatives. In addition, the alternatives were evaluated with regard to their contribution to the broader resiliency of the Texas coast, which assesses the region's ability to prepare, withstand, recover, and adapt from coastal storms and maintain the region's critical social, economic and support systems. Resilience metrics include critical infrastructure protected, life safety risks, and regional economic impacts for the CSRM features, and qualitative considerations of ER measures buffering navigation channels and adjacent landscapes.

Specific to the upper Texas coast, the Galveston Bay Storm Surge Barrier System is the NED plan, when evaluated at a system scale. The Gulf defense includes three components that cannot be evaluated as separable elements, because the Bolivar Roads Gate System is dependent upon stabilized barrier islands. A breach along the barrier islands would allow Gulf surge to reach the Bay, undermining the effectiveness of the system. The recommended beach and dune segments would assist in stabilizing Bolivar Peninsula and Galveston Island, providing an integrated line of defense along the Gulf. The Bay defenses are needed to provide redundancy and robustness for the system, considering Bay-surge risks, and to increase resiliency of bayside communities. Furthermore, Coastwide ER Plan Measure G28 works in tandem with adjacent CSRM measures to support a comprehensive approach employing multiple lines of defense to enhance resiliency along the upper Texas coast.

The Federal P&G establish four criteria for evaluation of water resources projects. These are completeness, effectiveness, efficiency, and acceptability. In selecting the Recommended Plan, each of these criteria were evaluated. This includes:

***Completeness: Does the plan include all the necessary parts and actions to produce the desired results?***

- The Recommended Plan includes layered features that address risk over a broad region and perform as a system.
- Other plans evaluated place unnecessary risk on the long term desired results by focusing on more concentrated landward alignment adjacent to development and

leave independent features such as a Galveston Ring Barrier open to risk from significant landscape changes associated with RSLC.

***Effectiveness: Does the plan meet the objectives?***

- The Recommended Plan addresses coastal risk in the broadest region, enclosing the most coastal landforms within the system.
- Other plans evaluated place residents in areas of increased risk, by placing the barrier alignment directly adjacent to communities. Furthermore, those plans also fail to meet the objective of reducing risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.) from storm surge impact.

***Efficiency: Is the plan cost effective?***

- The Recommended CSRM Plan provides for positive net benefits. Even under all RSLC scenarios and cost ranges, the Recommended Plan still obtains the highest net benefits, as compared to other plans evaluated.
- The Recommended ER Plan focuses on the most vulnerable and most critical nationally significant environmental resources while recommending the lowest cost comprehensive ER plan.

***Acceptability: Is the plan acceptable and compatible with laws and policies?***

- There are no identified insurmountable technical, economic, financial, environmental, social, political, legal, and institutional impediments to the implementation of the Recommended Plan
- Throughout the planning process, the study avoided, minimized, and reduced impacts associated with the Recommended Plan to ensure compliance with laws and policies.
- The Recommended Plan has been identified as the Least Environmentally Damaging Practicable Alternatives and has been assessed for environmental compliance through the attached Final EIS and is compatible with laws and policies.

Building on the broad evaluation summarized above, the following sections discuss the contributions of the Recommended Plan to the four accounts that the USACE uses in its standard planning process. Consideration of benefits to all four accounts supports identification of a more comprehensive solution which contributes to the broader resiliency of the areas.

### 2.11.1. National Economic Development (NED)

The core component of NED analysis is the quantification of avoided flood damages, which factor directly into the benefit cost ratio for the project. Both CSRM measures, the South Padre Island Beach Nourishment and Sediment Management measure and the Galveston Bay Storm Surge Barrier System, achieve significant flood damage reduction benefits, as detailed later in Section 3.8 of this report. Most importantly, the Galveston Bay Storm Surge Barrier System produces over $2 billion in average annual flood damage reduction benefits.

However, as discussed throughout this report, additional considerations beyond direct flood damage reduction were also considered. This includes the impact ER and CSRM features have in buffering USACE navigation channels and communities on the Texas coast from erosion, subsidence, and storm losses, which in turn indirectly equate to reductions of storm losses. In addition, nourishment of marshes that are eroding and degrading and construction of breakwaters along unprotected segments of the GIWW reduce long term maintenance activities along shallow draft channels. Opportunities for future beneficial use of dredged material within ER sites also equates to cost savings in the navigation arena which further increases NED benefits, although they are not currently captured in the NED calculations.

Similar to navigation, recreation benefits were not captured in the NED calculations for the beach and dune features associated with the both the ER Plan and the Galveston Bay Storm Surge Barrier System, although they were included for South Padre Island. While we do not expect to see large increases in recreational use, the larger beach profiles would improve the quality and experience of recreational users throughout the region.

### 2.11.2. Environmental Quality (EQ)

As discussed in Section 2.7.1, the Recommended Plan is the lowest cost comprehensive ER plan with the measures directly benefitting nationally significant resources. In addition, beyond the ER features, the natural and nature-based features included in the West Galveston and Bolivar Peninsula beach and dune CSRM features will also have significant benefits on critical national resources in the study area.

The study area encompasses critical coastal ecosystems including wetlands, seagrass beds, oyster reefs, and sea turtle nesting habitat. All the ER features and the CSRM beach and dune features directly or indirectly contributed to the protection or restoration of these habitats. This habitat is critical for many threatened and endangered species, including Piping Plovers, Red Knot, Whooping Crane, Attwater's Greater Prairie Chicken, West Indian Manatee, and sea turtles.

Features such as B2 – Follets Island Gulf Beach and Dune Restoration, W3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration and the CSRM beach and dune features on Galveston Island and Bolivar Peninsula would restore and provide a continues sediment sources in the future for the Critical Habitat for Piping Plover, Features such as CA6 – Powderhorn Shoreline Protection and Wetland Restoration, M8 – East Matagorda Bay Shoreline Protection, B12 – Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection and G28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection would have a direct impact for Whooping Crane habitat.

Audubon's priority species of the Central Flyway Migration Corridor, including the Red Knot, also occur in the study area, with shorelines and bird islands providing nesting habitat. The Recommended Plan will provide over 841.2 acres of additional nesting habitat through the creation new bird island or expanding the area of existing islands. As part of the CSRM features, over 64.28 million cubic yards of sediment would be added to Texas's barrier islands over the 50 years. This addition to the system's existing sediment budget will significantly improve the foraging habitats for these coastal nesting species.

The W-3 measure and also the addition of sediment from SPI to the longshore processes will have significant improvements on the Padre Island National Seashore and the Laguna Madre, one of a few hypersaline lagoons in the world. It is a rich and biologically diverse ecosystem that accounts for ~80% of all of Texas' seagrass beds.

Section 4.2.3.4.3 "National Significance" of Appendix A, the Planning Appendix, provides a detailed overview of each features National Significance, however the interactions and linkages been the ER and CSRM discussed above is one critical reasons why considerations for implementation of both measures should be considered equally when funded.

### 2.11.3. Regional Economic Development (RED)

The RED account addresses the impacts that the USACE expenditures associated with the construction of a coastal storm risk management system will have on the levels of income, output, and employment throughout the region. These impacts are not included in the NED analysis, but are indicators of regional economic resilience, and can still be used by decision makers as part of their investment decision process.

Due the large cost associated with CSRM structure system in the upper coast region, the local region the Houston-Sugar Land-Baytown metropolitan statistical area, which includes Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery and Waller counties will see the greatest impacts from the Federal action. A total of approximately 5,620 average annual full-time equivalent jobs would be created, generating $35 billion in labor income, $40.2 billion in the gross regional product, and $63.2 billion in economic output will be developed in the local impact area. More broadly, when also including areas outside of the local region, the expenditures support approximately 7,990 average annual full-time equivalent jobs created, generating $45.5 billion in labor income, $58.3 billion in the gross regional product, and $99.3 billion in economic output in the nation. Many of the benefits are associated with the construction of the Recommended Plan. As discussed in subsequent sections, OMRR&R will be required by the local non-Federal sponsor. Expenditures associated with these efforts would continue to create jobs and income through the life of the project. Further information on RED can be found in the Appendix E-4.

### 2.11.4. Other Social Effects (OSE)

The OSE account is intended to consider and account for benefits related to health and safety, social vulnerability and resilience, economic vitality, and social connectedness and identity. As discussed above, the recommended features were assembled as a comprehensive plan to achieve resiliency for communities and were formulated to be adaptive over time to maintain risk reduction in the face of coastal geomorphology and relative sea level changes. Resilience is captured as the system's ability to prepare, withstand, recover, and adapt from coastal storm risk. The Recommended Plan will reduce the harm to these systems, helping them prepare for and to withstand threats. The Recommended Plan would ensure that the economy and the region's critical infrastructure would continue to operate after a storm and that the stress and hardship associated with hurricane storm surge would be lessened. Key considerations, including critical infrastructure, evacuation/emergency access, and life safety are discussed in more detail in the following sections.

- ***Critical Infrastructure***
  As discussed in more detail in Section 3.8.3 of this report, under the future without project conditions approximately 253 critical infrastructure points would be impacted during a 1% AEP event. With the project in place, only ~94 critical infrastructure points would be impacted under the same event, representing a significant reduction in risk for infrastructure critical to the recovery of a region after a surge event.

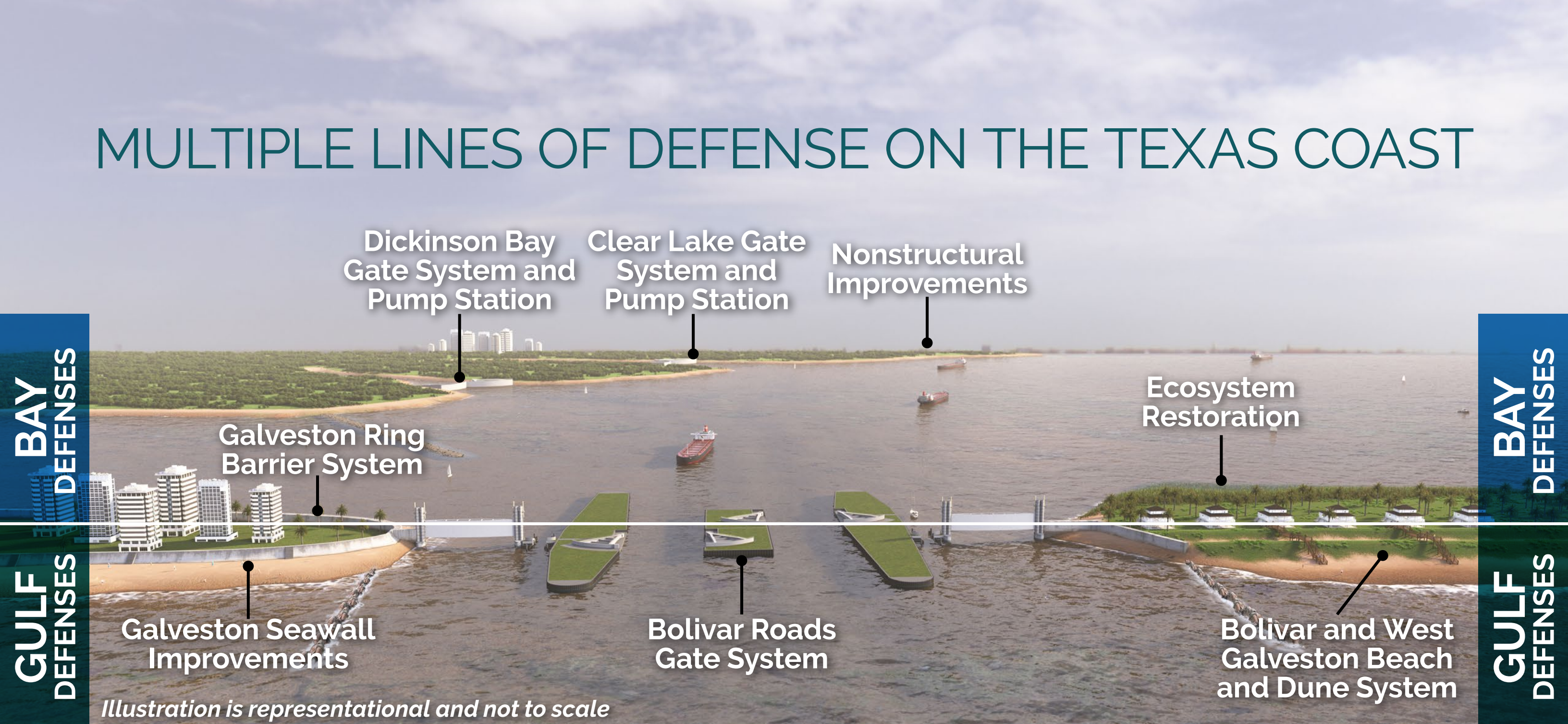
- ***Evacuation/Emergency Access***
  The Recommended Plan, due to its comprehensive coverage, reducing risk to all roadways in the area behind the coastal barrier. For example, the dune and beach features provide direct risk reduction to SH 124, which is at immediate risk. This was one of the key highways that was destroyed after Hurricane Ike, leaving the communities of Bolivar Peninsula with only ferry access from Galveston. The loss of the highways can have significant impacts on the recovery times for Galveston Island and surround communities. Another area of concern is the future risk to the I-10 corridor east of the City of Houston. As RSLC occurs and more habitat is lost along Smith's Point on the east side of Galveston Bay, the risk for surge inundating I-10 increases. Preventing water from entering Galveston Bay, and maintaining Bolivar Peninsula with the Recommended Plan, directly prevents water from flooding the I-10 corridor in the northeast portion of Galveston Bay. Flooding in this area would completely cut off the City of Houston from evacuating to the east, or securing emergency support from the east after a storm.

- ***Life Safety***
  In accordance with USACE policy, a Life Safety Risk Assessment (see Annex 25 of the Appendix D, the Engineering Appendix) was conducted to assess the benefits of the Recommended Plan on reducing life safety risk. In addition, this assessment quantified potential failure modes and potential consequences of failure to inform efforts to minimize residual life safety risk during PED.

  Specific to coastal storm surge, evacuation planning is the primary means to reduce risk to life safety in the study area, which falls within the A, B and C Evacuation Zones of the state of Texas's evacuation plan. Well ahead of tropical force winds or surge, the State of Texas will make plans to evacuate the projected area of impact. Under the State of Texas's evacuation planning guidance and local government evacuation planning, residents should be well outside of the study area during hurricane events. Historically, there is limited loss of life when evacuation planning is implemented.

Quantitative life safety benefits between the future without project and future with project conditions are not claimed because evacuation planning and response are the best means to assure the health and safety of the population. Importantly, the primary intent of the project is to reduce damages to homes, utilities, hospitals and emergency response facilities, and to support the efficient recovery from storm events. However, in the long term the prevention of these damages reduces health and life safety risk. The Recommended Plan also reduces the flooding and erosion of critical transportation routes, which keeps them open for maximum evacuation effectiveness, as well as enabling immediate post-storm access by emergency responders, repair crews and other critical services. Based on the assessment, overall public health and life safety risks are expected to be reduced with the Federal action, especially when considering the ancillary benefits associated with a faster and more complete recovery after a storm.

When comparing the Recommended Plan to other alternatives considered, life safety risks are less for multiple reasons. Primarily, other alternatives which included flood walls directly adjacent to populated areas (specifically Alternative D2) create significantly greater life safety risk than the Recommended Plan as the system ages. It is important to note, even though all residents should have evacuated from the area, there is still a risk that a failure of the system could impact any remaining population. The Life Safety Risk Assessment analyzes potential failure modes and the potential consequences of those failures. The findings presented in the Life Safety Risk Assessment are intended to support efforts in PED to refine designs to minimize life safety risk. While there may be localized flooding at a location of a failure, in general the overall depth of flooding in the study area would be much less than in the future without project condition, resulting in an increase life safety performance even when considering potential system failures. Further information on the Life Safety Risk Assessment is presented in Annex 25 of Appendix D, the Engineering Appendix.




*A representational illustration of multiple lines of defense*

# 3. Recommended Plan

After the Tentatively Selected Plan (TSP) was released in October 2018 for public comment, policy review, and agency technical review, multiple refinements were considered and developed to improve both the performance and acceptability of the proposed Coastal Storm Risk Management (CSRM) and Ecosystem Restoration (ER) features. Most significantly, the plan now excludes the proposed levee/floodwall segments that would have paralleled State Highway 87 on Bolivar Peninsula and FM 3005 on Galveston Island. These segments were removed from the plan to ensure compliance with existing policies and laws, specifically those related to the Coastal Barrier Resources Act (CBRA), and to minimize social and environmental impacts. Instead, the Bolivar and Galveston beach and dune systems initially proposed as ER measures in the TSP will be increased in size to also reduce storm surge impacts. In addition, among other changes at the Bolivar Roads crossing, two smaller deep-draft navigation gates are now proposed, instead of a single larger gate. Furthermore, the ring barrier on Galveston Island was refined to reduce impacts to surrounding neighborhoods and enclose more areas. In other changes, future nourishment cycles were removed from the proposed ER features and minor revisions were made to individual features as part of continued feasibility phase preliminary design efforts.

*A photo of downtown Galveston*

These revisions and refinements resulted in the identification of the Recommended Plan. To support development of the Recommended Plan, further environmental evaluations were advanced, cost and benefit analyses conducted, and implementation requirements and considerations determined. Below is a summary description of the Recommended Plan, detailing where in this chapter more detailed information can be found. Further technical details for the Recommended Plan can be found in the Technical Appendices. In addition, a discussion of the environmental impacts associated with the Recommended Plan is provided in Chapter 4 of this report, in addition to Chapters 4 and 5 of the attached Final Environmental Impact Statement (EIS).

*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 man-made infrastructure and to restore degraded coastal ecosystems through a comprehensive approach employing multiple lines of defense.*

## 3.1. Plan Summary

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 man-made 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 (RSLC). The Recommended Plan, shown in Figures 3.1 to 3.3, can be broken into three groupings, with section references indicating where they are described in more detail:

- **Section 3.2:** 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. ER plan benefits have been estimated with standard habitat valuation procedures. The lowest-cost comprehensive ER plan is recommended.
- **Section 3.3:** On the lower Texas coast, a CSRM beach restoration measure on South Padre Island (SPI) was formulated in a traditional National Economic Development (NED) framework to include 2.9 miles of beach nourishment and sediment management. The plan proposes beach nourishment on a 10-year cycle for the authorized project life of 50 years. The economic analysis confirms that beach nourishment is cost effective when considering construction costs, benefits, and real estate costs.
- **Section 3.4:** On the upper Texas coast, the Galveston Bay Storm Surge Barrier System was formulated as a system with multiple-lines-of-defense to reduce damage to communities, critical petrochemical and refinery complexes, Federal navigation channels, and other existing infrastructure in and around Galveston Bay from storm surge.

*A photo of the Galveston Seawall*

Specific to the upper Texas coast, the Gulf line of defense separates Galveston Bay from the Gulf of Mexico to reduce storm surge volumes entering the Bay. Components which make up the Gulf line of defense include:

- The Bolivar Roads Gate System, across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island;
- 43 miles of beach and dune segments 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; and
- Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge.

The Bay defenses enable the system to manage residual risks. Residual risks are driven by the run up of water contained within the Galveston Bay system plus any additional Gulf surge that overtops the Gulf line of defense. The Bay defenses also provide further resiliency against variations in storm track and intensity and RSLC. Bay defense components include:

- 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.

In total, the Recommended Plan represents a system-wide risk management strategy for the coastline of Texas integrating structural and non-structural coastal storm damage risk reduction actions with ecosystem restoration actions to enhance the resiliency of coastal communities and the living shoreline from coastal storms.

*The Coastal Barrier Resources Act and the Coastal Barrier Improvement Act are Federal laws that were enacted to minimize loss of human life by discouraging development in high-risk areas and to preserve the ecological integrity of areas Congress designates as a Coastal Barrier Resources System and Otherwise Protected Areas.*

As discussed in Chapter 2, several features included in the Recommended Plan are located within Coastal Barrier Resources Act (CBRA) system units (CBRA zones). The CBRA and the Coastal Barrier Improvement Act are Federal laws that were enacted to minimize loss of human life by discouraging development in high-risk areas and to preserve the ecological integrity of areas Congress designates as a Coastal Barrier Resources System and Otherwise Protected Areas. The laws prohibit all Federal expenditures or financial assistance for residential or commercial development in the CBRA zones, unless the activities meet one of the CBRA's exceptions. However, the CBRA imposes no restrictions on actions and projects within the CBRA zones that are carried out with state, local, or private funding. The USACE, in coordination with the GLO, has consulted with the U.S. Fish and Wildlife Service (USFWS) to ensure that the Recommended Plan is in compliance with the CBRA. The consultation with the USFWS is in the form of an opinion only, since the final responsibility for complying with the CBRA rests with the Federal funding agency, which is the USACE. Features located in CBRA zones have been identified in the sections below, and a detailed summary of CBRA coordination efforts is included in Appendix E of the Final EIS.

As stated above, Section 3.2, Section 3.3, and Section 3.4 provide a detailed review of the features associated with the Recommended Plan, starting with the Coastwide ER Plan, then the SPI Beach Nourishment and Sediment Management measure, and finally the Galveston Bay Storm Surge Barrier System, including both Gulf and Bay defenses. Summary information for the complete Recommended Plan is detailed in the following sections:

- **Section 3.5:** Mitigation Requirements
- **Section 3.6:** Adaptive Management and Monitoring
- **Section 3.7:** Real Estate and Relocation Requirements
- **Section 3.8:** Project Benefits
- **Section 3.9:** Project Costs
- **Section 3.10:** Operation, Maintenance, Repair, Rehabilitation, and Replacement
- **Section 3.11:** Benefit-Cost Analysis for the Galveston Bay Storm Surge Barrier System
- **Section 3.12:** Overall Benefit/Cost Summary of the Recommended Plan
- **Section 3.13:** Risk and Uncertainty and Adaptive Response

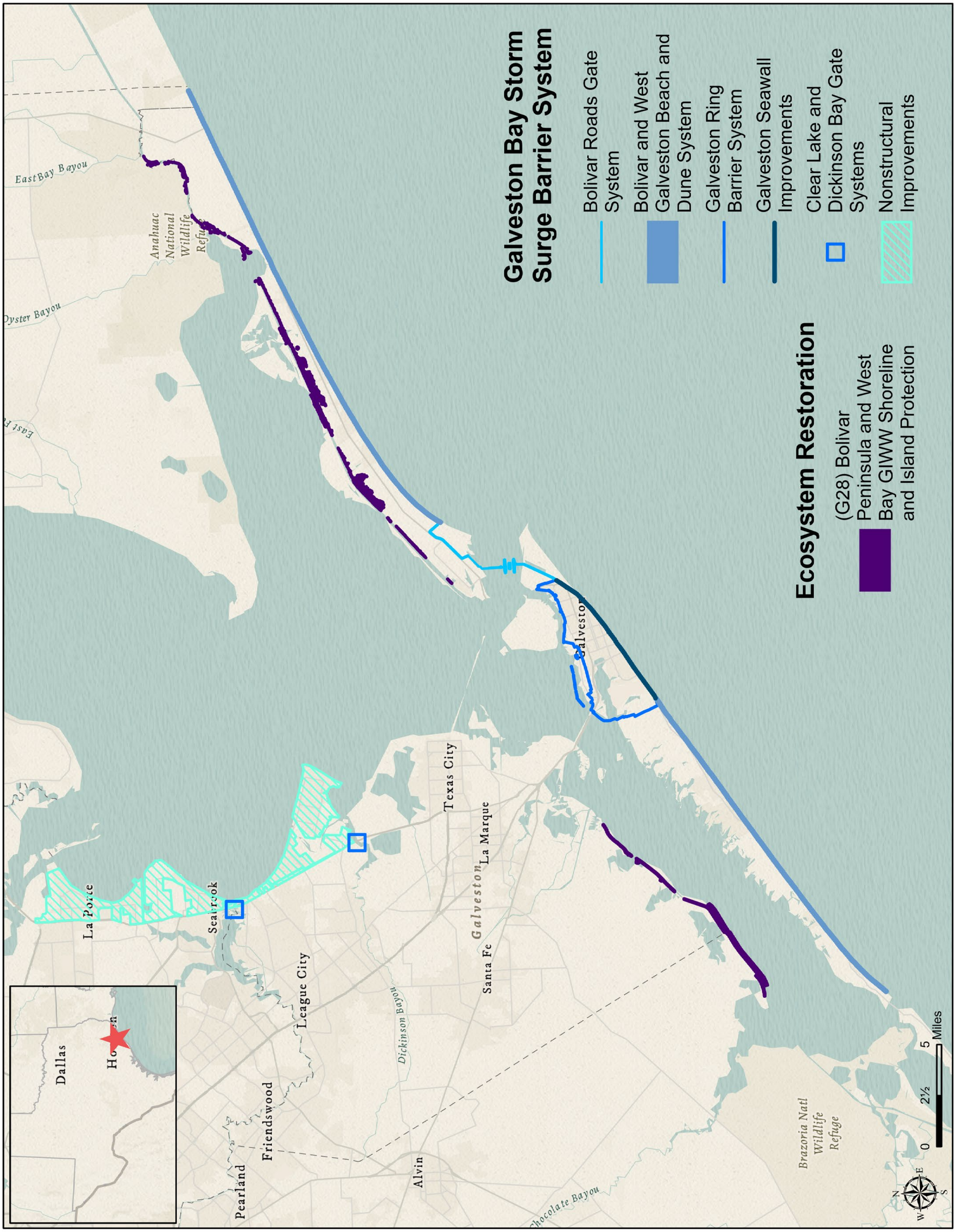



*Figure 3.1: Recommended Plan – upper coast*

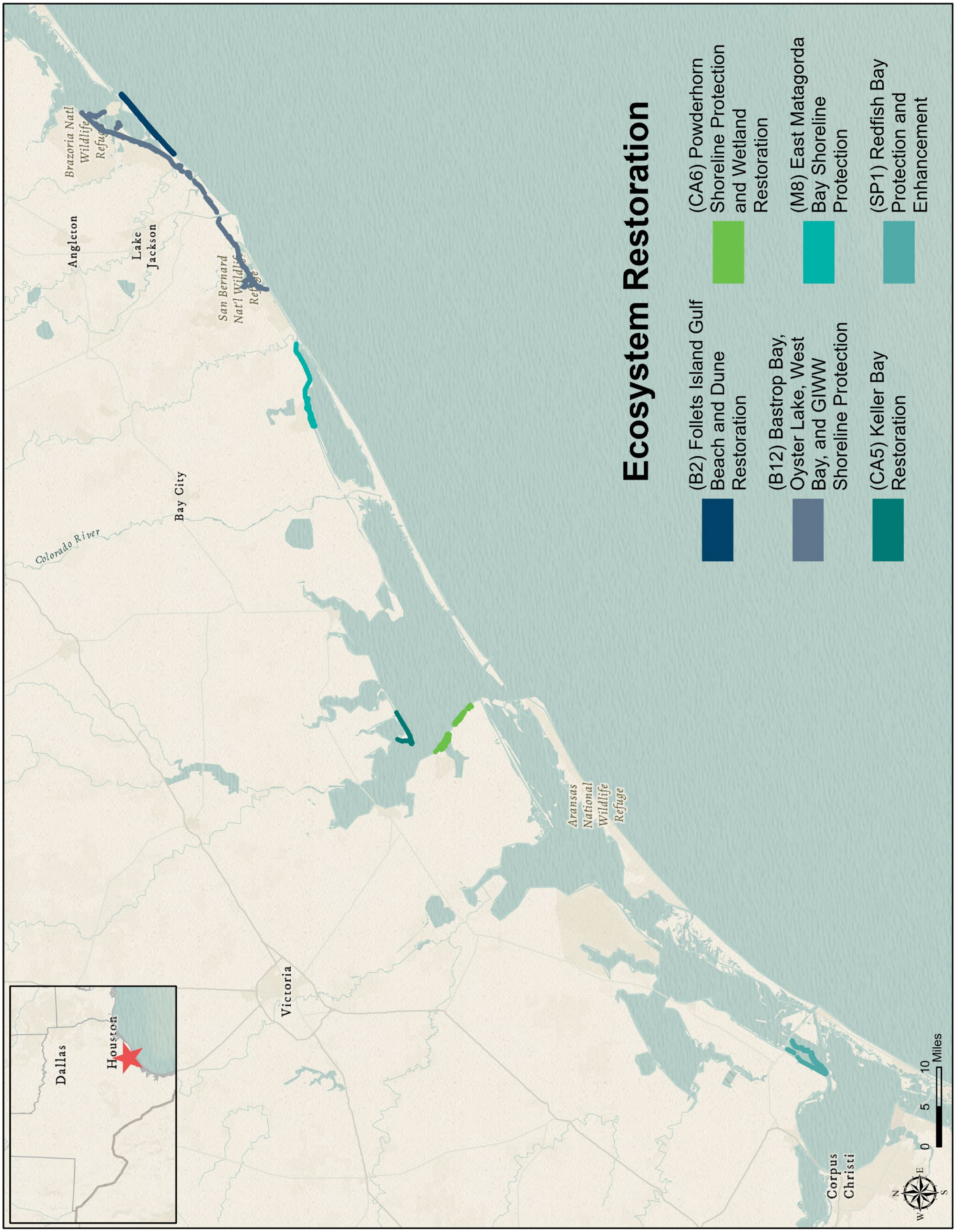



*Figure 3.2: Recommended Plan – mid coast*


*Figure 3.3: Recommended Plan – lower coast*

## 3.2. Ecosystem Restoration

As discussed in Chapter 2, the proposed ER features work in concert with the proposed CSRM features to provide redundant and resilient protection to and for Texas' coastal ecosystems and the communities nearby. These features fit into the multiple lines of defense strategy, as detailed below:

- 1st Line of Defense – Barrier Systems
  - This includes barrier shorelines, islands, and headlands as well as barrier beach, dune, and back marsh.
  - Restoration of this line of defense includes consideration of barrier system ecological and geomorphic functions.

- 2nd Line of Defense – Estuarine Bay System
  - This includes geomorphic bay features and estuarine habitats including bay shorelines and estuarine marsh, bird rookery islands, oyster reefs, and seagrass beds.
  - Restoration of this line of defense includes consideration of estuarine and bay ecological and geomorphic functions.

- 3rd Line of Defense – Bayhead Deltas
  - This includes bayhead deltaic features and associated habitats including adjacent bird rookery islands, reefs, subaquatic vegetation, and marsh.
  - Restoration of this line of defense includes consideration of bayhead delta ecological and geomorphic functions

ER measures included in the Recommended Plan are refined versions of those in the TSP described in Chapter 2. These measures are proposed at eight locations along the coast and include 114 miles of breakwaters, 15.2 miles of bird rookery islands, 2,052 acres of marsh, 12.32 miles of oyster reef, and 19.5 miles of beach and dune. The proposed measures address significant habitats and natural resources in the region, including numerous resources of national significance. These include the Central and Mississippi Flyways, critical coastal ecosystems including wetlands, seagrass beds, oyster reefs, and sea turtle nesting habitat. In addition, the measures provide habitat for many threatened and endangered species such as Piping Plovers, Red Knot, Whooping Crane, West Indian Manatee, and sea turtles. Further discussion on the Recommended Plan's benefit to resources of national significance is provided in Chapter 2, Section 4.2.3.4.3 of Appendix A - Plan Formulation, and in the Final EIS. These ER measures are detailed in the indicated sections as follows, with the location of each ER measure shown in Figure 3.4:

- **Section 3.2.1:** G28 - Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection
- **Section 3.2.2:** B2 - Follets Island Gulf Beach and Dune Restoration
- **Section 3.2.3:** B12 - Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection
- **Section 3.2.4:** M8 - East Matagorda Bay Shoreline Protection
- **Section 3.2.5:** CA5 - Keller Bay Restoration
- **Section 3.2.6:** CA6 - Powderhorn Shoreline Protection and Wetland Restoration
- **Section 3.2.7:** SP1 - Redfish Bay Protection and Enhancement
- **Section 3.2.8:** W3 - Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

Conceptual renderings of select common ER features, including breakwaters, oyster reefs, marsh restoration, and beach restoration, are shown in Figure 3.5.

**ER MEASURES**
*FAST FACTS*

**8** *PROPOSED LOCATIONS*

**114** *MILES OF BREAKWATERS*

**12.32** *MILES OF OYSTER REEF*

**19.5** *MILES OF BEACH & DUNE*

**15.2** *MILES OF BIRD ROOKERY ISLANDS*

**2,052** *ACRES OF MARSH*

*An example of deteriorated coastal wetlands*

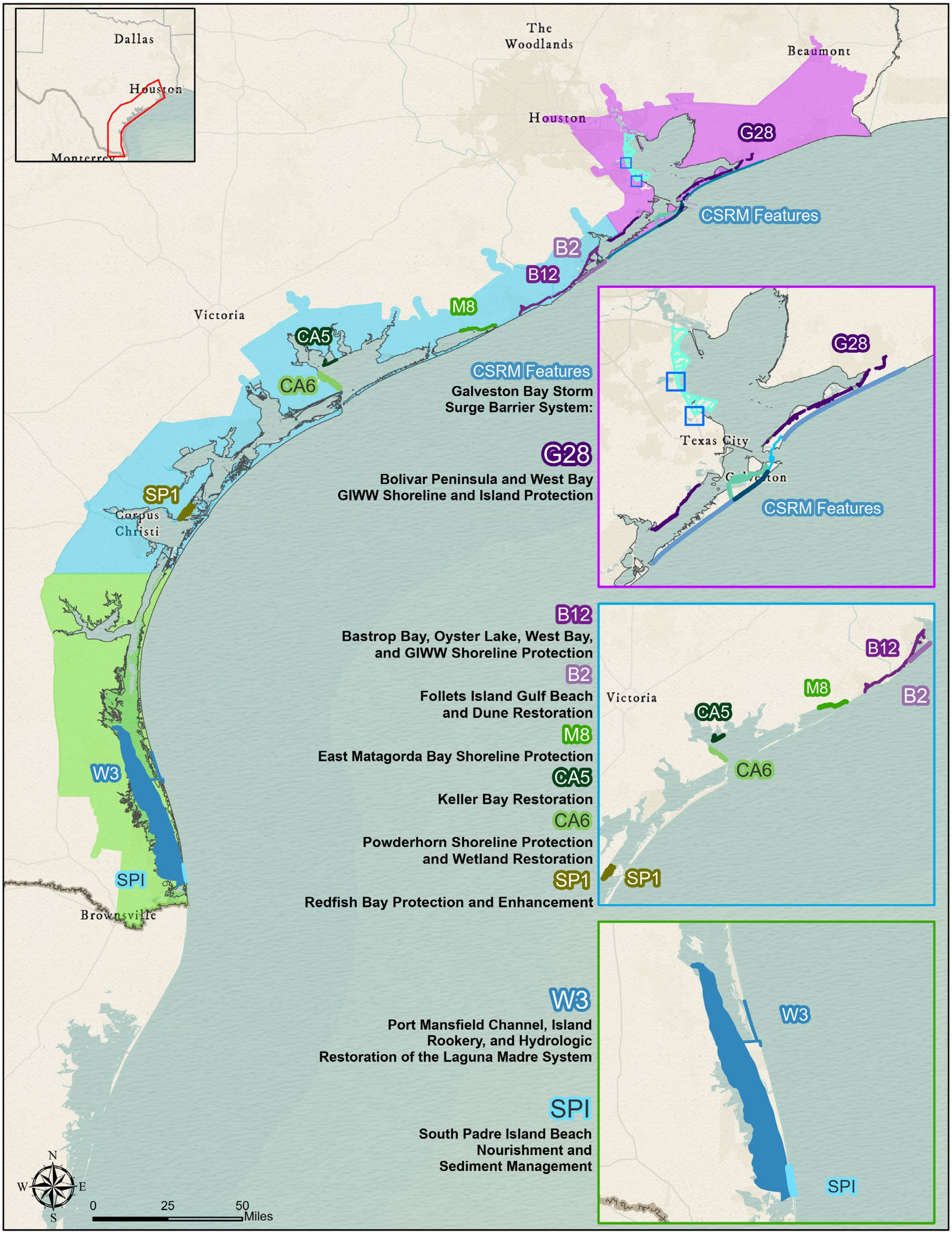



***Figure 3.4:*** *Coastwide ER plan*

# ECOSYSTEM RESTORATION MEASURES

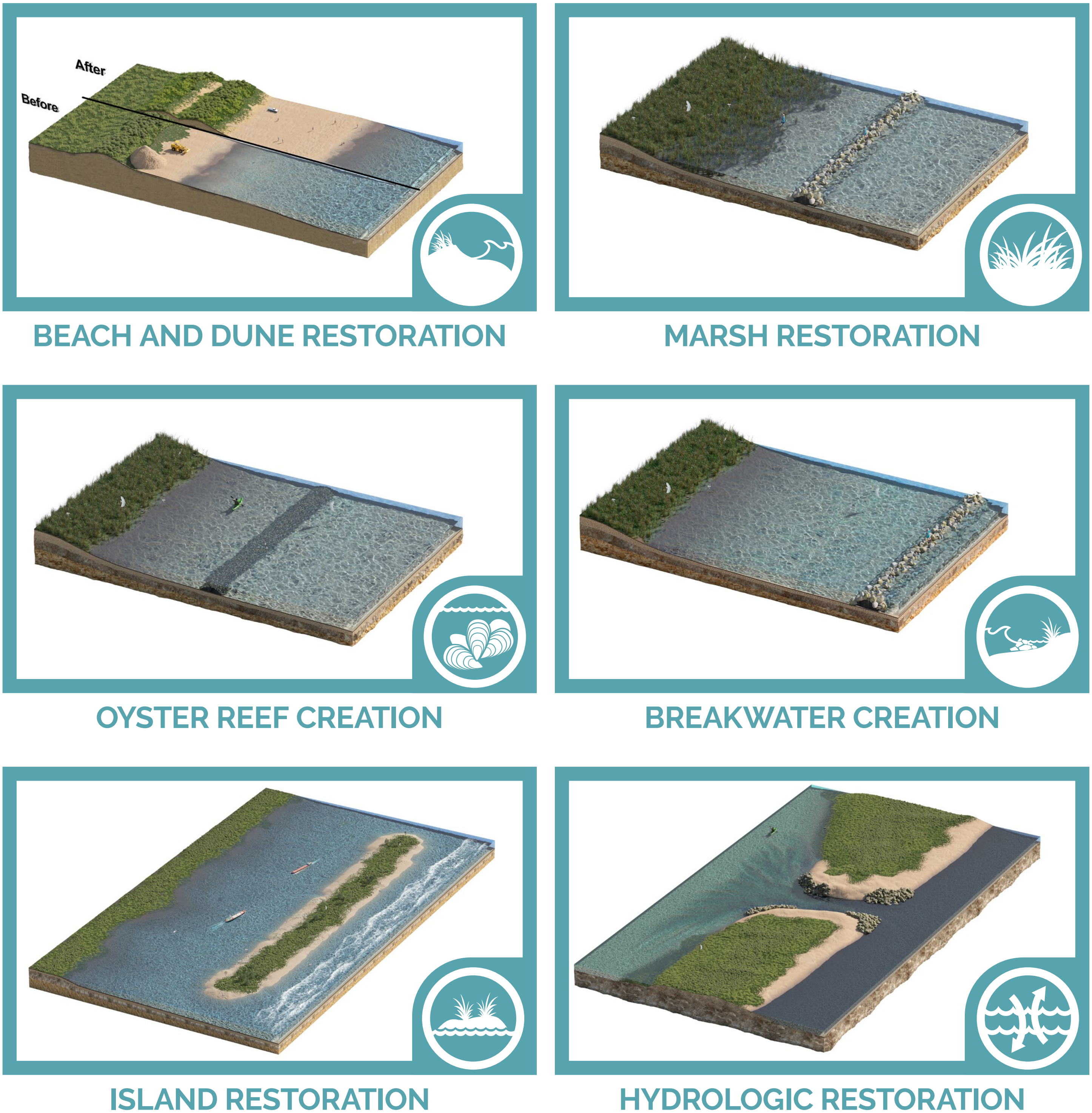



***Figure 3.5:*** *Conceptual renderings of ER measures*

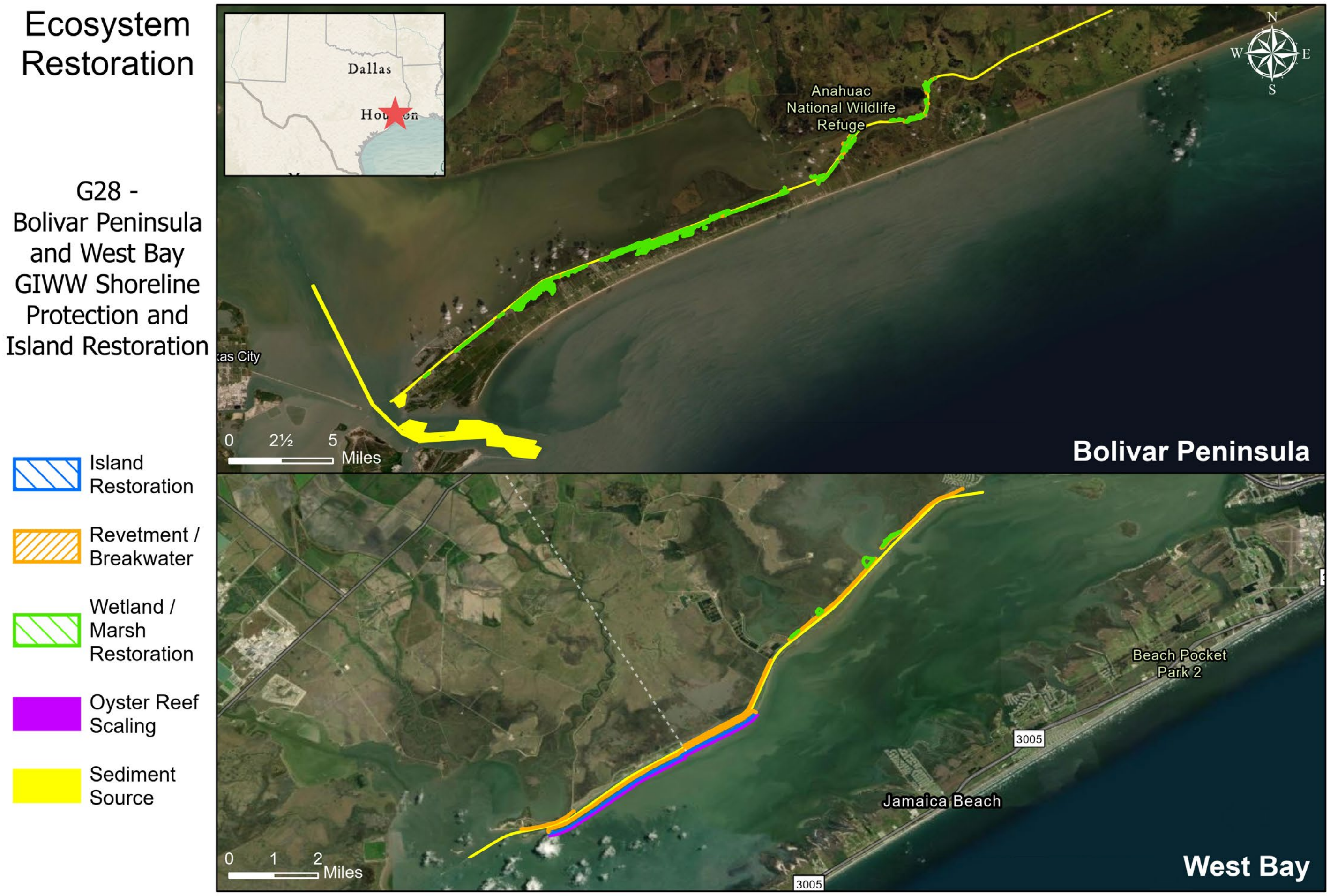



*Figure 3.6:* G28 - Bolivar and West Bay GIWW shoreline and island protection – east

## 3.2.1. G28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection

This ER measure involves shoreline protection and restoration consisting of 40.4 miles of rock breakwater at a crest height of 7 ft (NAVD88) with 2:1 (Horizontal [H] : Vertical [V]) side slopes and a base width of 46 ft, 18 acres of oyster cultch creation, 664 acres of marsh restoration, and 5 miles of island restoration. A total of 1,295.4 Average Annual Habitat Units (AAHU) would be created.

The construction of the rock breakwaters will reduce erosion of unprotected segments of shoreline along the GIWW on Bolivar Peninsula and along the north shore of West Bay, reducing or even reversing the loss of marsh habitat in these areas. Sediment from dredging the GIWW and the Bolivar Roads Gate System construction will be used to create 326 acres of island surface that once protected approximately 5 miles of the GIWW and the mainland in West Galveston Bay. Furthermore, the addition of 18 acres of oyster cultch will act as a natural breakwater to restore protection to the island on the bayside and provide critical habitat. Figure 3.6 shows the general location of these features. Additional detailed information related to ER measure G28 can be found in Section 7.2 of Appendix D.

As discussed in Section 3.1, G28 includes features located in a CBRA zone. However, for this feature, the USACE has determined that the feature would meet one of the CBRA's exceptions. Additional details related to the CBRA impacts can be found in Appendix E of the Final EIS.

### By the Numbers: G28

- *40.4 miles of breakwater*
- *18.0 acres/26,280 linear ft of bayside oyster reef creation*
- *664 acres of estuarine marsh restoration*
- *5 miles/326 acres of island restoration*


*Figure 3.7:* *B2 - Follets Island Gulf beach and dune restoration*

## 3.2.2. B2 – Follets Island Gulf Beach and Dune Restoration

This ER measure restores the existing beach and dune complex on 10.1 miles of Gulf shoreline on Follets Island in Brazoria county, covering approximately 1,113.8 acres of work. The dune would have a crest elevation of 9 ft (NAVD88) and a width of 12 ft, with 5H:1V slopes. The nourished beach width would be approximately 400 ft. A total of 240.1 AAHU would be created. An estimated 800,000 cubic yards of dredged material is anticipated to be sourced from the Sabine Heald Banks to restore the 10.1 miles of beach and dune.

This measure would create habitat and protect beaches and dunes from breaches and erosion caused by storm surge and RSLC. This measure would provide risk reduction for State Highway 257, which is the only evacuation route for this area. Construction of the beach and dunes on Follets Island will also protect Bastrop, Christmas, and Drum Bays, and the Brazoria National Wildlife Refuge. 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. Christmas Bay is also a Texas Parks and Wildlife Department Coastal Preserve. Figure 3.7 shows the general location of these features. Additional detailed information related to ER measure B2 can be found in Section 7.3 of Appendix D.

As discussed in Section 3.1, B2 includes features located in a CBRA zone. However, for this feature, the USACE has determined that the feature would meet one of the CBRA's exceptions. Additional details related to the CBRA impacts can be found in Appendix E of the Final EIS.

### By the Numbers: B2

- *10.1 miles of beach and dune restoration of Gulf shoreline, covering 1,113.8 acres of work.*

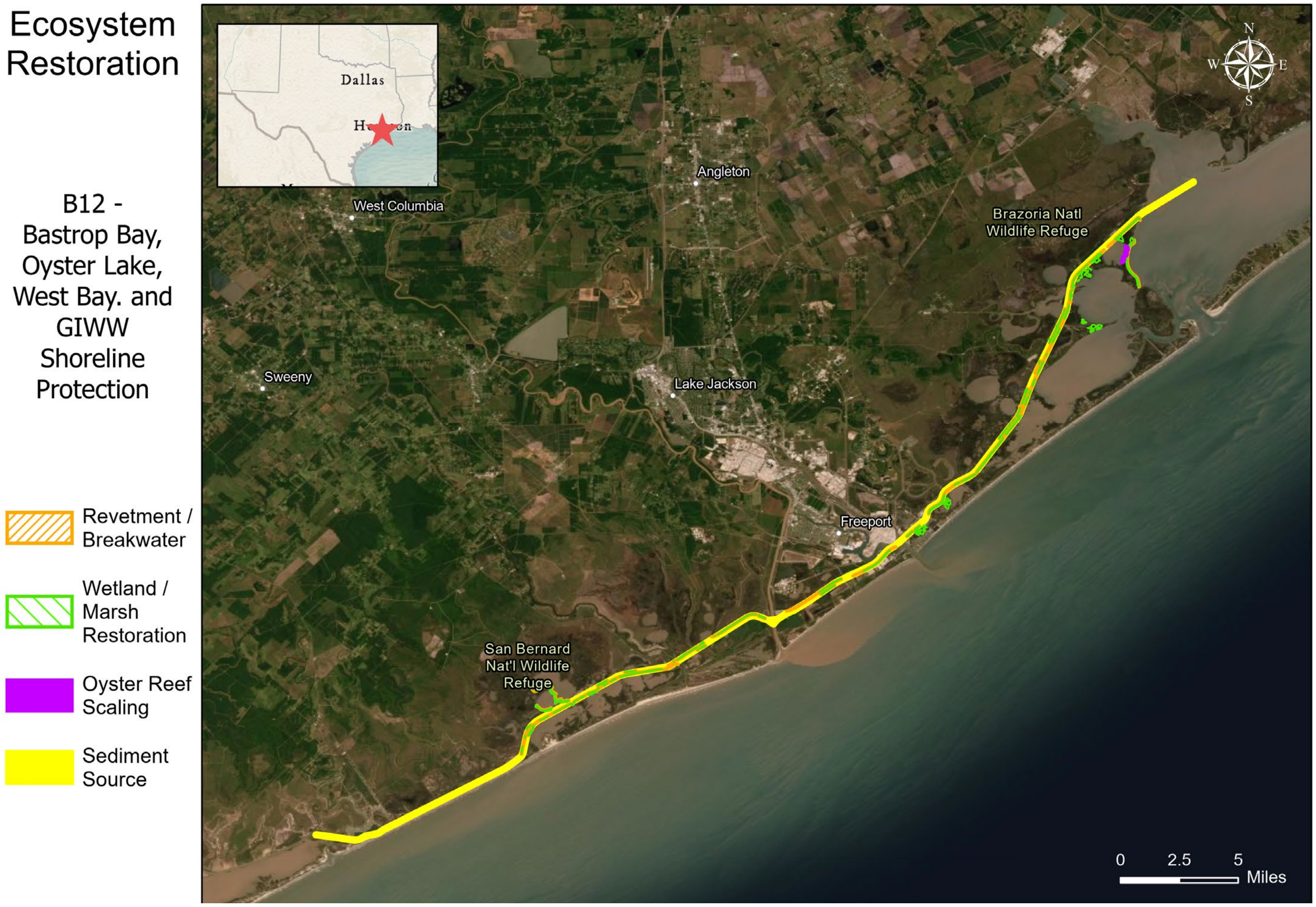



*Figure 3.8:* B12 - Bastrop Bay, Oyster Lake, West Bay, and GIWW shoreline protection

### 3.2.3. B12 – Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection

This ER measure involves shoreline protection and restoration consisting of 43.2 miles of rock breakwater at a crest height of 7 ft (NAVD88) with 2H:1V side slopes and a base width of 46 ft, and 551 acres of marsh nourishment. A total of 1,297.5 AAHU would be created.

The construction of the rock breakwaters will reduce erosion along critical shoreline on the western side of West Galveston Bay and Cowtrap Lakes, and for about 40 miles of GIWW in Brazoria County. The measure will protect critical reaches in Oyster Lake from breaching into West Bay by adding about 3,708 ft of oyster cultch to encourage the creation of oyster reef. Sediment from the GIWW will be used for marsh restoration and nourishment as indicated on Figure 3.8. Additional detailed information related to ER measure B12 can be found in Section 7.4 of Appendix D.

As discussed in Section 3.1, B12 includes features located in a CBRA zone. However, for this feature, the USACE has determined that the feature would meet one of the CBRA's exceptions. Additional details related to the CBRA impacts can be found in Appendix E of the Final EIS.

**By the Numbers: B12**

- *43.2 miles of rock breakwaters*
- *3,708 linear ft of oyster reef creation*
- *551 acres of estuarine marsh restoration*


*Figure 3.9:* *M8 - East Matagorda Bay shoreline protection*

## 3.2.4. M8 – East Matagorda Bay Shoreline Protection

This ER measure involves shoreline protection and restoration consisting of 12.4 miles of rock breakwater at a crest height of 7 ft (NAVD88) with 2H:1V side slopes and a base width of 46 ft. The measure provides for 96 acres of island restoration, 236.5 acres of wetland and marsh restoration, and 3.7 miles of oyster reef creation. A total of 481.5 AAHU would be created.

The construction of the rock breakwater will reduce erosion of 12.4 miles of unprotected segments of the GIWW shoreline and associated marsh along the Big Boggy National Wildlife Refuge shoreline and eastward to the end of East Matagorda Bay. No breakwaters would be constructed where portions of the GIWW shoreline are stabilized by adjacent dredged material placement areas. Sediment from the GIWW or Placement Area 8 would be used to restore a 96 acre island that once protected 3.5 miles of shoreline directly in front of Big Boggy National Wildlife Refuge. Oyster cultch will be placed on the bayside of the island. Figure 3.9 shows the general location of these features. Additional detailed information related to ER measure M8 can be found in Section 7.7 of Appendix D.

### By the Numbers: M8

- *12.4 miles of rock breakwater*
- *236.5 acres of estuarine marsh restoration*
- *96 acres/3.5 miles of island restoration*
- *3.7 miles of oyster reef creation*


***Figure 3.10:*** *CA5 - Keller Bay restoration*

### 3.2.5. CA5 – Keller Bay Restoration

This ER measure involves shoreline protection and restoration consisting of 3.8 miles of rock breakwater, at a crest height of 7 ft (NAVD88) with 2H:1V side slopes and a base width of 46 ft, and placement of reef balls along 2.3 miles of Sand Point in Lavaca Bay. A total of 240.1 AAHU would be created and maintained over 50 yrs.

The construction of the rock breakwaters would reduce erosion along approximately five miles of Matagorda Bay shoreline adjacent to Keller Bay and would aid in the protection of submerged aquatic vegetation that occurs within Keller Bay. The measure would prevent Matagorda Bay from breaching into Keller Bay, with subsequent loss of intertidal marsh, submerged aquatic vegetation beds, and oyster reef in Keller Bay. The measure also provides for the protection of an area north of Sand Point. Figure 3.10 shows the general location of these features. Additional detailed information related to ER measure CA5 can be found in Section 7.5 of Appendix D.

**By the Numbers: CA5**

- *3.8 miles of rock breakwaters*
- *2.3 miles of oyster reef creation*


*Figure 3.11:* *CA6 - Powderhorn shoreline protection and wetland restoration*

## 3.2.6. CA6 – Powderhorn Shoreline Protection and Wetland Restoration

This ER measure involves shoreline protection and restoration consisting of 5.0 miles of rock breakwater, at a crest height of 7 ft with 2H:1V side slopes and a base width of 46 ft, and 529 acres of wetland and marsh restoration. A total of 18.4 AAHU would be created .

The measure would restore marshes and reduce erosion along approximately 6.5 miles of Matagorda Bay shoreline fronting portions of the community of Indianola, Powderhorn Lake estuary, and Texas Parks and Wildlife Department's Powderhorn Ranch. Shoreline stabilization will include breakwaters, with gaps for maintaining circulation. The measure supports the protection of intertidal marsh and the ecological integrity of Powderhorn Lake estuary and several minor estuaries occurring along the Powderhorn Ranch shoreline. At present, the shoreline and various inlets have been eroding relatively rapidly. Figure 3.11 shows the general location of these features. Additional detailed information related to ER measure CA6 can be found in Section 7.6 of Appendix D.

### By the Numbers: CA6

- *5 miles of rock breakwaters*
- *529 acres marsh restoration*


*Figure 3.12: SP1 - Redfish Bay protection and enhancement*

## 3.2.7. SP1 – Redfish Bay Protection and Enhancement

This ER measure involves shoreline protection and restoration consisting of 7.4 miles of rock breakwater, at a crest height of 7 ft (NAVD88) with 2H:1V side slopes and a base width of 46 ft, 391.4 acres of island restoration, and 1.4 miles of oyster reef creation. A total of 3,500.5 AAHU would be created.

The measure provides for the restoration of the Dagger, Ransom, and Stedman Island complex in Redfish Bay through the construction of breakwater along the unprotected GIWW shoreline along the backside of Redfish Bay and on the bayside of the restored islands. Additional protection is provided to the island complex through the placement of reef balls between the breakwater and island complex to create 1.4 miles of oyster reef. The breakwater and islands would protect submerged aquatic vegetation (e.g., seagrass) within Redfish Bay, and it is assumed that additional submerged aquatic vegetation will form between the breakwater and the islands and support coastal water birds. Figure 3.12 shows the general location of these features. Additional information related to ER measure SP1 can be found inSection 7.8 of Appendix D.

### By the Numbers: SP1

- *7.4 miles of rock breakwater*
- *391.4 acres of island restoration*
- *1.4 miles of oyster reef creation*


*Figure 3.13: W3 - Port Mansfield channel, island rookery, and hydrologic restoration*

## 3.2.8. W3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration

This ER measure restores hydrologic connectivity and provides beach nourishment, island restoration, sediment management, and shoreline protection and restoration utilizing breakwaters. A total of 13,936.6 AAHU would be created.

This measure consists of three elements:

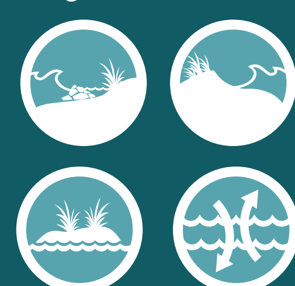
- Restoration and maintenance of the hydrologic connection between Brazos Santiago Pass and the Port Mansfield Channel by dredging 6.9 miles of the Port Mansfield Ship Channel, providing 112,864.1 acres of hydrologic restoration in the Lower Laguna Madre.
- 9.5 miles of beach nourishment along the Gulf shoreline north of the Port Mansfield Channel using the beach quality sand from the above described dredging.
- Protection and restoration of Mansfield Island with the 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 ft (NAVD88)

Footprints and sediment sources for the measure are indicated on Figure 3.13. Additional information related to ER measure W3 can be found in Section 7.9 of Appendix D.

As discussed in Section 3.1, W3 includes features located in a CBRA zone. However, for this feature, the USACE has determined that the feature would meet one of the CBRA's exceptions. Additional details related to the CBRA impacts can be found in Appendix E of the Final EIS.

### By the Numbers: W3

- *9.5 miles of beach nourishment*
- *0.7 miles of rock breakwater*
- *27.8 acres of island restoration*
- *112,864.1 acres of hydrologic restoration*



## 3.3. South Padre Island Beach Nourishment and Sediment Management

This CSRM measure would nourish the beach and dune along SPI to reduce risks from coastal storm surge to businesses, residents, and infrastructure in the highly developed area of SPI. In addition, nourishment will maintain beach nesting habitat for sea turtles and birds.

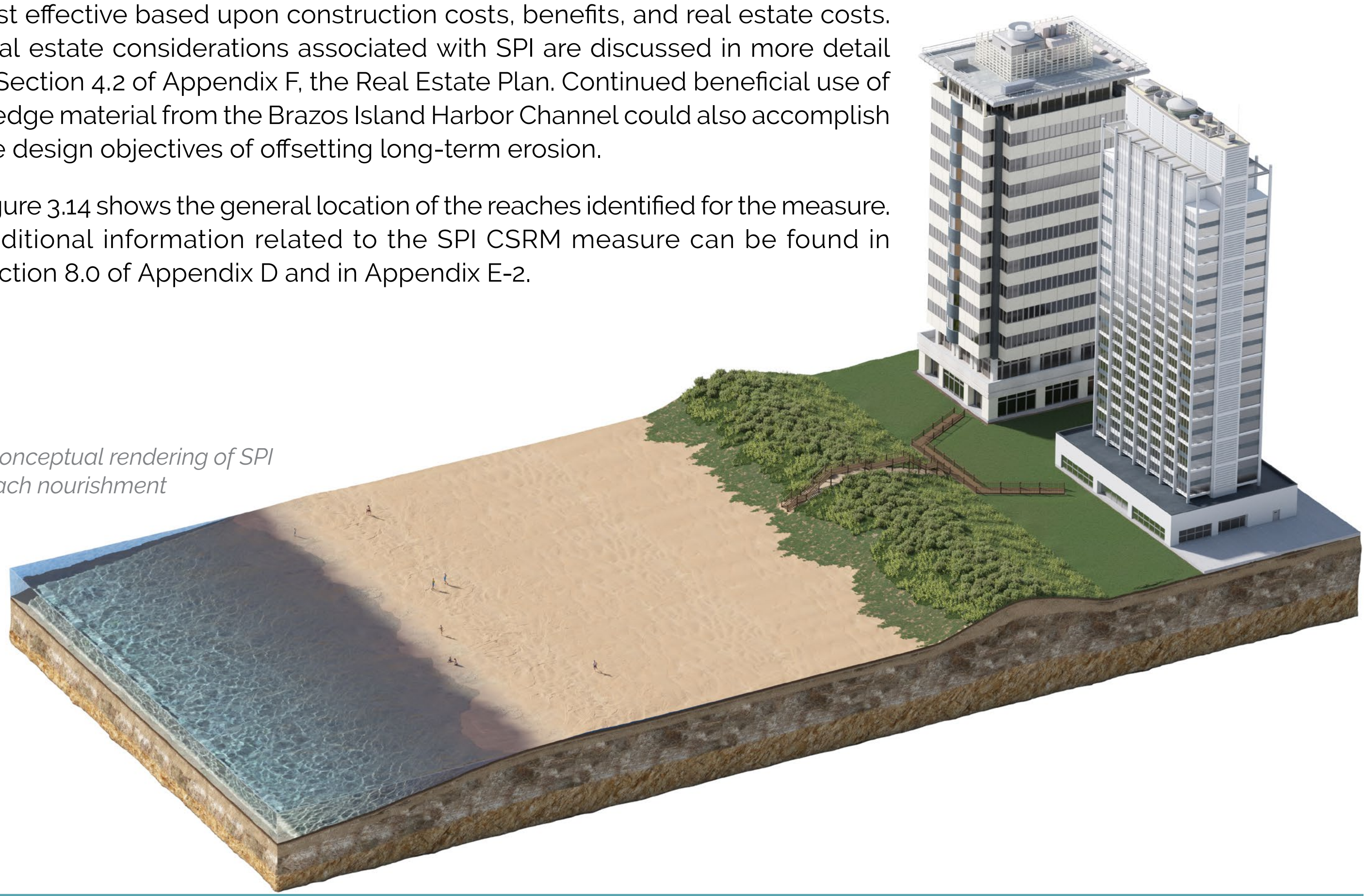
The planning evaluation focused on different scales of beach and dune measures because other structural measures such as revetments, seawalls, rock groins, or offshore breakwaters would disrupt the natural coastal setting without providing added erosion reduction. The relative risk to structures in the region can be managed through beach nourishment at a lower cost and with fewer environmental impacts than hardening the shoreline. A proactive practice of beneficially using sediment dredged from the Brazos Island Harbor Channel has proven that nourishment can sustain a robust beach profile. Also, nonstructural measures were initially considered but not carried forward due to the many nonstructural measures already being implemented by the community, and the relative cost effectiveness of beach nourishment.

This CSRM beach restoration feature was formulated in a traditional NED framework. Beach and dune nourishment is proposed to maintain a 120 ft wide beach and 12.5 ft (NAVD88) dune along 2.9 miles of the developed shorefront areas of SPI, from approximately East Sunny Isle Drive and East Marisol Street to the beginning of Andy Bowie Park (Reaches 3 through 5). Renourishment is proposed on a 10 year cycle for the authorized project life of 50 years (five total renourishments). The economic analysis confirms that beach nourishment is cost effective based upon construction costs, benefits, and real estate costs. Real estate considerations associated with SPI are discussed in more detail in Section 4.2 of Appendix F, the Real Estate Plan. Continued beneficial use of dredge material from the Brazos Island Harbor Channel could also accomplish the design objectives of offsetting long-term erosion.

Figure 3.14 shows the general location of the reaches identified for the measure. Additional information related to the SPI CSRM measure can be found in Section 8.0 of Appendix D and in Appendix E-2.

### By the Numbers: SPI Beach Nourishment

- *2.9 miles of beach nourishment*
- *168,000 cy sediment per cycle*



*A conceptual rendering of SPI beach nourishment*

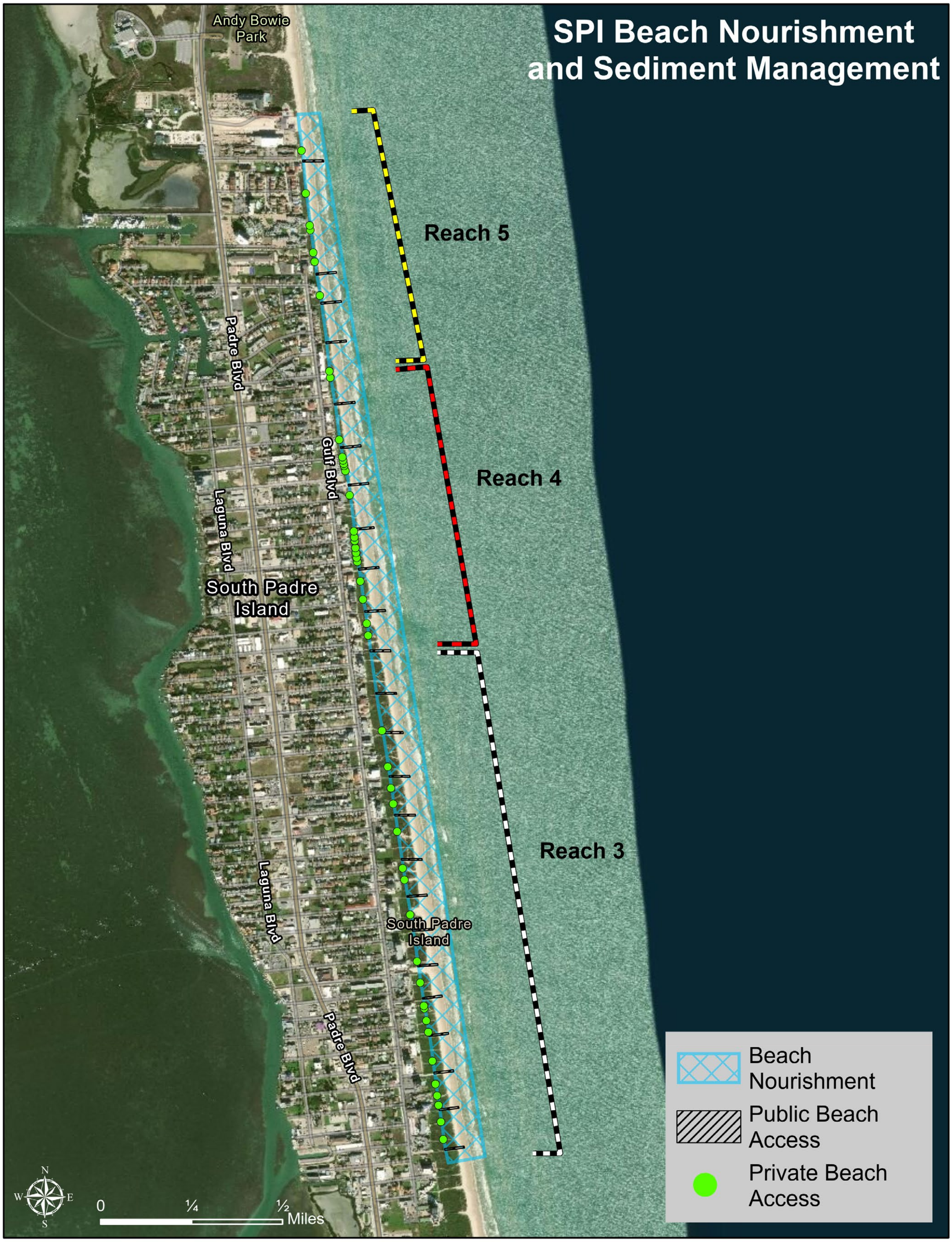



*Figure 3.14: SPI beach nourishment and sediment management*

# 3.4. Galveston Bay Storm Surge Barrier System

As discussed in Chapter 2, the Galveston Bay Storm Surge Barrier System was formulated with multiple lines of defense to provide a resilient, redundant, and robust solution to reduce risks to communities, industry, and natural ecosystems from coastal storm surge. This system includes a Gulf line of defense (Section 3.4.1) which separates the Galveston Bay system from the Gulf of Mexico to reduce storm surge volumes entering the Bay system, and Bay defenses (Section 3.4.2) which enable the system to manage residual risk from Bay waters already in Galveston Bay. The Galveston Bay Storm Surge Barrier System also integrates with Coastwide ER Plan Measure G28, which protects the shoreline from erosion and restores marshes and oyster reefs which enhance the resiliency of proposed adjacent CSRM measures.

## 3.4.1. Gulf Defenses

Similar to those proposed for the TSP, the Gulf defenses include three independent but connected features:

- **Section 3.4.1.1:** The Bolivar Roads Gate System, across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island;
- **Section 3.4.1.2:** 43 miles of beach and dune segments 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; and
- **Section 3.4.1.3:** Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge

The features which comprise the Gulf line of defense are shown in Figure 3.15. Additional detail on each of these features are provided in the following sections.

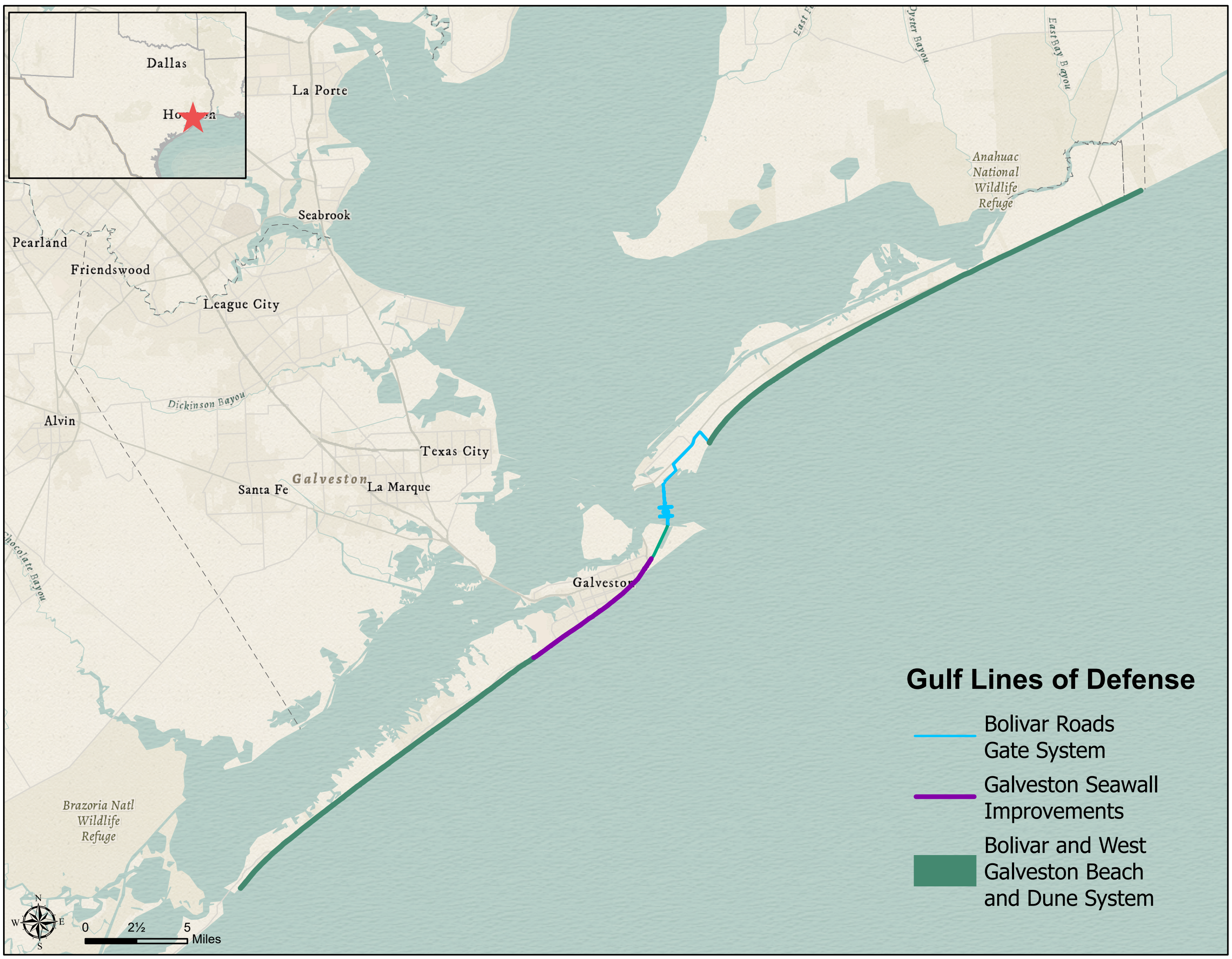



*Figure 3.15: Gulf line of defense*

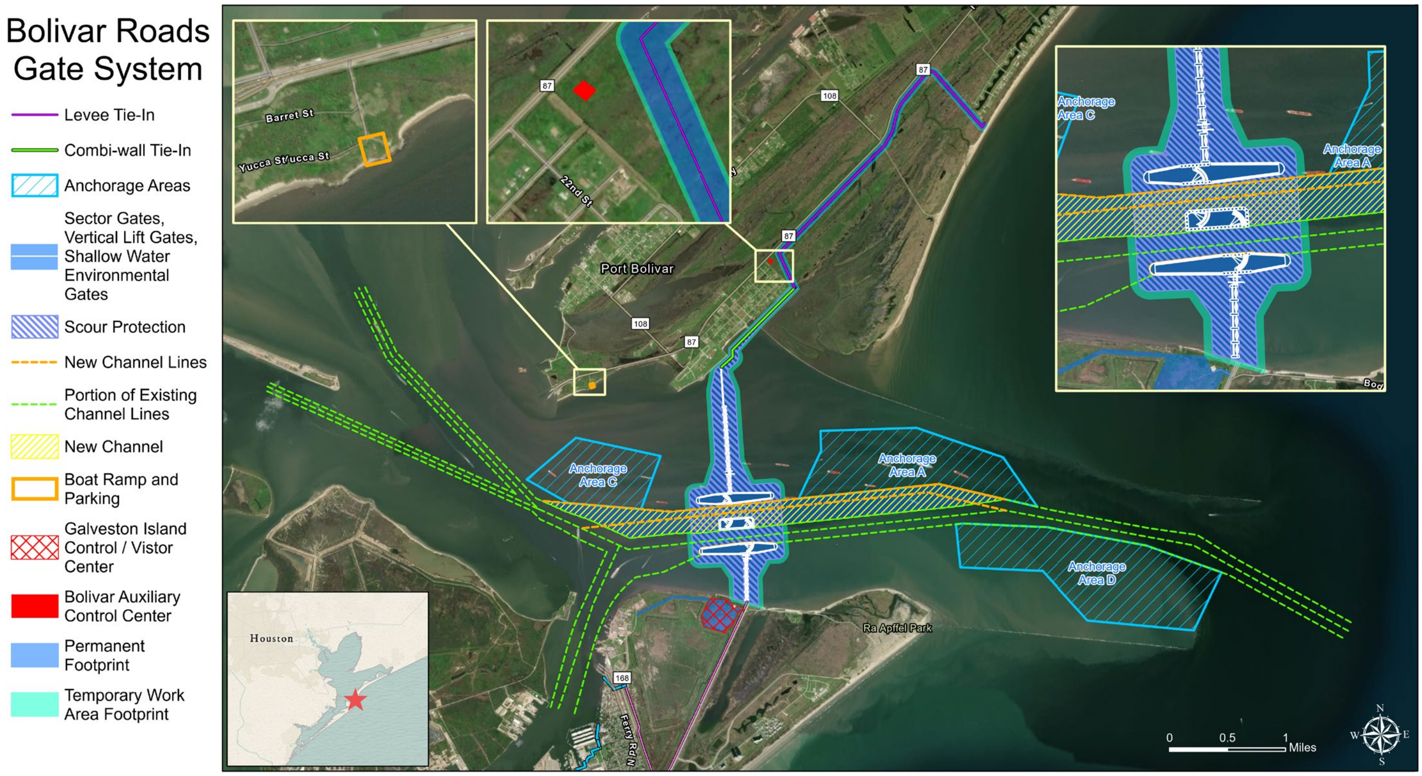



*__Figure 3.16:__ Bolivar Roads gate system - overview*

### 3.4.1.1. Bolivar Roads Gate System

The Bolivar Roads Gate System represents the most critical feature of the Gulf line of defense. Encompassing the Bolivar Roads Channel, the six primary features include:

- **Section 3.4.1.1.1**: A levee segment to tie into the dune system proposed on Bolivar Peninsula;
- **Section 3.4.1.1.2**: A combi-wall, to connect the levee segment to the shallow water environmental gates;
- **Section 3.4.1.1.3**: Shallow water environmental gates, connecting the combi-wall to the vertical lift gates, facilitating normal tidal flow and circulation;
- **Section 3.4.1.1.4**: Vertical lift gates, located on either side of the proposed navigation sector gates, further facilitating normal tidal flow and circulation;
- **Section 3.4.1.1.5**: Navigable floating sector gates, accommodating both recreational and commercial navigation traffic within Bolivar Roads and the Houston-Galveston Navigation Channels entrance channel; and
- **Section 3.4.1.1.6**: Operations Center and Auxiliary Operations Center, to support day-to-day operation of the overall complex.

## By the Numbers: Bolivar Roads Gate System

- *2 - 650' wide deep-draft sector gates*
- *2 - 125' wide smaller vessel sector gates*
- *15 Vertical Lift Gates*
- *16 Shallow Water Environmental Gates*
- *1 mile of combi-wall*
- *3 miles of levee*
- *Includes mitigation for direct and indirect impacts*

Figure 3.16 and Figure 3.17 provide the overall layout and conceptual rendering of the various structures which comprise the Bolivar Roads Gate System. The elevation of the walls and gates were set at an elevation of 21.5 ft (NAVD88), based on Total Water Level (TWL), which considers still water level and wave overtopping, with a 1% Annual Exceedance Probability (AEP) under the Intermediate Sea Level Rise Condition. Determination of this elevation, which is subject to revision during the Preconstruction Engineering and Design (PED) phase, is detailed further in Section 6.3 of Appendix D.


***Figure 3.17:*** *Bolivar Roads Gate System – conceptual rendering*

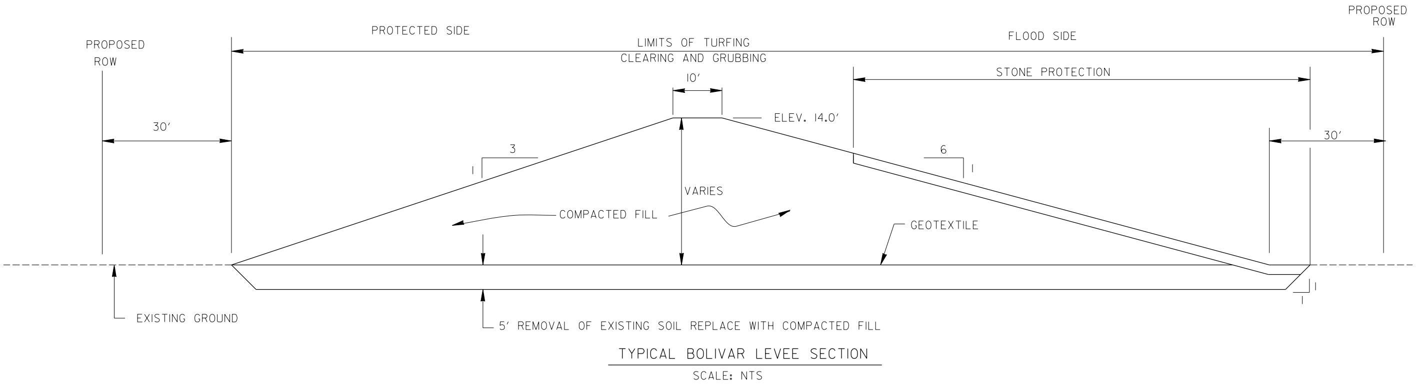



***Figure 3.18:*** *Tie-in levee cross section*

### 3.4.1.1.1. Tie-in Levee Section

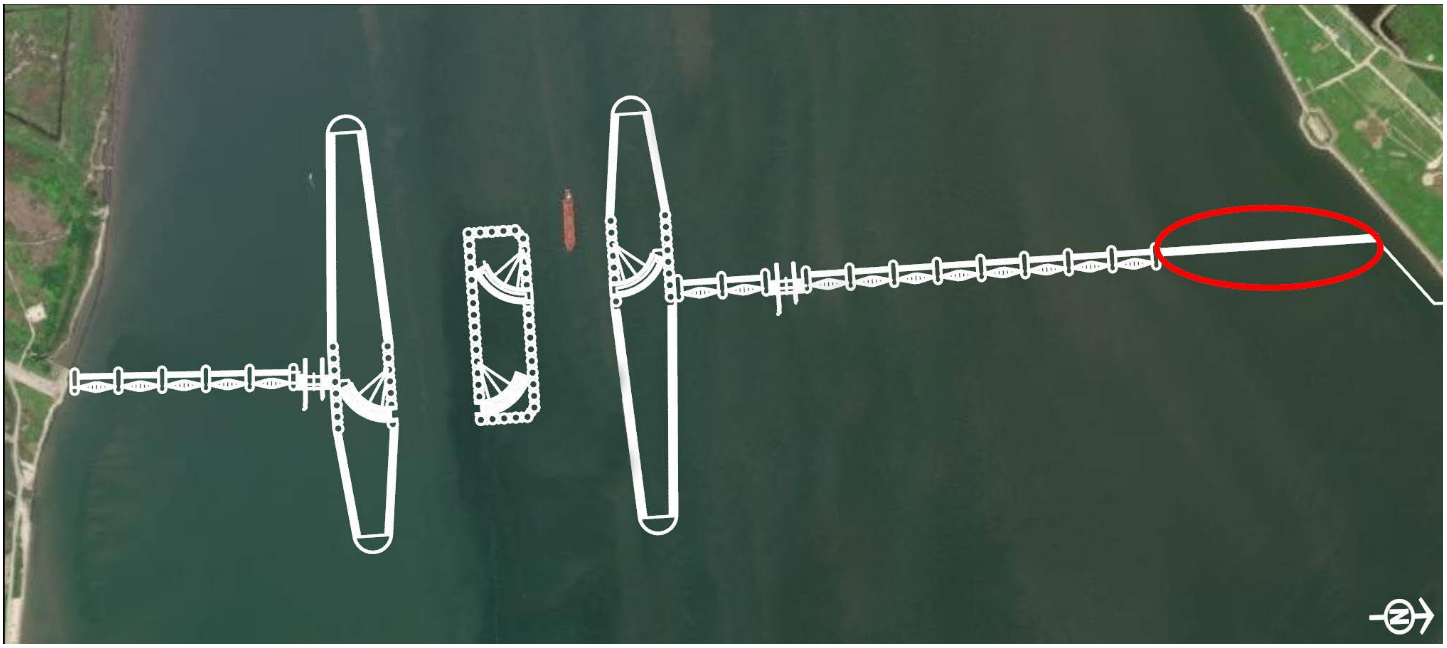
This CSRM feature starts on Bolivar Peninsula, joining the proposed beach and dune system at the end of Biscayne Beach Road, and provides 3 miles of earthen levee proceeding north-westerly to State Highway 87 and then turning south-westerly to near the intersection of Keystone and 23rd Streets. This location and alignment of this feature was refined to avoid highly sensitive environmental resources near the existing north jetty system. However, this refinement did not remove the feature from the CBRA zone, as discussed in Section 3.1. The USACE has determined that this feature would not meet one of the allowable CBRA exceptions, and therefore the cost of this feature would be the full responsibility of the non-Federal sponsor. Additional details related to CBRA considerations can be found in Appendix E of the Final EIS.

A typical section of levee is shown in Figure 3.18. The levee height is designed to 14.0 ft (NAVD88) elevation with a 1V:3H slope on the Bay side, 1V:6H slope on the Gulf side with stone protection, and includes a 30 ft. right-of-way on each side of the levee. The levee height transitions to a final height of 21 ft (NAVD88) at the start of the combi-wall discussed below. Additional detail on the tie-in levee section can be found in Section 4.2 of Appendix D.

### 3.4.1.1.2. Combi-Wall Section

The barrier continues southwest as a combi-wall for 5,300 ft before reaching the start of the gate system across Bolivar Roads. The proposed combi-wall system consists of vertically driven 66-in. diameter hollow concrete spun cast piles with 18-in. closure piles driven to complete the system. The lateral resistance for this system comes from a 36-in steel batter piles with concrete deck sections that ties the system together with a small parapet wall. Concrete deck sections will serve as an access roadway for the combi-wall and the other structures that make up the Bolivar Roads Gate System. A blanket of scour protection (stone) will be placed on both the Gulf and land sides of this structure to prevent erosion. To minimize the impact to marine habitat in this area, the combi-wall will be constructed from a temporary work platform instead a floatation channel. The crossing continues south with a series of gates as detailed below. Additional detailed information on the combi-wall section can be found in Section 6.3.3 of Appendix D.

***Figure 3.19:*** *Conceptual rendering of the combi-wall section*



*Location of SWEGs*

### 3.4.1.1.3. Shallow Water Environmental Gates

The 2.1 mile gate system crossing Bolivar Roads starts at the end of the combi-wall with 16 Shallow Water Environmental Gates (SWEGs) with a sill elevation (bottom of channel) of -5.0 ft (NAVD88). SWEGs are 16-ft by 16-ft automated stainless steel sluice gates within concrete towers. The gated structures provide multiple small openings to allow for tidal passage from both sides of the gate. The gates themselves are stored within the concrete towers, above the normal water elevation. The gated monoliths will require an access road on the Bay side of the structure to allow maintenance crews access to the gates and operating equipment. The road will consist of stainless steel industrial grating, which will allow sunlight to pass through into the water below, which is imperative for marine life. The location of the SWEGs are highlighted within the red circle above, and a conceptual rendering of the SWEGs in the closed position is shown in Figure 3.20.

The SWEGs are located in the shallow portion of the Bolivar Roads crossing. It is anticipated these structures will be constructed using equipment set on a floating platform. Excavation of an access channel for the dredge will be required during construction. After construction, a blanket of scour protection will be placed on both the Gulf and Bay side of this structure to prevent erosion. The access channel will either be filled with material similar to that removed or with a layer of stone, if deemed necessary. Additional detailed information related to the SWEGs can be found in Section 6.3.5 of Appendix D.

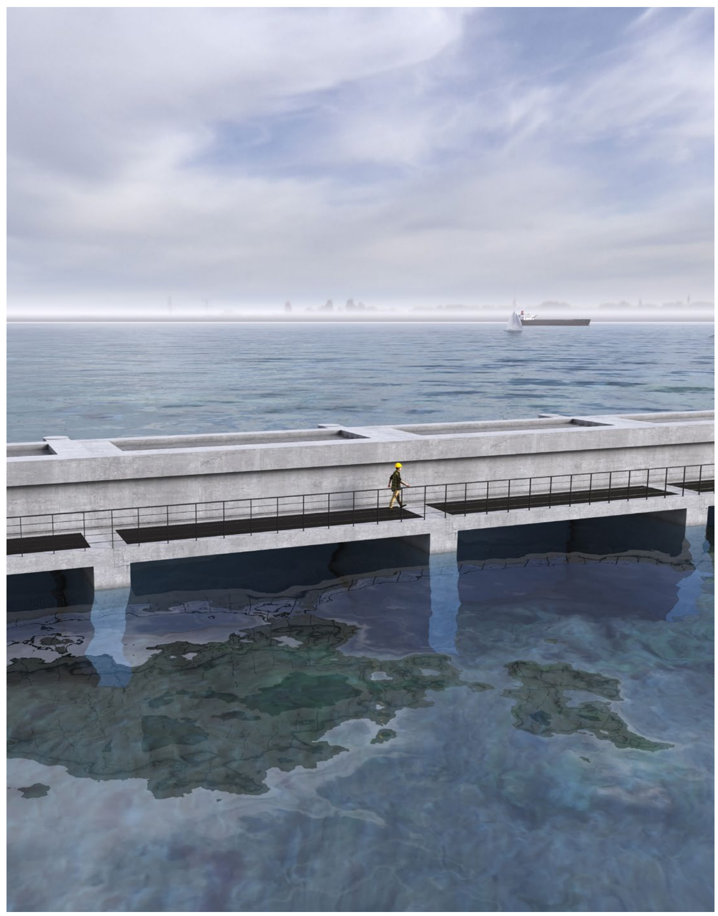
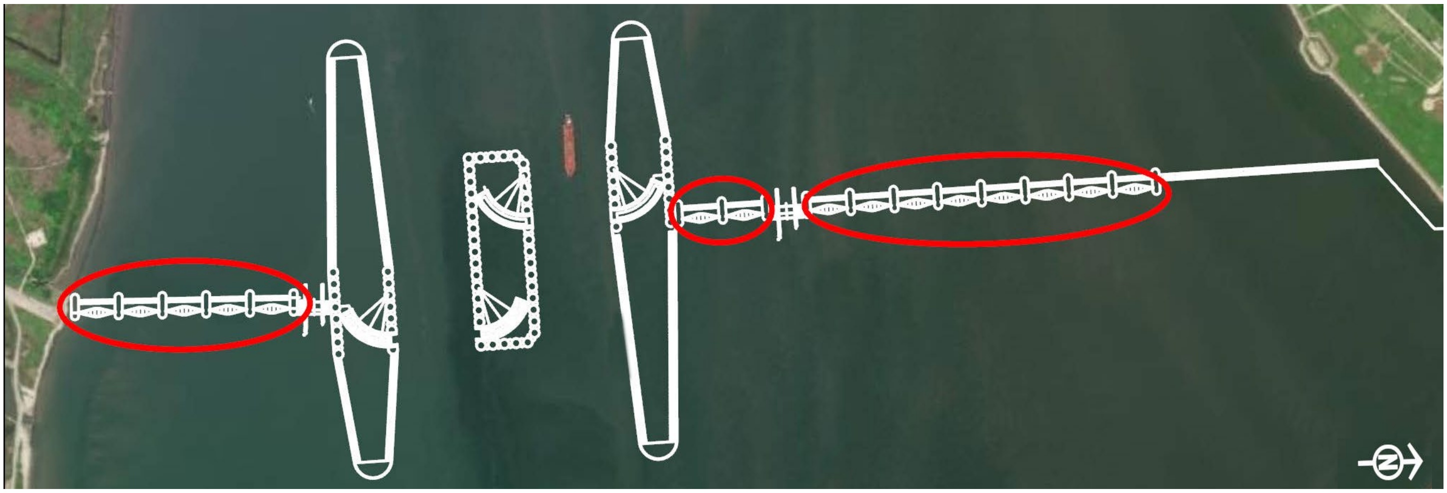


***Figure 3.20:*** *Location and conceptual rendering of shallow water environmental gates*



*Location of VLGs*

### 3.4.1.1.4. Vertical Lift Gates

The channel crossing continues with a series of Vertical Lift Gates (VLGs). The VLG's are suspended between concrete towers. The lift gates and the towers of the barrier have a unique shape: the gates are elliptical and the towers are oval. The vertical lift gates are driven by hydraulic cylinders with a long piston which are hinged to the side towers. The VLG's for the Bolivar Roads crossing have a clear opening of 300' in width with two different sill elevations. Across the entire barrier, the following VLGs are proposed:

- 5 VLGs with sill elevations at -20.0 ft (NAVD88) and 3 VLGs with sill elevations at -40.0 ft (NAVD88) are included on the east side of the first smaller vessel sector gate;
- 2 VLGs at a sill elevation of -40 ft (NAVD88) are included in between the first smaller vessel sector gate and the deep-draft navigation gates; and
- 2 VLGs at a sill elevation of -40 ft (NAVD88) and 3 VLGs with a sill elevation of -20 ft (NAVD88) on the west side of the deep-draft navigation gates which will tie into the end of the existing seawall at the San Jacinto Placement area on Galveston Island.

A blanket of scour protection will be placed on both the Gulf side and the Bay side of these structures to prevent erosion. The VLGs are assumed to be constructed using conventional cast in place construction methods. This includes a temporary retaining structure consisting of cellular cofferdams that are dewatered to facilitate construction of the structure.

The VLG's used for this study are modeled after the Hartel Canal storm surge barrier located in Spijkenisse, Netherlands. The VLG's provide a large opening to allow for tidal passage from both sides of the gates. These gates have a low clearance between the bottom of the gates in the stored position and the normal water surface elevation in Bolivar Roads. Therefore, the VLG are not intended for any type of navigation. As discussed below, the Bolivar Roads Gate System includes other navigation features to address large deep-draft vessels that typically use the Houston ship channel as well as recreational traffic. The VLGs will have an access bridge on the land side of the structure to allow maintenance crews access to the gates and operating equipment. The location of the VLGs are highlighted within the red circles above, and a conceptual rendering of the VLGs in the opened and closed positions are shown in Figure 3.21. Additional details related to the VLGs can be found in Section 6.3.4 of Appendix D.

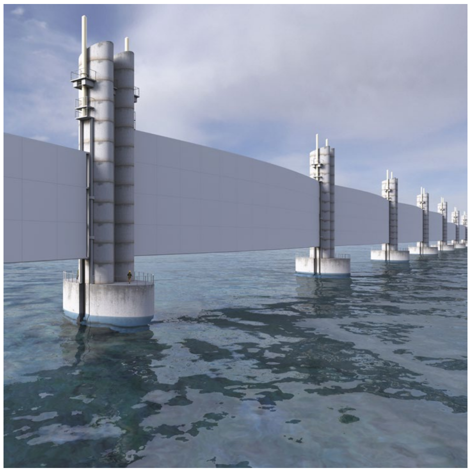


***Figure 3.21:*** *Location and conceptual rendering of the vertical lift gates in the open (top image) and closed (bottom image) positions.*

#### 3.4.1.1.5. Navigable Sector Gates

Smaller sector gates are located on each side of the large sector gates to minimize the number of smaller vessels (e.g. recreational vessels or other smaller industrial or commercial fishing vessels) crossing paths with deep-draft vessels. The smaller sector gates are proposed on both sides of the deep-draft navigation complex and will be 125 ft wide. These smaller sector gates are modeled after the Harvey Canal Sector Gate located in New Orleans. The smaller sector gate complexes will be reinforced concrete pile founded structures with steel fabricated gates. When the gates are open, they are stored in the structure gate bay to protect them from navigation vessel impacts. Timber guide walls are also part of the complex. The smaller sector gate structures will have maintenance dewatering bulkheads that allow the gate complex to be dewatered and required maintenance to be done in the dry. These smaller sector gates are designed with a sill elevation of -40.0 ft (NAVD88). A blanket of scour protection will be placed on both the Gulf side and Bay side of the structure to prevent erosion. The smaller sector gate complexes are assumed to be constructed using conventional cast-in-place construction methods. This includes a temporary retaining structure, consisting of cellular cofferdams that are dewatered to facilitate construction. The location of the smaller sector gates is shown in Figure 3.22. Additional details related to the smaller sector gates can be found in Section 6.3.8 of Appendix D.

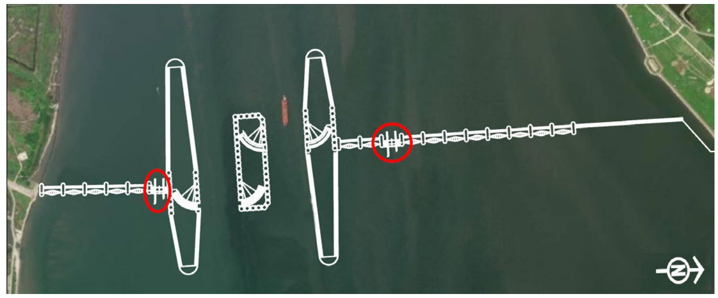


***Figure 3.22:*** *Location of the smaller sector gates*

The next feature is the largest feature of the entire gate system, the deep-draft navigation gates crossing Bolivar Roads. To improve navigation safety, enhance reliability, and reduce project cost, the Bolivar Roads crossing design was modified from that presented in the TSP, where a single gate was proposed, to a complex of two horizontally rotating floating sector gates, with associated artificial islands to store the gates. See Figure 3.23 for the location and conceptual renderings of these gates, in the open and closed positions.

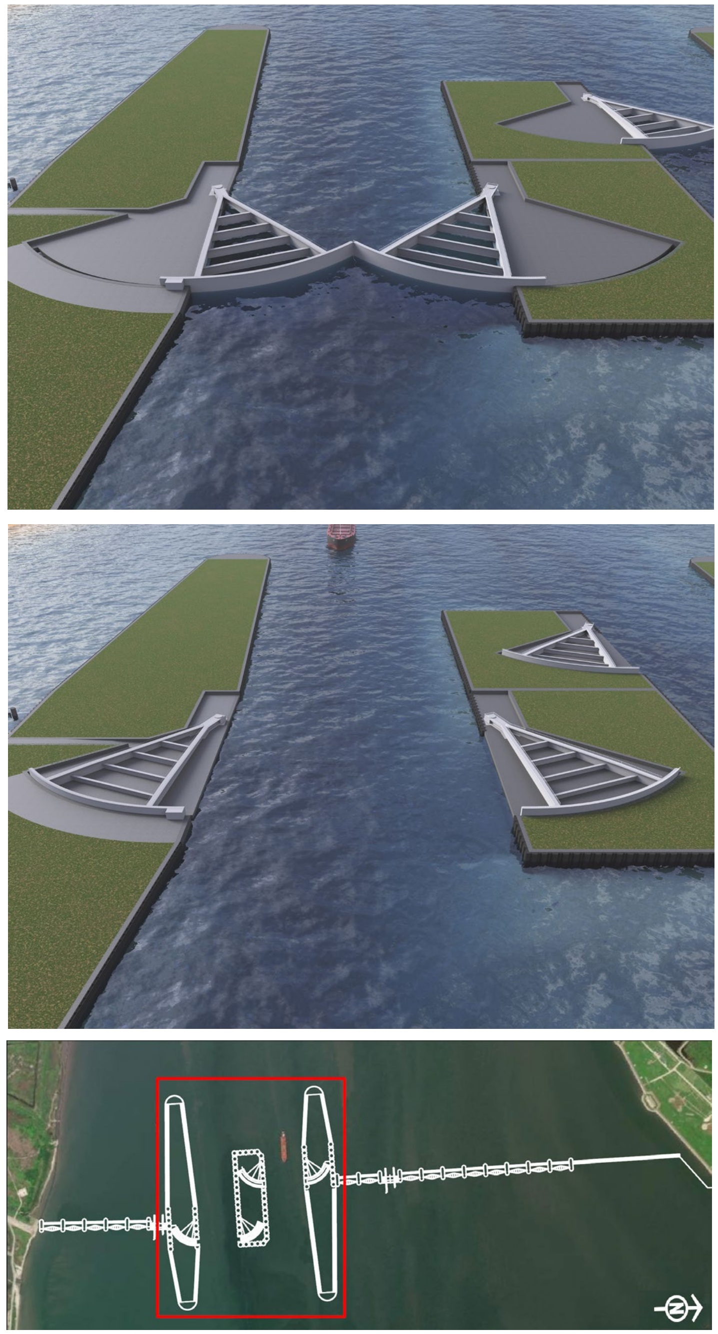


***Figure 3.23:*** *Location and conceptual rendering of the deep-draft navigation gates*

The deep-draft navigation gate openings are designed to be 650 ft wide each, with a sill elevation of -60.0 ft (NAVD88). The sill elevation across the ship channel will allow for future deepening of the Houston-Galveston Navigation Channels entrance channel, which is currently maintained at a depth of –48 ft MLLW. The deep-draft navigation gate opening was designed in accordance with USACE document EM 1110-2-1100, Coastal Engineering Manual. The gates are intended to remain open year-round to maintain continuous navigation and existing flow characteristics. The gates will be only be closed when a storm surge event threatens the Texas coast or for an annual maintenance check and inspection.

The deep-draft navigation sector gates across Bolivar Roads are anchored and housed in man-made “islands” on either side of the channel. The gates will be stored in dry docks within the manmade islands, which will help minimize the probability of vessel impacts while the gates are in the stored position. The gates will sit within the dry docks unless a storm requires closure or maintenance is being conducted. When it is time to deploy the gates, the dry docks will be flooded, allowing the gates to float into place and then water will be pumped in the sections of the gates allowing them to sink in place. Once the storm surge event has passed, the gate sections will be pumped out and the gates will be floated back to the dry docks on the artificial islands.

The artificial islands will be constructed as large cellular cofferdams backfilled with select fill material. The perimeter of the islands will be constructed first, followed by demucking the bay bottom, and finally backfilling with dredged material to the final design grade.

Before construction of any structures, and to minimize impacts to existing channel traffic, the navigation channel will be widened to accommodate the new inbound channel and the inbound sector gate. The widening of the channel will be north of the existing channel toe (bottom of inside slope where the dredged channel first reaches full depth), through existing anchorage areas, and will be maintained at a 800 ft toe to toe width and a depth of –48 MLLW, which is consistent with the existing channel authorized depths. Figure 3.24 shows the existing navigation channel, including anchorage areas as well as the proposed Bolivar Roads Gate System, and the new channel configuration.

Upon completion of the first gate and island complex, traffic will be diverted to the newly constructed channel and gate opening. At this point, the second gate and island complex will be constructed.

Due to the extension of the existing navigation channel toe to the east to accommodate an inbound lane through the deep-draft navigation sector gate, existing aids to navigation will be relocated and additional aids provided for the extension of the channel. New aids will also be required for the smaller sector gate structures. Existing and/or new aids to navigation would be of can or conical type. Further coordination with the Coast Guard and the shipping industry will be conducted during PED. This coordination will include additional ship simulations to identify velocity impacts to navigation.

The decision to construct two smaller gates in lieu of one large opening was, in part, to add resiliency to the system. After a storm surge event, if one of the gates has a problem opening, there will still be one lane open for navigation until the other gate is repaired. Further information on the deep-draft navigation gates is provided in Section 6.3.7 of Appendix D.

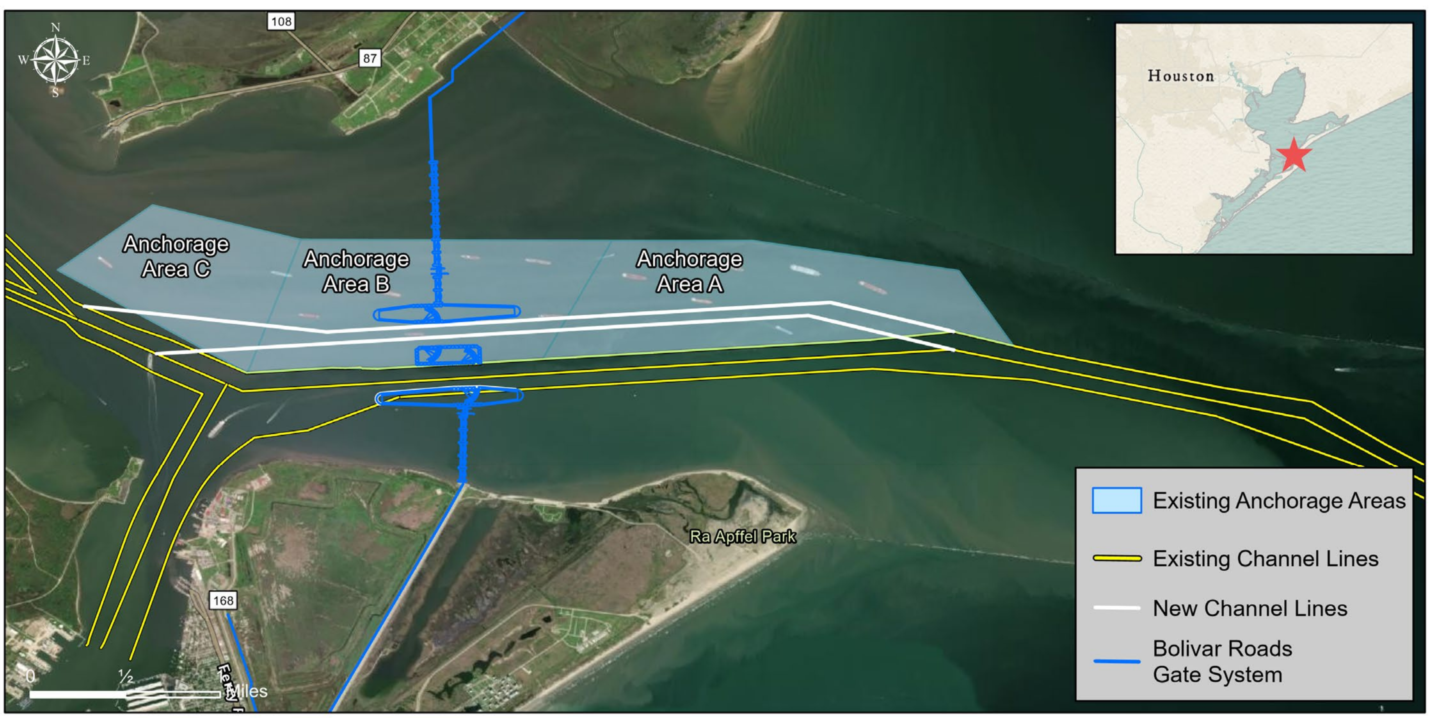



***Figure 3.24:*** *Bolivar Roads channel configuration*

### 3.4.1.1.6. Anchorage Areas

As shown in Figure 3.25, the system will have a significant impact on existing anchorages in the area. The proposed configuration results in Anchorage Area B being unusable due to construction of the sector gate island. Anchorage Areas A and B are impacted due to the extension of the existing channel toe to the east to allow for the construction of an inbound channel for ship traffic and the two deep-draft sector gate system across Bolivar Roads.

Coordination with the shipping industry was conducted to address the impacts and present proposed anchorage areas to mitigate the impacts to the existing anchorage areas.

As shown in Figure 3.25, the existing anchorage areas accommodate 11 swing circles (brown circles) and the proposed study anchorage areas provides 16 circles (green circles). The proposed new anchorage areas are naturally deep and provide a depth comparable to the existing anchorage areas. The proposed anchorage areas, shown in Figure 3.26, provides a total area of 2.4 square miles. Concern from industry has been expressed with Anchorage Area D, due to the currents and wind along the South Jetty. Due to this concern, the project cost now includes the installation of 12 mooring anchors in the area for vessel anchoring of the bow and stern, to limit the need for swing circles. Further analysis will be conducted during the PED phase to refine the anchoring system. See Section 4.2.3 of Appendix D for further information.

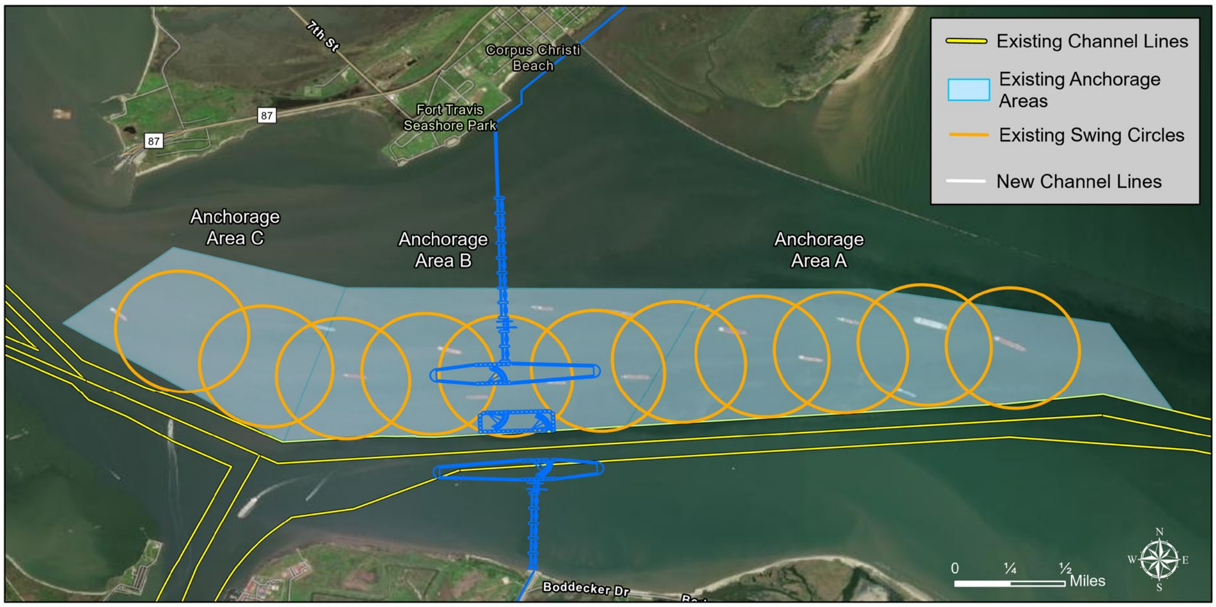



***Figure 3.25:*** *Existing anchorage areas*

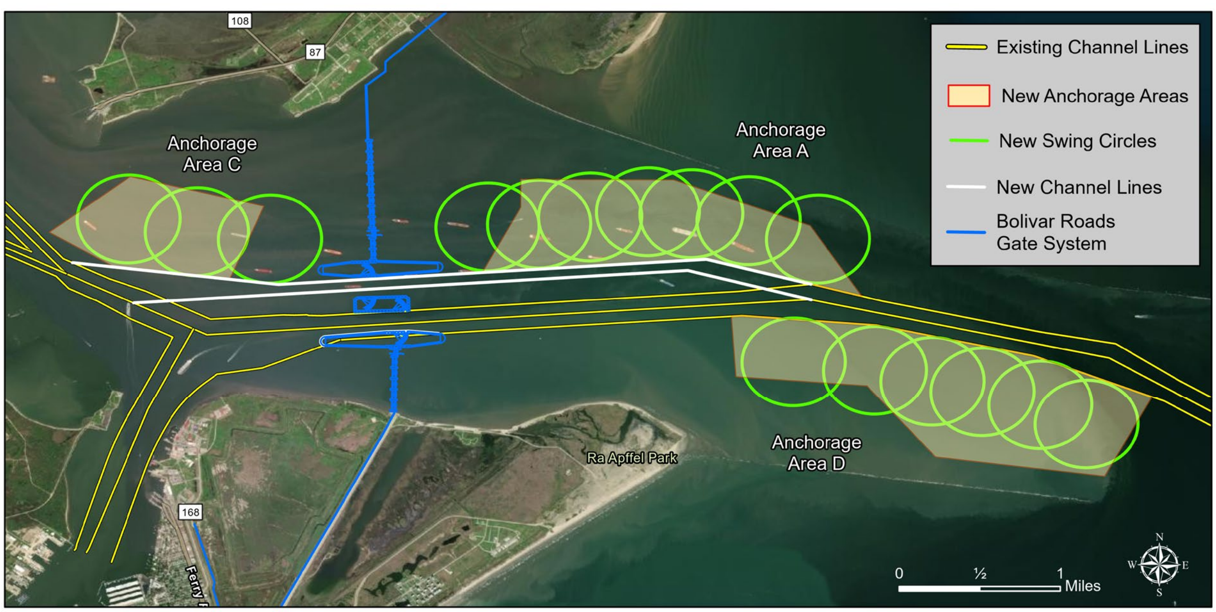



***Figure 3.26:*** *Proposed anchorage areas*

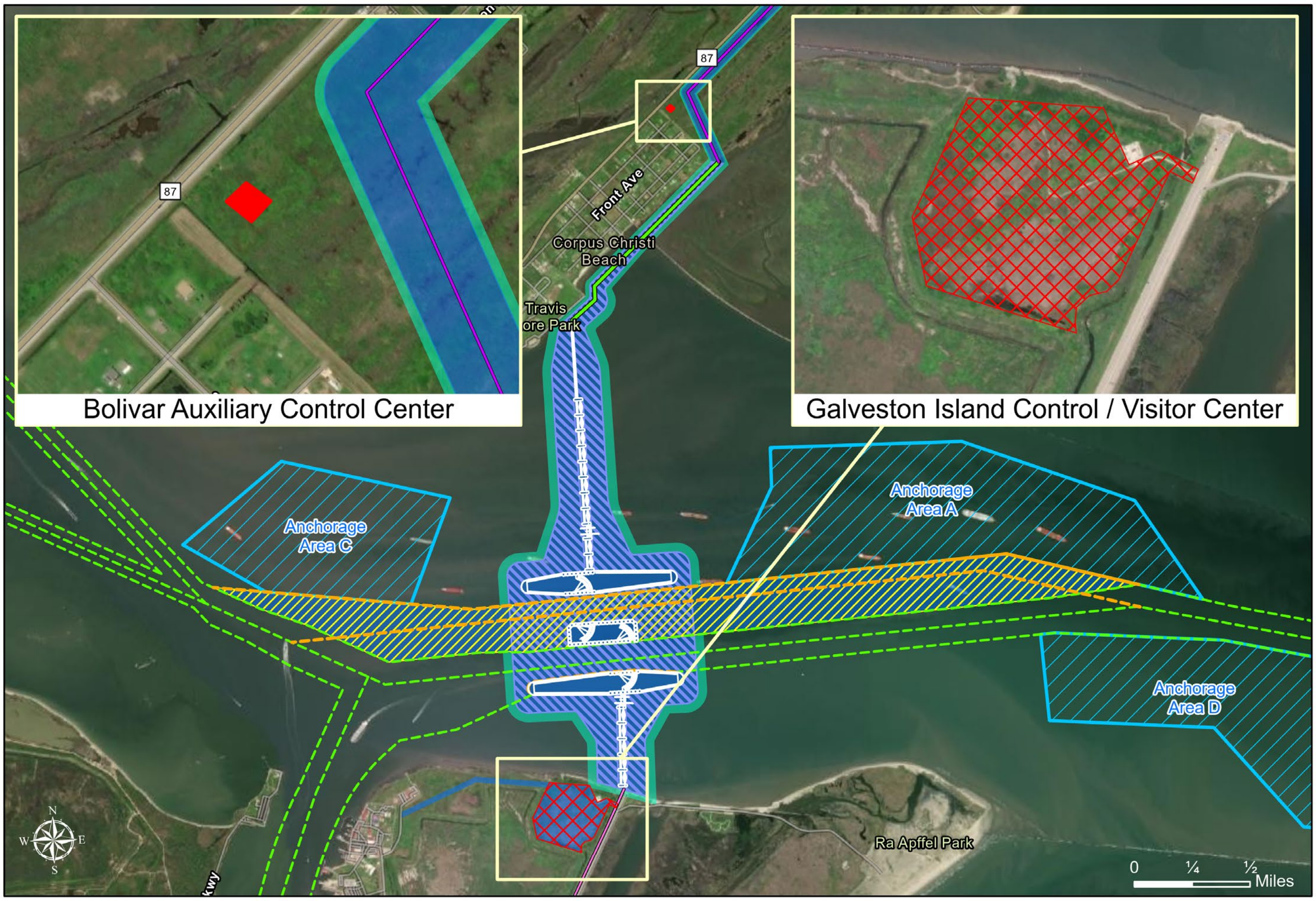



*Figure 3.27:* Control/visitor center locations

### 3.4.1.1.7. Operations Center

The Bolivar Roads Gate System will also include a central control/visitor center (called the Galveston Island Control/Visitor Center) on the island side of the barrier. This control/visitor center will be located on the Bay side of the barrier near the northeast corner of the San Jacinto Placement Area. The 5,000 square foot building will be on Government owned lands and will be accessible via the construction of an all-weather concrete road from the existing USMC Reserve Center access road to the building location. The road will be aligned outside the San Jacinto Placement Area perimeter levee, and have a width of 30 foot and crown elevation of at least 21.0 ft (NAVD88). The control/visitor center would be elevated and equipped with backup systems to allow for continued operation during surge events and power outages. Additionally, to assure redundancy in the operation of the gates, a 3,500 SF auxiliary operations center (called the Bolivar Auxiliary Control Center) would be located on Bolivar on the Bay side of the levee near the intersection of 23rd Street and State Highway 87. The facility would be at the same elevation as the Galveston Island Control/Visitor Center. The location of both facilities is shown in Figure 3.27.

A photo of West Galveston Beach

### *3.4.1.2. West Galveston and Bolivar Peninsula Beach and Dune System*

Beach and dune construction on West Galveston Island and Bolivar Peninsula form a first line of defense against Gulf of Mexico surge and are critical components of the coastal surge barrier and the overall comprehensive risk reduction plan for the upper Texas coast. On West Galveston Island, this CSRM feature would tie into the existing seawall. On Bolivar Peninsula, this CSRM feature would tie into the Bolivar Roads Gate System, supporting the continued integrity and function of the surge gate over time.

This CSRM measure differs significantly from levee/floodwall segments proposed in the TSP which would have paralleled State Highway 87 on Bolivar Peninsula and FM 3005 on Galveston Island. Chapter 2 of this report summarizes the plan formulation process which resulted in modifications to the TSP. Following public, technical, agency, and policy review, the levee system proposed in the TSP was removed because it was found to be unacceptable to the public and to ensure compliance with existing policies and laws. The beach and dune feature, originally proposed as an ER measure with only a single dune, was refined to add height and volume to improve its performance as a CSRM measure. While the beach and dune improvements, as refined, provide a lower level of risk reduction than the previously proposed levee system, they take advantage of the natural resiliency of sand systems, sustain the barrier island over time, and strengthen the tie-in to the Bolivar Roads Gate System. These changes were made in response to public comments and represent a solution which minimizes environmental and social impacts, while still achieving significant coastal risk reduction and complying with all policies and laws.

The proposed CSRM measure is a dual dune system, consisting of a 14 ft (NAVD88) landward dune and a 12 ft (NAVD88) Gulfward dune. Modeling confirms that a 14 ft (NAVD88) landward dune reduces the likelihood that Gulf surges will cross the barrier island system and increase water volumes in the Bay or create a breach of the barrier island. Modeling also confirms that a 12 ft (NAVD88) Gulfward dune will provide a source of material to renourish the beach over time. The West Galveston beach and dune system extends for approximately 18 miles and is described further in Section 3.4.1.2.1. The Bolivar Peninsula beach and dune system extends for approximately 25 miles, and is described further in Section 3.4.1.2.2.

**By the Numbers: West Galveston and Bolivar Beach and Dune**

- *43 miles on beach and dune system*
- *Typical 15' dune crest widths*
- *Typical 180' wide berm/beach*
- *Pedestrian and Vehicle Crossings*

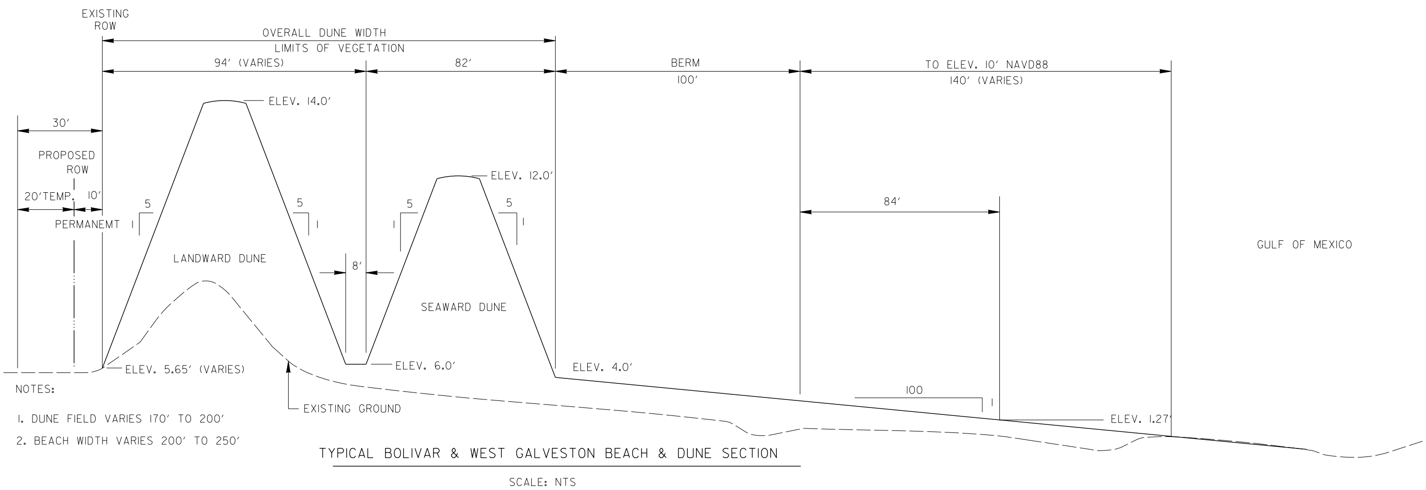



***Figure 3.28:*** *Engineering sketch of beach and dune system*

Figures 3.28 and 3.29 present this dual dune system, with beach nourishment (both as a conceptual rendering and as an engineering sketch) and illustrate typical existing conditions and typical CSRM design features. The performance of the profile is primarily based on the magnitude and duration of profile inundation during extreme surge events. The dunes are soft coastal features that can continue to provide protection past failure due to their residual elevation. Natural examples of this concept exist on the east end of Galveston Island and in other healthy beach systems across the Texas coast. Additional details on the dune design and refinement can be found in Section 5.0 of Appendix D.

The Recommended Plan will require 22.14 million cubic yards (CY) of sand for initial beach and dune construction along Bolivar peninsula (167.12 CY/ft) and 17.19 million CY of sand for initial beach and dune construction along West Galveston (177.43 CY/ft). Approximately 21.56 million CY (e.g., 2.156 CY/ft/year in Bolivar) will be needed for periodic nourishment every 6 years along Bolivar Peninsula and every 7 years on West Galveston, over a 50-year period of analysis considering the intermediate RSLC condition. Additional details regarding the beach and dune material sourcing and re-nourishment, including methodologies applied to calculate the volumes needed, are included in Section 5 of Appendix D. During PED, additional coordination will be necessary with the future Houston Ship Channel Expansion Channel Improvement Project and the Bolivar Roads Gate System, specifically as it relates to material sourcing.

The West Galveston Island and Bolivar Peninsula dune systems would be planted with grass species typically used along the Texas coast for dune construction. Dune plants would either be obtained from commercial sources or

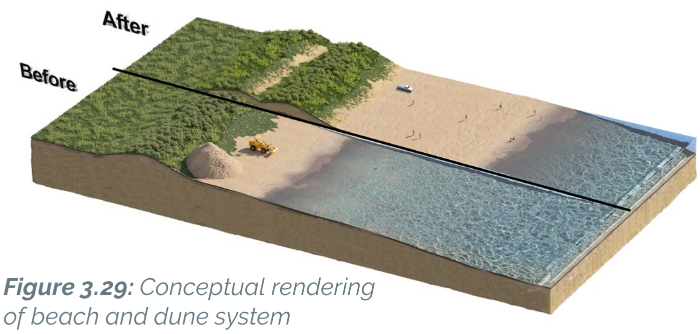



***Figure 3.29:*** *Conceptual rendering of beach and dune system*

transplanted from natural stands along the coast. Standard slatted wood sand fencing would be also be installed at appropriate locations to promote the sustainability of the dune system. A height of four feet, measured from the ground surface after installation, is recommended for dune-building structures. In areas where sand conditions are poor for dune building, a height of two feet will be utilized.

Currently there are 124 authorized beach access points; 66 vehicle crossing and 58 pedestrian crossings within the proposed beach and dune systems. Existing authorized pedestrian beach access crossings will be replaced with dune walkovers to minimize impacts to the newly created dune systems. Pedestrian traffic volume will be investigated during PED to determine an appropriate walkover width for the location and all up and down ramps for the crossovers would be designed to be ADA compliant. Dune walkovers will be constructed of treated lumber and galvanized hardware. In general, the structure height would be at least one to one and a half times its width (3 ft minimum), to allow sunlight to reach vegetation underneath the structure. An example of a typical pedestrian walkover is shown in Figure 3.30.

Existing vehicle access ramps would be modified to ramp up to the elevation of the landward dune and would ramp down to a break in the seaward dune. This approach would minimize the ramp length required to cross the dual dune system proposed for Bolivar Peninsula and West Galveston Island. Vehicle access ramps would be 12-feet in width, with a minimum ramp slope of 6%, and constructed of sand fill and 8" of gravel base material, stabilized with the utilization of a geogrid. All ramps would be oriented at an angle to the prevailing wind direction to reduce water and wind from being channeled along the ramp and minimize erosion of the dunes at the side of the road cuts. A conceptual rendering of vehicle and pedestrian crossovers is shown in Figure 3.31.

Existing authorized pedestrian and vehicle beach access points proposed to be modified are shown in Annex 11 (Bolivar) and Annex 13 (Galveston) of Appendix D. Access to the beach under the Recommended Plan will comply with the Texas Open Beaches Act of 1959.

New access points or modifications to existing pedestrian and vehicle access points would require a Section 408 permit after the project is implemented. To ensure that the dunes continue to provide their intended benefits to the public, Congress mandated that any use or alteration of a Civil Works project by another party is subject to the approval of USACE. Section 408, which was authorized in Section 14 of the Rivers and Harbors Appropriation Act of 1899, allows the USACE to grant permission for another party to alter a Civil Works project upon a determination that the alteration proposed will not be injurious to the public interest and will not impair the usefulness of the Civil Works project. Furthermore, this project, with its alterations to public access, will conform to the laws of the State of Texas and to the rules and regulations of the GLO. A Public Access Plan is provided as Appendix B.

***Figure 3.30:*** *Example of a pedestrian walkover*

***Figure 3.31:*** *Conceptual rendering of beach access crossovers*

### 3.4.1.2.1. West Galveston Island

The West Galveston beach and dune system consists of 18 miles of dune, of which 1.5 miles are within CBRA zones. The USACE has determined that the 1.5 miles of dune within the CBRA zone, as designed, would meet one of the CBRA's exceptions. The double dune system would have a gulfward dune elevation of 12.0 ft (NAVD88) and a landward dune elevation of 14.0 ft (NAVD88), both of which are subject to revision during the PED phase as discussed further in Section 11.1.3 and 11.7 of Appendix D. The West Galveston beach and dune system would start at the end of the existing Galveston seawall and continue westerly for 18 miles ending at San Luis Pass, as shown in Figure 3.32. Beach and dune material sourcing and re-nourishment is discussed above and in Section 5.4 and 9.1 (respectively) of Appendix D.

*The Texas Open Beaches Act states that the public has the free and unrestricted right to access Texas beaches. This means that the proposed project will maintain beach access to pedestrians and vehicles.*

Drainage regulations in the West Galveston Island reach are generally oriented towards protection of the dunes and beach. For example, Municipal Ordinance 84-40, passed by the City of Galveston in 1984, states that "…no drainage will be permitted into the Gulf of Mexico or onto the adjacent beach". However, the City's drainage plan clarifies that preexisting developments with beach drainage are exempt under a "grandfather clause." Due to this language, the study efforts included an initial investigation into the drainage features required with the newly proposed dunes. The focus was on the region west of the Seawall, including Jamaica Beach, at locations where proposed dune and beach nourishment features overlap with existing drainage flow paths that discharge stormwater runoff onto the beach. A hydrologic and hydraulic analysis was performed to develop culvert size/location design recommendations for drainage basins based on a 100-year design storm.

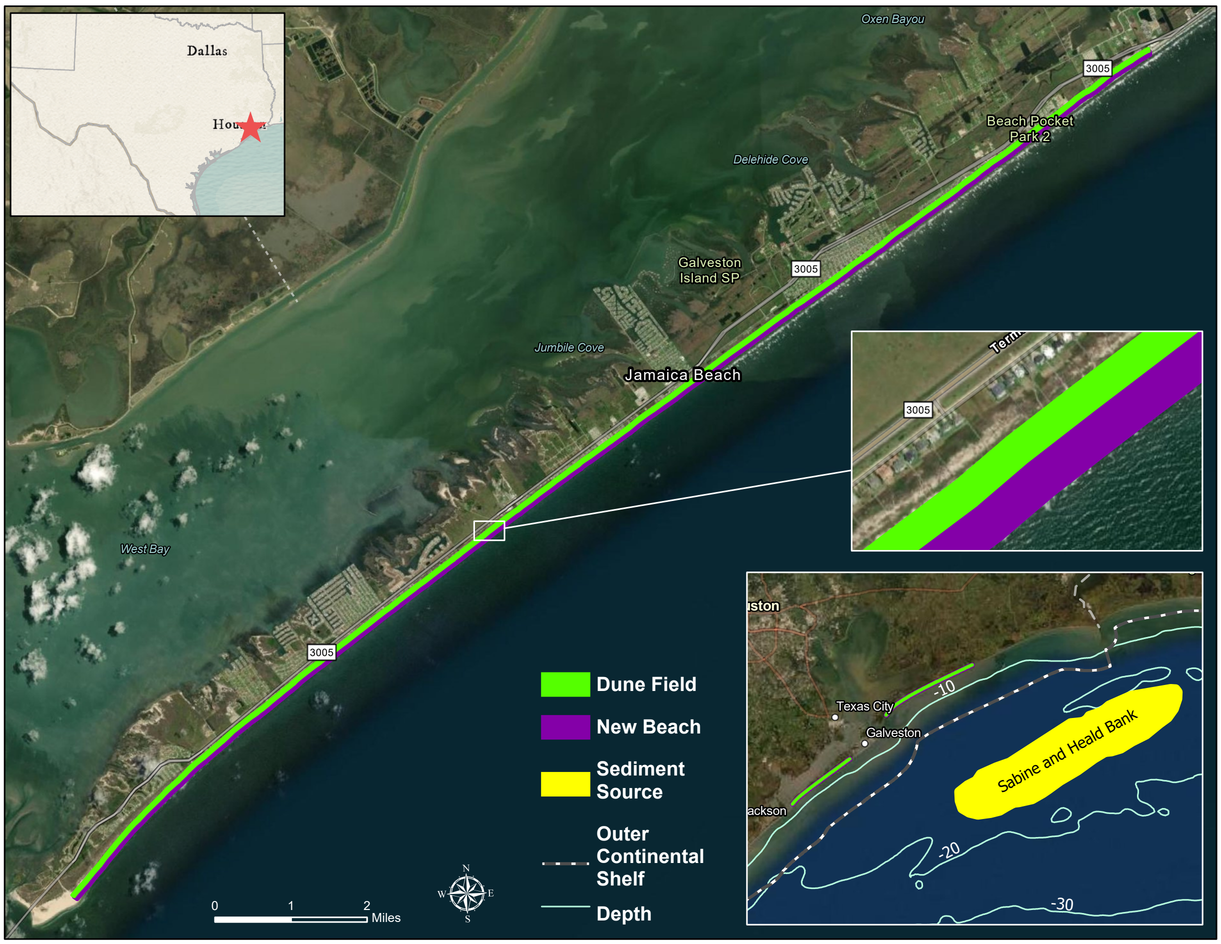



*Figure 3.32: West Galveston beach and dune system*

The Recommended Plan reroutes beach discharge through the dunes via culvert(s) while maintaining the same general footprint and flow pattern. The concept is intended to provide a minimal-impact solution, designed to match or improve existing drainage conditions, while simultaneously mitigating adverse impacts to the contiguous dune system. A total of 39 drainage culverts (24-in in diameter), with flap gates, are being recommended for the West Galveston. It should be noted that 12 of these may not be needed if conveyance to the bayside is adequate at Sunny Beach. This will be further evaluated in PED. Also, a landside ditch to along the base of the dune toe (location where the dune side slope meets natural ground) is being recommended in some locations to facilitate lateral drainage and connect features.

In the future, it is preferable to route all stormwater runoff to bayside outfalls. However, this may require significant construction efforts due to topographic challenges. The rerouting of surface drainage would alleviate maintenance challenges associated with the dynamic nature of the beach. In PED, individual drainages features will be further investigated to determine the ability to reroute the drainage to the bayside with minimum cost.

#### 3.4.1.2.2. Bolivar Peninsula

The Bolivar Peninsula beach and dune system reach is 25 miles in length, of which 10.7 miles are within CBRA zones. The USACE has determined that the 10.7 miles of dune within the CBRA zone, as designed, would meet one of the CBRA's exceptions. The double dune system would have a seaward dune elevation of 12.0 ft (NAVD88) and a landward dune elevation of 14.0 ft (NAVD88), both of which are subject to revision during the PED phase as discussed further in Section 11.1.3 and 11.7 of Appendix D. As shown in Figure 3.33, the Bolivar Peninsula beach and dune system ties into the McFaddin National Wildlife Refuge Beach Ridge Restoration Project, which starts approximately 2.0 miles east of State Highway 87, and continues southwest for 25 miles to the end of Biscayne Beach Road, where the system will tie-into an earthen levee system associated with the east side of the Bolivar Roads Gate System. Beach and dune material sourcing and re-nourishment is discussed above and in Section 5.4 and Section 9.1 (respectively) of Appendix D.

Much like Galveston Island, drainage regulations for the Bolivar Peninsula study area are outlined in the Galveston County Dune Protection and Beach Access Plan (2006). There are provisions within the protection plan that offer allowable mitigation measures to offset adverse impacts of beach drainage, which align with the nature of the beach nourishment and dune construction project.

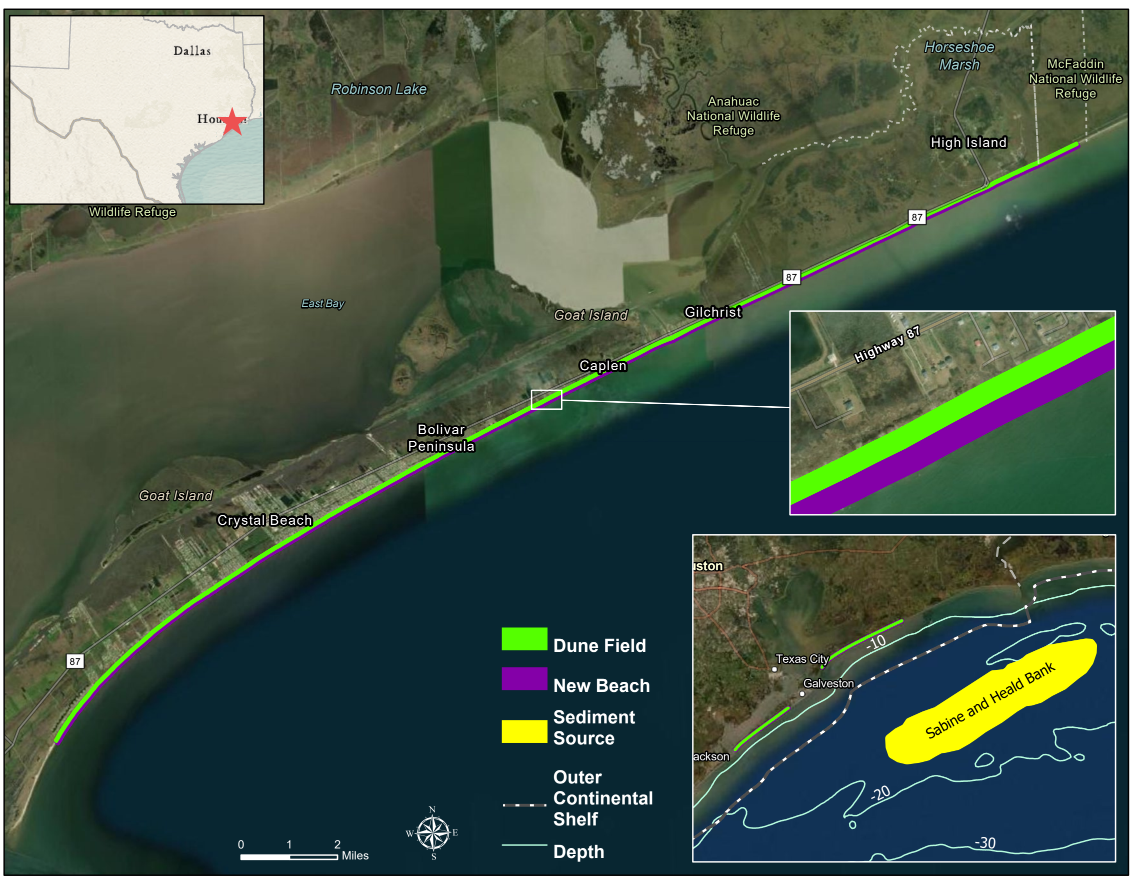



*Figure 3.33: Bolivar Peninsula beach and dune system*

To address the drainage concerns on Bolivar Peninsula, a beach drainage study was conducted in an area spanning from the wetlands near Fort Travis to the developed Crystal Beach area. Drainage on the low-lying peninsula is conveyed to six open-channel beachside outfalls via a system of sloughs, drainage ditches, and open-channels. The sloughs and many of the drainage ditches hold water during typical conditions due to topographic challenges and sedimentation of the channels. Beach discharge has created large breaches in the dunes at outfall locations.

The Recommended Plan routes existing beach discharge through the proposed dune features via culverts, while maintaining the same general footprint and flow pattern. The concept is intended to provide a minimal-impact solution, designed to match existing drainage conditions, while simultaneously mitigating adverse impacts to the contiguous dune system. A hydrologic and hydraulic analysis was performed to develop culvert size/location design recommendations for drainage basins based on a 100-year design storm. A total of 48 drainage culverts (sizes vary), with flap gates, are being recommended for the Bolivar Peninsula reaches. Also, a landside ditch along the northern toe of the dune is being recommended in some locations to facilitate lateral drainage and connect features.

In the future, it is preferable to route all stormwater runoff to bayside outfalls. However, this may require significant construction efforts due to topographic challenges. The rerouting would alleviate maintenance challenges associated with the dynamic nature of the beach. In PED, individual drainages features would be further investigated to determine the ability to reroute the drainage to the bayside with minimum cost.

*A photo of beach and dune on Bolivar Peninsula*


***Figure 3.34:*** *Galveston Seawall improvements*

### *3.4.1.3. Galveston Seawall Improvements*

The Galveston Seawall Improvements feature is a future adaptation to provide additional storm surge and wave overtopping reduction along the existing structure, which will connect to the Bolivar Roads Gate System on the east and the West Galveston beach and dune system on the west. The recommendation is to increase the height of 7.7 miles of the existing Seawall to reach a uniform level of protection of 21.0 ft (NAVD88). The initial design of the Galveston seawall provides protection from direct assault from the Gulf of Mexico to 17.0 ft (NAVD88). Subsequent modifications to the roadway and earthen embankment raised the combined level of protection to 21.0 ft (NAVD88). This higher elevation will significantly reduce the wave overtopping volume and pumping needs during extreme events. However, these elevations are not consistent across the entire Seawall feature. Modifications and development over the years, along with design changes during subsequent Seawall extensions, have resulted in the embankment being non-uniform in height. To address this concern and ensure a uniform elevation of 21.0 ft (NAVD88), an extension of the north sheet pile cutoff wall located at the north edge of the north sidewalk is proposed. This extension is a 3ft vertical wall that would have gated openings for vehicle and pedestrian access. The extension would go from the San Jacinto levee Seawall tie-in to the east to the west end tie-in of the GRBS. A road raising at 89th Street would allow for continued access to the west end of the Island during a storm surge event. Figure 3.34 shows the location of the proposed improvements to the Galveston Seawall, including several call-outs illustrating select features. Further information on the Galveston Seawall Improvements is provided in Section 6.9 of Appendix D.

## By the Numbers: Seawall Improvements

- *7.7 mi of Seawall Improvements*
- *130 vehicle and pedestrian gates*

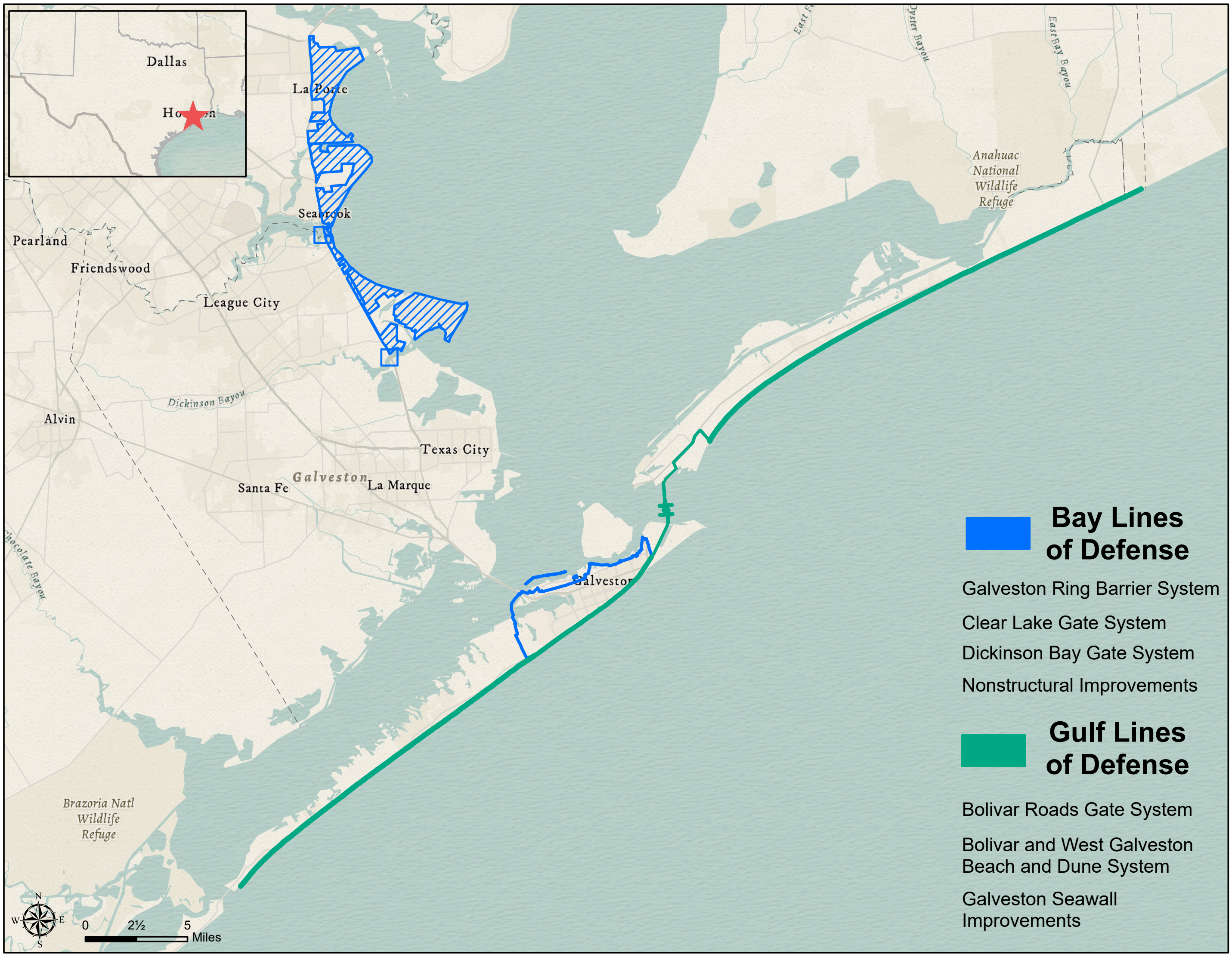



***Figure 3.35:*** *Bay defenses*

## 3.4.2. Bay Defenses

Similar to those proposed for the TSP, the Bay defenses include four independent but connected features, explained in detail in the indicated sections:

- **Section 3.4.2.1**: An 18-mile GRBS that impedes Bay waters from flooding neighborhoods, businesses, and critical health facilities within the City of Galveston;
- **Section 3.4.2.2**: A surge gate at Clear Lake that would reduce surge volumes that push into neighborhoods in the Clear Lake area;
- **Section 3.4.2.3**: A surge gate at Dickinson Bay that would reduce surge volumes that push into neighborhoods in the low-lying areas along Dickinson Bayou; and
- **Section 3.4.2.4**: Complementary non-structural measures to further reduce Bay-surge risks along the western perimeter of Galveston Bay.

The features which comprise the Bay defenses, and their location compared to the Gulf defenses, are shown in Figure 3.35. Additional detail on each of these features are provided in the following sections.

*A photo of Kemah on Clear Lake*

### *3.4.2.1. Galveston Ring Barrier System*

The GRBS, a CSRM measure consisting of a system of floodwalls, gates, pump stations, and levee sections, is proposed to address the residual risk that persists for the area as a result of wind driven storm surges from the Bay and provides flood risk management for approximately 15.8 square miles of the City of Galveston. The Bay is large enough that increased water surface elevations in the area can result from wind and fetch within the bay, even as the Bolivar Roads Gate System significantly reduces the storm surge entering the Bay from the Gulf of Mexico. The proposed GRBS ties into the existing Seawall and proceeds clockwise from the west end of the Seawall north in the proximity of 103rd Street to Offatts Bayou, crosses the Teichman Point area and ties into I-45, continues east along the Harborside area to the 47th street area, then continues north to the Galveston Ship Channel, then continues east through the Port of Galveston to the University of Texas Medical Branch (UTMB), turns northward to the Ferry and then back south to the Seawall. Numerous tradeoffs between project cost, project impacts and overall effectiveness of the GRBS were evaluated and made during the refinement of the alignment. The team will continue to avoid and minimize impacts where possible as the system is refined in the PED phase.

The elevation of the walls and gates were set at an elevation of 14.0 ft (NAVD88), based on TWL, which considers still water level and wave overtopping, with a 1% AEP under the Intermediate RSLC Scenario. Determination of this elevation, which is subject to revision during the PED phase, is detailed further in Section 2.7.1 in Appendix D.

The general layout of the GRBS is shown in Figure 3.37. Additional descriptions of the eleven primary segments/components of the GRBS are detailed in the following subsections. In addition, Figure 3.36 includes multiple conceptual renderings which show common features employed across the GRBS, including floodwalls, vehicle closure gates, and drainage structures. Additional information on the GRBS is provided in Section 4.4 and Section 6.4 of Appendix D.

**By the Numbers: GRBS**

- *10.0 mi of Floodwall*
- *Sector Gate at Offatts Bayou*
- *Gates at Roadways (34) and Rail Crossings (7)*
- *Dredging of Crash Boat Basin*
- *16 Drainage Structures*
- *4,500 cfs Pump Station at Offatts Bayou*
- *50 cfs Pump Station at Gas Pipeline*
- *Nonstructural Measures in Channelview*
- *Offshore breakwaters*
- *5,000 cfs pump station at 48th Street*
- *1,500 cfs pump station at Pier 19*
- *5,000 cfs pump station at UTMB*
- *500 cfs pump station at Fort Point Rd*
- *Mitigation for Direct and Indirect Impacts*

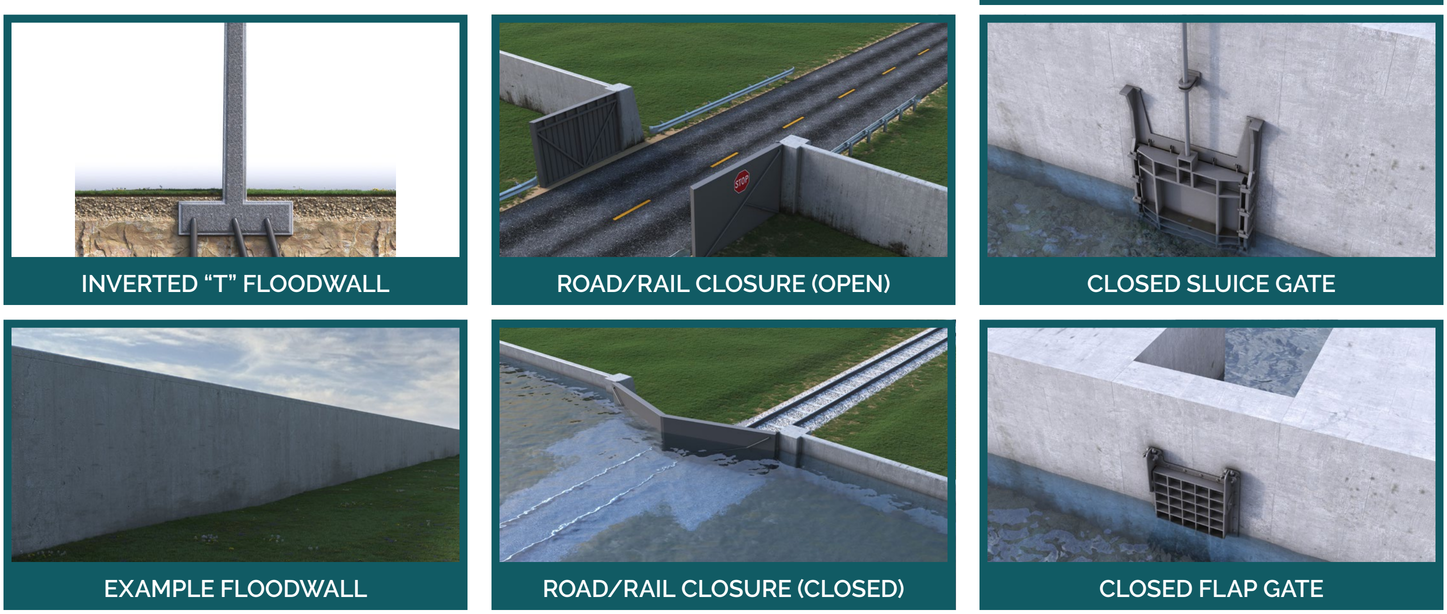



***Figure 3.36:*** *Conceptual renderings of GRBS components*

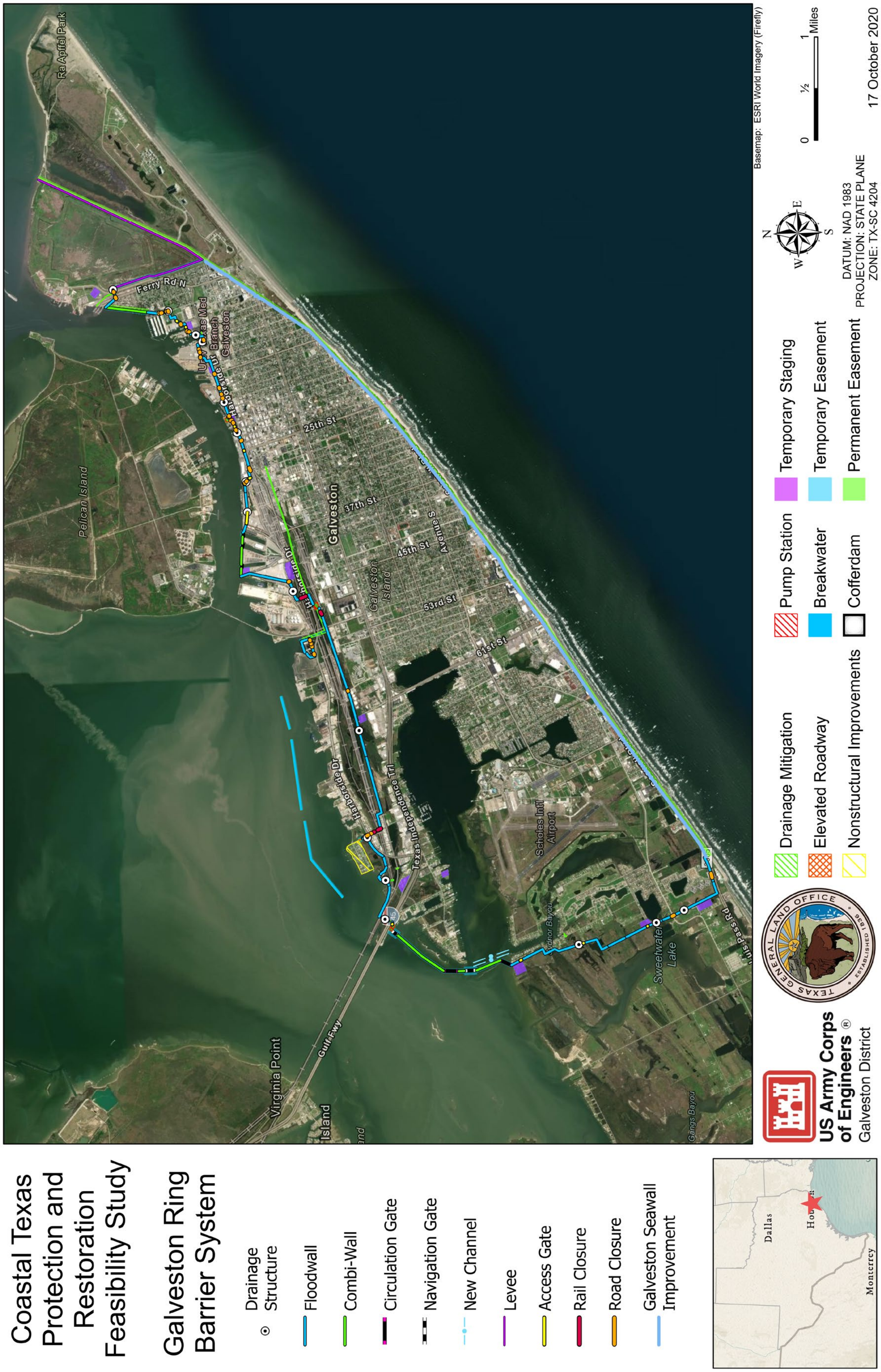



*Figure 3.37: Galveston Ring Barrier System*

#### 3.4.2.1.1. Seawall Tie-in

The start of the GRBS is at the west end of the Seawall tying into the existing backfill north of the north sidewalk of the Seawall. This section of floodwall extends west, crosses Cove View Boulevard with two vehicle gates, and continues west to the vicinity of the City's Sandhill Crane soccer fields. The barrier here would be an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). Existing drainage would be maintained and modified as needed to avoid any impacts from the construction of the floodwall. The tie-in to the Seawall was chosen to avoid gate closure structures across FM 3005. This allows for FM 3005 and the west end of Galveston Island to remain open to traffic during a storm surge event. This also places the tie-in for the west floodwall of the GRBS behind the Seawall, a more resilient location away from the high energy waves that the dune system may see.

*A photo of coastal marsh in West Galveston*

#### 3.4.2.1.2. Seawall Tie-in to Soccer Field Reach

The west floodwall of the GRBS continues north from FM 3005, adjacent to the City's Sandhill Crane soccer fields, and crosses Stewart Road with two vehicle gate structures. The barrier here would be an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). Existing drainage will be maintained and modified as needed to avoid any impacts from the construction of the floodwall. Currently one drainage structure is proposed for this reach of floodwall. Locating the floodwall adjacent to and on City of Galveston property limits the impact to adjacent private property owners while taking advantage of open areas and City land to utilize as staging areas. The staging area will have access to both of west Galveston's major roadways, FM 3005 and Stewart Road. The vehicle closure gates at Stewart Road would be closed during a storm surge event. The Stewart Road vehicle traffic will be redirected to FM 3005 during a storm surge event.

#### 3.4.2.1.3. Soccer Field to Galveston Bay Foundation (GBF) Preserve Reach

The west floodwall of the GRBS continues north onto the GBF Sweetwater Preserve until it reaches Offatts Bayou. The barrier here would be an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of +14 ft (NAVD88). Existing drainage will be maintained and modified as needed to avoid any impacts from the construction of the floodwall. Currently two drainage/circulation structures are proposed for this reach of floodwall, allowing for two-way water flow. The drainage structures will be 14 ft wide and 10 ft tall with sill elevations of -5 ft (NAVD88). This section of floodwall has three access gates to allow for maintenance of the GBF property. A small area of drainage impact mitigation is noted in this area to ensure that any impacts created by the construction can be addressed.

*Locating the floodwall on GBF property limits the impact to adjacent property while taking advantage of the open undeveloped areas along the property boundaries, avoiding the division of neighborhoods.*

Locating the floodwall on GBF property limits the impact to adjacent property while taking advantage of the open undeveloped areas along the property boundaries, avoiding the division of neighborhoods. The staging area will have access to Stewart Road and will be restored to previous condition when the project is complete.

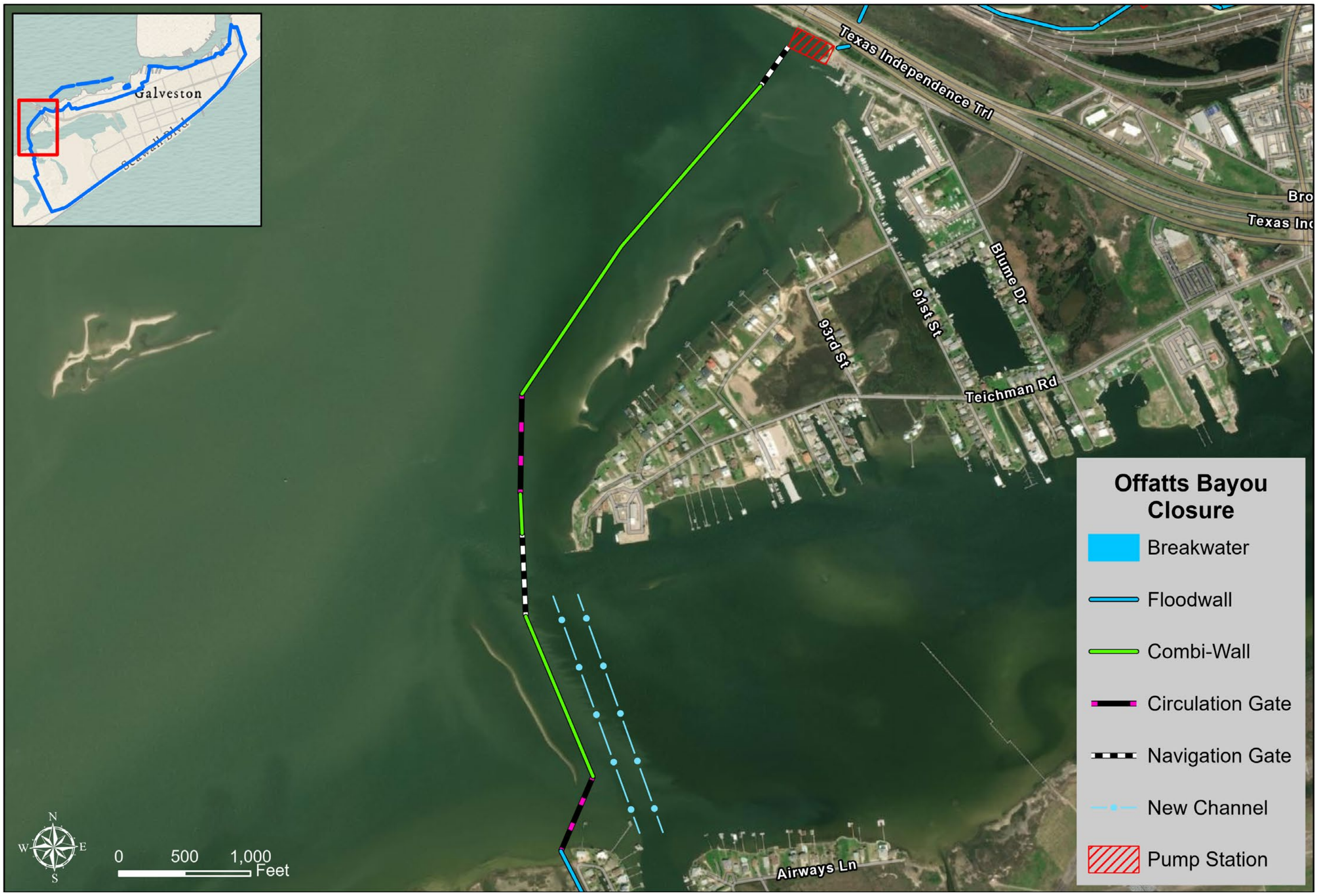



***Figure 3.38:*** *Offatts Bayou crossing*

### 3.4.2.1.4. Offatts Bayou Crossing Reach

The closure of Offatts Bayou starts at the edge of the GBF property, continuing north then northeast offshore of the Teichman Point neighborhood, then ending at the proposed Offatts Bayou pump station adjacent to the Galveston Causeway. This barrier is a combination floodwall system (combi-wall), consisting of vertical piling, batter piling, and a concrete cap system. This feature also includes sections of shallow water environmental gates/water circulation gates and two shallow-draft navigation sector gates. Figure 3.38 provides additional detail for the Offatts Bayou crossing.

Two main alternatives were evaluated for the Offatts Bayou crossing in the Teichman Road neighborhood. They consisted of the chosen alignment and an alternate alignment that excluded the neighborhood from the GRBS. The alternate alignment would have paralleled the shoreline of the Crash Boat Basin neighborhood and placed the Offatts Bayou pump station adjacent to a residential area. The alternate alignment would have an inverted "T" floodwall section with a road raising, road closures, and drainage features. The planning level assessment of the cost of the two alternatives resulted in the chosen alignment being taken forward in the study.

The Offatts Bayou crossing impacts the Crash Boat Basin access channel, so a new channel is proposed as shown. The shallow water circulation gates are placed in areas where existing circulation will be impacted by the construction. The shallow-draft navigation gates are shown as sector gates to ensure the existing use of the channels are not impacted by the construction. The offshore floodwall is located in an area to limit impacts to known habitat.

### 3.4.2.1.5. Offatts Bayou Pump Station and Galveston Causeway to 77th Street Reach

The proposed 4,000 cubic foot per second (cfs) Offatts Bayou pump station will be located at the intersection of the combi-wall and the Galveston Causeway. The pump station is situated at this location to allow for easy access during operations and to provide separation from residential structures. The sizing of this pump station will be refined during PED, when the interior drainage analysis is updated.

The Galveston Causeway crossing is a floodwall and vehicle closure gate from the Offatts Bayou pump station to the bridge abutment. The high ground of the bridge abutment will be incorporated into the alignment as a barrier at the I-45 crossing. An inverted "T" floodwall will then proceed east to the railroad bridge, where the high ground of the railroad bridge will be incorporated into the alignment as the barrier at the railroad crossing. The inverted "T" floodwall will continue east to southeast along the railroad abutment, then loop out to include the natural gas facility, and then continue east along Harborside Drive to 77th Street. This section of floodwall is an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). Existing drainage will be maintained and modified, as needed, to avoid any impacts from the construction of the floodwall. A circulation drainage structure is located on the floodwall section between I-45 and the railroad bridge, and a storm water drainage structure is located near the natural gas facility.

The utilization of the bridge abutments for crossing I-45 and the railroad bridge allows for GRBS to avoid closing off access to the Island. This alignment also limits impacts to the continuous functionality of the rail lines on and off the Island. The inclusion of the natural gas facility provides flood risk management to critical infrastructure.

*A photo of the Galveston Causeway*

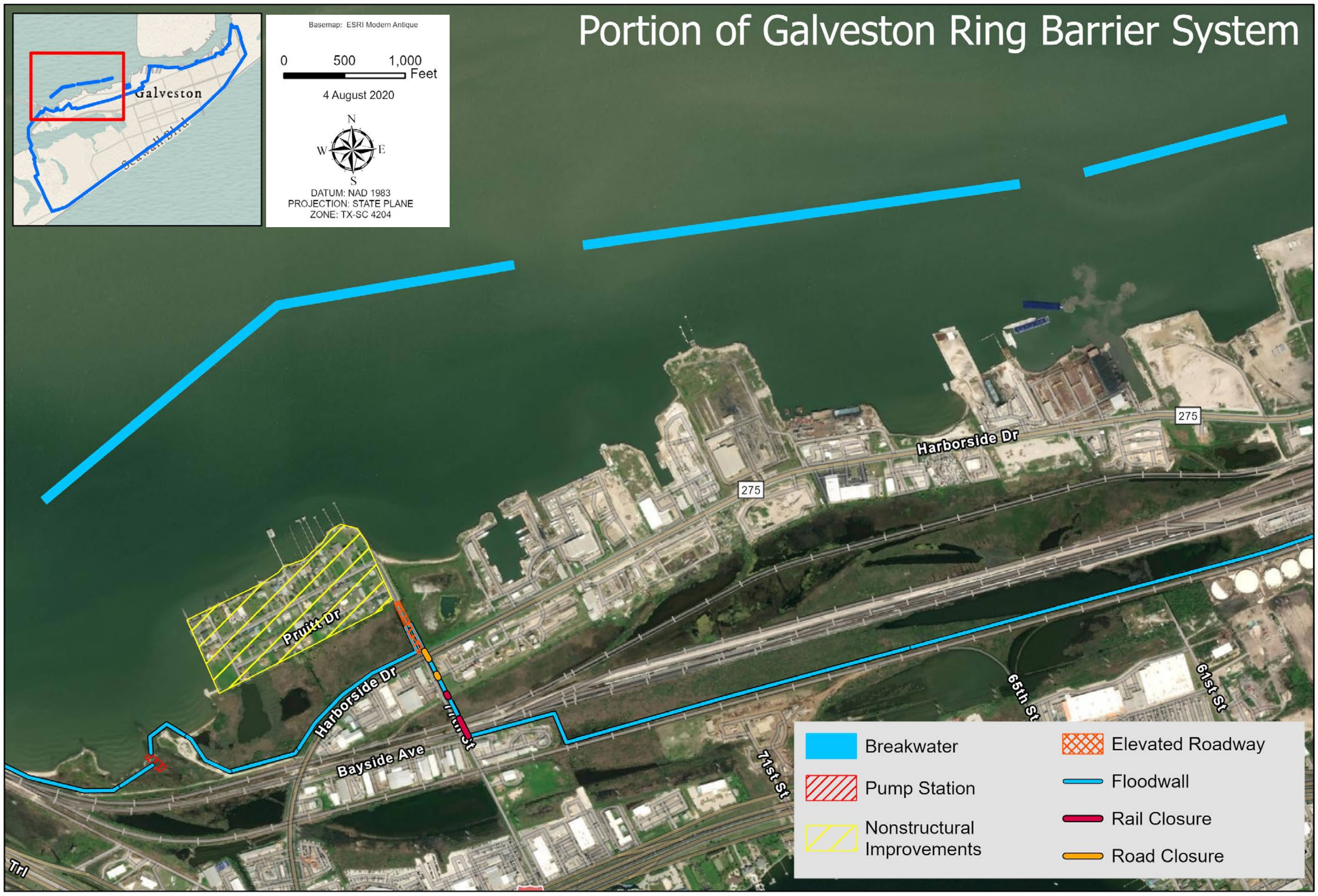



*Figure 3.39:* Channelview mitigation measures

### 3.4.2.1.6. 77th Street Crossing and the Channelview Neighborhood

The 77th Street crossing is proposed to be an elevated roadway crossing to eliminate the need for a gate structure and avoid locking out the residents located outside of the GRBS. This will allow for continuous access to the Channelview neighborhood during a surge event. The road raising will consist of a floodwall that will be buried under the roadway along with retaining walls that will allow for the entire roadway to be raised from Pruitt Street to Harborside Drive.

Many of the residential homes in the Channelview neighborhood are already raised to prevent inundation from coastal storm surges. However, a portion of the homes on the interior streets are still slab on grade homes. Due to the close proximity of residential structures to the floodwall, and due to concerns with wave action deflecting off the floodwall, mitigation measures are being included in the recommendation to address the uncertainty surrounding the issue.

Offshore breakwaters (blue lines on Figure 3.39) are recommended to reduce wave heights during storm events to mitigate part of the risk. Nonstructural measures for residential structures in the Channelview neighborhood (yellow cross hashed area in Figure 3.39) are also recommended to address risk due to the proximity of the neighborhood to the floodwall. Although a cost estimate was developed for voluntary home elevations, the uncertainty associated with successful implementation of raising houses caused this option to be set aside for nonstructural buyouts. The higher cost of buying out homes is carried forward in the recommendation. In PED, the existing surge risk, and induced surge risk from the floodwall, will be further investigated to determine if the nonstructural mitigation measures need to be implemented.

#### 3.4.2.1.7. 77th Street to 47th Street Pump Station

The GRBS alignment through the Harborside area, from 77th Street to the proposed 47th Street pump station, goes south from the 77th Street crossing, then east adjacent to the railroad track, then under the 51st Street bridge to the 47th Street pump station. This section of barrier is an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). Existing drainage will be maintained and modified as needed to avoid any impacts from the construction of the floodwall. This reach also includes an offshore breakwater, as noted in Section 3.4.2.1.6, to mitigate the wave impacts to residential and industrial areas.

The alternate alignments evaluated through this area included an alignment along the north side, south side and middle of Harborside drive, and immediately south of the industrial area along Harborside drive. The impacts of these alignments on the industrial area and traffic on Harborside were significant and the efforts to minimize the impacts resulted in the recommended alignment. The proposed alignment limits the required number of gate closure structures for rail and roads and maintains a comparable length to keep similar costs. This reach also includes a structural measure at the wastewater treatment facility at 51st Street. This measure is currently proposed as a floodwall but could potentially be reduced in scope or possibly eliminated in PED after the facility is thoroughly evaluated.

#### 3.4.2.1.8. Pump Station at 47th Street.

The proposed pump station at 47th Street is a 4,000 cfs in size and includes gravity drainage and drainage impact mitigation features that extend from Galveston Bay to 27th Street. The pump station is situated at this location to allow for easy access during operations and to provide separation from residential structures. The sizing of this pump station will be refined during PED, when the interior drainage analysis is updated. This pump station will have gravity drainage features that allow for the drainage of rainfall without the operation of the pumps.

This pump station also has two significant drainage impact mitigation features. The first drainage feature is the outlet channel. The pump station is located inland and will require a discharge channel to be constructed through an area that has significant existing railroad infrastructure. This will require replacing culverts along rail lines with bridges to allow for the flow of the water from the pump station to Galveston Bay. There is also a road that will need to be converted to a bridge to allow for the increased flow. The second drainage feature is an intake canal that will bring water to the pump station. This feature is required to connect some of the existing gravity drainage systems that will be cut off during construction and operation of the GRBS. This feature will proceed from the pump station at 47th Street, generally along the Mechanic Street corridor to 28th Street, and will be a combination of open channel and large buried drainage conduit. The size of these drainage impact mitigation features will be refined during PED when the interior drainage analysis is updated.

#### 3.4.2.1.9. 47th Street Pump Station through Port of Galveston to 19th Street.

The alignment of the barrier from the 47th Street pump station, through the Port of Galveston, and to the Pier 19 area is a combination of features including floodwall, moveable floodwall sections, and vehicle closure structures. The alignment starts at the 47th Street pump station then proceeds east to the Harborside Drive bridge abutment. The system turns north and passes through the bridge abutment, incorporating the bridge abutment into the alignment, then continues across the rail lines and proceeds in a north-northeast direction to the Galveston Ship Channel. This section of floodwall is an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). The alignment then turns east and proceeds across the dock and closes off the three existing shipping slips. This section of floodwall is also an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). The floodwall would include an above ground height of approximately 3 ft with limited areas of 4 ft above the ground height. The alignment continues east as a moveable floodwall section through the laydown area. The floodwall would consist of a moveable "stem" section, with the foundation, and footing below ground. The alignment then weaves through the grain elevator area and the cruise ship terminal to the Pier 19 area. This section of floodwall is also an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). The floodwall would have an above ground height of approximately 6 ft with limited areas of 8 ft above the ground height. Existing drainage will be maintained and modified as needed to avoid any impacts from the construction of the floodwall.

The alignment in this area was chosen to eliminate the need for vehicle closure gates on Harborside Drive and to minimize dissecting Port facilities. This alignment reflects adjustments made to conform to the Galveston Wharves Strategic Master Plan. Coordination with the port on the proposed alignment led to the elimination of a significant number of vehicle closures, and provides a shorter length of floodwall than was originally proposed. This coordination will continue in PED to further refine and enhance the project features in the port facility.

#### 3.4.2.1.10. Pier 19 Reach

The project features and alignment through the Pier 19 area were refined to conform with the proposed land use changes in the Galveston Wharves Strategic Master Plan. These changes reduced impacts to access and operations within the port area. This refinement also allowed for the elimination of rail closure structures and the consolidation of vehicle and access closure structures. This section of floodwall is an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). The floodwall will have an above ground height of approximately 6 ft.

The proposed pump station at Pier 19 is a 1,500 cfs pump station. This location is being coordinated with the City of Galveston and will likely shift to Pier 16 during PED, where the City is currently in the design phase for a City owned pump station. The size and final location of the Recommended Plan's pump station will be determined during PED, in close coordination with the City of Galveston.

*A photo of Harbor View*

#### 3.4.2.1.11. Pier 19 through Port of Galveston to UTMB

The project features and alignment from Pier 19 through the port were refined to conform to the proposed land use changes in the Galveston Wharves Strategic Master Plan. These changes allowed for the alignment to adjust and reduce impacts to access and operations within the port area. This refinement also eliminated the need for rail closure structures and allowed the consolidation of vehicle and access closure structures. This section is an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). The floodwall would have an above ground height of approximately 8 ft. Existing drainage will be maintained and modified as needed to avoid any impacts from the construction of the floodwall.

#### 3.4.2.1.12. UTMB to Harbor View Reach

The alignment of the GRBS through UTMB generally goes east from the Port of Galveston property, follows the shoreline near the helipad, turns north along the dock area, then east toward the Primary Care Pavilion (PCP), then north-northeast to the Galveston Yacht Basin, then continues to the shoreline at Harbor View Drive. This section is an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). The floodwall would have an above ground height of approximately 8 ft with some areas up to 12 ft. This reach also has a pump station and some drainage impact mitigation features.

The proposed pump station at UTMB is a 4,000 cfs pump station. The location is currently shown on UTMB property adjacent to a channel off of the Galveston Ship Channel. This pump station would require drainage features to bring the water to the pump station. These features would tie into the existing City drainage outlet that is in the vicinity of the proposed pump station. This reach was coordinated with UTMB and the initial alignment was adjusted to remove numerous closure structures and to relocate the pump station away from critical infrastructure. These changes allowed for a reduction in the length, complexity, and impacts of the GRBS. Additional coordination during PED could further enhance the project in this area. The alignment through the Galveston Yacht Basin was chosen to reduce the number of closure structures, while not impacting accessibility. Coordination during PED is needed to reduce impacts and capitalize on opportunities to increase benefits in this area.

*The alignment through the Galveston Yacht Basin was chosen to reduce the number of closure structures, while not impacting accessibility. Coordination during PED is needed to reduce impacts and capitalize on opportunities to increase benefits in this area.*

***Figure 3.40:*** *Harbor View Drive alternatives*

### 3.4.2.1.13. Harbor View Drive and Circle

The alignment of the GRBS along Harbor View Drive is located along the waterfront, on top of and incorporated into the existing old stone jetty. This feature would require raising the existing jetty to elevation 14 ft (NAVD88) and implementing seepage control measures to prevent seepage through the foundation and structure of the old jetty. These features would be constructed on and within the old jetty and would not extend to the residential structures but could impact pools or other backyard structures.

An alternative solution for this reach could be to raise the residential structures and place a floodwall structure beneath the homes, then backfill with acceptable fill material to place the alignment underneath the homes. This would be invasive to the homeowners but would potentially allow for a less expensive feature that could ultimately be less intrusive than raising the jetty. Conceptual renderings of these different alternatives are shown in Figure 3.40.

*A photo of East Galveston and Bolivar Roads*

### 3.4.2.1.14. Ferry Landing to Galveston Seawall East End Reach

The GRBS alignment continues from the north end of Harbor View as floodwall going east across Ferry Road to the Fort Point Road pump station, then crossing Fort Point Road, then turning south along the existing levee of the San Jacinto placement area and terminating at the Galveston Seawall. This section is an inverted "T" concrete floodwall with a deep foundation and a top of wall elevation of 14 ft (NAVD88). The floodwall would have an aboveground height of approximately 6 ft with some areas up to 10 ft. This reach also has a pump station and some drainage impact mitigation features along with a levee section.

The proposed pump station at Fort Point Road is a 1500 cfs pump station. The location is currently shown adjacent to Fort Point Road and would require drainage features to bring the water to the pump station and out to the Galveston Ship Channel. These features would tie into the existing City drainage outlet that is in the vicinity of the proposed pump station. The pump station would include gravity drainage features that would allow for drainage without running the pumps.

### 3.4.2.1.15. Pump Stations and Drainage Outlets Associated with GRBS

As discussed above, the GRBS includes a series of pump stations and drainage outlets. While the majority of drainage systems in the Galveston area are gravity driven, the City of Galveston is continuing to make improvements to the system, including forced, or pumped, drainage systems. As discussed below, the Recommended Plan only focuses on addressing rainfall when the system is closed. The pumping system has not been formulated or refined to address flooding from Urban Flood Control problems. More focused Urban Flood Control authorities exist in the Galveston area that could be enacted in the future to address localized rainfall flooding. The USACE will continue to work with the City to ensure that there are no conflicts between the City's current or future plans and the Recommended Plan.

*A photo of the Strand in Galveston*

As discussed above, the GRBS system would include a 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 gate closures for surges from hurricanes or tropical storms. When these gates are closed, the pump stations will need to operate to remove water due to rainfall within the GRBS and/or wave overtopping. While the pumps are initially designed to handle 25-year rainfall with surge tail water boundary conditions of 1% AEP (detailed in Section 2.7.4 in Appendix D, the Engineering Appendix), the compound interaction of rainfall and surge has not been fully explored in this phase of the study. The operational criteria of the gates and pump stations will need to be fully assessed in the PED phase. The gate operations will be dependent on the intensity, track and orientation of the approaching storm, which will dictate the trigger condition for gate closings. Pumps will be operated when the intake water level is higher than the outfall water level. This expected rate of closure would be the same regardless of the actual rate of relative sea level rise, as closure of the system is tied to tropical storm surge events and the elevation trigger would be adjusted as sea level rises. The risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in sea level rise. To manage rainfall induced flooding of the areas behind the structure, all drainage features through the system were sized to match the existing capacity of the gravity drainage system, and would mimic the existing drainage patterns. Any operational changes implemented to address changing sea level conditions, or for any other non-project-related purpose, would be considered a separate project purpose requiring separate authorization, new NEPA documentation, and/or permit approvals.

*The risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in sea level rise.*

The non-Federal sponsor will have obligations related to the operation of the project, specifically the pump stations, to prevent encroachments that would impact the utility of the project when the pump station is operating. The non-Federal sponsor will be required to comply with flood plain management requirements and ensure that project features, such as pump stations, would not be impacted by developments in the areas behind the risk reduction system. The pump system is designed to match the existing gravity drainage capacity. The non-Federal sponsor will have the responsibility to ensure that this operation of the project features is maintained.


*Figure 3.41: Clear Lake gate system and pump station*

## 3.4.2.2. Clear Lake Gate System and Pump Station

This CSRM feature consists of a gated closure structure, associated barrier walls, and a pump station to address the residual risk that persists in the Clear Lake area. The Bolivar Roads Gate System reduces the water elevation in Galveston Bay from storm surge entering from the Gulf, but does not eliminate wind driven surges inside the Bay, due to the large size of the Bay. This risk is not increased as a result of plan features.

As shown in Figure 3.41, a closure is proposed at State Highway 146 and Clear Lake to address Bay surge. The design includes a 75 ft sector gate with a sill elevation of -10 MLLW, to match the authorized width and depth of the channel, and a pump station with a design capacity of 20,000 cfs. The elevation of the walls and gates were set at an elevation of 17.0 ft (NAVD88), based on TWL, which considers still water level and wave overtopping, with a 1% AEP under the Intermediate Sea Level Rise Condition. Determination of this elevation, which is subject to revision during the PED phase, is detailed further in Section 2.7.2 in Appendix D, the Engineering Appendix.

The floodwall and closure structure would start on the west side of State Highway 146, near NASA Road 1, and end on the south side of the outlet, near Marina Bay Drive west of State Highway 146.

This feature would include drainage outlet structures, also called circulation gates, to allow hydrologic connectivity to be maintained, to the extent practicable, except during closure for hurricane or tropical storm surge events. While the pumps are designed to handle the 25-year rainfall with surge tailwater boundary conditions of 1% AEP (detailed in Section 2.7.5 in Appendix D, the Engineering Appendix), the compound interaction of rainfall and surge have not fully been

### By the Numbers: Clear Lake Gate System

- *75' Sector Gate at Clear Lake*
- *9,950 lf of floodwall*
- *20,000 cfs pump station*
- *Secondary Outlet*
- *Mitigation for direct and indirect impacts*

explored in this phase of the study. Hence, operation criteria of the gate and pump stations need to be explored in the PED phase and described in the future project feature Water Control Manual. The surge gate operation will be dependent on the intensity, track, and orientation of the approaching storm which will dictate trigger conditions in the Bay for gate closing.

The risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in sea level rise. To manage rainfall induced flooding of the areas behind the structure, all drainage features through the system were sized to match the existing capacity of the gravity drainage system and would mimic the existing drainage patterns. Any operational changes implemented to address changing sea level conditions, or for any other non-project-related purpose, would be considered a separate project purpose requiring separate authorization, new NEPA documentation, and/or permit approvals.

The non-Federal sponsor will have obligations related to the operation of the project, specifically the pump stations, to prevent encroachments that would impact the utility of the project when the pump station is operating. The non-Federal sponsor will be required to comply with flood plain management requirements and ensure that project features, such as pump stations, would not be impacted by developments in the areas behind the risk reduction system. The pump system was designed to match the existing gravity drainage capacity. The non-Federal sponsor will have the responsibility to ensure that this operation of the project features is maintained. Further information on the Clear Lake Gate System and Pump Station is provided in Section 2.7.5 of Appendix D.

*A photo of boats docked near the Kemah Boardwalk*

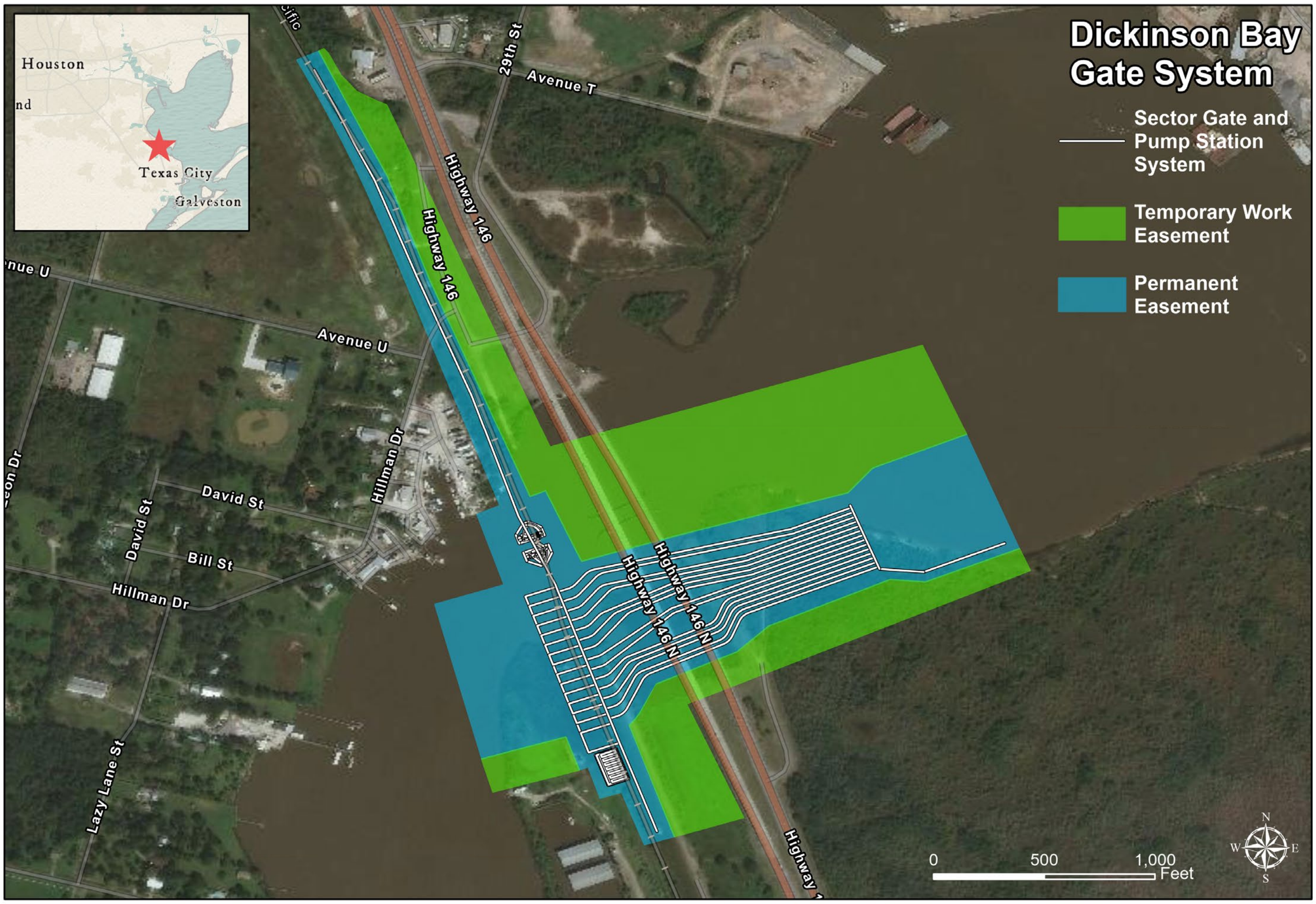



*Figure 3.42:* Dickinson Bay gate system and pump station

### *3.4.2.3. Dickinson Bay Gate System and Pump Station*

This CSRM feature consists of a gated closure structure, associated barrier walls, and a pump station to address the residual risk that persists for low-lying structures along Dickinson Bayou. The Bolivar Roads Gate System reduces the water elevation in Galveston Bay from storm surge entering from the Gulf, but does not eliminate wind driven surges inside the Bay, due to the large size of the Bay. This risk is not increased as a result of plan features.

As shown in Figure 3.42, a closure is proposed at State Highway 146 and Dickinson Bayou to address Bay surge. The design includes a 100' sector gate with a sill elevation of -9 MLLW, to match the authorized depth of the channel, and a pump station with a design capacity of 19,500 cfs. The gate width is 40 feet wider than the authorized channel width of 60 feet to allow for additional flow area/conveyance. The elevation of the walls and gates were set at an elevation of 18.0 ft (NAVD88), based on TWL, which considers still water level and wave overtopping, with a 1% AEP under the Intermediate Sea Level Rise Condition. Determination of this elevation, which is subject to revision during the PED phase, is detailed further in Section 2.7.2 in Appendix D, the Engineering Appendix.

The floodwall and closure structure would start on the west side of State Highway 146, near Avenue T, and end on the south side of the bayou, near Waterman's Harbor west of State Highway 146.

## By the Numbers: Dickinson Bay Gate System

- *100' Sector Gate at Dickinson Bayou*
- *6,547 lf of floodwall*
- *19,500 cfs pump station*
- *Drainage Outlet / Circulation Gates*
- *Mitigation for direct and indirect impacts*

This feature would include drainage outlet structures, also called circulation gates, to allow hydrologic connectivity to be maintained, to the extent practicable, except during closure for hurricane or tropical storm surge events. While the pumps are designed to handle the 25-year rainfall with surge tailwater boundary conditions of 1% AEP (detailed in Section 2.7.6 in Appendix D, the Engineering Appendix), the compound interaction of rainfall and surge have not fully been explored in this phase of the study. Hence, operation criteria of the gate and pump stations need to be explored in the PED phase and described in the future project feature Water Control Manual. The surge gate operation will be dependent on the intensity, track, and orientation of the approaching storm which will dictate trigger conditions in the Bay for gate closing.

The risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in sea level rise. To manage rainfall induced flooding of the areas behind the structure, all drainage features through the system were sized to match the existing capacity of the gravity drainage system and would mimic the existing drainage patterns. Any operational changes implemented to address changing sea level conditions, or for any other non-project-related purpose, would be considered a separate project purpose requiring separate authorization, new NEPA documentation, and/or permit approvals.

The non-Federal sponsor will have obligations related to the operation of the project, specifically the pump stations, to prevent encroachments that would impact the utility of the project when the pump station is operating. The non-Federal sponsor will be required to comply with flood plain management requirements and ensure that project features, such as pump stations, would not be impacted by developments in the areas behind the risk reduction system. The pump system designed to match the existing gravity drainage. The non-Federal sponsor will have the responsibility to ensure that this operation of the project features is maintained. Further information on the Dickinson Bay Gate System and Pump Station can be found in Section 2.7.6 of Appendix D.

*A photo of the Strand in Galveston*

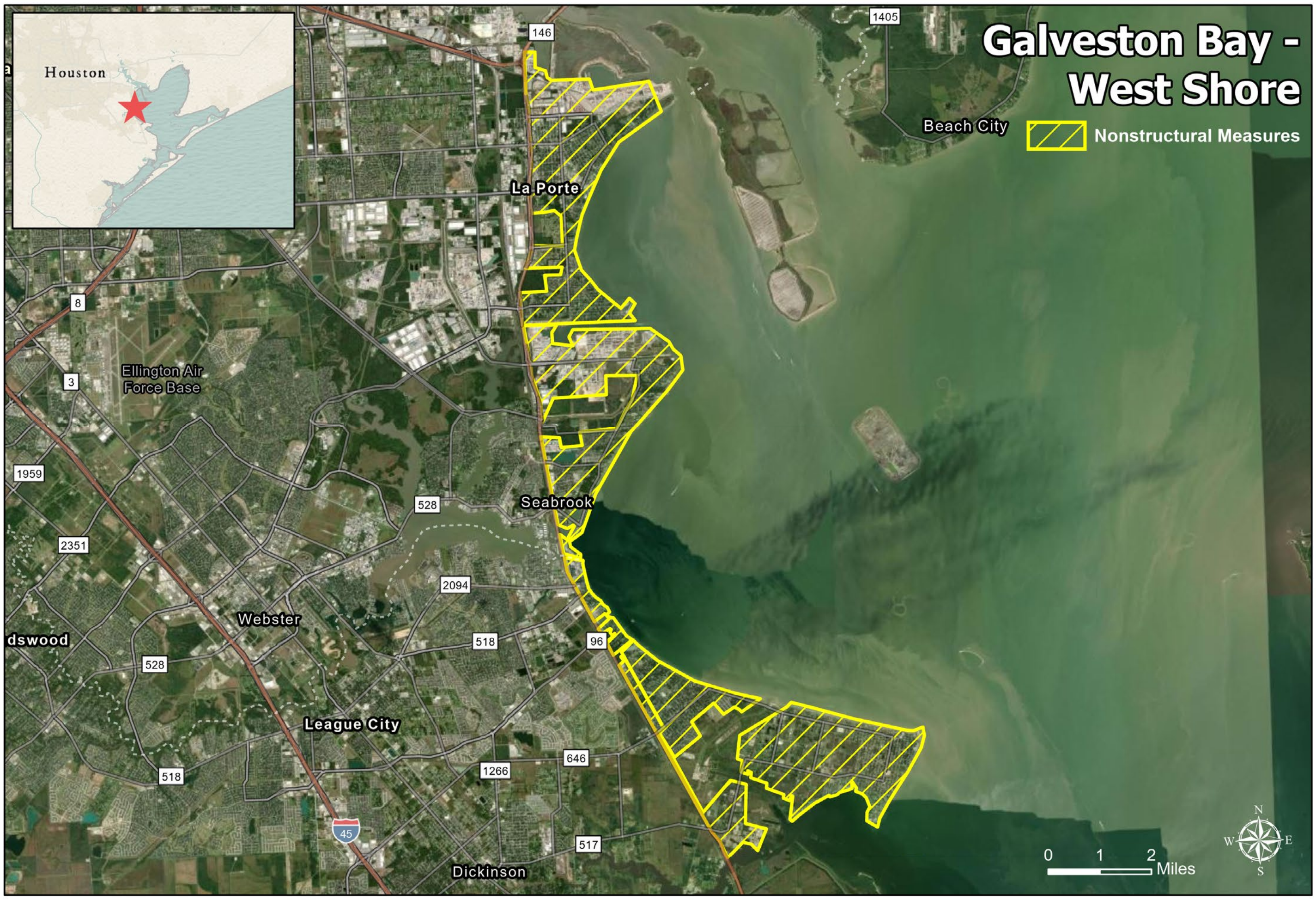



*Figure 3.43: Nonstructural improvements*

## 3.4.2.4. Nonstructural Improvements

Nonstructural measures are proposed for the west side of Galveston Bay, north of the Texas City hurricane protection levees, to address the residual risk that persists for the area as a result of wind driven storm surges from the Bay. The Bay is large enough that increased water surface elevations in the area can result from wind and fetch within the Bay, even as the Bolivar Roads Gate System significantly reduces the storm surge entering the Bay from the Gulf of Mexico.

The Study Team reviewed residential and nonresidential structures within the Galveston Bay system that are predicted to sustain significant damage in the 20-yr, 50-yr, 100-yr, or 200-yr flood event, under the future with project condition with the surge barrier in place. Based on an evaluation of cost and benefits and the ability to continue to buy down risk, structures still receiving damages in the 100-yr event were recommended for voluntary nonstructural raisings. 1,755 residential pier and slab-on-grade structures are being recommended to be raised to the future with project 100yr stage plus 1 ft. and 170 nonresidential slab structures are recommended to be flood proofed to 3ft above the existing ground elevation. If local floodplain standards are higher than these recommended elevations, the local standard should be followed. The general location of the areas where voluntary nonstructural raising will be offered are shown in Figure 3.43. Additional information on the Nonstructural Improvements is provided in Part 3 of Appendix E-1, the Coastal Storm Surge Reduction (Upper Coast) Appendix.

### By the Numbers: Nonstructural Improvements

- *1,755 residential structures to be raised*
- *170 nonresidential structures to be floodproofed*

### 3.4.3. Management Measures Associated with Gate Operations

While the Coastal Texas study included extensive hydraulic modeling of the future without project (FWOP) and future with project (FWP) scenarios, the level of modeling possible during the feasibility phase was not detailed enough to accurately capture the impact of gate operations and other structural features on induced flooding, or unmitigated localized increases in flood levels and potentially flood damages. Per Engineering Regulation 1105-2-100, "When a project results in induced damages, mitigation should be investigated and recommended if appropriate. Mitigation is appropriate when economically justified or there are overriding reasons of safety, economic or social concerns, or a determination of a real estate taking (flowage easement, etc.) has been made. Remaining induced damages are to be accounted for in the economic analysis and the impacts should be displayed and discussed in the report."

As discussed in Section 2.6.4 of Appendix D, evaluation of model outputs for the FWOP and FWP scenarios indicated that approximately 1% of the total structures evaluated were located in areas with modeled increases in flood stages, ranging from minor (e.g. 0.01 feet) to potentially significant (e.g. 0.5 feet). Analysis of potential induced flooding identified three primary causes for the modeled inducements:

- Minor instabilities or inaccuracies in the computational model, leading to small variances in stages near model boundaries or under both frequent and extreme storm simulations (e.g. 1,000 year storm). While quantified in the model outputs, after detailed review, the engineering team was able to determine that these inducements were not accurate and would not be reflected in future more detailed modeling during the PED phase.
- Minor inconsistencies between modeled scenarios and the final Recommended Plan, incorrectly indicating risk when it no longer exists. Due to schedule and cost limitations, it was not possible to model select final refinements to the Recommended Plan, such as final changes to the Galveston Ring Barrier System alignment. While quantified in the model outputs, after detailed review, the engineering team was able to determine that these inducements were not accurate and would not be reflected in future more detailed modeling during the PED phase.
- Limitations associated with modeling the operation of the large storm surge gates at Bolivar Roads. Specifically, modeling assumed the gates were closed for the entire duration of the storm simulation. This model limitation does not fully reflect FWP conditions, whereby the gates would have operational triggers that would determine when the gates would close and open. Essentially, the gates will not close for all storms, and if they do close, the duration for which they close will vary based on operational triggers established and communicated prior to completion of design and construction. Gate operations were not included during the feasibility phase due to the level of detailed and iterative analysis required.

After accounting for and excluding inducements associated with the first two items, the primary remaining concern is the third item related to gate operation. In certain scenarios, assuming a static gate can trap water inside the Bay resulting in potential impacts to approximately 450 structures located in areas around the inside of the gate: for example, near the Pelican Island and near the ferry landing on Bolivar. The design objective is to reduce or possibly eliminate this induced effect.

To meet the design objective related to induced flooding, the following actions or management measures have been included in the final recommendation:

- The first management measure is to conduct storm surge modeling in PED which will incorporate gate operations into the model simulations. Such modeling can better inform the Water Control Manual, which controls future gate operations, in order to limit or eliminate induced flooding concerns.
- The second management measure is to incorporate into the design, during PED, structures that can be immediately opened post storm or designed to address reverse head conditions where stages can build up behind the gate system. This will allow for greater flexibility in operating the gates and in limiting or eliminating induced flooding concerns.
- The third management measure is to include nonstructural measures in the authorization to address any future remaining inducement concerns. As part of this management measure, additional costs have been added to the Real Estate account as a contingency to implement nonstructural measures if deemed necessary. Specifically, acquisition costs for a total of 450 structures have been included (representing approximately 0.2% of total structures evaluated). The higher cost of buying out homes has been used in the cost estimate, due to the uncertainty associated with raising houses. In PED, the existing surge risk and induced surge risk from the gate operation will be further investigated to determine if the nonstructural mitigation measures need to be implemented.

## 3.5. Mitigation Requirements

Compensatory mitigation is required for unavoidable adverse impacts to the environment that are caused by the Recommended Plan. While there are no unavoidable adverse impacts requiring mitigation associated with the Coastwide ER Plan or the South Padre Island Beach Nourishment and Sediment Management measure, there are identified unavoidable adverse impacts to estuarine emergent wetland, palustrine emergent wetland, oyster reef, and open bay bottom associated with the Galveston Bay Storm Surge Barrier system, including both the Gulf and Bay defenses. Mitigation to offset the direct and indirect losses of these habitat types have been incorporated into the Recommended Plan. The impacts are divided into two categories, direct and indirect:

- **Direct Impacts** are caused by the footprint of CSRM feature construction
- **Indirect Impacts** are caused by construction induced changes to the environment that are not within the direct footprint.

*A photo of coastal marshes on Bolivar peninsula*

USACE Implementation Guidance for Sections 1162 and 1163 of WRDA 2016, for Mitigation for Fish and Wildlife and Wetlands Losses, and the standards and policies set forth in 33 CFR Part 332, outline the mitigation requirements for any report being submitted to Congress for approval, and also adds the requirement for mitigation plans to comply with the mitigation standards and policies of the USACE Regulatory Program.

A Mitigation Plan, which is included as Appendix C-1, details proposed plans to replace the lost functions and values of the impacted areas through creation or restoration activities that increase and/or improve the habitat functions and services within a mitigation site. Restoration would involve implementing actions to improve already existing low-quality habitat. Creation would involve creating a habitat type from open water or agricultural fields where none currently exists, but which historically occurred in the vicinity of the project area. The content and structure of the Mitigation Plan were developed to meet the requirements for Regulatory Program compensatory mitigation plans in 33 CFR 332.4(c).

To address reduced tidal flow into the Galveston Bay from the proposed Bolivar Roads Gate System, the Study Team used Adaptive Hydraulics (AdH) modeling to predict any changes in the tidal prism (volume of water which leaves or enters the bay between mean low tide and mean high tide) and tidal amplitude (height difference between mean low tide and mean high tide) and developed a spatial analysis using the NOAA Marsh Migration viewer outputs associated with a projected 1 ft. of rise in relative sea level. The Study Team addressed the permanent impacts to open bay bottom by the construction of the Bolivar Roads Gate System by working collaboratively with the resource agencies. They determined that mitigation for this can be satisfied through oyster reef creation and restoration by using Habitat Equivalency Analysis (HEA) though the USACE Institute for Water Resources (IWR) Planning Suite. In accordance with USACE planning policy, mitigation acreages were calculated by using USACE-certified species models to determine functional losses from impacts and functional gains (or "lift") from mitigation.

*To address reduced tidal flow into the Galveston Bay from the proposed Bolivar Roads Gate System, the Study Team used Adaptive Hydraulics (AdH) modeling to predict any changes in the tidal prism and tidal amplitude and developed a spatial analysis using the NOAA Marsh Migration viewer outputs associated with a projected 1 ft. of rise in relative sea level.*

Compensatory mitigation was formulated to occur within the same watershed as that of the impacts and to replace the functions and services of each habitat type with functions and services of the same habitat type. To be considered, mitigation measures were required to either restore or enhance the same habitat

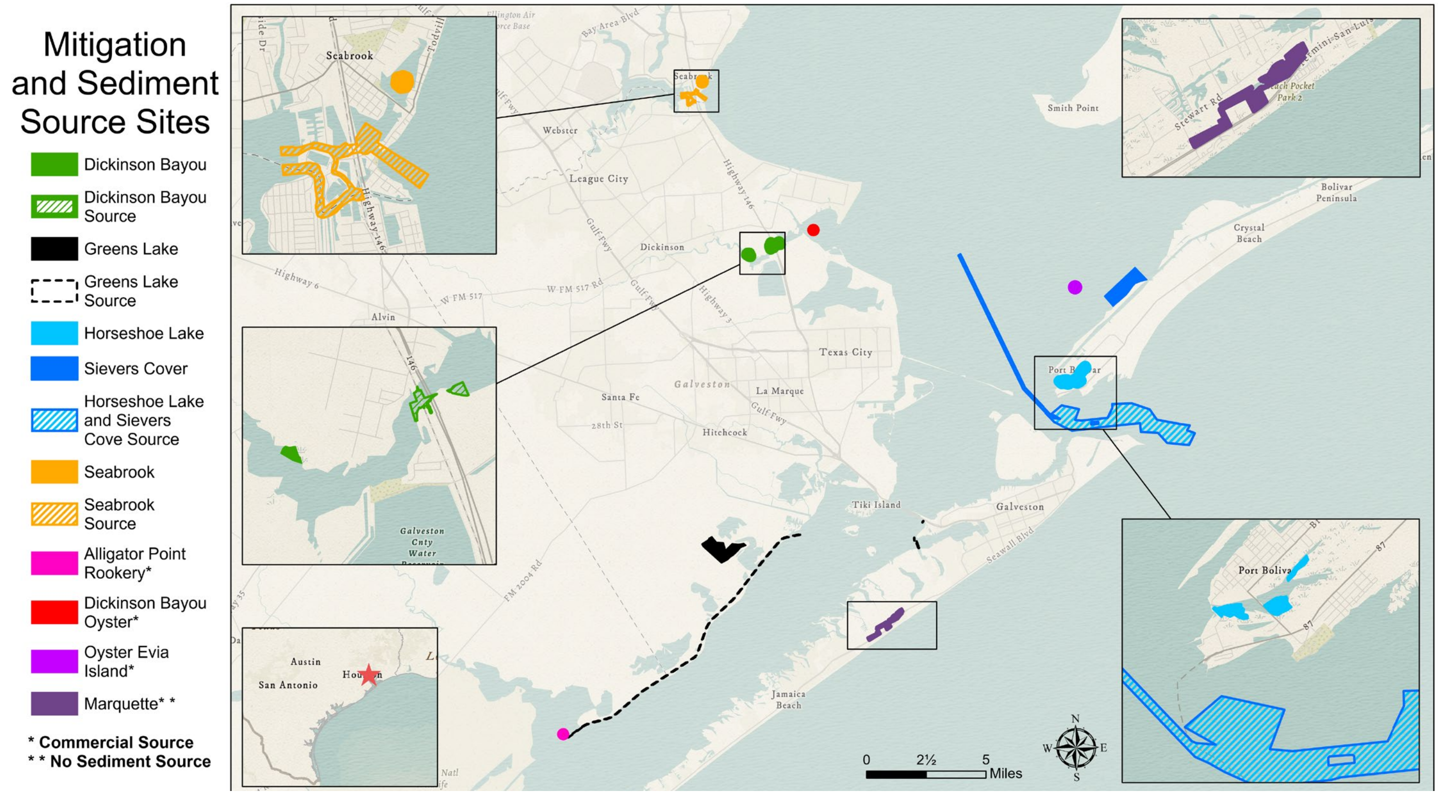



*Figure 3.44:* Mitigation and sediment source sites

types that were impacted (e.g., "habitat type for habitat type") with the construction of the Recommended Plan. As part of this study, preliminary design of the mitigation measures were completed by the Study Team, in close coordination with the resource agencies.

As summarized in Table 3.1, mitigation will be required for 1,577.6 acres of direct and indirect impacts to wetlands and oyster reefs. Mitigation will replace the lost functions and values of the impacted environment through restoration and enhancement activities that increase and/or improve the habitat functions and services within a mitigation site. Over 1,378 acres of habitat will be created or restored in order to offset the direct and indirect impacts of the proposed plan.

Potential locations for mitigation sites, as shown in Figure 3.44, have been developed with the interagency team, but will be refined further during the PED phase. Ultimately, the final size of the mitigation measures (width, length etc.) may change. However, due to the conservative nature of engineering and economic assumptions used in the development of the Recommended Plan, it is anticipated that design refinements of the proposed structures will result in equal or lesser environmental impacts than currently estimated. Further information on the Mitigation Plan is provided in Appendix C-1 and in the attached Final EIS.

| IMPACTS | Acres | AAHUs |
|---|---|---|
| **Direct** | | |
| Palustrine Wetlands | 128.0 | -20.8 |
| Estuarine Wetlands | 134.0 | -59.9 |
| Open Bay Bottom | 161.6 | -18.1 |
| Oyster | 6.0 | -2.8 |
| ***Total Direct Impacts*** | ***429.6*** | ***-101.6*** |
| **Indirect** | | |
| Tidal Prism change | 1,148.0 | -788.3 |
| ***Total Indirect Impacts*** | ***1148.0*** | ***-788.3*** |
| **TOTAL IMPACTS** | **1,577.6** | **-880.9** |

| MITIGATION | Acres | AAHUs |
|---|---|---|
| **Direct** | | |
| Palustrine Wetlands | 32.0 | 20.8 |
| Estuarine Wetlands | 92.0 | 59.9 |
| Oyster (Open Bay Bottom) | 40.0 | 18.5 |
| Oyster | 7.0 | 3.0 |
| ***Total Direct Mitigation*** | ***171.0*** | ***102.2*** |
| ***Total Indirect Mitigation*** | ***1,207.0*** | ***816.3*** |
| **TOTAL MITIGATION** | **1378.0** | **918.5** |

*Table 3.1:* Mitigation summary

*Example of marsh restoration planting on Galveston Island*

## 3.6. Adaptive Management & Monitoring

Adaptive management and monitoring (AM&M) activities in the Mitigation Plan address ecological and other uncertainties that could prevent successful implementation of mitigation project measures. The Monitoring and Adapative Management Plan (MAMP) identified potential and necessary monitoring activities for ER and mitigation features, outlines how results from the monitoring would be used to assess ER and mitigation feature success, and (if needed) adaptively manage the project features to achieve the desired objectives. The MAMP also specifies who would be responsible for monitoring and adaptive management activities and provides estimated associated costs.

The MAMP was prepared by members of the Coastal Texas Study Team in consultation with resource agencies, which included Texas Parks and Wildlife Department, US Fish and Wildlife Services, Texas Commission on Environmental Quality, National Marine Fisheries Service, US Environmental Protection Agency, National Park Service, Bureau of Ocean Energy Management, and the Natural Resources Conservation Service. The MAMP establishes a framework for decision making to guide future adaptations and to ensure the features succeed. It recommends specific monitoring practices to update area conditions and establishes "success criteria" for each type of habitat to guide and adjust management actions. Since ER and CSRM features may be further refined during the PED phase, the MAMP will be revised accordingly during that phase to incorporate more detailed monitoring, adaptive management plans, and cost breakdowns. The MAMP is attached as Appendix C-2 to this report.

# 3.7. Real Estate and Relocation Requirements

A Real Estate Plan, describing the real estate and relocation requirements and associated costs to the project, can be found in Appendix F. The non-Federal sponsor will have the responsibility of acquiring all necessary real estate interests for the project and ensuring that relocation of utilities and facilities are accomplished. In the Real Estate Plan, these are referred to as Land, Easements, Rights-of-Way, Relocation, and Disposal Areas (LERRDs).

## 3.7.1. Real Estate

The proposed footprint of the Coastwide ER Plan affects approximately 6,300 acres with a combination of public and private lands within Calhoun, Brazoria, Matagorda, San Patricio, Willacy, and Galveston counties. There are no residential or commercial relocations expected for this aspect of the project. Non-standard estates, or navigational servitude, will be required for the construction of the ER features. The non-Federal sponsor and the State will need to enter into an agreement, resulting in a non-standard estate requiring approval by USACE Headquarters as set forth in ER 405-1-12. The request for approval of the non-standard estate will be made by separate requests to USACE Headquarters and can be reasonably anticipated to take approximately twelve months. ER alignment measures overlap other state and federal owned lands such as the TPWD and USFWS. The Study Team has worked with TPWD and USFWS to assure the missions of TPWD and USFWS align with the purpose of this ecosystem restoration project, which should justify the non-standard estate and continuation of ownership by the State of Texas. As a result of the non-standard estate, the continuing care and maintenance of the project features will need to be addressed in the Project Partnership Agreement (PPA). In addition, the USACE and its construction cost-share sponsors will coordinate with the USFWS on the need for compatibility determinations and/or other real estate agreements at that time.

The non-Federal contribution of LERRDs for the Coastwide ER Plan is estimated to be $106 million, which includes the costs associated with acquiring lands in fee where restoration projects are not proposed on existing State or Federally owned lands.

The proposed footprint of CSRM measures affect approximately 3,400 acres with a combination of public and private lands acres within Harris, Galveston, Brazoria, and Cameron counties. The estates for CSRM measures are standard estate No. 1 (fee), No. 9 (flood protection levee), No.15 (temporary work area easement), No. 26 (perpetual beach storm damage reduction easement) and the application of navigational servitude for the construction of gate structures on state submerged lands. There are 65 dwellings that will be displaced. The occupants will be offered Relocation Assistance benefits required by PL 91-646, as amended. No residential occupant will be displaced without decent, safe, and sanitary replacement housing being made available to them.

*Example of a pedestrian dune walkover*

For CSRM features whose footprint will be located on submerged lands, the GLO has agreed to provide a long-term lease to a future cost share sponsor for the submerged land required to construct and operate the project. While navigational servitude is authorized for construction of structural CSRM features, it is not anticipated to be necessary as the cost share sponsor, through the GLO, is expected to secure necessary real estate rights as LERRD.

The non-Federal contribution of LERRDs for the SPI Beach Nourishment and Sediment Management measure is estimated to be $18 million, which includes the costs associated with an estimated 148 affected property owners that still have an ownership interest on the beach.

The non-Federal contribution of LERRDs for the Galveston Bay Storm Surge Barrier System is estimated to be approximately $878 million which includes the costs associated with acquisition of real estate interests for structural features and potential mitigation sites. A standard perpetual flood protection levee easement will be acquired for the construction of levees and floodwalls. A standard temporary work area easement will be acquired for staging areas. A nonmaterial deviation will be made to the standard road easement to revise the rights necessary for a temporary access easement to be acquired over existing private roads to allow access to the construction area. Mitigation lands for the Galveston Bay Storm Surge Barrier System will be acquired in fee, excluding minerals (with restrictions on use of the surface), are estimated to be approximately $12.5M, and must be borne by the non-Federal sponsor.

Costs for the nonstructural elevations were included as construction costs and not as separable real estate acquisition costs. In addition, a Chart of Accounts which captures the real estate costs associated with the plan implementation (and administrative costs for elevations) is included in the Real Estate Plan. A maximum of 2,000 structures are eligible for inclusion in the Recommended Plan. Additional discussion of the real estate requirements for the Recommended Plan features can be found in the Real Estate Plan (Appendix F). A high level review of tracts affected by the Recommended Plan is shown in Figure 3.45. Note that entire tracts are represented, however the entire tract may not be impacted.

### 3.7.2. Relocations Requirements with the Recommended Plan

Construction activities may cause relocations and/or temporary interruptions to pipelines or other similar utilities. Relocations are a part of the non-Federal sponsor's LERRDs responsibility. One hundred ninety-three utility/pipeline relocations have been identified within the Recommended Plan's footprint.

Relocation cost estimates assume that a pipeline floodwall would be required wherever a pipeline crosses the proposed CSRM alignment. The pipeline would cross through a cutoff wall under the pipeline floodwall. It was decided that the existing carrier line would remain in operation while a bypass line would be constructed through a sleeve in the T-wall cutoff piles. When the bypass is completed and in place, the switch over with the existing line then would follow, along with the removal of the abandoned pipeline.

For the Recommended Plan, it was assumed the pipeline would be relocated for the full right-of-way width of the proposed levee/floodwall. Although no determination of compensability was prepared for purposes of this Report, it is expected that all of the pipeline relocations would be compensable. The total costs for relocations are estimated to be $75,281,000, and are the responsibility of the non-Federal sponsor. Relocation costs include construction costs only, as there are no lands required for relocations. A final determination of compensability for utility/common carrier relocations will be refined during the PED phase. Additional discussion of the relocation requirements for Recommended Plan features can be found in the Real Estate Plan (Appendix F).

The Recommended Plan may also impact existing pedestrian walkovers and vehicular access points designated by GLO. Sixty-one pedestrian walkovers and sixty-five vehicular access points may be impacted by the Bolivar and West Galveston beach and dune features. Owners of privately owned pedestrian walkovers impacted by the beach and dune feature will be compensated for the removal of their structure. Compensation for the removal of privately owned pedestrian walkover structures will be evaluated on a case by case basis. The non-Federal sponsor will be responsible for relocation costs of of pedestrian walkovers

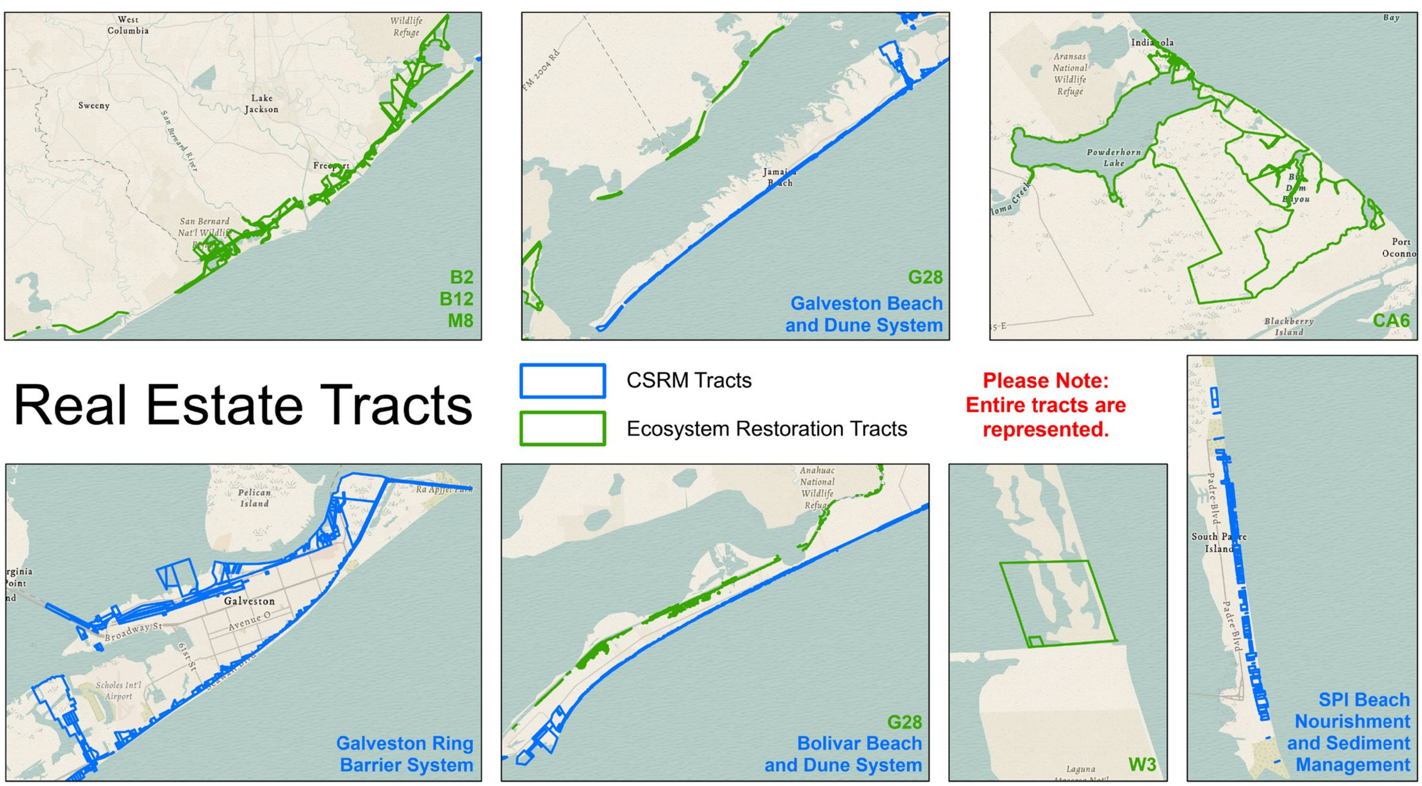



*Figure 3.45: Real estate tracts*

and vehicle access points impacted by the Recommended Plan. All interior drainage impacted by the beach and dune features will be cost shared between the Government and the non-Federal sponsor. The total cost of relocations, including utilities, pipelines, and walkovers/access points is $87,228,000.

## 3.8. Project Benefits & Effects

Benefits associated with the Recommended Plan have been segmented into three groupings, including the Coastwide ER Plan, the SPI Beach Nourishment and Sediment Management feature, and the Galveston Bay Storm Surge Barrier System. Summaries for each of these groupings can be found in the following sections. Appendix E, the Economics Appendix, provides more detailed information on benefit-cost calculations for each component of the Recommended Plan.

### 3.8.1. Project Benefits and Effects associated with Coastwide ER Plan

The Coastwide ER Plan would create a total of 21,010 AAHUs, as shown in Table 3.2. Compared to the "No Action Alternative", implementing Coastwide ER Plan would result in positive effects on resources which are institutionally, technically, and publicly recognized. Restoration supports the global, national, state, and locally significant resources within the area and the unique services, functions, and values provided by these resources.

Fresh, intermediate, brackish, and saline marshes will be enhanced within a framework of marsh restoration, shoreline protection/stabilization, and dune/beach features that interact to provide benefits greater than the sum of their parts. Together these features would help maintain fresh and saltwater flows, protect against substrate erosion, and provide important transitional estuarine habitat between upland and marine environments. Restoring lost wetlands, protecting existing wetlands, and reducing the profound environmental and habitat loss across the study area could also help support the CSRM portions of the recommendations. Part of the area's vulnerability to hurricane storm surge damages is directly related to the significant loss of wetlands the area has experienced. Restoring these important habitats helps to reduce the ability of coastal floodwaters to work their way into the communities that need risk reduction measures to help reduce damages from hurricane storm surge. Wetlands provide a buffer between ever-growing open water areas that allow water (and surge) to permeate further inland and thus more directly affect the surrounding infrastructure such as roads, residences, businesses, and critical infrastructure (i.e. electrical, water, sewer, and drainage facilities). Implementing the Coastwide ER Plan could help increase the effectiveness of the CSRM features and also increase resilience throughout the Texas coast.

Wetlands also provide important habitat that directly supports the viability of threatened and endangered species; commercially important species such as fish, shrimp, and crabs; and the economy through the creation of and support for industries that depend on wetlands such as fishing and hunting guides, bait/tackle shops, birding enthusiasts, and eco-tourism. Wetlands are a unique yet imperiled ecosystem in the nation and coastal Texas has experienced a tremendous loss of this important habitat.

| ER ID: | ER Feature Name: | Average Annual Habitat Units |
|---|---|---|
| G28 | Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection | 1,295.4 |
| B2 | Follets Island Gulf Beach and Dune Restoration | 240.1 |
| B12 | Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection | 1,297.5 |
| M8 | East Matagorda Bay Shoreline Protection | 481.5 |
| CA5 | Keller Bay Restoration | 240.1 |
| CA6 | Powderhorn Shoreline Protection and Wetland Restoration | 18.4 |
| SP1 | Redfish Bay Protection and Enhancement | 3,500.5 |
| W3 | Port Mansfield Channel, Island Rookery, and Hydrologic Restoration | 13,936.6 |
| | **TOTAL** | **21,010.1** |

***Table 3.2:*** *Coastwide ER Plan AAHU Benefits*

### 3.8.2. Project Benefits and Effects associated with SPI Beach Nourishment and Sediment Management

The benefits of the SPI portion of the Recommended Plan include reduction of storm risk measured, as a reduction of expected annual damages, recreation benefits to users of the SPI beach, and regional economic development. USACE policy provides for the consideration of incidental recreation benefits for project economic justification, but they cannot account for more than 50% of the benefits that justify the project. Recreation benefits were developed using the unit day value approach, as outlined in Economic Guidance Memorandum 20-03, Unit Day Values for Recreation for Fiscal Year 2020. Recreation criteria for the with and without project condition are assigned points based on judgment factors. More detail on the benefit assessment is provided in Appendix E-2. Calculated recreation benefits are shown in Table 3.3.

| Recreation Benefits | | | |
|---|---|---|---|
| Annual Visitation | Without Project ($7.90) | With Project ($11.32) | Annual Net Recreation Benefit |
| 750,000 | $5,925 | $8,490 | $2,565 |

*($1,000s, 2.50% Interest Rate, FY21 Price Level)*

***Table 3.3:*** *SPI Recreation Benefits*

*The economic analysis of lifecycle costs and sediment placement conducted within the Beach-fx model confirms that beach nourishment is cost effective based upon construction costs, benefits, and currently estimated real estate costs.*

The economic analysis of lifecycle costs and sediment placement conducted within the Beach-fx model confirms that beach nourishment is cost effective based upon construction costs, benefits, and currently estimated real estate costs. Further discussion of real estate considerations are provided in Section 4.2 of Appendix F, the Real Estate Plan. Table 3.4 details the benefit-cost calculations for the SPI Beach Nourishment and Sediment Management measure, which show a Benefit-Cost Ratio (BCR) of 0.68 before inclusion of recreation benefits. Table 3.5 shows a BCR of 2.03 with the inclusion of recreation benefits. Additional cost details can be found in Section 3.9 and in Section 6.2. The base year for computing average annual benefits and costs is assumed to be 2035, with a 50-year period of analysis.

| | w/o Project Damages | w/ Project Damages | Damages Avoided | Costs | Net Benefits | Benefit-Cost Ratio |
|---|---|---|---|---|---|---|
| Average Annual Values | $5,569 | $4,375 | $1,294 | $1,904 | -$610 | 0.68 |

*($1,000s, 2.50% Interest Rate, FY21 Price Level)*

***Table 3.4:*** *SPI Benefits and Costs Expressed as Present Value and Average Annuals (not including recreation benefits)*

| Cost Terms | CSRM Net Benefits | Recreation Benefit | Total Benefits | Costs | Net Benefits | Benefit-Cost Ratio |
|---|---|---|---|---|---|---|
| Average Annual Values | $1,294 | $2,565 | $3,894 | $1,904 | $1,955 | 2.03 |

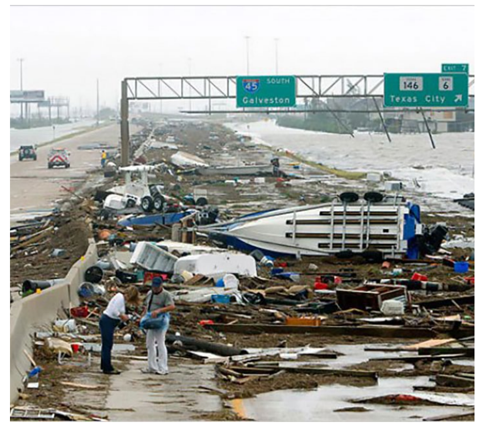
*($1,000s, 2.50% Interest Rate, FY21 Price Level)*

***Table 3.5:*** *SPI Benefits and Costs Expressed as Average Annuals (including recreation benefits)*

## 3.8.3. Project Benefits and Effects associated with the Galveston Bay Storm Surge Barrier System

Implementing the Galveston Bay Storm Surge Barrier System to reduce damages from hurricane storm surge in the study area serves multiple purposes. First, it would help to lessen the financial and social impacts that tropical storms and hurricanes can cause by reducing the risk of property damage that displaces residents, shuts down commercial and industrial services, and disrupts livelihoods. If structures avoid or experience fewer damages because of the Recommended Plan, families and businesses can rebound much more quickly after a tropical event. Examples of this include:

- Increasing the opportunity to return children to school where their residences and schools were not damaged from a hurricane storm surge event
- Reducing lost work days of workers who support the local or regional economy by decreasing the number of hurricane storm events that require repairs to hurricane storm surge damaged houses, businesses and other non-residential structures, by minimizing the debris from hurricane storm damaged structures that can affect other properties
- Generally improving the opportunity and time necessary for residents, businesses, and government to return to normal function after a hurricane storm event. Under the future without project conditions ~ 61,000 structures would be impacted during a 1% AEP event. With the project in place, only ~14,000 structures would be impacted under the same event. Table 3.6 shows estimated impact to the area's structures under the future without project and future with project conditions.




*A photo of storm surge debris from Hurricane Ike in 2008*

Second, time, money, and energy would not be lost to repairing structures damaged by storm surge, relocating to other areas due to displacement from a home or business, or disruptions in community cohesiveness. The Recommended Plan would also help to ensure that the economy and the region's critical infrastructure would continue to operate after a storm and that the stress and hardship associated with hurricane storm surge would be lessened. Under the future without project conditions ~253 critical infrastructure points would be impacted during a 1% AEP

| Structures Damaged by Probability Event Intermediate Sea Level Rise - Base year 2035 | | |
|---|---|---|
| Annual Exceedance Probability (AEP) | Total | |
| | Without Project Conditions | With Project Conditions |
| 0.99 (1 yr) | - | - |
| 0.10 (10 yr) | 4,374 | 1,097 |
| 0.05 (20 yr) | 9,125 | 2,060 |
| 0.02 (50 yr) | 32,240 | 7,215 |
| 0.01 (100 yr) | 61,053 | 13,851 |
| 0.005 (200 yr) | 88,133 | 23,009 |
| 0.002 (500 yr) | 111,321 | 41,826 |
| 0.001 (1000 yr) | 120,469 | 49,433 |

***Table 3.6:*** *Structures Impacted*

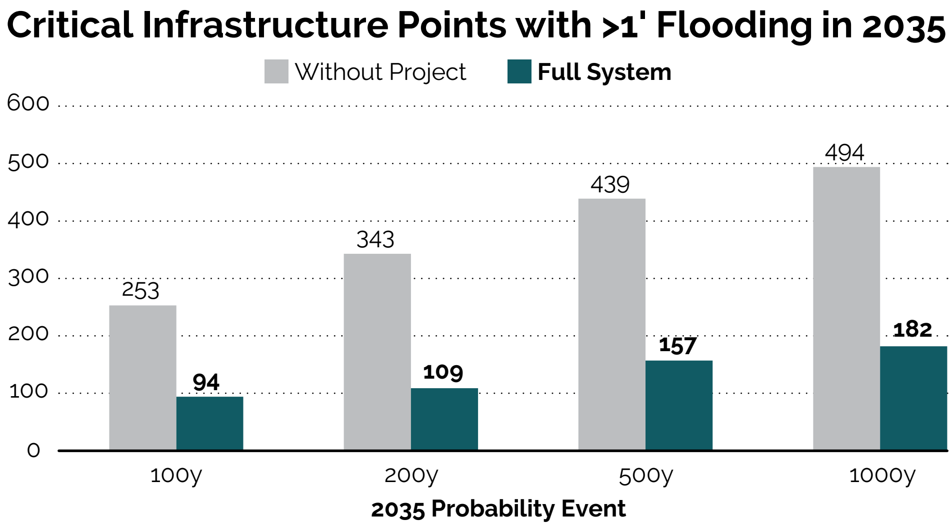



***Figure 3.46:*** *Critical Infrastructure Points*

event. With the project in place, only ~94 critical infrastructure points would be impacted under the same event. Figure 3.46 shows estimated impact to the area's critical infrastructure points under the future without project and future with project conditions.

*Under the future without project conditions ~253 critical infrastructure points would be impacted during a 1% AEP event. With the project in place, only ~94 critical infrastructure points would be impacted under the same event.*

The Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) Version 1.4.2 certified model was used to calculate the damages for the without project and with project conditions. Overall, $2.31 billion in annual damages would be prevented with the project in place, under the Intermediate RSLC Scenario. Net benefits are based on the following benefit categories:

- residential and commercial (structure/content/vehicles/debris removal)
- industrial (structures/contents/debris removal)
- transportation and infrastructure (highways/streets/railroad)
- above ground storage tanks, and avoided production losses (REMI Model).

Benefits for the Galveston Bay Storm Surge Barrier System are shown in Table 3.7. The table provides the final recommendation using the Federal FY21 discount rate (2.50%). The Coastal Texas Study is using the Intermediate RSLC Scenario to describe expected future storm risks and to present the benefits of the Recommended Plan. The RSLC evaluations have been used to establish project size and to evaluate future adaptability. This is consistent with other studies and projects across Texas and Louisiana. More detail on the Galveston Bay Storm Surge Barrier benefit assessment is provided in Appendix E-1.

| Component (RSLC Scenario) | Equiv Annual w/o Project Damages (2043-2092)* | Equiv Annual w/ Project Damages (2043-2092)* | Equiv Annual Benefits (2043-2092)* |
|---|---|---|---|
| Low Sea-Level Rise | $2,750,000 | $1,096,000 | $1,809,000 |
| Intermediate Sea-Level Rise | $3,925,000 | $1,796,000 | $2,306,000 |
| High Sea-Level Rise | $8,872,000 | $5,299,000 | $3,823,000 |

*($1,000s, 2.50% Interest Rate, FY21 Price Level)*

** 2043 represents a revised base year for the Galveston Bay Storm Surge Barrier System, considering construction sequencing and construction duration.*

***Table 3.7:*** *Galveston Bay Storm Surge Barrier Benefit Summary*

## 3.9. Project Costs

For the detailed cost estimate, project quantities were developed for all three project elements. The cost estimate was compiled using the MicroComputer Aided Cost Estimating System, Second Generation (MCACES 2nd Generation or MII). The detailed cost estimate for the Recommended Plan is based on combination of MII's Cost Book, estimator-created site-specific cost items, local subcontractor quotations, and local material suppliers' quotations. The individual components in the cost estimate are outlined in Chapter 10 of Appendix D, the Engineering Appendix. Additional information on Real Estate costs is also provided in Appendix F, the Real Estate Appendix. Cost contingencies were developed through a standard Cost and Schedule Risk Analysis (CSRA). Table 3.8 shows the project cost summary of the three project features. Further discussion of cost estimates and cost apportionment is provided in Chapter 6. As discussed in Section 3.1 and 3.4.1.1.1, the tie-in levee section associated with the Bolivar Roads Gate System, which is located in a CBRA zone, is not eligible for an exemption and therefore the full cost of this feature must by carried by the non-Federal sponsor. Additional details related to these CBRA discussions can be found in Appendix E of the Final EIS. The total first cost for the levee tie-in feature is $96,884,000.

*The detailed cost estimate for the Recommended Plan is a based on combination of MII's Cost Book, estimator-created site-specific cost items, local subcontractor quotations, and local material suppliers' quotations.*

The costs presented below are the full costs to implement the project, regardless of who spends the money. Further information on cost apportionment can be found in section 6.2 of this report.

| | South Padre Island Beach Nourishment and Sediment Management* | Galveston Bay Storm Surge Barrier System* | Coastwide ER Plan | Total First Costs |
|---|---|---|---|---|
| PED | $7,242 | $3,164,419 | $322,903 | $3,494,564 |
| Construction & Renourishment | $44,148 | $20,748,493 | $2,116,746 | $22,996,616 |
| LERRD | $18,328 | $964,985 | $106,079 | $1,002,165 |
| Construction Management | $2,638 | $1,250,143 | $127,005 | $1,379,786 |
| **Total Project First Costs** | **$72,357** | **$26,128,041** | **$2,672,733** | **$28,873,131** |
| **Total Average Annual Project Cost** | **$1,904** | **$1,208,000** | **N/A** | **N/A** |

*($1,000s, 2.50% Interest Rate, FY21 Price Level)*

** Includes OMRR&R in calculation of Total Average Annual Project Cost*

***Table 3.8:*** *Project Cost Summary*

## 3.10. Operation, Maintenance, Repair, Rehabilitation, And Replacement (OMRR&R)

The Recommended Plan is a complex system constructed in a marine environment. The purpose of OMRR&R is to sustain the constructed project and to maintain the stated level of benefits at the completion of construction and throughout the life of the project. The total estimated annual OMRR&R cost for the Recommended Plan is $131,000,000 based on the current Federal FY21 discount rate (2.50%). A majority of the annual OMRR&R costs are based upon sustaining the large gate structures. OMRR&R requirements would also include, but not be limited to, annual exercising of all of the gates and closure structures, grass mowing of levee and floodwall right of way, painting of numerous metal surfaces, routine pump station O&M, and general maintenance of drainage and navigation structures. The non-Federal sponsor is not obligated to address loss of risk reduction due to RSLC through future levee lifts or structure modification, but they will still be required to repair, rehabilitate or provide replacement of components to maintain the original project benefits. This also includes renourishment activities for the beach and dune systems after the 50-year construction period, in order to maintain project performance. The non-Federal sponsor has expressed their commitment and understanding of non-Federal cost share responsibilities for construction and OMRR&R.

The sections below provide a general overview of the OMRR&R tasks required to sustain the constructed project. As part of PED, a detailed OMRR&R manual will be developed to outline the expected OMRR&R requirements for each project component. This includes an emergency management plan to operate the gates in conjunction with navigation users in order to clear they Bay of large ships in advance of a storm event. A navigation work group has already been developed to coordinate future gate operations. After the District Engineer provides notice of construction completion for the project, or functional portion of the project, the non-Federal sponsor will commence OMRR&R responsibilities associated with the project.

### 3.10.1. OMRR&R: Coastwide ER Plan

The ER plan consists primarily of breakwaters, island creation, shore protection, and beach nourishment that do not have out-year nourishment. Shore protection features are designed for 50-years using intermediate sea level rise conditions. Unless there are needs for emergency repairs (e.g., collision with barge, scour hole), ER features are designed to last and perform for the intended 50-year project period. With this assumption, OMRR&R costs are expected to be minimal, and are therefore excluded for all ER features.

### 3.10.2. OMRR&R: SPI Beach Nourishment and Sediment Management

The annual OMRR&R costs for the SPI Beach Nourishment and Sediment Management feature are expected to be minimal, as beach nourishment is not Operations and Maintenance. Accordingly, no OMRR&R cost were included.

### 3.10.3. OMRR&R: Galveston Bay Storm Surge Barrier System

The OMRR&R for the Galveston Bay Storm Surge Barrier System includes, but is not limited to:

- maintenance and staffing of an Emergency Operations Center (EOC) to provide command and control for emergency operations related to tropical events. The local sponsors would also be required to coordinate with stakeholders for OMRR&R concerns and evacuation/ emergency action planning.
- the expense for staffing, training and stockpiling of typical flood fighting materials and equipment needed to respond to typical response events (i.e. heavy construction equipment including tractors, front end loaders, bulldozers, etc), sandbags , plastic sheeting, etc.
- a trial operation of all gates and pumps. The cost associated with collecting survey and instrumentation is also included in the OMRR&R estimate.
- mowing of the grass cover and maintaining a vegetation-free zone, a reliable corridor of access and permit proper inspection, manage pests, and inhibit weed encroachment to maintain the health and vigor of the grass stand.
- Annual dune and beach maintenance items include re-planting, maintenance of sand fencing, walkovers and drive overs.
- Drainage structures maintenance items including gate adjustments, gate rehab, clean-out of outfalls/trash tasks, and gate replacement (clean-out of outfalls and trash barrier; annually or pre-hurricane season, gate adjustment/ rehab every 5 year/replacement 10 yr).
- The cost associated with floodwall maintenance includes crack repair, repair, replacement of cracked scour protection, waterstop repair, and horizontal sealant at the wall joints. General floodgate (Roller, Swing, and Overhead Trolley) maintenance includes repairing damage or rusted areas, repair to galvanized surfaces, rubber gate seals replacement, etc.
- The cost associated with many individual components of both the gates and pump stations have defined periodic maintenance intervals that will be further developed in the PED phase of this project. For instance, the pumps are required to be exercised on a set schedule and each exercise should last long enough to bring all systems up to normal operating temperature and allow for run-time

inspections and assessments. The gates are also exercised periodically, on a defined schedule and in accordance with the completed construction documents.

The above mentioned OMRR&R is to ensure the features perform their intended purpose as expected during a tropical event. Estimates for routine maintenance and inspection occurring before, during and after hurricane season is included in the cost and will dictate the scope of the major repair work to be performed during dewatering. Additional details on the assumption of maintenance is included in Chapter 9 of Appendix D. The one area where the non-Federal sponsor is not obligated to provide OMRR&R is the flood proofing measures that constitute elevation of individual residential structures or construction of small ring berms around individual non-residential structures.

The annual OMRR&R cost also includes cost for maintaining mitigation sites. The non-Federal sponsor would be responsible for OMRR&R of functional portions of sites as they are completed. On a cost-shared basis, the USACE would monitor completed mitigation to determine whether additional construction, invasive species control, and/or planting are necessary to achieve mitigation success. A MAMP has been drafted, and will be refined over time to define specific success criteria and monitoring needs for mitigation features. The USACE would undertake additional actions necessary to achieve mitigation success in accordance with the MAMP and cost sharing applicable to the project and subject to the availability of funds. Once the USACE determines that the mitigation has achieved initial success criteria, monitoring would be performed by the non-Federal sponsor as part of its OMRR&R obligations. If, after meeting initial success criteria, the mitigation fails to meet its intermediate and/or long-term ecological success criteria, the USACE would consult with other agencies and the non-Federal sponsor to determine whether operational changes would be sufficient to achieve ecological success criteria. If instead, structural changes are deemed necessary to achieve ecological success, the USACE would evaluate and take appropriate actions, subject to cost sharing requirements, availability of funding, and current budgetary and other guidance; as well as coordination with the local non-Federal sponsor and resource agencies.

## 3.11. Benefit-Cost Analysis for the Galveston Bay Storm Surge Barrier System

The equivalent annual benefits were compared to the annual costs to develop a BCR for the Recommended Plan. The initial construction costs (first costs) and an expected schedule of expenditures were used to determine the interest during construction and gross investment cost at the end of the installation period. Based on feasibility level design, a revised base year (completion of construction) has been estimated as 2043, instead of the previously assumed 2035. Construction of the Recommended Plan is expected to begin in the year 2025 and to continue through the year 2043, which was established as the base year for analysis. The OMRR&R activities will begin in the year 2043 and will continue throughout the 50-year period of analysis. Using the FY21 Federal interest rate of 2.50 percent, the construction and OMRR&R costs were discounted to the base year and then amortized over the 50-year period of analysis to develop an annual cost for the project. The net benefits for the Recommended Plan were calculated by subtracting the annual costs from the equivalent annual benefits. The net benefits were used to determine the economic justification of the Recommended Plan.

Table 3.9 shows the equivalent annual net benefits for the Recommended Plan by benefit category, including the resultant BCR, for each of the three sea-level rise scenarios for the years 2043 (revised base year) through 2093. The Coastal Texas Study is using the Intermediate RSLC Scenario to describe expected future storm risks and to present the benefits of the Recommended Plan. The RSLC evaluations have been used to establish project size and to evaluate future adaptability. This is consistent with other studies and projects across Texas and Louisiana.

| Component (RSLC Scenario) | Equivalent Annual Benefits (Damages Reduced) | Total Annual Costs | Equivalent Annual Net Benefits | Benefit-Cost Ratio |
|---|---|---|---|---|
| Low Sea-Level Rise | $1,809 | $1,208 | $601 | 1.50 |
| Intermediate Sea-Level Rise | $2,306 | $1,208 | $1,097 | 1.91 |
| High Sea-Level Rise | $3,823 | $1,208 | $2,615 | 3.16 |

*($Millions, 2.50% Interest Rate, FY21 Price Level, 2043 Base Year)*

***Table 3.9:*** *Galveston Bay Storm Surge Barrier Benefit-Cost Results*

## 3.12. Overall Benefit/Cost Summary of the Recommended Plan

Table 3.10 provides a summary of the estimated costs and benefits of the Recommended Plan. This information is presented separately for each component, including the Coastwide ER Plan, the South Padre Island Beach Nourishment and Sediment Management measure, and the Galveston Bay Storm Surge Barrier System. As shown in the table, the Recommended Plan has a total first cost, or construction cost, of $28.87 billion. Each CSRM measure has a strong BCR, 2.03 for South Padre and 1.91 for Galveston Bay. A BCR over one indicates that the benefits of the project exceed the costs, which is a requirement for Federal investment. Most critically, if damages from storms were distributed equally across the fifty-year period of performance, the CSRM measures are anticipated to reduce average annual damages by $2.31 billion per year (FY21 Price Level, 2.50% Discount Rate), which represents a significant reduction in anticipated future flood damages and supports increased resiliency for the communities along the coast and the local, regional, and national economy.

In addition, the Coastwide ER Plan generates over 21,010 AAHUs through the creation or restoration of thousands of acres of coastal habitat, including global, national, state, and locally significant resources providing unique services, functions, and values. In addition, restoration efforts enhance the resiliency of natural and man-made systems and increase the effectiveness of other CSRM features along the coast.

These familiar metrics for project evaluation are not the sole basis for the selection of the Recommended Plan, however. Section 2.1.1 described the resilience framework that is used by cities to evaluate community resilience, which align closely with the four accounts that USACE uses in its standard planning process – Other Social Effects, National Economic Development, Regional Economic Development, and Environmental Quality. Accordingly, the resilience framework offers an opportunity to consider how the effects of the alternative plans would support or hinder resilience in the study area, while still making use of many of the familiar metrics produced in USACE studies. Redundancy, robustness, and adaptability are key characteristics of resilient systems, and they have been incorporated into the formulation and evaluation of the Recommended Plan to complement the familiar metrics.

To recap the evaluation processes, three sets of criteria were applied to the alternatives under consideration. First, the plans were evaluated with the traditional USACE metrics quantified above to identify the effectiveness of the proposed alternative in addressing the primary objective of providing storm risk management and ecosystem restoration. Then the alternatives were evaluated relative to the requirements of the P&G to be complete, effective, efficient, and implementable. And as a final criteria, the alternatives were evaluated with regard to their contribution to resiliency, which assesses the region's ability to prepare, withstand, recover and adapt from coastal storms and to maintain the region's critical social, economic and support systems.

This study is an important part of preparing for the impacts of future storms, erosion, and RSLC. The technical analyses have measured the range of effects the region will need to withstand over the next 50-100 years. The Recommended Plan will assist the region in withstanding the impacts of those future storms. As no single infrastructure system can prevent all harm, the plan has been developed to reduce impacts while also positioning the region for rapid recovery, using redundant measures and the protection of critical infrastructure. The intent of the Galveston Bay Storm Surge Barrier System is to keep storm surge in the gulf, substantially reducing the volume of surge entering the Bay. The system can be exceeded, however, so Bay defenses are included to reduce residual risk associated with water in the Bay.

| | South Padre Island Beach Nourishment and Sediment Management (2035 Base Year) | Galveston Bay Storm Surge Barrier System (2043 Base Year) | Coastwide ER Plan | Total First Cost |
|---|---|---|---|---|
| Project First Cost | $72,357 | $26,128,041 | $2,672,733 | $28,873,131 |
| Total Average Annual Cost | $1,904 | $1,208,000 | N/A | |
| Equivalent Annual Benefits | $3,894 | $2,306,000 | 21,010 AAHUs | |
| Equivalent Annual Net Benefits | $1,955 | $1,097,000 | N/A | |
| BCR | 2.03 | 1.91 | N/A | |

*FY21 Price Level, 2.50% Discount Rate, Presented in $1,000s*

***Table 3.10:*** *Estimated Costs and Benefits of the Recommended Plan.*

Furthermore, non-structural measures are included to help coastal neighborhoods withstand the effects of surge in the highest risk areas. Pump stations and interior drainage systems add another layer in this comprehensive set of redundant features.

The ecosystem restoration features in Galveston Bay are key contributors to resilience. The beach segments address the erosion threat on the gulf-front, while assisting in the sustainability of the barriers that the Bolivar Roads Gate System ties into. The marsh restoration features also support barrier sustainability and buffer the GIWW navigation channel, while providing important habitat for significant species.

The result is a comprehensive plan, employing multiple-lines-of-defense and focused on resiliency, redundancy, and robustness, that reduces risks to people, property, industry and ecosystems along the Texas coast.

## 3.13. Risk and Uncertainty and Adaptive Response

With the Recommended Plan in place, not all surge damages will be prevented, only reduced. It is important to understand that the project will not eliminate all risks to life and property. Even with primary line of defense (Gulf defenses) and secondary line of features (Bay defenses), residual damages can still occur from project exceedance events, rainfall events, and hurricane winds and windblown debris. The study area is still highly susceptible to rainfall flooding, particularly in upland areas where drainage features are restricted. As stated above, the recommended risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in relative sea level rise or by rainfall events outside of hurricane and tropical storm events.

In a study of this size, there will be inherent risk that can be mitigated in the design or captured in the cost and benefit uncertainties. Throughout the planning process, the Study Team used risk informed decisions to develop the Recommended Plan. Many of these decisions are captured in the technical appendixes, such as the Cost and Schedule Risk Analysis. By accounting for risk and uncertainty when determining the estimate cost, the proposed delivery schedule, and the environmental impacts, this Feasibility Report captures and accommodates the impacts and consequences of these risks and uncertainties.

RSLC, which increases the effective height of storm surges and the frequency of higher surge levels in the future, is the greatest uncertainty the study area faces. Features included in the Recommended Plan can be adapted in the future to RSLC. The Bolivar Roads Gate System, GRBS, seawall improvements, and Clear Lake and Dickinson Bay gate systems are each designed to be adapted in the future if RSLC exceeds the assumed projections. For example, the GRBS has adaption features built into the initial design. The trigger for implementing these measures is overtopping of the floodwall system, which would increase the likelihood of exceeding the pumping capacity of the interior drainage system. After construction of the GRBS, sea level rise will be monitored and overtopping rates will be updated regularly through the Inspection of Completed Works (ICW) program. If the ICW indicates a changed condition, meaning the trigger has been exceeded, a modification study can be initiated to determine appropriate adaptations to employ. These calculations will allow for continuous monitoring of the anticipated performance of the GRBS under updated design storm conditions. The adaptation measures are focused on increasing the height of the floodwalls, which can be constructed without requiring a complete rebuild, and adding additional pumping capacity to target areas of concern due to excessive overtopping along a given reach of the GRBS. Further expansion of nonstructural measures or managed retreat could also be considered as a future adaptation in order to respond to changing future conditions. Similar triggers exist related to the impact of differing future conditions on the ER measures, requiring active monitoring and potential future adaptations, such as marsh renourishment. The overall system is adaptable to sustain the performance level against changing conditions, but the timing and cost to adapt to those updated conditions are unknown at this time and will be subject to a modification study.

Table 3.11 provides an overview of the residual risks, and the mitigation measures proposed, or envisioned to help address them. Additional discussions on the systems, future adaptations and resiliency to changing conditions in the future is included in the Appendix D, the Engineering Appendix.

*A national guardsman surveys flooding from Hurricane Ike in 2008*

| Risk Driver | Description | Mitigation |
|---|---|---|
| **Wind** | The project will not reduce the damaging effects of hurricane winds. | • Construction practices<br>• Insurance<br>• Evacuate |
| **Overtopping** | The project will not prevent storm surge from overtopping the system in the most extreme storms. | • Multiple lines of defense<br>• Pumps<br>• Evacuation |
| **Sea level rise** | Sea level rise affects the total water level produced by tropical storms and increases the frequency of higher surge levels in the future. | • Design with RSLC in mind<br>• Monitor RSLC<br>• Modify project size/features in the future |
| **Precipitation** | This project does not reduce regional flooding from high-precipitation storms, like Hurricane Harvey. | • The project was placed on the Gulf-front, rather than the west perimeter of Galveston Bay so that it would not impede the drainage and increase flooding during high-precipitation storms.<br>• Pumps and drainage will ensure flooding is not made worse with the project. |
| **Breach** | Large storm surge may breach the barrier system, particularly the dune segments | • Structural segments and components are designed so that they do not fail during overtopping.<br>• Dunes will breach in large storms, so redundant measures are necessary<br>» Elevate homes and critical infrastructure<br>» Bay defenses<br>» Evacuation |
| **Forecast uncertainty** | Storm characteristics are widely variable. Forecasts of the storm track, wind speed, and surge levels change continuously as storms approach landfall | • Multiple lines of defense<br>• Detailed Project Operations Plan<br>• Evacuation |
| **Environmental uncertainties** | The Bolivar Road Gate System impact to the bay ecology | • Design the gates to minimize restrictions on the flows and tidal exchange between Gulf and Bay.<br>• Measure and mitigate impacts to the Bay ecology.<br>• Develop and apply a monitoring and adaptive management plan.<br>• Engage external scientists.<br>• Publish supplemental EIS documents.<br>• Engage the public and stakeholders.<br>• Coordinate with resource agencies. |
| **Evacuation uncertainty** | Rapidly developing or changing storm conditions or forecasts can hamper evacuation activities and increase public safety risks | • Emergency action plans<br>• Communications and awareness<br>• Evacuation |
| **Multiple storms** | Risks can increase if multiple storms strike the area, particularly if the system is damaged/ breached during the initial event and repair time is short | • Elevate homes and critical infrastructure<br>• Bay defenses<br>• Evacuation |

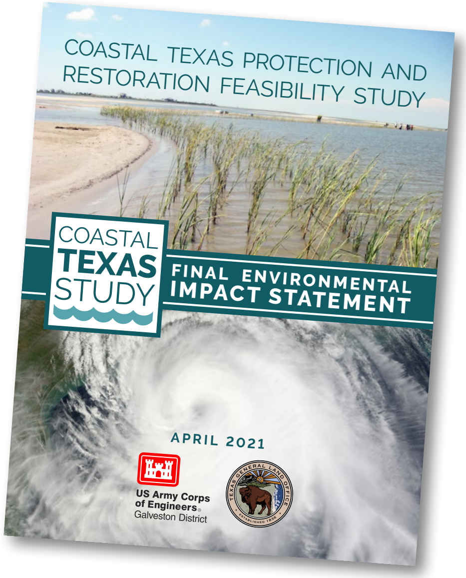
***Table 3.11:*** *Residual risks – Galveston Bay Surge Barrier System*

# 4. Environmental and Community Impacts

A photo of coastal wetlands near Port Lavaca

To comply with the National Environmental Policy Act (NEPA), a Federal agency must prepare an Environmental Impact Statement (EIS) if it is proposing actions that may significantly affect the quality of the natural and human environment. The NEPA environmental review process seeks to facilitate better-informed decisions, focused on avoiding, minimizing, or mitigating potentially negative impacts of a Federal action. Accordingly, an EIS has been prepared for the Coastal Texas Study in compliance with the regulations issued by the Council on Environmental Quality (CEQ) (40 Code of Federal Regulations [CFR] Part 1500-1508) and the USACE (33 CFR Part 230). The Final EIS is included as an attachment to this Feasibility Report.

Please note that in September of 2020 the CEQ updated their NEPA implementing regulations to modernize provisions, streamline infrastructure project development, and promote better decision making by the Federal government. These updates superseded the CEQ regulations in place at the time of the initial Draft EIS preparation. As a result, this EIS was completed in accordance with guidance allowing any project that has already published a Notice of Intent in the Federal Register by September 14, 2020, and has completed a substantial amount of the EIS following the previous regulations, to could continue to follow those regulations.  Section 4.4 of this chapter describes the tiered NEPA approach to document the overall broad review of the complete project. Subsequent NEPA documents will be prepared for the measures which have remaining uncertainty in their design or in the potential impacts. The subsequent NEPA documents will be prepared in accordance with the newer 2020 CEQ regulations.




Cover of the Coastal Texas Study Final EIS

The Final EIS characterizes the baseline "No Action Alternative"; describes the alternatives the USACE considered and the environment of the area affected by those alternatives; provides a discussion of the direct, indirect, and cumulative environmental effects of the proposed action and their significance; and presents proposed mitigation actions. A 45-day public comment period was required by law for the Draft EIS, which was issued in October of 2020, and the Final EIS must describe how the comments were considered. The Final EIS and Feasibility Report will be provided for a 30-day State and Agency review, and a Draft Record of Decision (ROD) will be prepared after responding to review comments. A Public Notice is then issued by the USACE for the Final EIS and the ROD, and a Notice of Availability will be published by the Environmental Protection Agency (EPA) in the Federal Register. Associated public and agency involvement and coordination conducted to date for the Coastal Texas Study are summarized further in Section 1.9 and Chapter 2 of this report and in Chapter 7 of the Final EIS. All comments received are included in Appendix M to the Final EIS.

Environmental, community, social, and economic impacts, both positive and negative, were considered at multiple points during the plan formulation process. Plan formulation involved multiple rounds of screening of conceptual alternatives to identify those that are shown to be feasible from an engineering standpoint, economically justified, and environmentally acceptable. Chapter 2 describes the assembly and evaluation of National Economic Development (NED) and National Ecosystem Restoration (NER) plans, with the refinement of the Recommended Plan detailed in Chapter 3. The EPA, the National Oceanic and Atmospheric Administration (NOAA)/National Marine Fisheries Service (NMFS), and the Bureau of Ocean Energy Management (BOEM) have been designated as Cooperating Agencies and have been intimately involved in the development and review of the Draft and Final EIS, along with state-level agencies such as the Texas Parks and Wildlife Department (TPWD), Texas Commission on Environmental Quality (TCEQ), and others. Representatives from these resource agencies participated throughout the entire planning process, including problem definition, identification of restoration goals and objectives, and measurement of the ecological lift and potential negative impacts of proposed measures, to ensure that environmental considerations were not an afterthought and, instead, drove key decision making during plan formulation. Resource agency coordination, including mandatory consultations under the Fish and Wildlife Coordination Act and other similar regulations, is detailed further in multiple locations in the Final EIS, including Chapter 6, Chapter 7, and Appendix A.

***Cooperating Agencies***

BOEM is responsible for overseeing sand and gravel, oil and gas, alternative energy, and other mineral development on the Outer Continental Shelf (OCS), including the extraction of sand. Under Public Law 103-426, if OCS sand resources are to be used for shore protection, beach restoration, or coastal wetlands restoration projects by Federal, State, or local government agencies, or use in construction projects authorized by or funded in whole or in part by the Federal Government, BOEM may enter into a negotiated agreement that addresses potential use of OCS sand and gravel resources. For purposes of this document, BOEM is serving as a cooperating agency. BOEM will serve as a joint agency, with USACE and GLO serving as the lead agencies for the overall project, at such time that a borrow area source is identified and dredging/sand mining is proposed in federal waters. Further discussion of the role of BOEM is provided in Section 1.4.1 of the Final EIS.

| | |
|---|---|
| **AVOID** | An early conceptual alternative, the Mid-bay Barrier Alignment (Alternative C), as an example, was eliminated in early screening because the environmental impacts were unacceptable when compared to other alternative alignments that performed comparably and appeared to be cost effective. The screening process included coordination with resource agencies to identify important ecological resources that would be impacted by alternative alignments. |
| **MINIMIZE** | Features that were shown to be effective at reducing coastal storm damage but whose design or operation produced negative environmental impacts were refined to reduce those impacts. Initial design of the Bolivar Roads Gate System was shown to substantially reduce the flow of water in and out of the Bay. A revised design reduced the constriction from over 25 percent to between 7 and 10 percent, reducing impacts to tidal amplitude from 0.5-feet to 1-inch, which reduced the projected impacts to estuarine wetlands to 1/6 of the original design. The shallow depth circulation gates of the barrier features were similarly refined to increase the flow potential, and to avoid physical conditions, such as shadows, that might impact fish passage. Additionally, all gate structures are engineered to have a ramped transition between the sill and the natural bay bottom to eliminate abrupt ledges that could inhibit movement of benthic organisms. The alignment of the Galveston Ring Barrier System was also revised to avoid sensitive habitat and minimize environmental impacts of its alignment along sensitive wetlands. |
| **MITIGATE** | Mitigation measures are required to compensate for unavoidable environmental impacts. The team developed a comprehensive assessment of direct and indirect impacts from the proposed structures and identified restoration measures to compensate for lost function of impacted areas. These mitigation measures are detailed further in Section 4.3 of this report and Appendix C-1, the Mitigation Plan. |

***Figure 4.1:*** *Example application of the avoid-minimize-mitigate hierarchy*

When evaluating measures for consideration, the Study Team first attempted to avoid negative environmental or community impacts. If impacts could not be avoided, the Study Team aimed to minimize these impacts. In select circumstances, impacts could neither be avoided nor minimized, and were therefore mitigated. Examples of the application of this avoid-minimize-mitigate hierarchy in the planning process are detailed in Figure 4.1. Greater detail is presented in Appendix A – Plan Formulation and in Chapters 4 and 5 of the Final EIS.

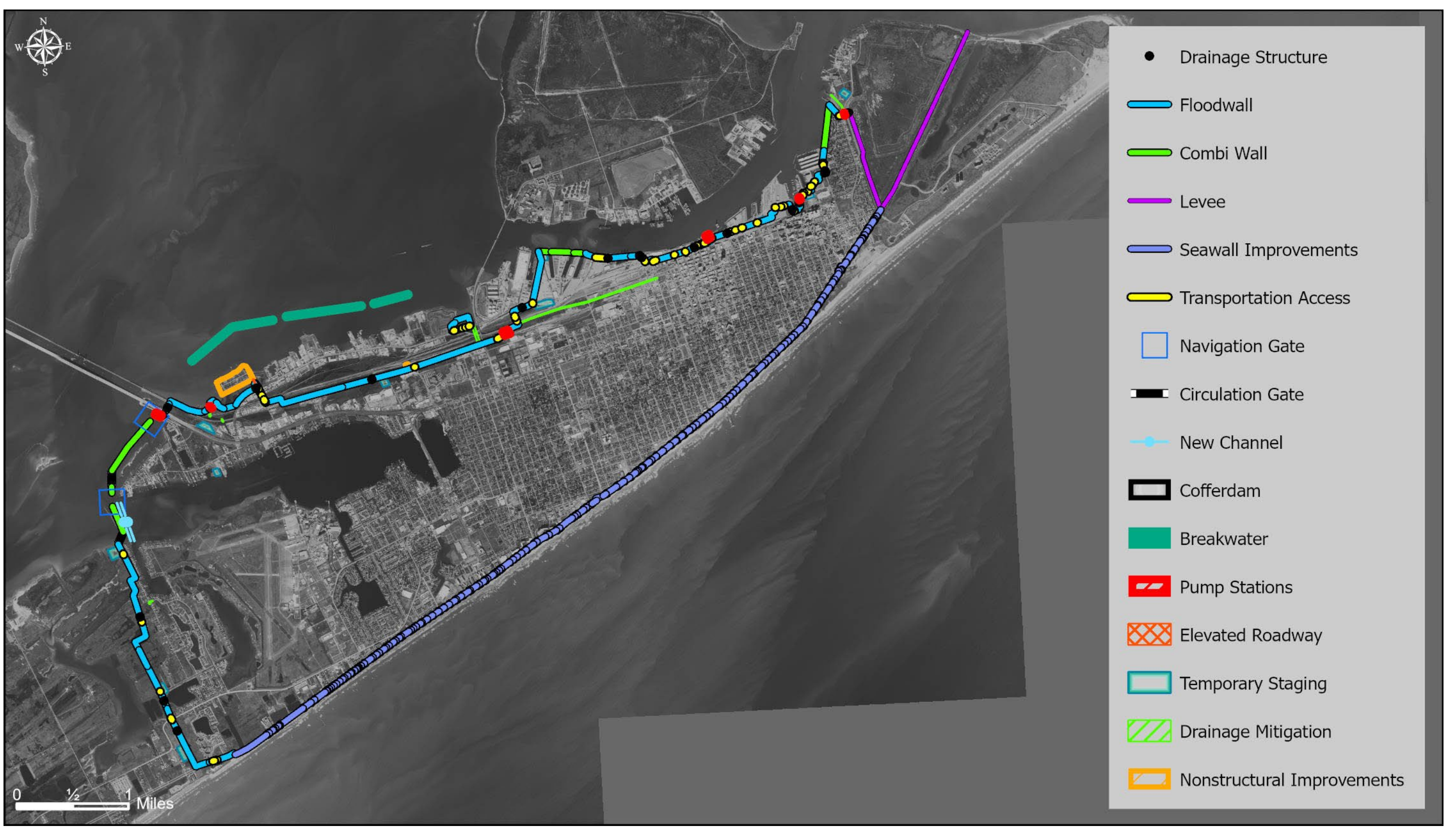
A first draft of the Coastal Texas Study's EIS was released in October 2018, as part of a Draft Integrated Feasibility Report and EIS (DIFR-EIS). Following public comment, further engineering design, environmental evaluation, and refinement of the Recommended Plan, a revised Draft Feasibility Report and Draft EIS were reissued in October of 2020, as separate documents, for a second round of public review and comment. The Final EIS incorporates further updates to respond to or address provided public and agency review comments. The following sections summarize the major considerations and outcomes of the NEPA analysis, which are detailed in the attached Final EIS.

## 4.1. Community Considerations

USACE policy, specifically the Principles and Guidelines (P&G) as referenced in Section 1.7, requires consideration of 'Other Social Effects', such as life, health, and safety, social vulnerability and resilience, economic vitality, social connectedness, identity and participation, and leisure and recreation to guide identification and development of water resources projects which are considered to be effective, acceptable, and fair. Accordingly, community resilience was a key consideration in the screening of the features and alignments, as measures can have comparable dollar-denominated benefits (as detailed in the Economic Appendix, Appendix E) but differ considerably in their impact on community resources. The Recommended Plan was selected through screening steps that assessed and compared community, social, and economic impacts and benefits.

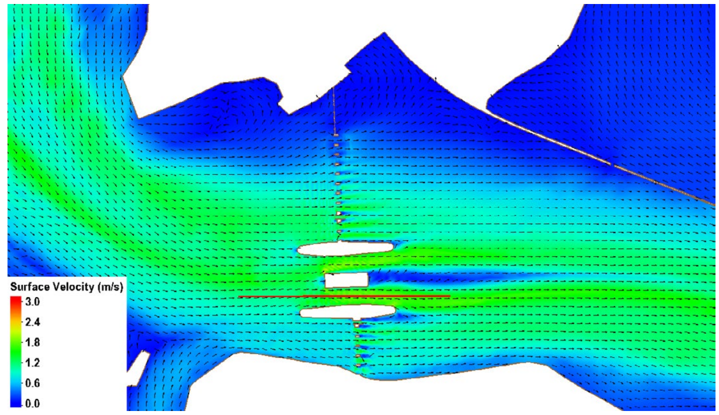
Community identity, considering a neighborhood's unique history, natural features, culture, and sources of community pride, was a key consideration throughout the planning process. Identification of the Recommended Plan sought to reduce risk without sacrificing the characteristics that make the community a desirable place to live and work. For example, beach and bay access are valued by coastal communities for recreational and commercial uses.

To minimize negative community social and economic impacts, the design of risk reduction features balanced engineering function with aesthetic and access considerations where possible. For example, the beach and dune feature on Bolivar Peninsula and West Galveston Island is designed to maintain beach access for community recreation and tourism. In this area, the originally proposed levee was removed from the Recommended Plan in response to public comments about the impacts of the levee feature along State Highway 87. The design of the Galveston Ring Barrier System alignment and scale was similarly influenced by transportation and access considerations. Alignments and gate features were refined to reduce distances between roadway gates for vehicles, for commercial activities that are dependent on bay access, and to include additional University of Texas Medical Branch facilities on Galveston Island. Community impacts in Lindale Park on Galveston Island were addressed with an alignment change to reduce property impacts and to maintain views and bay access from waterfront properties. The plan also includes measures to counteract the effects of subsidence and coastal erosion on Galveston Island and Bolivar Peninsula to protect important community resources, as is further discussed in Section 4.3 of the Final EIS.




*Map depicting the Galveston Ring Barrier System and features*

The Study Team also recognized that certain areas may face greater impacts from the construction of proposed measures and aimed to minimize or mitigate these impacts to the greatest degree possible. For example, the Bolivar Roads Gate System and its connecting features will reduce storm surge flooding across inland and Gulfward communities but the Gulfward communities will face the majority of the daily impacts to circulation and access that these features create, both during construction and regular operation. Accordingly, as discussed above, alignments and supporting features were refined (where possible) to address the concerns of local agencies, residents, business organizations, local leaders, and elected officials. Refinements will continue in the Preconstruction Engineering and Design (PED) phase to balance feature performance with reduced environmental and community impacts.



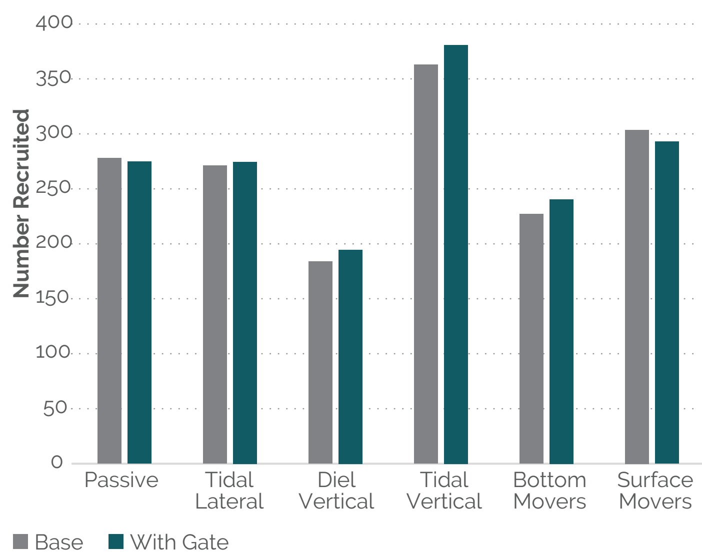

*Hydrodynamic model results at low tide*

## 4.2. Substantive Environmental Impacts

The Final EIS provides a comprehensive assessment of potential impacts associated with the various alternatives considered, including the Recommended Plan. The largest impacts identified in the Final EIS result from the potential alteration of flow and circulation patterns within Galveston Bay. Bolivar Roads is a primary route for storm surge passage from the Gulf to the Bay and inland communities during a coastal storm. The central features proposed to reduce the damage from storm surge will be sector gates that would close during storm events and connected structures designed to reduce the effects of storm surge on the region. The physical support components of the gates, including pillars and islands, will be placed in the bay bottom and will cause hydraulic changes even during open, non-storm, conditions. Potential direct and indirect environmental impacts of this change were assessed on a broad scale, by simulating water flow through the open gate and supporting features.

Species and their habitats in and around Galveston Bay could be altered by changes in the rate of flow of water in and out of the Bay during normal tides and/or rainfall events. Water characteristics such as salinity could affect species that thrive in a narrow range of fresh or saline conditions, such as oysters, vegetation, and marine mammals. Furthermore, the physical obstruction of the water column could create velocities around the gate as water is driven through a constricted area. Certain velocities could create hazards that could affect species' mobility and ability to feed and could also potentially impact habitat used for breeding. The graphic to the right illustrates the modeled impacts of the project on larval recruitment into the Bay system.

Preliminary studies conducted by the USACE also show that navigation gate structures, proposed as features of the Galveston Bay Storm Surge Barrier System, may affect wetland functions by constricting tidal exchange and the associated sediment transport and altering salinity gradients. This could potentially impact the ecology of the Galveston Bay estuary by decreasing the available habitat that can serve as nurseries, food, and refuge for various fish and shellfish species and could negatively impact birds and other wildlife species, which depend on the resources provided by wetland and marsh habitats. Additionally, two-dimensional and three-dimensional hydraulic modeling conducted by the USACE shows that construction of the gate structures would impact flow into and out of Galveston Bay by causing a constriction in the channel that would increase velocities along the opening of the gates. These effects could have long-term impacts on estuarine habitats and fauna within the bay.




*Potential larval recruitment effects*

Construction of the Galveston Bay Storm Surge Barrier System also has the potential to interrupt sediment transport within the bay system. Specifically, the proposed features would reduce overwash, where water and sediment flow over a coastal dune or beach crest during storm events and sediment is deposited. This could increase erosional impacts due to localized turbulences during storm events. These impacts could negatively impact marsh sustainability within the area.

Impact assessments proceeded in stages throughout the planning process. As features were proposed, initial impacts were assessed to estimate potential ranges of changed conditions. Once feature designs were more detailed, more thorough impact assessments were made. Repeated comparison of features when additional data were collected allowed for robust decision making and earlier public input on the refinement of project features. However, due to the complexity involved, some studies and evaluations have been deferred to the PED phase. This is discussed further in Section 4.4 and Section 4.5.

Positive environmental impacts of the Recommended Plan would occur from the proposed ER measures. These measures would restore, protect or increase the amount of habitat for dunes, beach, bird rookery islands, estuarine shoreline, oyster reef, estuarine wetlands, seagrass, and estuarine circulation. These positive impacts would occur in the estuarine and/or Gulf-facing portions of Galveston, Bastrop, Matagorda, Corpus Christi Bay, and Laguna Madre (Padre Island) bay systems. These measures are detailed in Chapter 3, under the description of ER measures of the Recommended Plan.

Further description of notable environmental impacts is provided in Figure 4.2 and Figure 4.3 on the following pages.

*An example of elevated homes on Bolivar Peninsula.*

# Summary of Notable CSRM Environmental Impacts*

***Bolivar Roads Gate System***

The piers and islands that support and connect the gates across the channel will replace open water and impact the flow of water in and out of the channel. The physical gate structure in the open condition will reduce tidal exchange, as the water will enter and exit the bay more slowly due to the obstruction in the channel. The gate design was revised and the navigation channel deepened to reduce the constriction of the channel to between 7-10% of the without project flow condition, and limit the tidal prism impact to 1-2 cm.

The tidal prism will be reduced as a result, and estuarine wetlands in the bay may experience lower high tides and higher low tides. The changed flow will also impact salinity across the bay as salt water and fresh water flows are affected. A 3D Adaptive Hydraulics (AdH) Model was run on the ADCIRC grid to simulate water flow and circulation in the bay and to estimate the range of impacts to salinity and velocity that may be expected from the constriction. Most of the with and without project salinities were close to identical near Bolivar Roads Gate System, but begin to diverge further into the system at the Mid Bay Marsh and Morgan's Point stations. However, these predicted changes in the mean salinity are within 2 ppt, and the difference is less than 1 ppt for all the stations across the bay.

Changes in sediment movement and shoaling can be expected, but have not been quantified yet, since gate design refinement will continue in PED phase. More details on the impacts can be found in Section 4.3 of the Final EIS and more details on the modeling can be found in Appendix D.

Since larval transport depends on flow in and out of the bay, potential impacts were evaluated with particle track modeling and ADCIRC results. Representative species were modeled as particles in the with and without project condition to assess whether significant reductions in larval movement resulted. The results showed no significant difference in larval transport between the with and without project conditions. Additional modeling will be conducted in PED once refinements are made to the gate design.

Sediment accumulation at the Piping Plover critical habitat at Big Reef, which is an area where sediment currently collects near the Galveston South Jetty, may be affected since it would be on the Gulf side of the Gate System. Temporary increases in noise and flow impacts, and air pollution from the equipment associated with the construction, may occur. The open physical structure will change the appearance of the channel, and species may alter their transit of the area, such as dolphins, which may prefer the openings with sector gates to the openings with an overhead structure, like the vertical lift gates.

***Clear Lake and Dickinson Bay Gates***

The barriers at Clear Lake and Dickinson Bay are predicted to reduce the tidal prism entering these systems by 14 to 16 percent. Although salinities were not modeled upstream of the barriers into these systems, the reduced tidal prism is expected to result in increased periods and extent of lower salinities than the condition without the barriers. Additional modeling of these systems will be conducted in PED as the systems are further refined.

***Galveston Ring Barrier System, including the Offatts Bayou Sector Gate***

This measure includes floodwall (T design), a 125-foot-wide sector gate with a 15-foot-deep sill at Offatts Bayou, 34 road gates, seven railway gates, dredging for a new entrance channel to the Crash Boat Basin, 16 drainage structures, and six pump stations. The alignment will cross wetlands and other aquatic resources in the areas of Galveston Island protected by the Seawall. The alignment and its design were refined to reduce the habitat impacts where possible. However, there will be permanent impacts to both estuarine and palustrine wetlands.

The proposed barrier at Offatts Bayou is predicted to reduce the tidal prism by approximately 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.

**This summary lists the primary impacts that have been assessed to date. Fuller consideration is presented in Chapters 4 and 5 of the Final EIS and Section 2.8 of Appendix D. The West Galveston and Bolivar Beach and Dune system, the Galveston Seawall Improvements, and the Nonstructural Improvements either had negligible environmental impacts or were considered beneficial, and therefore are not presented in this table. Additional coordination with USFWS is in process for the SPI Beach Nourishment and Sediment Management measure.*

***Figure 4.2:*** *Summary of Notable CSRM Environmental Impacts*

# Summary of Notable ER Environmental Impacts*

***Ecosystem Restoration Measures***

Temporary increases in noise and flow impacts, and air pollution from the equipment associated with the construction of breakwaters, dredging, and placement of sediment will occur as a result of the restoration efforts. Breakwaters will be constructed from barges with draglines or cranes in shallow water away from the banks, with excavation to install breakwater toe protection. Construction of breakwaters 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. Construction of breakwaters would result in temporary, adverse impacts to water quality.

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.

Restoration of the rookery islands would affect substrates at the placement site through the placement of clean fill and hard, structural material. 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. Adverse impacts would be minor and local. Long-term benefits would occur to the bottom substrates protected from erosion.

Oyster restoration through cultch and reef ball placement could result in short- and long-term, minor adverse impacts from activities that disturb sediments and/or convert soft bottom substrate to hard bottom. Long-term, beneficial impacts from creating or restoring oyster reefs include minimizing impacts to landward shorelines by attenuating wave energy and minimizing erosion and land loss. Also, long-term, beneficial impacts on water quality would be expected to last throughout the 50-year period of analysis.

Beach restoration will likely require a hopper dredge, with trailing suction heads to collect sand, and transport to floating hydraulic stations nearshore with sediment pumped to the shoreline. The use of hopper dredges may impact sea turtles, since they can get sucked into the suction head. Other types or combinations of dredging may also be employed. Best Management Practices and monitors will be used to minimize impacts and turtle strikes. 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. The restoration of a wider and higher dry beach can improve the quality of the nourishment area, which is characterized by severely eroded beaches. This can then provide improved quality of potential nesting habitats for sea turtles, and potential loafing, roosting, and nesting habitats for shorebirds and waterbirds.

**This summary lists the primary impacts that have been assessed to date. Fuller consideration is presented in Chapters 4 and 5 of the Final EIS and Section 2.8 of Appendix D.*

***Figure 4.3:*** *Summary of Notable ER Environmental Impacts*

## 4.3. Mitigation

A Mitigation Plan, which is included as Appendix J in the attached EIS, details proposed plans to replace the lost functions and values of the impacted areas through restoration or enhancement activities that increase and/or improve the habitat functions and services within a mitigation site. Enhancement would involve implementing actions to improve already existing low-quality habitat. Restoration would involve creating a habitat type from open water or agricultural fields where none currently exists, but which historically occurred in the vicinity of the project area. The non-Federal sponsor will be responsible for acquiring lands required for mitigation.

With feature refinement for the Recommended Plan expected to continue in the PED phase, the final size of the mitigation measures (width, length etc.) may change. However, due to the conservative nature of engineering and economic assumptions used in the development of the Recommended Plan, it is anticipated that design refinements of the proposed structures will result in equal or lesser environmental impacts than currently estimated.

The habitat types impacted by the Recommended Plan are summarized in Figure 4.4. The non-Federal sponsor will be responsible for acquiring lands required for mitigation.

USACE Implementation Guidance for Sections 1162 and 1163 of WRDA 2016, for Mitigation for Fish and Wildlife and Wetlands Losses, and the standards and policies set forth in 33 CFR Part 332, outline the mitigation requirements for any report being submitted to Congress for approval, and also adds the requirement for mitigation plans to comply with the mitigation standards and policies of the USACE Regulatory Program. As such, the content and structure of the Mitigation Plan were developed to meet the requirements for Regulatory Program compensatory mitigation plans in 33 CFR 332.4(c).

Specifically, compensatory mitigation was formulated to occur within the same watershed as that of the impacts and to replace the functions and services of each habitat type with functions and services of the same habitat type. To be considered, mitigation measures were required to either restore or enhance the same habitat types that were impacted (e.g., "habitat type for habitat type") with the construction of the Recommended Plan. As part of this study, preliminary design of the mitigation measures were completed by the Study Team, in close coordination with the resource agencies. While presented in detail in Appendix C-1, the Mitigation Plan, the core components of the Mitigation Plan are summarized in Section 3.5.

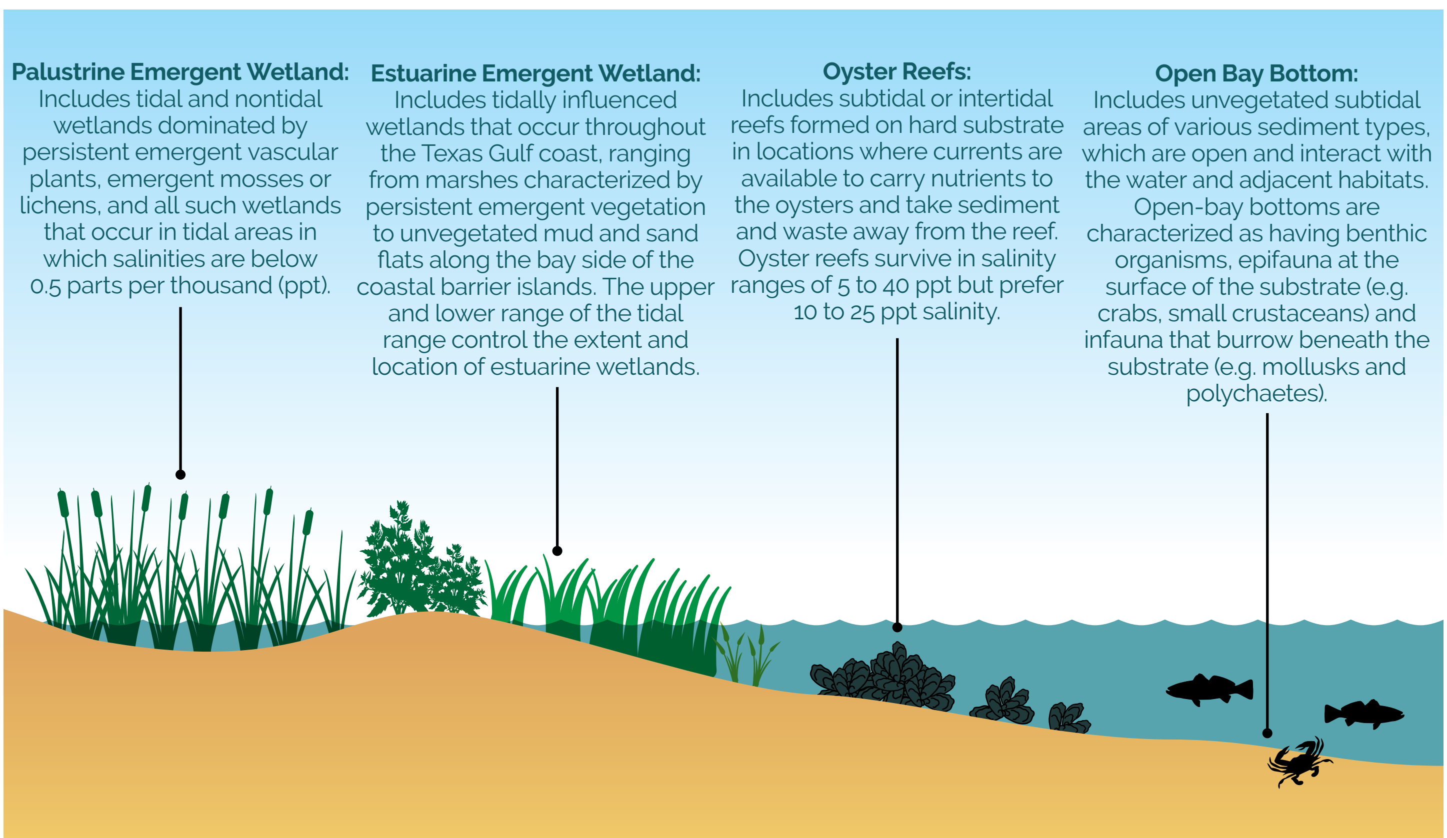



***Figure 4.4:** Habitat types impacted by the Recommended Plan*

## 4.4. Tiered NEPA

The CEQ's 'Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act' (40 CFR 1500 – 1508) and the USACE's own regulations (33 CFR 230.13) allow NEPA studies for large and complex projects, such as the Coastal Texas Study, to be carried out in a multi-stage or tiered process. This tiered approach involves the preparation of a first NEPA document, in this instance the attached Final EIS, that makes broad level decisions while taking into account the full range of potential effects to both the human and natural environments of the entire plan. For the Coastal Texas Study, the attached Final EIS includes differing levels of evaluation for "actionable" features and "Tier One" features. The Tier One features will have additional analyses and will involve preparation of one or more additional NEPA documents (either an EIS or Environmental Assessment [EA]) that build off this original EIS to examine individual components of the Recommended Plan in greater detail. Whether an EIS or EA is developed will be dependent on the significance of impacts anticipated from the action. In either situation, the Tier Two NEPA assessments will comply with CEQ Regulations, including providing for additional public review periods and resource agency coordination. The tiered NEPA process is discussed further in Chapter 1 of the attached Final EIS.

For the actionable features, sufficient level of design was completed which allowed for the completion of all necessary environmental compliance actions within the attached Final EIS. For these actionable features, a Tier Two NEPA assessment would not be necessary unless changes were made during the PED phase that warranted additional NEPA study, or if site conditions change significantly. Further discussions on environmental consequences and compliance with laws and regulations for these measures can be found in Chapter 5 and Chapter 6 of the Final EIS. The following actionable features in the Recommended Plan will have full environmental compliance at the time of the signed Chief's Report in 2021:

1. Restoration Measure G28 (Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection)
2. Restoration Measure B12 (Bastrop Bay, Oyster Lake, West Bay, and GIWW Shoreline Protection)
3. Restoration Measure M8 (East Matagorda Bay Shoreline Protection)
4. Restoration Measure CA5 (Keller Bay Restoration)
5. Restoration Measure CA6 (Powderhorn Shoreline Protection and Wetland Restoration)
6. Restoration Measure SP1 (Redfish Bay Protection and Enhancement)

The tiered NEPA document approach is being utilized due to the scale of the Recommended Plan and the complexity of its core element, the Bolivar Roads Gate System which requires further evaluation and design in the PED phase. Detailed hydraulic analysis of the Bolivar Roads Gate System was a study priority due to the magnitude of the potential impacts and its potential influence on alternative screening. However, due to the complexity involved, additional engineering analyses that could inform more specific impact questions related to gate function were deferred to the PED phase. Detailed hydrologic and hydraulic analysis of other features such as the Clear Lake and Dickinson Bay gates and the Galveston Ring Barrier System and its gate at Offatts Bayou, are also deferred to the PED phase since their designs are dependent upon the larger gate design and are proposed to address remaining risk from wind-driven surges in the bay. Since the detailed design of these features was deferred to the PED phase, the complete assessment of the potential

*A photo of South Padre Island existing beach and dunes* impacts will continue into the PED phase. In addition, the beach and dune features on Bolivar Peninsula, Galveston Island, and Follet's Island will need additional detail related to the borrow source; therefore, those features are Tier One requiring additional NEPA assessment during PED. The beach and dune feature at South Padre Island and ER measure W3 both require additional time for coordination with the U.S. Fish and Wildlife Services (USFWS), and are therefore also considered Tier One measures. All other environmental compliance requirements for these two measures have been met.

Once enough design details exist to fully evaluate impacts and document compliance with all environmental laws and regulations, these individual Tier One risk reduction and restoration features will be assessed through Tier Two NEPA assessments before advancing to the Construction phase. Features of the Recommended Plan requiring Tier Two NEPA assessments include:

1. Bolivar Roads Gate System
2. Bolivar and West Galveston Beach and Dune System
3. Galveston Ring Barrier System
4. Galveston Seawall Improvements
5. Nonstructural Improvements
6. Clear Lake Gate System and Pump Station
7. Dickinson Bay Gate System and Pump Station
8. South Padre Island Beach Nourishment and Sediment Management
9. Restoration Measure B2 (Follets Island Gulf and Beach Dune Restoration)
10. Restoration Measure W3 (Port Mansfield Channel, Island Rookery, and Hydrologic Restoration)

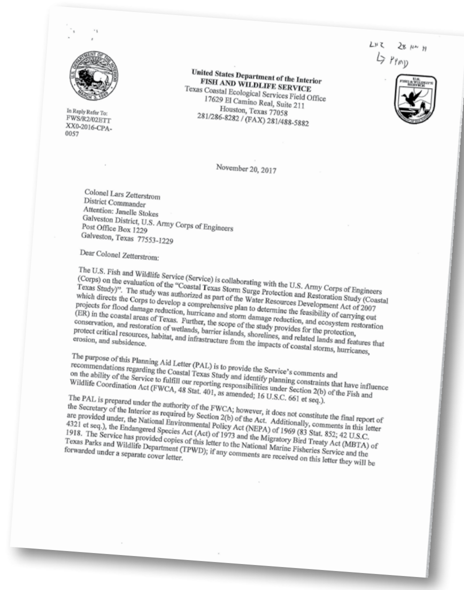
Each feature will require further design details to characterize potential impacts and minimize/avoid these impacts to a degree that satisfies the various resource agencies. For example, further hydrologic and hydraulic modeling will be necessary to capture the potential impacts of the gates to Big Reef (immediately adjacent to the gate structure). Habitat surveys are also needed to capture impacts attributed to the tie-ins flanking the gated system on the opposite side of the inlet. Ecosystem modeling will be required to update the mitigation plan and fully offset these impacts. Additionally, detailed information related to construction such as noise generation, dewatering, equipment scheduling, and a dredge management plan must be disclosed in order to minimize or eliminate adverse effects to threatened and endangered species in the vicinity. If necessary, further coordination will also be performed with BOEM to identify and assess potential Outer Continental Shelf (OCS) borrow sites and OCS borrow area impacts.

*Conceptual rendering of proposed environmental gates that would be used as part of the Bolivar Roads Gate System*

# 4.5. Continued Agency Coordination

For the features in the Recommended Plan that require Tier Two NEPA review (referred to as the remaining features), full compliance with all environmental requirements must be deferred to the PED phase. Deferral is necessary in order generate sufficient information required for coordination with the relevant resource agencies. Laying the groundwork for future NEPA studies, the Tier One Final EIS, specifically Chapter 4, concludes by identifying specific compliance data gaps for each of the remaining features and discusses plans to address those concerns in the Tier Two NEPA studies.

The resource agencies have expressed concurrence with the tiered NEPA process, and the plan to address compliance gaps in Tier Two NEPA studies, in writing during the consultation process. The consultation process included identification of the specific work and timing of future analyses to be conducted during the PED phase. Upon completion of Tier Two NEPA documents, all features will have achieved compliance with the Outer Continental Shelf and Lands Act, Magnuson-Stevens Act / Essential Fish Habitat, Marine Mammal Protection Act, Endangered Species Act, Fish and Wildlife Coordination Act, Clean Air Act, and Clean Water Act. Specific considerations related to the Fish and Wildlife Coordination Act, the National Marine Fisheries Service, and the Biological Assessment are detailed in the sections below.


United States Department of the Interior
FISH AND WILDLIFE SERVICE
Texas Coastal Ecological Services Field Office
17629 El Camino Real, Suite 211
Houston, Texas 77058
281/286-8282 / (FAX) 281/488-5882

In Reply Refer To:
FWS/R2/02ETT
XX0-2016-CPA-0057

November 20, 2017

Colonel Lars Zetterstrom
District Commander
Attention: Janelle Stokes
Galveston District, U.S. Army Corps of Engineers
Post Office Box 1229
Galveston, Texas 77553-1229

Dear Colonel Zetterstrom:

The U.S. Fish and Wildlife Service (Service) is collaborating with the U.S. Army Corps of Engineers (Corps) on the evaluation of the "Coastal Texas Storm Surge Protection and Restoration Study (Coastal Texas Study)". The study was authorized as part of the Water Resources Development Act of 2007 which directs the Corps 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 (ER) in the coastal areas of Texas. Further, the scope of the study provides 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.

The purpose of this Planning Aid Letter (PAL) is to provide the Service's comments and recommendations regarding the Coastal Texas Study and identify planning constraints that have influence on the ability of the Service to fulfill our reporting responsibilities under Section 2(b) of the Fish and Wildlife Coordination Act (FWCA, 48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

The PAL is prepared under the authority of the FWCA; however, it does not constitute the final report of the Secretary of the Interior as required by Section 2(b) of the Act. Additionally, comments in this letter are provided under, the National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852; 42 U.S.C. 4321 et seq.), the Endangered Species Act (Act) of 1973 and the Migratory Bird Treaty Act (MBTA) of 1918. The Service has provided copies of this letter to the National Marine Fisheries Service and the Texas Parks and Wildlife Department (TPWD); if any comments are received on this letter they will be forwarded under a separate cover letter.

*The USFWS Planning Aid Letter dated November 20, 2017*

## 4.5.1. Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act requires consultation with the USFWS and, in Texas, with Texas Parks and Wildlife Department (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.

The USFWS provided a Planning Aid Letter (PAL), dated November 20, 2017, with comments and recommendations related to impacts on fish and wildlife resources of the ER features only. A copy of the PAL is provided in Appendix A of the Final EIS. The PAL provided a list of USFWS's high action coastal priorities in Texas. The USFWS provided a Coordination Act Report, dated January 29, 2021, and also provided in the Final EIS, that assessed all components of the Recommended Plan and provided recommendations for future assessments for the Tier One measures and avoidance and minimization measures to further reduce the impacts the Recommended Plan could have on fish and wildlife species. The development of the Recommended Plan has been coordinated with the USFWS and other State and Federal resource agencies through regular interagency team meetings, where resource agency personnel provided input to the potential impacts assessment, mitigation, and restoration proposals.

It should be noted that the project cannot satisfy the Endangered Species Act until specific impacts to west indian manatee, piping plover, whooping crane, red knot, and sea turtles are assessed. In the attached Tier One Final EIS, the USACE expects to satisfy the Coordination Act for only the actionable features in the Recommended Plan. For the remaining features, the specific impacts cannot be determined before the design and operation of these features are more fully refined, and therefore compliance with the Coordination Act for these features will be deferred to the Tier Two NEPA studies.

### 4.5.2. National Marine Fisheries Service

The NMFS and the USACE have identified several data gaps that require additional design information to analyze potential impacts of the project. The Memorandum of Understanding (MOU) developed between NMFS and the USACE includes a commitment from the USACE to conduct or update existing hydraulic modeling for all plan features to identify and quantify potential secondary impacts from all gate structures. The MOU also commits the USACE to perform fish passage modeling for all gate structures to guide design decisions to avoid and minimize impacts and potentially help quantify any necessary mitigation. These required studies will be conducted as part of the Tier Two NEPA studies.

### 4.5.3. Biological Assessment

The Biological Assessment mirrors the tiering process employed in the Final EIS, in that some measures are described in sufficient detail to allow complete environmental compliance (actionable measures), while the remaining measures will have a review commensurate with the design available, acknowledging that subsequent environmental studies or analysis will be required when additional detail becomes available. The USACE has prepared the Biological Assessment, in coordination with NOAA and USFWS, to fulfill the requirements as outlined under Section 7(c) of the Endangered Species Act of 1973, as amended. The two sub-purposes of this Biological Assessment are first, to complete the Endangered Species Act requirements for the actionable measures, and second, to document the consultation and technical assistance provided thus far on the measures requiring Tier Two NEPA studies.

*The USACE has prepared the Biological Assessment, in coordination with NOAA and USFWS, to fulfill the requirements as outlined under Section 7(c) of the Endangered Species Act of 1973, as amended*

The actionable measures include 6 of the 8 Coastwide ER measures. While there would be temporary disturbances during construction, these restoration measures should have an overall beneficial impact on the ecosystem. Specifically, these measures would use hydraulic dredges to transport material from existing navigation channels and near shore borrow areas to nourish beaches and restore hundreds of acres of salt marsh. These measures would also include the use of barges to transport materials and mechanical equipment to construct breakwaters to protect the restored marshes and to stop erosion that is leading to the loss of important coastal habitats, including sea grass meadows on the middle coast. These measures also include island restoration and oyster reef creation, which are two important habitats that have suffered losses due to erosion and coastal storms.

*A Photo of Piping Plover*

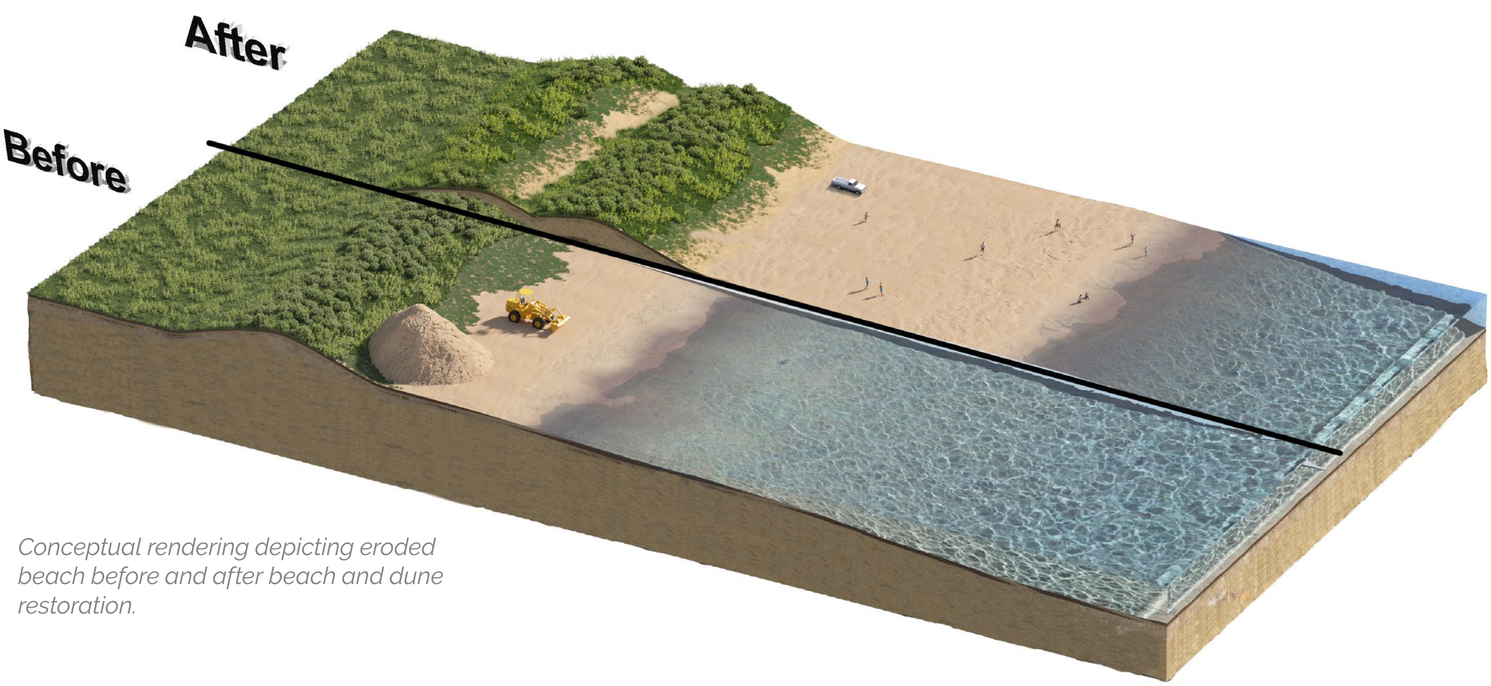
Notable issues raised by NMFS and USFWS include the need for avoidance, minimization, and compensation for direct impacts to Piping Plover critical habitat at Bolivar Flats, the need for analysis on the potential for the Bolivar Roads Gate System to indirectly impact Piping Plover critical habitat at Big Reef, and the potential for construction activities associated with the coastal storm risk management (CSRM) measures to cause a taking. Also, the Bolivar and West Galveston Beach and Dune System would have the potential to impact nesting sea turtles and overwintering Piping Plover and Red Knot.

## 4.6. Hazardous, Toxic, and Radioactive Waste

Under Engineering Regulation 1165-2-132, the USACE is required to conduct Hazardous, Toxic, and Radioactive Waste (HTRW) screening in the feasibility phase to reasonably identify and evaluate known HTRW conditions in and around the proposed project that could affect or be affected by the Recommended Plan. This screening involved a desktop assessment of recent and historic aerial photographs and a review of Federal, state, and local regulatory agency database information. An ASTM E 1527-05 Phase 1 Environmental Site Assessment has been completed for the project area and can be found in Appendix L of the Final EIS. Potential HTRW concerns were identified for the Recommended Plan, and measures were taken in feasibility level design to avoid those concerns where possible.

*Where HTRW concerns are not avoidable, remedial action and associated costs will be a non-Federal responsibility*

If a recognized environmental condition is identified in relation to the project site in the future, the USACE will take the necessary measures to avoid the recognized environmental condition so that the probability of encountering or disturbing HTRW would continue to be low. If avoidance is not possible, Engineering Regulation 1165-2-132 prohibits the use of project funds for HTRW removal and remediation activities. Any further remedial action for HTRW that occurs after the feasibility phase would be the responsibility of the non-Federal sponsor and would be subject to a credit against the non-Federal proportionate share of total project cost. Any response measures to relocate or mitigate HTRW materials, including Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) costs, are the sole responsibly of the non-Federal sponsor.




*Conceptual rendering depicting eroded beach before and after beach and dune restoration.*

# 5. Consistency with Other Federal, State, and Local Plans

A photo of the Galveston Seawall

Given the scale of the Recommended Plan, and its potential to impact ongoing and future efforts in the study area, emphasis was placed on coordinating closely with Federal, state, and local partners to promote consistency with and compatibility among the multiple agencies acting in concert to reduce storm risk and protect coastal resources. Recognizing the value of multiple lines of defense, the USACE supports scaled efforts at the individual and community level, on a neighborhood scale, and at the regional level, to best manage risk and enhance resiliency.

In addition, the Coastal Texas Study team recognizes that numerous entities have been studying coastal risks and successfully implementing a wide variety of restoration and risk management projects across the state. As such, the Study Team aimed to gather, assess, and incorporate key resources, lessons learned, and best practices in the development of the Recommended Plan. For example, the Study Team worked closely with resource agencies that are familiar with ongoing efforts to restore habitats within the study area to identify and employ best practices for inclusion in the Recommended Plan. Ecosystem restoration (ER) measures planned along the Gulf Intracoastal Waterway (GIWW) that would protect and restore estuarine wetlands, palustrine wetlands, and bird islands were modeled after similar projects constructed along the GIWW in the McFaddin National Wildlife Refuge (Jefferson County), the Anahuac National Wildlife Refuge (Chambers County), and the J.D. Murphee State Wildlife Management Area (Jefferson County). The specific breakwater design in the ER measures was based upon breakwaters constructed by the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department (TPWD) in their refuges and management areas.

*Widened beaches at McFaddin National Wildlife Refuge*

The following sections detail relevant past and current plans and projects, and how they were considered or incorporated into the development of the Recommended Plan. For ease of understanding, these plans are categorized at the Federal, state, and local levels.

## 5.1. Federal Plans

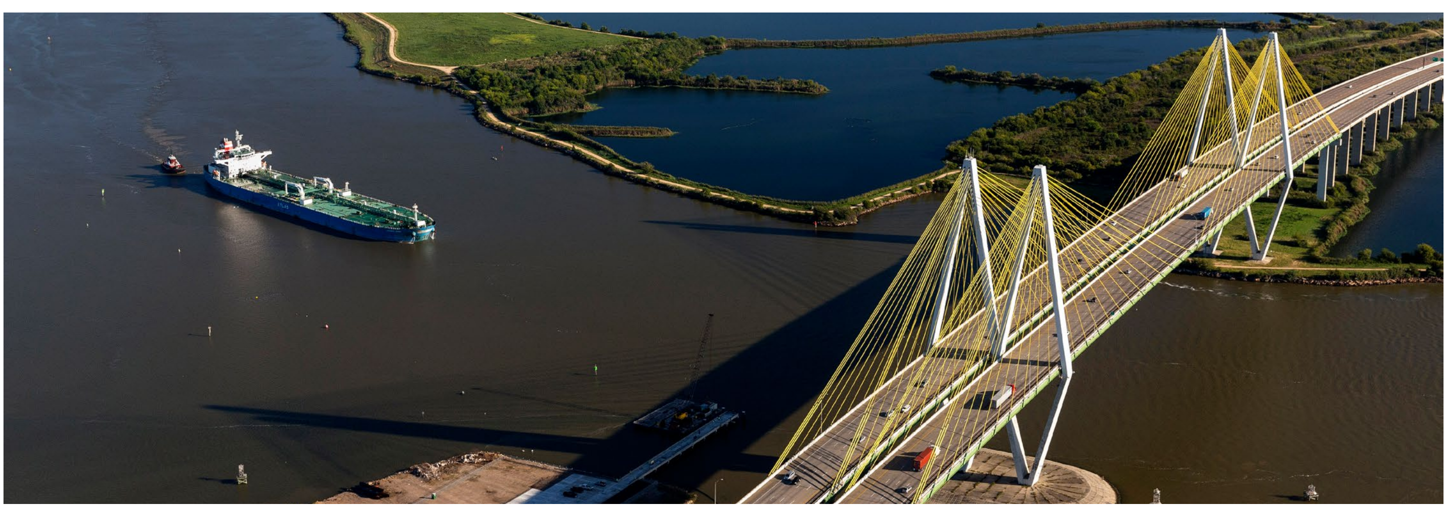
The USACE is highly active across the Texas coast advancing a variety of coastal storm risk management (CSRM), ER, and navigation projects. Accordingly, it was critical that the measures proposed as part of the Coastal Texas Study be coordinated closely with other Federal projects and programs in the vicinity of the proposed project.

Most importantly, two similar USACE led CSRM and ER Feasibility Studies were being conducted at the same time as the Coastal Texas Study. These included the Sabine Pass to Galveston Bay Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study and the Jefferson County Ecosystem Restoration Feasibility Study. Both studies are considered companion studies to the Coastal Texas Study, and address specific concerns inside specific geographies along the upper Texas coast. In combination, the three studies present a contiguous system of risk reduction measures for communities and habitats along the upper Texas coast. Coordination with these two companion studies is described in more detail in Figure 5.1.

In addition to CSRM and ER, the USACE is directly responsible for operating and maintaining more than 1,000 miles of deep draft and shallow-draft navigation channels across the Texas coast. Responsibilities include both maintenance activities (e.g., dredging) and channel improvement or channel expansion projects. Efforts were made during the study phase to discuss opportunities and to coordinate recommendations with the USACE's various navigation teams and their local partners (e.g., port authorities) across the state to ensure proposed activities induced no adverse impact to authorized navigation projects nor negatively affected the ability of authorized navigation projects to continue to fulfill their purpose. Most critically, this included coordination with the Port of Houston, Port of Texas City, Port of Galveston, Port of Freeport, and the Port of Brownsville. Specific to Galveston Bay, this included extensive coordination with the USACE/Port of Houston Authority study team leading the Houston Ship Channel Expansion Channel Improvement Project, which terminates at the proposed Bolivar Roads Gate System. Additional information on this project is provided in Figure 5.2.

## RELEVANT PLANS & PROJECTS


*A photo of the Houston Ship Channel at the Fred Hartman Bridge*



## USACE - Sabine Pass to Galveston Bay Study

The Sabine Pass to Galveston Bay Feasibility Study evaluated measures to reduce tropical event surge impacts and provide ecosystem restoration along the upper Texas coast, including Orange, Jefferson, Chambers Galveston, Harris and Brazoria counties. Although initially part of the evaluation, a decision was made to fully evaluate the Houston/Galveston Region in the Coastal Texas Study due to its complexity. The two studies support a coordinated approach to risk reduction along the coast. The Feasibility Study recommended:

- Increasing the level of performance and the resiliency of the existing Port Arthur and Vicinity Hurricane Flood Protection project in Jefferson County.
- Construction of a new levee/floodwall system along the edge of the Sabine and Neches River floodplains in Orange County.
- Increasing the level of performance and the resiliency of the existing Freeport and Vicinity Hurricane Flood Protection project in Brazoria County.

The Feasibility Report was approved by the USACE Chief of Engineers in 2017, and the Bipartisan Budget Act of 2018 funded the implementation of these projects, which are currently in the design phase and moving towards construction. Specific to the Coastal Texas Study, coastal flood risk management and restoration activities proposed as part of this project were coordinated closely with the Coastal Texas Study Team and are deemed complementary and do not overlap or provide redundant benefits. In general, these two projects work together to provide comprehensive solutions to addressing coastal risk and enhancing coastal resiliency along the upper Texas coast. Refer to Figure 5.3 for the location of the Sabine Pass to Galveston Bay components in relation to the Coastal Texas Study components.

## USACE - Jefferson County Ecosystem Restoration Study

This Civil Works study, led by the USACE Galveston District, investigated the feasibility of protecting and restoring environmental resources in Jefferson County. The recommended ecosystem restoration plan for Jefferson County would restore marsh and GIWW shoreline features that stabilize and sustain critical marsh resources. Specifically, this study recommended construction of 5,170 linear feet of armoring along the southern bank of the GIWW and restoration of 6,048 acres of brackish marsh habitat with dredged material from the federally authorized Sabine Neches Waterway navigation channel. The Feasibility Report was approved by the USACE Chief of Engineers in 2019, and the project is awaiting authorization and funding from Congress to finish Preconstruction Engineering and Design (PED) and initiate construction efforts. Specific to the Coastal Texas Study, restoration activities proposed as part of this project were coordinated closely with the Coastal Texas Study Team and are deemed complementary and do not overlap or provide redundant benefits. Refer to Figure 5.3 for the location of the Jefferson County components in relation to the Coastal Texas Study components.

***Figure 5.1:*** *Sabine Pass to Galveston Bay Study and the Jefferson County Ecosystem Restoration Study*

## USACE - Houston Ship Channel Expansion Channel Improvement Project

This Civil Works feasibility study, led by the USACE Galveston District in partnership with the Port of Houston Authority, examines the feasibility of improving navigation on the Houston Ship Channel. The project's Recommended Plan includes a combination of bend easing, turning basin improvements, and channel deepening at various portions along the ship channel to support safe and efficient navigation in the Houston Ship Channel. The Feasibility Report was approved by the USACE Chief of Engineers in April 2020, and the project is advancing through the PED phase. In addition to this specific effort, numerous other channel maintenance/dredging, beneficial use activities, and port facility projects associated with the Houston Ship Channel are ongoing and critical to the day to day functioning of the entire Houston-Galveston-Texas City navigation complex. Refer to Figure 5.3 for the location of the Houston Ship Channel in relation to the Coastal Texas Study components.

*A photo of the Houston Ship Channel*

***Figure 5.2:*** *Houston Ship Channel Expansion Channel Improvement Project.*

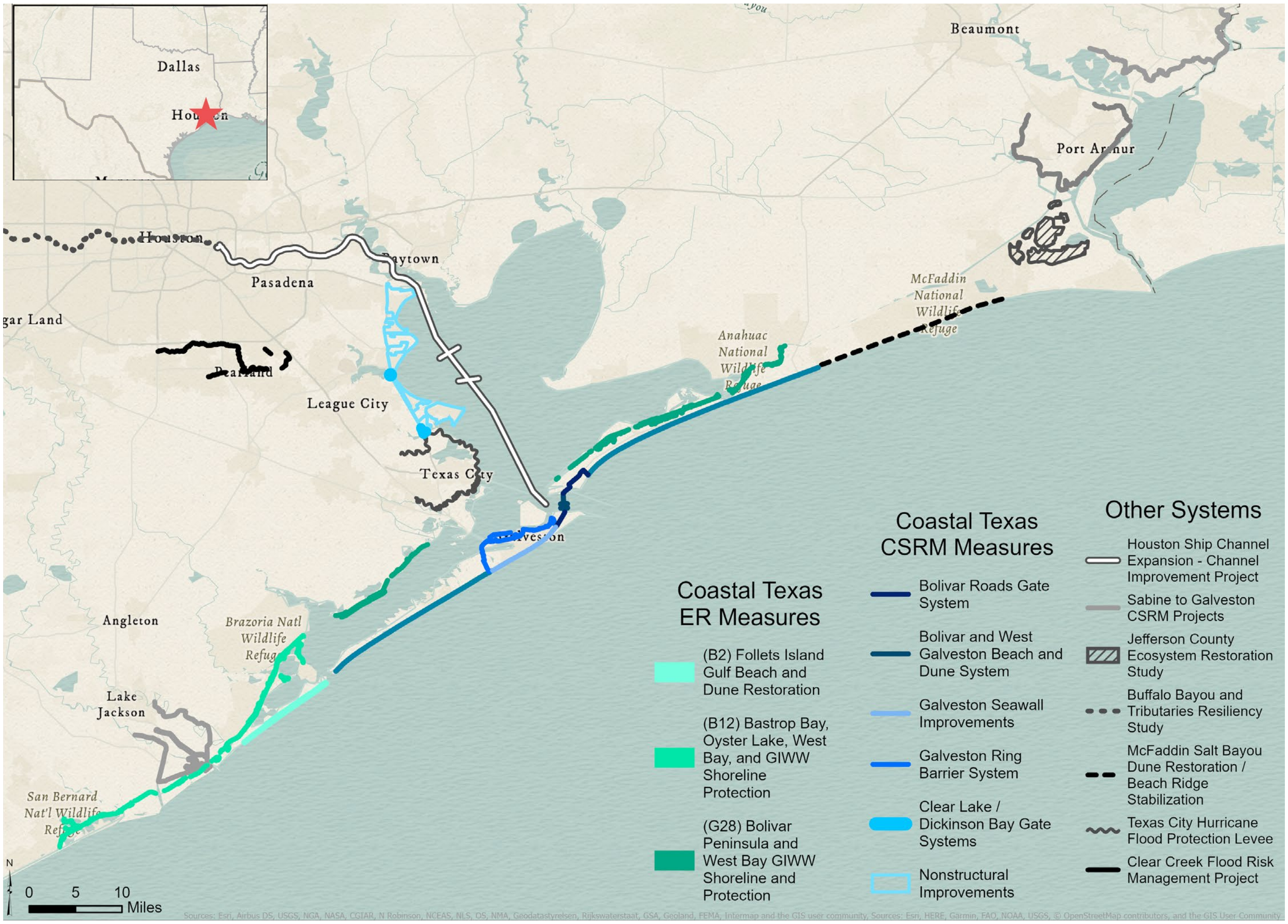



***Figure 5.3:*** *Coastal Texas Study CSRM measures, ER measures and other complementary systems or projects on the upper Texas coast*

Recommended CSRM and ER improvements associated with the Coastal Texas Study were coordinated closely with the Houston Ship Channel planning team to ensure proposed improvements do not impact or restrict the current and future function of the Houston Ship Channel system. It is also possible that dredge material from the Houston Ship Channel, particularly the material that is currently planned to be placed in offshore areas,could be used to support construction of certain features of the Coastal Texas Study's Recommended Plan. The Coastal Texas Study Team will continue to coordinate efforts with the Houston Ship Channel team, and its non-Federal partners, through the PED phase and in any future modifications of the Houston Ship Channel.

*Recommended CSRM and ER improvements associated with the Coastal Texas Study were coordinated closely with the Houston Ship Channel planning team to ensure proposed improvements do not impact or restrict the current and future function of the Houston Ship Channel system*

Besides the major coastal and navigation projects discussed above, the USACE is also responsible for planning, construction, and in certain circumstances the operation of inland flood risk management projects within or adjacent to the coastal areas covered by the Coastal Texas Study. Examples of these projects include but are not limited to the Clear Creek Flood Risk Management Project and the Buffalo Bayou Resiliency Study. When applicable, planning and analysis for the Coastal Texas Study's CSRM and ER features took into account the proper operation and drainage of these related inland flood risk management projects. The location of these projects are also shown in Figure 5.3.

*Widened beaches at McFaddin National Wildlife Refuge*

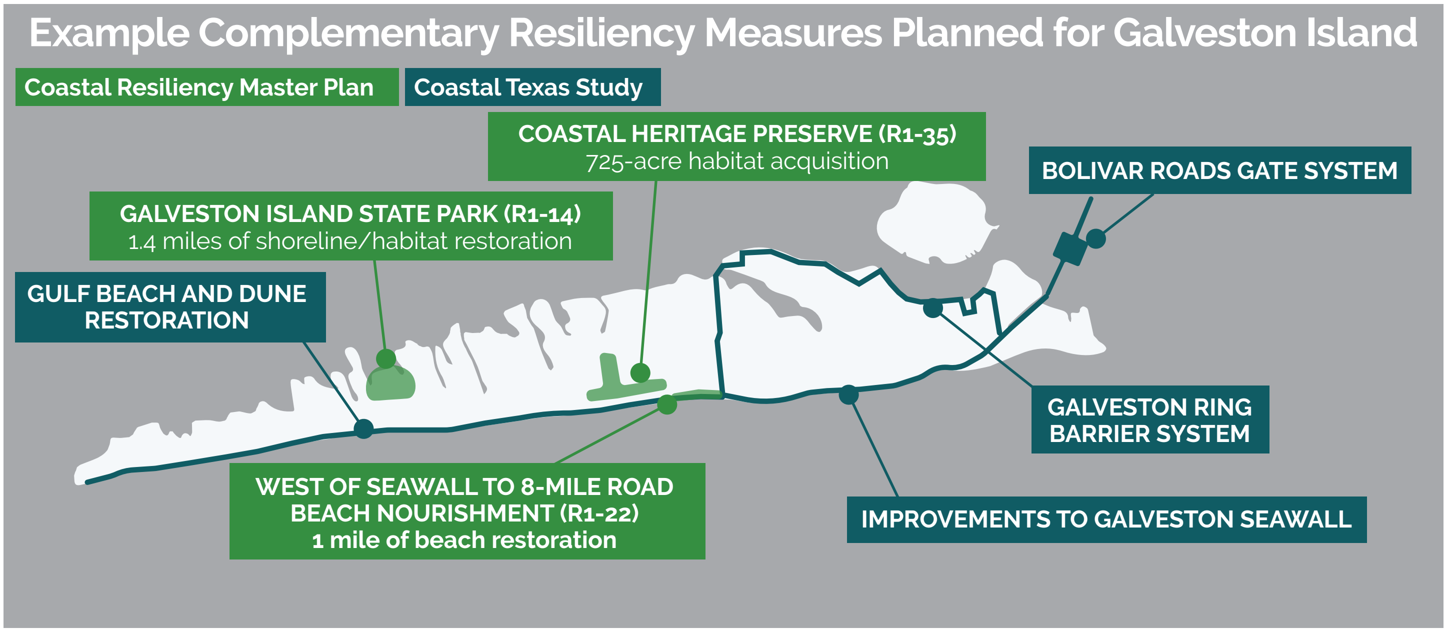
## 5.2. State Plans

Like the USACE, the GLO and other state agencies, such as TPWD, have a long history leading or supporting coastal storm risk reduction and ecosystem restoration initiatives and projects across the Texas coast. The GLO's efforts are multifaceted, ranging from proactive restoration and risk reduction programs to disaster response and recovery services. Through various programs, the GLO and other state agencies complete dozens of coastal planning, risk reduction, and ecosystem restoration projects each year aimed at achieving increased societal, economic, and ecological resiliency by bolstering protection to coastal environmental resources, communities, infrastructure, and wildlife habitats. In addition, as it does for the Coastal Texas Study, the GLO has also served as the non-Federal sponsor for USACE led projects.

*"By working together as a region - combining and coordinating local, state, and federal resources, we will directly address ongoing threats to the Texas coast for future generations."*
*George P. Bush,*
*Texas Land Commissioner*

Several state-led or state-funded projects interface directly with the Coastal Texas Study. Other similar studies are indirectly informed by or have provided input to the Coastal Texas Study. The most directly relevant state-led efforts are detailed in the following sections.

**GLO – Coastal Resiliency Master Plan**. The GLO's Coastal Resiliency Master Plan was developed concurrently with the Coastal Texas Study and represents the state's blueprint for advancing comprehensive coastal resiliency efforts. While each effort covers the same study area, the full Texas coast, they differ in the type and scale of projects which are generally considered or recommended. For example, while the Coastal Texas Study generally considers larger CSRM projects driven by benefit-cost analyses, the Coastal Resiliency Master Plan includes numerous smaller-scale ER projects which have been prioritized for a variety of different reasons. Furthermore, many of the proposed ER features in the Recommended Plan were generated directly from restoration opportunities identified in the Coastal Resiliency Master Plan. In general, the Coastal Resiliency Master Plan uses ER measures to protect and enhance critical coastal economic facilities and features, such as the GIWW. Addressing similar needs through slightly different means, the two plans aim to provide multiple complementary lines of defense against coastal hazards, which will work together to support the objectives of each effort. Further information on how the Coastal Resiliency Master Plan and the Coastal Texas Study complement each other can be found in Figure 5.4.




**TEXAS COASTAL RESILIENCY MASTER PLAN**

The Texas Coastal Resiliency Master Plan highlights the value of the coast and the hazards that endanger the environment and the economy of the coastal communities.

- The Plan is focused on both nature-based and infrastructure-based projects to enhance coastal resiliency.
- By providing a list of Tier 1 projects to address coastal concerns, the Plan is a coordinative vehicle that complements various coastal planning and coastal management initiatives of other entities at the Federal, state, and local levels.
- The Plan will continuously evolve along with the concerns and needs of the coast and its residents to ensure that recurrent and up-to-date coastal management is provided to Texas coastal communities.

US Army Corps of Engineers® Galveston District

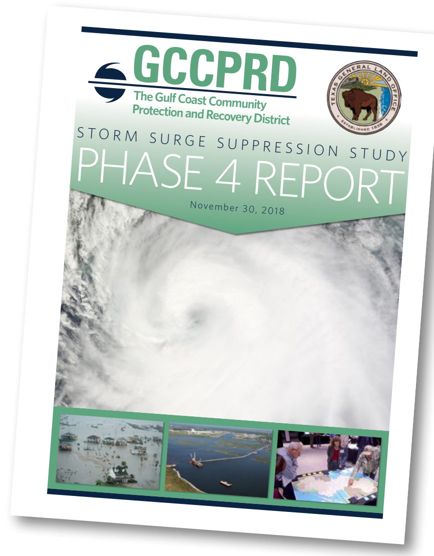
**COASTAL TEXAS STUDY**

The Coastal Texas Study identifies coastal storm risk management and ecosystem restoration measures to 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.

- Part One: An Environmental Impact Statement that studies what impacts the proposed projects might have on the environment and wildlife.
- Part Two: A Feasibility Report that identifies preventative, actionable projects that can be built to protect the coast and its inhabitants.
- The Coastal Texas Study currently recommends both man made and natural barriers to help prevent storm surge from causing extensive damages to Texas coastal communities.

***Figure 5.4:*** *Complementary efforts on the Texas coast*

**GLO - McFaddin Beach Restoration**. The Texas GLO and its local partner, Jefferson County, recently completed substantial restoration efforts at McFaddin Beach. This project will ultimately include approximately 20 miles of beach nourishment and creation of an 8-foot-tall ridge/dune which buffers the adjacent freshwater marsh habitat from tidal surges and salt water floods. Specific to the Coastal Texas Study, this beach and dune concept has been adopted as a core component of the Recommended Plan, with the proposed beach and dune system on Bolivar Peninsula slated to extend up the coast and connect to the GLO led improvements.



*Cover of the GCCPRD Phase 4 Report*

**Gulf Coast Community Protection and Recovery District – Storm Surge Suppression Study**. The Storm Surge Suppression Study was a four-phase conceptual planning study led by the Gulf Coast Community Protection and Recovery District (GCCPRD) with support from the GLO from 2013 to 2018. The goal of the study was to investigate the feasibility of reducing the vulnerability of the upper Texas coast to storm surge and flood damages. Accordingly, a conceptual plan was developed to protect life, health, and safety and provide environmental and economic resilience within the study region. Specific to the Coastal Texas Study, numerous work-products and recommendations from this effort were incorporated directly into the Coastal Texas Study. The Coastal Texas Study represents the extension and completion of many planning efforts initiated by the GCCPRD.

**GLO - Texas Coastal Infrastructure Study**. The 2016 Texas Coastal Infrastructure Study identified critical infrastructure assets, such as water treatment facilities, roads and bridges, within the 22-county coastal study area that are most vulnerable to future storm impacts. Specific to the Coastal Texas Study, this information supported further refinement of the Recommended Plan, which provides risk reduction for many of the infrastructure assets identified by the GLO. It is anticipated that any future state or local level implementation of infrastructure resiliency projects will be additive to the benefits achieved by the Recommended Plan.

**GLO - Regional Sediment Study**. This report provided a desktop inventory of the Texas coastal soft sediments available through a compilation of engineering and geoscientific reports, peer reviewed publications, and sediment databases in state and Federal programs. Specific to the Coastal Texas Study, data from this report was used to identify feasible sand/sediment sources needed for construction of both ecosystem restoration and coastal storm risk management features. Additional GLO led sediment management planning is also ongoing.

**TxDOT – Texas Gulf Intracoastal Waterway Master Plan**. The Texas Department of Transportation (TxDOT), the non-Federal sponsor for the Texas portion of the GIWW, is responsible for the maintenance and development of this critical waterway in accordance with Chapter 51 of the Transportation Code. To guide future activities, TxDOT developed and adopted the Texas Gulf Intracoastal Waterway Master Plan in 2014. Under Chapter 51, the primary responsibility of TxDOT is to provide right-of-way and disposal areas for byproducts of operations and maintenance of the GIWW. Specific to the Coastal Texas Study, the ecosystem restoration features of the Recommended Plan, including GIWW shoreline restoration, breakwater construction, and habitat restoration, are consistent with TxDOT's mission and reduce maintenance dredging needs and minimize safety risks associated with erosion. Detailed design of these restoration features will be coordinated closely with TxDOT and other GIWW stakeholders.

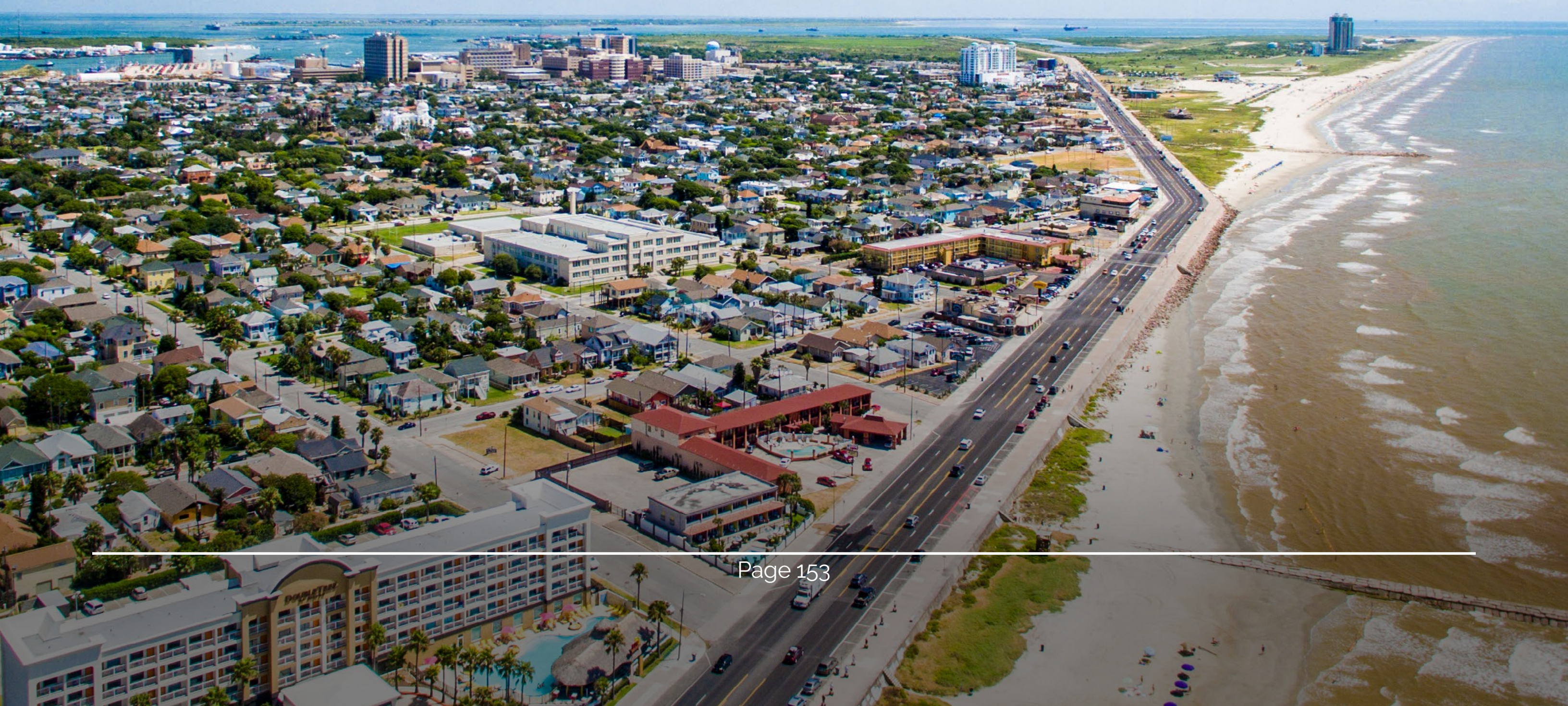

*Photo of the Gulf Intracoastal Waterway*

## 5.3. Local Plans

The USACE and GLO recognize that numerous locally led improvement projects are currently being developed, or are planned for the future, which may interface with or potentially be impacted by the Recommended Plan. In refining the Recommended Plan, the Study Team aimed to consider and accommodate, to the degree possible, these local efforts. Furthermore, as the Coastal Texas Study shifts into the PED phase, the USACE will continue to coordinate with local partners to support locally led efforts and to eliminate or minimize conflicts between the Recommended Plan and other beneficial infrastructure improvement projects. A select sampling of local projects which have been considered in the development of the Recommended Plan include:

- **TXDOT - SH146 Expansion**. State Highway 146, which runs through the heart of Seabrook, Texas and skirts the western Galveston Bay shoreline, is a main connection between Galveston and Houston and serves as a hurricane evacuation route for thousands of residents. In the Spring of 2019, TxDOT started construction on a project to widen and restructure the existing facility to a six to 12-lane freeway with grade separations at major intersections, access roads in select locations, and express lanes over Clear Lake. As one feature of the Recommended Plan includes a gated structure and pumping station at Clear Lake, the Study Team has met with TXDOT to discuss the integration of the highway expansion project with these features. As the Coastal Texas Study moves into the PED phase, the USACE will continue to coordinate efforts with TXDOT to best integrate the two projects in a cost-effective manner.
- **City of Galveston - 14th Street Drainage Improvements Project**. After Hurricane Harvey, the City of Galveston was awarded a Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant for the engineering, design and construction of a drainage pump station near 15th Street and Harborside Drive. To date, the initial hydrology and hydraulics study, draft Environmental Assessment, topographic surveying, preliminary design, and preliminary Benefit Cost Analysis for the project have been completed. The Coastal Texas Study Team is meeting with the City of Galveston's project delivery team on a monthly basis to coordinate activities and to integrate the City's effort with the Galveston Ring Barrier System proposed in the Recommended Plan.

*Photo of East Galveston Island*



- **Galveston Park Board - Beach Re-nourishment**. The Galveston Park Board of Trustees is continuously working with local stakeholders, the State of Texas, and USACE to coordinate efforts to manage available sediment in the region for the purpose of beach re-nourishment along Galveston's Gulf-facing beachfront. Since 2015, an estimated 2.5 million cubic yards of beach quality sand has been placed on Galveston beaches through these collaborative efforts, and future projects are in the planning phase. The Coastal Texas Study Team has provided regular study updates to the Park Board in an effort to coordinate the Recommended Plan's proposed beach and dune features with the Park Board's initiatives.
- **Port of Galveston - Strategic Master Plan**. Approved by the Galveston Wharves Board of Trustees in November 2019, the Galveston Wharves Strategic Master Plan provides a long-term view for organizing the Galveston port complex, suggesting locations for activities and improvements that will yield the most efficient use of land and marine resources and allow for investments in key infrastructure to further provide for demand in the realms of cargo, cruise, commercial, and industrial development. Several features proposed in the Recommended Plan (e.g., the Ring Barrier) have been aligned with features in the Strategic Master Plan in a synergistic manner, reducing costs and impacts of the proposed plan overall. The Coastal Texas Study Team will continue to coordinate its efforts with the Wharves Board through the PED phase of project development.

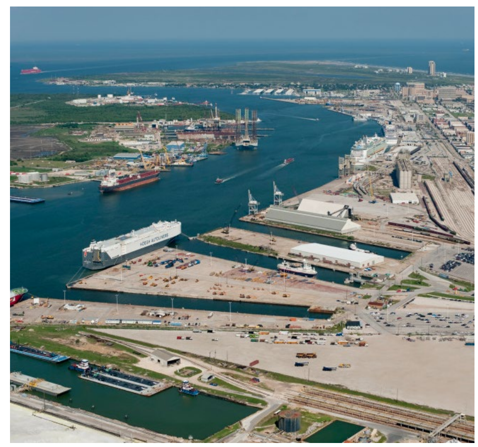


*Photo of Port of Galveston*

## 5.4. Parallel Academic Efforts

While not officially sponsored by either state or local government, the following two university driven initiatives were advanced at the same time as the Coastal Texas Study and presented various risk reduction strategies for the Galveston Bay region. These efforts have helped to educate stakeholders and introduced a wide variety of potential CSRM and ER measures for consideration by the Coastal Texas Study Team. Information generated by these initiatives was utilized heavily in the development of the Coastal Texas Study. While these efforts did not always result in similar recommendations, each effort provided valuable input, often from different viewpoints, which was considered in detail and broadened the inclusiveness of the Coastal Texas Study. All efforts agree that risks are high, and action must be taken, including a barrier at Bolivar Roads.

- **Rice University Severe Storm Prediction, Education, and Evacuation from Disasters (SSPEED) Center – Galveston Bay Park Plan**. The Galveston Bay Park Plan (GBPP) is a proposal conceived by Rice University's SSPEED Center to construct a levee (and park space) along the Houston Ship Channel using dredged material from a potential future expansion of the channel. This concept was developed as a public-private partnership. The GBPP could be compatible with the Coastal Texas Study's Recommended Plan and support comprehensive resilience for the Houston Ship Channel and adjacent areas.
- **Texas A&M University Galveston - Ike Dike**. The Ike Dike is a coastal barrier concept developed by Texas A&M University at Galveston, which proposed an extension of the existing Galveston Seawall along the rest of Galveston Island and along the Bolivar Peninsula to High Island. The proposed barrier, in general, would be a fortified dune on the beaches along with flood gate closures at both Bolivar Roads and San Luis Pass. The Ike Dike plan served as an initial design template for the Coastal Texas Study's Recommended Plan.

## 5.5. Similar Programs and Initiatives


*Beach re-nourishment on Galveston Island*

As was discussed in Section 1.5, numerous existing laws and programs aim to safeguard coastal resources and provide funding for restoration projects. Projects developed through these programs are generally complementary, and not mutually exclusive, to those proposed in the Recommended Plan. In the future, it is anticipated that smaller-scale restoration projects will be developed and constructed in the general vicinity of the Recommended Plan to address site specific needs. Many of these projects will likely be selected from opportunities identified in the GLO's Coastal Resiliency Master Plan. Examples of select programs which are anticipated to support restoration efforts along the Texas coast are detailed in Figure 5.5.

### Coastal Erosion Planning and Response Act

The Coastal Erosion Planning and Response Act (CEPRA) Program implements 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. Under CEPRA, the GLO implements erosion response projects and studies through partnership with Federal, state, and local governments, non-profit organizations and other potential project partners. Upon appropriation from the Texas Legislature, the CEPRA program provides funding on a biennial basis for the following types of projects and studies, with priority given to projects that include construction of an erosion response solution during the biennium.

- Beach nourishment on both Gulf of Mexico and bay beaches
- Shoreline stabilization
- Habitat restoration and protection
- Dune restoration
- Beneficial uses of dredged material for beach nourishment, habitat restoration, etc.
- Coastal erosion related studies and investigations
- Demonstration projects
- Structure relocation and debris removal

### Coastal Management Program

The Texas Coastal Management Program (CMP), funded by NOAA, focuses on the state's coastal natural resource areas. The program is managed by the GLO and brings approximately $2.2 million in Federal Coastal Zone Management Act (CZMA) funds to Texas, the majority of which goes to state and local entities to implement projects and program activities. The GLO funds projects in all parts of the coastal zone for a wide variety of purposes, including:

- Coastal Natural Hazards Response
- Critical Areas Enhancement
- Public Access
- Waterfront Revitalization and Ecotourism Development
- Permit Streamlining/Assistance, Governmental Coordination and Local Government Planning Assistance
- Water Sediment Quantity and Quality Improvements

### Natural Resource Damage Assessment

Natural Resource Damage Assessment (NRDA) is a legal and technical process under state and Federal laws to determine the type and amount of restoration needed to compensate the public for harm to natural resources that occur as a result of an unauthorized release of hazardous substances or oil. Associated with the Oil Pollution Act (OPA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the GLO, TWPD, and the Texas Commission on Environmental Quality (TCEQ) serve as the three state-level natural resources trustees responsible for overseeing the restoration of injured natural resources. Projects initiated through this program are generally compatible with other restoration activities and would not conflict with the measures proposed in the Recommended Plan.

Critical laws which impact implementation of the Recommended Plan are the Texas Open Beaches Act, the Dune Protection Act, and 31 TAC § 15A.These state laws and regulations require that coastal local governments adopt and implement programs for the preservation of dunes and the preservation and enhancement of the public's use of and access to and from public beaches. These state laws are adopted as beach access and dune protection plans. The GLO is tasked with reviewing local beach access plans and certifies that they meet the minimum state standards set forth in the Open Beaches Act, the Dune Protection Act, Texas Code and the General Land Office's Beach/Dune Rules. Measures included in the Recommended Plan were screened for and conceptually optimized for compliance with the Texas Open Beaches Act. However, further evaluation will be necessary during the PED phase to ensure full compliance with the Texas Open Beaches act prior to initiation of construction.

***Figure 5.5:*** *Additional restoration efforts on the Texas Coast*

*Waves from Hurricane Ike crash against the Galveston Seawall in 2008 (photo credit: Scott Pena)*

# 6. Implementation Requirements and Strategy

This section provides a summary of the implementation requirements for the project, including the cost-share requirements for the non-Federal sponsor(s) and the associated required items of cooperation. The cost-share requirements and obligations of the Federal government and the non-Federal sponsor(s) will be documented in Project Partnership Agreements (PPAs), covering the different components of the Recommended Plan, which must be approved and executed prior to the start of construction. The PPAs set forth the obligations of each party.

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. Various entities within the State of Texas, including the GLO and the Gulf Coast Protection District (GCPD), will serve as the non-Federal sponsors, with support from local entities, for future phases of the Coastal Texas Protection and Restoration Plan. Specifically, the GLO has issued a Letter-of-Intent stating its intent to serve as the non-Federal sponsor for the ER measures and the South Padre Island Beach Nourishment and Sediment Management measure, while the GCPD has issued a Letter-of-Intent stating its intent to serve as the non-Federal sponsor for the upper Texas coast CSRM features. In addition, 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 GLO, GCPD, and the USACE in the implementation of this project.

*The GLO and GCPD have issued Letters-of-Intent stating their intent to serve as non-Federal sponsors, with support from local entities, for future phases of Coastal Texas*

Federal implementation of the project would be subject to the non-Federal sponsor(s) agreeing to comply with applicable Federal laws and policies. Furthermore, the non-Federal sponsor(s) shall, prior to implementation, agree to perform the required items of cooperation detailed in Section 6.1.1 and 6.1.2 of this report.

Project implementation decisions will require strategic considerations due to the scale and variety of the features. The Recommended Plan has been formulated to be adaptable and effective under multiple implementation scenarios, if phased implementation is required. Different strategies are possible to construct the project features, including prioritization of risk reduction performance or leveraging efficiencies by syncing action with source material generated by other projects. These considerations are discussed in greater detail in Section 6.3.

*Project implementation decisions will require strategic considerations due to the scale and variety of the features. The Recommended Plan has been formulated to be adaptable and effective under multiple implementation scenarios, if phased implementation is required.*

## 6.1. Division of Responsibilities and Cost-Sharing Requirements

The following sections describe the division of responsibilities and cost-sharing requirements between the Federal government and the non-Federal sponsor(s). The ecosystem restoration (ER) and coastal storm risk management (CSRM) portions of the Recommended Plan have different financial and cost-sharing considerations, and therefore are presented separately.

The ER portions would be cost shared 65% Federal and 35% non-Federal. For the CSRM portions, the cost share will be 65% Federal and 35% non-Federal for all initially constructed features. However, for renourishment cycles for the beach and dune portions, the cost share would be split 50%/50%. Note that the general division of responsibilities discussed below only cover the initial constructed features (65%/35%), and are presented as a general example. The final division of responsibilities for each feature would be set with the signing of a PPA before beginning construction. The PPA is a legally binding agreement between the Government and a non-Federal sponsor for construction of a water resources project. It would describe the final responsibilities of the Government and the non-Federal sponsor in the cost sharing and execution of work.

As discussed in Chapter 3, a portion of the Bolivar Roads Gate Sytem, the levee tie-in, is located within a Coastal Barrier Resources Act (CBRA) zone and is not eligible for an exemption. As such, the cost for this feature must be born by the non-Federal sponsor. Accordingly, the cost for this feature is excluded from the 65% Federal / 35% non-Federal cost share calculation.

*Example of marsh restoration planting*

### 6.1.1. ER Components of the Recommended Plan

As discussed in Chapter 3, the Recommended Plan includes a Coastwide ER Plan consisting of eight ER features formulated to restore degraded ecosystems that buffer communities and industry along the Texas coast from erosion, subsidence, and storm losses. The Coastwide ER Plan is the lowest-cost comprehensive plan considered, would have synergy with other ongoing and planned restoration projects, and would add geomorphic stability and resilience to the CSRM components of the Recommended Plan.

The Coastwide ER Plan's project first cost is estimated as $2,672,733,000 at FY21 price levels. The Federal share of the Coastwide ER Plan's project first cost is $1,809,409,000. The non-Federal share of the project first cost is $863,324,000, pending Land, Easements, Rights-of-Way, Relocations, and Disposal Areas (LERRD) credits. As it relates to cost allocation and implementation, there are portions of ER Measure B12 and ER Measure M8 that fall within U.S. Fish and Wildlife Service (USFWS) property. A Coastal Boundary Survey conducted prior to construction, pursuant to Texas Natural Resources Code Section 33.136, will establish the boundary between State-owned submerged lands and other lands, such as USFWS lands. Separate authorization and funding will be necessary for approximately $403 million of restoration measures B12 and M8 that are on or benefiting only the National Wildlife Refuge's lands. The remaining portions of ER Measure B12 and ER Measure M8 will be the responsibility of the USACE and the non-Federal ER sponsor. The above identified Federal share of the Coastwide ER Plan ($1,809,409,000) includes this $403 million increment. However, it should be noted that the success and benefits associated with the remainder of the Coastwide ER Plan are not dependent on the construction of the ER measures to be separately authorized and funded.

*Photo of a barge placing material for oyster reef creation*

The GLO, in partnership with various local entities, is anticipated to serve as the non-Federal sponsor for PED, construction, and OMRR&R of the Coastwide ER Plan. Among other responsibilities, the non-Federal sponsor must provide all LERRDs required for the project. Due to the nature of the work, there is expected to be limited OMRR&R. Additional details will be developed in PED. OMRR&R for this component is a 100 percent non-Federal sponsor responsibility.

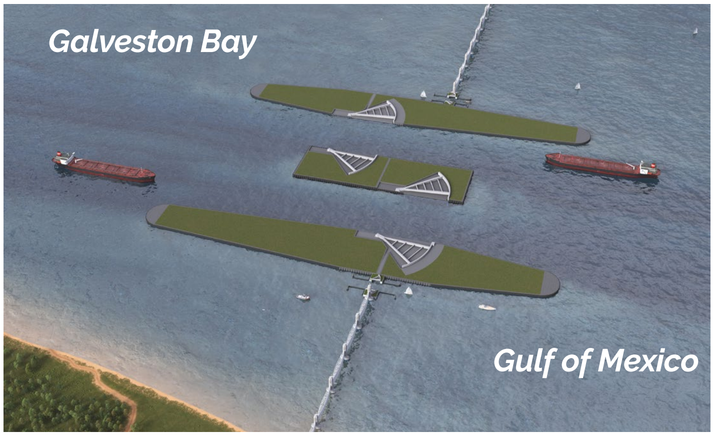
Federal implementation of the Coastwide ER Plan, not including the portions of ER Measure B12 and ER Measure M8 located on USFWS property, would be subject to the non-Federal sponsor(s) agreeing in a binding written agreement to comply with applicable Federal laws and policies, and to perform the following required items of cooperation:

*Example of artificial oyster reef balls*

1. Provide 35 percent of total ecosystem restoration costs as further specified below:
   - Provide the non-Federal share of design costs allocated by the Government to ecosystem restoration in accordance with the terms of a design agreement entered into prior to commencement of design work for ecosystem restoration features of the project;
   - Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs allocated by the Government to ecosystem restoration;
   - Provide all lands, easements, and rights-of-way, including those required for relocations, borrow material and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material, all as determined by the Federal Government to be required or to be necessary for the construction, operation, and maintenance of the ecosystem restoration features of the project;
   - Provide, during construction, any additional funds necessary to make its total contribution equal to 35 percent of total ecosystem restoration costs.
2. Do not use funds provided by a Federal agency under any other Federal program, to satisfy, in whole or in part, the non-Federal share of the cost of the project unless the Federal agency that provides the funds determines that the funds are authorized to be used to carry out the project;
3. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 Code of Federal Regulations (CFR) Part 24, in acquiring lands, easements,

and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, borrow material, or the disposal of dredged or excavated material; and informing all affected persons of applicable benefits, policies, and procedures in connection with said Act;

4. For so long as the project remains authorized, the non-Federal sponsor will operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, and these costs will be borne by the non-Federal sponsor at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;
5. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;
6. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;
7. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 CFR Section 33.20;
8. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5), and Section 103 of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element;
9. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army" and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c et seq.);
10. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;
11. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;
12. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA;
13. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the ecosystem restoration features, hinder operation and maintenance of the project, or interfere with the project's proper function; and,
14. Not use project or lands, easements, and rights-of-way required for the project as a wetlands bank or mitigation credit for any other project.




*Conceptual rendering of Bolivar Roads Gate System*

*Conceptual rendering of South Padre Island beach nourishment*

## 6.1.2. CSRM Components of the Recommended Plan

As discussed in Chapter 3, the Recommended Plan consists of two CSRM components, South Padre Island (SPI) Beach Nourishment and Sediment Management and the Galveston Bay Storm Surge Barrier System. For the SPI Beach Nourishment and Sediment Management feature, the expected equivalent annual net benefits are estimated at $1,955,000 (FY21 price level, 2.50% discount rate) with $72,357,000 in project first costs, at a FY21 price level, and a Benefit-Cost Ratio (BCR) of 0.68, without inclusion of recreation benefits, and 2.03 when including recreation benefits. The Federal share of the project first cost is $28,735,000. The non-Federal share of the project first cost is $43,622,000, subject to LERRD crediting.

For the Galveston Bay Storm Surge Barrier System, expected equivalent annual net benefits are estimated at $1,097,000,000 (FY21 price level, 2.50% discount rate), with $26,128,041,000 in project first costs, at a FY21 price level, and a BCR of 1.91. The Federal share of the project first cost, including renourishment, is $16,140,058,000. The non-Federal share of the project first cost, including renourishment, is $9,987,983,000, subject to LERRD crediting. The Federal and non-Federal share of the project first cost of renourishment is $544,111,000 (50 percent each).

*The Recommended Plan consists of two CSRM components, South Padre Island (SPI) Beach Nourishment and Sediment Management and the Galveston Bay Storm Surge Barrier System*

The Federal Government will be responsible for PED and construction of the project in accordance with the applicable provisions of Public Law 99-662 (WRDA of 1986), as amended. The Federal Government, subject to Congressional authorization, the availability of funds, and the execution of a binding agreement with the non-Federal sponsor(s) in accordance with Section 221 of the Flood Control Act of 1970, as amended, and using those funds provided by the non-Federal sponsor(s), shall expeditiously construct the project, applying those procedures usually applied to Federal projects, pursuant to Federal laws, regulations, and policies.

The GCPD, in partnership with various local entities, is anticipated to serve as the non-Federal sponsor for PED, construction, and OMRR&R of the upper Texas coast CSRM features. The GLO, in partnership with various local entities, is anticipated to serve as the non-Federal sponsor for PED, construction, and OMRR&R of the South Padre Beach Nourishment and Sediment Management measure. Among other responsibilities, the non-Federal sponsor must provide all LERRDs required for the project. Work-in-kind (WIK) associated with the construction of CSRM features will be negotiated with the non-Federal sponsor(s), contingent upon approval at the Assistant Secretary of the Army for Civil Works (or appropriate designee) and in accordance with applicable guidance and regulations.

*Example of a beach access point over a dune on South Padre Island*

OMRR&R for SPI Beach Nourishment and Sediment Management is anticipated to be coordinated with the City of South Padre Island and Cameron County, with support of the GLO. However, due to the nature of the work, there is expected to be limited OMRR&R. Additional details will be developed in PED. OMRR&R for this component is a 100 percent non-Federal sponsor responsibility. OMRR&R for the Galveston Bay Storm Surge Barrier System is anticipated to be coordinated with a newly created entity, with support of the GLO. OMRR&R for this component is estimated to cost $131,000,000 (FY21 price level, 2.50% discount rate) on an average annual basis and is a 100 percent non-Federal sponsor responsibility.

*The Federal Government will be responsible for PED and construction of the project. The USACE shall expeditiously construct the project, pursuant to Federal laws, regulations, and policies*

In addition, the non-Federal sponsor and/or it's local partners are required to:

- Prepare and implement a Floodplain Management Plan in coordination with the USACE to maintain the integrity, purpose and functionality of the project;
- Participate in and comply with floodplain management programs;
- Provide annual notifications regarding the extent of risk reduction afforded by the project; and
- Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) which might reduce the level of risk reduction the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function.

Federal implementation of the CSRM components of the Recommended Plan would be subject to the non-Federal sponsor(s) agreeing in a binding written agreement to comply with applicable Federal laws and policies, and to perform the following required items of cooperation:

1. Provide 35 percent of total project costs as further specified below:
   » Provide the required non-Federal share of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

*Conceptual rendering depicting the Bolivar dune system connected to the proposed levee system*

- » Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs;
- » Provide all lands, easements, and rights-of-way, including those required for relocations, borrow material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material, all as determined by the Government to be required or to be necessary for the construction, operation, maintenance, repair, rehabilitation and replacement of the project;
- » Provide, during construction, any additional funds necessary to make its total contribution equal to 35 percent of total project costs;

2. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the funds verifies in writing that such funds are authorized to be used to carry out the project;
3. Not less than once each year, inform affected interests of the extent of protection afforded by the project;
4. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;
5. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a PPA, and to implement such plan not later than one year after completion of construction of the project;
6. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the project;
7. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function;
8. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601- 4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, borrow material, or the disposal of dredged or excavated material; and informing all affected persons of applicable benefits, policies, and procedures in connection with said Act;
9. For so long as the project remains authorized, OMRR&R costs for the project or functional portions of the project, including any mitigation features, will be borne by the

non-Federal sponsor at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and state laws and regulations and any specific directions prescribed by the Federal government; provided, however, the non-Federal sponsor shall not be obligated to OMRR&R costs associated with flood proofing measures that constitute elevation of individual residential structures or flood proofing around individual non-residential or light industry/warehouse structures.

10. Give the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;
11. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;
12. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 CFR Section 33.20;
13. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c et seq.);
14. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the CERCLA, Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be required for construction, operation, and maintenance of the project, including those lands, structures and interests necessary for the implementation of all of the localized storm surge risk reduction components of the Project as described in this report. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;
15. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;
16. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, the non-Federal sponsor will operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and
17. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element;
18. Shall not use any project features or lands, easements, and rights-of-way required for such features as a wetlands bank or mitigation credit for any other project;
19. Pay all costs due to any project betterments or any additional work requested by the sponsor, subject to the sponsor's identification and request that the Federal Government accomplish such betterments or additional work, and acknowledgment that if the Federal Government in its sole discretion elects to accomplish the requested betterments or additional work, or any portion thereof, the Federal Government shall so notify the non-Federal sponsor in writing that sets forth any applicable terms and conditions.

## 6.2. Cost Apportionment Summary

Table 6.1 provides a summary of the estimated costs and benefits for the Recommended Plan. This information is presented separately for each component, including the Coastwide ER Plan, SPI Beach Nourishment and Sediment Management, and the Galveston Bay Storm Surge Barrier System. Each CSRM measure has a strong BCR, 2.03 for South Padre and 1.91 for Galveston Bay, and the Coastwide ER Plan generates over 21,010 average annual habitat units (AAHUs). A BCR over one indicates that the benefits of the project exceed the costs, which is a requirement for Federal investment.

| | South Padre Island Beach Nourishment and Sediment Management (2035 Base Year) | Galveston Bay Storm Surge Barrier System (2043 Base Year) | Coastwide ER Plan | Total First Cost |
|---|---|---|---|---|
| **Project First Cost** | $72,357 | $26,128,041 | $2,672,733 | $28,873,131 |
| **Total Average Annual Cost** | $1,904 | $1,208,000 | N/A | |
| **Equivalent Annual Benefits** | $3,894 | $2,306,000 | 21,010 AAHUs | |
| **Equivalent Annual Net Benefits** | $1,955 | $1,097,000 | N/A | |
| **BCR** | 2.03 | 1.91 | N/A | |
| FY21 Price Level, 2.50% Discount Rate, Presented in $1,000s | | | | |

***Table 6.1:*** *Total Costs and Benefits of the Recommended Plan*

Tables 6.2 through 6.4 provide the cost apportionment for the CSRM and ER portions of the Recommended Plan. More detailed information on cost estimates is provided in Chapter 10 of Appendix D, the Engineering Appendix. Additional information on Real Estate costs is also provided in Appendix F, the Real Estate Appendix.

*The Federal Plan cost represents the total Federal investment to fully fund the CSRM and ER features included in the Recommended Plan*

In addition, as stated in Chapters 2 and 3, the tie-in levee section associated with the Bolivar Roads Gate System is located in a CBRA zone and is not eligible for an exemption. Therefore, the cost of this feature must be borne fully by the non-Federal sponsor. As such, the costs for this feature have been added exclusively to the non-Federal cost share. Additional details related to these CBRA discussions can be found in Appendix E of the Final EIS. In addition, all LERRDs are subject to credit against the construction cost.

| | South Padre Island Beach Nourishment and Sediment Management | Galveston Bay Storm Surge Barrier System | Coastwide ER Plan | Total First Cost |
|---|---|---|---|---|
| **PED** | $7,242 | $3,164,419 | $322,903 | $3,494,564 |
| **Construction/Renourishment** | $44,148 | $20,748,493 | $2,116,746 | $22,909,388 |
| **LERRD** | $18,328 | $964,985 | $106,079 | $1,089,392 |
| **Construction Management** | $2,638 | $1,250,143 | $127,005 | $1,379,786 |
| **Total Project First Costs** | $72,357 | $26,128,041 | $2,672,733 | $28,873,131 |

*FY21 Price Level, Presented in $1,000s*

***Table 6.2:*** *Recommended Plan – Cost Summary (Project First Costs)*

| | Coastwide ER Plan | | Total First Cost |
|---|---|---|---|
| | FED (65%)[1] | NON-FED (35%)[2] | |
| **PED** | $227,540 | $95,363 | $322,903 |
| **Construction** | $1,492,330 | $624,417 | $2,116,746 |
| **LERRD** | -- | $106,079 | $106,079 |
| **Construction Management** | $89,540 | $37,465 | $127,005 |
| **Total Project First Costs** | $1,809,409 | $863,324 | $2,672,733 |

*FY21 Price Level, Presented in $1,000s*

*[1] Federal cost includes approximately $403 million of cost anticipated to be separately authorized and funded.*
*[2] Non-Federal cost includes 35% of the Coastwide ER Plan, excluding the approximately $403 million anticipated to be separately authorized and funded.*

***Table 6.3:*** *Coastwide ER Plan – Cost Apportionment (Project First Costs)*

| | Cost Share % | | South Padre Island Beach Nourishment and Sediment Management | | Galveston Bay Storm Surge Barrier System[1] | | Total First Cost | |
|---|---|---|---|---|---|---|---|---|
| | FED | NON-FED | FED | NON-FED | FED | NON-FED | FED | NON-FED |
| ***INITIAL CONSTRUCTION*** | | | | | | | | |
| **PED** | 65% | 35% | $1,278 | $688 | $1,962,653 | $1,066,863 | $1,963,931 | $1,067,551 |
| **Construction** | 65% | 35% | $5,834 | $3,141 | $12,858,390 | $6,990,747 | $12,864,224 | $6,993,889 |
| **LERRD**[2] | | 100% | -- | $18,328 | -- | $964,985 | -- | $983,313 |
| **Construction Management** | 65% | 35% | $343 | $185 | $774,905 | $421,277 | $775,248 | $421,461 |
| | **SUB TOTAL** | | **$7,455** | **$22,342** | **$15,595,948** | **$9,443,872** | **$15,603,403** | **$9,466,215** |
| ***RENOURISHMENT*** | | | | | | | | |
| **PED** | 50% | 50% | $2,638 | $2,638 | $67,452 | $67,452 | $70,090 | $70,090 |
| **Renourishment** | 50% | 50% | $17,587 | $17,587 | $449,678 | $449,678 | $467,265 | $467,265 |
| **LERRD**[2] | | 100% | -- | -- | -- | -- | | -- |
| **Construction Management** | 50% | 50% | $1,055 | $1,055 | $26,981 | $26,981 | $28,036 | $28,036 |
| | **SUB TOTAL** | | **$21,280** | **$21,280** | **$544,111** | **$544,111** | **$565,390** | **$565,390** |
| | ***GRAND TOTAL*** | | ***$28,735*** | ***$43,622*** | ***$16,140,058*** | ***$9,987,983*** | ***$16,168,793*** | ***$10,031,605*** |

*FY21 Price Level, Presented in $1,000s*

*[1] Non-Federal costs for the Galveston Bay Storm Surge Barrier System include 100% of the costs of the Levee Tie-in located in the CBRA zone.*
*[2] LERRDs are the responsibility of the Non-Federal sponsor. However, LERRDs are subject to crediting against the construction cost.*

***Table 6.4:*** *CSRM Measures – Cost Apportionment (Project First Costs)*

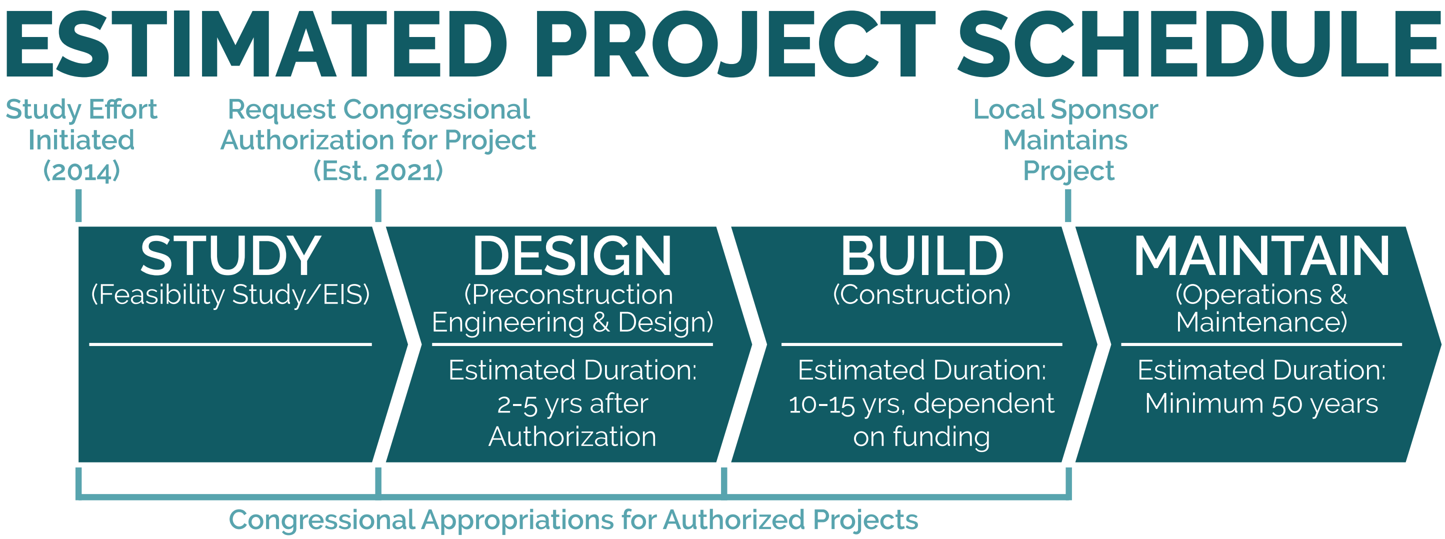



***Figure 6.1:*** *Coastal Texas Study project phases*

## 6.3. Preconstruction Engineering and Design and Construction Sequencing

At the completion of the Feasibility Study, and upon approval by the Chief of Engineers of the United States Army, the Recommended Plan would be provided to Congress for authorization and funding. If authorized and funded by Congress, subsequent phases of the project would include PED, Construction, and Operations and Maintenance. This project lifecycle, showing anticipated durations of each phase, is illustrated in Figure 6.1.

Completion of PED and construction of the Recommended Plan, specifically the pace of construction, is highly dependent on Congressional approval and funding. Assuming an ample funding stream, the Recommended Plan described could be designed and then constructed over a period of 12 to 20 years. Furthermore, construction sequencing will also be dependent on completion of supplemental environmental studies, in accordance with the tiered National Environmental Policy Act (NEPA) approach described more fully in Chapter 4. Ultimately, implementation activities will be optimized to consider the size and frequency of funding infusions, environmental clearance of individual components, and beneficial sequencing. Shown on the following pages are a variety of prioritization strategies which could be employed to phase or sequence the various components of the Recommended Plan.

At the macro level, should a regionalized implementation strategy be employed, it will be critical to consider the interconnected nature and dependencies of the various CSRM and ER features which comprise the envisioned multiple lines of defense. Accordingly, the following regional grouping should be considered:

- **Upper Texas Coast**: including the Galveston Bay Storm Surge Barrier System and ER measures G28, B12, and B2.
- **Mid to Upper Texas Coast**: including ER measures M8, CA5, and CA6
- **Mid Texas Coast**: including ER measure SP1
- **Lower Texas Coast**: including the South Padre Island Beach Nourishment and Sediment Management measure and ER measure W3


*Conceptual rendering of the proposed Bolivar Roads Gate System, which is a key component of the Galveston Bay Storm Surge Barrier System*

## Prioritization Strategies

***Due to the size of the efforts, uncertainty in funding, and varied timelines for future NEPA compliance, different prioritization strategies were reviewed as part of this study. The different strategies presented below should be reviewed by decision makers as funding streams are discussed and construction sequencing is finalized.***

### *First Line of Defense*

This strategy would focus on the first line of defense features, specifically closing off Galveston Bay to surges (and prioritizing construction of the Bolivar Roads Gate System first). This would achieve the greatest level of risk reduction in the earlier increments. This approach would still leave many of the backbay communities, including the City of Galveston, open to surges washing over Galveston Island and Bolivar Peninsula. However, it would prioritize funding for the surge gate, which is the main feature contributing to the system's overall performance. This strategy would also focus on implementing Ecosystem Restoration features in areas of high erosion in order to take steps to slow or stop erosion. This would prevent the problem from becoming worse or more expensive as the landscape changes.

### *Sync Action with Source Material*

This strategy would focus on developing and maximizing cost savings as the system is built. In the development of the cost estimates for this report, linking of beneficial use between construction elements or beneficially using dredged materials from adjacent navigation projects, such as the Houston Ship Channel project, was not conducted. This strategy would prioritize the funding and construction of features based on the potential to use material beneficially. For example, the construction of the surge gate would excavate 14.8 million cubic yards of material. Much of this material could be used for adjacent ER sites, or for the beach and dune features on Galveston Island and Bolivar Peninsula. Also, recently, Congress authorized a portion of the Houston Ship Channel Expansion Project 11, which may also be a source of material for project features. The Houston Ship Channel project is estimated to produce ~ 30 million cubic yards of dredge material between the proposed Federal and local efforts. Although not all of the dredged material from the gate construction, or adjacent navigation projects, will be suitable for beneficial use, nor may the timing of funding line up, it represents a significant potential cost savings to investigate in PED and to consider when finalizing construction sequencing.

### *NEPA Driven*

This strategy would focus on constructing increments of the project as environmental compliance is achieved for individual measures. Initially, this would include construction of six of the eight ER measures, as these measures will have full environmental compliance at the time of the signed Chief's Report in 2021. By acting as soon as environmental compliance is achieved, this method would prevent the existing landscape from being further degraded as the final design and final NEPA evaluation of remaining components (e.g. the Bolivar Roads Gate System) is completed. As discussed in Chapter 2, the natural and nature-based features serve as the backbone of the overall system, when the entire system is in place. The NEPA driven strategy can also be seen as a constrain since many of the complex structural system would not start construction until the NEPA compliance is completed.

### *Equitable Regional Distribution*

This strategy would focus on building components in each region along the Texas coast. This would ensure that both ER and CSRM problems would be treated equally and would also equitably distribute work across the region to allow for a broader distribution of Regional Economic Development benefits. Such a strategy would also support the non-Federal sponsor's goal of advancing comprehensive coastal resiliency throughout the entire Texas coast. Critically, many of the ER measures also increase the resiliency of critical coastal economic facilities and features, such as the Gulf Intercoastal Waterway.

### *"No Regrets"*

This strategy would be based on a risk evaluation considering funding uncertainties and the potential that the entire Recommended Plan may not be constructed. Questions such as "can this individual feature be implemented alone and still be functional?" would have to be investigated in PED. Other questions such as "would there be an increased life safety risk or financial risk if features would be implemented alone?" would also have to be investigated. Ultimately, this strategy would prioritize measures which could stand alone, separate from any other recommended plan features.

Regardless of the prioritization strategy, the Bolivar Roads Gate System is still one of the most complex features to design and has one of the longest construction durations. Critical activities, related to the Bolivar Roads Gate system, which are anticipated to occur during PED include:

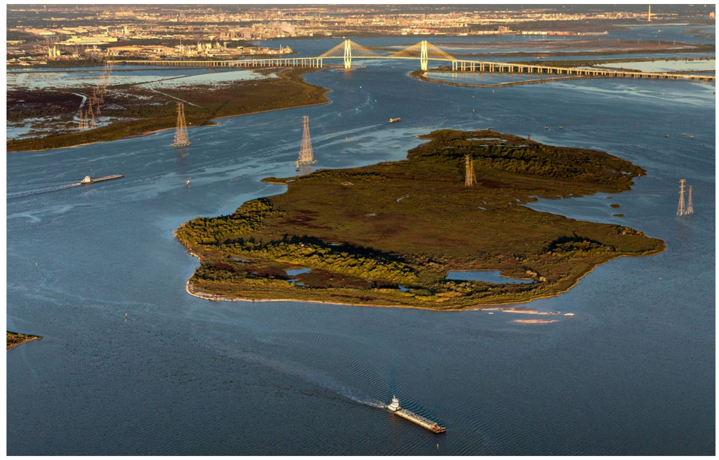
- Geotechnical investigation
- Preliminary Design
- Physical Modeling
- Ship Simulation
- Hydrodynamic, wave, and sediment transport modeling, to include beach morphology
- Environmental Modeling
- Final Design
- Completion of Tier Two NEPA environmental document

Also, as discussed in one of the called out prioritization strategies, due to the critical need to prevent further degradation of the barrier islands, the remaining Gulf defense features (and the ER features that support them) are recommended to be designed and constructed first while final design for the Bolivar Roads Gate System is being completed. This would ensure that the Bolivar Roads closure would have an established tie in point when the construction activities are ready to begin on the Bolivar Roads Gate System.

Accordingly, the initial focus should be on designing and constructing the 43 miles of beach and dune improvements on Bolivar Peninsula and West Galveston Island and the 10 miles of Galveston Seawall Improvements. Initial contracts should focus on the dune segments on Bolivar Peninsula near the proposed levee tie-in, north of the Bolivar Roads Jetty System. From that point, the design and construction sequence should expand outward to ensure that changes in the future landscape over the 10 to 15-year construction period would not impact the design of the large gate system. Key considerations, related to the Bolivar and West Galveston beach and dune system, to be evaluated during PED include:

- Hydrologic and hydraulic modeling
- Development of the Drainage Plan
- Identification of sediment sources
- Completion of Tier Two environmental document

ER features that provide resilience to recently constructed beach and dune features should also be designed and constructed in the initial years. Also, the NEPA driven prioritization process is equally important as six of the eight features in the Coastwide ER Plan will have full environmental compliance at the time of the signed Chief's Report in 2021. This would allow dredging contracts to be linked to the beach and dune work and other similar ER features. The Study Team has already identified nearshore and offshore sediment sources that could be linked to the initial construction contracts. As discussed in the material prioritization strategy, there are also



*Dredge material from the Houston Ship Channel Expansion Channel Improvement Project may serve as source material for constructing select portions of the Galveston Bay Storm Surge Barrier*

opportunities to source material from upcoming dredging associated with the recently authorized Houston Ship Channel Expansion Channel Improvement Project, or similar future efforts. As part of the Houston Ship Channel Feasibility Study, the USACE and the Port of Houston Authority developed a Dredged Material Management Plan that estimated over 300 million cubic yards of shoaling material would have to be dredged over the 50-year life of the project. Part of the PED process would be to investigate what material may be used beneficially to support construction of the ER and beach and dune features proposed in the Recommended Plan.

Other features along the Texas Coast, such as the remaining ER features outside of the upper coast, or the SPI Beach Nourishment and Sediment Management feature, should be constructed as soon as environmental clearance is achieved and final designs are completed. Furthermore, as the Recommend Plan is based on current conditions, further degradation of the environment would only add to the overall cost of the Recommended Plan.

The design and construction of the Gulf defense features used to manage the residual risks are recommended to be linked to the estimated completion date of the Bolivar Roads Gate System. Primarily, this includes the Galveston Ring Barrier System and the two surge gates at Clear Lake and Dickinson Bay. Critical activities to be conducted for these features during PED include design refinement, and completion of Tier Two NEPA environmental documentation. Given that the final design of these features are impacted by the overtopping rates of the dune features, and also by changes in relative sea level rise over the next 10 to 15 years, these features should be adaptable based on the final design of the Gulf defense features.

A photo of beach and dunes at Padre Island National Seashore

# 7. Recommendations

USACE Feasibility Reports are required to conclude with a statement from the Commander of the lead USACE District conducting the study, in this instance the Galveston District, attesting to the information and findings presented and recommending approval and funding of the subject project. As such, the following sections represent the findings and recommendations of the USACE Galveston District Commander, Colonel Timothy Vail, reflecting the information available at this time.

## 7.1. Overview

I have given consideration to all significant aspects in the overall public interest and concur with the findings presented in this report, the Coastal Texas Protection and Restoration Feasibility Study. The Recommended Plan developed is technically sound, economically justified, and socially and environmentally acceptable. In accordance with the National Environmental Policy Act (NEPA), a diligent effort was made to coordinate and collaborate with resource agencies, local industry, and environmental interests. Environmental resource concerns were addressed through the study process to assure that adverse impacts were avoided to the maximum extent practicable. To ensure the Recommended Plan complies with all applicable laws and policies and is acceptable to the public, this Final Feasibility Report and attached Final Environmental Impact Statement (EIS) has undergone multiple rounds of public, policy, and technical review. The Study Team has addressed all outstanding issues raised during the reviews. As necessary, supplemental environmental documentation, in the form of Tier Two NEPA assessments, will be prepared and released as additional design work is completed.


*Col. Timothy R. Vail*
*U.S. Army Corps of Engineers*
*Galveston District Commander*

Along the Texas coast, vital resources critical to the social, economic, and environmental welfare of the nation are at risk. When tropical disturbances negatively impact the man-made and natural environments of the Texas coast, the immediate fallout and the continued aftermath affects not only the people who live in these coastal counties and the biologic and economic productivity of the Texas coast, but also the entire nation.

The Recommended Plan includes a combination of ecosystem restoration (ER) and structural and non-structural coastal storm risk management (CSRM) features that function as a system to reduce the risk of coastal storm damages to natural and man-made 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 and is adaptable to future conditions. The Recommended Plan, as illustrated in Figure 7.1, can be broken into three groupings:

- 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. ER plan benefits have been estimated with standard habitat valuation procedures. The lowest-cost comprehensive ER plan is recommended.
- On the lower Texas coast, a CSRM beach restoration measure on South Padre Island (SPI) was formulated in a traditional National Economic Development (NED) framework to include 2.9 miles of beach nourishment and sediment management. The plan proposes beach nourishment on a 10-year cycle for the authorized project life of 50 years.
- On the upper Texas coast, the Galveston Bay Storm Surge Barrier System was formulated as a system with multiple lines of defense to reduce damage to communities, critical petrochemical and refinery complexes, Federal navigation channels, and other existing infrastructure in and around Galveston bay from storm surge.

  Specific to the upper Texas coast, the Gulf defenses separate Galveston Bay from the Gulf of Mexico to reduce storm surge volumes entering the Bay. Components which make up the Gulf defenses include:

  » The Bolivar Roads Gate System, across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island;

  » 43 miles of beach and dune segments 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; and

  » Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge.

  The Bay defenses enable the system to manage residual risks. Residual risks are driven by the combination of water from Galveston Bay and Gulf surge that overtops the front-line defenses. The Bay defenses also provide further resiliency against variations in storm track and intensity and relative sea level changes. Bay defense components include:

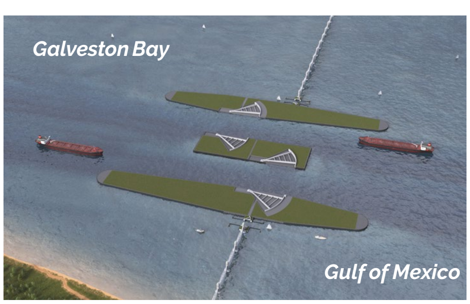
  » An 18-mile Galveston Ring Barrier System that impedes Bay waters from flooding neighborhoods, businesses, and critical health facilities within the City of Galveston;

  » 2 surge gates on the west perimeter of Galveston Bay (at Clear Lake and Dickinson Bay) that reduce surge volumes that push into neighborhoods around the critical industrial facilities that line Galveston Bay; and

  » Complementary nonstructural measures, such as home elevations or floodproofing, to further reduce Bay-surge risks along the western perimeter of Galveston Bay.

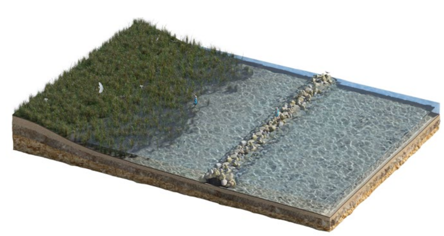
Over 1,378 acres of habitat will be created or enhanced to offset potential direct and indirect impacts to wetlands and oyster reefs under Recommended Plan.

By coordinating efforts across projects and between different entities, the Coastal Texas Study achieves its goal of identifying the specific projects necessary to fill in the gaps of a state-wide comprehensive CSRM and ER program.




*Conceptual rendering of Bolivar Roads Gate System*

*Conceptual rendering of South Padre Island beach nourishment*



*Conceptual rendering of marsh restoration with a rock breakwater*

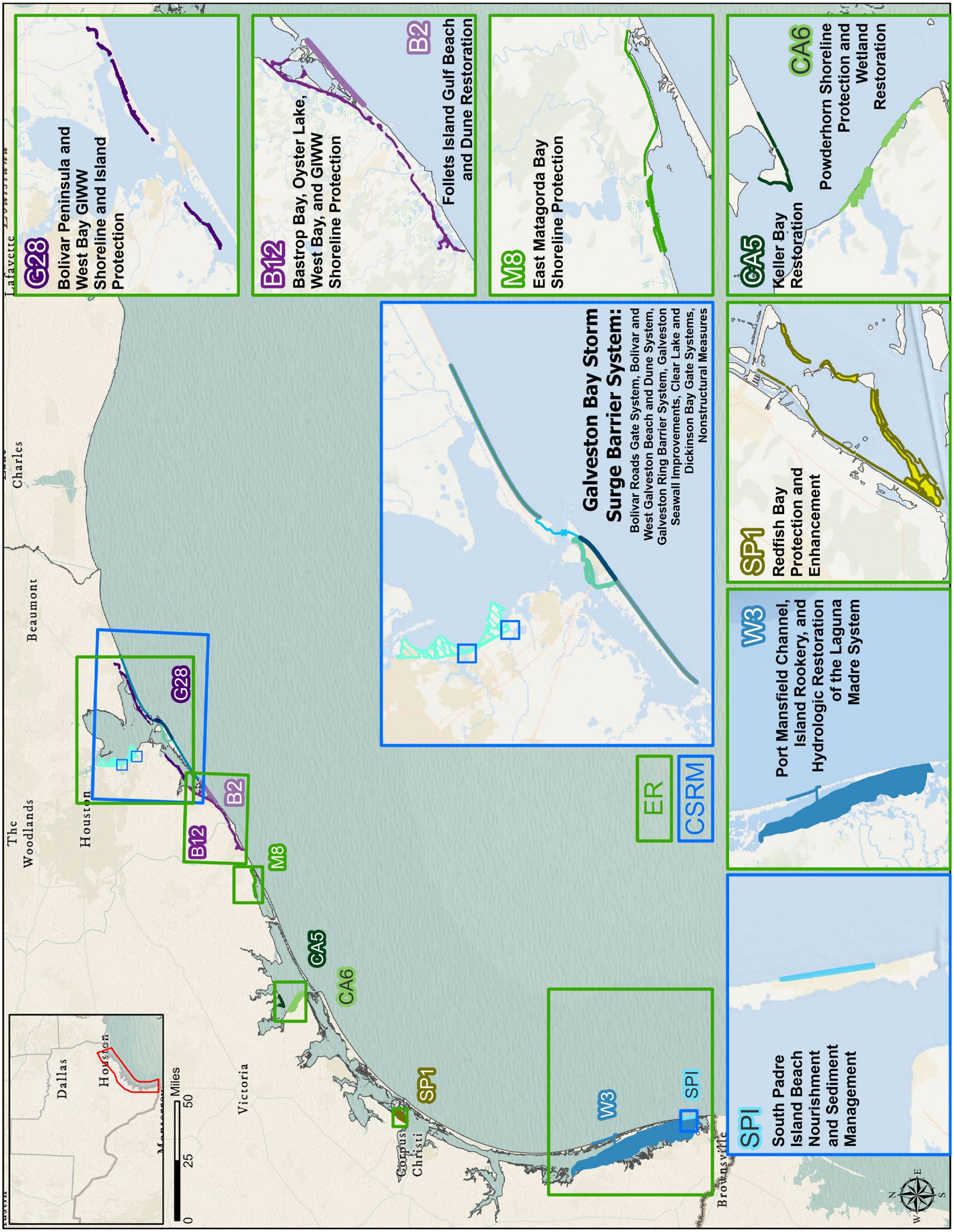



*Figure 7.1: Recommended Plan*

Land, Easements, Rights-of-Way, Relocations, and Disposal Areas (LERRDs) required for the Recommended Plan are detailed as follows:

- The CSRM features will require approximately 3,400 acres of public and private lands within Harris, Galveston, Brazoria, and Cameron counties. Estates required for the CSRM features are standard estates (No. 1, 9, 15, and 26), in addition to the application of navigational servitude for the construction of gate structures on state submerged lands. 65 parcels with residential structures may require P.L. 91-646 home relocation assistance. One hundred ninety-three utility/pipeline relocations have been identified within the CSRM footprint.
- The ER features will require approximately 6,300 acres of public and private lands within Calhoun, Brazoria, Matagorda, San Patricio, Willacy, and Galveston counties. Non-standard estates and fee estate (No.1) will be required for the construction and future O&M of the ER features. There are no residential or commercial relocations expected for this aspect of the project.

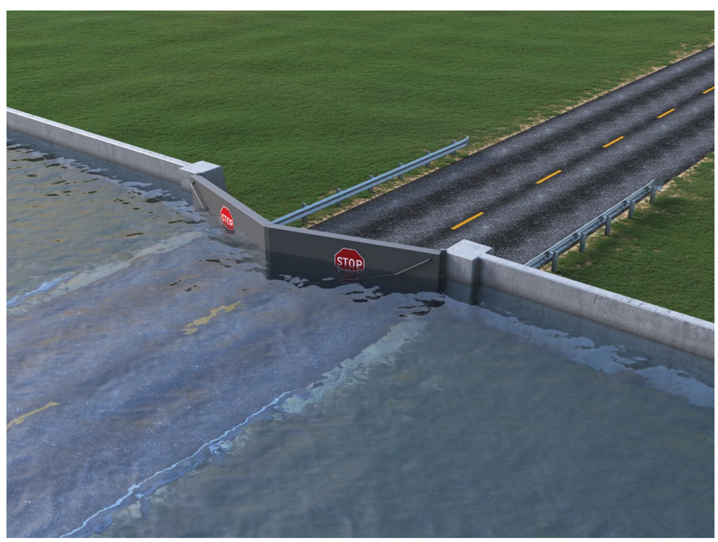
The Coastwide ER Plan would generate a total of 21,010 average annual habitat units (AAHUs) by creating or restoring 114 miles of breakwaters, 15.2 miles of bird rookery islands, 2,052 acres of marsh, 12.32 miles of oyster reef, and 19.5 miles of beach and dune within eight locations across the coast. The project first cost of the Coastwide ER Plan is estimated at $2.67 billion (FY21 Price Level), and cost-share for the design and construction of the project will be 65% federal and 35% non-Federal, not including the costs anticipated to be separately authorized and funded.

The SPI Beach Nourishment and Sediment Management measure's expected equivalent annual net benefits are estimated at $1.96 million (FY21 Price Level, 2.50% Discount Rate). This reflects the net difference between average annual costs and equivalent annual benefits (including recreation and flood risk reduction), assuming both costs and damages from storms were distributed equally across a fifty-year period of analysis. The project first cost is estimated at $72.36 million (FY21 Price Level). The Federal share of the project first cost is $28.74 million. The non-Federal share of the project first cost is $43.62 million, subject to LERRD crediting. A Benefit-Cost Ratio (BCR) of 0.68 is attained prior to inclusion of recreation benefits, and this BCR increases to 2.03 with the inclusion of recreation benefits. A BCR over one indicates that the benefits of the project exceed the costs, which is a requirement for Federal investment.

The Galveston Bay Storm Surge Barrier System's expected equivalent annual net benefits are estimated at $1.1 billion (FY21 Price Level, 2.50% Discount Rate). This reflects the net difference between average annual costs and equivalent annual benefits (including flood risk reduction and regional economic development), assuming both costs and damages from storms were distributed equally across a fifty-year period of analysis. The project first cost is estimated at $26.13 billion (FY21 Price Level). The Federal share of the project first cost is $16.14 billion, including renourishment. The non-Federal share of the project first cost is $9.99 billion, including renourishment. OMRR&R is estimated to cost $131 million on an average annual basis (FY21 Price Level, 2.50% Discount Rate). The BCR is 1.91.

For the overall combined project, the project first cost is estimated $28.87 billion. The Federal share of the combined project first cost is $17.98 billion. The non-Federal share of the combined project first cost is $10.89 billion, pending LERRD credits. The combined BCR for the CSRM measures is 1.91.

In addition to these traditional USACE metrics, the Recommended Plan embraces a comprehensive approach to enhancing community resilience, considering the four USACE accounts (National Economic Development, Regional Economic Development, Environmental Quality, and Other Social Effects) and supporting the region's ability to prepare, withstand, recover, and adapt from coastal storms and to maintain critical social, economic, and support systems. Employed in a systems approach, the ER features also contribute to resilience, creating, protecting, or enhancing sensitive and nationally significant ecosystems while helping to sustain the barriers that the major structural systems (e.g. the Bolivar Roads Gate System) tie into. The result is a system-wide risk management strategy for the coastline of Texas integrating structural and non-structural coastal storm damage risk reduction actions with ecosystem restoration actions to enhance the resiliency of coastal communities and the living shoreline from coastal storms.




*Conceptual rendering of highway flood gate proposed as part of the Galveston Ring Barrier System*

The Recommended Plan conforms to the essential elements of the U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G), as referenced in Section 1.7, and complies with other Administration and legislative policies and guidelines for project development. If the project were to receive funds for Federal implementation, it would be implemented subject to the cost sharing, financing, and other applicable requirements of Federal law and policy, including WRDA 1986, as amended; and would be implemented with such modifications as the Chief of Engineers deems advisable within his discretionary authority.

## 7.2. Non-Federal Responsibilities

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 PED, Construction, and Operations and Maintenance. Various entities within the State of Texas, including the GLO and the Gulf Coast Protection District (GCPD), will serve as the non-Federal sponsors, with support from local entities, for future phases of the Coastal Texas Protection and Restoration Plan. Specifically, the GLO has issued a Letter-of-Intent stating its intent to serve as the non-Federal sponsor for the ER measures and the South Padre Island Beach Nourishment and Sediment Management measure, while the GCPD has issued a Letter-of-Intent stating its intent to serve as the non-Federal sponsor for the upper Texas coast CSRM features. In addition, 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 GLO, GCPD, and the USACE in the implementation of this project.

Federal implementation of the project would be subject to the identified non-Federal sponsor(s) agreeing to comply with applicable Federal laws and policies. Furthermore, the non-Federal sponsor(s) shall, prior to implementation, agree to perform the required items of cooperation detailed in Chapter 6 of this report.

## 7.3. Recommendation

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels with the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorizations and implementation funding. However, prior to transmittal to the Congress, the non-Federal sponsor, the state, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

26 APRIL 2021
Date

Timothy R. Vail
Colonel, U.S. Army
Commanding

**COASTAL TEXAS COSTS & BENEFITS**
*BY THE NUMBERS...*

**~$2.31 Billion**
*EQUIVALENT ANNUAL BENEFITS*

**1.91 BCR**
*FOR THE COMBINED CSRM MEASURES*

**IN A 1% AEP SURGE EVENT:**

**~77%**
*REDUCTION IN DAMAGED STRUCTURES*

**~64%**
*REDUCTION IN FLOODED CRITICAL INFRASTRUCTURE POINTS*

**21,010**
*AAHUs ECOLOGICAL LIFT*

**6,610**
*ACRES HABITAT IMPROVED*

**~$28.87 Billion**
*TOTAL RECOMMENDED PLAN PROJECT FIRST COST (CSRM & ER)*

US Army Corps of Engineers®
Galveston District

# KEY TERM LIST

**Actionable Features (aka Actionable Measures):** For purposes of this study, and within the context of a Tiered NEPA strategy, **Actionable Features** are defined as portions of the Recommended Plan that have sufficient site-specific detail to fully understand the context and intensity of the anticipated impacts of the feature on the environment at the time of this report, thereby allowing for the completion of all necessary environmental compliance consultation and documentation in the accompanying Environmental Impact Statement (EIS).

For these actionable features, additional environmental compliance documentation would not be necessary in the future unless changes were made during the PED phase that warranted additional NEPA study, or if site conditions change significantly.

See also, **Tier One Features**

**Alternative:** Potential solutions to address a specific concern or issue. An alternative may be a combination of one or more measures that, together, would address one or more of the study objectives.

**Annual Exceedance Probability (AEP):** The estimated chance (probability) that a storm will happen in any given year. For example, a 100-year storm event has a 1 percent chance (or 1-in-a-100 chance) of occurring in any given year. The term "100-year storm" allows us to place a particular weather event in context with other similar events. Note that the probability remains even after a storm has occurred. *It does not mean* that a storm of that size will happen only once in 100 years.

**Associated Cost:** Any public or private Federal or non-Federal expenditures necessary to achieve estimated benefits for each project alternative, such as recreational facilities for incidental recreational benefits claimed.

**Average Annual Habitat Unit (AAHU):** A unit of measure (like feet or dollars) that captures the effects of restoring a habitat (or impacting one) in terms of both the acres restored and the quality of that acreage with respect to the needs of fish, fowl or mammal. The unit is averaged and annualized to generate a habitat value on a yearly basis so that it can then be compared against yearly costs. These units can then be compared across alternatives to determine which solutions provide the most benefit for the least cost.

**Base Year:** The year when the proposed project is expected to be operational. For example: Forecasts should begin from the base year and extend to the end of the period of analysis.

**Batter Piling:** Long slender columns of steel or reinforced concrete driven into the ground at an angle and attached to a floodwall to provide support. The angled arrangement of the piles will provide resistance against forces (e.g., surge and waves) that push against the structure.

**Bay Bottom Habitat:** Includes unvegetated subtidal areas of various sediment types, which are open and interact with the water and adjacent habitats. Open-bay bottoms are characterized as having benthic organisms, epifauna at the surface of the substrate (e.g. crabs, small crustaceans) and infauna that burrow beneath the substrate (e.g. mollusks).

**Beach:** The narrow strip of shore land in immediate contact with the sea is called a beach when unconsolidated sediments, usually sand, are present.

**Beach-fill:** The artificial building up and/or widening of the beach by direct placement of fill material (usually sand) on the shore.

**Benefit:** A calculated return on investment. For CSRM features, benefits are usually calculated through the assessment of damage reduction (without project damages - with project damages = benefits). For CSRM features, benefits are captured in dollars. For ER features, benefits are captured using **average annual habitat benefits**.

**Benefit-Cost Analysis:** An assessment that summarizes the overall relationship between the relative costs and benefits of a proposed project.

**Benefit-Cost Ratio (BCR):** The ratio of discounted project benefits to discounted project costs. BCR's are less than one when a project's costs exceed its benefits, and BCRs are greater than one when a project's benefits exceed its costs.

**Berm (vs. Beach):** The dry, gently sloping, slightly elevated part of the beach that is found at the foot of sand dunes, while the beach face is the wet sloping surface that extends from the berm to the water.

**Breakwater:** A barrier built out into a body of water to protect a coast or harbor from the force of waves.

**CBRA zones:** The Coastal Barrier Resources Act (CBRA) of 1982 and its amendments prohibit most new federal expenditures that encourage development or modification of coastal barriers. The main prohibition affecting property owners is the prohibition on new federal flood insurance within the Coastal Barrier Resources System (CBRS). The CBRS consists of relatively undeveloped coastal barriers and other areas located the Atlantic, Gulf of Mexico, Great Lakes, U.S. Virgin Islands, and Puerto Rico coasts. The CBRS currently includes 585 System Units, which comprise nearly 1.4 million acres of land and associated aquatic habitat. These units of land are oftentimes referred to as CBRA zones.

**Cellular Cofferdams:** When building structures in the water, cofferdams are used to exclude water allowing engineers to construct features within a dry area (i.e., a cell). Cellular cofferdams are a series of interlinked sheet pile to form the cells, which are then filled with free-draining granular material (e.g., sand in this instance).

**Coastal Storm Risk Management (CSRM):** The implementation of features (or measures) to effectively reduce the risks of vulnerable coastal communities and increase coastal resilience. See CSRM Measure.

**Coastal Barrier System:** Landscape features that protect the mainland, lagoons, wetlands and salt marshes from the full force of wind, wave and tidal energy

**Coastal System:** Dynamic environments in which landscapes develop by the interaction of winds, waves, currents, and terrestrial and marine sediments.

**Combi-wall:** A type of floodwall utilized in deep waters that is constructed from a combination of deeply embedded piles (heavy columns) and partially embedded lighter piles that are interlocked and offer high resistance to the forces of waves and surge.

**Consequence:** The effect, result, or outcome of flooding as reflected in the potential loss of life, economic losses, and/or adverse environmental impacts.

**Critical Infrastructure:** The physical and cyber systems and assets that are so vital to the United States that their incapacity or destruction would have a debilitating impact on our physical or economic security or public health or safety.

**CSRM Measure (or CSRM Feature):** In the USACE planning process, Coastal Storm Risk Management measures (or features) are solutions that can be implemented at a specific geographic site to address the risks of potential impacts caused by coastal storm surge.  This includes measures such as surge gates and floodwalls.

**Crown Elevation:** The height of a dune. For purposes of this study, the top of the dune (its crown) is measured relative to mean sea level using the NAVD88 datum.

**Damages:** In economic terms, damages refer to the losses of residential and non-residential properties, transportation infrastructure, above ground storage tanks and their contents and production losses to the petrochemical industries due to flooding from storms.

**Demucking:** The removal of dirt or rock in advance of project construction.

**Depth:** Distance of the water surface straight down to the point of interest, such as the ground surface.

**Discounting:** The process of equating monetary values over time. It defines future sums of money in an equivalent value today. Discounting requires the use of a **discount rate**. This provides a common base of reference for projects.

**Discount Rate:** The rate society would use to equate amounts of money at different points in time. Using the discount rate, values can be expressed in current dollars and spread over the life of the project producing an "annual average" value for costs and for benefits.

**Dune:** A common feature of sandy coasts composed of wind-blown sand, generally in long ridges paralleling the shore and usually above the level of storm waves. Coastal dunes typically have a unique ecological niche with ecosystems that vary by elevation.  Dunes also protect the land against storm waves.

**Ecosystem:** A dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems.

**Ecosystem Restoration:** The process of restoring significant ecosystem function, structure, and dynamic processes to a system that has been degraded.

**Elevation:** The distance that any point on the ground is above a certain point.

**Equivalent Annual Benefits:** The economic value of the differences between the with- and without-project conditions during the entire period of analysis. National Economic Development (NED) benefits are measured in terms of dollar values of the physical losses to residential and nonresidential structures, their contents, vehicles, and in this study, impacts to above ground storage tanks and their contents.

**Equivalent Annual Damages:** Losses in economic value that occur under the with- and without-project conditions during the entire period of analysis due to coastal storm events. Most of National Economic Development (NED) damages are the physical losses to residential and nonresidential structures, their contents and vehicles. For this evaluation, impacts to above-ground storage tanks and their contents were included in the damages.

**ER Measure (or ER Feature):** In the USACE planning process, ecosystem restoration (ER) measures (or features) are solutions that can be implemented at a specific geographic site to improve the structure, function, and dynamic processes of ecosystems.

**Erosion:** The loss of beach or dune material, wetlands, or other coastal substrates,by the action of wind, waves, and currents.

**Estuarine Emergent Wetlands:** A habitat that includes tidally influenced wetlands that occur throughout the Texas Gulf coast, ranging from marshes characterized by persistent emergent vegetation to unvegetated mud and sand flats along the bay side of the coastal barrier islands. The upper and lower range of the tidal range control the extent and location of estuarine wetlands

**Estuarine System:** A partially enclosed, coastal water body where freshwater from rivers and streams mixes with salt water from the ocean. Estuaries, and their surrounding lands, are places of transition from land to sea.

**Feasibility Study:** In the USACE, a feasibility study is used to investigate the Federal interest, engineering feasibility, economic justification and environmental acceptability of a recommended water resources project. A feasibility study determines if Congressional authorization and implementation of a specific USACE Civil Works project is warranted.

**Fetch:** The distance traveled by wind or waves across open water. The area in which waves are generated by a wind having a fairly constant direction and speed.

**Floating Sector Gates:** A type of surge risk reduction barrier comprised of pie-shaped arms that, when activated, are floated out across the opening and sink down to provide a seal or closure across an inlet. The gates are housed on man-made islands when not in use.

**Flood Risk:** A measure of the probability and severity of undesirable consequences that may arise from inundation by flood waters.

**Floodwall (aka T-wall):** Structures that consist of a reinforced concrete wall and base in the shape of an inverted "T". Below the base, is a "cut-off" wall designed to prevent (or cut-off) seepage from groundwater compromising the wall's base. The floodwall itself is supported underneath by concrete of steel piles driven to resist the force of surge and waves.

**Geomorphic Functions:** The materials and processes (such as waves, winds, and tides) occurring at a given location which shape the landforms in terms of position, slope, elevation, aspect, geometry, etc.

**Geomorphic Landforms or Systems:** Landscape features that act as critical barriers between waterbodies.

**Geotechnical Investigations:** An assessment to obtain information about the physical properties of soils and foundations underlaying the proposed structures (e.g., the surge gates, floodwalls, levees, etc.). These investigations identify potential construction problems and evaluate distress to earthworks and structures caused by weakness or failure of subsurface materials. This information is needed in order to create foundation designs and other structural plans.

**Hazard:** A potential source of harm (e.g. fire, earthquake, flood, etc) to a valued asset (e.g. humans, animals, property, natural, economic, or social) or a situation with a potential to cause loss.

**Hydraulic Cylinders :** A hydraulic cylinder is made up of a steel tube, a piston with a rod attached that sticks out of the side and mounting accessories. Hydraulic cylinders are used to create mechanical force in a linear motion. They are used to lift something, push something, press something, and many other types of work. When you take your car to a mechanic and he raises it on a lift to inspect or work underneath, it is usually a hydraulic cylinder that accomplishes that.

**Hydrologic Connectivity :** The physical linkage of water from one location to another which, for example, can be attained by dredging channels to reconnect back bays to the Gulf of Mexico, or by adding drainage structures to allow water exchange between areas on land and the Bays/Gulf of Mexico.

**Incidental Recreation Benefits:** A measure of secondary outputs that can be assessed independently of the traditional National Economic Development (NED) benefits to capture the possible recreation value of a given feature.

**Iterative Process:** An approach to generating a final solution by repeatedly evaluating the outcomes. An iterative process should be convergent. In other words, the iterative process should come closer to the desired result as the number of iterations increases.

**Lifecycle Costs:** The sum of the construction costs, the interest incurred during construction, and the OMRR&R costs for an alternative.

**Life Safety Analysis:** Evaluating the risks of lives lost from the failure of a storm risk management feature (or system).

**Levee:** A bank of earth designed to prevent surge from flooding an area.

**Loading Frequency:** The rate of occurrence of an event measured in terms of the number of a particular type of event expected to occur in a particular time period of interest

**Multiple Lines of Defense Strategy:** A methodology to design coastal storm surge risk reduction through the use of man-made features (e.g., surge gates and floodwall) and natural features (e.g., beach and dune systems) in combination to provide redundancy and assure coastal resilience.

**Morphology:** The shape of the shore, nearshore, and offshore surface contours.

**National Economic Development (NED) Plan:** In the USACE Civil Works planning process, this is the plan that reasonably maximizes net national economic benefits consistent with protecting the nation's environment.

**National Ecosystem Restoration (NER) Plan:** In the USACE Civil Works planning process, this is the ecosystem restoration plan that that meets the planning objectives and constraints and reasonably maximizes net environmental benefits and is shown to be cost effective with reasonable cost increases for additional restoration benefit increments.

**Navigational Servitude:** A doctrine in United States constitutional law that gives the Federal Government the right to regulate navigable waterways as an extension of the Commerce Clause in Article I, Section 8 of the Constitution.

**Non-structural Improvements:** Changes to the assets that reduce the potential for flood damage, such as building elevation, retrofits, relocation, acquisition, and wet or dry floodproofing. Non-structural measures are distinct from "structural" measures that reroute the flow of the flood water within the study area.

**Non-standard Estates:** Any real estate conveyance document (i.e. deeds, easements, right of way, etc.) associated with a Federal project that deviates from Federally pre-approved language and must be individually approved by USACE Headquarters on a case-by-case basis.

When acquiring real estate for a Federal project, "standard estate" language is required. The government has a series of pre-approved standard estates that can be selected based on project needs (i.e. Standard Estate No. 8 "Channel Improvement Easement" might be used for a channel improvement project). The use of standardized language allows project reviews and approvals to remain on-schedule while minimizing legal exposure to the government.

A "non-standard estate" may be permitted in the event there is not an existing "standard estate" that fits unique project situations and can be adequately justified

**Out-year Nourishment:** A plan to replace lost sediment (usually sand, lost through longshore drift or erosion) on a regular cycle throughout the life of the project (in "out-years").

**Open Bay Bottom:** A habitat that includes unvegetated subtidal areas of various sediment types, which are open and interact with the water and adjacent habitats. Open-bay bottoms are characterized as having benthic organisms, epifauna at the surface of the substrate (e.g. crabs, small crustaceans) and infauna that burrow beneath the substrate (e.g. mollusks).

**Optimization:** The phase in plan formulation that assesses incremental additions or reductions in size, extent or scale of a feature in the alternative to identify the final, most cost-effective scale. An engineering design methodology that is used to improve upon designs by assessing performance of variations of the design which leads to the selection of the optimal solution.

**Outer Continental Shelf (OCS):** Submerged lands lying seaward of a state's seaward boundary which are under the jurisdiction of the Bureau of Ocean Energy Management.

**Oyster Reef:** A habitat that includes subtidal or intertidal reefs formed on hard substrate in locations where currents are available to carry nutrients to the oysters and take sediment and waste away from the reef.

**Palustrine Emergent Wetland:** A habitat that includes tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinities are below 0.5 parts per thousand (ppt).

**Physical Modeling:** A smaller physical copy of an object which allows engineers to investigate how water will move around a physical structure constructed in a system. The results of the modeling can then inform modifications to the design to improve performance and reduce environmental impacts.

**Piling:** Long slender columns of steel or reinforced concrete.

**Performance:** Achievement of the project's objective(s), often measured in reduction of water surface elevations with an alternative in place. Ability to meet function requirements. The performance of an item is described by various elements, such as coastal storm risk management, reliability, capability, efficiency, and maintainability.

**Preconstruction, Engineering and Design (PED) Phase:** A phase in the USACE process that follows identification of the Recommended Plan when the designs are refined. and then the features of the plan are constructed as directed by Congress.

**Probability:** A measure of the likelihood, chance, or degree of belief that a particular outcome or consequence will occur. A probability provides a quantitative description of the likelihood of occurrence of a storm event expressed as a value between zero and one.

**Project First Cost:** The estimated cost of the Recommended Plan (without OMRR&R costs included), calculated at the current price level, and submitted to Congress in request for authorization and appropriation.

**Reach:** A subregion of a study area to allow analysis and plan development to consider geographically distinct areas and impacts. The primary economic analysis unit or sub-unit within a contiguous, morphologically homogenous area. The shoreline and associated upland areas are divided into reaches throughout the project unit area in which geomorphic structures, erosion conditions, or human development patterns have been determined to remain relatively constant.

**Real Estate Conveyance Document:** Deeds, easements, right of ways, etc. associated with a Federal project.

**Redundancy:** The inclusion of extra components, which are not strictly necessary to functioning, in case of failure in other components. The goal of **redundancy** is to prevent or recover from the failure of a specific component or system due to a hazard.

**Relative Sea Level Change (RSLC):** The change in sea level that is observed with respect to a land-based reference.

**Reliability:** The likelihood of successful performance of a given project element over a specified time period. It may be measured on an annualized basis or for some other specified time period of interest.

**Renourishment:** A process by which sediment, usually sand, lost through longshore drift or erosion is replaced from other sources.

**Residual Elevation:** The surge levels at coastal locations during storms which includes not only the still water level, but the additional water levels attributed to tides. Along the coast, this increase in water level is assumed to be due to wind and atmospheric pressure, but in some cases the increase in mean water levels can be due to the presence of breaking waves (i.e., wave setup).

**Residual Risk:** The remaining level of risk for people and assets located in a floodplain that remains after implementation of coastal storm risk management actions.

**Resilience/Resiliency:** The ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or man-made, under all circumstances of use. The ability of people and assets to return to pre-storm conditions and functionality in the aftermath of realizing storm damage.

**Revetment:** A veneer of stone, concrete, or other material built along a bank or shore to prevent loss of land and damage to landward structures caused by wave action or currents.

**Risk:** A measure of likelihood (probability) and severity of undesirable consequences.

**Risk Management:** The process of problem finding and initiating action to identify, evaluate, select, implement, monitor, and modify actions taken to alter levels of risk, as compared to taking no action. The purpose of risk management is to choose and prioritize technically sound integrated actions to reduce risk.

**Robustness:** Ability of a system to continue to operate correctly across a wide range of operational conditions (the wider the range of conditions, the more robust the system), with minimal damage, alteration, or loss of functionality.

**Runup:** The uprush of water along a beach or structure due to breaking waves. If this exceeds the height of the beach or structure, overtopping occurs.

**Seawall:** A structure similar to, but more substantial than, a revetment. It is usually constructed of pour-in-place concrete. Seawalls are generally built in areas where a high degree of protection is warranted.

**Sediment Management Features:** Sand placement that reestablishes natural coastal processes by retrieving sand that has accumulated in a sediment sink, often a channel or inlet, and returning it to the beach or barrier island system.

**Shallow Water Environmental Gate:** A type of surge risk reduction barrier comprised of large box-shaped culverts, with vertical sliding gates inside, that drop down to close off an inlet in advance of a storm.

**Ship Simulation:** A computer program that simulates maneuvering various ships in different environments through features like surge gates.

**Shoaling:** The gradual process of a bay, inlet, or channel becoming shallower, usually caused by sediment deposition.

**Sill Elevation:** The depth of a sill or bottom of a feature such as a surge gate.

**Stage:** Water height measures as the vertical distance in feet (meters) above or below a local or national elevation datum.

**Standard Estate:** Federally pre-approved language, as outlined in Federal regulations, to be included in any real estate conveyance instruments (i.e. deeds, easements, right of way, etc.) associated with a Federal project.

**Still Water Level:** The flood level not including the effects of waves.

**Storm Surge:** A rise in local water level above the tide level due to a combination of wind and low atmospheric pressure during a tropical storm or hurricane.

**Storm Track:** The path followed by the center of low pressure of a storm.

**Submerged Aquatic Vegetation:** A term used to describe rooted, vascular plants that grow completely underwater except for periods of brief exposure at low tides.

**Subsidence:** The gradual caving in or sinking of an area of the land due to underground material movement oftentimes linked to the removal of water, oil, natural gas, or mineral resources out of the ground by pumping, fracking, or mining activities.

**Surge Attenuation:** The reduction of the force and effect of surge.

**Surge Barrier:** Structures built across the entrances of bays, lagoons, sounds, and estuaries to block the progression of storm setup or surge into these areas. These barriers generally consist of dikes with circulation and/or navigation openings which are left open during fair weather and closed when coastal storms threaten to flood the area.

**System:** Integrated whole of the natural and built environments that can be defined geographically, technically, and politically.

**System Performance:** The capability of the system to accommodate the flood hazard as a single event or load.

**Tiered NEPA:** The National Environmental Policy Act is a United States environmental law that promotes the enhancement of the environment. Tiered NEPA is the process by which an agency characterizes the general potential environmental effects of the entire recommended plan in a broadly-scoped environmental impact statement (EIS), and then produces subsequent follow-on EIS(s) describing the potential environmental effects of site-specific features as their details become refined enough to accommodate assessment. The process of producing the multiple EISs (the consultation with natural resource agencies as well as the assessment of impacts) is referred to as **tiering**.

**Tier One Assessment:** Within the context of a Tiered NEPA strategy, this is an analysis of the project on a broad scale, while taking into account the full range of potential effects to both the human and natural environments from potentially implementing proposed solutions.

**Tier One Features (aka Tier One Measures):** Within the context of a Tiered NEPA strategy, these are the features that will require separate independent NEPA analysis (in a Tier Two Assessment) once the impacts are fully understood in the next phase of the project (i.e., in the PED phase), at which time a separate Consistency Determination would be sought for those measures.

**Tier Two Assessment:** Within the context of a Tiered NEPA strategy, this is an analysis of the project which involves the 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 once refinements and additional information is gathered.

**Total Water Level:** The water level at the shoreline that includes a combination of tides, surge, and wave runup (i.e., the maximum onshore elevation reached by a wave).

**Uncertainty:** Measure of imprecision of knowledge of parameters and functions used to describe the hydraulic, hydrologic, geotechnical, and economic aspects of a project plan.

**Unit Day Values (for Recreation):** A measurement that quantifies recreation benefit through a technique that relies on expert or informed opinion and judgment to estimate the average willingness of recreational users to pay for recreational services or pay to use recreational facilities.

**Vertical Lift Gate:** A type of surge barrier that looks like a floodwall and is suspended over an inlet by a set of towers. When needed, the towers lower the wall down into the inlet, sealing off the opening and preventing surge from entering the system.

**Vertical Piling:** Long slender columns of steel or reinforced concrete driven straight into the ground (on the vertical) and attached to a floodwall to provide support.

**Vulnerability:** Susceptibility to life, property, and the environment to damage if exposed to the hazard.

**Water Surface Elevation:** The maximum height of waters resulting from a particular flood at a particular location in a floodplain, as measured in relation to a specified vertical datum.

**Wave Height:** The vertical distance between a wave crest (the highest point of a wave) and the preceding trough (the lowest point of a wave).

**Wave Overtopping:** The rate at which a wave runs up and flows over the crest of a slope, be it a beach, dune, or structure

**With-project Condition:** The set of future conditions the team believes most likely to prevail for each project implementation over the period of analysis. These conditions may vary for each project alternative.

**Without-project Condition:** The set of future conditions most likely to prevail in the absence of the proposed project. It does not describe conditions as they exist at the time of the study but describes the conditions that are expected to prevail over the planning horizon in the absence of a project.