TEXAS COASTAL RESILIENCY MASTER PLAN

MARCH 2017

George P. Bush, Commissioner
Texas General Land Office

Cover photographs, clockwise from top:

Whooping Cranes on the Matagorda Island Unit of the Aransas National Wildlife Refuge.

Port of Galveston.

View of Seawall Boulevard on Galveston Island.

Recreational fishing boat in Port Aransas Ship Channel.

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ABBREVIATIONS & ACRONYMS

BMMP - Beach Monitoring and Maintenance Program
CEPRA - Coastal Erosion Planning and Response Act
CSRM - Coastal Storm Risk Management
FEMA - Federal Emergency Management Agency
GCCPRD - Gulf Coast Community Protection and Recovery District
GDP - Gross Domestic Product
GIWW - Gulf Intracoastal Waterway
GLO - Texas General Land Office
HUC - Hydrologic Unit Code
IOC - Issue of Concern
NWR - National Wildlife Refuge
Plan - Texas Coastal Resiliency Master Plan
RESTORE - Revived Economies of the Gulf Coast States Act
SLOSH - Sea, Lake and Overland Surges from Hurricanes
TAC - Technical Advisory Committee
TCOON - Texas Coastal Ocean Observation Network
Planning Team - GLO's Planning Team
USACE - U.S. Army Corps of Engineers
USFWS - U.S. Fish and Wildlife Service
WMA - Wildlife Management Area

MESSAGE FROM THE COMMISSIONER

George P. Bush, Commissioner, Texas General Land Office

As the Commissioner of the Texas General Land Office, I am committed to making sure that this state does all it can to protect the people, economy and natural resources of the Texas coast. As Texans, we are resilient. Following Hurricane Ike, we pulled ourselves up by the bootstraps, got back to work and helped our neighbors get back on their feet. Despite the resiliency demonstrated by our fellow Texans, the state is in need of a coastal plan to mitigate the damage from the next big storm. To do this, we must reach out to each other across communities and agencies, pool our knowledge and resources, and collectively identify and implement the best measures to protect our coastal communities.

Right now, however, we're not doing enough. With 65 percent of the Texas Gulf shoreline eroding at an average rate of more than two feet per year, and in some areas much more rapidly, we are not only losing our beaches, we are leaving our homes and businesses vulnerable to storm surge and flooding.[113] Protecting the Texas coast is vitally important not just to this state, but to the entire nation. The Texas coast is home to the Gulf Intracoastal Waterway, the nation's third busiest inland waterway[58], 25 percent of the nation's refining capacity[107], four of the 15 busiest ports in the country[102], most of the nation's strategic petroleum reserves[105], and numerous strategic military deployment and distribution installations. Tied directly to this industry activity and these strategic sites are the coast's natural resources, beaches, dunes, wetlands, oyster reefs and rookery islands that serve as natural storm barriers and are the backbone for coastal tourism and the ocean economy. The population and economic activity along the coast is also growing – 6.5 million people and total wages in excess of $37 billion are located on the Texas coast.[10,90] This growing population and economic activity puts our state and country at greater risk of storm surge damage, and places increasing pressure on our natural barrier systems.

The Texas Coastal Resiliency Master Plan (Plan) is an important step to help us be as prepared as possible and will give us a framework for community, socio-economic, environmental and infrastructure protection from coastal hazards. The Plan will consist of preferred projects to safeguard the coast, which will require coordination with our partners to implement.

In addition to this Plan, the Texas General Land Office (GLO) is directing several other separate studies to help protect our coastal communities. An infrastructure study for the Texas coast was completed last year and is being used by coastal communities to help inform their decisions for future infrastructure needs and funding. The GLO is also conducting three coastal storm risk management studies. Two of those studies, the Gulf Coast Community Protection and Recovery District Study and the U.S. Army Corps of Engineers (USACE) Sabine to Galveston Study, will be completed later this year and will determine the feasibility of constructing large storm risk management structures, like levees, seawalls and flood gates, in the Upper Texas Coast region. The final study, the USACE Coastal Texas Study, will determine the feasibility of constructing storm risk management and large ecological restoration projects for the entire Texas coast.

The need for the Texas Coastal Resiliency Master Plan has never been greater, and the commitment to the Texas coast has never been stronger. While our response in the face of disaster is important, it's equally important to have a plan for mitigation of impact. The Texas Coastal Resiliency Master Plan does that, and it will continue to evolve as the needs and vulnerabilities of the coast change; ensuring a strong coast for a strong Texas, now and in the future.

1. INTRODUCTION

1.1. The Importance of the Texas Coast and the Need for a Coastal Plan

From the mouth of the Rio Grande River to the Sabine River, the Texas shoreline is ecologically diverse and biologically productive. Its habitats maintain native plant and animal populations, provide nurseries, nesting and foraging areas for fish and wildlife, and reduce the impacts of coastal hazards.

The Texas coastal region plays a major role in the country's energy security, with Texas leading the nation in energy production, mainly from crude oil and natural gas. Other critical state and national economic generators along the Texas coast include waterborne commerce, military transportation, chemical manufacturing, commercial fishing, recreation and tourism.

The Texas coast, however, is vulnerable to an array of coastal hazards, such as coastal erosion, sea level rise, coastal storm surge, habitat loss and degradation, water quality degradation, and other issues that are putting the environmental and economic health of the coast at risk. In addition, events within the past decade, such as Hurricane Ike and Hurricane Dolly, caused further environmental and economic devastation along the Texas coast and highlighted the urgency for better protection.

As Commissioner of the Texas General Land Office (GLO), George P. Bush recognizes the need for a plan to address the Issues of Concern that negatively impact the coast and to ensure that the state's coastal communities become more resilient. To support the GLO's mission to preserve and enhance the state's coastal natural resources while promoting economic growth, Commissioner Bush directed the development of a Texas Coastal Resiliency Master Plan (Plan).

The Plan is founded on the principle to create resilient coastal communities – the ability of coastal resources and infrastructure to withstand and rebound from natural and human-induced disturbances. Achieving coastal resiliency will reduce the state's vulnerability to coastal hazards, and protect the state's coastal assets and environments.

If action is not taken now, the Issues of Concern that are altering the Texas coast will adversely affect the infrastructure, coastal resources, economic activities and the health and safety of our coastal communities. This, in turn, will directly impact the economic success of our state and the nation. The protection of our coastal resources must be a priority.

2. THE PLANNING APPROACH

Due to the expansive and diverse nature of the Texas coast, the Commissioner of the Texas General Land Office determined that a piecemeal approach to coastal protection and restoration is not sufficient, and directed the development of an overarching plan that coordinates the efforts of many parties, produces carefully selected and evaluated projects, and provides efficient and cost-effective methods to achieve a resilient coast.

2.1. A Vision for a Resilient Texas Coast

The vision for the Texas Coastal Resiliency Master Plan is to protect and promote a vibrant and resilient coast that supports and sustains a strong economy and healthy environment for all who live, work, play or otherwise benefit from the natural resources and infrastructure along the Texas coast. The Plan will provide a thorough understanding of coastal conditions, Issues of Concern, resiliency goals and objectives, the planning process, and recommendations to achieve a resilient coast through the selection and implementation of priority projects.

The Plan promotes coastal resiliency, defined as the ability of coastal resources and coastal infrastructure to withstand natural or human-induced disturbances and quickly rebound from coastal hazards. This definition encompasses the two dimensions of resiliency: 1) taking actions to eliminate or reduce significant adverse impacts from natural and human-induced disturbances; and 2) responding effectively in instances when such adverse impacts cannot be avoided. To keep pace with the dynamic Texas coastline, the Plan will be updated regularly to allow the state to continually assess changing coastal conditions and needs, and to determine the most suitable way to implement the appropriate coastal protection solutions.

The Planning Framework

A set of planning principles, goals, objectives and assumptions provided the basis for a multi-step planning methodology, all of which guided the development of the Texas Coastal Resiliency Master Plan. The Plan was developed by GLO personnel, contractors and an academic institution, known as the Planning Team. Through the identification of coastal Issues of Concern, potential solutions and a series of Resiliency Strategies are established in the Plan to address coastal hazards in a system-wide approach.

The GLO formed a Technical Advisory Committee (TAC) – a group of statewide and regional coastal decision makers and technical experts working in state and federal agencies, universities, local governments, non-profit organizations, engineering firms, ports and regional trusts, foundations and partnerships – to inform the development of the Plan. The TAC provided critical input throughout the planning process with regard to scientific and specialized knowledge of coastal Issues of Concern, identification and evaluation of candidate projects and review of draft Plan elements.

Plan Principles

The Texas General Land Office adopted four principles that steered all aspects of planning activity.

1. Recognize that the entire state of Texas and the nation will benefit from projects that restore, preserve, protect and manage coastal natural resource areas and coastal community assets.
2. Engage in an objective course of action that considers the environmental, economic, cultural and social needs of coastal communities.
3. Pursue a partnership-based approach to collaborate with coastal-related public, private and non-governmental sectors.
4. Use a thorough, impartial and science-based approach to identify and assess Issues of Concern and project solutions to achieve a resilient coast.

Plan Goals and Objectives

Within the planning framework are three goals and associated objectives that collectively yield recommended projects to achieve a resilient coast.

Goal 1: The GLO will use the Plan to direct its authority to restore, enhance and protect the Texas coast.

Objective 1: Identify, characterize and prioritize the Issues of Concern that inhibit coastal resiliency along the entire Texas coast as a means to focus the overall planning effort.

Primary Actions:

- Undertake a comprehensive review and analysis of existing and relevant data to identify the coastal Issues of Concern that will be addressed in the Plan.
- Form a coastal Technical Advisory Committee and solicit member input to determine the level of severity of each Issue of Concern within localized subregions of the four coastal regions, and to prioritize the Issues of Concern for each region.
- Document and characterize the environmental and economic importance of the Texas coast to highlight the impact that Issues of Concern have on not only coastal communities, but on the entire state and nation.

Objective 2: Identify, evaluate and select projects that reduce or eliminate the identified Issues of Concern and enhance coastal resiliency.

Primary Actions:

- Undertake a comprehensive review and analysis of existing and relevant projects, focusing on projects that address the identified Issues of Concern and enhance coastal resiliency.
- Gather new project ideas through outreach to the TAC and coastal stakeholders, as well as through technical analyses.
- Develop and apply a repeatable project screening process and elicit data and input from the TAC to evaluate project candidates in an objective, science-based manner that correlates project actions with mitigation of Issues of Concern.
- Drawing on expert knowledge from the TAC and further assessments by the Planning Team, select projects with high-performing potential and organize them into Resiliency Strategies to target coastal Issues of Concern.

Goal 2: Maintain ongoing communication with the Technical Advisory Committee, resource agencies and stakeholders throughout Plan development and implementation to garner support for the Plan.

Objective 1: Develop and maintain strong partnerships to assist with Plan development and facilitate and promote Plan implementation (e.g., TAC members, public agencies, private businesses, academia, non-profits, local governments and user groups).

Primary Action:

- Host meetings with TAC members and stakeholders to gather and incorporate their input and to communicate Plan updates.

Objective 2: Communicate the value of the Texas coast to statewide and national audiences to increase awareness of coastal resiliency.

Primary Actions:

- Conduct meetings with interested parties along the Texas coast to share the findings of the Plan and communicate the value of coastal resiliency projects.
- Produce materials and tools to highlight the Texas coast, its environmental and economic value, and the consequences of inaction.

Goal 3: Develop an adaptable plan that accommodates changing coastal conditions and their impacts on the coastal environment and the infrastructure protected by this natural first line of defense.

Objective 1: Maintain and update the Plan on a regular basis.

Primary Actions:

- Design and implement an adaptable process that reflects changing conditions, needs and preferences of coastal communities and their coastal ecosystems.
- Continue engaging TAC members and interested stakeholders to advance the collection and incorporation of applicable expert knowledge and scientific data into Plan updates.
- Continue refining and enhancing Resiliency Strategies presented within the Plan.

Planning Methodology

1. Establish a Resiliency Planning Framework
2. Project Identification
3. Identify Coastal Issues of Concern
4. Project Screening
5. Technical Advisory Committee and Technical Analyses
6. Develop Resiliency Strategies
7. Prepare a "Living Plan"

Methodology

The methodology used to prepare and manage the Plan includes seven primary steps. The Plan's project life cycle involved continual data gathering, technical analysis and consultations with the Technical Advisory Committee and coastal stakeholders.

1. ***Establish a Resiliency Planning Framework*** – Form the Planning Team and the Technical Advisory Committee, and create the Plan's scope, schedule, format, content and review protocols.
2. ***Project Identification*** – Collect, catalog, analyze and review past and present coastal management efforts (including state statute, policies, programs and institutional arrangements) to identify projects that support coastal resiliency.
3. ***Identify Coastal Issues of Concern*** – Using available data, identify and define the predominate Issues of Concern that adversely impact the environmental and economic resiliency of coastal communities.
4. ***Project Screening*** – Establish the process by which all candidate projects are evaluated for prospective inclusion in the Plan, and employ the evaluation criteria, technical analysis and stakeholder input to screen candidate projects and generate a list for inclusion in the Plan.
5. ***Technical Advisory Committee and Technical Analyses*** – The TAC and the Planning Team will use scientific and coastal expertise to determine the level of severity of each Issue of Concern and technically evaluate potential projects by assessing cost, economics, physical and environmental feasibility, and overall consistency with the Plan's resiliency goals.
6. ***Develop Resiliency Strategies*** – Identify categories of coastal resiliency measures consistent with Plan goals, and organize recommended projects within those categories.
7. ***Prepare a "Living Plan"*** – The Plan will adapt to evolving issues, needs and social conditions along the Texas coast.

Assumptions

The following assumptions further define the development of the planning framework and associated methodology:

- The identification and evaluation of projects for potential inclusion in the Plan reflect a mix of qualitative and quantitative analyses, technical assessments, economic analysis, consultations with stakeholders, expert elicitation from the TAC and the best professional judgment of the Planning Team;
- The listing of priority projects will change in future iterations of the Plan to appropriately address the dynamic nature of the coast and the resiliency issues facing coastal communities at that time. Completed priority projects will be cataloged in a GLO project database;
- As the Plan is refined in future years, additional emphasis will be placed on gathering, generating and analyzing new information to address identified gaps; and
- The planning process and outcome will yield a GLO blueprint to achieve coastal resiliency and will complement and advance other coastal planning efforts.

2.2. How the Plan Will Guide Coastal Management

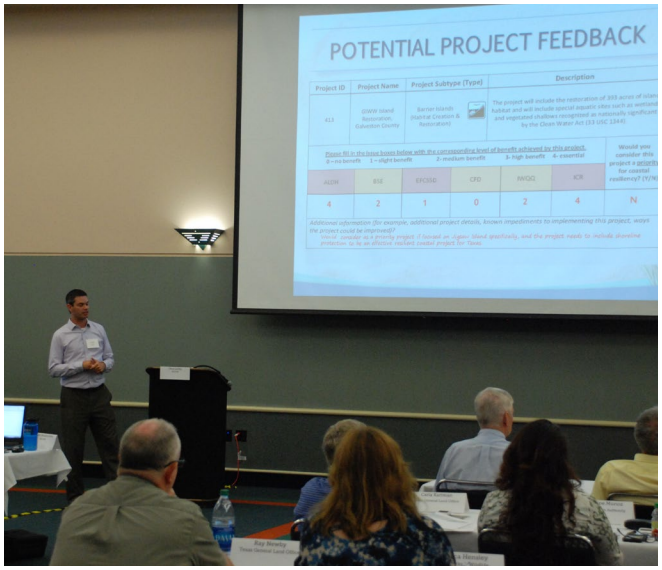
As the steward of state-owned lands, the GLO is responsible for management of the Texas coastline from the beach to nearshore waters and out to 10.3 miles into the Gulf of Mexico, as well as millions of acres of submerged land in our coastal bays. The GLO will use the Texas Coastal Resiliency Master Plan to actively guide the execution of its responsibilities and provide Texas coastal communities with a set of scientifically sound, feasible and cost-effective coastal protection and restoration projects to advance coastal resiliency.

Specifically, the GLO will examine the existing rules and procedures of its coastal programs to better align with the Issues of Concern and the resiliency needs and priorities of the coastal communities. The various coastal programs the GLO manages includes:

- The Texas Coastal Management Program;
- The Coastal Erosion Planning and Response Act Program (CEPRA);
- Community Development and Revitalization;
- Oil Spill Prevention and Response;
- The Beach Monitoring and Maintenance Program;
- The Beach Access and Dune Protection Program;
- The Gulf of Mexico Energy Security Act Program;
- The Coastal Non-Point Source Pollution Program;
- The Texas Coastal Ocean Observation Network Program;
- The Beach Maintenance Reimbursement Fund Program; and
- The Adopt-A-Beach Program.

Collectively, these GLO programs contribute to coastal protection and restoration by nourishing eroding beaches, rebuilding dunes, protecting and stabilizing shorelines, restoring marsh habitat, mitigating damage to natural resources, enhancing public access to beaches, assisting with beach maintenance costs for statutorily-approved counties, providing the public with access to updated beach water quality information, enhancing coastal infrastructure and ensuring that oil stays out of Texas coastal waters.

With a ready list of vetted projects identified through the planning process, the GLO can directly fund resiliency-related projects that will strengthen the agency's goal of protecting, restoring and enhancing the Texas coast. These projects can receive funding from a variety of sources, both in coordination with the GLO or independently. Furthermore, the Plan can be used by coastal communities to highlight the Issues of Concern in their regions, and to solicit actions to make their communities more resilient and less vulnerable to the next big storm.



Technical Advisory Committee meeting in Texas City.

2.3. Coastal Coordination

The GLO recognizes that coastal planning is a collaborative effort that involves policy makers, technical experts and other interested parties from all levels of government, non-profit organizations, the private sector and citizens in general. To advance the implementation of the Plan, the GLO will continue to coordinate with public entities that have legislative authorities and mandates involving coastal planning, protection and restoration. These public entities include:

- The U.S. Army Corps of Engineers;
- U.S. Environmental Protection Agency;
- U.S. Fish and Wildlife Service;
- The U.S. Geological Survey;
- Texas Commission on Environmental Quality;
- Texas Parks and Wildlife Department;
- Texas Water Development Board;
- Texas Department of Transportation;
- Railroad Commission of Texas;
- Texas State Soil and Water Conservation Board;
- Texas Sea Grant College Program;
- Multiple river authorities; and
- The many coastal communities within the 18 coastal counties in the Coastal Zone Management Act.

This planning process is not a one-time undertaking. The Plan will continuously evolve along with the concerns and needs of the coast to ensure that the GLO provides recurrent and up-to-date coastal management to coastal communities while working together with planning partners. The ability to adapt will ensure that the Plan will provide a long-term framework to protect the environment and economic assets from the Issues of Concern that threaten communities along the Texas coast.

The GLO's Coastal Planning Efforts

Figure 2.1: *The GLO's Coastal Planning Efforts*

Other GLO coastal plans were initiated in prior years to research specific coastal regions or particular coastal issues, with several taking place through partnerships with federal and local entities.

2.4. Related GLO Coastal Planning Efforts

The Texas Coastal Resiliency Master Plan is one of many GLO-related coastal planning efforts. Other GLO coastal plans were initiated in prior years to research specific coastal regions or particular coastal issues, with several taking place through partnerships with federal and local entities. The GLO-related coastal plans recently completed or in-progress are shown in Figure 2.1 and include:

Coastal Planning Study (GLO, 2012)

In 2012, the GLO collaborated with the Harte Research Institute at Texas A&M Corpus Christi to form a Technical Advisory Committee consisting of coastal experts to identify priority issues facing the Texas coast. Outreach meetings involving the TAC were held along the Texas coast in each of four regions. Lists of projects were identified for each of these regions, and priorities for implementation of those projects were developed. Due to ongoing coastal studies involving the GLO, however, incorporation of the regional priorities into a formal plan was delayed. This planning effort laid the foundation for the development of the Texas Coastal Resiliency Master Plan.

Texas Coastal Infrastructure Study (GLO, 2016)

Completed in April 2016, the study identified critical infrastructure assets, such as water treatment facilities, roads and bridges within the coastal counties that are most vulnerable to storm impacts. Community outreach meetings were held with local officials to help identify and prioritize critical infrastructure needs in preparation for future storms. The information was consolidated and shared with coastal communities to help inform their decisions about future infrastructure planning and funding.

Sabine Pass to Galveston Bay Study (USACE, 2017)

The USACE and GLO are conducting a feasibility study to evaluate potential upgrades to existing Coastal Storm Risk Management (CSRM) systems in Brazoria and Jefferson counties, and construction of a proposed CSRM system for Orange County. The feasibility analyses will determine if there is a federal interest in funding potential CSRM projects in the identified areas. The final report is scheduled for completion in March 2017. The GLO is a non-federal sponsor on this study.

Storm Surge Suppression Study (GCCPRD, 2016 and 2017)

In 2013, the GLO entered into an agreement with the Gulf Coast Community Protection and Recovery District (GCCPRD) to conduct a phased Storm Surge Suppression Study of the upper six coastal counties, which include Brazoria, Chambers, Galveston, Harris, Jefferson and Orange counties. Phases 1, 2 and 3 are complete and resulted in modeling and cost-benefit analysis of potential storm protection projects, public scoping meetings, and a July 2016 report with three recommended systems of flood damage reduction and storm surge suppression measures. The fourth phase of the project began in Fall 2016 to further examine the structural engineering, economics and environmental impacts of the recommended projects. The fourth phase is expected to conclude in December 2017.

Coastal Texas Protection and Restoration Feasibility Study (also known as the Coastal Texas Study; USACE, 2021)

The U.S. Army Corps of Engineers, in partnership with the GLO, began an examination in November 2015 of the feasibility of constructing projects for Coastal Storm Risk Management and Ecosystem Restoration along the Texas coast. The Coastal Texas Study is estimated to cost $20 million, with a 50/50 federal to non-federal cost share split. A significant portion of the GLO's cost share is expected to be through work-in-kind and contracting with GLO professional service providers. The study will involve engineering, economic and environmental analyses on approximately 10 to 12 large-scale projects, which could be considered by Congress for authorization and funding. The feasibility study and report will be complete in 2021.

The GLO will utilize the resources and outcomes from these various coastal planning efforts, when appropriate, to minimize redundancy and to enhance the ongoing development of the Texas Coastal Resiliency Master Plan. Similarly, the results of the Plan can inform the various coastal plans in progress.

These related planning efforts are being coordinated with the Texas Coastal Resiliency Master Plan in order to consolidate coastal planning efforts between the GLO and its partners.

3. A VALUABLE TEXAS COAST

To fully understand the significance of the Texas coast, it is necessary to examine the environmental and economic characteristics of the coast – which are intricately intertwined – and the benefits the coast provides to the entire state and nation. The benefits of coastal environments are typically realized through their ecosystem services, while the benefits of the coastal economy are commonly presented in terms of industries and businesses that are built along the coast and the products they produce. The coastal region is made up of a range of natural environments that vary widely from the upper to lower coast and interact with the man-made surroundings. Similarly, the economic generators along the coast differ in scale and function, and are often dependent on the availability of healthy coastal resources. This section of the Plan will present a coastwide characterization of the coastal environments and the coastal economy, with a more detailed regional look at the natural and man-made environments of the Texas coastline.

3.1. The Characterization of Texas' Coastal Environments

This overview will describe features of the coastal landscape, highlighting the dynamic interactions that take place between the Gulf of Mexico and Texas' bays and barrier islands. These features form the foundation for coastal ecosystems that provide a range of protective measures and supply various economic benefits to coastal communities, the state and the nation. All of this underscores the importance of safeguarding what we value.

Features of the Coastal Landscape

Bays and Estuaries

Bays: Bodies of water that are partially enclosed by land, bounded on the Gulf side by barrier islands and peninsulas, and connected to the Gulf by passes and inlets.

Estuaries: Bodies of water where freshwater from rivers and streams empties and mixes with saltwater from the Gulf of Mexico.

Texas' coastal region is characterized by eight major bay systems: Sabine Lake, Galveston Bay, Matagorda Bay, San Antonio Bay, Aransas Bay, Corpus Christi Bay, Upper Laguna Madre and Lower Laguna Madre (Figure 3.1). The bay systems are bodies of water that are partially enclosed by land, and are separated from the Gulf of Mexico by barrier islands and peninsulas, except for openings (passes and inlets) that allow for water to flow from the Gulf of Mexico into bays.

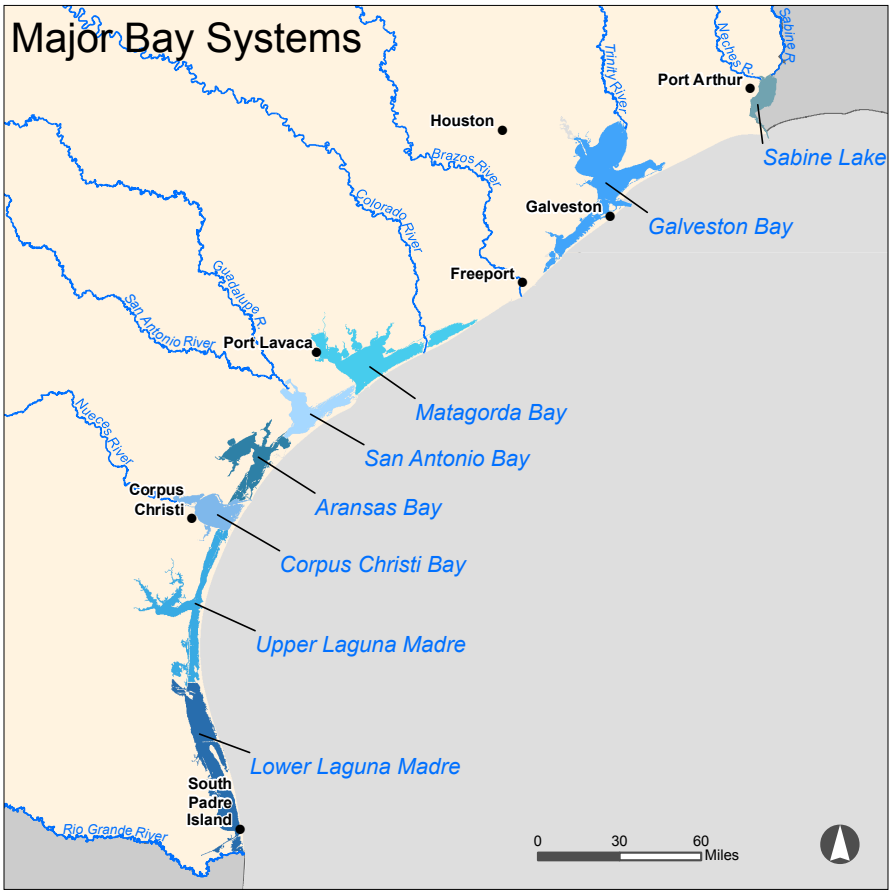


Figure 3.1: *Major Bay Systems – The eight major bay systems in Texas and the major rivers that supply freshwater to the estuaries.*[110]

Estuarine wetlands in the Upper Laguna Madre.

In Texas, many bays are also estuaries, or bodies of water where freshwater from rivers and streams empties and mixes with saltwater from the Gulf of Mexico. The major estuaries in Texas are named for the primary rivers emptying into them. The Trinity-San Jacinto Estuary (Galveston Bay) is the largest estuary in Texas. Estuaries form a transition zone between river environments and marine environments, and this mixture of freshwater and saltwater is known as brackish water. In estuaries, freshwater does not flow directly into the open Gulf, but is blocked by bordering mainland, peninsulas, barrier islands or fringing wetlands. Estuaries are affected by both marine (tides, waves and saltwater) and riverine (inflows of freshwater and sediments) influences. These fresh and saltwater influxes provide high levels of nutrients in the water column and sediments, which supports diverse wetland habitats for fish and wildlife that have adapted to brackish water.

Spartina alterniflora, a smooth cordgrass commonly found in wetlands.

The land area where sediment is deposited at the mouth of a river when it empties into a bay, or the Gulf of Mexico, is called a delta. A delta grows as sediment from the river accumulates, causing the river to break off into smaller channels, creating wetland habitat. Upstream disruptions to the river can impact delta formation.

These bay systems and the environments they support are influenced by regional weather patterns. About twice as much rain falls in the Sabine Lake region than along the Texas-Mexico border. Texas bays and estuaries follow a similar gradient in terms of salinity, which affects the types of coastal environments along the coast. In the Upper Coast, estuaries have lower salinity levels from increased precipitation that allow smooth cordgrass, known as *Spartina alterniflora,* to thrive in the wetlands. Towards the south, wetlands transition from more freshwater to higher salinity environments and become more sparse due to the arid climate. In the southernmost part of the Texas coast, in the high salinity environment of the Laguna Madre, sparsely vegetated tidal flats are more common.

San Jose Barrier Island.

Barrier Islands and Peninsulas

Along the majority of the Texas coast, there is a near-continuous chain of peninsulas and barrier islands that divides the bays and estuaries from the Gulf of Mexico. Barrier islands are long, relatively narrow offshore deposits of sand and sediment that run parallel to the mainland along the coast, whereas peninsulas also run parallel to the mainland, but are still connected to the mainland. Shallow bays or lagoons divide barrier islands and peninsulas from the mainland. Barrier islands and peninsulas are predominately characterized by a Gulf-facing beach and dune system that gradually slopes down to the interior bayside shoreline, supporting various habitats such as wetlands and tidal flats. The Texas Gulf shoreline has two peninsulas and six barrier islands (Figure 3.2), including Padre Island, the longest undeveloped barrier island in the world.

By nature, barrier islands are not static landforms; they are dynamic systems, constantly shifting and migrating as sand is moved by waves, tides, currents and changing sea levels. The barrier islands and peninsulas are segmented by numerous natural and man-made passes, or inlets, that allow vessel access between the bays and Gulf, and water circulation of sediment and nutrients vital for bay ecosystem health. Tides and currents carry sediment from the bays – delivered by rivers and streams – into the Gulf where they can be deposited onto Gulf-facing beaches, and from the Gulf to bayside beaches. This provides natural beach nourishment and shoreline protection from erosive wave action. Water movement through an inlet can also deposit sand at

Barrier islands and peninsulas are predominately characterized by a Gulf-facing beach and dune system that gradually slopes down to the interior bayside shoreline, supporting various habitats such as wetlands and tidal flats.

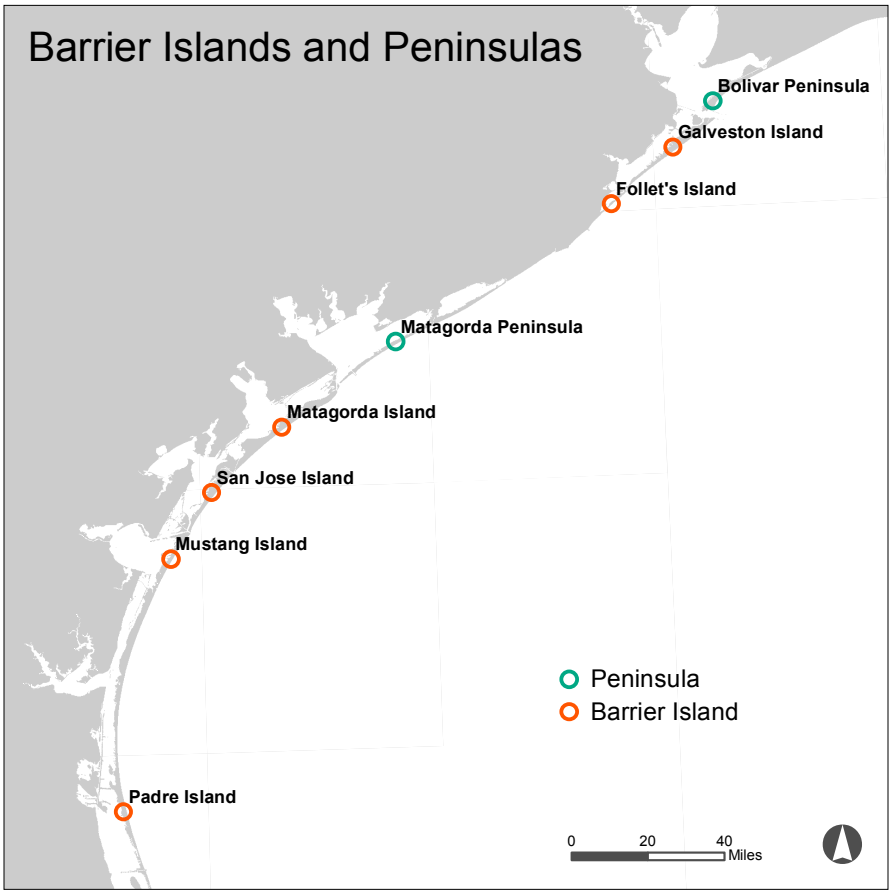


Figure 3.2: *Barrier Islands and Peninsulas*

both ends of the inlet's mouth, forming tidal deltas. Storm surge enters bays through these inlets and washes over barrier islands, and at weak points, causes breaching and forms new channels from erosion. As storm surge washes over the island, it carries sand from the beach and dunes, depositing it into the bay. This process, called "rolling over," is the method by which a barrier island migrates landward. After a storm, built up water in the bay causes shoreline flooding as it slowly funnels back into the Gulf through inlets.

Coastal Environments and the Ecosystem Services They Provide

The coastal landscape provides the foundation for a range of coastal environments, including beaches and dunes, wetlands, coastal uplands, oyster reefs and rookery islands. The primary natural coastal environments found along the Texas Gulf coast are shown in Figure 3.3. The economic benefits offered by the natural environments along the coast are diverse and include both traditional and non-traditional factors. Traditional economic factors include the dollars generated for the state through profitable activities such as fishing, ecotourism and recreation. Non-traditional economic factors, known as ecosystem services, are the benefits provided by the environment that support, sustain and enrich human life.[118] For example, some ecosystem

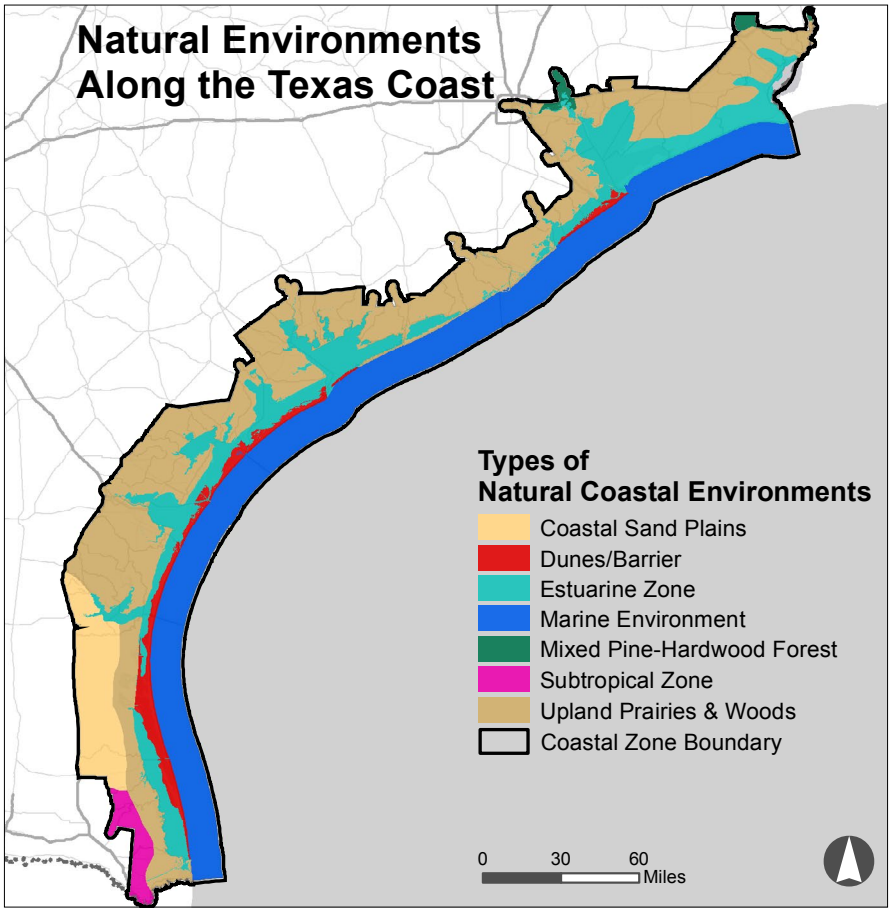


Figure 3.3: *Natural Environments Along the Texas Coast - Natural subregions developed by the LBJ School of Public Affairs in 1978 for use as a common point of reference for scientists, students, and the general public interested in studying and preserving the natural diversity of Texas; updated by the Texas Parks and Wildlife Department in 2010.*[83]

An economic benefit offered by the wetlands in Galveston Bay: Per acre, wetlands supported an estimated $171 to $279 in shrimp production.[29]

Commercial shrimp landings support the local and state economy.

services provided by a wetland include habitat, water purification, erosion control and flood and storm protection. The Multihazard Mitigation Council estimates that every dollar spent on natural hazard mitigation saves an average of $4 in future benefits.[49]

Estuaries are nursery areas for brown and white shrimp, which serve as the primary food source for juvenile red snapper, a commercially important species.

Texas' estuaries may vary in size, ecological characteristics and the amount of precipitation and freshwater inflows received, yet cumulatively they support unique and productive habitat for numerous fish and wildlife species due the high levels of nutrients provided by the brackish waters. The abundant fish and wildlife populations supported by the sheltered waters of estuaries are important to the coastal ecosystem and state economy. Approximately 95 percent of the Gulf's recreationally and commercially important fish (e.g., red drum and spotted seatrout), shellfish (e.g., crab and shrimp) and other marine species rely on estuaries during some part of their life cycle.[37] Juvenile fish, crab and shrimp depend upon estuaries that have adequate freshwater inflows to balance salinity. This critical nursery habitat for the majority the majority of Gulf commercial and recreational finfish and shellfish species provides food and shelter as the species mature, before migrating out into the open waters of the Gulf. Oysters, found only in estuaries, comprise the basis for a thriving commercial harvesting industry and are dependent upon the estuary's brackish waters. Estuaries provide habitat for birds, fish, amphibians, insects and other wildlife to live, forage, nest and reproduce. Because they are so biologically productive, resident and migratory birds, by the tens of thousands, rest and feed in estuarine marshes.

Habitats associated with estuaries, such as freshwater and saltwater wetlands, mud and sand flats, oyster reefs, river deltas and seagrass beds act like enormous filters, helping to remove sediments and pollutants to improve water quality.

Estuaries provide many ecosystem services, such as water filtration and nutrient regulation and cycling, and contribute to storm surge protection and shoreline stabilization by trapping sediments and rebuilding fringing wetlands. Rivers carry nutrients from upland watershed areas into estuaries, contributing to their high productivity, in addition to sediment and pollutants, which can decrease their productivity. Habitats associated with estuaries, such as freshwater and saltwater wetlands, mud and sand flats, oyster reefs, river deltas and seagrass beds act like enormous filters, helping to remove sediments and pollutants to improve water quality. Improved estuarine water quality also contributes to healthy ocean waters and marine life as the water exchanges from the bay to Gulf. Estuaries and their surrounding wetlands stabilize bay shorelines against erosion and act as natural buffers to protect coastal areas, inland habitats, and communities and infrastructure from flooding and storm surge.

Coastal communities and economies are built around estuaries because they provide commercial and recreational opportunities and support natural resource-based jobs and businesses. Estuaries provide recreational areas to boat, swim, fish, and bird and wildlife watching. The protected waters of estuaries are also important areas for ports and harbors and benefit waterborne transportation and commerce. The economic prosperity of many coastal communities is linked to the health of their respective estuary and the many services and resources provided.

Beaches and Dunes

The Gulf-facing beaches and dunes along Texas barrier islands are highly dynamic systems that provide a first line of defense against the destructive impacts of hurricanes and tropical storms on inland development and sensitive coastal environments. Texas beaches and dunes also provide valuable tourism and recreation opportunities to Texas residents and visitors, and are a strong driver of economic activity throughout the coastal zone. Beaches and dunes provide many economic and social benefits, including flood protection, erosion control, water catchment and purification, habitat and foraging for wildlife, tourism and recreation, and aesthetic views.[118]

Residents and visitors enjoying the beach and dune system in Port Aransas.

Gulf beaches and their dune systems provide natural protection for upland areas and landward structures during storms. Beaches also supply foraging and nesting habitat for wildlife, including threatened and endangered species, such as piping plovers and sea turtles. In addition, migratory birds use sand dunes and barrier islands as landing or resting areas after flying thousands of miles over the Gulf of Mexico.

Along the barrier island Gulf shoreline, the interface of sand and sea produces sloping sand dunes and beaches of varying widths. The beach and dune system is integral to the dynamic beach environment and is constantly in flux due to sand exchange from wind, tides, currents, erosion and storm impacts. Longshore currents in the Gulf of Mexico play an important role in the configuration of Texas' Gulf-facing beaches and dunes. Along the Upper Coast a longshore current runs from north to south, while another longshore current runs from south to north, carrying sediment with them. These two currents meet at a convergence zone along the central Texas coast on Padre Island, near the Upper Laguna Madre. At this convergence zone, the beach is wide and the dune ridge is high and continuous, whereas the beaches in the northern and southern portions of the state are more narrow, with less continuous dune ridges. Sand is continually moved along the beach shoreline by longshore currents, and from the beach into the dunes by the wind (see Figure 3.4). During typical wave conditions, sand is transported by waves to and from offshore sand bars and the surf zone to the beach, contributing to the formation of the beaches.

Beach/dune system: *The land from the line of mean low tide of the Gulf of Mexico to the landward limit of dune formation.*[69]

Longshore current: *Currents that move parallel to the shoreline.*

Longshore sediment transport: *The movement of sand and sediment along the shoreline.*

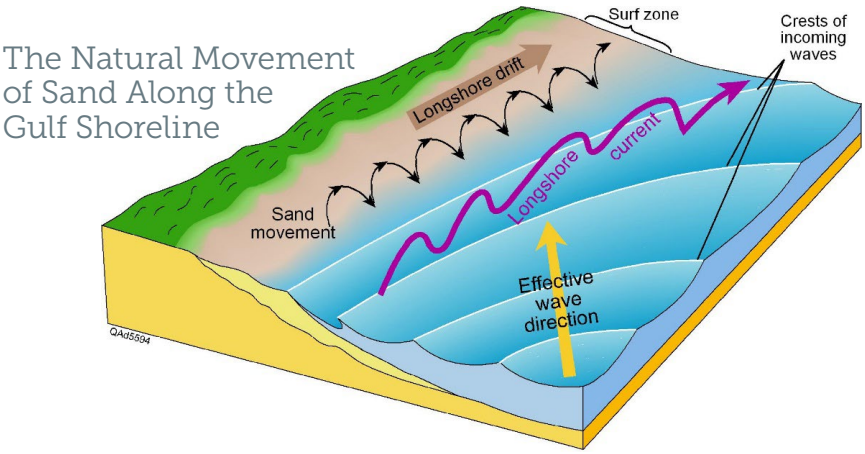


Figure 3.4: *The Natural Movement of Sand Along the Gulf Shoreline – Sand moves along Texas' Gulf shoreline, or longshore, and to and from the beach in an onshore-offshore direction. The movement of sand and water along the shoreline is caused by waves approaching at an angle to the shoreline, and tidal currents and wind pushing water along the beach.*

Dune Blowout and Washover

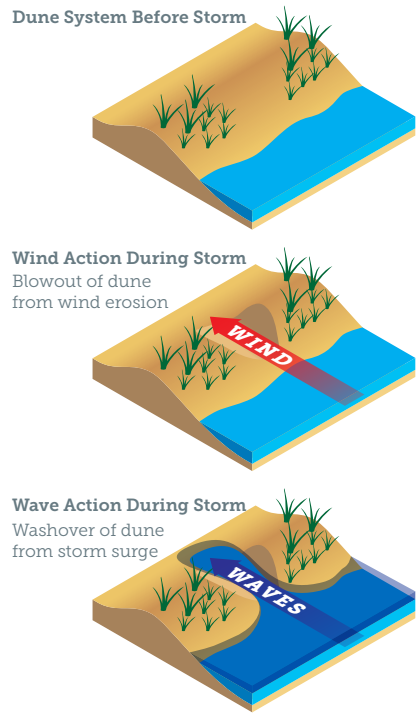


Figure 3.5: *Dune Blowout and Washover Areas*

A blowout of the dune system just North of Packery Channel.

Areas where washover of the dune system occurred on Matagorda Peninsula.

Dunes develop when wind blows sand inland where it is trapped by dune vegetation, thereby gradually building up the size of the dune. Wind and rain from seasonal storms can remove sand from the dunes and deposit it back onto the beach. During more severe storms, large amounts of beach and dune sand can be moved out into nearshore water. Storm surges and wind associated with tropical storms and hurricanes, however, can completely washover barrier islands or completely breach the dune, known as a blowout, flattening dunes and depositing the sand behind the dunes and in the bays (see Figure 3.5). In these cases, depending on sediment supply and other factors, recovery can take years to decades, leaving inland infrastructure and habitats more vulnerable to subsequent storms.

Sand dunes provide a resilient natural barrier to the destructive forces of wind and waves, and are therefore the least costly defense against storm-surge flooding and beach erosion. Sand dunes help prevent loss of life and property by absorbing the impact of storm surge and high waves and by stopping or delaying intrusion of water inland (see Figure 3.6). Dune areas are essential to the protection of infrastructure and roads from nuisance flooding, erosion, storm surge, and high wind and waves.

Vegetated dunes are more effective at trapping wind-blown sand to replenish eroded beaches after storms. The health of dune grasses, shrubs and other stabilizing plant life is critical to the balance of this system. Loss of dune vegetation makes the dunes and inland areas more susceptible to wind and water erosion, especially during storms, decreasing the ability of sand dunes to properly protect habitats and ecosystems behind the volatile beach environment. In many areas, beaches have greatly decreased in width over the past several decades, resulting in extremely narrow, and in some cases, a complete loss of the beach and dune system.

Dune Profiles Pre-storm and Post-storm

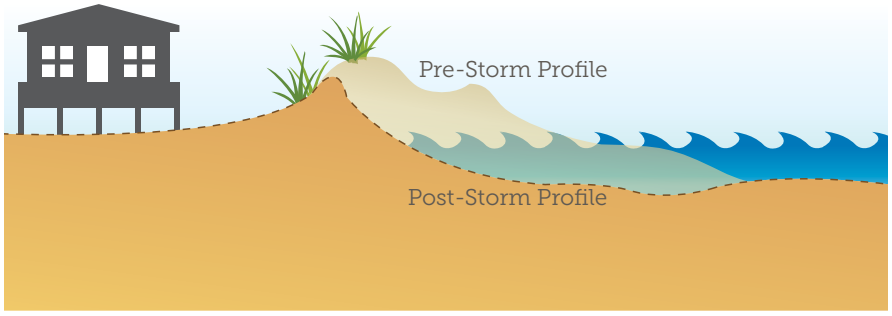


Figure 3.6: *Dune Profiles Pre-storm and Post-storm – Dunes help prevent loss of life and property by absorbing the impacts of storm surge and wave action. They also slow shoreline erosion and replenish eroded beaches after storms.*

Wetlands

Wetlands are naturally occurring or restored lands, including marsh and tidal flats, that are transitional between terrestrial and aquatic systems and, therefore, are periodically saturated or flooded with shallow water. Wetlands are characterized by herbaceous (non-woody) plants that can withstand temporary inundation and are adapted to wet soil conditions.

In the Plan, coastal wetlands are classified as either estuarine wetlands or freshwater wetlands:

Estuarine Wetlands

Estuarine wetlands are found along the bay shorelines within an estuary and directly inland of beaches, dunes and barrier islands. These estuarine ecosystems support unique plant and animal communities that have adapted to brackish water, requiring tidal and freshwater exchange. Salt marshes are the most prevalent types of estuarine wetlands and are characterized by salt-tolerant plants such as smooth cordgrass, glasswort and saltgrass. Of wetland ecosystems, salt marsh has one of the highest rates of primary productivity due to the influx of nutrients from surface and tidal waters.[108]

Estuarine wetlands provide spawning grounds, nurseries, shelter and food for finfish, shellfish, birds and other wildlife.[4] The abundance and health of adult stocks of commercially harvested shrimp, blue crabs, oysters and other species are directly related to the quality and quantity of estuarine wetlands.[15,45] This is especially true in the Gulf, where 97 percent (by weight) of the fish and shellfish caught by fishermen are dependent on wetlands at some point in their life cycle.[41] Migratory birds use estuarine wetlands as foraging and hunting areas. A frequent Pressure to this ecosystem is reduced freshwater inflows, which can result in an increase in salinity, sometimes beyond what estuarine species can tolerate.

Freshwater Wetlands

Freshwater wetlands are areas that receive periodic or permanent influxes of freshwater to support plant life, and often are inundated or completely covered with freshwater. These wetlands derive most of their water from surface waters, including floodwater and runoff, but also receive some groundwater. In the coastal zone, freshwater wetlands typically exist where rivers and streams merge with other bodies of water, including the initial outflows of rivers to estuaries and lagoons. They can also be found in the coastal upland areas along stream banks, lakeside meadows or low-lying areas that receive adequate overland flow of rainwater or stream overflow. These freshwater wetlands support many species that depend upon consistent access to water that is neither too deep nor too brackish. This ecosystem provides a variety of habitat for birds, reptiles, amphibians, mammals and insects.

Coastal estuarine and freshwater wetlands are among the most biologically productive ecosystems and therefore, provide an important suite of ecosystem services and economic and social benefits.[13] Coastal wetlands provide habitat for plants, fish and wildlife, clean water, convey and store floodwaters, trap sediment, reduce water pollution, help nutrient cycling and soil retention, and can protect shorelines from storms by diffusing wave energy.[113] Many bird species, including rare and endangered species, depend on coastal wetlands for foraging, roosting and nesting areas that are also critical to both migratory and wintering waterfowl.[15,46,98]

Coastal Uplands

Coastal uplands are areas adjacent to coastal wetlands and can encompass various ecosystems, including swamps, bottomland hardwood forests, coastal prairies, live oak woodlands and thorny brush. Coastal uplands can be used for agriculture and grazing, and provide a dry land base for developing communities and cities. Coastal uplands are also important because they provide a buffer for wetland migration as sea levels rise. Common coastal uplands in Texas include coastal prairies and bottomland hardwood forests:

Coastal prairie

Coastal Prairies

Coastal prairies are large, open expanses of coastal uplands with continuous grassy vegetation that are located immediately inland of coastal marshes extending along the Gulf of Mexico shoreline. The dominance of grasses in these uplands can be attributed to the heavy clay soil that makes it difficult for woody plant species to establish.[32] Specific areas with coastal prairies include a number of barrier islands, and the resacas, or disconnected channels, of the Laguna Madre.[117] The natural history of Texas indicates that most of the land surrounding the bays and estuaries of the Texas coast were once a coastal prairie ecosystem, and consisted of relatively flat ground with a very subtle, gradual rise in elevation. Once covering over 6.5 million acres of Texas land, coastal prairies now only occupy 65,000 acres, or less than 1 percent of the original acreage.[3]

Bottomland hardwood forest

Coastal prairie vegetation consists mostly of grasses overlain by a diverse variety of wildflowers and other plants. Areas nearer to the coast typically have shorter grasses and plant life that are accustomed to occasional coastal breezes and storms, whereas areas farther from the coast and slightly higher in elevation have taller grasses and shrubs. The unique flat grasslands and thorny scrublands of the coastal prairie and adjacent marsh areas provide habitat for waterfowl and other wildlife, including endangered species such as the ocelot, the Attwater's Prairie Chicken and the Jaguarundi. Grasslands used for grazing, with some oak savannah and mesquite vegetation, provide ample habitat for the various species that utilize this ecosystem. Ecosystem services associated with coastal prairies along the Texas Gulf Coast include enhancing water quality and providing bird habitat.

Bottomland Hardwood Forests

In East Texas and near Galveston Bay, there are large forested areas adjacent to streambanks and floodplains called bottomland hardwood forests. The primary source of water for these hardwood forests is from riverbank flooding, however, their soil is not as wet as swamps. Common tree species found in these forested areas include bald cypress, water tupelo, oaks, hickory, elm, green ash, red maple and black willow. These forested areas are home to endangered mammals and birds, as well as rare plants and other species. Ecosystem services associated with bottomland hardwood forests include the harvest of timber, flood control, groundwater supply, habitat, hurricane protection, enhanced water quality and recreational opportunities.

Oyster Reefs

Oyster reefs are submerged colonies of oysters found in nearshore rocky areas, bays and estuaries, especially near river mouths where waters are brackish and shallow. Oyster reefs in Texas are built primarily by the eastern oyster, *Crassostrea virginica*, through reproduction and settlement of oyster larvae onto existing reef structures, creating large mounds of oysters and oyster shells. Oysters settle on hard substrates, like concrete barriers and rocks, but prefer to colonize on other oyster shells, as they cannot thrive on sandy or soft muddy bay bottoms. As successive generations of oysters settle and grow, large reef structures can amass, comprised of many individual oysters. It is estimated that oyster reefs have 50 times the surface area of an equally sized flat bottom.[64]

Oyster reefs increase biodiversity and provide valuable habitat for more than 300 marine aquatic species to forage and spawn, creating ideal locations for commercial and recreational fishing.[88] Additional ecosystem services provided by oyster reefs include sediment stabilization, shoreline protection, erosion control, and water filtration and circulation within estuaries.[25]

Oysters have the ability to filter water by removing pollutants and sediment, providing a vital service to some of the most impaired coastal waters (see Figure 3.7). A single adult oyster can filter roughly two gallons of water every hour.[11] The multitude of ecosystem services provided by oyster reefs are integral to the health and vitality of estuaries.

The 2014 restoration of Half Moon Reef in Matagorda Bay resulted in a diversified habitat that attracted recreational anglers, which added $691,000 to the state's gross domestic product and generated an additional $1.27 million in economic activity annually.[67]

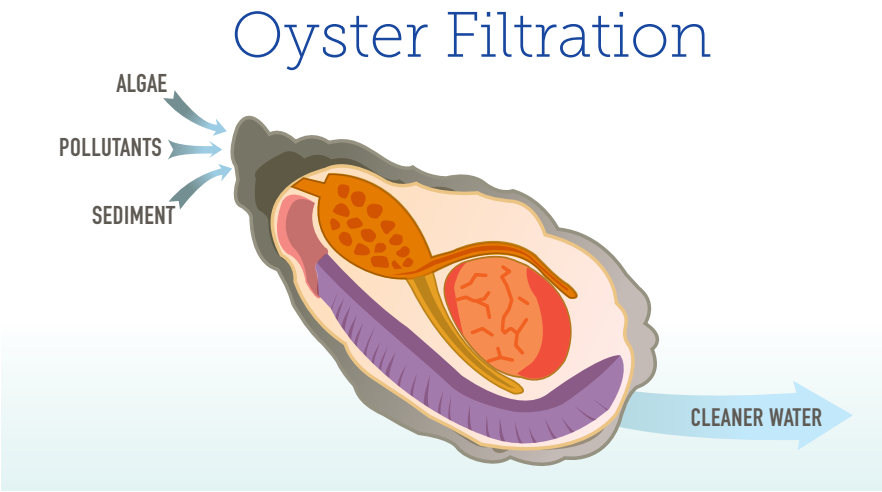


Figure 3.7: *Oyster Filtration – Oyster reefs act like giant filters; they pull out harmful pollution, toxins, sediment and algae from bays and estuaries. By keeping the water clean and clear, oyster reefs also boost aquatic life, which is beneficial for the overall ecosystem and for commercial and recreational fishing.*

Rookery islands: *Islands that provide foraging, roosting, cover and nesting habitats for colonial and migratory birds.*

Rookery Islands

Rookery islands are typically quite small – only a few acres or less in size – and while some naturally exist, most were formed from the placement of dredged material during the creation or maintenance of nearby navigation channels, such as the Gulf Intracoastal Waterway, or smaller channels and basins supporting ports and marinas.[86] These islands that dot the back side of the barrier islands and the adjacent bays protect bay shorelines and navigation channels from erosion.

Birds on a rookery island.

Rookery islands are isolated from the mainland and are too small to sustain predator populations, thereby providing optimal foraging, roosting, breeding, nesting and rearing habitats for migratory birds and a wide variety of colonial waterbirds and coastal shorebirds, including herons, terns, pelicans, egrets and cormorants. Colonial waterbirds rely on open water, mud flats, estuarine wetlands and seagrass for foraging. Rookery islands provide areas for birdwatching, ecotourism and recreational fishing. Nesting pairs on rookery islands can range from a few pairs to thousands depending on island size.

Preservation of rookery islands becomes increasingly important as changes in the bays, such as relative sea level rise and sediment management practices, are resulting in the loss and degradation of islands. Several studies conducted in the Galveston Bay estuary found a link between declining waterbird populations and decline in wetland area, including wetlands found on rookery islands – underscoring the need for island preservation.[86]

Shamrock Island in Corpus Christi Bay.

3.2. The Characterization of Texas' Coastal Economy

In addition to the numerous ecosystem services provided by the state's coastal environments, the economic value of the coast is characterized by the benefits offered by coastal communities and development, commerce and maritime transportation.

Coastal Communities & Development

Texas' greatest coastal asset is its people. The Texas coast consists of a myriad of population centers ranging in size from a major metropolis with greater than 2 million inhabitants, to small, sparsely-populated coastal towns. Currently, 6.5 million people live within the 18 coastal counties, with projections that over 9 million will live within this area by 2050.[90] As of 2014, these counties had a population density of 439 persons per square mile; four times greater than that of the state as a whole.[90] A population density map for the Texas coast is shown in Figure 3.8.

Population growth and commercial and industrial development is spurred by the unique opportunities and amenities the coast provides. Due to this development along the coast, property value can be used as a way to estimate the value of the built environment. In 2014, over $600 billion of real property was located in the 18 coastal counties, with an aggregated market value of $40.5 million per square mile.[71] By 2050, the real property market value within the coastal counties is expected to approach $880 billion.[71] The development activity along the coast alters the natural environment to a built environment and, consequently, can affect ecosystems and associated natural processes. If a coastal resiliency management approach is not incorporated, this transformation of the Texas coast will continue to expose coastal communities, economic assets and natural resources to coastal hazards and their negative impacts.

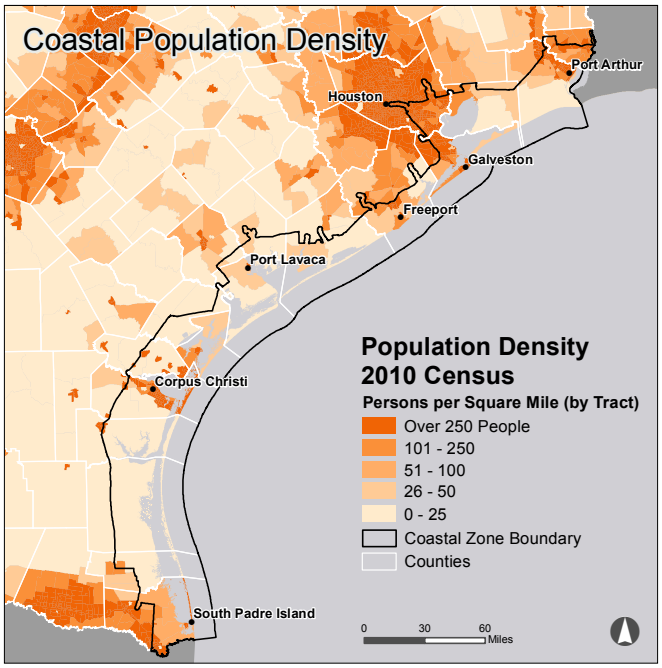


Figure 3.8: *Coastal Population Density – The number of people per square mile for each census tract, according to the 2010 U.S. Census.[17] A census tract is a subdivision of a county that is roughly equivalent to the size of neighborhood. The average population density of the Texas coastal counties is more than four times greater than the average of Texas as a whole. The two largest population centers on the Texas coast are the greater Houston area, the fourth largest metropolitan complex in the United States, and Corpus Christi, the eighth largest city in Texas.*

Coastal community of Port Aransas.

Coastal Commerce

Easy access to low-cost water transportation, as well as proximity to open bay and Gulf waters, supports economic diversity and prosperity along the Texas coast. Activities that rely on coastal features, resources and amenities include waterborne commerce, petroleum exploration and refining, petroleum and chemical product manufacturing, commercial and recreational fishing, and tourism and ecotourism. The ocean economy supports over 70,000 businesses and 1.6 million workers in Texas with total wages in excess of $37 billion within the coastal counties.[10] Overall, residents of Texas coastal counties capture one-third of the employment and almost half of the wages paid in the state in ocean economy industrial sectors.[10] Table 3.1 presents the sectors and industries that comprise the state's ocean economy, and Table 3.2 presents the ocean economy sectors' collective contributions to each coastal county's economy.

The ocean economy supports over 70,000 businesses and 1.6 million workers in Texas with total wages in excess of $37 billion within the coastal counties.[10]

Table 3.1: Texas Ocean Economy Industrial Sectors[12]

Sector	Industry
Living Resources	Fish Hatcheries and Aquaculture
	Fishing
	Seafood Processing
	Seafood Markets
Marine Construction	Marine Related Construction
Marine Transportation	Deep Sea and Coastal Transportation
	Inland Water Transportation
	Support Activities for Water Transport
Ship and Boat Building	Ship Building and Repair
	Boat Building and Repair
Leisure and Hospitality	Arts, Entertainment, and Recreation
	Accommodations and Food Services
Mineral Exploration and Extraction	Crude Petroleum Extraction
	Natural Gas Liquid Extraction
	Construction Sand and Gravel Mining
	Industrial Sand Mining
	Drilling Oil and Gas Wells
	Support Activities for Oil and Gas Operations
	Geophysical Surveying and Mapping Services
Petroleum Refining and Chemical Manufacturing	Petroleum and Coal Products Manufacturing
	Chemical Manufacturing
	Plastics and Rubber Products Manufacturing
Oil and Gas Pipeline Construction	Oil and Gas Pipeline and Related Structures Construction
Pipeline Transportation	Pipeline Transportation

Table 3.2: Ocean Economy – Annual Average Employment, Business Establishments and Wages in Texas Coastal Counties, 2014[10]

Region	Coastal County	Employment	Establishments	Annual Wages	Average Wage per Employee
1	Harris	383,857	12,051	$30,037,073,329	$78,251
1	Jefferson	26,231	657	$1,764,648,387	$67,273
1	Galveston	23,973	842	$978,847,818	$40,831
1	Brazoria	21,504	648	$1,445,543,411	$67,222
1	Orange	4,539	160	$279,720,798	$61,626
1	Chambers	2,510	117	$216,358,762	$86,199
All 1		**462,614**	**14,475**	**$34,722,192,510**	**$75,056**
2	Victoria	5,268	252	$176,046,236	$33,418
2	Calhoun	3,681	88	$289,214,318	$78,569
2	Matagorda	1,495	118	$34,195,803	$22,873
2	Jackson	90	42	$6,628,807	$73,653
All 2		**10,534**	**500**	**$506,085,164**	**$48,043**
3	Nueces	32,205	1225	$1,439,596,955	$44,701
3	San Patricio	3,785	184	$157,720,275	$41,670
3	Aransas	1,682	123	$46,948,652	$27,912
3	Kleberg	1,497	80	$21,793,759	$14,558
3	Refugio	550	54	$39,831,952	$72,422
All 3		**38,842**	**1,666**	**$1,642,692,003**	**$42,292**
4	Cameron	15,799	753	$286,619,064	$18,142
4	Kenedy		7		
4	Willacy		33		
All 4		**15,799**	**793**	**$286,619,064**	**$18,142**
Coastal Counties		**527,789**	**17,434**	**37,157,588,736**	**$70,402**
Coastal Counties % of State		**32.8%**	**24.8%**	**47.0%**	**143.3%**
Texas Statewide		**1,609,726**	**70,298**	**$79,109,672,145**	**$49,145**

The Energy Industry

The energy industry is the major contributor to economic activity in Texas, and includes industrial sectors such as resource exploration and recovery, transportation of materials, product manufacturing, and construction of pipelines, refineries, ships, offshore platforms and barges.

Mineral Resources Extraction

Predominant mineral resource extraction industries along the Texas coast include oil and gas, limestone, sand and gravel. The oil and gas extraction industry in Texas accounts for 57 percent of the nation's value added for that industrial sector.[9] In addition, support activities for mining in Texas account for half of the nation's value added from that sector.[9] Texas coastal counties account for approximately 20 percent of the statewide extraction business, as well as nearly one-third of employment and one-half of all wages.[10]

Petroleum Refining, Petrochemical, Chemical and Plastics Manufacturing

Texas coastal counties account for one-third of the state's petroleum refining, petrochemical, chemical and plastics manufacturing business, and one-half of total employment in these high-paying industrial sectors. Close to 850 businesses representing these industrial sectors in coastal counties employ nearly 70,000 workers, with a total annual payroll of almost $8 billion.[10]

Oil and Gas Industry-Related Construction

The oil and gas industries in Texas are present in a variety of industrial sectors, and include construction of pipelines, oil refineries, petrochemical plants and storage tanks. Over half of the state's employment in this sector is located in coastal counties that are home to 200 businesses and 22,600 workers, with the latter accounting for almost $2 billion annually in wages.[10]

Pipeline Transportation

Transportation of petroleum, natural gas and associated products by pipeline supports energy and manufacturing industries, and contributes to the local, state and national economies. Two-thirds of the employment in this support service is found along the Texas coast, where products are moved to and from ports and manufacturing plants.[10] This industry supports over 200 businesses and 11,000 workers with annual wages of $1.7 billion.[10]

Ship Building and Repairs

The ship building, parts and repairs industry supports offshore mineral exploration and extraction activities, as well as commercial fishing and waterborne transportation along the Gulf Intracoastal Waterway and the open waters of the Gulf. This industry sector includes construction and repair of barges, ships, commercial fishing boats, towboats, and offshore oil and gas floating platforms. Two-thirds of employment in this sector is found in Texas coastal counties, with approximately 60 businesses employing 3,400 workers with annual wages of $215 million.[10]

Marine Construction

This sector of the economy includes construction of breakwaters, bulkheads, channels, canals, harbors, jetties and other marine structures. Given that marine construction is not differentiated among many other forms of heavy construction, its contribution to the Texas coastal economy cannot be calculated with precision. However, heavy construction constitutes one-quarter of the state's overall employment in the coastal counties, with 4,200 workers accounting for $320 million annually in wages.[10]

Commercial Fishing

The wetland systems and coastal bays along the Texas coastline, as well as adjacent Gulf waters, provide an abundance of commercial fishing opportunities. This is an important sector of the coastal economy, and one that is highly dependent upon healthy ecosystems to support populations of commercially harvested fish and shellfish.

The commercial fishing industry in Texas in 2015 accounted for 81.5 million pounds of seafood, valued at $174.8 million.[52] In 2015, its shrimp, blue crab and red snapper harvests ranked highest by weight of all commercial seafood in Texas.[52] In fact, about one-third of Gulf shrimp landings and about one quarter of all shrimp landings in the United States come from Texas.[112] In 2015, Texas harvested 1.6 million pounds of oysters worth

$8.2 million.[52] Texas is regularly one of the top three states nationally in oyster landings, and frequently one of the top two landings of Eastern Oyster.[52] Texas also accounts for about one-quarter of the red snapper harvested in the Gulf.[112]

The commercial fisheries industry supports commercial harvesters, seafood processors, seafood distributors, grocers and restaurants. During 2014, there were 26,500 workers with annual wages of $567 million derived directly from the seafood caught in Texas bays and the Gulf of Mexico, excluding imports.[51] Sales generated from these landings exceeded $1.6 billion with a value-added contribution of $800 million.[51]

Recreation, Tourism/Leisure and Hospitality

Tourism and recreation activities are important industrial sectors to the coastal economy and include sightseeing, beach-going, wildlife watching, fishing, boating and other forms of recreation and leisure activities. The recreational, tourism/leisure and hospitality industry along the Texas coast employs approximately 300,000 coastal residents across a variety of enterprises, from hotel and restaurant services to boat dealers and offshore fishing guides.[10] These workers make a total of $6 billion in wages annually, working at nearly 14,000 businesses within coastal counties.[10]

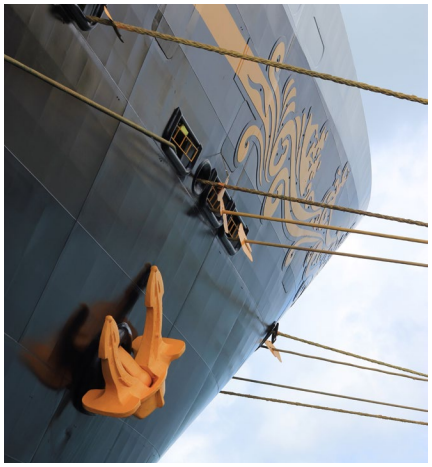
Marine Recreational Boating and Fishing

Marine fishing and boating expenditures are categorized into the following expenditure types: for-hire trips, private boat trips, shore trips and durable equipment expenditures related to marine recreational fishing. Expenditures include fishing tackle and gear, fishing-related equipment, boats, vehicles and second homes. In 2011, $400 million was spent by 750,000 anglers for these activities and goods, who also took part in 5.2 million fishing trips in the state's marine waters.[103]

Recreational expenditures for marine fishing averaged $77 per trip in 2011.[103] Marine recreational fishing supported 16,500 jobs in 2014 and provided $757 million in income to full and part-time workers.[51] Over $1.8 billion in sales and $1.2 billion in value added from recreational fishing expenditures contributed to the gross domestic product (GDP) of the state.[51]

Cruise Ship Industry

Galveston County and Galveston Island are popular tourist destinations, not only for their beaches and historical and recreational attractions, but also as a result of the cruise ship industry. Proximity to open, deep water has buoyed this growing industry on the island and, with more than 901,000 passenger and crew embarkations annually (2013), the Port of Galveston is ranked as the nation's fourth-largest cruise market.[63] With over $1.2 billion in direct spending related to cruise passengers or tourists that directly benefits the local economy and nearly 20,300 jobs paying $1.16 billion in wages, Texas accounted for 6.3 percent of the North American cruise industry's direct expenditures, 5.6 percent of the industry's total employment impact and 6.3 percent of the income impact nationwide.[63] Other ports in Texas are also working to become ports for the cruise industry.



With more than 901,000 passenger and crew embarkations annually (2013), the Port of Galveston is ranked as the nation's fourth-largest cruise market.[63]

Ecotourism

Ecotourism is defined as "environmentally responsible travel to natural areas to enjoy and appreciate nature."[96] Ecotourism is intended to have a low impact on the local community and promote conservation. Texas' environmental diversity has made Texas an important destination for ecotourism. The continued popularity for wildlife watching highlights the importance of maintaining diverse, accessible and robust fish and wildlife populations.[109]

Texas is within the North American Central Flyway for bird migrations that traverse the Texas Gulf Coast, making bird tourism (i.e., avitourism) an important industry and source of revenue for the state.[87] Texas is the number one birdwatching state in North America and the Rio Grande Valley in Region 4 is often considered the number two birdwatching destination in North America.[43]

Texas Maritime Transportation System

The state's maritime system is a critical gateway to international trade, and provides Texas and the entire nation with a multitude of economic opportunities through the movement of waterborne commerce.

Texas is home to multiple deep draft and shallow draft ship channels that provide vessel access to 21 Texas ports (Figure 3.9). Texas is one of the nation's leading states for waterborne commerce, with Texas ports generating over $82.8 billion in economic value to the state.[89] More than 552 million tons of cargo – 22 percent of all United States port tonnage – pass through Texas ports annually, including machinery, grain, seafood, oil, cars, retail merchandise and military freight.[76] Seven Texas ports rank in the top 50 of all United States ports in terms of annual 2015 tonnage, and the following four rank in the top 15: Houston (2nd), Beaumont (5th), Corpus Christi (6th) and Texas City (15th).[102] Texas ports support $1.4 million in jobs that translate to consumer spending and provide $6.5 billion in state and local taxes per year, or approximately 25 percent of the total state GDP.[89] The vast economic benefits of Texas ports to the state and national economies became more apparent

Inner harbor of the Port of Corpus Christi.

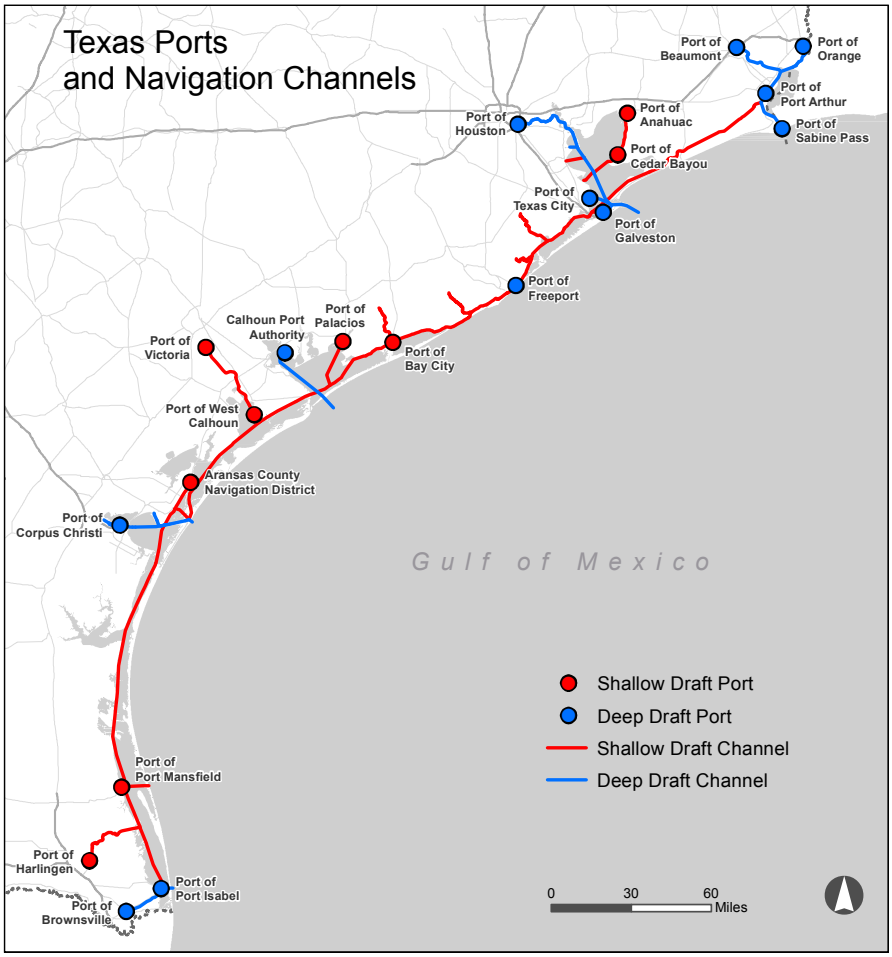


Figure 3.9: *Texas Ports and Navigation Channels – The shallow and deep water channels that provide vessel access to the 21 ports in Texas.[77] Twenty percent of all U.S. port tonnage passes through Texas ports annually, generating over $82 billion in economic value to the state.[89]*

when Hurricane Ike came ashore in 2008, closing the Port of Houston for five days and resulting in $1.6 billion in economic losses (approximately $322 million per day).[82] Texas ports offer critical links to other modes of transportation throughout the United States, such as major railroad lines, trucking routes and shipping.

Three Texas ports are designated by the Department of Defense as "strategic military ports," providing surface deployment and distribution for strategic military cargo worldwide. The Port of Beaumont, Port of Port Arthur and the Port of Corpus Christi all serve in the U.S. Maritime Administration's National Port Readiness Network, supporting deployment of United States military forces during defense emergencies.[75]

The Port of Beaumont handles more military cargo than any other port in the United States.[75] In addition, a larger volume of energy products, such as jet and diesel fuel, is delivered from the Texas coastal region to the U.S. military – more than any other state.[75] Furthermore, the majority of the nation's strategic petroleum reserves are located near Houston.[102]

The Coast Guard is ubiquitous along the Texas Gulf Coast with more than 2,000 personnel stationed at operational facilities from Port Arthur to South Padre Island.[68] The Texas coast is also home to four Department of Defense installations: Ellington Field Joint Reserve Base in Harris County (Region 1), Naval Air Station Kingsville in Kleberg County (Region 3), Naval Air Station Corpus Christi in Nueces County (Region 3) and Corpus Christi Army Depot in Nueces County (Region 3).[104]

The economic contribution of these installations is displayed by region and is included in the statewide total in Table 3.3. Within Texas' coastal counties, the U.S. military presence employs nearly 40,000 persons generating an annual $2.3 billion in personal income.[60] The economic contribution of the military's coastal facilities to the state is $6 billion and the contribution to the state's GDP is estimated at $3.8 billion.[60]

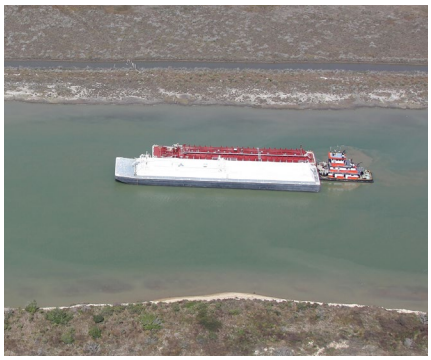
Military ship docked in the inner harbor of the Port of Corpus Christi.

The Port of Beaumont, Port of Port Arthur and the Port of Corpus Christi all serve in the U.S. Maritime Administration's National Port Readiness Network, supporting deployment of United States military forces during defense emergencies.[75]

Table 3.3: Economic Impact of Military Installations: Statewide and in Regions 1 and 3, 2015 [60,72]

	Statewide Total	Coastal Region 1	Coastal Region 3
Total Employment	805,685	4,155	35,577
Output to the Texas Economy	$136,648,713,000	$777,245,000	$5,331,910,000
GDP	$81,388,385,000	$452,059,000	$3,298,933,000
Disposable Personal Income	$48,094,627,000	$259,880,000	$2,114,827,000

The Gulf Intracoastal Waterway



Tugboat pushing barge to efficiently transport petrochemicals along the GIWW.

Important to the state and national economy, the Gulf Intracoastal Waterway (GIWW) is an integral feature along the Texas coast because it connects the state's ports and navigation channels, creating a thoroughfare for barge and other commercial waterway traffic from Brownsville, Texas to Carrabelle, Florida. Commercial uses of the GIWW involve harvesting fish and shellfish, providing water-based access to refineries, and the movement of domestic and international cargo, including manufactured goods, farm products, machinery, petroleum products and chemicals.[40] The U.S. Army Corps of Engineers (USACE) is responsible for dredging the GIWW, which is the nation's third busiest inland waterway.[58]

The Texas portion of the GIWW stretches 406 miles in length and handles over 63 percent of the GIWW's total traffic with a cargo value of $25 billion.[74] Approximately 53,000 barges move more than 73 million tons of cargo through the Texas GIWW annually.[40] In comparison, it would take more than 3 million container trucks, or 570,000 rail cars, to transport the same cargo volume.[40] The use of the GIWW along the Texas coastline is forecasted to increase due to the expansion of the Panama Canal to accommodate the growth in worldwide waterborne trade, which could lead to a positive economic impact on the Texas petrochemical, agriculture, and manufacturing industries that use the GIWW to transfer their products.[76]

Waterway traffic within the state is dominated by movements of crude petroleum and petroleum products, such as gasoline, diesel and jet fuel, making up over three-quarters of all commodities moved within the state's waterway system.[101] Of this tonnage, 65 percent moves on the Sabine River to Galveston segment of the GIWW, much of it consisting of petroleum and chemical-related products.[101]

Healthy wetlands protect the GIWW shoreline from erosion.

The GIWW also provides ecological and recreational benefits to the state. Even though the GIWW is considered a shallow-draft channel, having a maintained depth of 12 feet, it is deeper than the natural depth of most Texas bays adjacent to the GIWW. The shielded design of the waterway provides an ideal setting for recreational activities, such as fishing, waterskiing, sightseeing and boating.

Dredged material from the initial dredging and subsequent maintenance of the channel created many small islands that line the channel and protect the navigation route from silting in. Texas colonial waterbirds seek out and heavily utilize these islands as "rookeries," for nesting and raising their chicks in large groups with protection from predators and human disturbance.

3.3. Characterization of the Four Coastal Regions

The study area of the Plan is defined by the Texas Coastal Zone Boundary from the Texas Coastal Management Program, which is the area the GLO is required to regulate through state and federal laws. This area is immense – making up one-tenth of the state's total land area. This includes over 6 million residents, representing nearly 25 percent of the state's total population.[90]

Because of the diversity and expanse of the Texas coast, the coast is broken up into four regions for the purposes of this planning effort to provide a more focused assessment of the needs in these coastal areas. All or portions of the following counties are included in these four regions (Figure 3.10):

- **Region 1** – Brazoria, Chambers, Galveston, Harris, Jefferson, Orange
- **Region 2** – Calhoun, Jackson, Matagorda, Victoria;
- **Region 3** – Aransas, Kleberg, Nueces, Refugio, San Patricio; and
- **Region 4** – Cameron, Kenedy, Willacy.

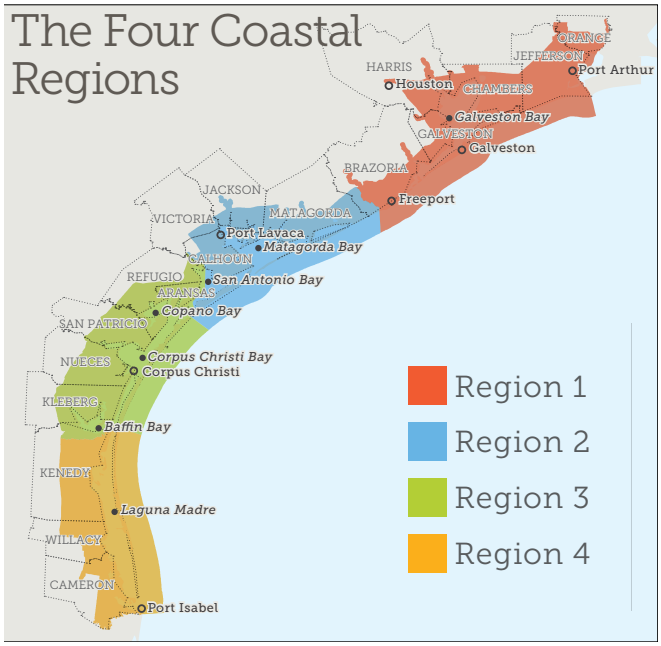


Figure 3.10: *The Four Coastal Regions – The planning area includes the 18 counties within the Coastal Zone Boundary of the Texas Coastal Management Program.*

These regions are diverse in their environmental characteristics and land use patterns, providing a multitude of economic and environmental benefit. Each of the four regions are described by unique characterizations, such as shoreline change, coastal environments and development.

Shoreline change is determined by historical erosion rates and the Texas Administrative Code defines "eroding areas" as, "A portion of the shoreline which is experiencing an historical erosion rate of greater than two feet per year based on published data of the University of Texas at Austin, Bureau of Economic Geology."[69]

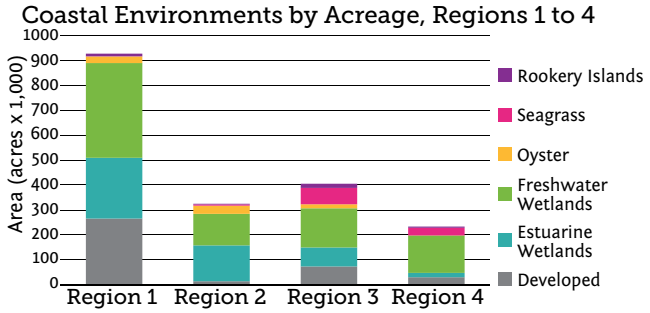


Figure 3.11: *Coastal Environments by Acreage, Regions 1 to 4 – The area of coastal environments in thousands of acres, Regions 1 to 4.[21,53] Region 1 is the most heavily developed and contains the largest area of freshwater and saltwater marshes out of the four regions. Region 2 is sparsely developed, but contains extensive oyster beds and freshwater and estuarine wetlands. Region 3 is the second most developed and includes the most abundant seagrass and rookery islands relative to the other regions. Region 4, similarly to Region 2, is also mostly undeveloped with abundant freshwater wetlands and seagrass beds.*

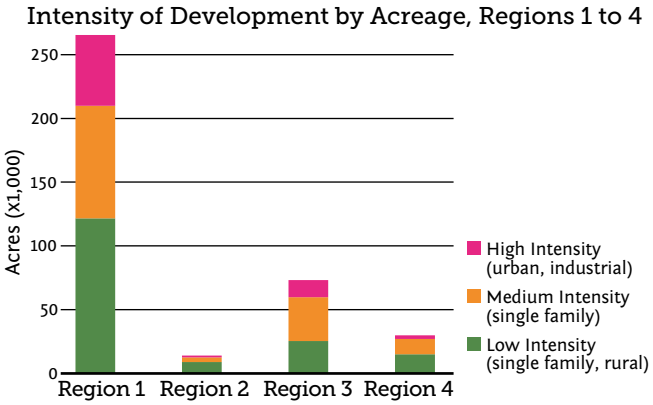
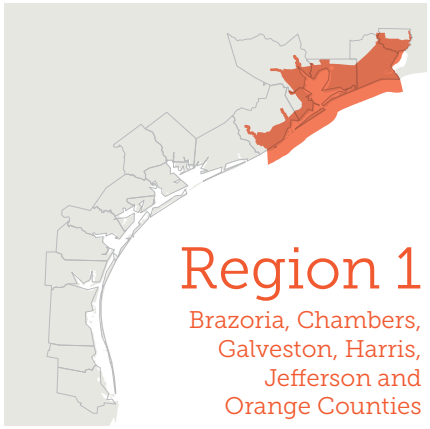


Figure 3.12: *Intensity of Development by Acreage, Regions 1 to 4 – A recent study from Texas A&M University indicates that high-intensity, clustered development patterns tend to be more flood resilient than low intensity developments when viewed at the county level. To mitigate flood risks in medium intensity developments, the most protection is afforded by high connectivity networks (roads) and ample protection of open space.[6,53]*



Region 1

Brazoria, Chambers, Galveston, Harris, Jefferson and Orange Counties

Bays and Estuaries

Sabine-Neches Estuary

The Sabine-Neches watershed receives an average of 55 inches of rainfall per year making its waters the least saline of the estuaries along the Texas coast.[92] Sources of freshwater for the Sabine-Neches estuary include the Sabine River and Neches River, and several minor watersheds. Sabine Pass connects Sabine Lake to the Gulf of Mexico at the Texas-Louisiana border.

Trinity-San Jacinto Estuary

The Galveston Bay system includes Galveston Bay and several secondary bays including East Bay, Trinity Bay and West Bay. The estuary is known as the Trinity-San Jacinto estuary – the state's largest estuary and the seventh largest in the United States.[93] The area receives about 50 inches of rainfall per year.[92] Freshwater enters the estuary by way of the Trinity and San Jacinto rivers and surface runoff from surrounding watersheds. Bolivar Peninsula and Galveston Island shield the estuary from the wave action in the Gulf of Mexico.

Galveston Bay.

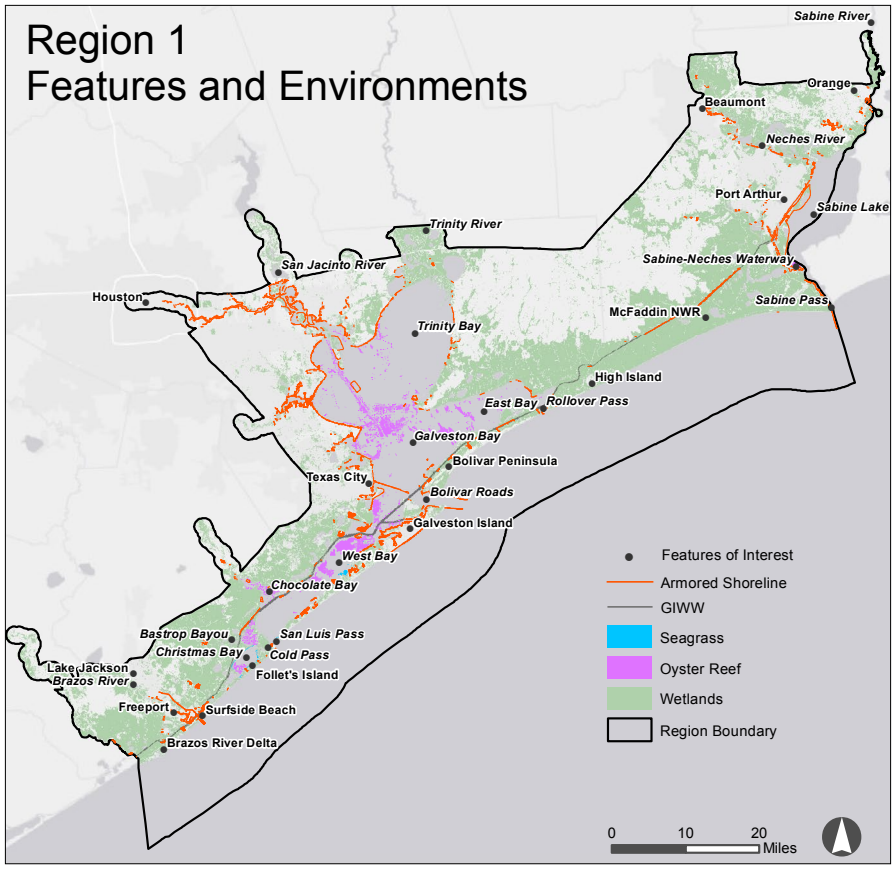


Figure 3.13: *Region 1 Features and Environments – The primary bays, habitats, landmarks and shoreline composition for Region 1.[21,53] Compared to the other regions, Region 1 contains the most armored shoreline and is the most heavily developed. This region contains a portion of the Greater Houston metropolitan area, Beaumont, Galveston and Texas City, among others. Despite the presence of industrial and urban development, this region is also home to expansive coastal resources.*

Saltwater enters the Galveston Bay system through inlets at Bolivar Roads, San Luis Pass and Rollover Pass. Christmas Bay is a separate minor estuary on the western side of this region and is protected from the Gulf of Mexico by Follets Island. Christmas Bay receives freshwater from Bastrop Bayou and is connected to Galveston Bay by Cold Pass.

The primary bays, habitats (wetlands, oyster reef and seagrass), landmarks and shoreline composition for Region 1 are shown in Figure 3.13.

Gulf and Bay Shorelines

Shoreline Change

About 74 percent of Gulf-facing beaches in this region are considered eroding areas.[113] The average rate of erosion in these eroding areas is almost 10 feet per year.[113] The high rate of erosion in this region can be partly attributed to a naturally sand-starved setting, exacerbated by engineered structures such as the dredged channels and jetties at Sabine Pass and Bolivar Roads that interrupt the longshore transport of sediments along Bolivar Peninsula and Galveston Island.[46] Sand carried by longshore currents is trapped by the jetties, causing localized areas of shoreline accretion, while exacerbating shoreline erosion in other areas as the trapped sand is not distributed along the shoreline by the current to assist with natural beach rebuilding.[47] Including eroding and accreting shorelines, the average rate of Gulf shoreline change in Region 1 is approximately 5.7 feet per year of loss.[113] The highest rates of Gulf shoreline erosion are found along the shoreline that runs from High Island to Sabine Pass.[61,113] Region 1 experiences shoreline erosion within the bays as well, but full data coverage of bay shoreline change within the entire region is not yet available. As a result, bay shoreline erosion within Region 1 is identified primarily through individual studies and datasets that target local areas.

About 74 percent of Gulf-facing beaches in Region 1 are considered eroding areas. The average rate of erosion in these eroding areas is almost 10 feet per year.[113]

Shoreline along San Luis Island near San Luis Pass.

The west end of Galveston Beach with an extremely low dune system.

Existing dune complexes in Region 1 are generally low in height and have poor continuity, which diminishes the natural protection dunes provide to coastal communities.

Dunes

Texas' uppermost region is characterized by a scarcity of dunes due to a lack of sediment availability. In Jefferson and Chambers counties, the Sabine River carries silt rather than sand to the coast creating a shoreline of low-lying marshes and tidal flats with intermittent thin, linear sand ridges called chenier plains. Dunes are also scarce further south along the Brazos-Colorado river where insufficient dune-building sand is delivered by the longshore current.

On portions of Follets Island and Galveston Island, few naturally occurring dunes can be found because many were wiped out during catastrophic storm events. The landfall of Hurricane Ike in 2008 left the dune system along the Galveston Seawall barren. Shoreline development and high erosion rates continue to inhibit dune recovery. Existing dune complexes are generally low in height and have poor continuity, which diminishes the natural protection dunes provide to coastal communities.

Environments

Most recent and best available data were used to characterize the environments along the Texas coast. Data for wetland and upland environments were developed in 2011, and oyster and seagrass beds were delineated in 2009.[21,53] Estuarine wetlands cover almost 244,000 acres of Region 1, concentrated on the barrier islands, around the fringes of West Bay and East Bay, and in the areas between East Bay and Sabine Pass.[53] Freshwater wetlands occupy 380,000 acres of the region and are found along the San Jacinto and Trinity rivers and coastal uplands.[53] Oyster beds, while abundant in this region and covering more than 27,000 acres of bay bottom, suffered a 60 percent loss after Hurricane Ike and are still in need of restoration.[18] Seagrass is relatively sparse, covering only 660 acres of bay bottom.[21] The distribution of coastal environments in Region 1 is shown in Figure 3.11.

Development

Region 1 is the most heavily developed of the four regions, with built environments covering about 14 percent of the land area.[53] Proportionally, Region 1 contains the highest percentage of armored shorelines, both along the Gulf-facing beaches, with 13.4 percent armored, and bay shorelines with 21 percent armored by seawalls, bulkheads, jetties, riprap or other shoreline stabilization methods.[30] The intensity of development in Region 1 is shown in Figure 3.12.

Pleasure Pier on Galveston Island.

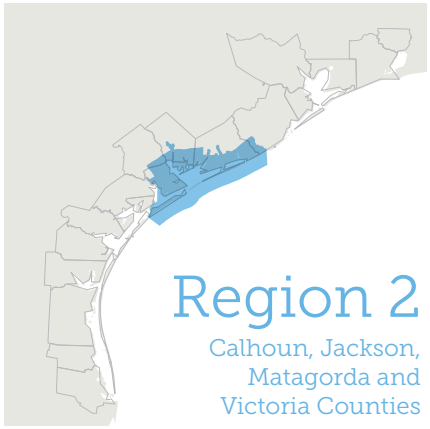
Of the developed area in Region 1, about 21 percent is urban or industrial development, and contains the Texas Gulf Coast Refining District, with 5,000 energy-related companies and 15 of the 20 largest oil pipeline companies in the nation.[26,53] This region consists of three primary population centers. The largest of these is the Houston-Galveston metropolitan complex, which surrounds the majority of Galveston Bay and includes Galveston Island and Bolivar Peninsula. The second comprises the eastern limit of the region, and includes the Beaumont-Port Arthur-Orange metropolitan area (known as the Golden Triangle), located along the northern shore of the Sabine Lake and its surrounding riverine systems. The third is the Freeport-Lake Jackson metropolitan area, which is the smallest of the three population centers and is directly bordered by the Gulf and the Brazos River near the western limit of the region.

Region 1 includes three deep draft navigation channels that are not only important to the region's industries and economy, but also play a key role in understanding the coastal dynamics of the area. Each of the major population centers is home to a primary network of deep draft channels made up of the Sabine, Houston and Freeport channel networks. Shallow draft navigation is primarily provided by the Sabine-Neches Waterway and the GIWW.

Notable man-made structures in the region are storm damage reduction systems maintained by USACE. Three of these are levee systems located in Port Arthur, Texas City and Freeport that provide flood risk reduction and community protection during and in response to coastal storms. The fourth structure of note is the approximately 10.5-mile-long Galveston Seawall, which runs parallel to Galveston's Gulf beachfront and provides the City of Galveston with protection from severe storm events.

> Region 1 contains the Texas Gulf Coast Refining District, with 5,000 energy-related companies and 15 of the 20 largest oil pipeline companies in the nation.[26]

Boardwalk Park in Port Arthur.



Region 2

Calhoun, Jackson, Matagorda and Victoria Counties

Bays and Estuaries

Colorado-Lavaca Estuary

The Colorado-Lavaca Estuary encompasses Matagorda and Lavaca bays as well as Carancahua, Tres Palacios, Keller and Cox bays. The Matagorda Bay system primarily includes East Matagorda Bay, Matagorda Bay and Lavaca Bay. Freshwater is delivered to the estuary via the Colorado, Lavaca and Tres Palacios rivers, and numerous creeks and surrounding coastal watersheds. The Matagorda Bay system is protected from the Gulf of Mexico by the Matagorda Peninsula. The Matagorda Ship Channel and Pass Cavallo provide hydrologic connections to the Gulf as water enters the estuary through the Gulf Intracoastal Waterway.

East Matagorda Bay is a minor estuary in the Matagorda Bay system with an average depth of just over 3 feet.[93] The estuary has limited riverine inflow, and receives freshwater from direct precipitation on the bay and surface runoff from surrounding coastal watersheds. Precipitation in the East Matagorda Bay area averages around 42.5 inches per year.[92]

Alcoa Bird Tower in Port Lavaca.

Coastal wetlands in Port Lavaca.

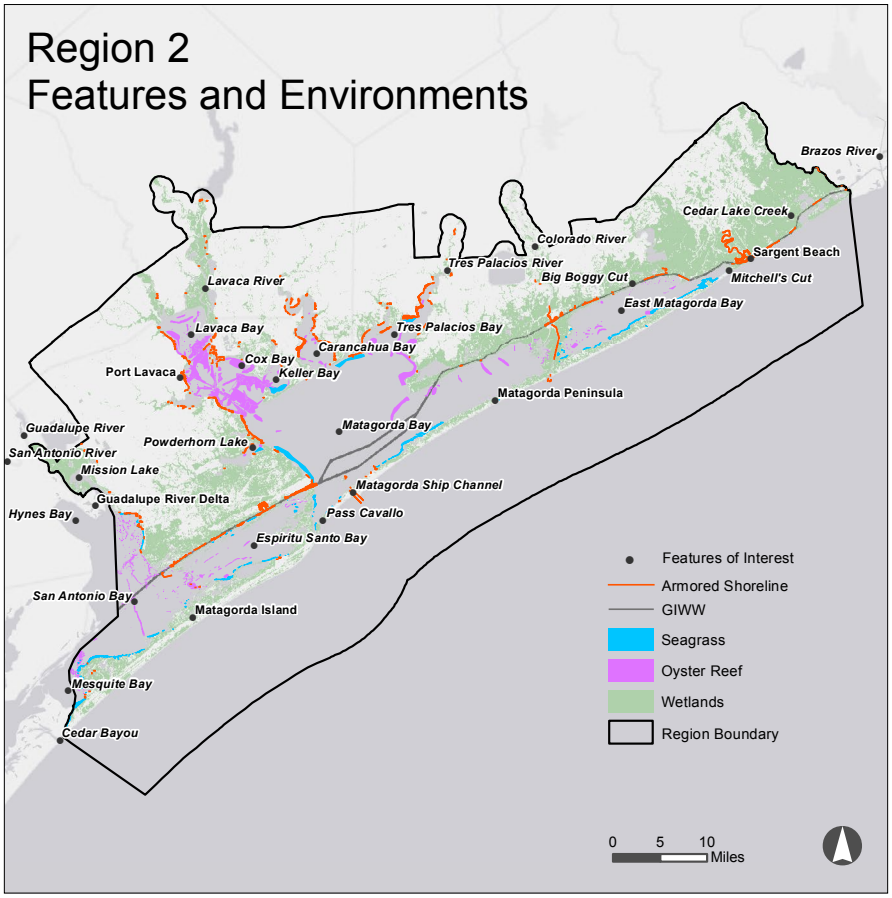


Figure 3.14: *Region 2 Features and Environments – The primary bays, habitats, landmarks and shoreline composition for Region 2.[21,53] This region is the least developed of the four regions. The lack of industrial and urban development means extensive natural resources are present in this region, including the bay systems of East Matagorda Bay, Matagorda Bay and the eastern portion of San Antonio Bay.*

Guadalupe Estuary

The Guadalupe estuary encompasses the San Antonio Bay system, which includes San Antonio Bay and the secondary bays of Espiritu Santo Bay and Mission Lake on the east (Region 2), and Hynes Bay and Mesquite Bay on the west (Region 3). The estuary receives freshwater inflows from the Guadalupe and San Antonio rivers and surface water runoff from surrounding coastal watersheds. The Guadalupe estuary is protected from the Gulf of Mexico by Matagorda Island, and the only connections to the Gulf are through the recently dredged Cedar Bayou on Matagorda Island and indirectly through Pass Cavallo in the Colorado-Lavaca estuary. Rainfall in the Guadalupe estuary averages about 37.5 inches per year.[92]

The primary bays, habitats (wetlands, oyster reef and seagrass), landmarks and shoreline composition for Region 2 are shown in Figure 3.14.

Gulf and Bay Shorelines

Shoreline Change

Relative to the other regions, Region 2 has the fewest eroding shorelines, with 58 percent of the Gulf shoreline considered an eroding area.[113] However, the average rate of erosion within these areas is more than 11 feet per year, which can be attributed to a few localized areas of extreme Gulf shoreline erosion on an otherwise relatively stable Gulf shoreline.[113] Major areas of shoreline erosion include the Brazos and Colorado rivers, and on Matagorda Peninsula west of the Colorado River.[113] A notable area of shoreline accretion is on a segment of Matagorda Peninsula in part due to the adjacent jetty at the Matagorda Ship Channel.[113] Region 2 also experiences shoreline erosion within the bays, but full data coverage of bay shoreline change within the entire region is not yet available. As a result, bay shoreline erosion within Region 2 is supplemented by data retrieved from local or regional studies and datasets.

Dunes

Further south, limited shorefront development has allowed continuous, well-defined dune ridge systems to develop and remain on Matagorda and San Jose islands. Most dune complexes average 15 feet to 20 feet above sea level.[79]

Although this area is typically categorized by healthier dune complexes, the upper Matagorda Peninsula experiences frequent overwash from periodic storms. This has created low and patchy dune complexes in the north, with the complexes becoming more continuous and wider on the southern part of the peninsula.

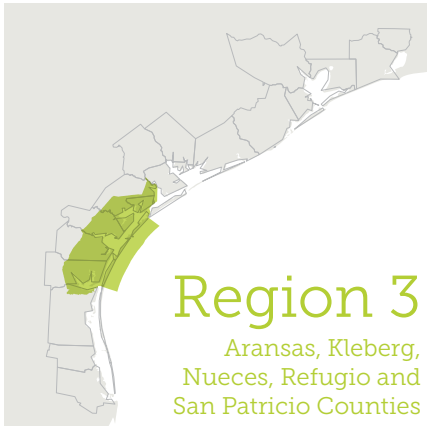
Environments

Region 2 has abundant estuarine wetlands, totaling 144,000 acres, fringing Matagorda Bay.[53] Freshwater wetlands cover 127,000 acres within the region, and are concentrated around Cedar Lake Creek and the Colorado River.[53] Oyster reefs are also abundant in this region, found on approximately 33,000 acres, particularly in Lavaca Bay.[21] Seagrass occupies 4,700 acres, more than can be found in Region 1, but considerably less than observed in Regions 3 and 4.[21] The distribution of coastal environments in Region 2 is shown in Figure 3.11.

Development

Region 2 is the least developed of the four regions, with development covering only 14,000 acres or approximately 1 percent of land area.[53] In Region 2, about 1.8 percent of Gulf-facing beaches and 6.6 percent of bay shorelines are armored.[30] About 10 percent of the growth in Region 2 is urban or industrial, and Port Lavaca is the largest city.[53] The lack of industrial and urban development allows for the presence of vast and valuable natural resources. The intensity of development in Region 2 is shown in Figure 3.12.

The Matagorda Ship Channel is the only deep draft channel in the region and has had significant adverse effects on the bay system since its introduction. The channel inlet through the Matagorda Peninsula altered the water and sediment exchange for the Matagorda Bay System by diverting most flood and tidal flows from the natural inlet that is Pass Cavallo, at the southwestern end of the bay, to the man-made channel further east.[39] This change in tidal dynamics has had two notable impacts: 1) An increase in the currents and subsequent erosion at the man-made channel entrance, which increases the risk of grounding for deep draft vessels, and 2) A decrease in the currents and an increase in siltation at Pass Cavallo, which has narrowed in width from 11,000 feet in 1965 to 2,100 feet in 1999.[39,44] Shallow draft navigation in Region 2 is provided by the GIWW and other minor waterways. The GIWW cuts through protected marshes in this region, and strong wakes from boat traffic contribute to high rates of channel erosion and wetland habitat loss.



Region 3

Aransas, Kleberg, Nueces, Refugio and San Patricio Counties

Bays and Estuaries

Mission-Aransas Estuary

The Mission-Aransas estuary contains Copano Bay, Aransas Bay and secondary bays including Saint Charles, Mission and Redfish bays. The Mission and Aransas rivers and surrounding coastal watersheds are the main conveyances of freshwater into the estuary. The estuary is largely protected by San Jose Island, and the only direct connection to the Gulf of Mexico is Aransas Pass, the natural inlet to the Corpus Christi Ship Channel at the southern end of the estuary. The area receives an average of 34.5 inches of rainfall per year.[92]

Nueces Estuary

The Nueces estuary includes Corpus Christi Bay, Nueces Bay and Oso Bay. Mustang Island separates the estuary from the Gulf of Mexico. Aransas Pass is the estuary's primary connection to the Gulf on the north end, while Packery Channel, a man-made inlet at the south end, provides additional water exchange. Average rainfall in the estuary totals about 32.5 inches per year, and freshwater flows in to the Nueces estuary by means of the Nueces River, Oso Creek via Oso Bay, and surrounding coastal watersheds.[92,93]

View of Oso Bay from Ward Island in Corpus Christi.

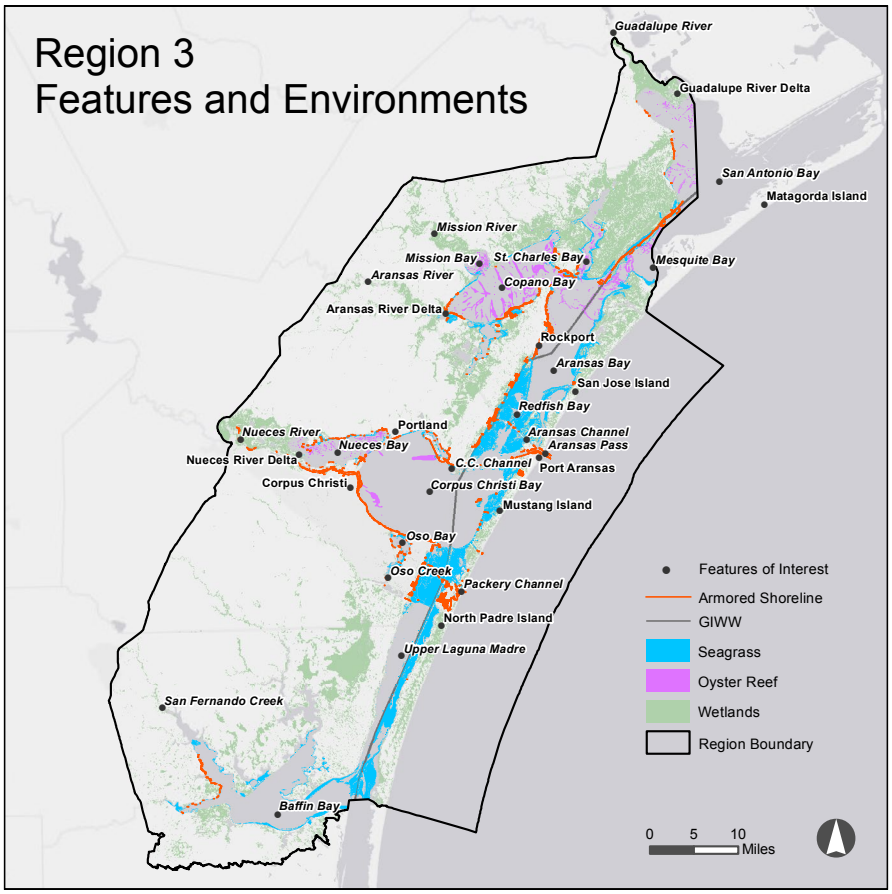


Figure 3.15: *Region 3 Features and Environments – The primary bays, habitats, landmarks and shoreline composition for Region 3.[21,53] Region 3 is the second most developed region among the four, including portions of the cities of Corpus Christi, Rockport, Port Aransas and Portland. Of the four regions, seagrass is the most abundant in this region, with seagrass beds found in Aransas Bay, Redfish Bay and in the Laguna Madre.*

Laguna Madre Estuary – Upper Laguna Madre

The Laguna Madre estuary, with an average depth of 4.5 feet, begins just south of Corpus Christi Bay and terminates near the Texas-Mexico border. The Laguna Madre is the only hypersaline lagoon (a body of water saltier than most seawater) in the United States, and one of only a handful in the world.[93] Padre Island, the longest barrier island in the world, separates the Laguna Madre from the Gulf of Mexico, with the only direct connection in Region 3 located at Packery Channel.[93] The Laguna Madre is divided into an upper section in Region 3 and a lower section in Region 4 by a land mass known as Saltillo Flats or the Landcut. The Upper Laguna Madre connects to Baffin Bay, which provides a contributing source of freshwater from San Fernando creek and other minor coastal watersheds. Rainfall in the Upper Laguna Madre area averages about 29 inches per year.[87]

Upper Laguna Madre.

The primary bays, habitats (wetlands, oyster reef and seagrass), landmarks and shoreline composition for Region 3 are shown in Figure 3.15.

Gulf and Bay Shorelines

Shoreline Change

Of the four regions, Region 3 has the lowest Gulf shoreline erosion due to its healthy beach and dune system. However, about 63 percent of Gulf-facing beaches in this region are considered eroding areas, with an average rate of erosion of 4.1 feet per year.[113] The highest rates of shoreline erosion occur along most of San Jose Island and northern Padre Island. Shoreline erosion rates along Mustang Island are relatively low, with localized areas of long-term shoreline accretion near Aransas Pass and on Padre Island near Baffin Bay.[113] Given the heavy use of beaches for coastal recreation and the protection they provide to coastal communities, it is important to keep the Gulf-facing shorelines of Region 3 restored and maintained. Bay shoreline erosion hotspots in Region 3 include shorelines along the backside of Mustang Island and San Jose Island, and along the Corpus Christi and Aransas ship channels.[113] Additional areas of bay shoreline erosion exist, but the datasets utilized to quantify shoreline erosion along Region 3 bays lack the resolution to identify all of these erosive locations. As a result, bay shoreline erosion within Region 3 is identified through individual studies and datasets that target local areas.

Given the heavy use of beaches for coastal recreation and the protection they provide to coastal communities, it is important to keep the Gulf-facing shorelines of Region 3 restored and maintained.

Port Aransas shoreline.

Well developed and vegetated dune complex provides storm surge and flood protection to Port Aransas, including the University of Texas Marine Science Institute, which is located behind this beach and dune complex.

The most highly developed dune formations are found in Nueces and northern Kleberg counties, where dune ridges consist of several rows of dunes that average 20 to 25 feet in height while some dunes reach a height of 40 feet.[79]

Dunes

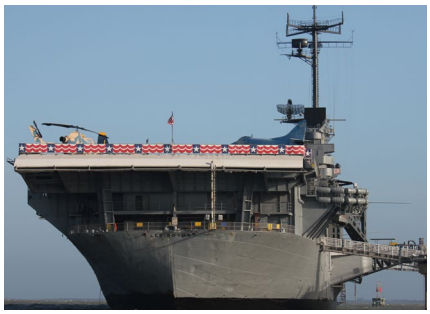
Increased sediment supply and regular rainfall contribute to a vegetated and well developed dune complex in Region 3 on Mustang Island and North Padre Island. Wide beaches contribute to stabilizing dunes and the increased precipitation nourishes dune vegetation, which traps additional wind-blown sand. The most highly developed dune formations are found in Nueces and northern Kleberg counties, where dune ridges consist of several rows of dunes that average 20 feet to 25 feet in height while some dunes reach a height of 40 feet.[79]

Environments

Freshwater wetlands cover a large area (157,000 acres) in Region 3, especially between Copano Bay and Mesquite Bay, and on the interior portion of the barrier islands.[53] Estuarine wetlands cover 76,000 acres, with prominent wetlands on San Jose Island and fringing the barrier islands.[53] Seagrass is abundant in this region, covering approximately 65,600 acres, with seagrass beds found in Aransas Bay, Redfish Bay and in the Laguna Madre estuary.[21] The region's 16,000 acres of oyster reefs are concentrated mainly in Copano Bay.[21] Bay shoreline erosion and coastal development contribute to habitat loss and jeopardize the health and water quality of this region's bay environments, which provide important nursery areas for commercial and recreational fisheries, and wetland habitat for wildlife and resident and migratory waterfowl. The distribution of coastal environments in Region 3 is shown in Figure 3.11.

Development

In Region 3, about 3.6 percent of Gulf-facing beaches are armored, while about 12.6 percent of bay shorelines are armored by seawalls, bulkheads, jetties, riprap or other shoreline stabilization materials.[30] This is the second most developed region along the coast, with development covering 73,000 acres and includes portions of the cities of Corpus Christi, Rockport, Port Aransas and Portland.[53] Developed area covers about 5 percent of the land area in Region 3, about 18 percent of which is categorized as urban or industrial.[53]



The USS Lexington in Corpus Christi.

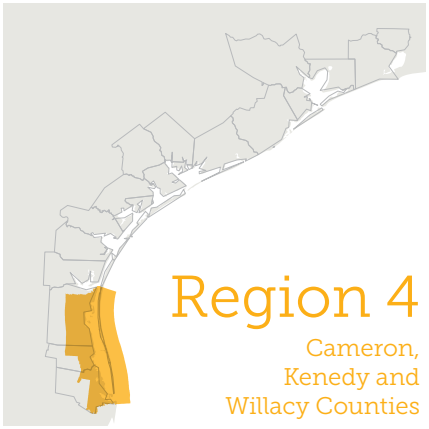
The City of Corpus Christi is the primary population center for the region, with over 300,000 inhabitants. Protecting downtown Corpus Christi from the adjacent bay is a concrete seawall, fronted by a variety of marinas and bay beaches, that reduce flood risk from coastal storm surges. There are also small sections of levees in Nueces and San Patricio counties, as well as a seawall on Padre Island, immediately south of Packery Channel. The intensity of development in Region 3 is shown in Figure 3.12.

Region 3 is home to the Corpus Christi Ship Channel, which is the sole deep draft navigation channel in the region. The rookery islands adjacent to the ship channel are experiencing erosion due to wave energy within the adjacent bays. This has been documented during multiple completed, ongoing or proposed island restoration and armoring projects primarily focused on protecting the rookery island shorelines that are exposed to the ship channel.

Region 3 is home to the Corpus Christi Ship Channel, which is the sole deep draft navigation channel in the region.

Packery Channel, located on Mustang Island, carries water from the Gulf into Corpus Christi Bay. It was reopened more than 10 years ago, and has since become a component of both the bay's tidal dynamics, based on measured currents in the channel and measured changes in the shoreline's sediment transport characteristics.[116]

View of Shoreline Boulevard and marina in Corpus Christi Bay.



Region 4

Cameron, Kenedy and Willacy Counties

Bays and Estuaries

Laguna Madre Estuary – Lower Laguna Madre

In the Lower Laguna Madre and South Bay, freshwater enters the Laguna Madre estuary through the Arroyo Colorado river and surrounding watersheds. The Port Mansfield Channel and Brazos-Santiago Pass provide hydrologic connectivity to the Gulf. Annual rainfall in the Lower Laguna Madre area is about 26 inches per year; roughly half of what the Sabine Lake region (Region 1) receives.[92] The Lower Laguna Madre is protected from the Gulf of Mexico by Padre Island.

The primary bays, habitats (wetlands, oyster reef and seagrass), landmarks and shoreline composition for Region 4 are shown in Figure 3.16.

Gulf and Bay Shorelines

Shoreline Change

Beach along South Padre Island.

About 64 percent of the Gulf-facing beaches in Region 4 are considered eroding areas, and are eroding at an average rate of almost 9 feet per year.[113] Specifically, on South Padre Island, the net rate of shoreline erosion averages 7.4 feet per year, including eroding and accreting shorelines.[113] Shoreline erosion rates of

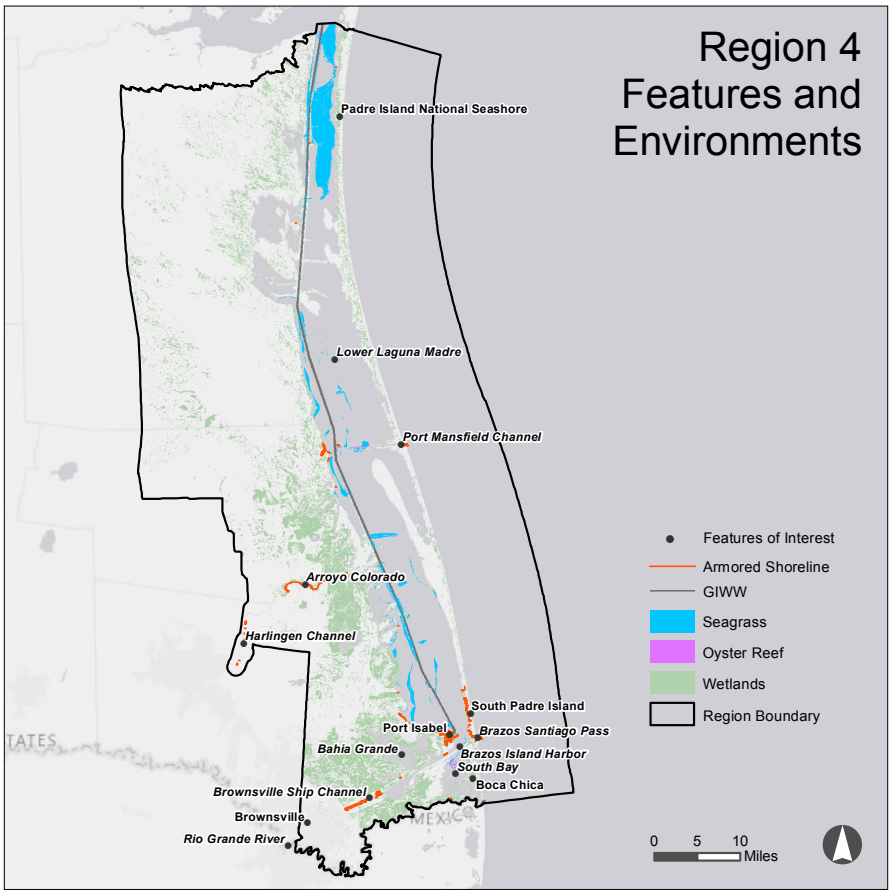


Figure 3.16: *Region 4 Features and Environments – The primary bays, habitats, landmarks and shoreline composition for Region 4.[21,53] Region 4 is sparsely developed, but is rich with valuable coastal resources, including abundant seagrass beds and the extensive beach and dune system that borders the community of South Padre Island on the Gulf shoreline.*

Surfer on South Padre Island beach.

greater than 10 feet per year were measured north of the Mansfield Channel jetties and south of Brazos-Santiago Pass.[113] Due to the interruption in the longshore sediment transport, a local area of shoreline accretion exists just south of the Mansfield Channel jetties.[113] Shoreline erosion and habitat loss is of significant concern in this region due to the value these coastal ecosystems provide to the local and state economies. Region 4 experiences shoreline erosion within the bays as well, but full data coverage of bay shoreline change within the entire region is not yet available. As a result, bay shoreline erosion within Region 4 is identified primarily through individual studies and datasets that target local areas.

Dunes

As rainfall decreases southward along the Texas coast, dunes in Region 4 have less of the vegetative cover necessary for stabilization, thus the erosive forces of wind, tides, and storms have a larger impact. In Kenedy, Willacy and Cameron counties, the dune ridge lacks continuity and is breached by numerous washovers and blowouts. Although this environment is typically characterized by discontinuous and unstable dune complexes, some dunes may become quite robust.

Environments

Freshwater wetlands cover approximately 150,000 acres in Region 4, concentrated along the Rio Grande River, the Arroyo Colorado River and around the Bahia Grande wetland complex.[53] Freshwater scrub and shrub land cover increases towards the Texas-Mexico border. Estuarine wetlands cover 17,000 acres, and are found mostly fringing the Lower Laguna Madre.[53] Large seagrass beds cover 31,000 acres in the Lower Laguna Madre.[21] Oyster reefs in this region are sparse covering only 170 acres.[21] The Bahia Grande is a large lagoon complex that has undergone multiple transformations as its freshwater and saltwater inlets have been filled or diverted by development, emphasizing the need for restoration to ensure natural tidal flow and exchange. The distribution of coastal environments in Region 4 is shown in Figure 3.11.

Development

This region is sparsely developed, with only 30,000 acres of development (approximately 2 percent of land area), and includes the cities of South Padre Island, Port Isabel and a portion of Brownsville.[53] About 1.4 percent of the Gulf-facing beaches and 7.5 percent of the bay shorelines in Region 4 are armored.[30] Similar to Region 2, only about 9 percent of the developed area in Region 4 is classified as urban or industrial development.[53] Tourism is a primary economic generator for the City of South Padre Island, a community that is reliant on a healthy beach and dune system to attract visitors.

Region 4 has one deep draft channel, the Brownsville Ship Channel, which services the Brazos Island Harbor. The channel cuts through the Brazos Santiago Pass – the natural inlet of the Lower Laguna Madre – but turns south, bisecting the large-scale wetland complexes of Bahia Grande and Boca Chica. Shallow draft navigation is made accessible through the GIWW, the Port Mansfield Channel and the Harlingen Channel. The intensity of development in Region 4 is shown in Figure 3.12.

Bolivar Peninsula after Hurricane Ike.

4. A VULNERABLE TEXAS COAST

A vulnerable coast is one that is exposed and sensitive to disturbances, damage or transformations without the commensurate adaptive capacity to cope with the consequences of these alterations.[22] To achieve a resilient Texas coast – one that can withstand and rebound from natural and human-induced disturbances – we must first examine the main Drivers, Pressures and Issues of Concern that threaten the state's coastal natural resources and the communities and businesses that benefit from a healthy coastal environment. Analyzing the factors that change coastal ecosystems can lead to the development of environmentally sound management and policies to reduce a coastal community's vulnerability to the next big storm.

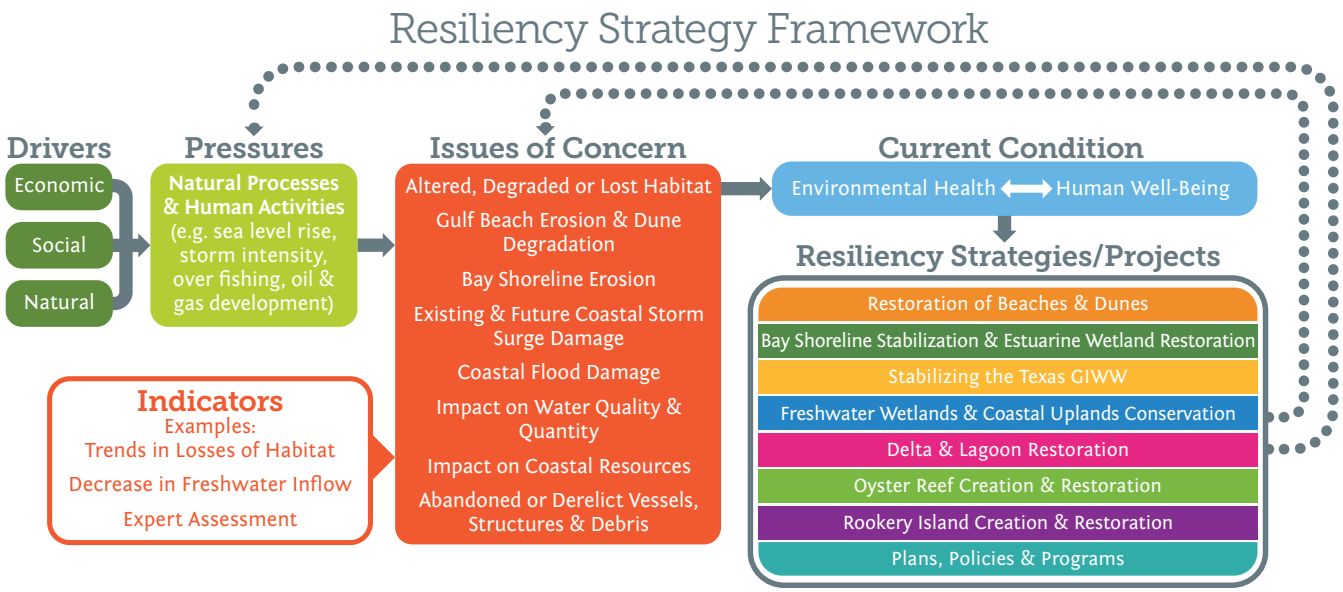


Figure 4.1: *Resiliency Strategy Framework*

The Resiliency Strategy Framework (Figure 4.1) illustrates the Drivers, Pressures and Issues of Concern that influence the current conditions (e.g., environmental health and human well-being) of the coast. Drivers can be social, economic or natural, are largely external to the coastal system and are instigated by need, including demand for food, clean water and energy. Pressures resulting from these Drivers cause Issues of Concern along the coast, which directly disturb the established natural and built environments. For instance, social Drivers, such as an increase in the number of people moving to the coastal region seeking a different lifestyle or for jobs, may create Pressures on the coastal system by expanding development in natural areas. Economic Drivers, such as increased profitability of oil and gas exploration along the coast, can cause Pressure on coastal environments through increases in exploration and industry activities. Natural Drivers, like long-term changes in weather patterns, can result in Pressures such as sea level rise and shifts in precipitation and storm intensities.

The GLO, through the Plan, will enhance the coast to effectively reduce or eliminate the impacts of the Issues of Concern on coastal communities, since much of the state's economic activity is directly tied to the health of the coastal environment.[111] The coastal Issues of Concern will not resolve themselves and, if left unaddressed, will continue to have adverse impacts on infrastructure, natural resources, economic activities, and the health and safety of residents and visitors.

4.1. Coastal Pressures

Coastal Pressures can be either nature-based or built environment-based, and tend to be large-scale and long-term while varying by location. These Pressures are subject to change over time, and may increase or decrease depending on the social, economic or natural Drivers; but all impact the resiliency of the Texas coast. This section highlights several Pressures that can directly alter coastal communities and increase their vulnerability.

Nature-Based Coastal Pressures

Texas' coastal areas are threatened by the nature-based Pressures of erosion, flooding and storm surge, sea level rise, subsidence, depletion of freshwater inflows and sediment deficit. The increasing vulnerability of coastal areas to natural disasters is exacerbated by the loss of natural protective features against flooding and storm surge due to factors such as shoreline erosion and dune degradation, wetland loss, sea level rise and deterioration of other natural resources.[99] Coastal hazards also have social impacts, since water supplies, energy infrastructure and evacuation routes are particularly vulnerable to higher sea levels and storm surges, inland flooding and erosion.[99]

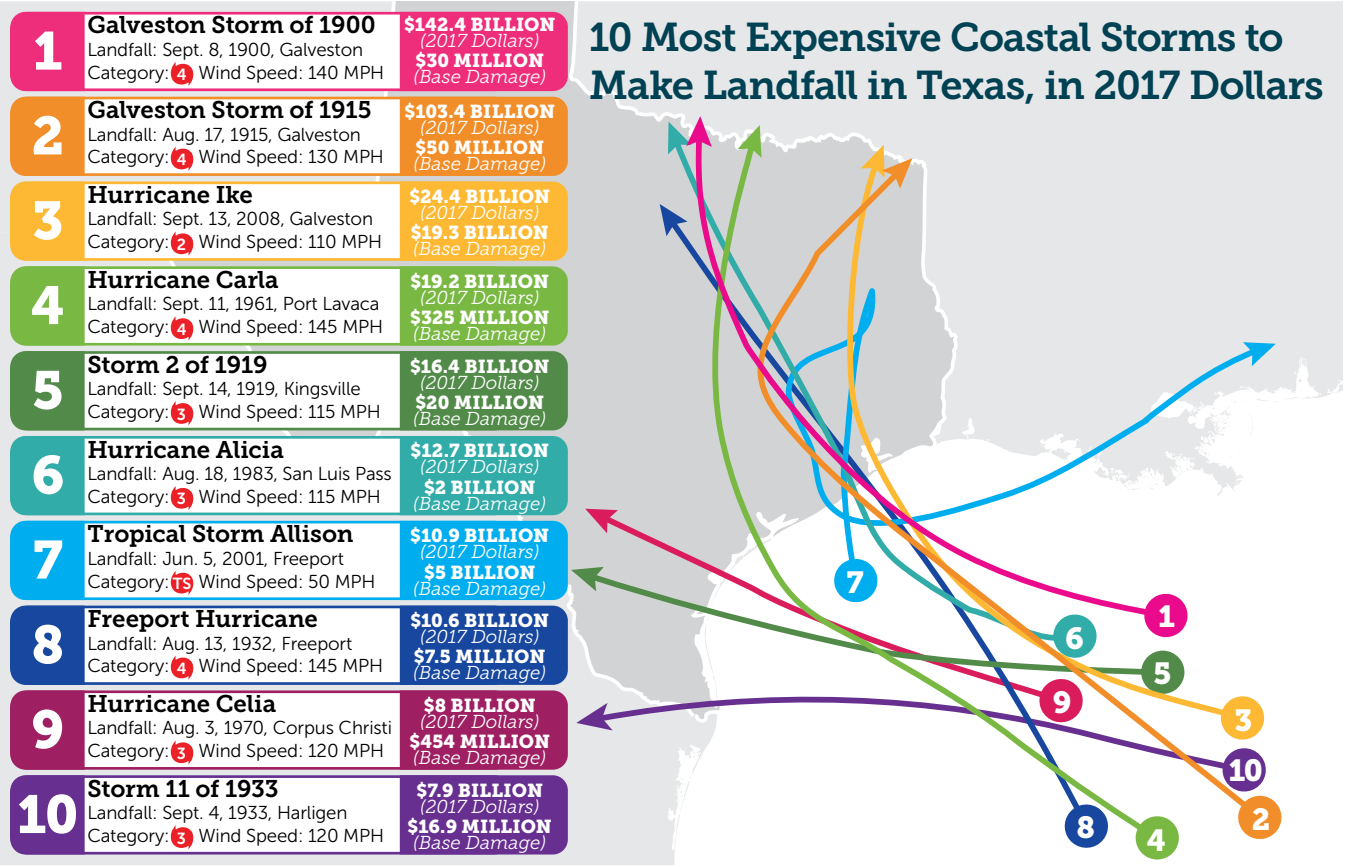


Figure 4.2: *10 Most Expensive Coastal Storms to Make Landfall in Texas in 2017 Dollars.[33] The iCAT Damage Estimator does not include Hurricane Rita in the Texas data because it made landfall in Louisiana.*

Tropical Storms, Hurricanes and Extreme Weather Events

The Texas coast is increasingly vulnerable to tropical storms, hurricanes and extreme weather events that take human life and damage property and coastal ecosystems.

House ravaged by Hurricane Ike.

In recent decades, extreme weather events, such as floods and high surf, are occurring more frequently and with greater intensity. The damages from hurricanes and tropical storms become more severe as wind speed is projected to intensify with sea level rise and increasing ocean temperatures.[65] Between 1957 and 2010, Texas had 20 presidential major disaster declarations due to hurricanes and tropical storms.[20] The latest hurricanes to impact the Texas coast were Hurricane Rita in 2005, and Hurricanes Dolly, Gustav and Ike in 2008. The 2008 hurricane season was particularly devastating for Texas, with estimated damages at $29.4 billion; including $1.9 billion for critical infrastructure, $1.1 billion for forestry agriculture and fisheries, and $3.2 billion for navigation and waterways.[80] According to Property Claim Services, Hurricane Ike (fourth) and Hurricane Rita (ninth) are ranked in the top 10 most expensive Hurricanes to hit the United States.

The physical impacts of hurricanes and tropical storms are devastating to the coastal communities in their path, and can also cripple the state and nation economically. The longer we wait to protect the coastal shorelines, the more expensive it may be for us to recover. Figure 4.2 lists the 10 most expensive hurricanes and tropical storm to make landfall in Texas, when the base damage is adjusted to 2017 dollars.

Bolivar Peninsula: Before and After Hurricane Ike

2006 imagery of Rollover Pass along Bolivar Peninsula before Hurricane Ike.

Imagery of Rollover Pass along Bolivar Peninsula just after Hurricane Ike made landfall on September 13, 2008.

2010 imagery of the recovering shoreline near Rollover Pass along Bolivar Peninsula, almost 2 years after Hurricane Ike.

2015 imagery of Rollover Pass along Bolivar Peninsula, 7 years after Hurricane Ike.

Observed changes in the amount of precipitation falling in Texas during very heavy storm events (the heaviest 1 percent of all storm events) between 1958 and 2012 show a 10 percent to 19 percent increase in total precipitation, which is larger than historical natural variations.[115] In 2014, the National Climate Assessment concluded that changes to weather patterns are increasing across the United States, impacting an array of coastal lifelines, from water supply and energy infrastructure to evacuation routes and human health and safety.[48]

Vulnerability to storm events affects the full extent of the built environment, including industrial and manufacturing facilities, coastal natural resource-based businesses, and waterborne commerce at Texas ports and along navigation routes. In Texas, the presence of offshore petroleum exploration and extraction activities and the concentration of petroleum and petrochemical manufacturing on the coast exposes critical economic assets (as well as the surrounding natural and built environments) to adverse impacts. Power plants, oil and gas refineries, storage tanks and transmission lines are some of the industrial assets located in the coastal floodplain. The National Climate Assessment predicts that the incremental annual damage to assets (20 percent of which are in the oil and gas industry) due to weather-related events along the Gulf coast, including Texas, could be between $8.3 billion and $13.2 billion by 2050.[48] As a result, adaptive measures must account for storm-related flooding, erosion and inundation to avoid a disruption of oil supplies and consumer goods, and most importantly, to protect human health and safety during storm events.

Relative Sea Level Rise

The combined impacts of land loss due to both subsidence and sea level rise, known as relative sea level rise, is a Pressure that can dramatically decrease the resiliency of coastal communities if appropriate planning is not incorporated at the local, state and federal levels of government.

Global mean sea level has risen close to 8 inches since 1880 and is projected to rise another 1 to 4 feet by 2100.[115] Rates of relative sea level rise are higher along the Upper Texas Coast because these coastal land areas are also subsiding due to groundwater pumping and sediment compaction.[38] The combination of these Pressures will create a setting for greater storm surge impacts that can reach farther inland, particularly with the annual increase of high tides and severe flooding events,[2] and can increase the salinity of groundwater and potentially affect the drinking water supply.[48]

The continued expansion of development and growing populations along the coast increase the vulnerability of coastal ecosystems to sea level rise. Development inhibits the natural inland migration of wetlands in response to sea level rise. It also changes the amount of sediment delivered to the bays and beaches, which would otherwise combat shoreline erosion and mitigate impacts from sea level rise. As land loss continues, coastal infrastructure, residents and ecosystems are more exposed to extreme weather events.

Understanding the future magnitude of sea level rise is dependent on many factors and expectations. To help discern the data, there are a range of projected sea level rise scenarios that correspond to various potential future conditions. A moderate scenario projected by the Intergovernmental Panel on Climate Change correlates with the National Oceanic and Atmospheric Administration's Lowest and Intermediate-Low Global Sea Level Rise Scenarios and predicts between 0.65 feet and 1.65 feet of sea level rise by 2100.[i,62] Figure 4.3 and Figure 4.4 show inundation projections for ranges of sea level rise (e.g., 1 foot, 3 feet, 5 feet) along the Texas coast.

Depletion of Freshwater Inflows

The brackish waters of Texas' coastal estuaries are highly dependent upon freshwater inflows from Texas' rivers. Reduced freshwater inflows to these coastal estuaries, as a consequence of increasing population and upstream water use, is a serious Pressure impacting the health of coastal ecosystems and the benefits they afford to wildlife and people. Ecosystem services provided by freshwater inflows include maintaining brackish water conditions in estuaries for wetlands and wildlife to thrive, distributing juvenile species within bay systems, controlling predators and diseases, maintaining water quality, transporting nutrients to bays and estuaries, depositing sediments downstream to stabilize shorelines, and providing water for downstream agriculture, commercial and recreational use. Droughts will further reduce freshwater inflows into the bays and estuaries, thereby raising salinities and negatively impacting the entire ecosystem.

Many commercially and recreationally important species rely on balanced salinity conditions within estuaries for critical nursery habitat. Adequate inflows are essential to support and maintain healthy coastal estuarine habitats that provide food, nurseries and protection to many organisms, including finfish, crustaceans, shellfish, birds, reptiles, insects and mammals. Estuarine species are dependent upon adequate inflows during critical periods of reproduction and growth, thus seasonal timing of freshwater inflows is biologically important. When freshwater inflows are lacking, water quality also suffers, rendering many species unable to grow or reproduce.[37] Extended periods of reduced inflows lead to increased salinity and nutrient reductions in bay, estuarine and nearshore waters, altering the composition and distribution of plant and animal populations, and thereby impacting the larger ecosystem diversity and productivity.

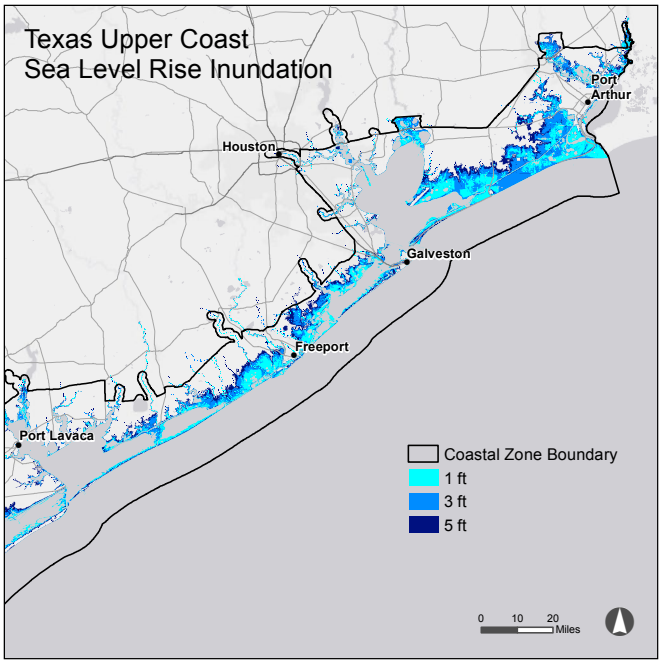


Figure 4.3: *Texas Upper Coast, Sea Level Rise Inundation – The potential inundation extent due to sea level rise on the Upper Texas Coast under 1 foot, 3 feet and 5 feet of rise during the highest of high tides, derived from a modified bathtub approach that attempts to account for both local tidal variability and hydrological connectivity.*[54]

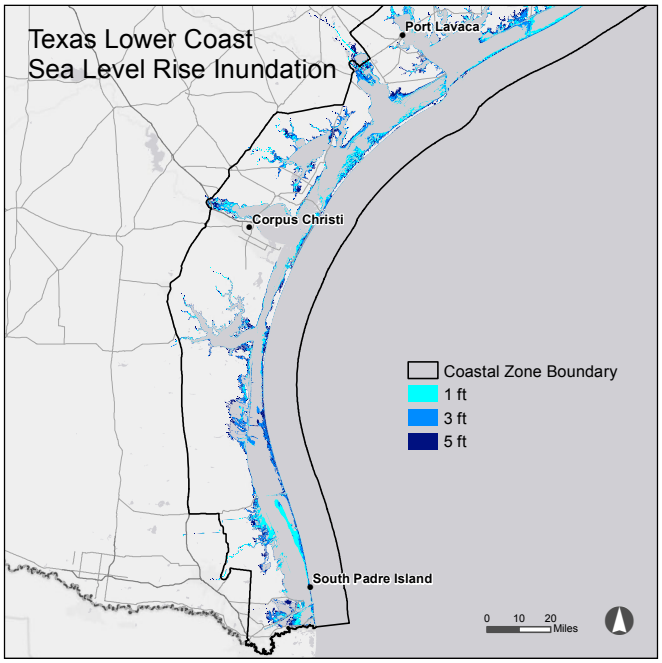


Figure 4.4: *Texas Lower Coast, Sea Level Rise Inundation – The potential inundation extent due to sea level rise on the Lower Texas Coast under 1 foot, 3 feet and 5 feet of rise during the highest of high tides, derived from a modified bathtub approach that attempts to account for both local tidal variability and hydrological connectivity.*[54]

[i] *This moderate scenario was based off of the Intergovernmental Panel on Climate Change scenarios and is a combination of the A1B and B2 scenarios, with a likely temperature change of 1.4 to 4.4°C, and likely sea level rise between 0.20 to 0.48 meters (in 2090-2099 relative to 1980-1999).*[35]

Freshwater inflows: *Freshwater that travels from rivers to coastal bays and estuaries, carrying sediments and nutrients downstream and regulating the salinity levels in coastal waters.*

Sediment deficit: *A lack of sufficient natural material (e.g., sand), in quality and/or quantity, for shoreline stabilization or beach nourishment.*

Decreased freshwater inflows impact the viability of coastal wetlands, which play a key role in the hydrologic cycle by recharging the state's aquifers – the source of 60 percent of the water annually used in Texas.[94]

Decreased inflows also impact the viability of coastal wetlands, which play a key role in the hydrologic cycle by recharging the state's aquifers – the source of 60 percent of the water annually used in Texas.[94] The continued decline and loss of coastal habitats due to degraded water qualities and reduced quantities will also have multiple adverse impacts on the commercial and recreational activities that rely on a healthy and diverse estuarine ecosystem.

Growing populations along the coast and in cities along major rivers threaten to impair the quantity and quality of freshwater supply to estuaries. To meet increasing upstream demands, the construction of dams and channels diverts water for community use, and in so doing, decreases downstream freshwater inflows. Decreased freshwater inflows increase river salinities further upstream, potentially contaminating freshwater aquifers that provide drinking water for local communities. Thus, as freshwater demands continue, proper management is needed to preserve freshwater inflows to sustain critical coastal estuarine ecosystems.

Sediment Deficits

The Texas coast has a unique landscape subject to coastal processes that affect sediment transport and supply to the Gulf and bay shorelines. The Texas Gulf shoreline is largely considered "sediment starved," or characterized by a prevailing lack of natural material for beach nourishment. This is primarily due to a lack of sufficient sand, both in quality and quantity, along substantial portions of its Gulf shoreline.

There are many reasons for these deficits, including: lack of sediment influx and reductions in inflows from major river systems (e.g., due to deprivation of sediments from the upstream damming of rivers); circulation patterns and currents in the Gulf of Mexico deprive the Upper and Lower Coast of sediment; construction of nearshore structures in the Gulf and bays, such as jetties and channels, which trap and accumulate sediment and remove it from the system; and the underlying geologic structure of the coast, which is formed on an inner continental shelf dominated by mud, rather than fine-grained sandy sediment deposits.[1, 114] Construction of navigation channels, jetties and upstream river dams has accelerated erosion of the bay and Gulf shorelines. The sediment deficit contributes to the loss of much of the beach and dune systems.

The coastal Pressures of sea level rise and sediment deficits accelerate the rate of erosion at Surfside Beach.

Built Environment-Based Coastal Pressures

Infrastructure and Development

Development along the Texas coast is increasing, encroaching upon the natural environment and replacing coastal habitats with the housing developments, highways, shopping centers, industrial complexes and airports. The impacts of a built environment can interrupt natural processes, straining natural coastal ecosystems and the beneficial resources they provide. The construction of urban, suburban, commercial and industrial infrastructure replaces natural vegetation with impervious surface areas (e.g., roads, parking lots and concrete sidewalks), altering the natural absorption of water by the landscape. This increases stormwater runoff and reduces aquifer recharge, resulting in more frequent flooding and a lower water table in developed areas.

In many cases, urban planners are considering developmental impacts on environmental functions, and are designing projects that adapt to or mimic native ecosystems by incorporating nature-based or green infrastructure components (e.g., vegetative planting, rain gardens, green roofs) and mitigation techniques within development areas. When steps are not taken to consider the surrounding coastal habitat, however, a built environment can limit the natural system's ability to respond to environmental changes in a resilient manner. For example, as the coast experiences increases in sea levels, wetland and island systems naturally respond by migrating inland or rolling over. Developing the existing shoreline with hardened structures, such as seawalls, revetments and bulkheads eliminates space and prevents these natural responses.

Development in low-lying coastal areas exposes human populations to various risks associated with coastal hazards, such as flooding, storm surge, erosion and relative sea level rise. Social vulnerability is an indicator of how resilient a community or population is to environmental hazards. Knowledge of social vulnerability factors can help with emergency mitigation, preparedness, response and recovery. A high social vulnerability index identifies populations that are at a greater risk to suffer consequences of adverse events, typically due to an "uneven capacity for preparedness and response."[31] Indicators of social vulnerability include age, race and ethnicity, gender and socio-economic status. Figure 4.5 shows a social vulnerability map for the Texas coast.

Industry Activity

Industrial infrastructure critical to the state and nation is found along the Texas coast in close proximity to waterways for transportation and waterborne commerce. While coastal industries provide economic benefits to the state, they also place direct Pressures on the surrounding environments, contributing to habitat loss and degraded water quality. Habitat loss can occur from erosive vessel wakes, vessel groundings and activities from coastal construction. Commercial vessels traversing the bay systems and navigating the GIWW create large wakes that erode adjacent coastal wetlands, uplands, barrier islands and peninsulas. Water quality can be impacted by pollution from shipping and industrial waste, oil spills, runoff from residential neighborhoods, and derelict vessels and abandoned oil and gas wells. Degraded and abandoned coastal infrastructure, vessels and wells can also pose risks to public safety and navigational risks to commercial and recreational boaters.

Texas' coastal industries are critical to the economic makeup of the coast. In recent years, many of these industries have championed, supported and funded restoration and mitigation activities that offset industrial impacts on the coastal environment. To achieve a thriving coastal economy and resilient natural environment, it is imperative that future proposed projects provide mutual benefits to both the state's industries and its coastal habitats and waters.

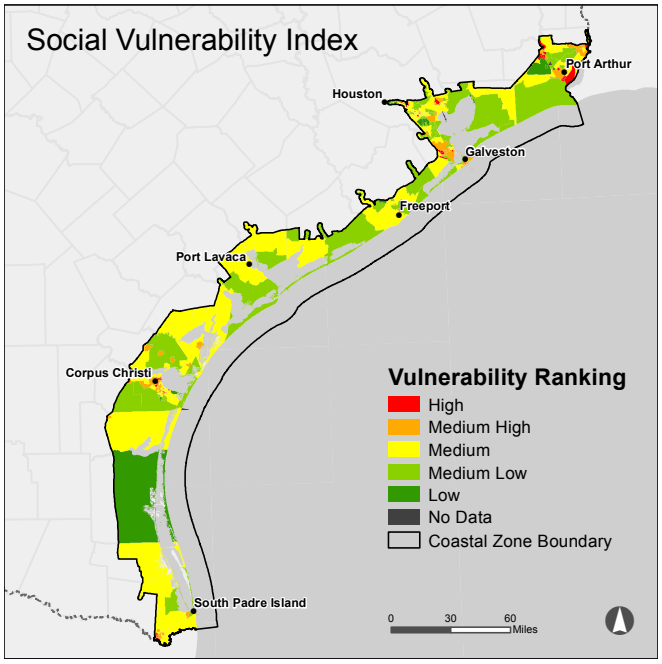


Figure 4.5: *Social Vulnerability Index – Depicts the social vulnerability of census tracts to environmental hazards, ranked by quantile, that are relative and comparable across the State of Texas. The index is based on U.S. Census 2010 tracts and 5-year American Community Survey socioeconomic data from 2006-2010. The Social Vulnerability Index synthesizes 27 socioeconomic variables, which research literature suggests contribute to the reduction of a community's ability to prepare for, respond to and recover from environmental hazards.*[31]

4.2. Coastal Issues of Concern

Bayland Park in Baytown.

A major component of the Texas Coastal Resiliency Master Plan is the identification and evaluation of natural and human-induced disturbances, which are referred to as Issues of Concern (IOCs). The IOCs were identified based on an understanding of the Pressures exerted on the coastal system (such as tropical storms, hurricanes, depletion of freshwater inflows, sediment deficits, infrastructure and development) that stem from social, economic and natural Drivers.

Addressing these IOCs is the primary goal when evaluating methods to improve coastal resiliency. The most resilient project solutions are those that can mitigate or eliminate the IOCs in a feasible and cost effective manner. Identifying where specific IOCs exist and the severity to which they impact Texas' environments at the time of this study provided the basis to analyze projects for prospective inclusion in the Plan.

The eight IOCs, representing the problems introduced by the primary Drivers and Pressures facing the Texas coast, are as follows:

Altered, Degraded or Lost Habitat

Coastal Pressures include: Tropical Storms, Hurricanes and Extreme Weather Events, Relative Sea Level Rise, Depletion of Freshwater Inflows, Sediment Deficits, Industry Activity, and Infrastructure and Development.
Example Considerations: Seagrass, Mangroves, Estuarine and Freshwater Wetlands, Bottomland Hardwood Forests and Coastal Prairies.

Whooping cranes on the Matagorda Unit of the Aransas National Wildlife Refuge enjoy the protected and specific habitat provided by the coastal barrier island ecosystem, which is vital to the survival of this endangered species that breeds in Canada and winters in Texas.

Healthy bays, wetlands and estuaries provide the critical foundation for sustainable environments and thriving economies. These coastal habitats help maintain wildlife and plant populations, improve water quality, support fishing and hunting activities, enhance local tourism and maintain community resilience by reducing the impacts from coastal hazards, such as flooding and storm surge. Land-use change, coastal development, erosion, subsidence and sea level rise are causing fragmentation and loss of coastal habitats and their ecosystem services. Whether the habitats are altered, degraded or entirely lost, changes to the natural environment can have compounding effects.

The recent conversion along the Central Texas coast of *Spartina alterniflora,* a smooth cordgrass, to mangroves in estuarine wetlands is an example of altered habitat. Although both mangrove and *Spartina* wetlands function similarly, some species are dependent on specific habitat characteristics of one or the other. Specifically, the endangered whooping crane depends on estuarine wetlands for blue crabs and other prey, but will not forage among mangroves or other vegetation that grows higher than its own field of view. The intrusion of mangroves into the whooping cranes' historic winter foraging grounds impacts the ability of the cranes to survive and thrive.

Distinct from habitat alteration, degraded habitats do not experience a change in habitat type, but lose a degree of their original functionality. An example of habitat degradation is the fragmentation of estuarine wetlands caused by a disconnection of water flow to the wetlands. Urbanization and

the construction of roads and dams is fragmenting coastal habitats by changing water circulation patterns and altering movements of sediment and nutrients to coastal habitats. Habitat degradation can have significant negative impacts on the biodiversity, abundance, distribution and population dynamics of coastal ecosystems. The remaining fragmented habitats may not be large enough or close enough in proximity to support species that need large territories in which to find mates and food. This also affects migratory species that are dependent upon large areas along their migration routes with access to resources for feeding and resting.

Habitat can also be completely lost due to landscape changes from development, erosion or relative sea level rise. Habitat loss also occurs as wetlands are dredged or filled, and vegetation is cleared to accommodate urban, industrial and agricultural development. Habitats can be damaged or lost due to impacts from ship hulls, propellers, anchors, destructive fishing practices, and the installation and maintenance of pipelines and fiber optic cables on the ocean and bay bottoms. Approximately 60 percent of seagrass beds along the Texas coast, for example, have been destroyed by storms, dredging, boat propellers, increased water siltation and degraded water quality.[66] In Texas' coastal counties, a total of 37,000 acres of all wetlands were lost between 1996 and 2010 (Figure 4.6).[53] From 2006 to 2010, over 5,700 acres were lost, with the majority of losses occurring in the Upper Coast area.[53]

Coastal Pressures, including tropical storms, relative sea level rise, depletion of freshwater inflows, sediment deficits, development and industry activity, place coastal habitats at even greater risks of conversion or loss. These Pressures and impacts are interrelated and require careful planning to provide the best protection for habitats. In the case of wetlands, for instance, the need for coastal planning begins many miles upstream of the wetlands themselves. In order for wetlands to maintain or expand their current coverage, the rates of sedimentation in wetland areas must be equal to or greater than the rate of relative sea level rise. Upstream construction of dams and reservoirs limits the quantity of sediments reaching the coast, reducing sedimentation rates. The resulting wetland deterioration can, in turn, lead to the decline of commercially and recreationally important coastal species, impacting coastal businesses, commerce, tourism and recreation.

The health and well-being of coastal communities are directly affected by habitat alterations, degradation and losses. Damages to coastal habitats also decrease their ability to provide the shoreline stabilization and flood water absorption that protects inland areas, infrastructure and communities from coastal hazards. Conservation and restoration of coastal habitats from loss and fragmentation is critical to the future health of ecosystems, coastal communities and economies.

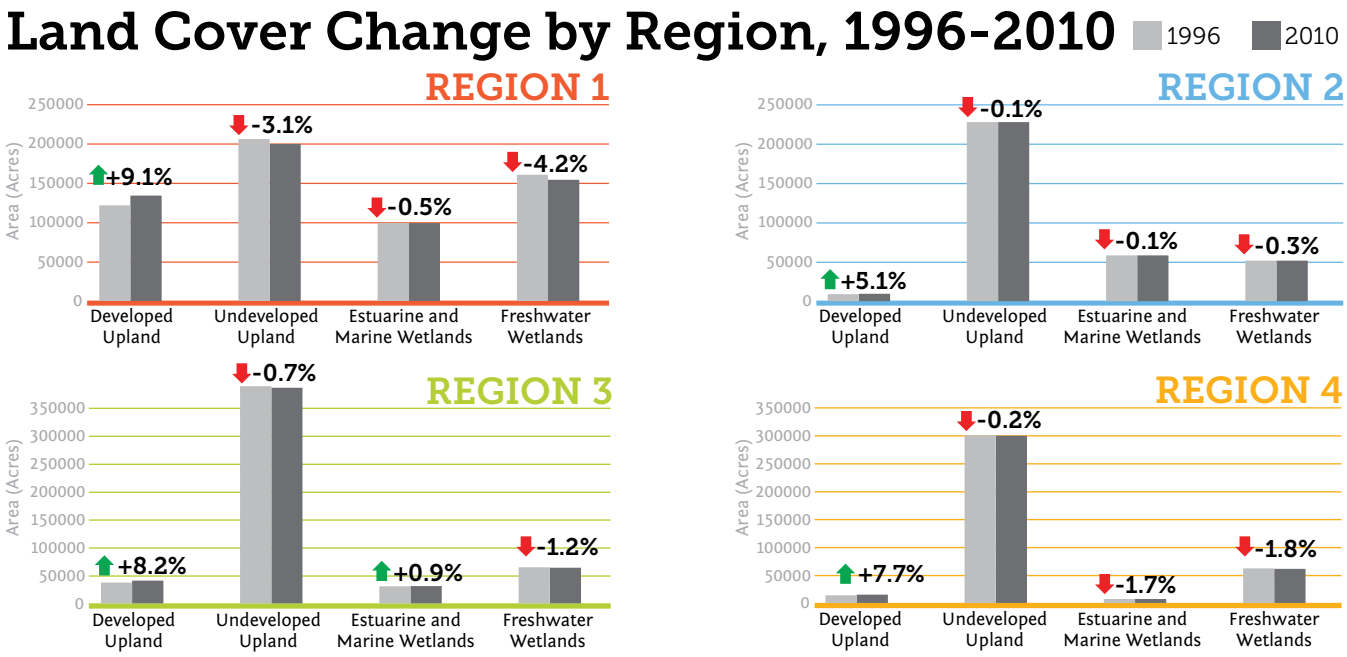


Figure 4.6: *Landcover Change by Region, 1996-2010*[53]

Gulf Beach Erosion and Dune Degradation

Coastal Pressures include: Tropical Storms, Hurricanes and Extreme Weather Events, Relative Sea Level Rise, Sediment Deficits, and Infrastructure and Development.
Example Considerations: Subsidence, Sediment Deficit, Impacts from Development, Storm Impacts, Erosion and Sea Level Rise.

Approximately 65 percent of the Texas Gulf shoreline are considered eroding areas, with some extreme areas losing as much as 55 feet per year (Figure 4.7 and Figure 4.8).[113] An eroding area is defined by state regulation as a portion of the shoreline eroding at a rate of greater than 2 feet per year.[69] Erosion is a threat to public beach use and access, public and private property and infrastructure, fish and wildlife habitat, and public health and safety.

Major contributors to erosion include coastal development, storm events, lack of sediment availability, subsidence and sea level rise. The erosion of beach and dune habitats decreases dune height and volume, and causes beaches to become more narrow. Increased development on and recreational use of barrier island beaches also threatens the stability of the dune system. Structures built too close to the shoreline can inhibit the natural landward movement of dunes in response to sea level rise. Loss of dune vegetation and its stabilizing root systems allows for further dune degradation and erosion as dunes are exposed to wind and waves, resulting in blowouts, washovers or breaches of the dune. These disruptions create open areas in the dunes, allowing floodwaters to move inland during storm events and making inland areas more vulnerable during coastal storms.

As well as putting people and property at increased risk, shoreline erosion also impacts many important sectors of the Texas coastal economy. When the Texas coast erodes:

- Property values are impacted, and homes and businesses are lost;
- Tourism suffers, along with local economies that depend upon it;
- Farming and fishing industries are impacted;
- Ports, roads and industrial infrastructure are at risk; and
- Beaches and dunes are negatively impacted and less likely to protect the coastal communities from high tides and storms surge.

Beaches and dunes serve as a natural first line of defense from storm surge for inland populations, infrastructure, evacuation routes and coastal habitats by absorbing the impact of high energy waves, and by stopping or delaying intrusion of water inland. Natural or restored Gulf beaches and dunes provide recreation areas and foraging and nesting habitat for wildlife, including threatened and endangered species, such as sea turtles and piping plovers. Mitigating erosion of these critical beach and dune systems requires comprehensive management to safeguard coastal habitats and natural resources, and to prevent loss of life and property.

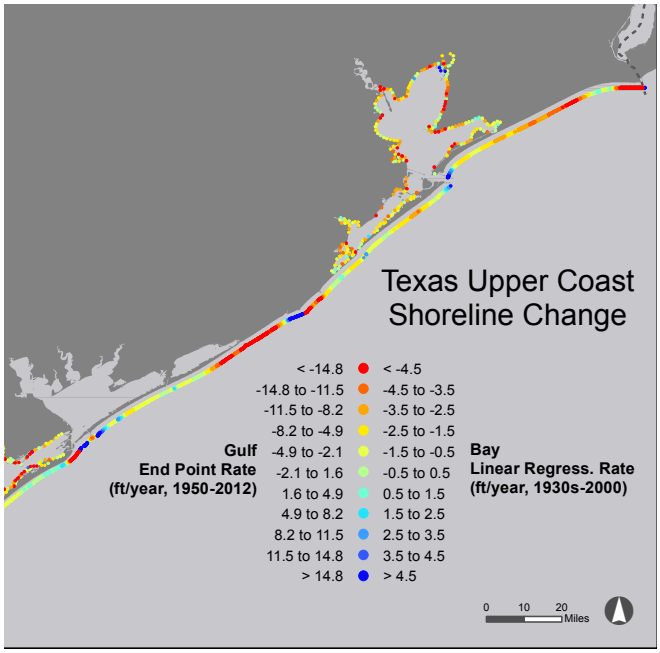


Figure 4.7: *Texas Upper Coast Shoreline Change*[91,113]

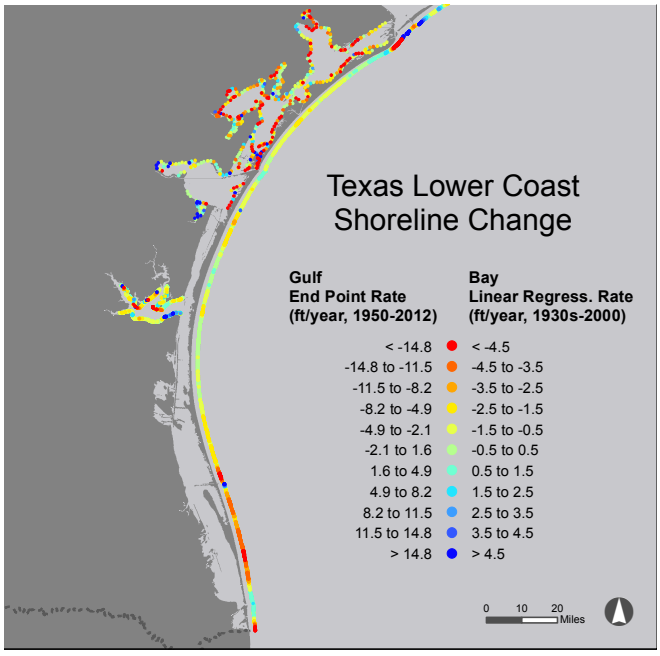


Figure 4.8: *Texas Lower Coast Shoreline Change*[91,113]

Bay Shoreline Erosion

Coastal Pressures include: Tropical Storms, Hurricanes and Extreme Weather Events, Relative Sea Level Rise, Sediment Deficits, Industry Activity and Infrastructure and Development,
Example Considerations: Subsidence, Sediment Deficit, Impacts from Development, Storm Impacts, Erosion and Sea Level Rise.

The Texas bay shorelines are experiencing many of the same erosion issues as the Gulf shorelines due to impacts from storms, coastal development, habitat loss, subsidence and sea level rise, in addition to impacts from recreational and commercial vessel activity. Loss of land along the bay shoreline can also be attributed to a lack of sediment entering the bay systems from decreased freshwater inflows and erosive vessel wakes along the ship channels and GIWW. Erosion in these coastal areas contributes to surrounding habitat loss, water quality degradation, loss of property and reduced protection from storm surge, flooding and other coastal hazards. In some areas, the effects of bay shoreline erosion can be drastic. Waves can batter shoreline bluffs, causing large portions of land to slide into the bays. Low-lying roadways and bridges can be impacted by bay shoreline erosion, potentially cutting off communities from emergency services and causing millions of dollars in road repairs.

Shoreline erosion at Virginia Point in Galveston Bay.

Erosion and land loss are particularly prevalent along the ship channels and the GIWW because of wave energy and wakes from vessel traffic along them. Wetlands are commonly subject to erosion caused by vessel traffic, particularly along the bay side of the barrier islands fronting the GIWW.[97] As these barrier islands erode, they fail to protect the GIWW and its inland shoreline, exposing both to wave action generated over longer distances within the bays. Addressing shoreline loss is an important component of efforts to maintain and enhance the economic benefits of the GIWW while mitigating environmental impacts associated with its operation.

Erosion along North Shoreline Boulevard at Corpus Christi Bay.

Hard shoreline stabilization structures, such as seawalls and bulkheads along bay shorelines, can exacerbate the effects of erosion adjacent to the structures. In addition to adversely affecting the built environment, persistent erosion of bay shorelines can compromise the integrity of the natural environment. For example, erosion can cause breaches into estuaries, wetlands and marshes, changing ambient salinity gradients and land formations. Eroding bay shore areas lose their abilities to protect upland habitats from erosion and storm damage, and adjacent wetlands and waterways from water quality degradation. Further, habitat loss and degradation compromise recreational fishing and hunting opportunities, as well as other water-based recreational activities.

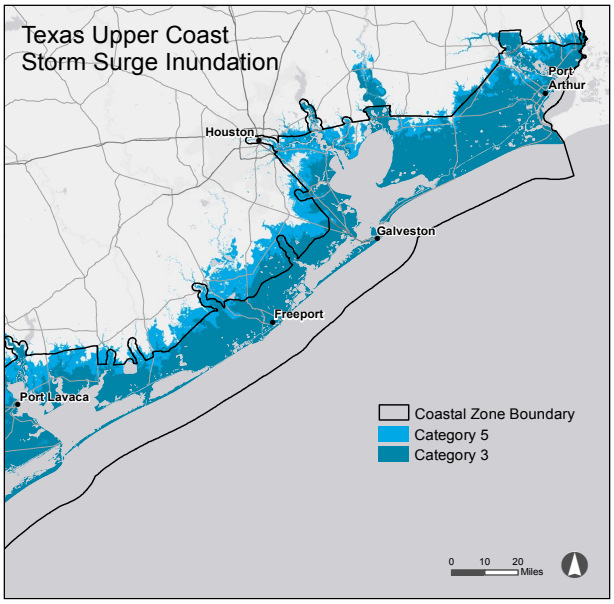


Figure 4.9: *Texas Upper Coast Storm Surge Inundation – Upper Texas coast worst case storm surge inundation for hurricane categories 3 and 5, derived from an ensemble of SLOSH model results of hurricanes with various combinations of forward speed, trajectory and high tide levels (with additional National Elevation Data processing by the Harte Research Institute to determine inundation areas).*[36] *A single hurricane trajectory will not cause the regional flooding shown here, but these maps provide important information for resiliency planning in all coastal areas.*[24]

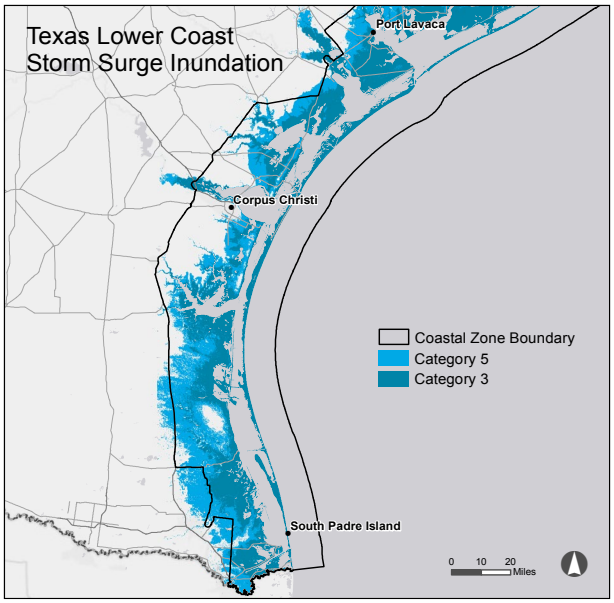


Figure 4.10: *Texas Lower Coast Storm Surge Inundation – Lower Texas coast worst case storm surge inundation for hurricane categories 3 and 5, derived from an ensemble of SLOSH model results of hurricanes with various combinations of forward speed, trajectory and high tide levels (with additional National Elevation Data processing by the Harte Research Institute to determine inundation areas).*[36] *A single hurricane trajectory will not cause the regional flooding shown here, but these maps provide important information for resiliency planning in all coastal areas.*[24]

Existing and Future Coastal Storm Surge Damage

Coastal Pressures include: Tropical Storms, Hurricanes and Extreme Weather Events, Relative Sea Level Rise, and Infrastructure and Development.
Example Considerations: Sea Level Rise, Coastal Storms and Impacts from Development.

Coastal storms and hurricanes present a major threat to people and property near the coast, with many long-lasting impacts on communities, the natural environment and the economy. Increased coastal development have led to larger areas of impervious surface, and greater rates of erosion, relative sea level rise and wetland loss, which contribute to increased risk and exposure of coastal communities to coastal storm surge and other related hazards. As sea level continues to rise, the impacts of storms will be magnified by raising the base elevation upon which storm surge builds.

Texas has never been hit by a Category 5 hurricane, however, if such an extreme storm event hit the Houston Ship Channel, it could cause storm surges of up to 30 feet.[5] If a storm of this magnitude hit Galveston Bay, models predict that up to 20 feet of water could submerge the upper bay, which includes the Port of Houston and a dense concentration of industry.[5]

The inland reach of damage from storm surge depends on the topography of the land. In flat, low-lying areas, a sizable storm surge can penetrate miles inland, flooding and destroying buildings, disrupting transportation routes, pushing ships onto land, washing debris out to sea, contaminating food and water supplies, and taking out communication lines, power lines, and critical facilities and services.[57] Figure 4.9 shows the Upper Texas Coast's worst-case storm surge inundation for Category 3 and Category 5 hurricanes, derived from an ensemble of Sea, Lake and Overland Surges from Hurricanes (SLOSH) model results for hurricanes with various combinations of forward speed, trajectory and high tide levels.[36] Figure 4.10 illustrates the respective hazards for the Lower Texas Coast.

Preventative measures that improve coastal resiliency are relatively inexpensive compared to the tens of billions of dollars that are lost when storms strike vulnerable communities. Maintaining and enhancing the coast's natural barriers and protective features is critical to minimizing the impact of future storms and hurricanes, and avoiding their associated population, infrastructure and economic losses that impact the state and the nation. The $1.6 billion in economic losses to the Port of Houston from Hurricane Ike emphasize the importance of taking preventative measures and safeguarding our natural protective landscapes.[82]

Coastal Flood Damage

Coastal Pressures include: Relative Sea Level Rise, Sediment Deficits, and Infrastructure and Development.
Example Considerations: Rainfall, Riverine Flooding, Nuisance Flooding and Impacts from Development.

Much of the Texas coastal zone lies in a floodplain susceptible to storm and nuisance flooding that impacts and disrupts coastal communities, damages property and natural environments, and poses risks to human health and safety. Coastal areas are preferred locations for both private and commercial development because they provide opportunities for trade, jobs, transportation and recreation.[19] Floods, including flooding due to hurricanes and tropical storms, are some of the most frequent, destructive and costly natural hazards affecting Texas – constituting 90 percent of the disaster-related damages experienced in the state.[78] Of the 18 coastal counties, only two have experienced fewer than 16 flooding events between 1960 and 2012. Brazoria, Galveston, Jefferson and Orange counties, however, encountered more than 46 floods, and Harris County encountered over 74 floods for the same time period.[78] Flood events can last from a few hours to several days or even months under certain weather conditions. High tide events, in combination with increased watershed loadings from upstream precipitation, cause coastal flooding in low-lying areas and along rivers and streams. Increased development in the floodplain, wetland loss and ongoing processes such as erosion, subsidence and sea level rise, however, exacerbate the impacts of coastal flooding. Continued landscape changes, particularly those that do not incorporate nature-based and green infrastructure features, will increase a coastal community's risk and exposure to flooding hazards, even in areas not previously prone to flooding.

Of the 18 coastal counties, only two have experienced fewer than 16 flooding events between 1960 and 2012. Brazoria, Galveston, Jefferson and Orange counties, however, encountered more than 46 floods, and Harris County encountered over 74 floods for the same time period.[78]

Impacts on Water Quality and Quantity

Coastal Pressures include: Tropical Storms, Hurricanes and Extreme Weather Events, Depletion of Freshwater Inflows, Industry Activity, and Infrastructure and Development.
Example Considerations: Freshwater Inflows, Nutrients, Water Pollution (Chemical), Sediment, Saltwater Intrusion, Non-point Source Pollution, Hydrologic Connectivity, Harmful Algal Blooms and Oil Spills.

Oso Bay in Corpus Christi is experiencing water quality issues due to high levels of bacterial contamination, discharge from wastewater facilities and an increase in impervious surface coverage.

Degraded water quality near Harbor Island.

Increased urban development, non-point source pollution and decreased freshwater inflows negatively impact water quality and quantity in bays, estuaries, lagoons and nearshore Gulf environments. Upstream water use places demands on water resources, reducing the quantity of freshwater that flows downriver to estuaries, altering salinity levels and affecting water quality. Adequate inflows are essential to maintain salinity levels and water quality in estuaries to support healthy coastal habitats and wildlife. Changes in salinities and water quality can create conditions for bacteria, harmful algae and parasites to thrive, which can impact the health of coastal habitats, marine life and humans.

Water quality is a growing issue along the coast, and in many places, the presence of contaminants leads to coastal water bodies being classified as impaired.[70] Non-point sources of water pollution include stormwater runoff from residential neighborhoods, commercial sites and agricultural fields. Stormwater runoff carrying nutrient pollution, such as excess nitrogen and phosphorous, into estuaries leads to an explosion in algae growth that depletes oxygen in the water, killing fish and other marine life. Urban and agricultural runoff carries waste, chemicals, fertilizers, pesticides, pet waste and other contaminants into bays and estuaries that can degrade water quality and the health of seagrass beds, wetlands and other coastal habitats and the species they support.

The conversion of coastal habitats to impervious cover increases the amount of stormwater runoff into estuaries and decreases the replenishment of Texas aquifers, including the Gulf Coast Aquifer. The Gulf coast aquifer is one of nine major aquifers in Texas and runs along the state's entire coastline. The Gulf Coast aquifer is primarily used to support industrial, municipal and irrigation functions. The Texas Water Development Board documented that the decline in the Gulf Coast Aquifer water levels led to land subsidence in Galveston and Harris counties.[95]

Additional sources of water pollutants include sewage effluents from sewage collection systems and failing septic systems – often caused by outdated or overstressed infrastructure due to population growth – which lead to increased bacteria and viruses in water bodies.[42] Water quality can also be impacted by oil spills and industrial activities, suspended sediments from boat activities, and illegal dumping of waste, chemicals and abandoned or derelict vessels and structures. Poor water quality leads to habitat and wildlife degradation, public health and safety issues, and negative economic impacts on tourism, recreation and commercial activities.

Impacts on Coastal Resources

Coastal Pressures include: Tropical Storms, Hurricanes and Extreme Weather Events, Relative Sea Level Rise, Depletion of Freshwater Inflows, Sediment Deficits, Industry Activity, and Infrastructure and Development.
Example Considerations: Oysters, Turtles, Birds, Fish, Crabs and Endangered Species.

The coastal zone of Texas boasts an abundance of resources, including oysters, fish, birds, turtles, crabs and several endangered species, all of which are sensitive to environmental Pressures from human activity and the alteration of natural habitats. Several threatened and endangered species are found in the Texas coastal zone, including the whooping crane, piping plover and Kemp's ridley sea turtle. These living resources are essential to maintaining healthy coastal ecosystems and a robust economy, as they support ecotourism and recreational and commercial fisheries, all of which generate tax revenue for coastal communities and the state. Impacts on coastal resources are often interrelated to the other Issues of Concern described in the Plan.

Declining oyster reefs are key indicators of degraded water quality from bacteria and other contaminants in Texas bays. Deterioration of certain oyster reefs in portions of Corpus Christi, Aransas, Redfish, Matagorda and Lavaca bays forced the state to restrict oyster harvesting in those bays to protect the public's health. Pollution concerns in November 2016 completely closed Sabine Lake to oyster harvesting.[73] Reduced freshwater inflows into the bays have altered salinities, to which oysters are highly sensitive. This has also increased oyster exposures to disease, affecting the abundance and vitality of oyster reefs. In addition, coastal storms degraded or destroyed a significant number of oyster reefs, increasing pressures on this already over-stressed resource and leading to further harvesting restrictions.

Fisheries are also threatened by overfishing, bycatch, habitat loss, non-point source discharges, harmful algal blooms, low dissolved oxygen and decreases in freshwater inflows. The unsustainable harvesting of fish stocks and shellfish has consequences for the ecological balance of the aquatic environment. Bycatch from commercial trawl fishing threatens non-targeted species, such as juvenile finfish and endangered and threatened species, such as sea turtles. Changes to water conditions (e.g., salinity, temperature, nutrients, sedimentation), alteration of nursery and foraging habitat, and the presence of invasive species and disease also contribute to declines in fish stocks for recreational and commercial fisheries. In addition, excess nutrients in estuaries can cause harmful algal blooms that kill aquatic life. In the summer of 2012, the Texas Parks and Wildlife Department reported that approximately 1 million fish were killed along 20 miles of beach shoreline – including parts of Bolivar Peninsula, Galveston Island and Surfside Beach – due to harmful algal blooms.[84]

Bird populations are adversely impacted by habitat losses from coastal development, erosion (especially in the case of rookery islands), human disturbance of nesting areas and predation. In recent years, these impacts resulted in notable declines in populations of wading colonial waterbirds that nest in vegetation, as well as migratory birds that use Texas' coastal habitats as stopover areas.[42]

Invasive species, including various fish, shellfish and aquatic plants that are not native to Texas, may threaten native species and habitats by predation, competition for food and space, or introduction of disease. Invasive species can quickly multiply and spread because they lack natural enemies in their new environments. Changing environmental conditions can contribute to the spread of invasive species.

Coastal resources are vulnerable to a variety of disturbances, including population growth, natural resource extraction, habitat loss and degradation, pollution and lower water qualities, salinity changes, reduced freshwater inflows, invasive species, diseases and storms. Careful ecosystem monitoring, mitigation and restoration efforts are, therefore, critically important to ensure a healthy and productive coastal environment.

Coastal Pressures impact oysters.

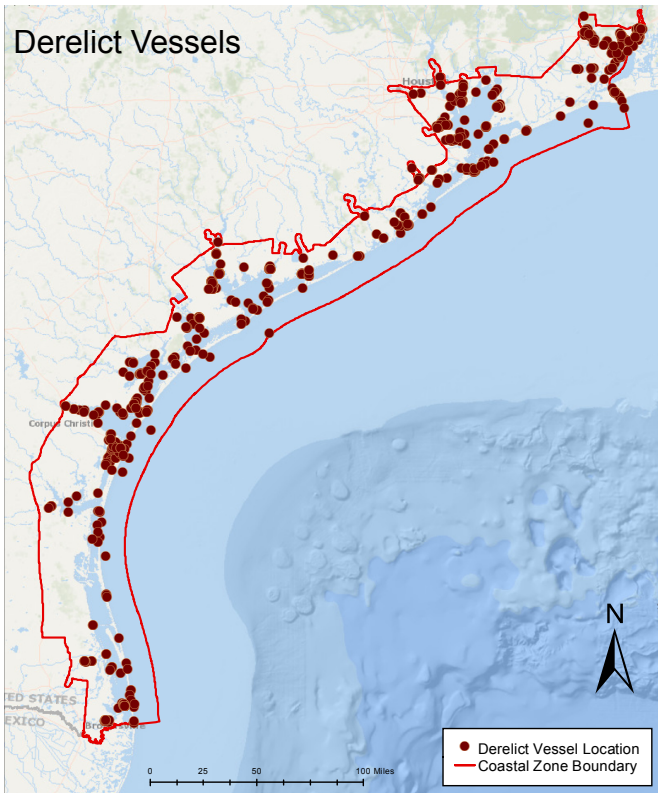


Figure 4.11: *Derelict Vessels – Locations of abandoned vessels documented by the Texas General Land Office.*

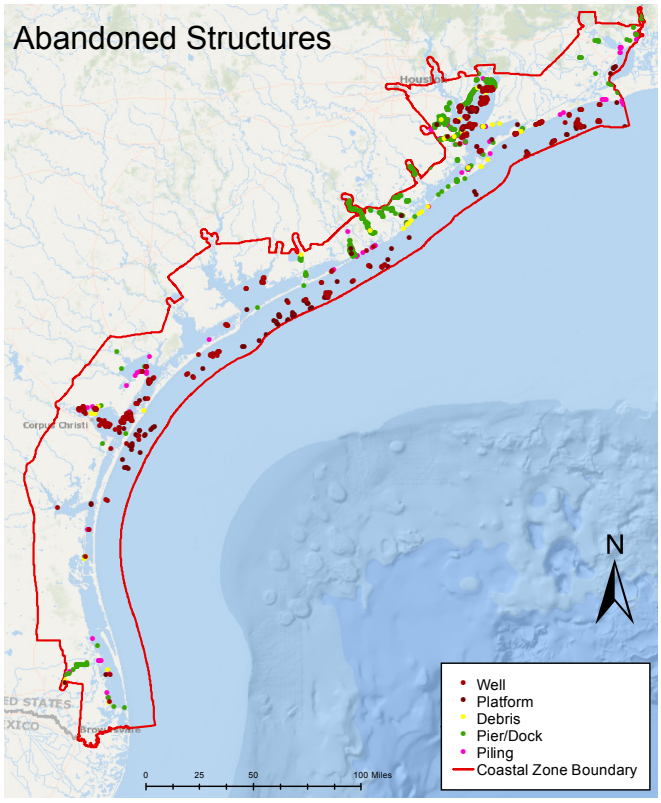


Figure 4.12: *Abandoned Structures – Locations of various abandoned structures documented by the Texas General Land Office.*

Abandoned or Derelict Vessels, Structures and Debris

Coastal Pressures include: Tropical Storms, Hurricanes and Extreme Weather Events, Relative Sea Level Rise, Industry Activity, and Infrastructure and Development.
Example Considerations: Obstructions to Public's Easement, Abandoned Oil and/or Gas Wells, Abandoned Boats, Dock Pilings and Post Storm Cleanup.

Abandoned and derelict vessels, structures and other debris can become hazards to navigation and public safety, and can pose risks to waterborne transportation and recreation along coastal bays, Gulf waters and beaches. When left neglected, vessels and structures can destroy or degrade Gulf and bay habitats by altering coastal processes, such as water circulation, and by dispersing oil and toxic chemicals due to movement or sinking during storms.[55]

Removal of maritime debris promotes cleaner and safer coastal environments by eliminating sources of contaminants and dangerous obstacles from waterways.[81] State law prohibits leaving, abandoning or maintaining any structure or vessel in coastal waters or on state-owned submerged land that is in a wrecked, derelict or dismantled condition that can cause a threat to the natural environment. The GLO identifies and documents derelict and abandoned vessels (Figure 4.11) and structures (Figure 4.12) along the entire Texas coastline.

Corroded steel barge on Lavaca Bay Shoreline in Calhoun County.

5. TECHNICAL ASSESSMENT

To develop the Texas Coastal Resiliency Master Plan, the GLO and the Planning Team undertook a technical assessment approach to identify priority coastal Issues of Concern and potential projects that could help create and maintain a resilient Texas coast. This technical approach was supplemented with expert input by the Technical Advisory Committee, which contributed to the prioritization of the Issues of Concern and projects, and development of the GLO's Resiliency Strategies.

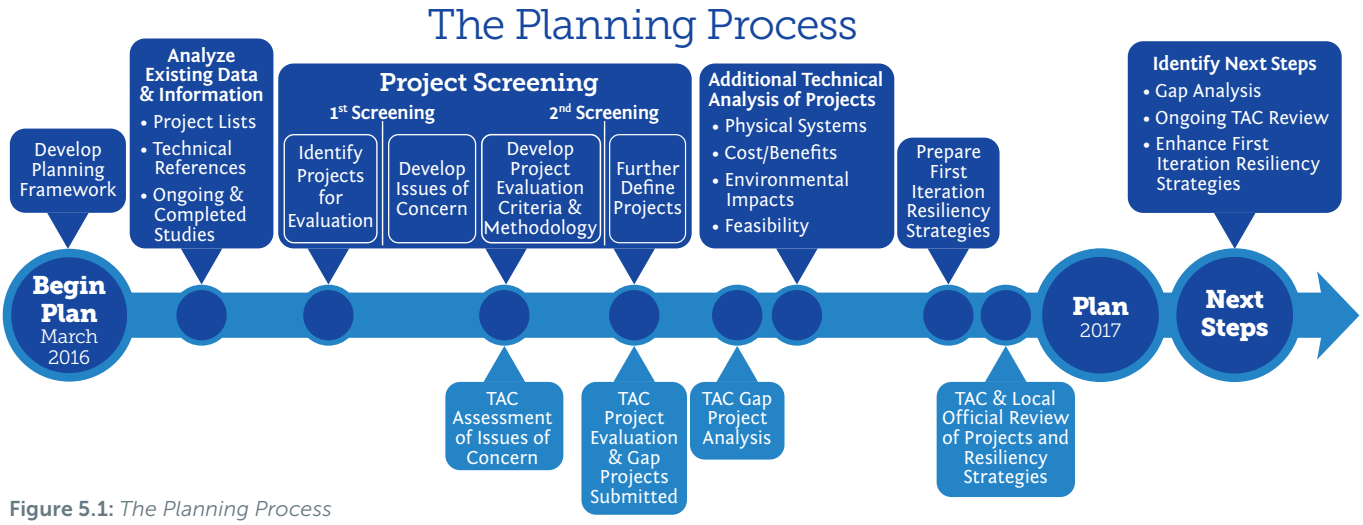


Figure 5.1: *The Planning Process*

TAC members identifying project locations at meeting in Corpus Christi.

Presented in this section is a summary of the process used to determine the severity of the issues affecting the coast and identify and evaluate candidate projects for inclusion in the Plan (Figure 5.1). The technical assessments identified in this section are documented in detail in Appendix A (Technical Report to the Plan).

As described in Section 4, the Resiliency Strategy Framework diagram (Figure 5.2) illustrates the social, economic and natural Drivers that lead to Pressures (e.g., storm intensity, pollution, sea level rise) and result in the Issues of Concern that influence the current conditions of the coast. The framework outlines the various interactions that must be considered prior to assessing projects and Resiliency Strategies that can mitigate or eliminate both the pressures and the Issues of Concern.

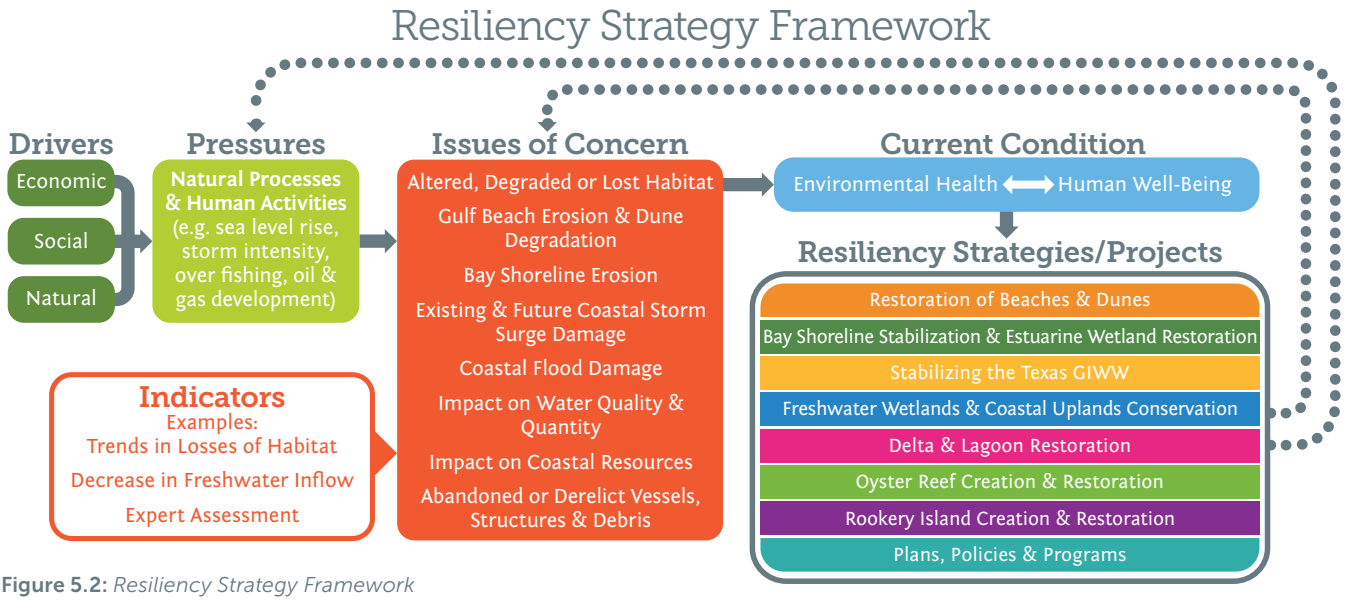


Figure 5.2: *Resiliency Strategy Framework*

5.1. Analyzing Existing Data and Information

An initial step in the Plan's development process entailed casting a broad net to compile a list of projects with prospective merit to achieve a resilient Texas coast. This effort involved two dimensions: 1) capturing project ideas appearing in other planning documents; and 2) identifying new ideas based upon a gap analysis undertaken by the TAC. This project identification process considered all currently proposed projects relevant to coastal resiliency and removed projects not applicable to the GLO's mission or purview.

The GLO and the Planning Team undertook an extensive literature review of past Texas coastal planning documents and databases (e.g., CEPRA, Coastal Management Program, Coastal Impact Assistance Program, Texas RESTORE Act), as well as more recent and ongoing studies and plans from a multitude of federal, state, local and non-governmental entities. Stakeholder consultations were also incorporated into the information gathering process.

5.2. Project Screening

First Project Screening

This initial literature search resulted in the identification of over 900 coastal projects that had potential project outcomes and prospective abilities to contribute to coastal resiliency. The first screening process removed projects that did not have sufficient data or were duplications, resulting in approximately 500 projects warranting further evaluation.

Projects that passed the initial screening were further defined using a series of attributes (i.e., project-specific information) populated based on the project descriptions. These attributes pertained to key characteristics, such as primary classification (e.g., structural, non-structural or nature-based feature), project type (e.g., land acquisition, shoreline stabilization), project subtype (e.g., levee, groin, marsh creation), project scale or extents and geospatial location. A listing of project types and subtypes considered during the planning process is included in Figure 5.3.

Project Categorization

Project Type	Project Subtypes
Beach Nourishment	» Bay » Gulf
Dune Restoration	» Dune
Shoreline Stabilization	» Seawall » Bulkhead » Revetment » Breakwater » Misc. Wave Break » Jetty » Groin
Flood Risk Reduction	» Levees » Flood Wall » Storm Surge Barrier » Road Elevation
Habitat Creation & Restoration	» Marsh » Oyster Reef » Estuarine and Freshwater Wetlands » Barrier Islands » Coastal Prairies and Bottomland Hardwood Forests » Rookery Islands
Wildlife	» Fisheries » Birds » Oysters » Sea Turtles » Invasive Species Control
Environmental	» Freshwater Inflows » Hydrologic Restoration
Structure/ Debris Removal	» Abandoned Oil and/or Gas Wells » Abandoned Boats » Dock Pilings » Post Storm Cleanup and Structure Removal
Public Access & Improvements	» ADA Accessibility » Walkovers » Piers, Boat Ramps
Land Acquisitions	» Acquisitions » Conservation Easements » Fee Simple
Studies, Policies & Programs	» Erosion Response Plans » Structure Raising » Setbacks » Studies » Sediment Management

Figure 5.3: *Project Categorization – Project types and corresponding subtypes used during the project screening process.*

Coastal Issues of Concern

The GLO and the Planning Team identified the Issues of Concern based on an understanding of the Drivers and Pressures exerted on the coastal system, such as tropical storms, hurricanes, depletion of freshwater inflows, sediment deficits and development. The eight IOCs, identified and detailed in Section 4, include:

- Altered, Degraded or Lost Habitat;
- Gulf Beach Erosion and Dune Degradation;
- Bay Shoreline Erosion;
- Existing and Future Coastal Storm Surge Damage;
- Coastal Flood Damage;
- Impacts on Water Quality and Quantity;
- Impacts on Coastal Resources; and
- Abandoned or Derelict Vessels, Structures and Debris.

To supplement incomplete or outdated datasets, the Plan relied on the expertise of the TAC for evaluation of the severity of each IOC by region. To facilitate this screening process, the GLO and the Planning Team divided the four coastal regions into 68 subregions primarily defined by watershed extents (Figure 5.4). Included in the 68 subregions are four Gulf-facing beach and dune subregions that were created to consider the unique challenges facing the barrier island and peninsula dune and beach complex as a large integrated system.

The subregions were delineated according to U.S. Geologic Survey Hydrologic Unit Code (HUC) 10 watersheds and bounded landward by the Texas Coastal Zone Boundary.[59] The HUC-10 watershed units were chosen because they consider area ecology, coincided neatly with the bay systems and were small enough to provide for local level analysis, yet could be combined in meaningful ways to make larger units for landscape level analysis. Using the watershed dataset allowed for contiguous coverage across the Texas coast.

The TAC collectively evaluated the IOCs for their levels of concern within each of the 68 subregions, under the perspective of achieving a resilient coast. Each level of concern was determined by evaluating indicators of ecological health and human well-being, such as the trend in loss of wetlands or the susceptibility of storm or flood damage, based on the current conditions of the coast.

Figure 5.4: *Planning Regions and Subregions – To facilitate the project screening process, the four coastal regions were divided into 68 subregions.*

The TAC was asked to consider resiliency concepts and provide a numerical valuation for the level of concern for each IOC in subregions with which they were familiar. The example concepts include: "Is the ecological health of a location so poor that a large storm could erode marsh to the extent that it cannot recover in the face of ongoing sea level rise?" Or "Will this Issue of Concern in turn increase the exposure of a community to flooding or impact the local fishing industry making the region less resilient to the next storm?"

The TAC evaluated the IOCs in each of 68 subregions along the Texas coast on a scale from zero to four, with zero being "not at all concerned," and four being "extremely concerned." The Planning Team compared average TAC responses and scores for each IOC. High levels of concern suggest high needs for project solutions that can address the IOCs, an idea that was developed more fully during the subsequent TAC Analysis (Section 5.3) and Project Prioritization (Section 5.4).

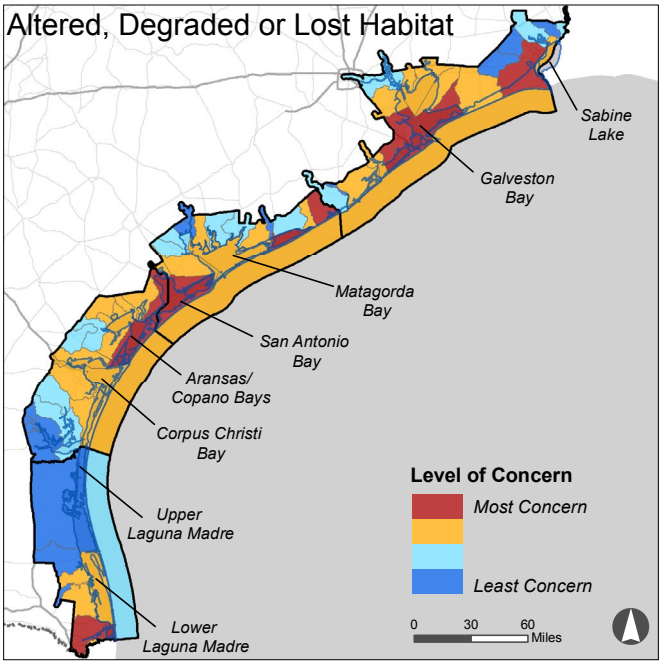


Figure 5.5: *Altered, Degraded or Lost Habitat – Level of concern based on TAC assessments.*

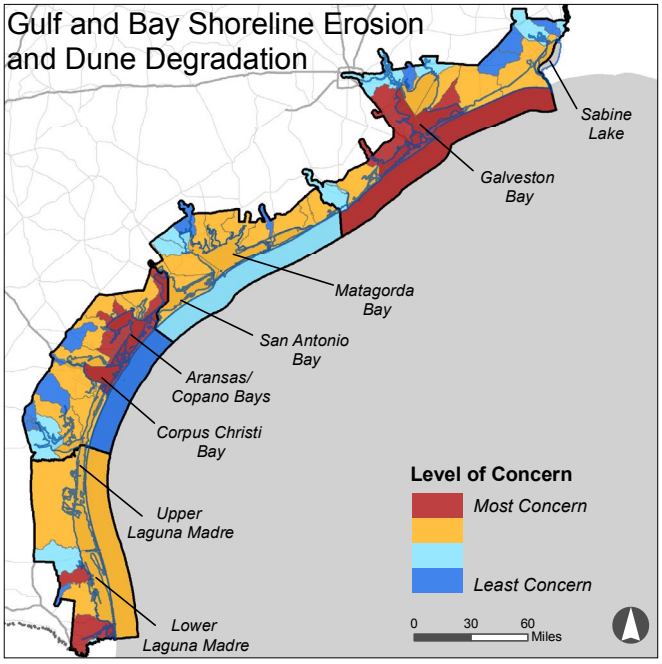


Figure 5.6: *Gulf and Bay Shoreline Erosion and Dune Degradation – Level of concern based on TAC assessments.*

TAC assessment results of certain IOCs by subregion are shown in Figure 5.5 (Altered, Degraded or Lost Habitat), Figure 5.6 (Gulf and Bay Shoreline Erosion and Dune Degradation), and Figure 5.7 (Existing and Future Coastal Storm Surge Damage). These figures graphically relay the relative level of concern for each IOC in each subregion ranging from most concern to least concern.

A level of concern for a particular issue within a subregion that was more than one standard deviation above the mean level of concern for that Issue indicated "Most Concern" (dark red). A level of concern greater than one standard deviation below the mean level of concern for that issue indicated "Least Concern" (dark blue). Levels of concern within one standard deviation above (orange) or below (light blue) the mean indicated moderate concern. The Technical Report to the Plan provides figures and tables documenting the TAC's assessment of each individual IOC by subregion.

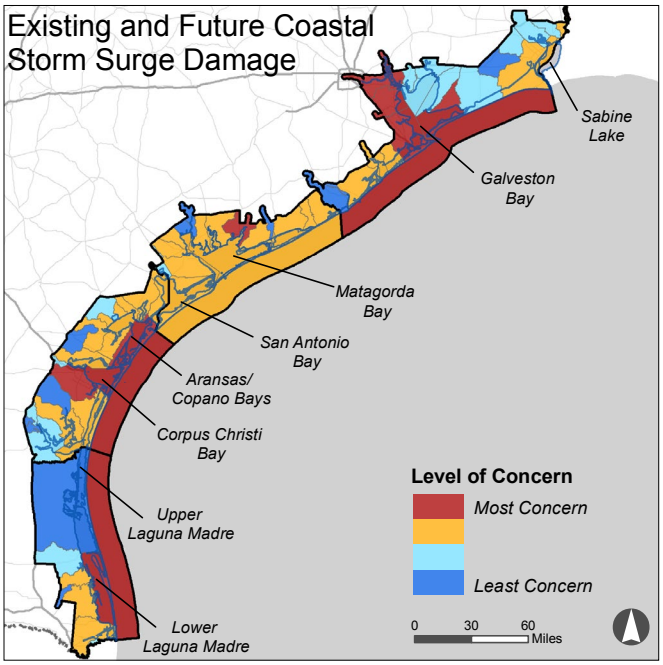


Figure 5.7: *Existing and Future Coastal Storm Surge Damage – Level of concern based on TAC assessments.*

Second Project Screening

The Planning Team conducted a second screening to further narrow the list of candidate projects. The second screening entailed a desktop programmatic model featuring an unbiased, repeatable and systematic method to calibrate relationships between anticipated physical and ecological benefits in relation to the identified IOCs.

The second screening used a matrix to associate the expected, qualitative resiliency benefits achieved by various project types (e.g., breakwaters generally provide shoreline erosion benefits) to the eight identified coastal IOCs. The resiliency benefits expected for each individual project were predicted based upon both the project's defined attributes, as well as the level of concern of IOCs (as determined by the TAC) in the project's subregion. The matrix then outputs a quantitative metric to predict the resiliency benefits for each individual project. The desktop programmatic model selected 177 projects that most effectively address the IOCs, based upon their project types and locations.

The desktop programmatic model did not screen projects that did not pass the initial screening, described previously. Similarly, the TAC did not review projects that did not pass the programmatic model. The Project Evaluation Tables in Appendix A (Technical Report to the Plan) give a full listing of these projects. More information on the desktop programmatic model can also be found in Appendix A.

5.3. Technical Advisory Committee Analysis

Project Evaluation

During a series of regional meetings, the TAC evaluated the 177 projects that passed the preliminary and secondary screenings. The TAC individually assessed each project on the basis of its overall scope and merit, considering factors such as its proposed location, expected impacts on the natural and built environments, size or scale, proposed methodology or restoration technique, feasibility of construction or completion, and overall consistency with the Plan's resiliency goals. The TAC's evaluations took place by means of a series of four in-person meetings, with time provided for group discussion on individual candidate projects and the opportunity to provide additional, written comments.

Project Gap Analysis

The GLO asked the TAC to take a big picture look at coastal issues in light of the identified projects, and propose any additional gap projects that would address unmet needs. In total, the TAC proposed and evaluated an additional 61 gap projects. The GLO and the Planning Team also recognize that there are existing and anticipated project gaps along the Texas coast that have not yet been captured through this project gap analysis and will require further research, assessment and evaluation in future iterations of the Plan.

5.4. Additional Technical Analysis of Projects

The project screenings, evaluation and gap analysis, as described above, were complemented by a series of additional technical analyses to better define the projects. These included:

- Project Cost;
- Economics and Benefits;
- Physical and Risk Impacts;
- Project Feasibility and Constructibility;
- Environmental Impacts; and
- Sediment Management.

These assessments were completed for projects that were part of the TAC analysis to provide additional detail, as necessary, and are described in detail in Appendix A. This further informed the next steps of Plan preparation, including the development of eight Resiliency Strategies that facilitated grouping the various candidate projects.

Technical Advisory Committee and local officials meeting in Houston.

5.5. Project Prioritization (Tiers)

The preceding technical assessment activities yielded 238 projects consistent with Plan goals and objectives from the original 900 projects plus the 61 projects identified in the gap process. To help classify the projects, three project tiers were constructed based on assessment results. The additional technical analyses, in conjunction with TAC input, resulted in the designation of 63 Tier 1 projects (high priority) and Tier 2 and Tier 3 projects. Only Tier 1 projects are listed in this document. Tier 2 and Tier 3 projects are recorded in Appendix A and will be further considered in future iterations of the Plan.

One of the key considerations when categorizing projects into tiers was the TAC members' "yes" or "no" responses to the question, "Would you consider this project a priority for coastal resiliency?" The parameters of the question, verbally defined at the regional TAC meetings, and the yes/no basis of the question allowed for a direct and commensurate dataset indicating the general approval rating for the project.

Projects qualified as Tier 1 if the projects had high TAC approval ratings (typically exceeding 80 percent), high feasibilities, and the benefits a project provides to mitigate the Issues of Concerns in the project's subregion. The Tier 1 projects represent the most resilient and actionable project solutions recommended for the state, as identified by the planning process described herein.

A Tier 2 project signifies that the project received moderate (60 percent to 80 percent) TAC approval based on the current development of the project, moderate feasibility projections, and project benefits to address Issues of Concerns in the project's subregion. These projects may still effectively contribute to the resiliency and viability of the coastal zone, and will be evaluated further moving forward with this planning effort. The remaining projects, those in Tier 3, are in need of further research and development in future iterations of the Plan or are already captured under another, larger project.

A project recommendation of Tier 2 or Tier 3 is not necessarily indicative of the project's merit to receive funding, nor does a project recommendation of Tier 1 indicate that a project will receive funding. The Project Evaluation Tables in Appendix A (Technical Report to the Plan) provide this data and other values related to the project screening (e.g., programmatic model results, TAC numerical valuations) for all projects identified at any level of the technical assessment.

Identified Tier 1 projects are further defined by the Resiliency Strategy they primarily address. Section 6 of the Plan presents the Resiliency Strategies, the process of their development and the projects associated with each Resiliency Strategy by region.

Project Tiers

Tier 1 Projects

- High TAC approval ratings (typically over 80 percent)
- High feasibility
- Benefits mitigate IOCs in projects subregion
- Most resilient and actionable project solutions recommended for the state

Tier 2 Projects

- Moderate TAC approval ratings (between 60 percent and 80 percent)
- Moderate feasibility projections
- Benefits address IOCs in project's subregion
- May still effectively contribute to resiliency and viability of coastal zone

Tier 3 Projects

- Need further research and development in future iterations of the Plan or already captured under another, larger project

6. RECOMMENDED RESILIENCY STRATEGIES FOR THE TEXAS COAST

Through extensive research, expert input and local stakeholder consultation, the technical assessments of possible project solutions yielded eight Resiliency Strategies, or categories of restoration and protection to enhance coastal resiliency, that collectively address the Issues of Concern identified over the course of the planning process.

The Aransas Pass Light Station, also known as the Lydia Ann Lighthouse, is a resilient structure that became operational in 1857. Mangroves protect the lighthouse from vessel wakes.

The Resiliency Strategies will enhance the GLO's mission to restore, enhance and protect the coast by providing insight to the greatest needs along the coast, and proposing specific projects to achieve that mission with a statewide frame of reference to enhance resiliency.

Evaluations by the TAC and additional technical analyses revealed that across the regions there were common project types needed to best address the Issues of Concern identified regionwide. Similar project types were then grouped into Resiliency Strategies, based on commonality.

This system-wide approach is intended to maximize the benefits of the projects within each region and provide multiple lines of defense when the strategies are implemented collectively. Moreover, the Resiliency Strategies will enhance the GLO's mission to restore, enhance and protect the coast by providing insight to the greatest needs along the coast, and proposing specific projects to achieve that mission with a statewide frame of reference to enhance resiliency.

6.1. Resiliency Strategies For the Texas Coast

The planning methodology yielded the following Resiliency Strategies:

- **Restoration of Beaches and Dunes** – Provides renourishment of sediment to beach and dune complexes to address erosion, shoreline loss and limited sediment supply.
- **Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines)** – Addresses shoreline erosion problems within bay and estuarine systems and will provide shoreline stabilization through combined shoreline protection and habitat creation projects (e.g., living shorelines).
- **Stabilizing the Texas Gulf Intracoastal Waterway (GIWW)** – Addresses critical shoreline erosion, habitat loss and environmental degradation problems along the GIWW or other navigation channels.
- **Freshwater Wetlands and Coastal Uplands Conservation** – Conserves and protects ecologically significant freshwater wetlands and coastal uplands through various land acquisition, conservation and restoration projects.
- **Delta and Lagoon Restoration** – Mitigates hydrologic and water quality impairments within major delta and lagoon systems along the coast.
- **Oyster Reef Creation and Restoration** – Provides for the identification and restoration or re-establishment of productive oyster reefs.
- **Rookery Island Creation and Restoration** – Provides for the identification and restoration or re-establishment of rookery island nesting habitats to support colonial waterbird populations.
- **Plans, Policies and Programs** – Establishes a framework to address coastal resiliency priorities through legislative and administrative changes and coastal program enhancements.

Each of the Tier 1 projects included in the Plan aligns with the Resiliency Strategy that best corresponds to its primary goal, recognizing that any given project may have secondary benefits that relate to other Resiliency Strategies.

In developing the Resiliency Strategies and associated projects, the GLO and the Planning Team acknowledge that Texas' coastal Issues of Concern are constantly evolving. The eight Resiliency Strategies presented in the Plan, and the Tier 1 projects associated with them, reflect high priority recommended actions centered on projects that provided ecosystem resilience.

As such, it is recognized that there are other Resiliency Strategies that are integral to comprehensive coastal resiliency for Texas beyond the eight identified in the Plan. Projects and strategies that were not incorporated into this planning process include, but are not limited to:

- Certain project types or strategies addressed in other ongoing studies (i.e., storm surge reduction, community infrastructure);
- Projects for which other agencies oversee certain Issue of Concern-related outcomes (i.e., water regulations); and
- Strategies that will become relevant as the Plan evolves and expands beyond nature-based projects (as referenced in Section 7).

Presented on the following pages is a detailed description of each of the eight Resiliency Strategies, including the Drivers, Pressures and Issues of Concern that correspond to each Strategy, and the environmental features that can be protected using proposed resiliency measures. Also featured are potential economic benefits that can be realized through the projects associated with each strategy.

Restoration of Beaches and Dunes

Coastal erosion remains a continuing threat to the Texas Gulf and bay shorelines. The Texas coast has some of the highest coastal erosion rates in the country, with approximately 65 percent of the Gulf shoreline considered an eroding area.[113] Shoreline erosion is exacerbated by coastal development, habitat loss, storm events, lack of sediment availability, subsidence and sea level rise.

The erosion of Texas beaches and dunes degrades natural barrier systems that provide a first line of defense for coastal communities and infrastructure against the impacts from hurricanes, tropical storms and coastal flooding.[56] Degradation and erosion of shorelines, conversely, permits saltwater intrusion into inland coastal habitats, reducing vegetative buffers that would otherwise provide water absorption during storm events.

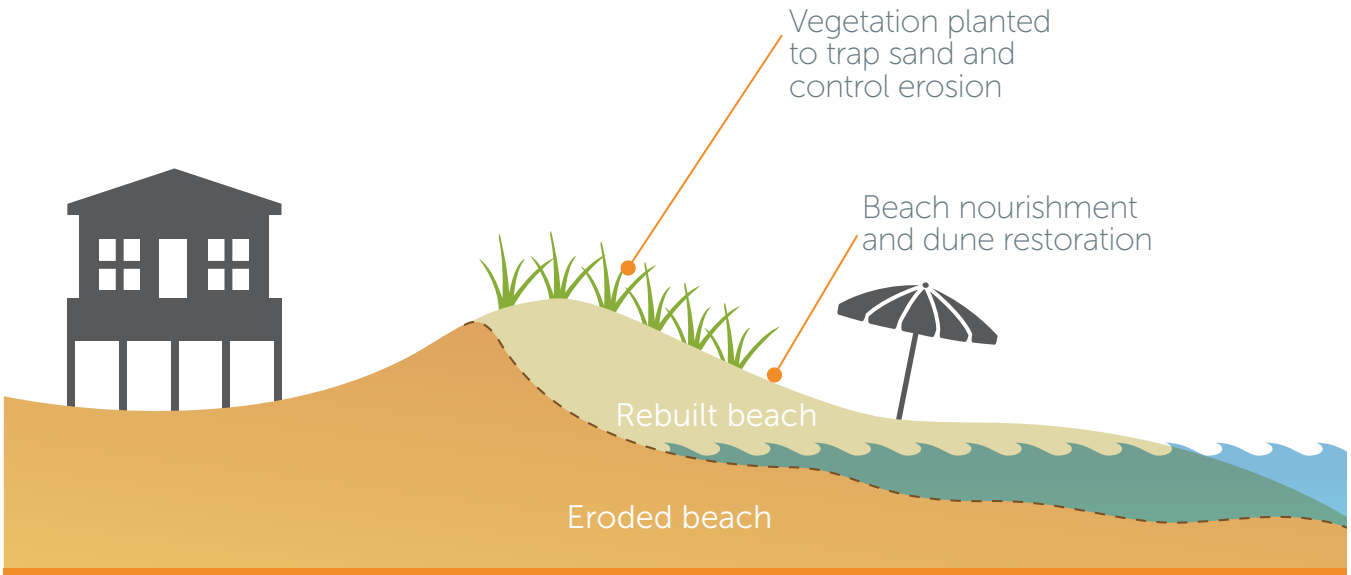
This Resiliency Strategy identifies potential methods to address critical shoreline erosion by improving sediment retention in the bay and Gulf beach and dune systems. Primary approaches include beach nourishment and dune restoration. Beach nourishment places sand to replenish and widen the existing beach. Beach nourishment is typically done in conjunction with dune restoration. Dune restoration consists of enhancing the stability of dunes by the addition of material or planting vegetation (dune grass) to trap windblown sand, thereby increasing the natural beach formation. This Resiliency Strategy also identifies potential engineered solutions, where appropriate, such as groins, to improve sediment retention on select beaches. Factors such as available sediment, areas with critical erosion and feasibility of project funding contributed to the selection of projects within this Resiliency Strategy.

While sand loss is an inherent part of coastal processes, it can be mitigated with proper planning and implementation of erosion response and sediment management practices. Identifying long-term sediment sources and collaborative management of resources will improve the capabilities of the state to rebuild beaches and dunes, and assist in the protection of coastal ecosystems and communities. Texas contends with a general lack of beach-quality sand sources, in terms of grain size and composition, which presents challenges for beach nourishment efforts. However, as currently authorized dredged material placement areas are reaching capacity, other governmental and private entities may be motivated to provide opportunities for beneficial use of dredged materials to offset placement area capacity burdens. In most cases of beneficial use, the result is positive for both the entity disposing of the dredged material as well as the recipient.

Successful examples of coordination between federal and state entities for the beneficial use of dredged sediments from navigation channels for beach nourishment include the ongoing nourishment of the City of South Padre Island beaches and the 2015 nourishment in front of the Galveston Island Seawall.

A sediment management plan for the entire Texas coast will be beneficial to optimize coastwide coordination for large and small-scale uses of its sediment resources. Such a plan will benefit the Restoration of Beaches and Dunes Resiliency Strategy, as well as the GLO's Beach Monitoring and Maintenance Program, to outline a future path for nourishment of existing and engineered beaches. The sediment management plan and the BMMP are both examples of programs that fall in the purview of the Plans, Policies and Programs Resiliency Strategy (discussed later in this section), underscoring how multiple strategies implemented together can increase the effectiveness of this Plan.

South Padre Island Isla Blanca County Park after beach nourishment.



Restoration of Beaches & Dunes

Economic Benefits

Under the Texas Open Beaches Act, the public has the right to access Texas' Gulf-facing beaches from the water to the line of mean high tide. The social and economic benefits that coastal communities and the state draw from Texas beaches are based on the recreational values derived from their availability and accessibility.

Coastal erosion results in the loss of property, which may reduce property values and reduce tourism in local communities. Local economies, such as Bolivar Peninsula, Galveston Island, Sargent Beach and South Padre Island, rely on the restoration of beaches and dunes to attract beach visitors, which supports tourism, recreational businesses and employment, and translates to tax revenue for local and state government budgets. The market appeal of healthy beaches and dunes and ocean views generates extensive residential and commercial development along the coast. Leisure and hospitality services, of which tourism and recreational services are a part, employ 300,000 coastal residents earning in excess of $6 billion yearly.[10] Over one-quarter of all Texans working in leisure and hospitality services are employed within the state's 18 coastal counties.[10]

Wide beaches and continuous and robust dune systems provide the first line of defense from storm surge and low-energy waves, mitigating coastal flood damage and shoreline erosion. Healthy dune systems function as natural sand reservoirs for beach nourishment, as sand is moved from the dune to the beach and nearshore waters during storms.[16] Dunes provide habitat for wildlife within the beach and dune ecosystem and contribute to the overall recreational experience of beach visitors.

A representative example of a project within this Resiliency Strategy is a beach nourishment and dune restoration project within Cameron County (included in this Plan) that was reviewed for direct, indirect and induced economic impacts, to determine short-term economic benefits for a typical project. Using an approximate construction cost of $7.2 million, it is estimated that every dollar spent on a beach nourishment and dune restoration project will generate $1.58 for the county's economy and $1.98 at the state level. Further detail of this economic analysis can be found in Appendix A (Technical Report to the Plan).

Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines)

Long-term coastal shoreline change shows an erosive trend in many of the Texas bay systems, with average annual rates of land loss along the Texas coast averaging 178 acres per year since 1930.[61] Erosion along the Texas coastline contributes to loss of critical coastal habitats, such as estuarine wetlands that are sensitive to disturbances and thrive in low-energy environments where they are protected from direct wave action. The wetlands found along estuaries, bays, rookery islands and the backside of barrier islands are naturally altered by erosion, subsidence, inundation, sea level rise, insufficient sediment supply and storms. Bay shorelines and estuarine wetlands are also degraded by direct and indirect human impacts, such as vessel travel, urbanization and pollution.

Restoration or enhancement of bay shoreline habitat can be achieved by implementing living shorelines. Living shorelines are shoreline stabilization measures that incorporate nature-based solutions to fully or partially reduce the impact of erosive forces on the shoreline to protect property and critical estuarine wetland habitat. Living shorelines use a variety of stabilization and habitat restoration techniques that can be categorized into two basic approaches. The first approach uses only "soft" organic material in construction (e.g., vegetative plantings, bay beach nourishment), without any hard structures. The second approach uses a combination of soft and hard structures to protect shorelines from wave energy. This hybrid approach can include the use of geotextile tubes, organic fiber mats, revetments, breakwaters, sand fill, stone and oyster reefs to prevent waves from directly hitting the shoreline, allowing wetlands to flourish.

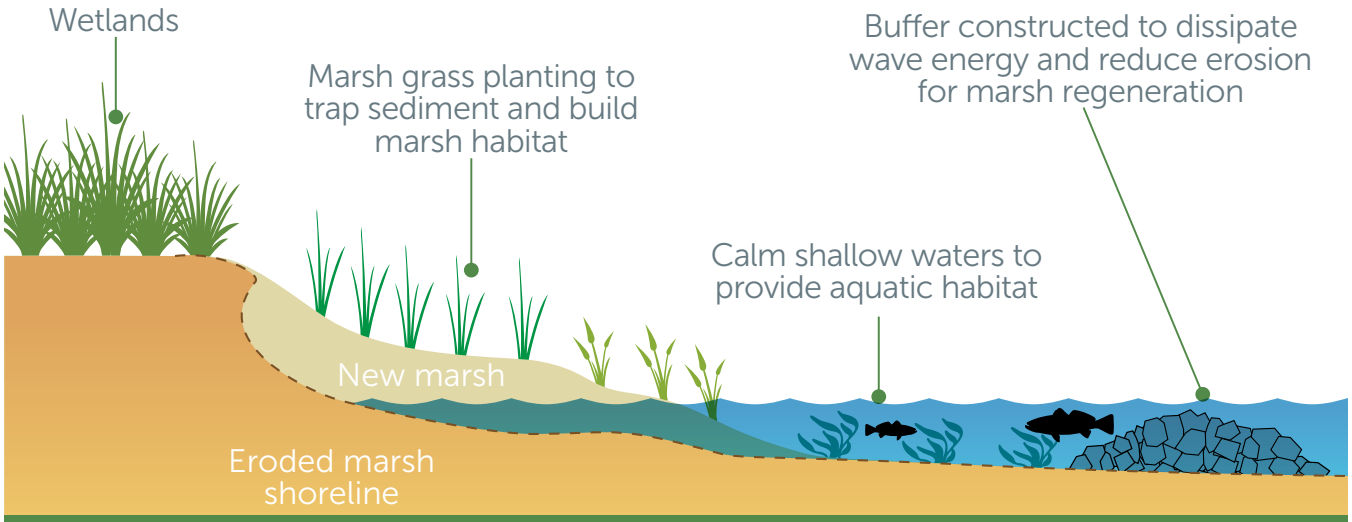
Hard structures, such as bulkheads, revetments and breakwaters, are commonly used without soft materials to mitigate shoreline erosion, but are unable to adapt to changing conditions the way natural vegetation can acclimate.[99] Moreover, these hard structures can interrupt the natural processes of sediment movement and cause additional erosion to nearby areas if not properly planned and constructed. Hard structures can also affect the circulation between bay and delta systems, which becomes an important design factor in the location and orientation of the structures. These downsides are often best mitigated when combined with nature-based solutions, and are the cause for the increasing use of living shorelines to stabilize bay shorelines in place of traditional hard structures.

In areas where erosion control structures, like bulkheads, are failing, living shorelines can be installed in front of the structure to build wetlands and stabilize the shoreline. The wetlands incorporated into living shorelines provide substantial protection to shorelines, can restore critical fishery habitat, and can increase long-term shoreline integrity to allow shorelines to better adapt to relative sea level rise and storm inundation.[23]

Compared to traditional shoreline protection measures, properly designed living shorelines provide ecosystem services such as: habitat for fish, birds and plants, water quality improvements, sediment stabilization and wave energy attenuation, while also providing natural landscape aesthetics. Without pursuing mitigation efforts, relative sea level rise and continued coastal development will exacerbate wetland and coastal habitat loss in bays and estuaries. Protecting Texas' bay shorelines from further erosion while keeping pace with relative sea level rise is a critical goal for the state to restore and rebuild lost habitat that offers storm protection for communities and industries near the coast.

This Resiliency Strategy identifies areas of notable deterioration along Texas bay shorelines and potential locations that will benefit from the installation of living shorelines to lessen erosion and provide shoreline protection for property and wetland habitat. This Strategy also identifies areas of estuarine wetlands that have experienced significant levels of degradation and loss, and proposes solutions to restore or rebuild these critical habitats. Additionally, this strategy considers shorelines that currently do not have wetland habitat, but are still viable candidates for this type of shoreline protection solution.

Bayside shoreline erosion protection project in Copano Bay.



Bay Shoreline Stabilization & Estuarine Wetland Restoration

Economic Benefits

Persistent erosion affects natural areas, property owners, businesses and recreational users. Coastal infrastructure impacted by bay erosion include the Gulf Intracoastal Waterway, ports and ship channels, petrochemical facilities, and roads and evacuation routes. Erosion can cause breaches into estuaries, wetlands and marshes, changing the ambient salinity and land gradient. This can result in the loss of estuarine habitat that is critical for the development of species that support birdwatching, commercial and recreational fishing, and hunting. Providing additional habitat will aid and protect the valuable species that sustain economic diversity along the coast.

To determine short-term economic benefits for a typical, representative project within this Resiliency Strategy, a sample marsh creation and shoreline protection project in Chambers County (included in the Plan) was reviewed for direct, indirect and induced economic impacts. Using an approximate construction cost of $24.8 million, it is estimated that every dollar spent would generate $1.20 for the county's economy and $1.61 for the state. Further detail of this economic analysis can be found in Appendix A (Technical Report to the Plan).

Moses Lake shoreline erosion.

Moses Lake shortly after living shoreline installation.

Stabilizing the Texas Gulf Intracoastal Waterway

The Gulf Intracoastal Waterway is a man-made, shallow-draft navigation channel that runs along the entire Texas coast and is separated from adjacent bays and the mainland by peninsulas and a series of small islands, with some portions cutting through estuarine and freshwater wetlands and upland interior areas (Figure 6.1). For most of its length, the Texas GIWW is protected from the open waters of the Gulf of Mexico or large bays by small islands, many of which originated as dredged material placement areas and are subject to erosion.

Navigation, construction and maintenance activities along the channel increase susceptibility of the shoreline to erosion and breaching. Vessel traffic within the GIWW creates strong wakes that contribute to high rates of shoreline erosion and wetland loss along the channel and dredged material placement islands that line the GIWW. This not only negatively impacts shoreline stability within those areas but also contributes to repeated silting in of the channel and necessitates more frequent and costly channel dredging and maintenance.

As shorelines and fringing wetlands erode, the saltwater from the GIWW can breach the estuarine wetlands lining the channel and penetrate into the freshwater wetland habitats and lakes, known as saltwater intrusion. Subsidence and erosion have increased the frequency of saltwater intrusion from the GIWW into the historically

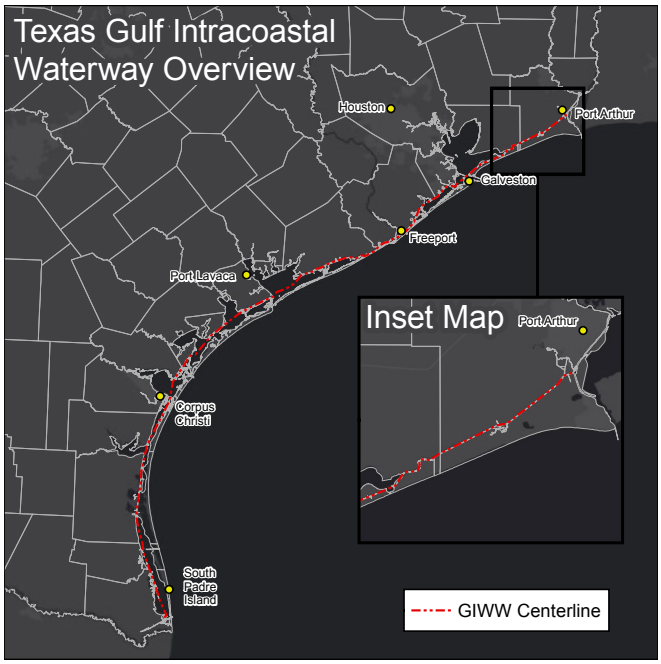
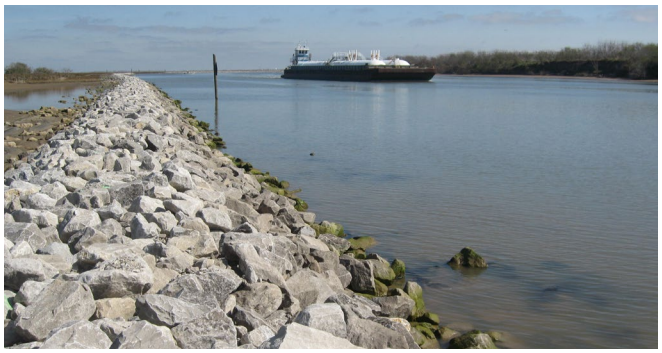


Figure 6.1: *Texas Gulf Intracoastal Waterway Overview*



Shoreline armoring along the GIWW.

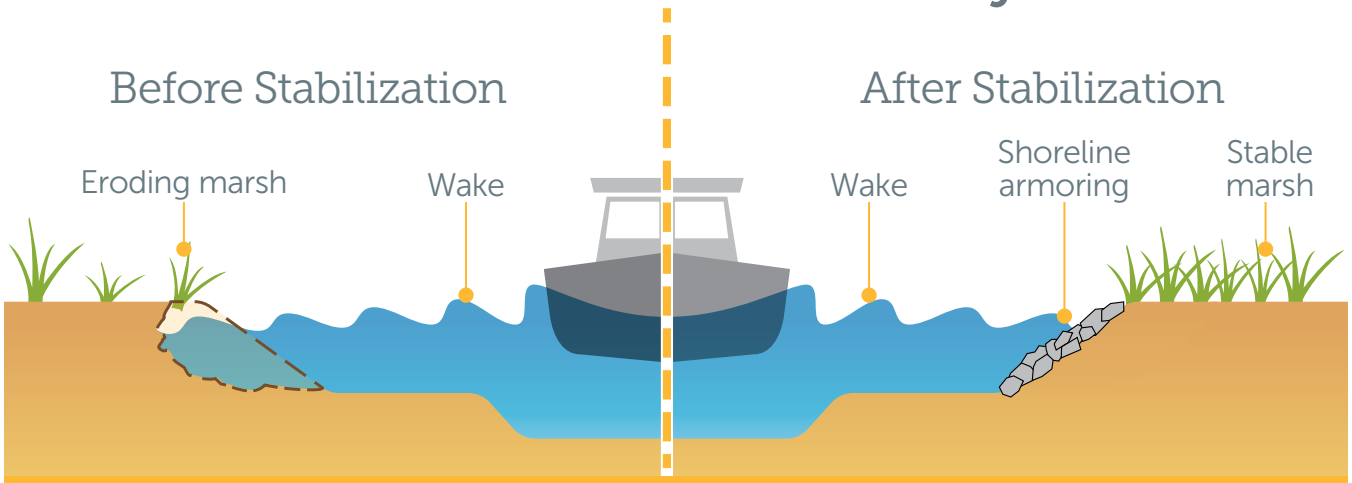
fresh wetlands, thereby altering the composition and ecosystem of these wetlands as they become more brackish. The erosion of adjacent wetlands impacts not only the stabilization of the GIWW shoreline, but also reduces valuable habitat used by diverse aquatic and avian species for feeding, breeding and nursery areas.

In areas where the GIWW cuts through coastal uplands, it diverts or disconnects the natural flow of water between inland freshwater wetlands and lakes along the waterway. The saltwater channel created by the GIWW disrupts inland freshwater inflows to regional areas of wetlands, with one of the most notable areas of occurrence at Salt Bayou between Galveston and Port Arthur (See inset map on Figure 6.1).[85]

This Resiliency Strategy identifies areas along the GIWW with the greatest need for shoreline protection for adjacent wetlands and dredge material placement islands, creation of new dredged material placement areas, and hydrologic restoration in adjacent freshwater wetlands and lakes. This strategy pinpoints critical breaching areas along the GIWW and other navigation channels for possible restoration. Shoreline erosion due to insufficient shoreline stabilization and ongoing channel use[97] could be rectified by implementing a living shoreline approach or other shoreline stabilization method to mitigate erosion along the channel and placement islands.

Shoreline stabilization of the dredged material placement islands provides critical colonial waterbird nesting habitat, as well as protection for adjacent habitats along the GIWW, such as fringe marshes and seagrass beds that are vital to the bay ecosystems and promote habitat resiliency. Where possible, protection of these islands will attempt to utilize living shoreline approaches, which promote habitat creation in conjunction with, or in addition to, shoreline stabilization. In addition, shoreline stabilization of these islands reduces channel siltation and the islands serve to buffer the GIWW from longer fetches that can increase wave action, benefiting vessel traffic by improving navigability and maneuvering along the channel.

Effect of boats and barges on the Gulf Intracoastal Waterway



Stabilizing the Texas GIWW

Economic Benefits

The GIWW is a critical navigation system that allows for safe and efficient transportation of over 1 million tons of commodities to Texas ports, refineries and manufacturing facilities along the entire Gulf coast.[100] The transportation efficiencies afforded by the GIWW provide a tremendous benefit to Texas as a whole.

The GIWW is a commercially efficient and a navigationally safe way to transport cargo, when compared to transportation via rail or truck. Protecting the GIWW supports numerous ocean economy sectors by securing safe transport of commodities and by safeguarding estuaries from a breach due to shoreline erosion that will lead to saltwater intrusion into freshwater habitats and negatively impact commercial and recreational fisheries. In addition, protecting the GIWW with the restoration of islands and other landforms provides habitat for avian species that are important to the ecotourism industry in Texas. The overall economic benefit of stabilizing the GIWW is the direct support the waterway provides to the diversification and success of an array of industrial sectors, thereby increasing coastal economic resiliency.

To determine short-term economic benefits for a typical GIWW stabilization project, a representative island restoration project in Orange County (included in the Plan) was reviewed for direct, indirect and induced economic impacts. With an approximate construction cost of $8.4 million, it is estimated that every dollar spent would generate $1.33 for the county's economy and $1.73 for the state. Further detail of this economic analysis can be found in Appendix A (Technical Report to the Plan).

Protecting the GIWW supports numerous ocean economy sectors by either securing safe transport of commodities or by protecting estuaries that support commercial and recreational fisheries from saltwater intrusion by breach avoidance or repair.

Freshwater Wetlands and Coastal Uplands Conservation

Freshwater wetlands and coastal uplands along the Texas coastline have experienced significant declines in acreage and habitat due urban expansion and the associated residential, commercial and industrial development, increased water use and agricultural clearing in coastal counties.[42] Data shows that freshwater wetlands, specifically, experienced net losses of over 161,000 acres in the Gulf of Mexico region between 2004 and 2009.[14] This conversion of land use results in habitat fragmentation, the spread of invasive species, and negatively impacts the hydrology and ecosystem services provided to coastal communities by freshwater wetlands and coastal uplands.

These wetlands and upland areas provide critical environmental benefits by serving as filters for urban stormwater runoff prior to entering aquifers, streams or lakes. Upstream stormwater runoff is increased by urban development and expansion of paved areas, such as roads and parking lots, which further degrades downstream water quality. These areas also perform as detention zones that collect and slowly release floodwaters to mitigate coastal flood damage and provide important habitat for many species of birds and other wildlife.

Increased inland water use may limit the amount of freshwater that reaches the coast by rivers, which is important for the survival of freshwater wetlands and coastal uplands. Water flow across wetland areas can also be disconnected or reduced by development impacts, such as roads or dredged channels, like the GIWW, which cut through wetlands. These types of obstructions that lead to reductions in freshwater inflows can severely degrade wetland functionality. When wetlands are deepened or drained for development, they become less productive and lose their ability to buffer against storm surge and provide habitat for wildlife. Maintaining and restoring the state's freshwater wetlands and coastal uplands enhances water quality, the diversity of flora and fauna, the fishing and ecotourism industries, and the overall health of Texas coastal ecosystems.

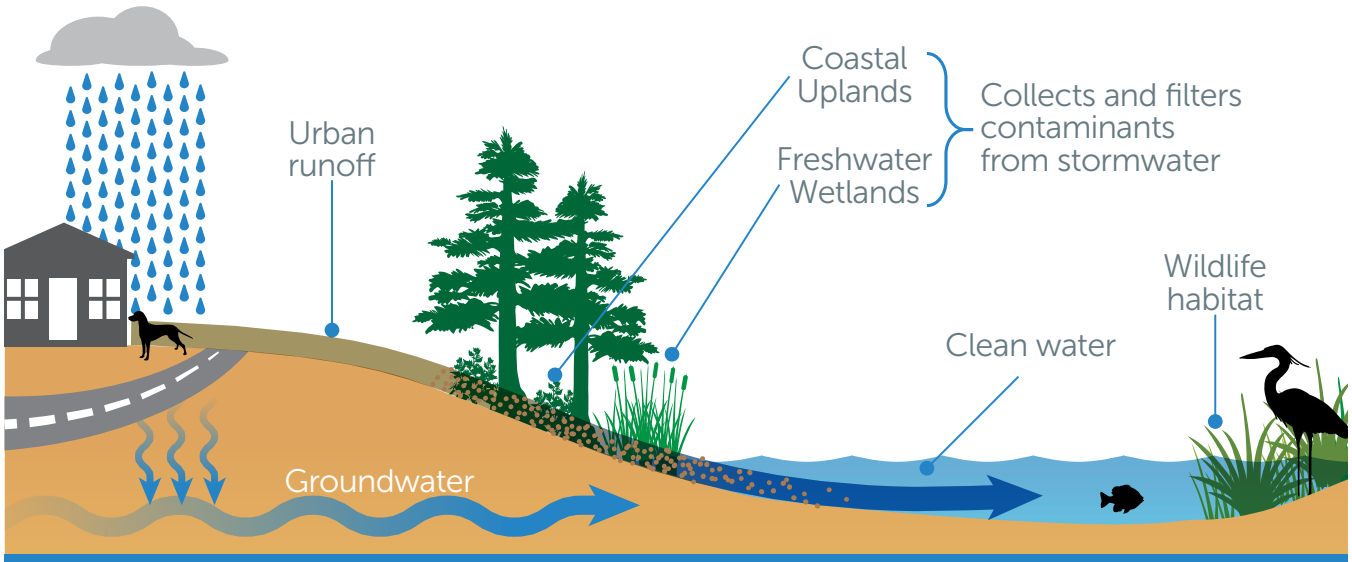
This Resiliency Strategy identifies freshwater wetlands and coastal uplands that will benefit from restoration, conservation or enhancement. The following are factors that are taken into consideration to identify these areas:

- The location of properties in comparison to existing protected areas, conservation easements or floodplains;
- Cooperation of current land owners;
- The relative importance of wetlands and uplands for wildlife foraging, breeding habitat and migration corridors; and
- Availability of dredged material designated for beneficial use to restore subsided lands.

The focus on freshwater wetlands and coastal uplands within this Resiliency Strategy serves to differentiate between solutions more typical of estuarine wetlands, discussed within the Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines) Resiliency Strategy.

Solutions may involve expanding or restoring existing coastal protected areas, such as National Wildlife Refuges (NWRs) and Wildlife Management Areas (WMAs), through property acquisitions or conservation easements. Other projects considered under this Resiliency Strategy may include restoring local hydrology through the use of siphons, channel reconfiguration and land conservation planning. Wetland restoration can also be designed to improve watershed drainage. Large-scale hydrologic restorations, typical of riverine systems, are discussed in the Delta and Lagoon Restoration Resiliency Strategy.

Installed siphons in Matagorda Island National Wildlife Refuge.



Freshwater Wetlands & Coastal Uplands Conservation

Economic Benefits

Land acquisition and conservation establish a dedicated land use for the preservation of wildlife habitat. These techniques preclude future land use development, thereby avoiding the economic losses associated with storm surge and inundation risks to coastal residents and businesses.

The permitted alteration of wetlands across Texas coastal counties from 1997 to 2001 is estimated to have increased the average cost of property damage from floods by over $38,000 per jurisdiction per flood.[7] Conversely, a percent increase in freshwater wetlands in the Gulf Coast region can reduce insured flood losses by over $7,500 per watershed per year by absorbing, storing and slowly releasing rainfall.[8]

The ecosystem services provided by freshwater wetlands and coastal uplands include water and air quality improvements, which enhance and preserve breeding and nursery areas for the species that support commercial fishing, recreational fishing, hunting, birdwatching and ecotourism. Conservation of these ecosystems is critical for the proliferation of wildlife habitat and is necessary for the growth of these industries.

Freshwater wetlands in Armand Bayou Nature Center in Pasadena.

Freshwater wetlands and coastal uplands serve as filters for storm water runoff prior to water entering rivers and aquifers, and can improve watershed drainage.

Delta and Lagoon Restoration

Deltas (Deltaic): *Sediment deposits at the mouth of a river; over time, a complex of channels, sand bars and marshes may form.*

Lagoons: *Protected areas of calm water, between the coast and the barrier beaches or islands, that receive little fresh water input. Lagoons may also be separated from the Gulf or bays by sand bars.*

In several watersheds along the coast, inland development and construction of dams, levees, navigation channels and other water control features have disrupted the hydrology, or the flow of water, into deltas and lagoons. Upstream water use and the diversion of rivers from their original courses has reduced the quantity of water entering rivers and coastal watersheds, thus reducing the quantity of water flowing into coastal deltas. Disruptions to watershed hydrology and natural river flow can cause a reduction in the necessary sediment, mineral and nutrient deposits freshwater inflows carry to deltas and associated lagoons to maintain a healthy deltaic ecosystem.

Sediments carried by freshwater inflows help build and maintain bay shorelines, mudflats and other shallow water habitat features. The reduction of sediment from upstream obstructions can lead to bay shoreline erosion throughout the bay.

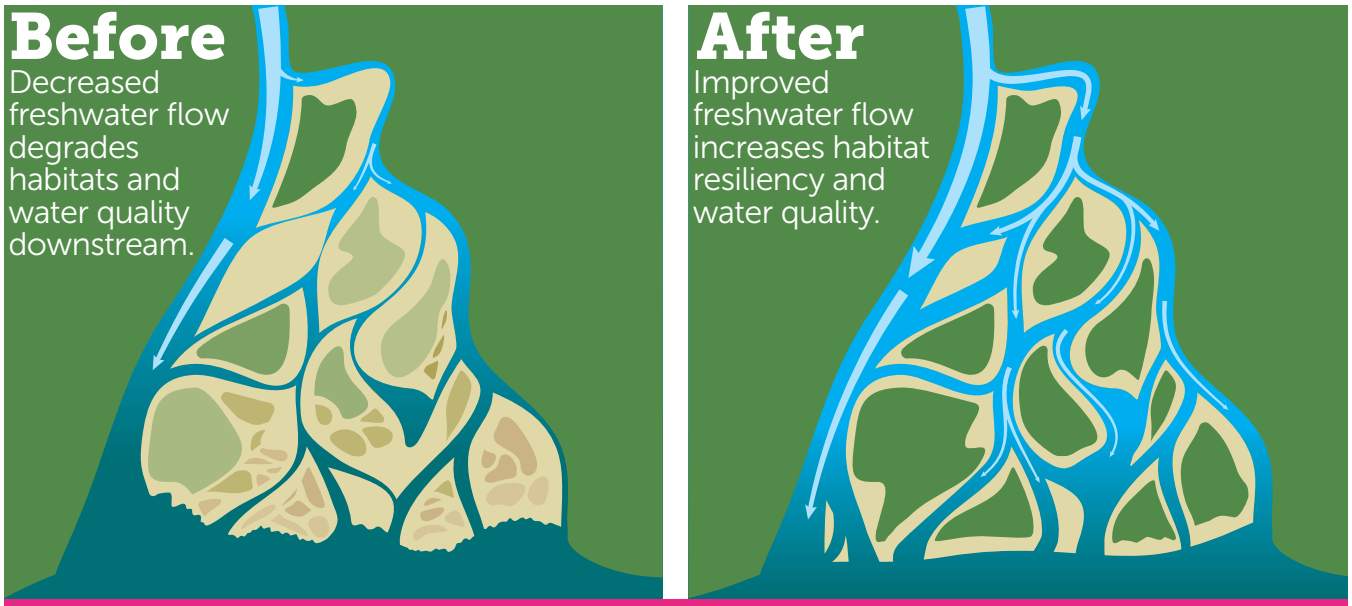
Nueces River Delta.

Freshwater inflows maintain the proper salinity and nutrient balances vital to the health of aquatic life within delta systems. An imbalance in estuarine nutrients from reduced flows can lead to harmful algal blooms, decreased water quality, and other negative environmental and public health impacts.

In addition, during storm events rivers can convey heavy influxes of stormwater and wastewater carrying pollution into the delta, which alters salinity levels and further impairs water quality. Avoiding these widespread impacts by ensuring enough freshwater from rivers reaches Texas' bays and estuaries is a proactive strategy to maintain the overall health of delta ecosystems.

Lower Laguna Madre.

Much of the water flowing through Texas' rivers is permitted for withdrawal through perpetual water use permits, which in some instances contributes to lower freshwater inflows to estuaries. Since the Texas Legislature passed Senate Bill 3 in 2007, the Basin and Bay Expert Science Teams and the Basin and Bay Area Stakeholder Committees developed a series of studies recommending environmental flow standards. The Senate Bill 3 standards recommend the amount of water "adequate to support a sound ecological environment in the state's rivers and estuaries," particularly during drought periods, and determine how to protect environmental flows in Texas watersheds. The Texas Commission on Environmental Quality adopted environmental flow standards based on these recommendations through their rule-making process and the Texas Water Development Board provided administrative and technical support through this process. The Plan's Resiliency Strategies relating to freshwater inflows will work within the recommendations set forth by these studies when considering potential solutions, and will be coordinated with the appropriate agencies.



Delta & Lagoon Restoration

This Resiliency Strategy identifies specific delta and lagoon systems that are experiencing the greatest changes to the hydrology of their major estuaries. Cost-effective techniques can be used to remove hydrological obstructions or artificial drainage to restore connectivity and benefit habitat restoration projects within the larger ecosystem. Other approaches to address the reduction of freshwater inflows may include smart land-use planning to protect critical coastal habitats and watershed areas that provide storage and filtration of storm water runoff, restoring freshwater inflows with land contouring or installed infrastructure (such as siphons), and terracing designed to restore drainage. When restoring freshwater inflows is not a viable option, this Resiliency Strategy will consider adaptive management for the estuaries to respond to the changing conditions.

Economic Benefits

When delta or lagoon hydrology is disturbed, cascading impacts on the system can occur to coastal ecosystems and local communities, as well as interdependent regional economies. Delta and lagoon restorations are integral to the functionality and viability of many of the other Resiliency Strategies, and therefore contribute to the economic benefits realized under those strategies. The state's coastal ecosystems depend on healthy water resources in their river deltas and lagoons to provide an abundance of habitats and wildlife that support important industries throughout the state, including oyster harvesting, commercial and recreational fishing, birdwatching, ecotourism, and a variety of other water-based recreational activities.

The reduction of sediment from upstream obstructions can generate widespread erosion throughout the bay, and an imbalance in estuarine nutrients from reduced flows can lead to harmful algal blooms, decreased water quality, and other negative environmental and public health impacts.

Oyster shell recycling program at local coastal restaurant.


Bagged recycled oyster shell.


Volunteers place bagged oyster shell to rebuild reef in bay.

Oyster Reef Creation and Restoration

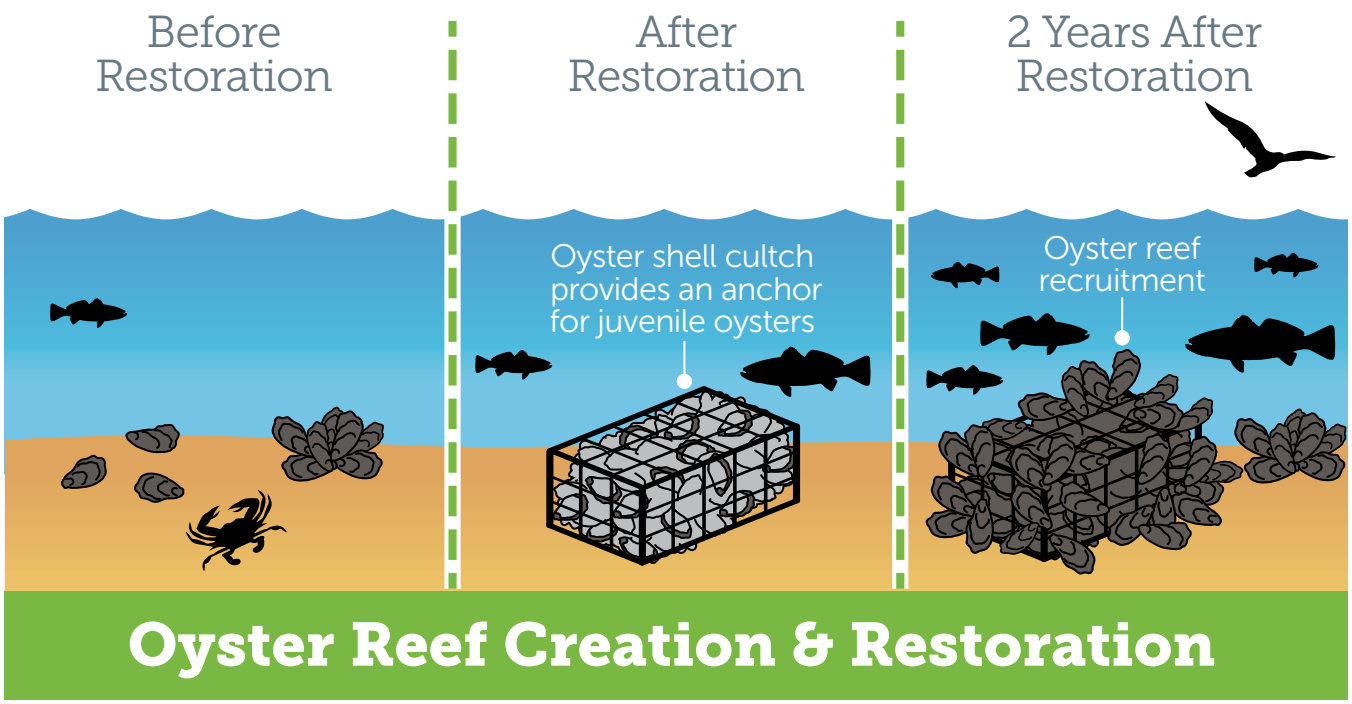
Texas bay systems are experiencing ongoing degradation of oyster reefs as a result of both natural and man-made processes. Oyster reefs are in decline from habitat loss due to dredging, turbidity, vessel traffic, destructive fishing practices, storms, over-harvesting, disease, and degraded water quality (e.g., increased contaminants from runoff). Watershed alterations due to upland development, which change the characteristics of downstream water quality and flow quantity, also play a role in degrading oyster reefs. In addition, hurricanes and tropical storms can disturb and deposit significant amounts of sediment on top of oyster reefs, often damaging or destroying them. In 2008, according to the Texas Parks and Wildlife Department, Hurricane Ike destroyed 50 to 60 percent of oyster reef habitat in Galveston Bay.[18]

As filter-feeders, oysters prefer certain water conditions to thrive, and fluctuations in salinity, temperature and turbidity can impact oyster reproduction, growth, recruitment and exposure to disease. Poor water quality contributes to oyster reef degradation. Consequently, water quality becomes further impaired as the loss of oysters results in reduced water filtration capacity, which is necessary to support healthy aquatic ecosystems.

Oyster reefs provide numerous ecosystem services for estuaries and surrounding environments, and are critical to the health of bay systems, due to their roles in maintaining water quality and circulation through water filtration and biodiversity by building structural habitat for numerous species. Oyster reefs are also a natural line of defense, functioning as a buffer to dissipate wave energy from storms and, when placed nearshore, are effective in reducing bay shoreline erosion.[42]

This Resiliency Strategy focuses on restoring oyster reefs in bay systems that are ecologically best suited to sustain them. The restoration efforts include studying, collaborating and researching the optimal locations and scale for oyster restoration projects within the identified bay systems to most effectively apply this Strategy. Oyster reef restoration techniques may include constructing a linear reef to stabilize the shoreline, collecting and bagging recycled oyster shell for re-use to establish new oyster reefs, or placing discarded oyster shell or cultch for larval oysters to attach to and grow, in addition to other large-scale oyster reef restoration techniques.


Clusters of oysters in bay.



Oyster Reef Creation & Restoration

Economic Benefits

Notable benefits of oyster habitat creation are commercial oyster harvest, recreational fishing, water filtration, aquatic habitat diversity and shoreline protection. The state's thousands of square miles of coastal estuaries and shallow bays support oyster harvests – an important commercial fishery in Texas – that had a landings value of $8 million in 2015.[52] The recreational value associated with species diversity found among oyster reefs helps to support the $1 billion marine recreational fishing industry.[50]

To determine the short-term economic benefits for a typical project within this Resiliency Strategy, an oyster reef restoration project in Galveston County (included in the Plan) was reviewed for direct, indirect and induced economic effects. With an approximate construction cost of $15 million, it is estimated that every dollar spent would generate $1.50 for the county's economy and $1.97 for the state. Further detail of this economic analysis can be found in Appendix A (Technical Report to the Plan).

The recreational value associated with species diversity found among oyster reefs helps to support the $1 billion marine recreational fishing industry.[50]

Rookery Island Creation & Restoration

Many rookery islands along the Texas coast are experiencing significant erosion or are at risk of complete degradation due to vessel wakes, and wind and wave erosion. A recent study by Audubon Texas predicts that over half of 60 identified rookery island sites located within 2,500 feet of the GIWW will be considered at "high" risk of being unusable by waterbirds in the next 25 years, based on current erosion rates.[28] Without rookery islands for nesting shorebirds and migratory birds, bird populations begin to congregate in nearshore coastal habitats and become more susceptible to inland predators and impacts from human activity. Over time, threatened bird populations begin to decrease, sometimes to the point of endangerment or extinction.

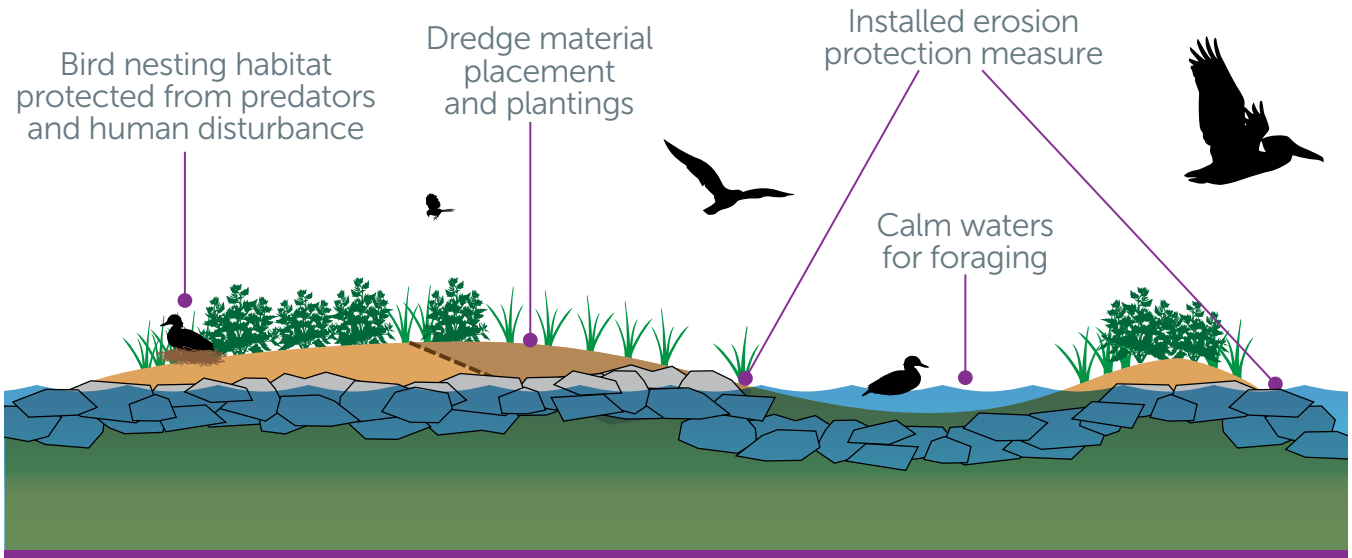
Young pelicans in their nest on a rookery island.

The Texas coast has historically been a habitat for a vast number of colonial shorebirds, migratory waterbirds and Neotropical songbirds, including threatened and endangered bird species. Rookery islands serve as nesting, breeding, foraging and rearing areas for these birds because they are isolated from the mainland and are too small to sustain populations of predators. A fully functioning, contiguous rookery island system along the whole Gulf Coast is necessary to support migratory birds during the critical migration seasons.

Over 1 million persons, of which 90 percent are bird watchers, participate in wildlife watching and take 12 million trips a year for the activity.[103]

This Resiliency Strategy considers how rookery islands function as a contingent, coastwide system and proposes a blueprint to ensure that a continuous chain of rookery islands exists along the entire Texas coast to allow bird populations to nest, migrate and flourish. This Resiliency Strategy also identifies existing rookery islands in need of restoration and proposes locations for the creation of additional rookery habitats. In conjunction with ongoing sediment management planning efforts, sediment sources may be identified for beneficial use in constructing or restoring rookery islands. To promote long-term stability for the islands, rookery island restoration solutions may need to work in tandem with living shoreline approaches, and wetland and oyster reef restoration initiatives.

Shamrock Island in Corpus Christi Bay.



Rookery Island Creation & Restoration

Economic Benefits

Bird populations contribute to both ecotourism and the ecologic diversity of the coast. Wildlife watching supports a $1.4 billion dollar industry in Texas.[103] Over 1 million persons, of which 90 percent are bird watchers, participate in wildlife watching and take 12 million trips a year for the activity.[103] The availability of temporary and seasonal habitat is critical for the millions of migrating birds that fly through Texas on semi-annual migrations. Re-establishing and expanding habitat that has been lost to erosion and degradation is important to the growing popularity of birdwatching.

To determine short-term economic benefits for a typical project, a sample rookery island restoration project was reviewed for direct, indirect and induced economic impacts. With an approximate construction cost of $1.9 million, it is estimated that every dollar spent would generate $1.42 for the county's economy and $1.88 for the state. Further detail of this economic analysis can be found in Appendix A (Technical Report to the Plan).

Birds on a rookery island.

Birds on a rookery island.

Beach maintenance along South Padre Island.

Derelict pilings along South Padre Island marina.

Plans, Policies & Programs

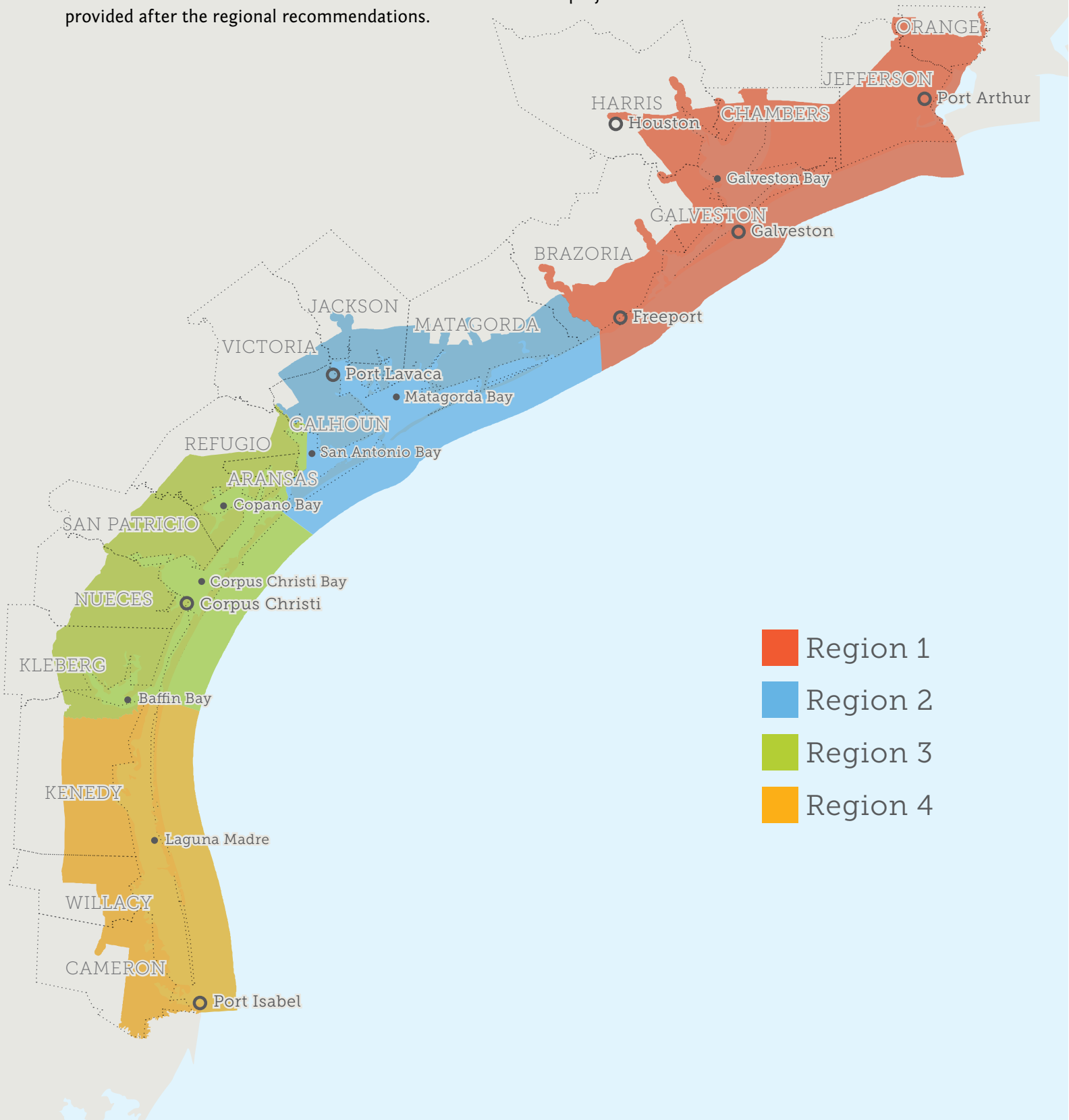
Complementing site-specific projects directed at achieving coastal resiliency are plans, policies and programs that typically have a broad geographic reach with implications that affect many, if not all, Resiliency Strategies. Coastal management policies and coastal management plans can contribute to the selection of priority projects and the determination of funding availability.

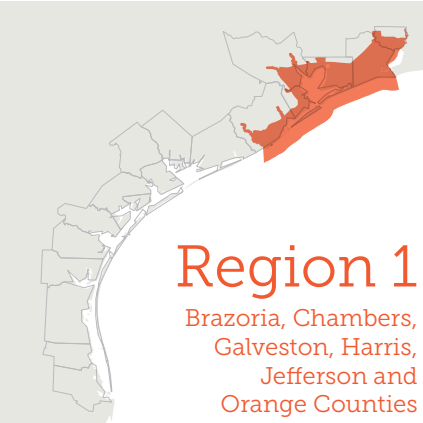
To advance coastal resiliency, it is necessary to have robust coastal programs that can operate continuously and with dedicated annual funding to mitigate the Issues of Concern that they were created to address. Up and running coastal programs are particularly important in the aftermath of a hurricane or another type of coastal disaster, when an immediate response is needed to safeguard Texans and their property.

This Resiliency Strategy identifies coastwide programs and plans that can help address the Issues of Concern, such as beach monitoring and maintenance, sediment management plans for beach nourishment and other restoration projects, and the removal of abandoned and derelict structures, vessels and petroleum production structures. Additional policy and program recommendations can be expected in future iterations of the Plan as coastal issues, concerns and needs evolve.

6.2. Recommended Projects

Presented on the following pages are regional listings of priority Issues of Concern and the recommended Tier 1 projects, organized by Resiliency Strategy. Accompanying each listing is a summary table that provides an estimated cost range for each grouping of projects within a Resiliency Strategy. In this Plan, not every Resiliency Strategy will be applied to each region. This does not preclude a region from Tier 1 projects under and Resiliency Strategies in future iterations of the Plan. Recommendations for coastwide projects are provided after the regional recommendations.





Region 1

Brazoria, Chambers, Galveston, Harris, Jefferson and Orange Counties

Resiliency Strategies for Region 1

- Restoration of Beaches & Dunes
- Bay Shoreline Stabilization & Estuarine Wetland Restoration
- Stabilizing the Gulf Intracoastal Waterway
- Freshwater Wetlands & Coastal Uplands Conservation
- Oyster Reef Creation & Restoration
- Rookery Island Creation & Restoration

Beach at the end of the Galveston Seawall after nourishment.

Priority Issues of Concern for Region 1

1. ***Gulf Beach Erosion and Dune Degradation*** – Some of the highest rates of Gulf shoreline erosion in Texas occur in Jefferson County (almost 13 feet per year) and to the west end of the Galveston seawall.[61] Additionally, much of the Galveston Island dune system that was washed out by Hurricane Ike has still not recovered, leaving the Houston/Galveston metropolitan area vulnerable to the next major storm.
2. ***Altered, Degraded or Lost Habitat*** – Critical habitats in Galveston Bay, such as wetlands, seagrass and oyster reefs have suffered extreme losses from development, erosion, subsidence, invasive species and changing bay salinities.
3. ***Existing and Future Coastal Storm Surge Damage*** – Houston is the fourth most populated city in the United States, with the second largest port in terms of tonnage (Port of Houston), and is home to the most important oil and gas production complexes in the United States.[9, 106] Due to the dense population and critical infrastructure, the region is highly vulnerable to coastal storm surge damage, which would cause nationwide impacts.
4. ***Coastal Flood Damage*** – High tide events, in combination with subsidence and increased rainwater in the watersheds, flow into Galveston Bay and cause coastal flooding in the low-lying areas of the region and along rivers and streams. These events cause disruptions to businesses, damage to property and natural environments, and pose risks to human health and safety.

Region 1 Recommendations

The recommended Resiliency Strategies and projects for Region 1 are summarized below and in Table 6.1. Project locations are shown in Figure 6.2 through Figure 6.5.

Restoration of Beaches and Dunes – Since much of the Region 1 shoreline is experiencing significant erosion, with an average erosion rate exceeding the Texas coastwide average of 4 feet per year, the projects recommended in this Plan will work to counteract the high rates of sediment loss at severely eroding stretches of beaches and dunes. In particular, the Region 1 recommended project areas include the Bolivar Peninsula shoreline, the Galveston Island shoreline immediately west of the seawall, the McFaddin NWR shoreline near Sea Rim State Park and the Follets Island shoreline. The project at Follets Island will involve beach nourishment in conjunction with erosion control groins to retain sediment. The following presents a potential phasing of these beach nourishment efforts to a manageable scale:

- The nourishment efforts including the Bolivar Peninsula *(R1-1, Bolivar Peninsula Beach & Dune Restoration)* and McFaddin NWR *(R1-7, McFaddin National Wildlife Refuge Shoreline Restoration)* would primarily rely on sand sources originating from the offshore Trinity and Sabine sediment deposits. Due to sediment restrictions and funding availability, a recommendation for nourishment of 2-mile stretches of shoreline focused on critical needs is proposed, at a cost of $10 million to $20 million per phase. Possible efficiencies could be realized by splitting placement of material to two sites, one focused on the Bolivar vicinity and one focused on the McFaddin vicinity, but doing so under a single mobilization to reduce contractor costs.

- The nourishment efforts for the Follets Island shoreline do not have a significant local offshore sand source that is viable, creating a challenge of

either pursuing small scale projects using upland sand sources or promoting larger projects that benefit from a single mobilization that requires a more distant sand source. It is recommended that the region pursue projects on the scale of 2.5 miles of shoreline at a cost of $15 million to $25 million per phase, with a strong emphasis on beneficial use of dredged materials to reduce the cost, even at the expense of executing a reduced scope project. Additionally, it is anticipated that the groin structures located at Surfside Beach will reduce the erosion of that area, assisting in elongating the project life cycle *(R1-2, Follets Island Nourishment and Erosion Control)*.

- Recent nourishment efforts on Galveston Island were achieved through improved coordination of dredged materials between federal and state agencies. Continued coordination will keep costs feasible for the proposed nourishment of the shoreline immediately west of the seawall to 8 Mile Road *(R1-22, Galveston Island West of Seawall to 8 Mile Road Beach Nourishment)*.

Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines) – Proposed solutions include:

- ***Acquisitions***:
  - » Acquiring the 1,200 acre Settegast Coastal Heritage Preserve as a conservation area on West Galveston Island adjacent to West Bay *(R1-10, Coastal Heritage Preserve – Phase 4)*;
  - » Purchasing 275 acres of land for the Sweetwater Preserve Expansion adjacent to Sweetwater Lake *(R1-11, Sweetwater Preserve Expansion)*. Key attributes of the property include coastal grasslands, brackish and estuarine wetlands, direct access to West Galveston Bay and Sweetwater Lake, and extensive salt barrens and sand flats; and
  - » Acquiring and protecting an additional 1,300 acres on Follets Island *(R1-23, Follets Island Conservation Initiative)*.

- ***Living Shorelines:***
  - » Restoration of a 1,210-acre marsh at Old River Cove *(R1-4, Old River Cove Marsh Restoration)*;
  - » 1.6 miles of shoreline stabilization and restoration of the 2,000-acre Pierce Marsh *(R1-12, Pierce Marsh Living Shoreline)*;
  - » 1.6 miles of shoreline stabilization and restoration of up to 600 acres of marshland at the IH-45 Causeway, immediately south of the Pierce Marsh complex *(R1-13, IH-45 Causeway Marsh Restoration)*;
  - » Marsh habitat restoration on Follets Island, on the west side of Christmas Bay *(R1-18, Follets Island Marsh Restoration)*;
  - » Shoreline protection and restoration of the 1,700-acre Gordy Marsh, a coastal wetland and prairie habitat that borders Trinity Bay *(R1-8, Gordy Marsh Restoration & Shoreline Protection)*;
  - » Construction of 8,000 linear feet of nearshore, segmented breakwaters in Moses Lake, including placement of dredged material to restore elevations suitable to support emergent vegetation and upland coastal species *(R1-14, Moses Lake Wetlands Restoration – Phase 3)*; and
  - » Restoration of an historical marsh complex at Bessie Heights Marsh in the Lower Neches WMA that was lost to subsidence *(R1-21, Bessie Heights Marsh Restoration)*. Improvement of degraded marsh will increase viability for protected species and provide habitat for migrating birds.

Virginia Point shoreline protection and estuarine wetland restoration project in Galveston Bay.

Stabilizing the Texas Gulf Intracoastal Waterway – Erosion breached the narrow stretch of land separating the Brazoria NWR GIWW shoreline from Christmas Bay. This project includes reinforcing the banks on the bay side to prevent further erosion and creating emergent marsh habitat *(R1-17, Brazoria National Wildlife Refuge Shoreline Protection)*. Similar projects are recommended for 9 miles of shoreline along the Anahuac NWR *(R1-5, Anahuac National Wildlife Refuge Living Shoreline)*; a series of degraded islands at the northern end of Sabine Lake near Pleasure Island and Old River Cove *(R1-3, Old River Cove Barrier Island Restoration)*; and 6,000 linear feet of shoreline stabilization and adjacent wetland restoration at Willow Lake in the McFaddin NWR *(R1-6, Willow Lake Shoreline Stabilization)*. Restoring and stabilizing waterway barrier islands north of Pleasure Island *(R1-19, North Pleasure Island Barrier Island Restoration)* and island habitats at the mouth of the Neches River in Sabine Lake *(R1-20, Sabine-Neches Waterway Barrier Island Habitat Restoration)* will provide protection for inland freshwater marshes, promote habitat resiliency and improve channel navigation.

Freshwater wetlands at the Armand Bayou Nature Center in Pasadena.

Freshwater Wetlands and Coastal Uplands Conservation – Hydrologic restoration at Salt Bayou and acquisition of land parcels at Sabine Ranch to expand federal protected lands will provide water quality and habitat benefits to the region.

- The Salt Bayou siphons will restore hydrologic connectivity between the freshwater marsh systems north of the GIWW and degraded marshes south of the GIWW *(R1-15, Salt Bayou Siphons)*. Hydrologic modeling indicates benefits to 4,300 acres of marsh from structures in J.D. Murphree WMA and up to 22,500 acres of marsh from a siphon constructed in McFaddin NWR.
- Protection of the 12,100 acre Sabine Ranch property, located almost entirely within the McFaddin NWR, is a top conservation priority for the upper Texas coast *(R1-24, Sabine Ranch Habitat Protection)*. Sabine Ranch's central position within approximately 100,000 acres of federal and state protected beach and marshes make the permanent protection of this coastal habitat critical for the entire complex.

Oyster Reef Creation and Restoration – The goal of the proposed projects is to restore Galveston Bay oyster reef habitats in response to large-scale impacts from Hurricane Ike and increased harvest pressures due to Deepwater Horizon and population growth. The projects will also restore up to several hundred acres of oyster reefs throughout Galveston County, particularly in Trinity, Galveston and West bays, with locations established from existing and proposed planning studies for the area *(R1-25, Galveston Bay Oyster Reef Planning & Restoration)*. Criteria for monitoring restoration success will compare recruitment of oysters at restored sites to adjacent control sites.

Rookery Island Creation and Restoration – The Dickinson Bay and Galveston Bay rookery islands are identified as those in most immediate need of restoration, due to current and anticipated erosion. In Dickinson Bay, the project will provide multiple habitat functions, including approximately 5 acres of nesting habitats for colonial waterbirds and 2 acres of oyster reef *(R1-16, Dickinson Bay Rookery Island Restoration)*. In Galveston Bay, the project will restore elevation and provide shoreline protection for several Galveston Bay rookery islands, extending as far east as Rollover Bay and as far west as San Luis Pass *(R1-9, Galveston Bay Rookery Island Restoration)*. The proposed project will create additional acres of potential nesting habitat by re-establishing estuarine wetland. Additional restoration needs may be pursued as funding becomes available or in future iterations of the Plan.

Table 6.5: Region 1 Recommendations

Strategy	ID	Tier 1 Projects	Estimated Cost Range
Restoration of Beaches and Dunes	R1-1	Bolivar Peninsula Beach & Dune Restoration	$50 M - $95 M
	R1-2	Follets Island Nourishment and Erosion Control	$60 M - $115 M
	R1-7	McFaddin National Wildlife Refuge Shoreline Restoration	$100 M - $190 M
	R1-22	Galveston Island West of Seawall to 8 Mile Road Beach Nourishment	$2 M - $12 M
Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines)	R1-4	Old River Cove Marsh Restoration	$10 M - $30 M
	R1-8	Gordy Marsh Restoration & Shoreline Protection	$15 M - $35 M
	R1-10	Coastal Heritage Preserve – Phase 4	$3 M - $10 M
	R1-11	Sweetwater Preserve Expansion	$1 M - $3 M
	R1-12	Pierce Marsh Living Shoreline	$25 M - $45 M
	R1-13	IH-45 Causeway Marsh Restoration	$5 M - $18 M
	R1-14	Moses Lake Wetlands Restoration – Phase 3	$1 M - $3.5 M
	R1-18	Follets Island Marsh Restoration	$30 M - $50 M
	R1-21	Bessie Heights Marsh Restoration	$5 M - $25 M
	R1-23	Follets Island Conservation Initiative	$4.5 M - $15 M
Stabilizing the Texas Gulf Intracoastal Waterway	R1-3	Old River Cove Barrier Island Restoration	$5 M - $15 M
	R1-5	Anahuac National Wildlife Refuge Living Shoreline	$50 M - $105 M
	R1-6	Willow Lake Shoreline Stabilization	$3 M - $8 M
	R1-17	Brazoria National Wildlife Refuge GIWW Shoreline Protection	$20 M - $35 M
	R1-19	North Pleasure Island Barrier Island Restoration	$1.5 M - $5 M
	R1-20	Sabine-Neches Waterway Barrier Island Habitat Restoration	$0.5 M - $1.5 M
Freshwater Wetlands and Coastal Uplands Conservation	R1-15	Salt Bayou Siphons	$3 M - $7 M
	R1-24	Sabine Ranch Habitat Protection	$65 M - $120 M
Oyster Reef Creation and Restoration	R1-25	Galveston Bay Oyster Reef Planning & Restoration	$5 M - $60 M
Rookery Island Creation and Restoration	R1-9	Galveston Bay Rookery Island Restoration	$45 M - $80 M
	R1-16	Dickinson Bay Rookery Island Restoration	$0.5 M - $2 M
		Total for Region 1:	***$510 M - $1.1 B***

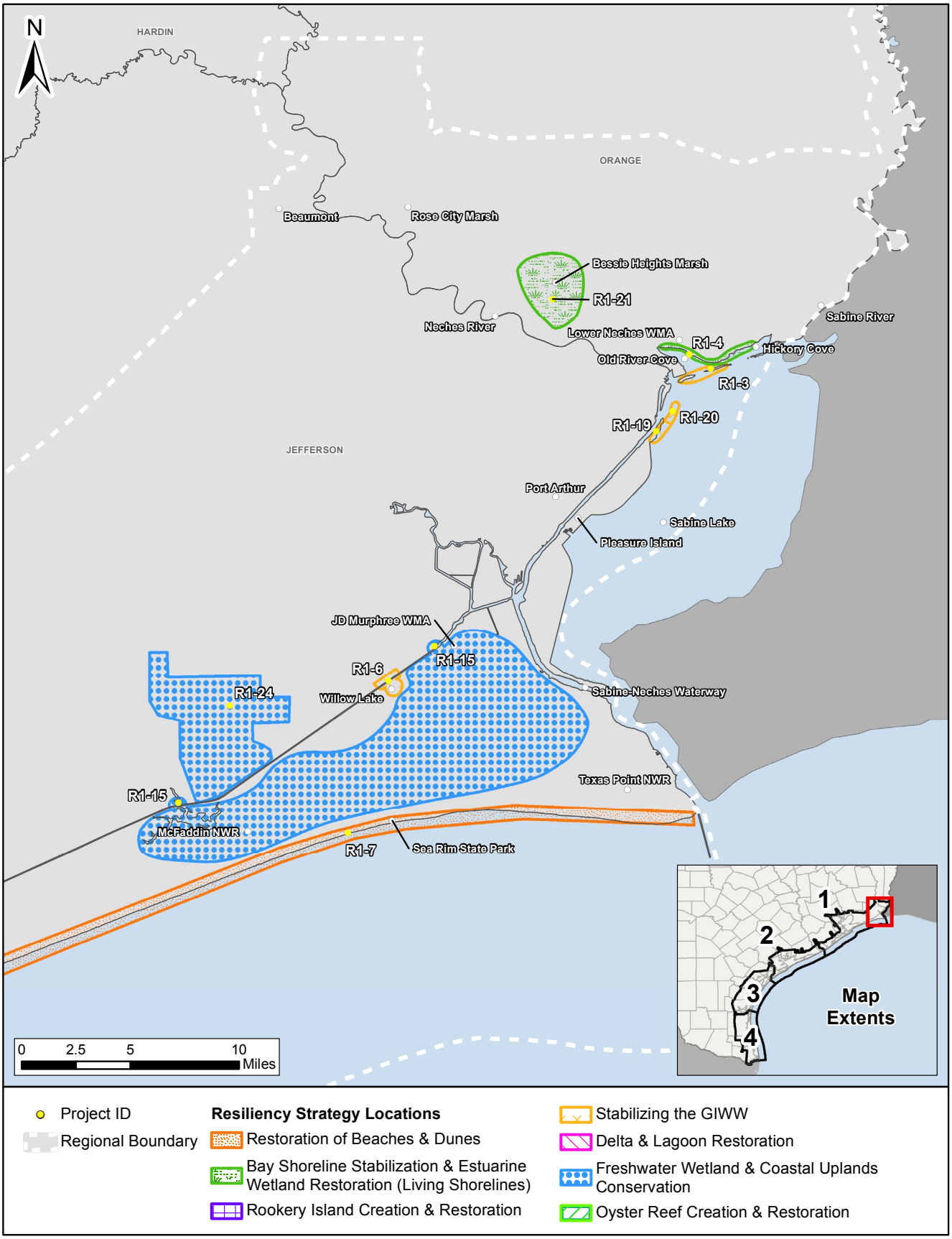


Figure 6.2: *Region 1 Resiliency Strategies Overview Map 1*

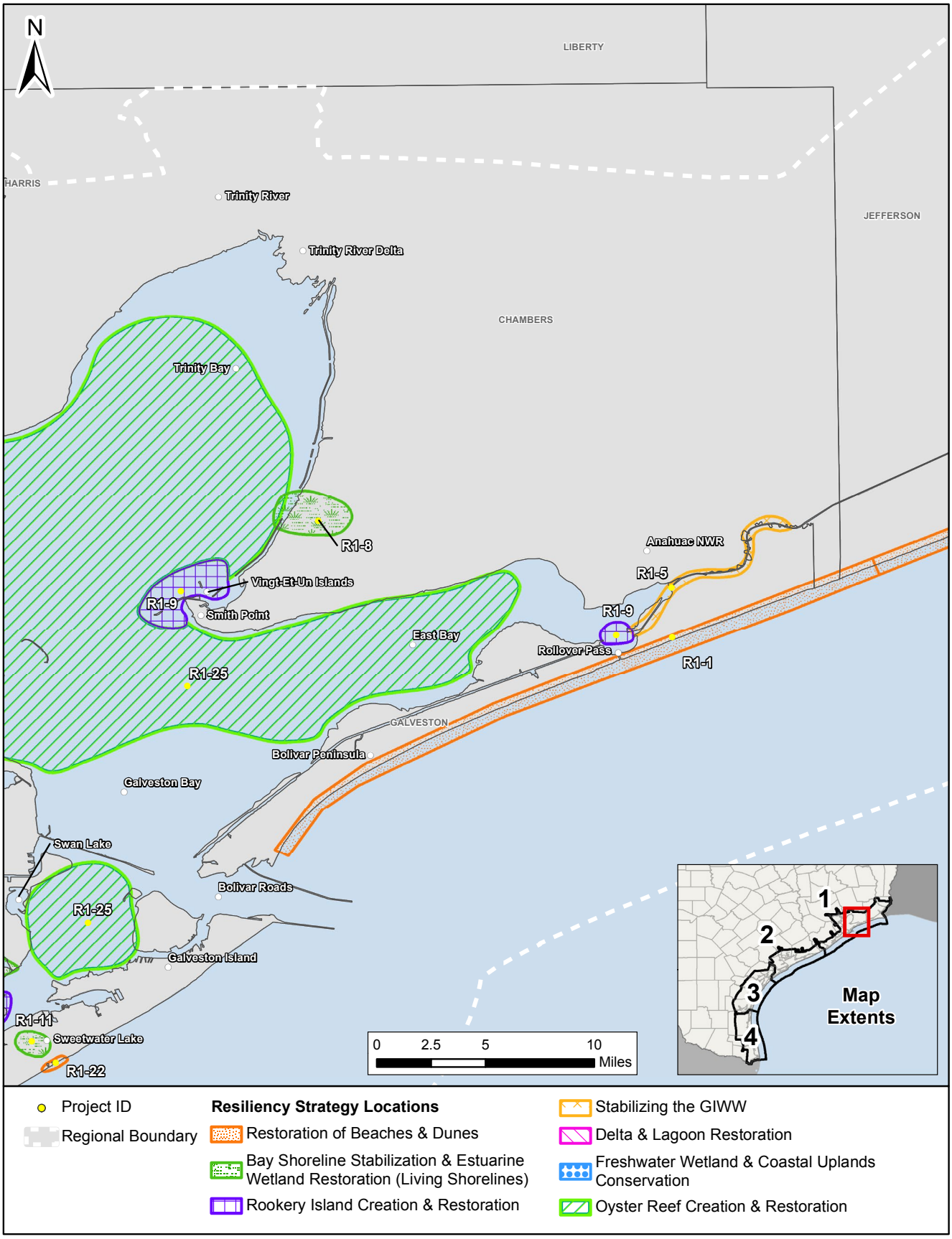


Figure 6.3: *Region 1 Resiliency Strategies Overview Map 2*

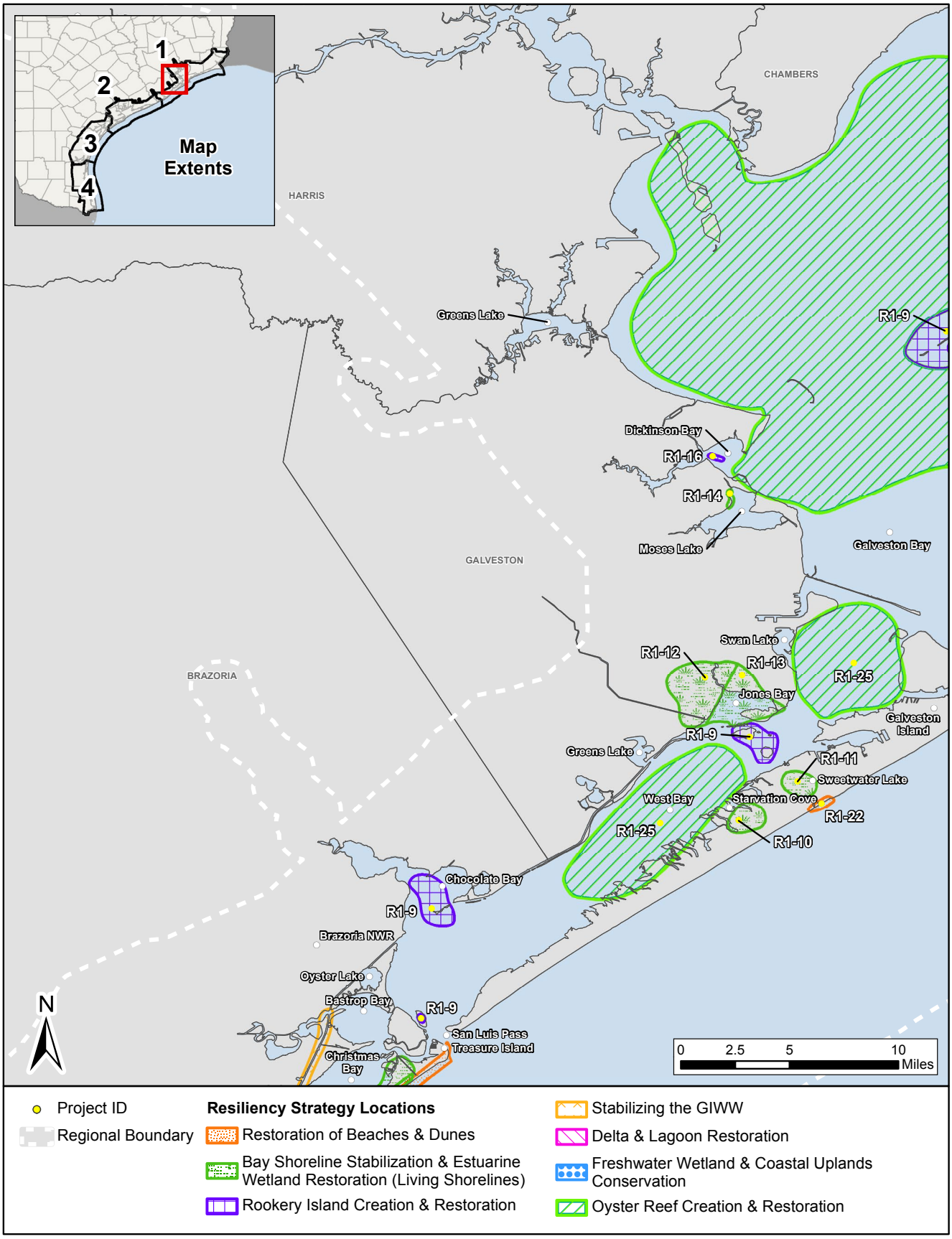
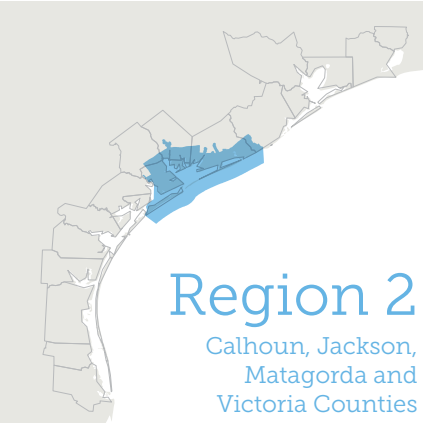


Figure 6.4: *Region 1 Resiliency Strategies Overview Map 3*

Figure 6.5: *Region 1 Resiliency Strategies Overview Map 4*



Resiliency Strategies for Region 2

- Restoration of Beaches & Dunes
- Bay Shoreline Stabilization & Estuarine Wetland Restoration
- Stabilizing the Gulf Intracoastal Waterway
- Freshwater Wetlands & Coastal Uplands Conservation
- Delta & Lagoon Restoration
- Oyster Reef Creation & Restoration
- Rookery Island Creation & Restoration

Matagorda Island National Wildlife Refuge.

Priority Issues of Concern for Region 2

1. ***Altered, Degraded or Lost Habitat*** – Erosion of the marshes and upland areas adjacent to the GIWW, and the reduction of freshwater inflows into the bay contribute to degradation of coastal habitats.
2. ***Gulf Beach Erosion and Dune Degradation*** – While the majority of the area experiences only moderate erosion, the Upper Matagorda Peninsula and Sargent Beach experience erosion rates ranging from 12 feet to 24 feet per year.[61]
3. ***Impacts on Coastal Resources*** – Recreational and commercial fishing and other coastal activities are highly important to the culture and economy of this region, and are dependent upon the health of the natural environments.
4. ***Impacts on Water Quality and Quantity*** – The delivery of inadequate quantities of upstream freshwater into the Matagorda Bay and San Antonio Bay system causes higher than normal salinity, which impacts fish and wildlife, including endangered species like the whooping crane.

Region 2 Recommendations

The recommended Resiliency Strategies and projects for Region 2 are summarized below and in Table 6.2. Project locations are shown in Figure 6.6 and Figure 6.7.

Restoration of Beaches and Dunes – There is a continual need for nourishment of Sargent Beach (East and West), which erodes at a historical rate up to 24 feet per year *(R2-7, Sargent Beach & Dune Restoration)*. The beach was last nourished in 2012 using truck and barge hauls; but for long-term viability, a more cost-efficient sand source needs to be identified. If feasible, locating an offshore source would provide significant cost savings to future nourishment efforts. This project will nourish up to 8 miles of shoreline, with structural solutions such as groins or breakwaters to alleviate sediment losses. An estimated potential phasing of this beach nourishment effort to a manageable scale follows:

- The nourishment efforts along the Sargent Beach project area will primarily rely on sand sources that have developed nearshore along the Brazos and San Bernard River deltas. Additionally, there is the possibility of a source offshore in the Colorado River Delta. A recommendation of 2-mile stretches of shoreline focused on critical need areas is proposed, with a cost of $7.5 million to $15 million per phase. Additionally, it is anticipated that groin or breakwater structures constructed at Sargent Beach will reduce the erosion of that area, assisting in elongating the project life cycle.

Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines) – Proposed projects include approximately 3 miles of breakwaters and living shorelines to correct a critical breach at Redfish Lake *(R2-6, Redfish Lake Living Shoreline)*, and to prevent further erosion of estuarine wetland near Schicke Point *(R2-11, Schicke Point Living Shoreline)*. Restoration will preserve special aquatic habitats such as oyster reefs, marsh, seagrass and vegetated shallows.

Stabilizing the Texas Gulf Intracoastal Waterway – The proposed solutions involve approximately 20 miles of breakwater or living shoreline construction along the GIWW at Big Boggy Cut *(R2-2, Boggy Cut GIWW Stabilization)* and restoration of marshes adjacent to the channel near Big Boggy Creek and from Cedar Lake to the Brazos River *(R2-1, Brazos River to Cedar Lake Creek GIWW Stabilization)*. The

projects may also include acquisition of private property adjacent to the GIWW. These efforts will improve mainland erosion from ship wakes, wind and waves, and will reduce current hazards to navigation.

Freshwater Wetlands and Coastal Uplands Conservation – The proposed acquisition of Sargent Ranch includes approximately 8,000 acres of habitat surrounded by the San Bernard National Wildlife Refuge *(R-2-12, Sargent Ranch Addition to San Bernard National Wildlife Refuge)*. The ranch stretches from the Gulf inland and includes beaches, dunes, prairies, extensive salt and freshwater wetlands and Columbia Bottomland forests dominated by large old live oaks. The acquisition of the ranch will connect large portions of the refuge and make it possible to protect important coastal dune and beach habitat for nesting sea turtles, piping plovers and a great diversity of waterbirds and shorebirds. Protection of the dunes will also improve the resiliency of this portion of the coast to storms and relative sea level rise, and allow the natural migration of marshes and wetlands and other habitats over time.

Delta and Lagoon Restoration – The Matagorda Bay system is suffering from environmental degradation due to a lack of freshwater inflows from the Colorado River and Lavaca River, as well as numerous other smaller water bodies. This project recommends a study or regional plan that includes prioritized actions; further restoration efforts are anticipated pending future study results *(R2-8, Matagorda Bay System Hydrologic Restoration Study)*. While there are limited options to rectify the variability of freshwater inflows to the bay, a study or plan will provide an approach that is rooted in identifying the most effective and feasible projects to be undertaken in the region that are intended to either restore flows or maximize the ecosystem's ability to adapt to reduced flows while providing ecological benefits. Restoration of the system will preserve aquatic habitat and wetlands in Matagorda, East Matagorda, Tres Palacios, Carancahua and Lavaca bays.

Oyster Reef Creation and Restoration – The proposed projects will restore approximately 50 acres of reef habitat in Matagorda Bay and East Matagorda Bay, particularly at Half Moon Reef, Oliver Point and Chinquapin *(R2-4, Half Moon Oyster Reef Restoration – Phase 3; R2-9, Oliver Point Oyster Reef Restoration; R2-5, Chinquapin Oyster Reef Restoration)*. Completed projects will improve water quality, increase recreational fishing opportunities, enhance biodiversity, create more productive habitats and provide a first line of defense from storm events.

Rookery Island Creation and Restoration – The San Antonio Bay bird rookery islands have significantly declined due to erosion. The loss of suitable nesting habitat has led to a decline in herons, egrets, black skimmers and brown pelicans. This project proposes restoration of an historical rookery island near Seadrift utilizing dredged material from adjacent channels, if possible *(R2-10, San Antonio Bay Rookery Island Restoration)*. A second project will aim to reduce erosion of Chester's Island and add 30 acres of land *(R2-3, Chester's Island Restoration)*. Potential solutions include nearshore breakwater structures and invasive species control.

Table 6.5: Region 2 Recommendations

Strategy	ID	Tier 1 Projects	Estimated Cost Range
Restoration of Beaches & Dunes	R2-7	Sargent Beach & Dune Restoration	$45 M - $80 M
Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines)	R2-6	Redfish Lake Living Shoreline	$5 M - $15 M
	R2-11	Schicke Point Living Shoreline	$2.5 M - $7.5 M
Stabilizing the Texas Gulf Intracoastal Waterway	R2-1	Brazos River to Cedar Lake Creek GIWW Stabilization	$35 M - $65 M
	R2-2	Boggy Cut GIWW Stabilization	$4.5 M - $13 M
Freshwater Wetlands and Coastal Uplands Conservation	R2-12	Sargent Ranch Addition to San Bernard National Wildlife Refuge	$40 M - $80 M
Delta & Lagoon Restoration	R2-8	Matagorda Bay System Hydrologic Restoration Study	$1 M - $5 M
Oyster Reef Creation & Restoration	R2-4	Half Moon Oyster Reef Restoration – Phase 3	$2 M - $5 M
	R2-5	Chinquapin Oyster Reef Restoration	$1.5 M - $5 M
	R2-9	Oliver Point Oyster Reef Restoration	$1.5 M - $5 M
Rookery Island Creation & Restoration	R2-3	Chester's Island Restoration	$1.5 M - $5 M
	R2-10	San Antonio Bay Rookery Island Restoration	$6 M - $19 M
		Total for Region 2:	***$145.5 M – $304.5 M***

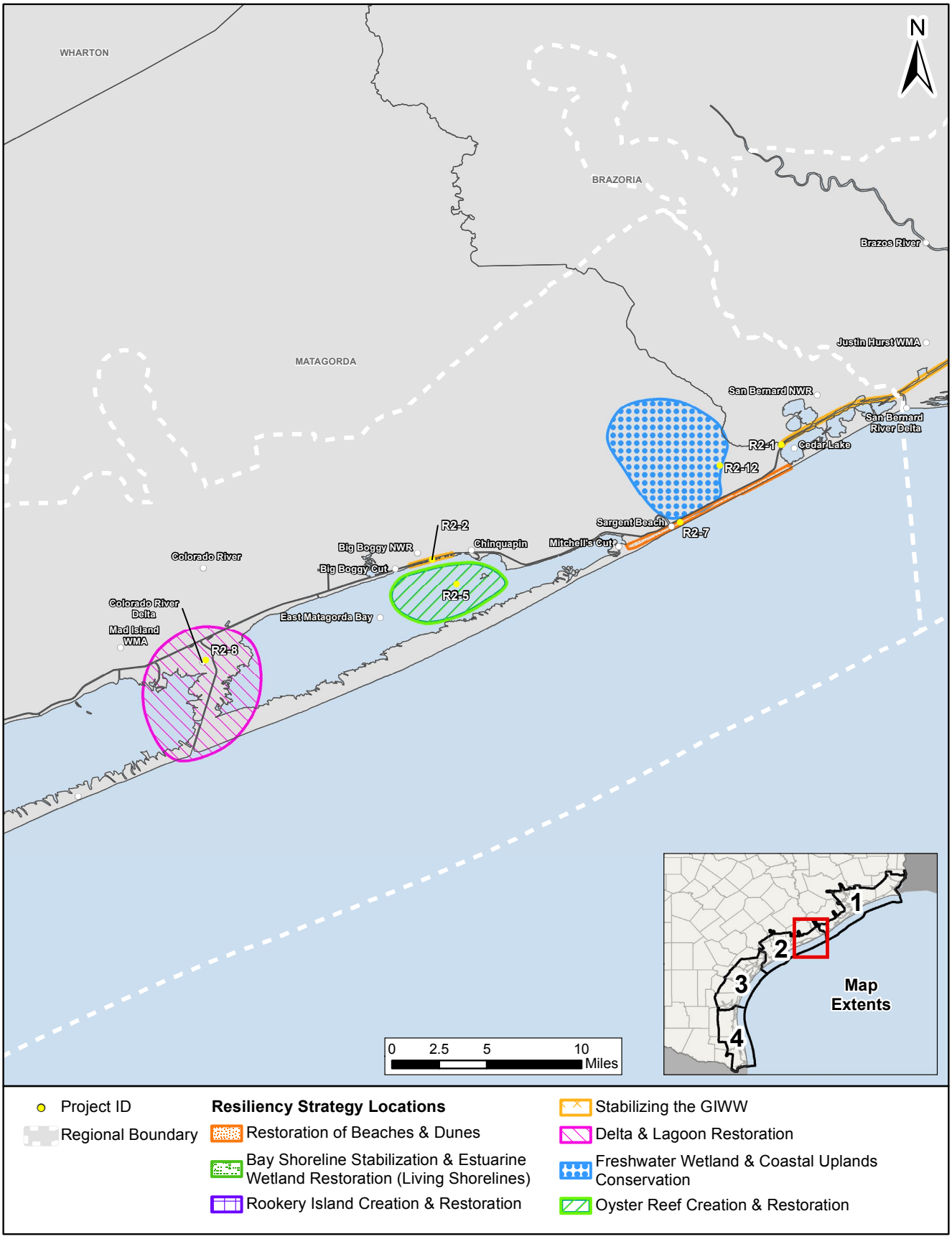


Figure 6.6: *Region 2 Resiliency Strategies Overview Map 1*

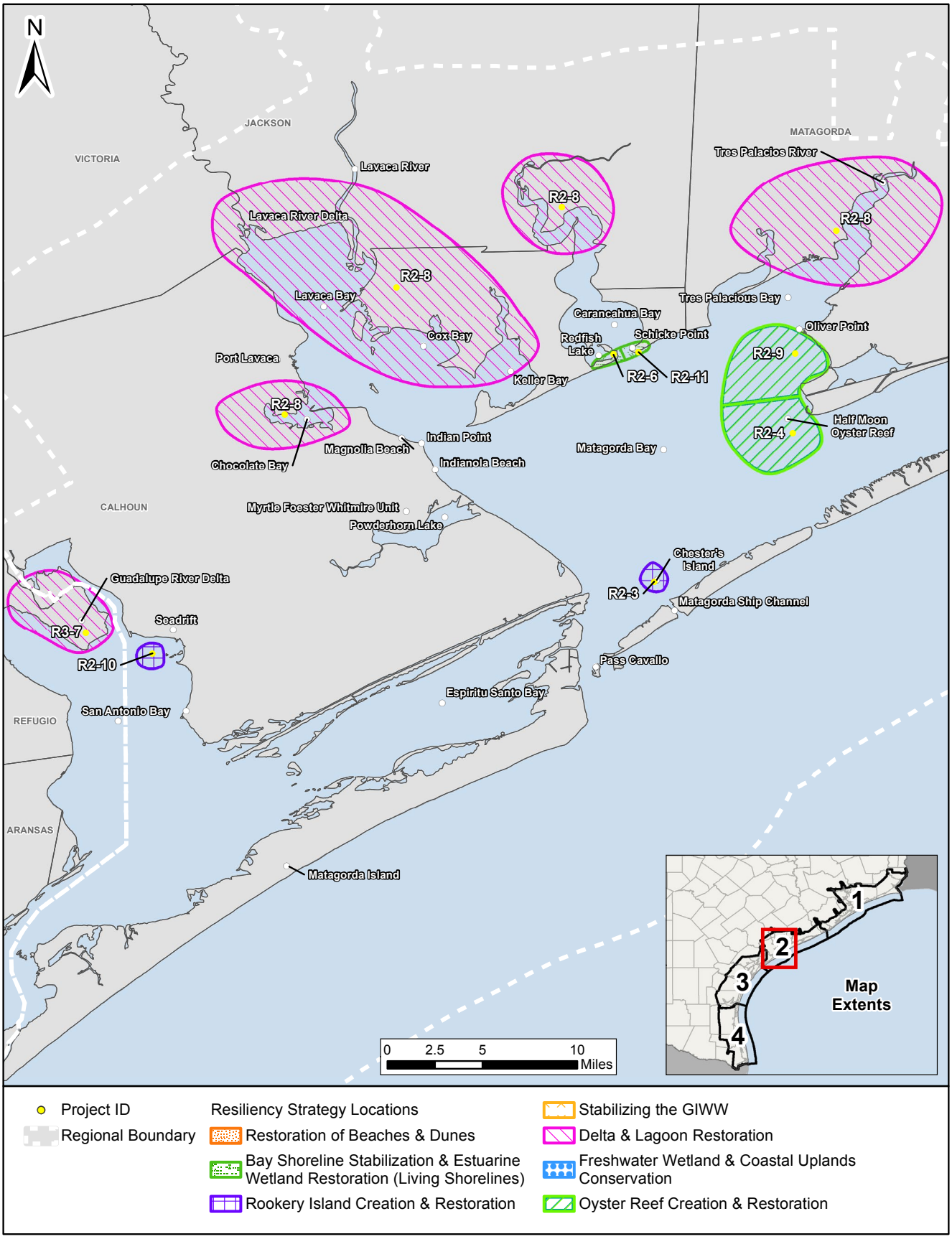
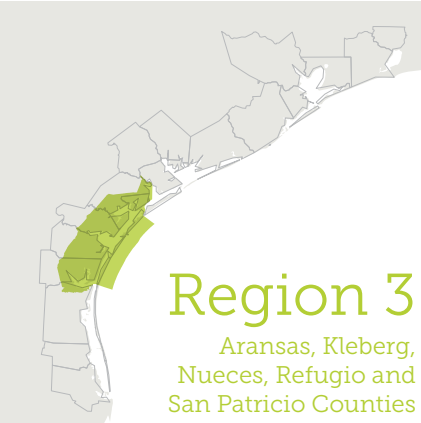


Figure 6.7: *Region 2 Resiliency Strategies Overview Map 2*



Resiliency Strategies for Region 3

- Bay Shoreline Stabilization & Estuarine Wetland Restoration
- Freshwater Wetlands & Coastal Uplands Conservation
- Delta & Lagoon Restoration
- Oyster Reef Creation & Restoration
- Rookery Island Creation & Restoration

Wetlands at Leonabelle Turnbull Birding Center.

Priority Issues of Concern for Region 3

1. ***Altered, Degraded or Lost Habitat*** – Development and degraded water quality in the Nueces River Delta adversely impact coastal habitats and rookery islands.
2. ***Impacts on Coastal Resources*** – Recreational and commercial fishing are economically and culturally important in this region, and are dependent upon a healthy coastal bay system.
3. ***Gulf Beach Erosion and Dune Degradation*** – Though Region 3 has some of the most stable beaches and dunes along the Texas coast, maintaining a healthy barrier island dune system remains a high priority to provide protection to coastal communities.[113]
4. ***Impacts on Water Quality and Quantity*** – Water quality issues related to urban stormwater runoff from the City of Corpus Christi into Corpus Christi Bay and Oso Bay contributes to habitat degradation, with negative impacts on recreational and commercially important species.

Region 3 Recommendations

The recommended Resiliency Strategies and projects for Region 3 are summarized below and in Table 6.3. Project locations are shown in Figure 6.8 and Figure 6.9.

Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines) – Proposed projects for Region 3 include:

- ***Acquisitions:***
  - » Acquisition of parts of Mustang Island for Mustang Island State Park to create a contiguous 5,100 acre conservation area along the barrier island that will enhance the net biological value of the island *(R3-4, Mustang Island State Park Acquisition)*; and
  - » Purchasing additional development rights and creating conservation easements to protect essential habitat on the Coastal Bend Gulf barrier islands, particularly on Mustang Island and North Padre Island, at locations to be determined *(R3-10, Coastal Bend Gulf Barrier Island Conservation)*.
- ***Living Shorelines:***
  - » Shoreline and habitat protection of the critical estuarine wetland habitats that make up 25 acres of Goose Island State Park *(R3-1, Goose Island State Park Living Shoreline)*;
  - » Construction of up to 4 miles of breakwaters with marsh planting along Fulton Beach in Aransas County *(R3-8, Fulton Beach Road Living Shoreline)*;
  - » Construction of approximately 1,760 linear feet of breakwaters to protect over 50 acres of seagrass, wetlands and related habitat from shoreline erosion at Indian Point in Corpus Christi Bay *(R3-5, Indian Point Shoreline Protection)*;
  - » Construction of breakwaters along 2 miles of the Nueces River Delta to dissipate wave energy, which is causing estuarine wetland loss *(R3-3, Nueces River Delta Shoreline Stabilization)*;
  - » Creation of a living shoreline in southwest Portland that will act as a buffer to mitigate impacts on water quality in Nueces Bay *(R3-12, Portland Living Shoreline)*;
  - » Creation of approximately 1.5 miles of living shoreline to act as a buffer between Flour Bluff and the erosional shoreline of the Laguna Madre *(R3-15, Flour Bluff Living Shoreline)*; and

» Shoreline stabilization of Dagger Island, on the southern edge of Redfish Bay just north of Corpus Christi Bay *(R3-14, Dagger Island Living Shoreline)*.

Freshwater Wetlands and Coastal Uplands Conservation – Strategic solutions include the acquisition of approximately 400 acres of coastal habitats that support coastal prairie, freshwater wetlands, Mima mounds and estuarine wetlands at Shell Point Ranch *(R3-13, Shell Point Ranch Wetlands Protection)*. This mosaic of habitats supports mottled ducks and whooping cranes, in addition to other wildlife.

Delta and Lagoon Restoration – One project involves restoration of river flows to the terminal end of the Guadalupe River Delta, in addition to creating a living shoreline to guard against wind and wave erosion *(R3-7, Guadalupe River Delta Estuary Restoration)*. The project recommends the diversion of Traylor Cut to reconnect river flows to help mitigate erosion and maintain the functionality of the estuary. An additional project is restoration of freshwater flows within the Nueces River Delta *(R3-11, Nueces County Hydrologic Restoration Study)*. While there are limited options to rectifying the variability of freshwater inflows in the Nueces River Delta, a study or plan will provide an approach that is rooted in identifying the most effective and feasible projects to either restore flows or maximize the ecosystem's ability to adapt to reduced flows while providing ecological benefits.

Oyster Reef Creation and Restoration – This project will focus on restoring oyster reefs where there is evidence of previously existing reefs in Corpus Christi and Nueces bays *(R3-9, Corpus Christi & Nueces Bays Oyster Reef Restoration)*. Because the effects of dredging and harvesting in Texas bays eliminated much of the vertical structure of the reefs, one proposed approach is to rebuild vertical structure into the restored reefs; but the restoration requires further study to ensure proper location and scale of restoration.

Rookery Island Creation and Restoration – Proposed solutions include placement of dredged material on the Long Reef rookery island to raise its elevation and installation of breakwaters and sediment retention structures *(R3-2, Long Reef Rookery Island Shoreline Stabilization)*; installation of additional breakwaters and filling a breach at Shamrock Island *(R3-6, Shamrock Island Restoration – Phase 2)*; and restoring important rookery habitat at Causeway Island *(R3-16, Causeway Island Rookery Habitat Protection)*. These rookery islands support thousands of breeding colonial waterbirds per year and harbor numerous threatened and priority avian species.

Table 6.5: Region 3 Recommendations

Strategy	ID	Tier 1 Projects	Estimated Cost Range
Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines)	R3-1	Goose Island State Park Living Shoreline	$1 M - $3 M
	R3-3	Nueces River Delta Shoreline Stabilization	$3 M - $8 M
	R3-4	Mustang Island State Park Acquisition	$3 M - $10 M
	R3-5	Indian Point Shoreline Protection	$0.5 M - $2 M
	R3-8	Fulton Beach Road Living Shoreline	$4.5 M - $15 M
	R3-10	Coastal Bend Gulf Barrier Island Conservation	$0.5 M - $1.5 M
	R3-12	Portland Living Shoreline	$1 M - $3.5 M
	R3-14	Dagger Island Living Shoreline	$1 M - $2.5 M
	R3-15	Flour Bluff Living Shoreline	$1.5 M - $4.5 M
Freshwater Wetlands and Coastal Uplands Conservation	R3-13	Shell Point Ranch Wetlands Protection	$2 M - $5 M
Delta & Lagoon Restoration	R3-7	Guadalupe River Delta Estuary Restoration	$2 M - $6.5 M
	R3-11	Nueces County Hydrologic Restoration Study	$0.5 M - $2.5 M
Oyster Reef Creation & Restoration	R3-9	Corpus Christi & Nueces Bays Oyster Reef Restoration	$1 M - $10 M
Rookery Island Creation & Restoration	R3-2	Long Reef Rookery Island Shoreline Stabilization	$1 M - $3 M
	R3-6	Shamrock Island Restoration – Phase 2	$6 M - $18 M
	R3-16	Causeway Island Rookery Habitat Protection	$0.5 M - $2 M
		Total for Region 3:	***$29 M - $97 M***

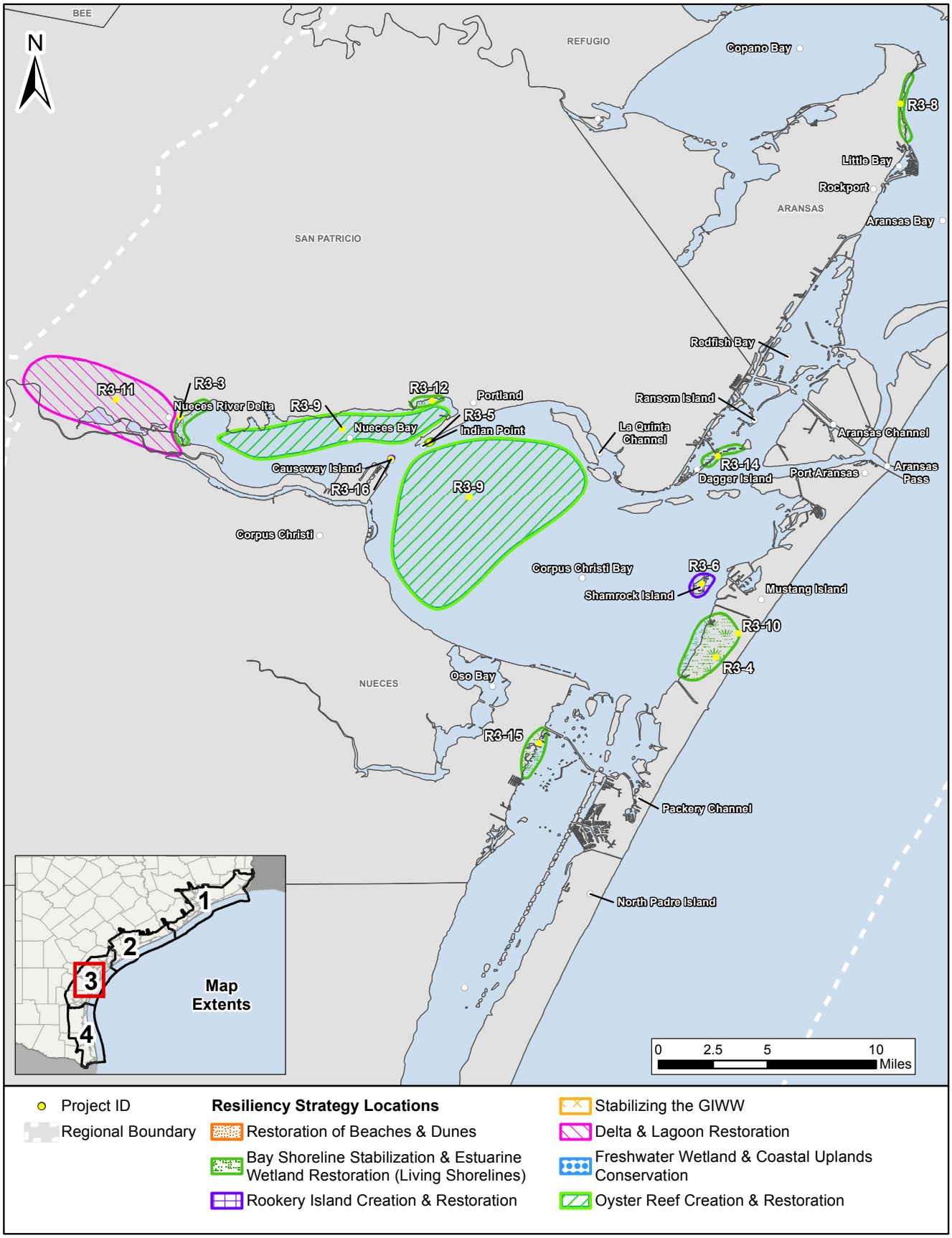


Figure 6.8: *Region 3 Resiliency Strategies Overview Map 1*

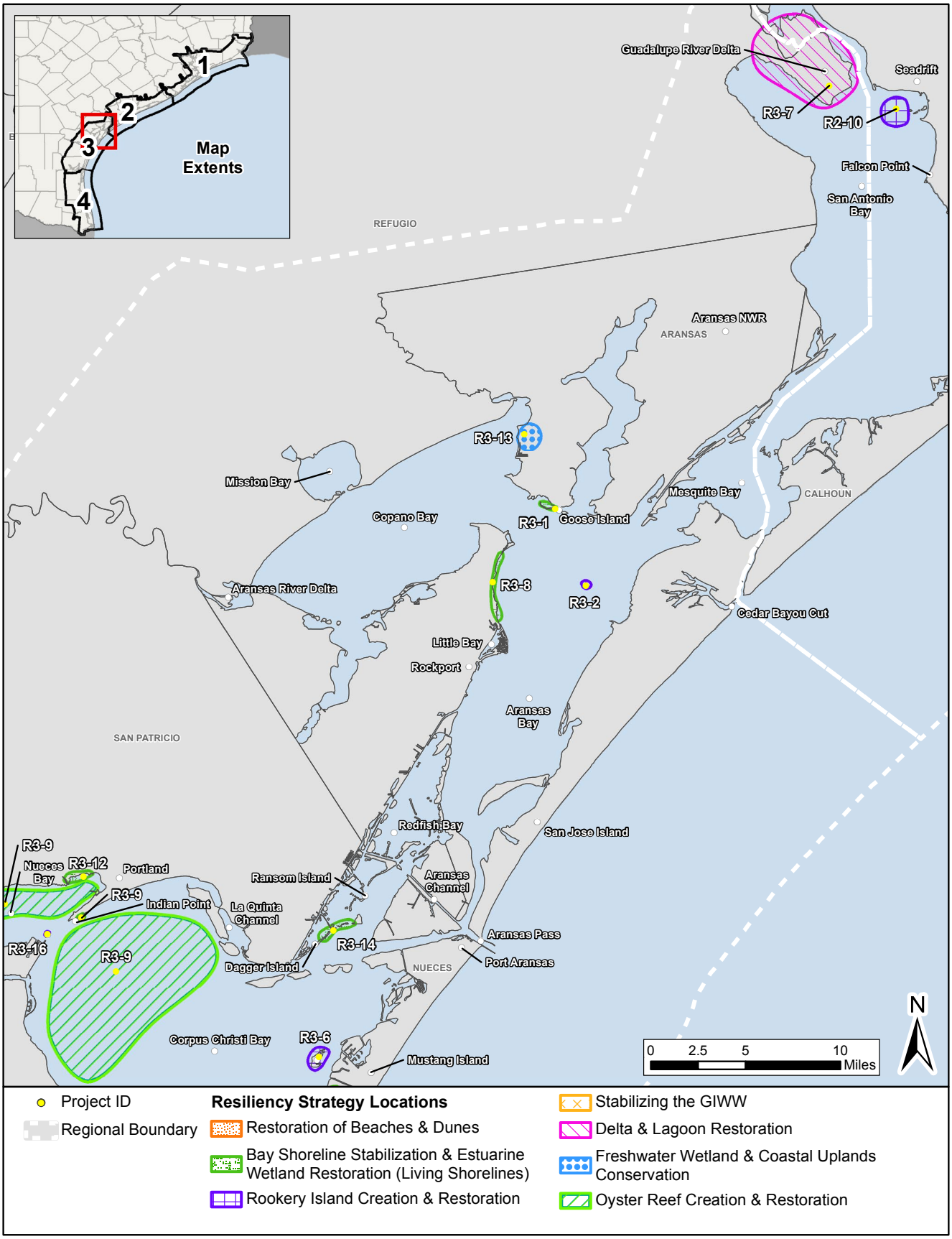
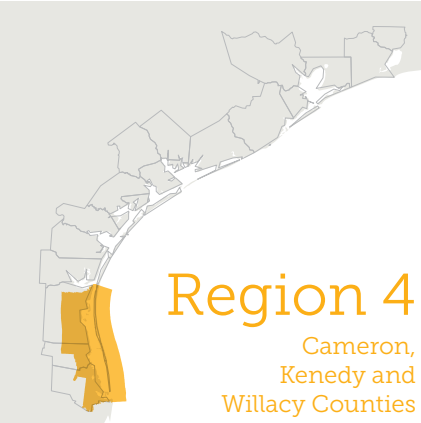


Figure 6.9: *Region 3 Resiliency Strategies Overview Map 2*



Resiliency Strategies for Region 4

- Restoration of Beaches & Dunes
- Bay Shoreline Stabilization & Estuarine Wetland Restoration
- Delta & Lagoon Restoration
- Rookery Island Creation & Restoration

Priority Issues of Concern for Region 4

1. ***Gulf Beach Erosion and Dune Degradation*** – The Gulf-facing beaches and dunes of South Padre Island are a major economic driver for the region, and a well maintained beach and dune system is vital for both a healthy tourism industry and resiliency to storm impacts.
2. ***Altered, Degraded or Lost Habitat*** – Historical hydrologic impacts on the Bahia Grande have significantly altered the function of the saltwater wetlands. Ongoing restoration efforts are beginning to show improvements to the system, but more restoration work is needed.
3. ***Impacts on Water Quality and Quantity*** – There is concern that reduced freshwater inflows from the Rio Grande and surface watersheds may be impacting the ecological health of the Lower Laguna Madre and the habitats and wildlife it supports.
4. ***Impacts on Coastal Resources*** – Coastal recreation is a huge part of the economy and cultural identity, therefore, maintaining healthy fisheries and other coastal resources are a high priority for commercial fishing, ecotourism and recreation.

Region 4 Recommendations

The recommended Resiliency Strategies and projects for Region 4 are summarized below and in Table 6.4. Project locations are and shown in Figure 6.10.

Restoration of Beaches and Dunes – This project will provide beach nourishment and dune restoration for the City of South Padre Island's Gulf shoreline primarily through the beneficial use of dredged materials. The following is an estimate of potential phasing of this beach nourishment effort to a manageable scale:

- The nourishment efforts along the City of South Padre's project area will primarily rely on beneficial use sources from the adjacent ship channel, but there is also a larger sand source offshore in the Texas Mud Blanket complex. A recommendation of 1.5-mile stretches of shoreline focused on critical needs is proposed, with a cost of $7.5 million to $15 million per phase. This is a continuation of similar beach nourishment activities that were undertaken in past years for the area *(R4-1, City of South Padre Island Gulf Shoreline Restoration)*.

Beach and dune system on South Padre Island.

Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines) – The stabilization, restoration and preservation of marshes, wetlands and associated habitats promote clean water and healthy fisheries, while maintaining the scenic beauty of the area. The Bahia Grande shoreline needs protection from existing erosion due to wind, vessel traffic from the adjacent ship channel, and future increases in tidal flow rates associated with proposed hydrologic restorations in the region. The proposed solution involves the creation of a living shoreline near the inlet to the Bahia Grande, using naturally-based, native materials *(R4-5, Bahia Grande Living Shoreline)*.

Delta and Lagoon Restoration – The proposed projects will enhance the Bahia Grande ecosystem by ensuring natural tidal flow and exchange. Widening and deepening the existing inlet channel to the Bahia Grande will help to fully restore the natural biological functions of the wetlands *(R4-2, Bahia Grande Hydrologic Restoration)*, as will restoring hydrologic connectivity between Paso Corvinas and the Bahia Grande *(R4-3, Paso Corvinas Wetlands & Hydrologic Restorations)*. Another proposed project will protect wetland, coastal prairie and thornscrub habitat adjacent to the Bahia Grande unit of the Laguna Atascosa NWR through acquisition of the 1,400 acre Laguna Heights parcel *(R4-6, Laguna Heights Wetland Acquisition)*.

Rookery Island Creation and Restoration – To control erosion and reduce the loss of critical bird habitat, this project will construct approximately 1 mile of breakwaters to protect Bird Island and Heron Island, two rookery islands located in the Bahia Grande *(R4-4, Bird Island & Heron Island Restoration)*.

United States Coast Guard Station on South Padre Island along the Lower Laguna Madre.

Table 6.5: Region 4 Recommendations

Strategy	ID	Tier 1 Projects	Estimated Cost Range
Restoration of Beaches & Dunes	R4-1	City of South Padre Island Gulf Shoreline Restoration	$40 M - $80 M
Bay Shoreline Stabilization and Estuarine Wetland Restoration (Living Shorelines)	R4-5	Bahia Grande Living Shoreline	$1 M - $5 M
Delta & Lagoon Restoration	R4-2	Bahia Grande Hydrologic Restoration	$3 M - $12 M
	R4-3	Paso Corvinas Wetlands & Hydrologic Restorations	$0.5 M - $2 M
	R4-6	Laguna Heights Wetlands Acquisition	$6 M - $16 M
Rookery Island Creation & Restoration	R4-4	Bird Island & Heron Island Restoration	$1 M - $10 M
		Total for Region 4:	***$51.5 M - $125 M***

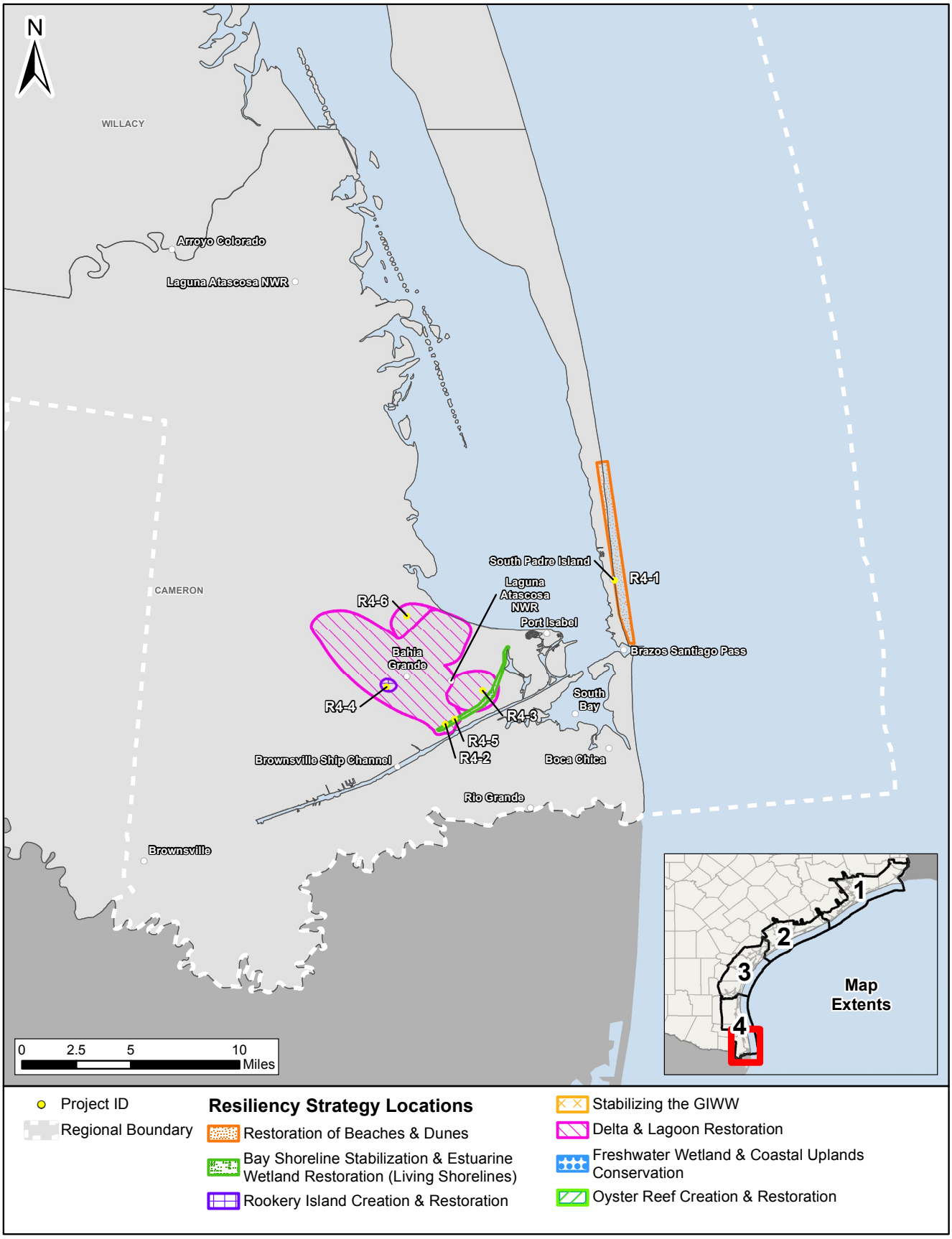


Figure 6.10: *Region 4 Resiliency Strategies Overview Map*

Plans, Policies and Programs

The GLO oversees various coastwide programs that are vital to the resiliency of the Texas coast. These programs, including the ones listed below, do not receive dedicated annual funding to mitigate the Issues of Concern that they were created to address. The recommended Coastwide programs are summarized below and in Table 6.5.

Beach Monitoring and Maintenance Program (BMMP) – The BMMP was established to provide ongoing monitoring and maintenance of beaches enhanced through engineering along the Texas coast to maintain Federal Emergency Management Agency (FEMA) funding eligibility. A Beach Monitoring and Maintenance Program is a prerequisite for Texas to receive funding under FEMA's Public Assistance Program, which provides grants to states for the replacement of sand on engineered public beaches impacted by federally declared disasters, such as tropical storms and hurricanes.

A beach may be considered eligible for disaster assistance funding when: the beach was constructed by the placement of imported sand (of proper grain size) to a designed elevation, width and slope, a maintenance program involving periodic renourishment with imported sand has been established and adhered to by the applicant, and the maintenance program preserves the original beach design.

The GLO, with funding through the Coastal Erosion Planning and Response Act Program, tracks and collects this information to accurately identify the areas impacted and the amount of sand lost during natural disasters. Without a BMMP in place, FEMA has indicated that federal funding, which covers 90 percent of the costs for repairs to these identified areas, will not be approved. A key component of the BMMP, therefore, is the ability to regularly monitor and record engineered beach sand loss.

Abandoned and Derelict Structure and Vessel Removal Program – The GLO identifies, prioritizes, removes and properly disposes of derelict and abandoned vessels and structures along the entire Texas coastline. Under Texas Natural Resources Code Sections 40.108 (b) and 51.3021, the Land Commissioner has the authority to remove and dispose of derelict vessels and structures abandoned in coastal waters and on state-owned lands.

Currently, there are over 190 vessels coastwide that are in need of removal, and that number continues to grow. The size of derelict and abandoned vessels addressed by this program range from a 12-foot recreational vessel to a 77-foot steel hulled commercial fishing vessel, all the way up to 100-plus foot barges.

The GLO also identified nearly 1,700 abandoned structures in need of removal. Such structures include piers, docks, pilings, debris, duck blinds and floating cabins.

Abandoned and Derelict Petroleum Production Structure Removal Program – The GLO identifies, prioritizes, removes and properly disposes of abandoned or unauthorized petroleum production structures in coastal waters and on state-owned land. The authority for this program is also found in Texas Natural Resources Code Sections 40.108 (b) and 51.3021.

Approximately 400 abandoned oil and gas wells, and over 170 offshore platforms and associated structures litter the Texas coast. Due to the highly corrosive effects of saltwater and the brute force of tropical storms, abandoned wells and platforms present risks of leaking and causing damage to the state's natural resources and economic viability. These orphaned wells and platforms can exude toxic pollutants, such as chlorides, hydrocarbons, arsenic, barium, lead and mercury. These contaminants endanger the public's health and safety, as well as the plants, fish, shellfish and mammals that all rely on healthy offshore waters, coastal bays, wetlands and estuaries. Abandoned wells and their surrounding structures also pose a navigational hazard for recreational and commercial vessels.

Sediment Management Plan – Maintenance of Texas ports and navigation channels requires periodic dredging. Finding upland sites for disposal of dredged material is becoming difficult due to competition for space and increasing costs. At the same time, most of the Texas coast is eroding. A holistic approach to sediment management along the sand-starved Texas coast can provide the umbrella for a coordinated and organized process that optimizes the use of available sediment sources for coastal management. Economic benefits will accrue to both maritime transportation interests and those that rely on natural resources and amenities for jobs and income. A sediment management plan for the entire Texas coast is necessary to allow for coastwide coordination in sediment resources. The ultimate goal is a full-fledged program to coordinate the beneficial use of dredged material with the U.S. Army Corps of Engineers and other identified partners.

Table 6.6: Coastwide Recommendations

Strategy	Tier 1 Projects	Estimated Annual Cost
Plans, Policies and Programs	Beach Monitoring and Maintenance Program	$5M per year
	Abandoned and Derelict Structure and Vessel Removal Program	$3M per year
	Abandoned and Derelict Petroleum Production Structure Removal Program	$20M per year
	Sediment Management Plan	$1M per year

7. NEXT STEPS

To effectively guide coastal management, the Texas Coastal Resiliency Master Plan must be as dynamic as the Texas coast. Over time, coastal conditions, coastal hazards and societal preferences will change, as will the financial resources available to address them. Consequently, the Plan must be adaptable, monitored and reviewed regularly, and amended as needs dictate. This document represents the initial iteration of the living Plan, and while this is a critical first step, the GLO understands that the planning process and framework will continuously evolve along with the issues, concerns and needs of the coast to ensure that the Plan remains relevant and robust.

Port Aransas Nature Preserve at Charlie's Pasture.

Moving forward, the Plan will include greater depth and breadth of analysis by employing additional data and analytical techniques. Future iterations of the Plan are anticipated to include emphasis on project life cycle, economic benefits of individual projects, adaptability to future conditions, integration of storm surge defense and flood risk reduction projects in accordance with ongoing state and federal studies, and the inclusion of coastal infrastructure projects related to coastal resiliency.

7.1. Future Enhancements

Refine Project Costs

Beach renourishment project at Surfside Beach.

The Plan currently estimates project costs using a standardized process based on typical project templates. In the future, this process will be refined to expand the existing cost template and subsequently apply it to all newly identified projects. The expanded cost template will be specific to Tier 1 projects, and will be based on a wider range of project characteristics. These additional characteristics may include information such as sediment availability, feasibility and other project details that can enhance the standard cost template. Known costs of completed projects will be compared to estimated costs using the existing and updated templates, to allow for calibration.

Determine Economic Benefits of Projects

In the Plan, the economic benefits of prospective coastal resiliency projects are primarily qualitative. The analysis provides a basic understanding of the direct benefits of prospective projects and broadly captures their value to coastal communities and the state. A component of this analysis identifies short-term economic benefits per project type by applying IMPLAN, an economic Impact Analysis for Planning model, to example projects. Understanding the economic benefits of coastal resiliency projects is a key component to relay the financial value of these efforts to coastal communities, stakeholders and public officials.

The Plan will build upon these efforts with the goal of producing cost-benefit analyses or standardized benefit scoring for Tier 1 projects to directly compare expected project efficiencies, or project costs compared to expected benefits. This information will help inform the GLO's project decision-making process, thus allowing the GLO to target available coastal funds for projects that constitute a sound investment by the state.

To achieve this, the Planning Team will define the life cycles of prospective projects. The approach will also entail further development of economic valuations at the Resiliency Strategy level to bolster the justification for related projects. In addition, the Planning Team will identify and work to quantify the benefits that ecosystem restoration activities provide to critical infrastructure, communities and local economies along the coast.

Understanding the economic benefits of coastal resiliency projects is a key component to relay the financial value of these efforts to coastal communities, stakeholders and public officials.

Conduct Gap Analyses

The GLO and the Planning Team will work with the Technical Advisory Committee and stakeholders to re-assess the Issues of Concern and to identify areas along the coast that have high priority needs with regard to coastal resiliency, but do not have Resiliency Strategies or specific projects identified to address those needs. Project scopes will be expanded to include not only nature-based projects, but also coastal infrastructure-related projects to fully capture the essence of coastal resiliency.

The Planning Team will also conduct a technical gap analysis to identify any additional coastal resiliency issues that need to be addressed. This may include modifying existing projects or developing entirely new projects or Resiliency Strategies based on identified needs.

Meeting with Technical Advisory Committee members and local elected officials at the Victoria College Conference & Education Center.

Leonabelle Turnbull Birding Center in Port Aransas.

Evaluate Adaptation to the Future

In an effort to promote long-term resiliency, the Planning Team will work to further integrate projections of relative sea level rise and future scenarios of storm surge inundation into the planning process. The Planning Team will assess potential impacts of relative sea level rise and storm surge inundation on the state's coastal environments and infrastructure, and will identify strategies to combat those impacts through concepts such as multiple lines of defense.

This entails looking at how natural resources and coastal infrastructure work together to provide longevity to coastal resiliency, particularly in how they adapt to the changes in coastal Pressures in the years to come. This effort will enhance the GLO's overall ability to communicate the need to protect our valuable coastal resources and habitats from changing conditions.

Assess Resiliency Strategies for Expansion

The Planning Team will further define the Resiliency Strategies and proposed projects by incorporating outcomes from the gap analyses, Technical Advisory Committee feedback and ongoing internal technical analysis. The Resiliency Strategies will continue to evolve through the incorporation of additional individual projects, refined projects (e.g., costs, benefits, acreage, regional needs), or project statuses (e.g., conceptual only, permitted, designed or under construction).

In an effort to better understand the scope of individual projects within a Resiliency Strategy, a project's status (e.g., conceptual, engineered, permitted, completion) will become a central element of the project's definition. Refining this element will lead to a more strategic Plan that tracks project implementation progress and gives a greater understanding of immediate funding needs. As applicable, this will include accounting for completed projects associated with a particular Resiliency Strategy, indicating the Resiliency Strategy's progress.

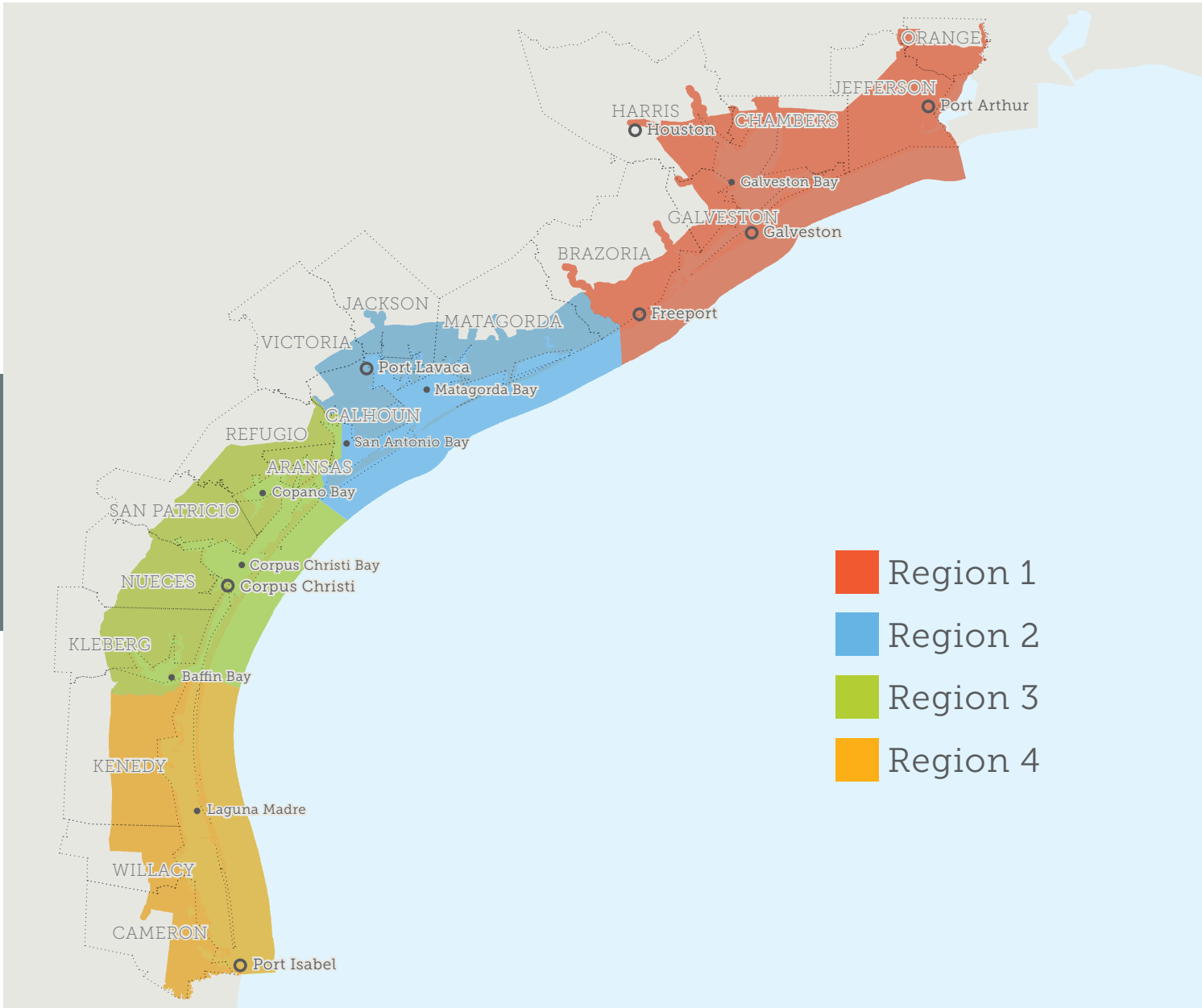
During the development of the Plan, multiple proposed projects and Resiliency Strategies were noted as being under evaluation through other ongoing studies, and were not further defined or evaluated. The Plan's next iteration will incorporate ongoing and existing study results, datasets and other relevant data sources into the discussions for future proposed projects or Resiliency Strategies.

7.2. Shoring Up The Future For The Texas Coast

The future of the Texas coast is threatened by eroding shorelines, intensifying storms, rising sea levels and a growing population that places increasing demands on the coastal resources that provide the first line of defense from storm surge and flooding. The natural protection provided by beaches and dunes, barrier islands, wetlands, coastal uplands, oyster reefs and rookery islands is critical to the economic vitality of major industries and small businesses along the coast. Deteriorating coastal habitats not only harm the species dependent on them, they also impact Texas' greatest asset – its people.

The Texas Coastal Resiliency Master Plan provides a strategic pathway to restore, enhance and protect the coast. But this can't be done alone. It will require a coordinated effort to address the Issues of Concern and identify the appropriate solutions to create a resilient Texas coast. The Texas General Land Office will continue to work with its Technical Advisory Committee and stakeholders to seize these opportunities.

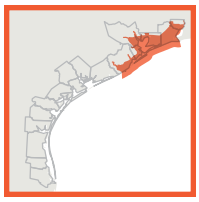
A resilient coast is the responsibility of all Texans. We all benefit from a healthy environment and an economically viable coast. It's a shared future, a resilient future, and we look forward to working together to ensure a strong coast for a strong Texas.


ORANGE
JEFFERSON
Port Arthur
HARRIS
Houston
CHAMBERS
Galveston Bay
GALVESTON
Galveston
BRAZORIA
Freeport
JACKSON
MATAGORDA
VICTORIA
Port Lavaca
Matagorda Bay
CALHOUN
REFUGIO
San Antonio Bay
ARANSAS
Copano Bay
SAN PATRICIO
Corpus Christi Bay
NUECES
Corpus Christi
KLEBERG
Baffin Bay
KENEDY
Laguna Madre
WILLACY
CAMERON
Port Isabel
Region 1
Region 2
Region 3
Region 4

INDIVIDUAL PROJECT DESCRIPTIONS BY REGION

To highlight the recommended Tier 1 projects, a listing of the projects is presented by region in the following pages. Also included are individual project description sheets that identify the specific resiliency strategy the project addresses, the need for the project, and benefits provided by the project, the applied project types that would be utilized, an estimated project cost range and a map of the project location.

Region 1 Project Summaries



Counties:
Brazoria, Chambers, Galveston, Harris, Jefferson, Orange

Total Estimated Cost Range for Projects:
$510,000,000 - $1,100,000,000

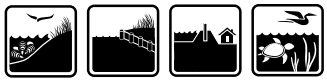
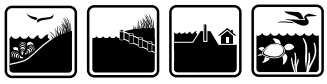
Priority Issues of Concern:

- Gulf Beach Erosion & Dune Degradation
- Altered, Degraded or Lost Habitat
- Existing & Future Coastal Storm Surge Damage
- Coastal Flood Damage

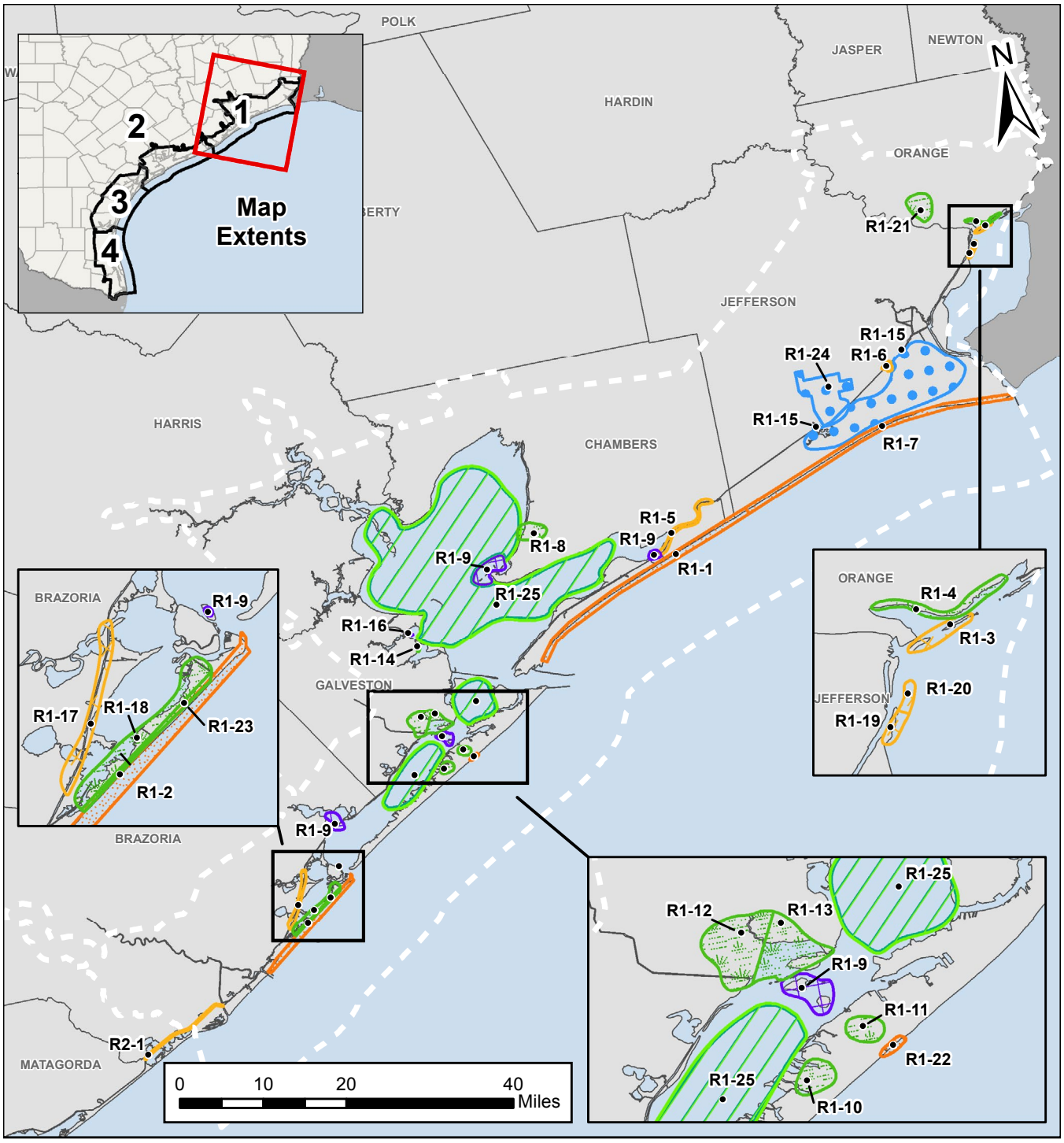
Region 1 – Tier 1 Projects

ID	Tier 1 Projects	Project Type(s)*
R1-1	Bolivar Peninsula Beach & Dune Restoration	
R1-2	Follets Island Nourishment and Erosion Control	
R1-3	Old River Cove Barrier Island Restoration	
R1-4	Old River Cove Marsh Restoration	
R1-5	Anahuac National Wildlife Refuge Living Shoreline	
R1-6	Willow Lake Shoreline Stabilization	
R1-7	McFaddin National Wildlife Refuge Shoreline Restoration	
R1-8	Gordy Marsh Restoration & Shoreline Protection	
R1-9	Galveston Bay Rookery Island Restoration	
R1-10	Coastal Heritage Preserve – Phase 4	
R1-11	Sweetwater Preserve Expansion	

**Reference Figure 5.3 – Project Categorization – on page 65 for a listing and explanation of the project types addressed by the recommended Tier 1 projects.*

ID	Tier 1 Projects	Project Type(s)*
R1-12	Pierce Marsh Living Shoreline	
R1-13	IH-45 Causeway Marsh Restoration	
R1-14	Moses Lake Wetlands Restoration – Phase 3	
R1-15	Salt Bayou Siphons	
R1-16	Dickinson Bay Rookery Island Restoration	
R1-17	Brazoria National Wildlife Refuge GIWW Shoreline Protection	
R1-18	Follets Island Marsh Restoration	
R1-19	North Pleasure Island Barrier Island Restoration	
R1-20	Sabine-Neches Waterway Barrier Island Habitat Restoration	
R1-21	Bessie Heights Marsh Restoration	
R1-22	Galveston Island West of Seawall to 8 Mile Road Beach Nourishment	
R1-23	Follets Island Conservation Initiative	
R1-24	Sabine Ranch Habitat Protection	
R1-25	Galveston Bay Oyster Reef Planning & Restoration	

Region 1 Project Summaries



Resiliency Strategy Project Locations

- Restoration of Beaches & Dunes
- Bay Shoreline Stabilization & Estuarine Wetland Restoration (Living Shorelines)
- Rookery Island Creation & Restoration
- Stabilizing the GIWW
- Freshwater Wetland & Coastal Uplands Conservation
- Oyster Reef Creation & Restoration

Bolivar Peninsula Beach & Dune Restoration

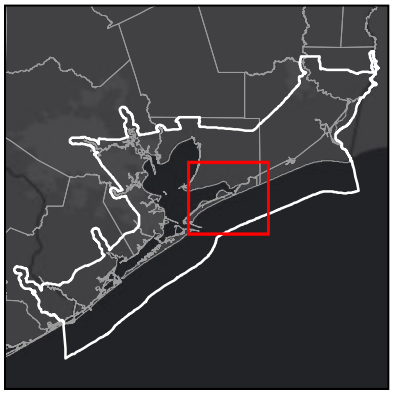
(Project ID R1-1)

Resiliency Strategy Addressed:

Restoration of Beaches & Dunes

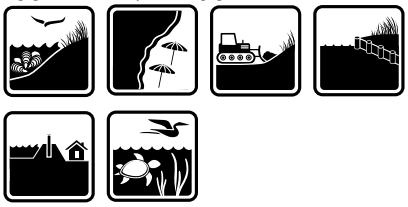
County: Galveston

Location:
Bolivar Peninsula from High Island to Caplen



Estimated Project Cost:
$50,000,000 – $95,000,000

Applied Project Types:



Project Description:

The project proposes to reconstruct severely eroded beaches and dunes along an approximately 10-mile stretch of beach between the communities of High Island on the east to Caplen on the west, while indirectly addressing erosion over the entire 25-mile stretch of shoreline extending from High Island to Bolivar Roads. Due to sediment restrictions and funding availability, a recommendation of 2-mile stretches of shoreline restoration, with a focus on critical areas, is proposed at a cost of $10 million to $20 million per phase. The nourishment efforts would primarily rely on sand sources originating from the mouth (outlet) of the Trinity and Sabine Rivers.

Project Benefits:

Beach nourishment and construction of continuous dune systems in this area will provide coastal communities with the first line of defense from storm surge and flooding, and will enhance tourism and recreational value that beaches and beachfront amenities provide to the local economy. This project will also protect State Highway 87, the only access and evacuation route along the peninsula.

Project Need:

There is significant shoreline erosion in this area, making the communities in the vicinity extremely susceptible to flood damage, and endangering effective emergency evacuations. Over the next 50 years, more than 300 acres are projected to erode based on historic rates, if this project does not occur.

Follets Island Nourishment and Erosion Control

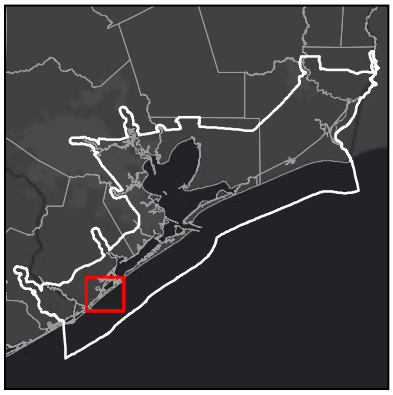
(Project ID R1-2)

Resiliency Strategy Addressed:

Restoration of Beaches & Dunes

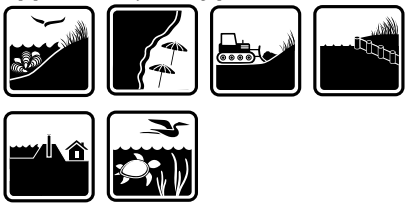
County: Brazoria

Location:
Follets Island from Surfside to Treasure Island



Estimated Project Cost:
$60,000,000 – $115,000,000

Applied Project Types:



Project Description:

The project involves Gulf shoreline protection and restoration by using stone groins at Surfside Beach and placement of beach nourishment material. The nourishment effort does not have a significant offshore sand source that is locally viable, creating a challenge of either pursuing small scale projects using upland sand sources or promoting larger projects that benefit from a single mobilization that requires a more distant sand source. It is recommended that the region pursue projects on the scale of 2.5 miles of shoreline at a cost of $15 million to $25 million per phase (excluding structures), with a strong emphasis on beneficial use of dredged materials to reduce the cost.

Project Benefits:

This project will stabilize the shoreline, and the groin structures will reduce the erosion around Surfside, assisting in elongating the project life cycle. A stabilized beach will provide benefits to the local economy as the beach is heavily utilized for local recreation. Additional benefits include protecting State Highway 257, the Bluewater Highway, which is the only access along the peninsula for residents and business in that area.

Project Need:

Highly trafficked Surfside Beach is experiencing rapid washout. Without a structural solution to prevent offshore sediment transport, the beach will not naturally stabilize. This will continue to threaten public use and homes along the beach, in addition to industry and other infrastructure. Over the next 50 years, more than 800 acres are projected to erode based on historic rates if this project does not occur.

Old River Cove Barrier Island Restoration

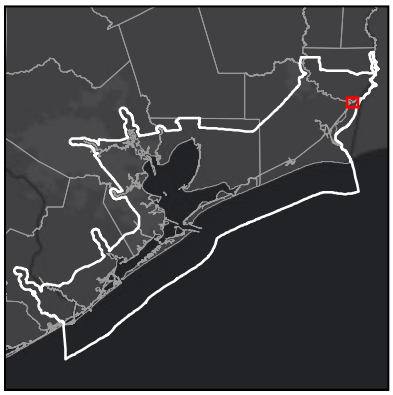
(Project ID R1-3)

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

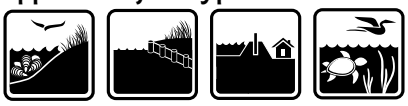
County: Orange

Location:
Sabine Lake (Old River Cove at the Mouth of the Neches River)



Estimated Project Cost:
$5,000,000 – $15,000,000

Applied Project Types:



Project Description:

This project will rebuild up to 131 acres of a series of degraded islands that once protected the Sabine-Neches Waterway at the northern end of Sabine Lake in front of Old River Cove.

Project Benefits:

The restored islands will protect the Old River wetlands from intrusion of higher salinity waters from the Sabine-Neches Waterway, and will protect the wetlands from erosion caused by wind fetch across Sabine Lake. Protecting the waterway from tides and fetch enhances navigational safety and efficiency of barges that carry approximately 103 million tons of cargo across this segment of the Sabine-Neches Canal and GIWW annually. This project has the potential to beneficially use dredged material from channel maintenance activities to restore rookery island habitat that supports migratory and resident bird populations and avitourism in Texas.

Project Need:

A breach of the channel could potentially strand barges and tugboats if they were located south of the breach. A breach of a barrier island could also result in saltwater intrusion into existing estuaries and wetlands, and diminish the habitat that is vital to commercial and recreational fisheries.

Old River Cove Marsh Restoration

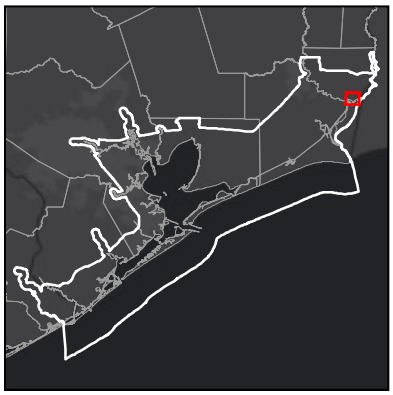
(Project ID R1-4)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

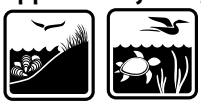
County: Orange

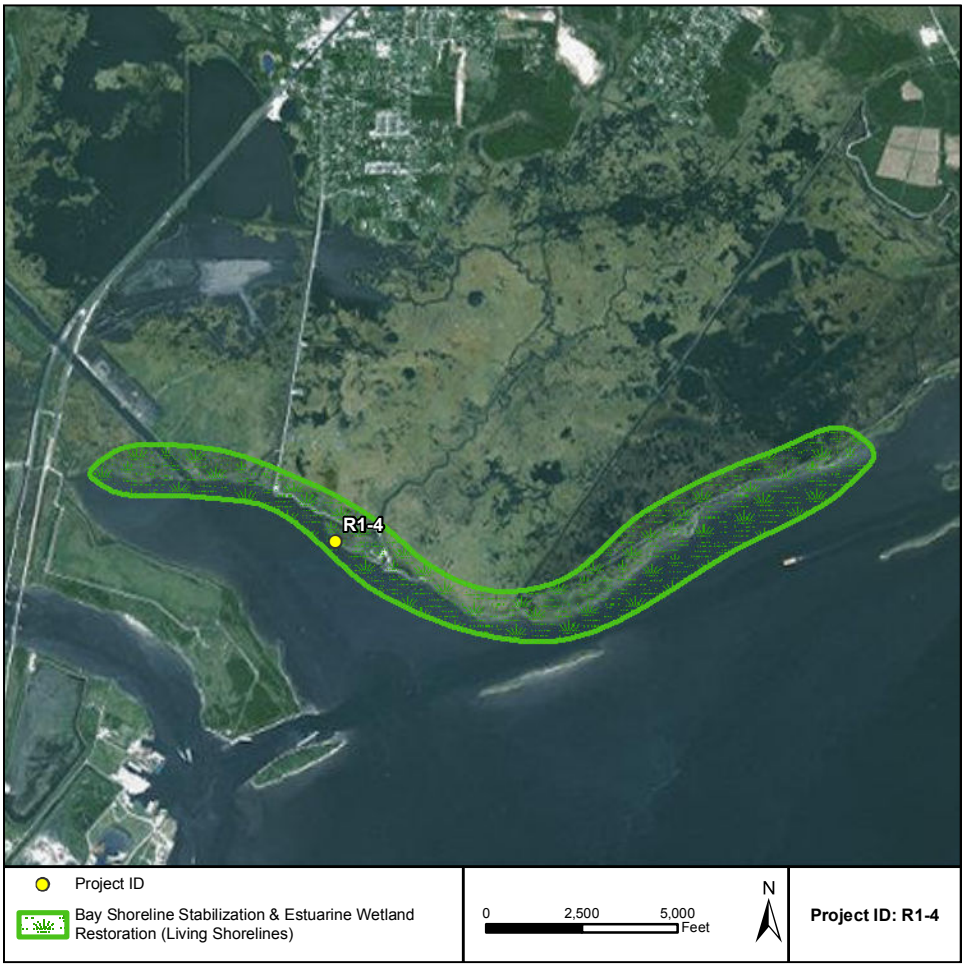
Location:
Sabine Lake (Old River Cove at the Mouth of the Neches River)



Estimated Project Cost:
$10,000,000 – $30,000,000

Applied Project Types:





Project Description:

This project will restore portions of Old River Cove's 640 acres of estuarine wetlands, 140 acres of shallow-water habitat and 430 acres of freshwater wetlands or uplands. The resiliency of this project is dependent upon the restoration of the Old River Cove barrier island (Project ID R1-3).

Project Benefits:

The project will prevent the loss and degradation of wetland vegetation from increased salinity, and conversion of wetlands to open water. Wetland restoration and creation provides habitat that supports aquatic species, migratory waterfowl, wading birds and neotropical migratory songbirds. There is a potential to beneficially use dredged material from channel maintenance for the restoration.

Project Need:

Estuarine marshes are exceptionally scarce and declining nationally, with some of the greatest losses occurring along the Gulf Coast. Restoration of these wetlands is needed to provide a variety of ecosystem services to the area, including benefits to water quality, species nesting and nursery habitat, nutrient cycling, soil retention and recreational opportunities.

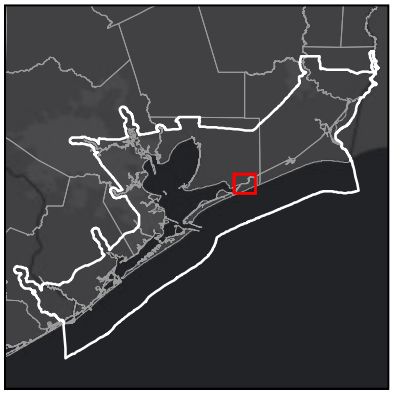
Anahuac National Wildlife Refuge Living Shoreline *(Project ID R1-5)*

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

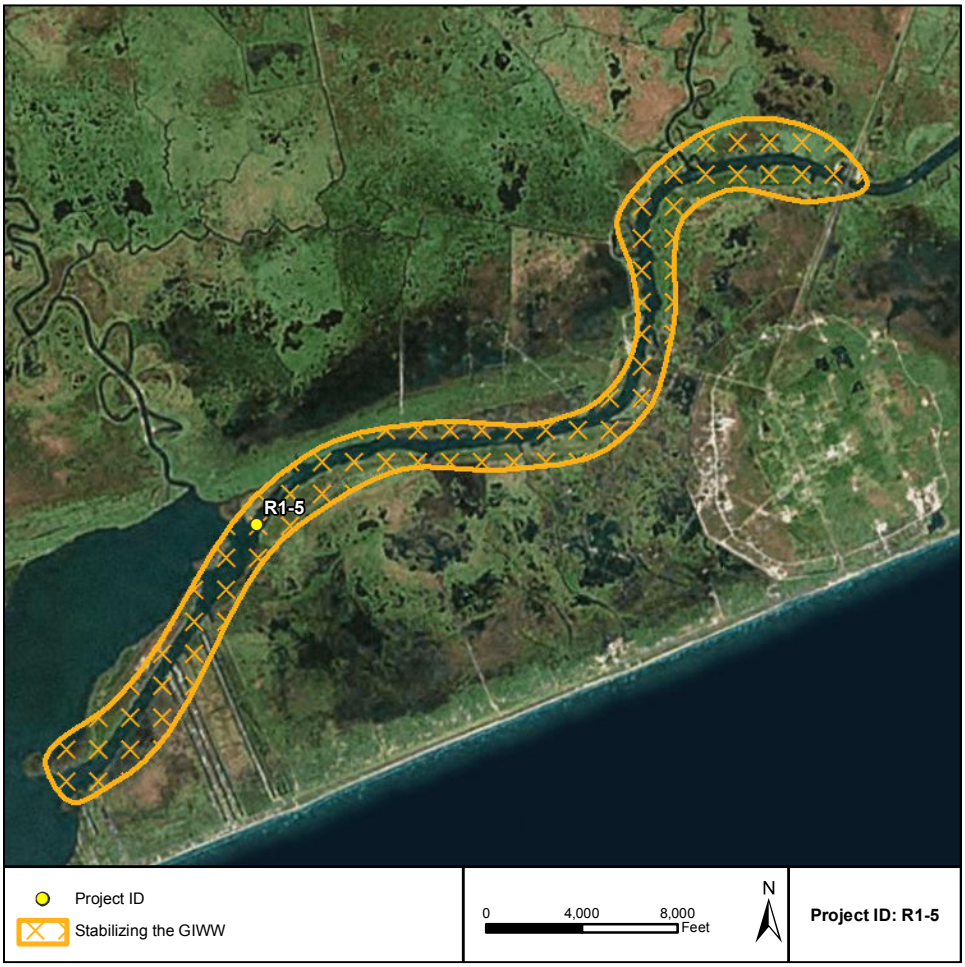
Counties: Chambers, Galveston

Location:
Along the GIWW Near East Bay and the Anahuac National Wildlife Refuge



Estimated Project Cost:
$50,000,000 – $105,000,000

Applied Project Types:



Project Description:

This project will restore estuarine wetland habitat along the GIWW using a living shoreline construction for up to 9 miles of eroding shoreline.

Project Benefits:

Stabilizing the banks of the GIWW promotes navigational safety and efficiency of barges that carry approximately 103 million tons of cargo across this segment of the GIWW annually. Wetland protection and restoration provides habitat for recreationally and commercially important aquatic and avian species, and encourages species diversity. This project has the potential to beneficially use dredged material from the GIWW.

Project Need:

Abutting the Anahuac National Wildlife Refuge, this eroding portion of the GIWW is an important wildlife conservation area and a critical commercial navigational channel. This project is needed to protect the thoroughfare, and benefits the state's $1.4 billion ecotourism industry.

Willow Lake Shoreline Stabilization

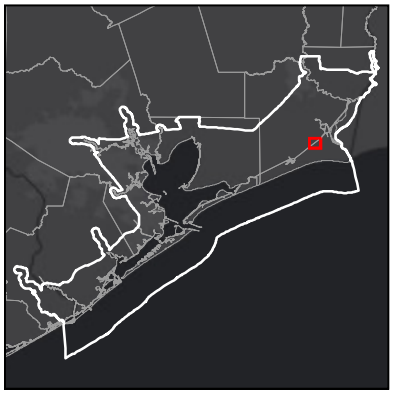
(Project ID R1-6)

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

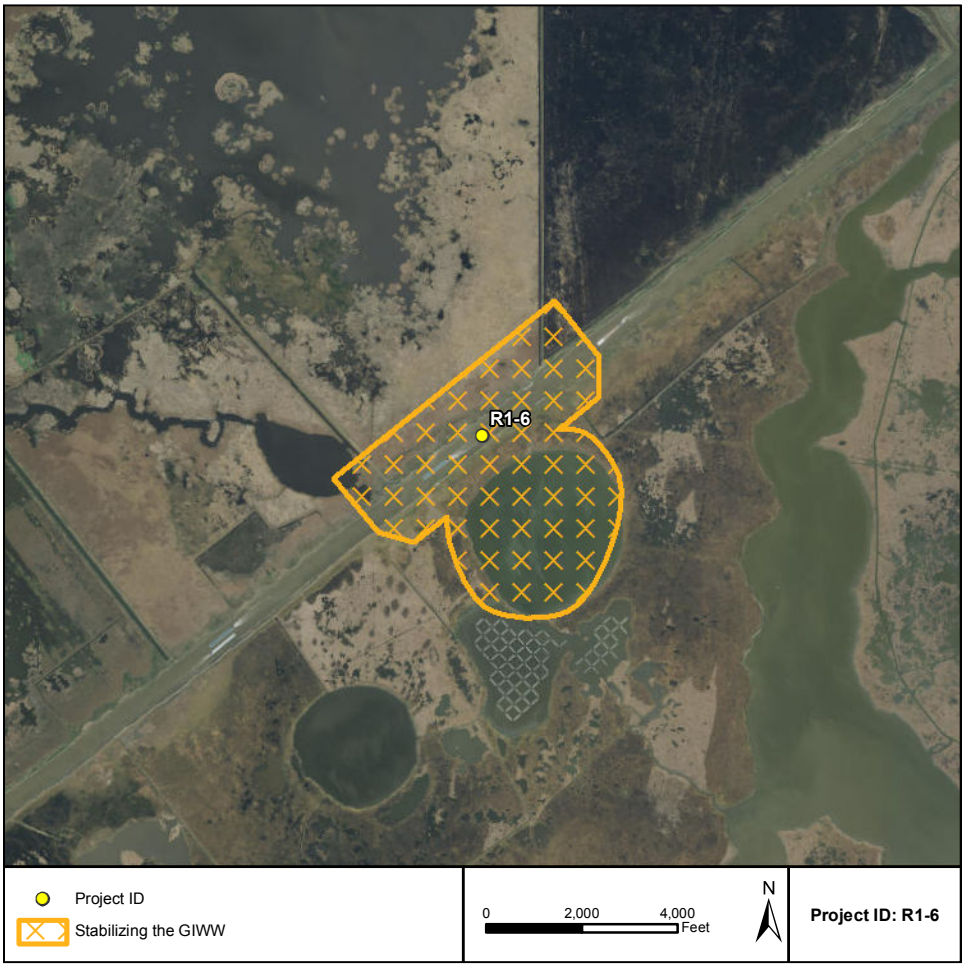
County: Jefferson

Location:
Willow Lake at the
McFaddin National Wildlife Refuge



Estimated Project Cost:
$3,000,000 – $8,000,000

Applied Project Types:



Project Description:

The project will construct approximately 6,000 linear feet of breakwater structures along the GIWW and more than 20,000 linear feet of marsh terraces. The project also will construct a 1,000-foot-long inverted siphon, as well as a 2,200-foot-long diversion ditch on the south side of the GIWW to deliver freshwater to the higher elevations of the lower Willow Lake Watershed in the McFaddin National Wildlife Refuge.

Project Benefits:

This project will restore more than 150 acres of estuarine wetland habitat and protect 3,600 acres of existing coastal wetlands from degradation. The proposed siphon will transport freshwater from north of the GIWW to the south, restoring the natural hydrology of the system and benefiting more than 29,000 acres of coastal wetlands. Restoring the freshwater inflows into the southern part of the system can restore the ecological value to the area for commercially and recreationally important species, supporting the diversification and economic health of coastal economies.

Project Need:

Estuarine wetlands south of the GIWW are susceptible to degradation due to a lack of freshwater inflows, and the altered salinity gradient contributes to the instability of the Gulf facing beaches in this region. Without a structural barrier between the GIWW and the neighboring wetlands, the wetlands in the McFaddin National Wildlife Refuge are at risk of further degradation, leading to the loss of valuable ecosystem services that provide critical nesting and nursery habitat for wildlife and migratory birds, and benefits to water quality and recreation.

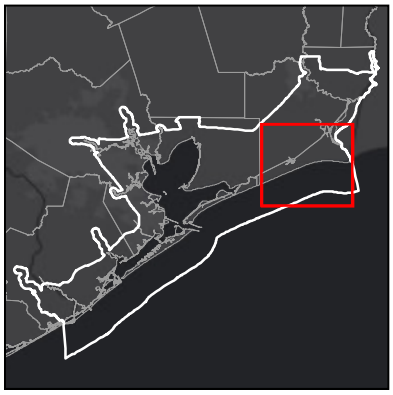
McFaddin National Wildlife Refuge Shoreline Restoration *(Project ID R1-7)*

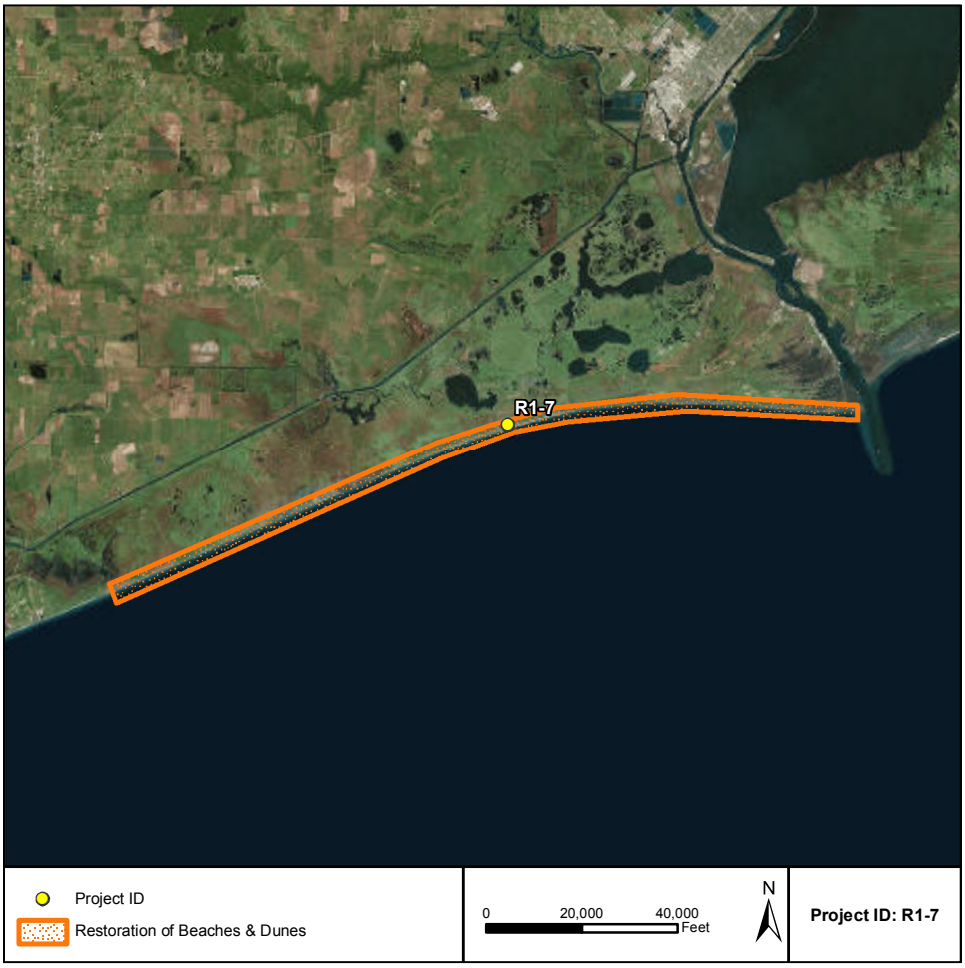
Resiliency Strategy Addressed:

Restoration of Beaches & Dunes

County: Jefferson

Location:
The Gulf Shoreline of the McFaddin National Wildlife Refuge





Estimated Project Cost:
$100,000,000 – $190,000,000

Applied Project Types:

Project Description:

This beach nourishment and dune restoration project will offset the rate of shoreline and dune erosion along 30 miles of existing beach ridge at McFaddin National Wildlife Refuge and extending eastward to Texas Point National Wildlife Refuge, and will protect the estuarine and freshwater wetlands of the refuge from saltwater inundation from the Gulf of Mexico. Due to lack of sediment and funding availability, a recommendation of 2-mile stretches of shoreline focused on areas of critical need is proposed, at a cost of $10 million to $20 million per phase. The nourishment efforts would primarily rely on sand sources originating from the mouth (outlet) of the Trinity and Sabine rivers. The first 2 miles of nourishment are currently funded.

Project Benefits:

This project will continue to build upon the success of existing efforts using sand mined from offshore sources to rebuild dunes damaged by Hurricanes Ike and Rita. Construction of continuous dune systems provides the first line of defense from frequent coastal flooding, and can extend the life of the nourishment project. Beach nourishment, dune creation and wetlands restoration provide beach and wetland habitat for commercially and recreationally important aquatic and avian species. Nourishing this beach will also provide for less-costly removal of abandoned oil wells, due to enhanced access, and will allow for monitoring of fill to provide basis for assessment of future projects.

Project Need:

Over the next 50 years, more than 1,000 acres are projected to erode based on historic rates without the project. Restoring Texas's protected lands also provides a variety of ecosystem services, contributes to the state's $262 million commercial fishing industry, $1 billion marine recreational fishing industry and supports the $1.4 billion ecotourism industry.

Gordy Marsh Restoration & Shoreline Protection

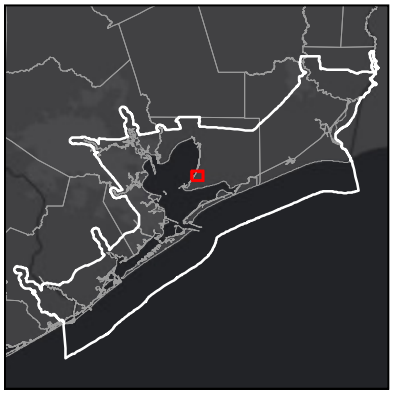
(Project ID R1-8)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

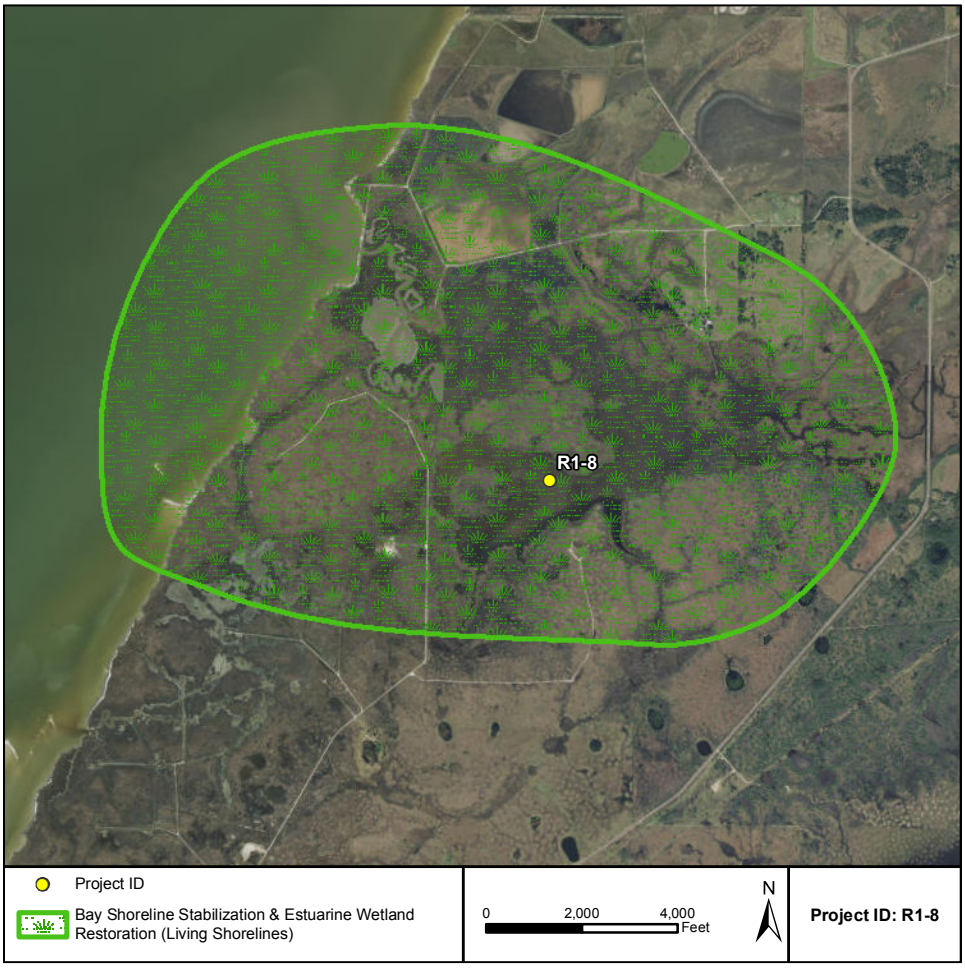
County: Chambers

Location:
South of Trinity Bay on Smith Point Road/FM 562



Estimated Project Cost:
$15,000,000 – $35,000,000

Applied Project Types:



Project Description:

This project will provide shoreline protection and estuarine wetland restoration at Gordy Marsh, a 1,700 acre coastal wetland and prairie habitat that borders Trinity Bay.

Project Benefits:

Gordy Marsh is located in an area rated as a high conservation priority by Chambers County and the Galveston Bay Foundation. Providing additional habitat with the creation of estuarine wetlands and shallow water habitat, as well as protecting existing habitat for commercially and recreationally valuable species, will support the commercial and recreational fishing industries, and other recreational activities such as bird watching. This project is a candidate for beneficial use of dredged material to create and restore the habitat periodically to mitigate relative sea level rise.

Project Need:

The rapid erosion this shoreline is experiencing will continue unless protective measures are taken. Over the next 50 years, more than 60 acres are projected to erode based on historic rates if this project does not occur. Restoration of these wetlands is needed to provide a number of ecosystem services to the area, including benefits to water quality, nesting and nursery habitat, and providing recreational benefits.

Galveston Bay Rookery Island Restoration

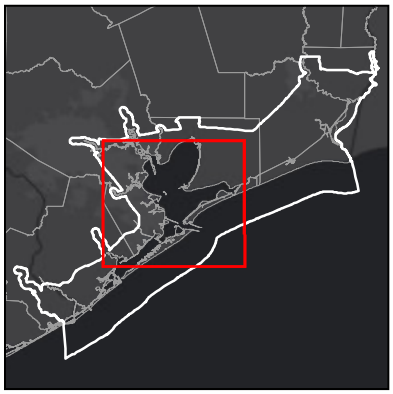
(Project ID R1-9)

Resiliency Strategy Addressed:

Rookery Island Creation & Restoration

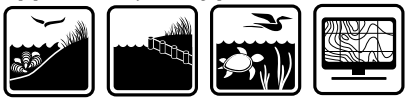
County: Galveston

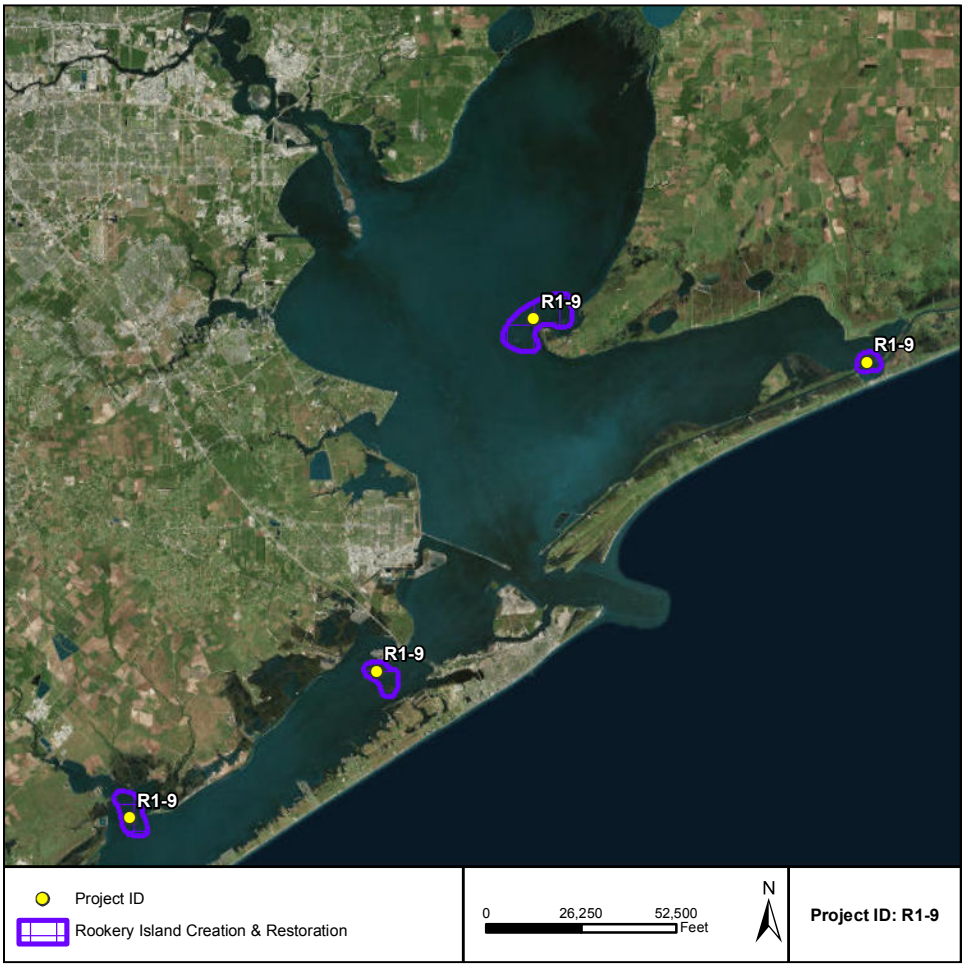
Location:
Islands in Trinity Bay and West Bay



Estimated Project Cost:
$45,000,000 – $80,000,000

Applied Project Types:





Project Description:

The project will prioritize, restore elevation and provide shoreline protection for several identified rookery islands, including Jigsaw Island, the Vingt-Et-Un Islands, Chocolate Point Island, West Bay Bird Island and Smith Point Island. The proposed project will create additional acres of potential nesting habitat by re-establishing estuarine wetland habitat, which will promote shoreline stabilization.

Project Benefits:

A fortified rookery island system in Galveston Bay will provide essential nesting and migratory habitat for bird populations. Creation of rookery habitat will benefit the avian habitat along the Great Texas Coastal Birding Trail – one of the most popular birdwatching trails in the nation – and will support the growing ecotourism industry along the Texas coast. Several of the islands identified are good candidates for restoration using beneficial use of dredged material.

Project Need:

Erosion, subsidence and sea level rise threaten the vitality of nesting and migratory bird habitat in this area. Restoring the Galveston Bay rookery islands will engage Galveston County's ecotourism and recreational activities industry.

Coastal Heritage Preserve – Phase 4

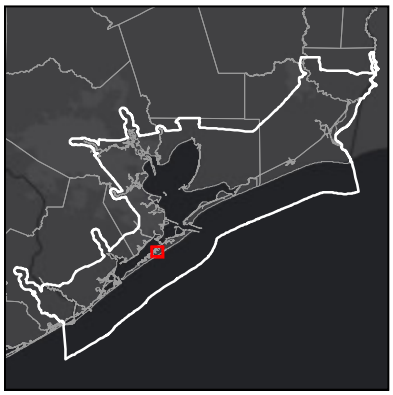
(Project ID R1-10)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Galveston

Location:
West Galveston Island
near Starvation Cove



Estimated Project Cost:
$3,000,000 – $10,000,000

Applied Project Types:

Project Description:

The Settegast Coastal Heritage Preserve project is a conservation area on West Galveston Island adjacent to West Bay. This phase of the initiative involves two adjacent acquisitions of 635 acres and 205 acres, respectively. This will bring the total preserve area to 1,200 acres. There is a fee simple agreement in place for this property. Full funding for this project is the limiting factor.

Project Benefits:

Acquisition of these lands will provide essential buffer zones on Galveston Island to mitigate the losses associated with flooding and storm events to surrounding communities. This acquisition represents a unique opportunity to extend the protected status of vanishing habitats along the Texas coast, including key wetland buffer areas, protected species habitat, and estuarine wetland migration zones.

Project Need:

The Galveston Bay system is an estuary of national significance, and acquiring and conserving this land will provide essential water quality benefits to promote diversity of wildlife and avian species that contribute to ecotourism and other recreational activities.

Sweetwater Preserve Expansion

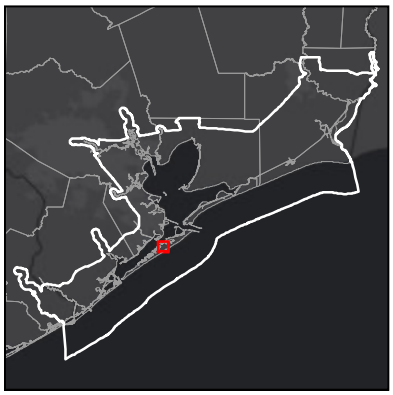
(Project ID R1-11)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Galveston

Location:
West Galveston Island
at Sweetwater Lake



Estimated Project Cost:
$1,000,000 – $3,000,000

Applied Project Types:

Project Description:

The project involves the purchase of 275 acres of land situated immediately west of Galveston Bay Foundation's Sweetwater Preserve, and adjacent to Sweetwater Lake, West Galveston Bay and 8 Mile Road. There are willing sellers for these properties, but full funding for the project is the limiting factor and must be coordinated in a timely manner.

Project Benefits:

Key attributes of the property include coastal grasslands, brackish and estuarine wetlands, frontage along West Galveston Bay and Sweetwater Lake, and extensive salt barrens and sand flats. Preservation of Galveston Island's estuarine and freshwater wetlands and associated habitats ensures long-term ecosystem benefits, such as clean water and habitat for wildlife, fish, crabs and other shellfish.

Project Need:

This area is critical and productive habitat, and its acquisition will help to preserve the state's coastal prairie, uplands and wetlands from accelerated losses occurring due to hurricanes, oil spills and urban expansion.

Pierce Marsh Living Shoreline

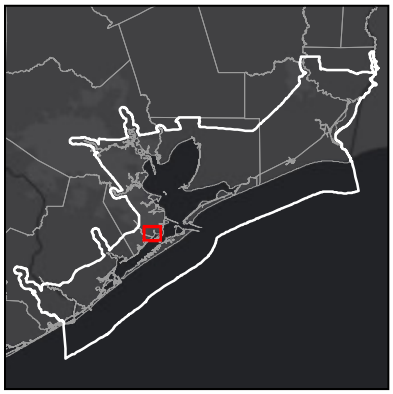
(Project ID R1-12)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

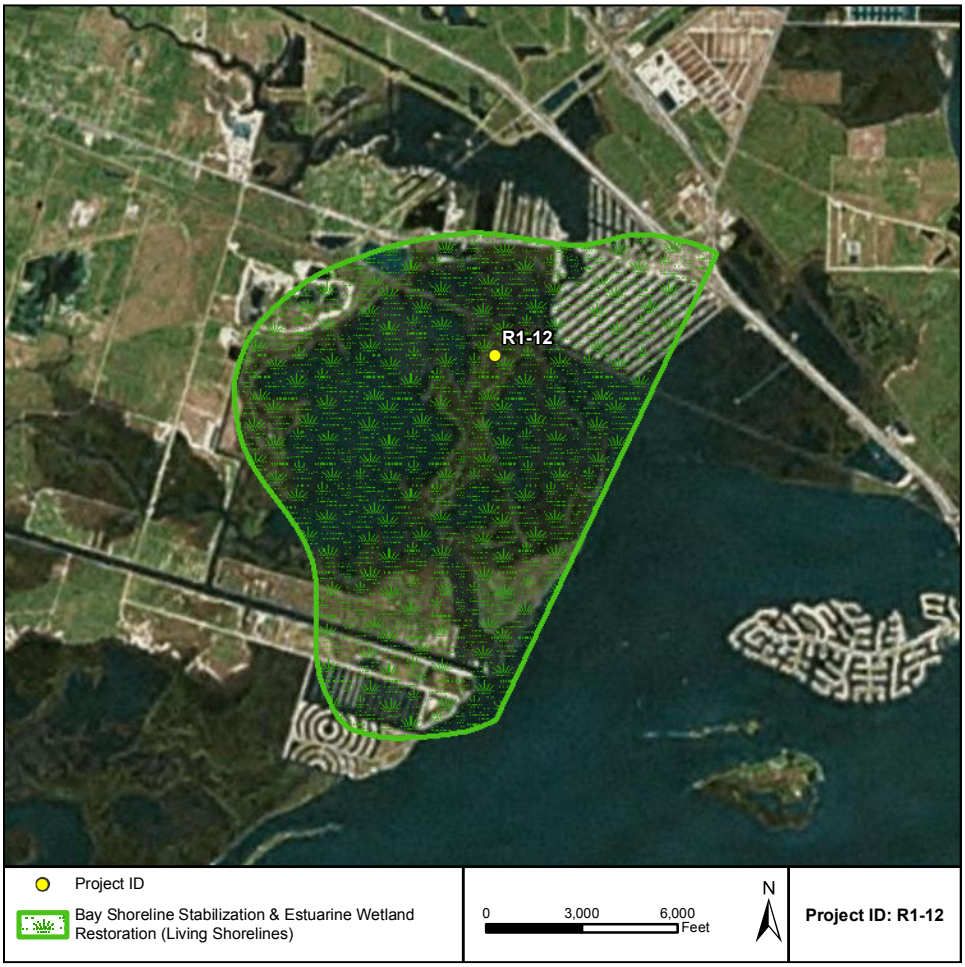
County: Galveston

Location:
Estuarine Wetlands West of Bayou Vista



Estimated Project Cost:
$25,000,000 – $45,000,000

Applied Project Types:



Project Description:

Pierce Marsh is a 2,000 acre estuarine wetland complex located northwest of the Interstate Highway 45 causeway, and west of the railroad and Bayou Vista. The project will restore the wetlands using 1.6 miles of bay shoreline protection.

Project Benefits:

This project will protect the mainland shoreline from wave impacts and reduce erosion of the existing wetlands. Improvement of degraded wetlands will increase viability for protected species and provide potential foraging for migrating birds. The project will build upon existing wetland restoration in the immediate vicinity, which increases the opportunity for various species to fully utilize the area. This project is a candidate for beneficial use of dredged material to create and restore the habitat periodically to keep up with relative sea level rise.

Project Need:

The estuarine wetlands in this area are experiencing high rates of degradation due to continued developments in the surrounding areas. Over the next 50 years, if this project does not occur, 35 acres are projected to erode based on historic rates. Restoration of these wetlands is needed to provide a number of ecosystem services to the area, including benefits to water quality, and nesting and nursery habitat.

IH-45 Causeway Marsh Restoration

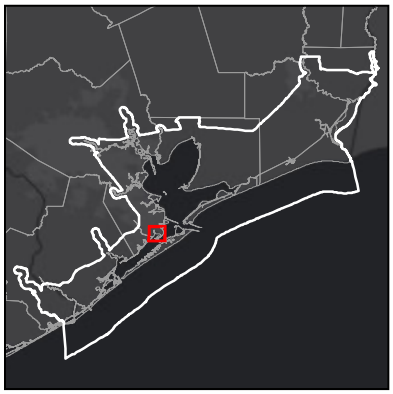
(Project ID R1-13)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

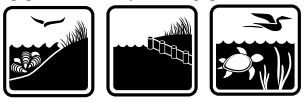
County: Galveston

Location:
Estuarine Wetlands East of Bayou Vista



Estimated Project Cost:
$5,000,000 – $18,000,000

Applied Project Types:



Project Description:

This project, located near the Interstate Highway 45 causeway and east of Bayou Vista, includes bay shoreline protection of 1.6 miles and restoration of close to 600 acres of estuarine wetlands.

Project Benefits:

This project will provide additional habitat with the creation of estuarine wetlands and living shorelines, and will protect existing habitat for commercially and recreationally valuable species that support local economies and recreational use. This site is located near several colonial waterbird rookeries and, therefore, could serve as foraging ground for these birds. It also is recommended to restore this area periodically to mitigate relative sea level rise. This project is a candidate for long-term beneficial use of dredged material to create the habitat.

Project Need:

Over the next 50 years, close to 50 acres are projected to erode based on historic rates if this project does not occur. Restoration of these wetlands is needed to provide a number of ecosystem services to the area, including benefits to water quality, nesting and nursery habitat, nutrient cycling, soil retention and recreation.

Moses Lake Wetlands Restoration – Phase 3

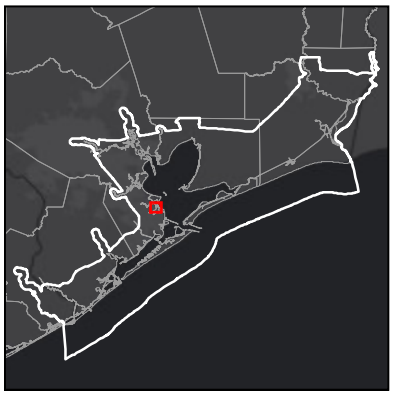
(Project ID R1-14)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Galveston

Location:
Moses Lake, in West Galveston Bay near Texas City



Estimated Project Cost:
$1,000,000 – $3,500,000

Applied Project Types:

Project Description:

The third phase of this project seeks funding for construction of 8,000 linear feet of nearshore segmented breakwater structures in Moses Lake and placement of materials to restore elevations suitable to support wetland vegetation and upland coastal species. The project is designed, permitted and is partially funded.

Project Benefits:

This project will build upon previous shoreline stabilization efforts along Moses Lake to protect this upland coastal prairie. The lake contains estuarine wetlands adjacent to western Galveston Bay, which provide highly productive habitat for a number of species, including shrimp, red drum and blue crab.

Project Need:

Shoreline erosion, subsidence and saltwater intrusion have negatively impacted these ecologically productive areas and depleted valuable habitat. Over the next 50 years, 16 acres are projected to erode based on historic rates if this project does not occur. This project also will contribute to the state's $262 million commercial fishing industry and $1 billion marine recreational fishing industry.

Salt Bayou Siphons

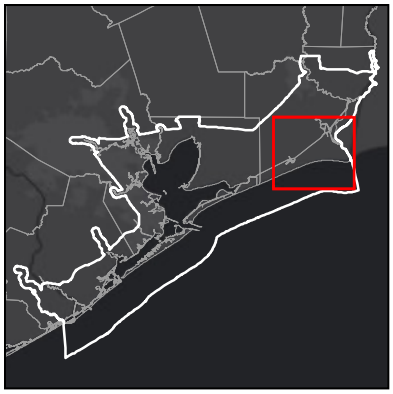
(Project ID R1-15)

Resiliency Strategy Addressed:

Freshwater Wetlands & Coastal Uplands Conservation

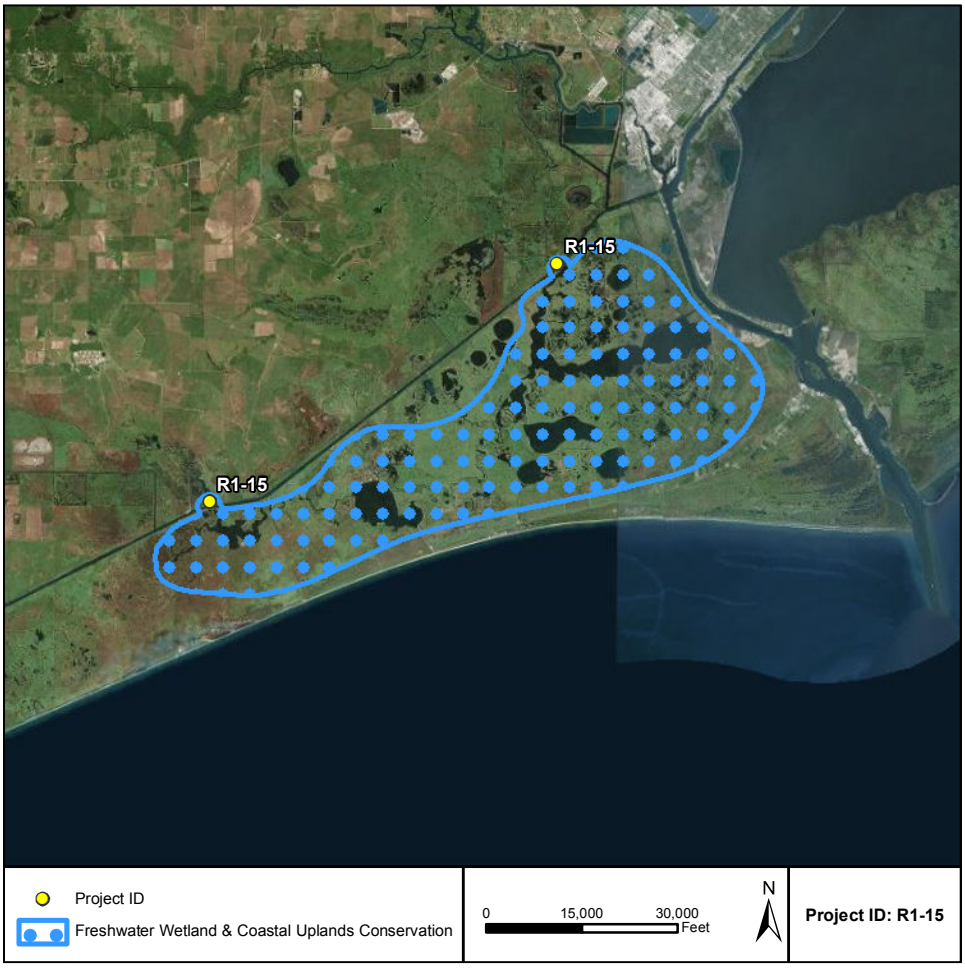
County: Jefferson

Location:
The GIWW at the McFaddin National Wildlife Refuge and J.D. Murphree Wildlife Management Area



Estimated Project Cost:
$3,000,000 – $7,000,000

Applied Project Types:



Project Description:

The project involves the placement of siphons at multiple locations in the Salt Bayou system to restore a hydrologic connection between the freshwater wetland systems north of the GIWW, and degraded wetlands south of the GIWW.

Project Benefits:

Hydrologic modeling indicates benefits to at least 4,300 acres of wetlands from a siphon set in J.D. Murphree Wildlife Management Area and up to 22,500 acres of wetlands from a siphon set in McFaddin National Wildlife Refuge. Restoring the freshwater inflows into the southern part of the system can restore the ecological value to the area for commercially and recreationally important species. The project is of critical importance given the beneficial impact expected to both the National Wildlife Refuge and Wildlife Management Area, which are managed habitat areas that provide ecological and economic value to this region. Additionally, this project enhances the previous state and federal investments at these sites by providing greater environmental returns through revitalizing the wetlands.

Project Need:

Failing to restore the flow regimes in this system will continue to degrade the wetlands and shoreline south of the GIWW, and will undermine other proposed projects in these areas. Restoration of these wetlands is a critical step needed to support the area's ecosystem services that provide benefits to water quality, nesting and nursery habitat, nutrient cycling, and recreational opportunities, as well as Texas residents' annual $6 billion wildlife-associated expenditures.

Dickinson Bay Rookery Island Restoration

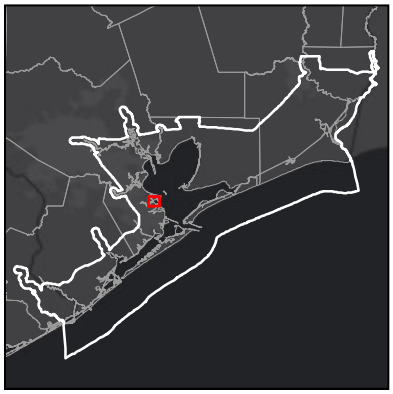
(Project ID R1-16)

Resiliency Strategy Addressed:

Rookery Island Creation & Restoration

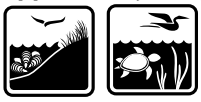
County: Galveston

Location:
Dickinson Bay, Western Galveston Bay



Estimated Project Cost:
$500,000 – $2,000,000

Applied Project Types:



Project Description:

The objective of this project is to restore two 5 to 7 acre colonial water bird rookery islands and adjacent oyster reef habitats in Dickinson Bay, which will be Phases II and III of the original Dickinson Bay Island Marsh Restoration Project. Design and partial funding are in place for these phases. The project will be constructed to provide multiple habitat functions, including approximately 5 acres of nesting space for colonial water birds and 2 acres of oyster reef. Approximately 4,000 cubic yards of suitable oyster cultch will be provided to expand the oyster reef already constructed.

Project Benefits:

Restoration of the colonial bird rookery island will greatly increase habitat suitability for migrating birds. Oyster bed restoration will provide water quality improvements, as well as food chain benefits to migrating birds and other protected species.

Project Need:

The Texas Gulf Coast serves as one of North Americas flyways and supports the Texas Birding Trail - a major ecotourism generator. The current and future habitat for shorebirds is in decline in Galveston Bay, which diminishes the functionality of the entire rookery island chain related to this flyway. Restoration of these islands will provide essential habitat for the bird populations. The supplemental creation of oyster reef in Galveston County supports the second largest oyster fishery in the nation and helps restore the 60 percent of oyster habitat lost to Hurricane Ike.

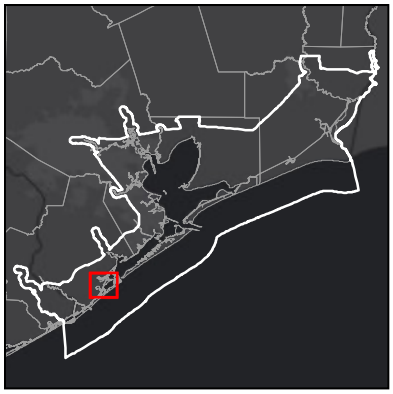
Brazoria National Wildlife Refuge GIWW Shoreline Protection *(Project ID R1-17)*

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

County: Brazoria

Location:
The GIWW at Christmas Bay and the Brazoria National Wildlife Refuge, North of Follets Island



Estimated Project Cost:
$20,000,000 – $35,000,000

Applied Project Types:

Project Description:

This project will reinforce the banks on the bay side to prevent further erosion, create wetland habitat, and more closely monitor erosion along the shoreline.

Project Benefits:

Stabilizing the GIWW promotes navigational safety and efficiency of barges that carry approximately 35 million tons of cargo across this segment of the GIWW annually, and protects the sensitive wetland shorelines from the wakes created from these vessels. Safeguarding the bay from saltwater intrusion supports aquatic species that are recreationally and commercially valuable. There are opportunities to beneficially use dredged materials to stabilize the shoreline, as well as to raise sediment beds for estuarine wetland creation.

Project Need:

The critical and narrow stretch of land separating the Brazoria National Wildlife Refuge GIWW Shoreline from Christmas Bay, Drum Bay and Long Pond is breached by erosion and is in danger of exacerbated erosion that could lead to additional breaches. Over the next 50 years, close to 200 acres are projected to erode based on historic rates if this project does not occur. The project is a priority to protect a Texas Gulf Ecological Management Site and a Coastal Preserve.

Follets Island Marsh Restoration

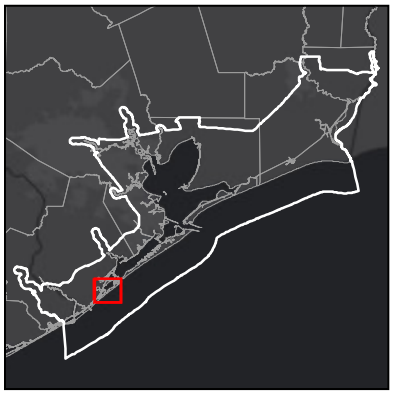
(Project ID R1-18)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

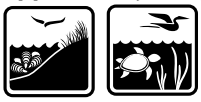
County: Brazoria

Location:
Follets Island, West of Christmas Bay



Estimated Project Cost:
$30,000,000 – $50,000,000

Applied Project Types:



Project Description:

The project proposes up to 2,600 acres of wetlands restoration on Follets Island, on the southwest side of Christmas Bay, to protect critical habitat including estuarine and freshwater wetlands and tidal flats.

Project Benefits:

Restored estuarine wetlands on the island will act as buffer zones to mitigate coastal flood damages and protect shorelines from erosion by attenuating wave energy, in addition to State Highway 257 - part of the Great Texas Coastal Birding Trail and one of the most popular bird watching trails in the nation. Creation of estuarine wetland habitat along this highway will preserve and enhance shorebird nesting and wildlife habitat, which support the growing ecotourism industry of the Texas coast. This project is a candidate for beneficial use of dredged material to create and restore the habitat periodically to mitigate relative sea level rise.

Project Need:

Major tropical events and development have caused extensive habitat erosion on the island. If action is not taken, estuarine wetlands will continue to decline and become even more scarce.

North Pleasure Island Barrier Island Restoration

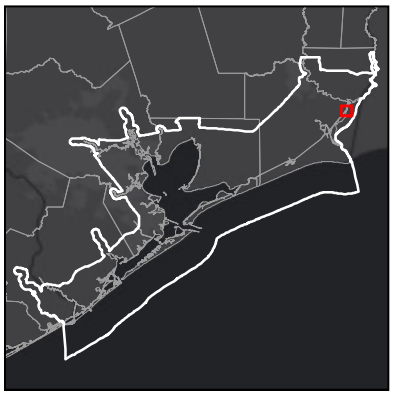
(Project ID R1-19)

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

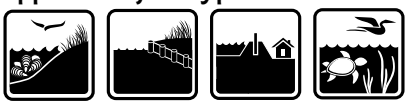
County: Jefferson

Location:
North Pleasure Island, Along the Sabine-Neches Waterway



Estimated Project Cost:
$1,500,000 – $5,000,000

Applied Project Types:



Project Description:

This project will restore remnants of a 15 acre island that once protected the navigation channel at the northern end of Sabine Lake at Pleasure Island by using dredged material to build up the island and construct up to 2,000 feet of breakwater.

Project Benefits:

Protection of the navigation channel will limit shoaling, thereby reducing the frequency and cost of maintenance dredging activities. This project has the potential to beneficially use dredged material from channel maintenance activities.

Project Need:

This project is needed to improve navigational safety and to protect the shorelines adjacent to the waterway. Over time, the barrier islands in this area eroded due to channel use. As a result, the inland wetlands, lakes and their habitats are no longer protected from channel navigation activities or long stretches of fetch across the bay.

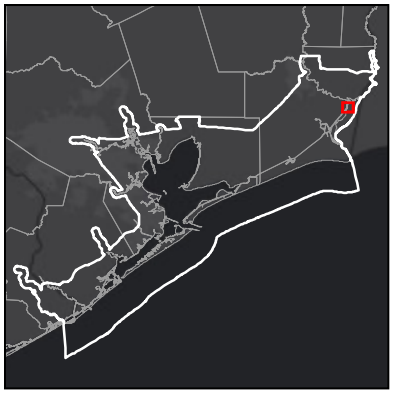
Sabine-Neches Waterway Barrier Island Habitat Restoration *(Project ID R1-20)*

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

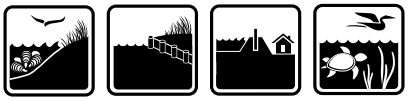
County: Jefferson

Location:
At the Entrance to the Sabine-Neches Waterway, near the Mouth of the Neches River



Estimated Project Cost:
$500,000 – $1,500,000

Applied Project Types:



Project Description:

The project will restore up to 40 acres of island habitat along the Sabine-Neches Waterway in Jefferson County, along the southern boundary of the navigation channel, separating the channel from Sabine Lake. The restored habitat will contain wetlands and vegetated shallows.

Project Benefits:

The restored island will provide additional protection to the channel and wetlands along Old River Cove from the longer fetches of Sabine Lake. Protecting the navigation channel from tides and fetch promotes navigational safety and efficiency for barges that carry approximately 103 million tons of cargo across this segment of the waterway annually. Restoration of the island has the potential to greatly increase viability of fish and bird species utilizing area rookeries, and may greatly increase the fish populations. This project has the potential to beneficially use dredged material from channel maintenance activities.

Project Need:

Further degradation of the existing islands will result in increased erosion of estuaries, which are vital to the state's commercial and recreational fisheries, and will impact inland wetlands. The project is also needed to restore navigational safety and efficiency.

Bessie Heights Marsh Restoration

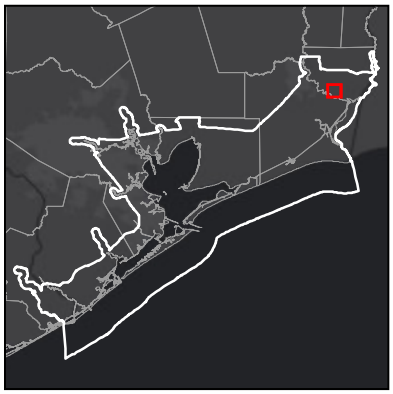
(Project ID R1-21)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

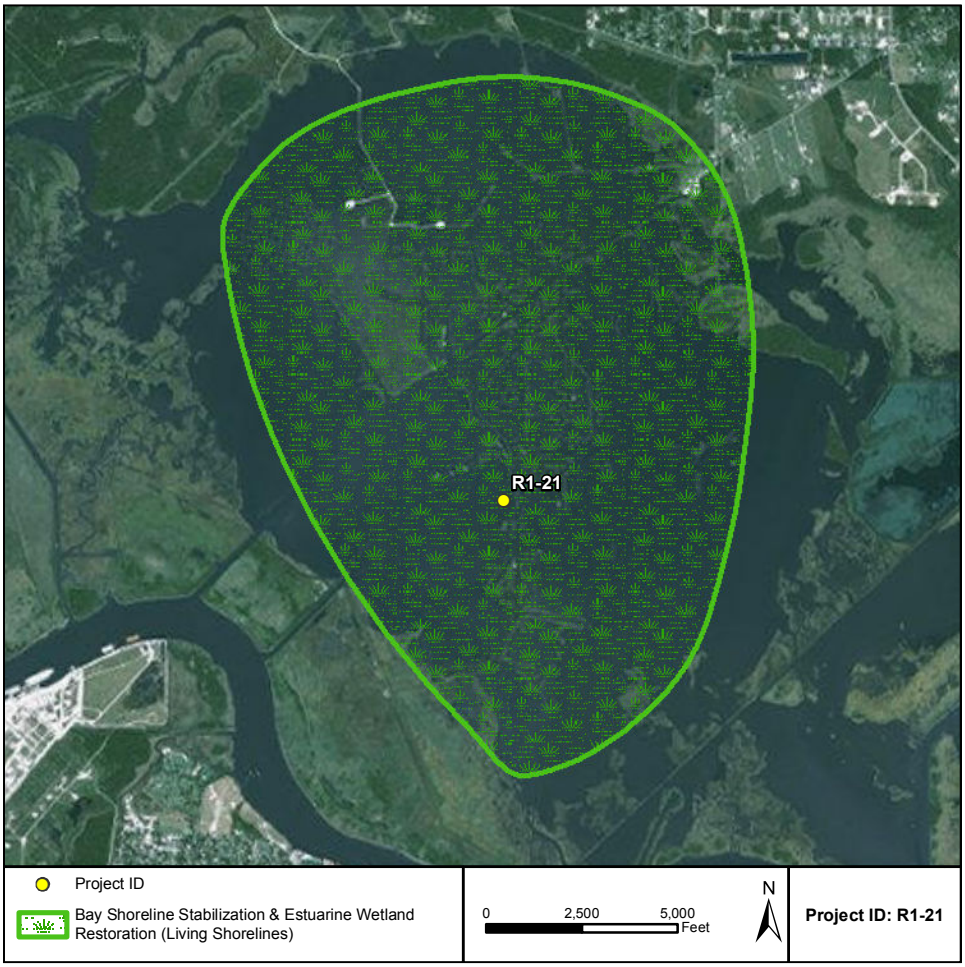
County: Orange

Location:
Northeast of Port Neches



Estimated Project Cost:
$5,000,000 – $25,000,000

Applied Project Types:



Project Description:

The project will restore up to 1,000 acres of an historical estuarine wetland complex at Bessie Heights Marsh in the Lower Neches Wildlife Management Area that has been negatively impacted by subsidence. The wetland restoration methodology will be beneficial use of dredged material cells with containment berms.

Project Benefits:

Improvement of degraded wetlands will increase viability for protected species and provide potential foraging habitat for migrating and wading birds. The project location is near an existing Wildlife Management Area, which will create a greater expanse of open space and habitat for migrating birds, protected species and estuarine rare species. This project is a candidate for beneficial use of dredged material to create and restore the habitat periodically to mitigate relative sea level rise.

Project Need:

The estuarine wetlands in this area are experiencing high rates of degradation, primarily due to subsidence. Restoration of these wetlands is needed to provide ecosystem services to the area, including benefits to water quality, nesting and nursery habitat, nutrient cycling, soil retention and recreation.

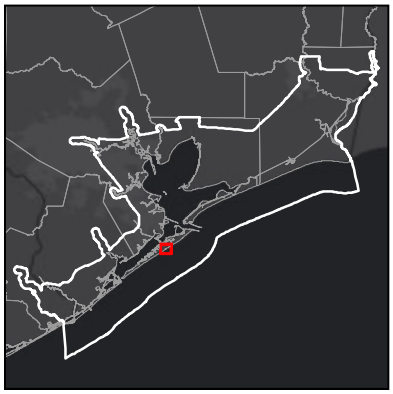
Galveston Island West of Seawall to 8 Mile Road Beach Nourishment *(Project ID R1-22)*

Resiliency Strategy Addressed:

Restoration of Beaches & Dunes

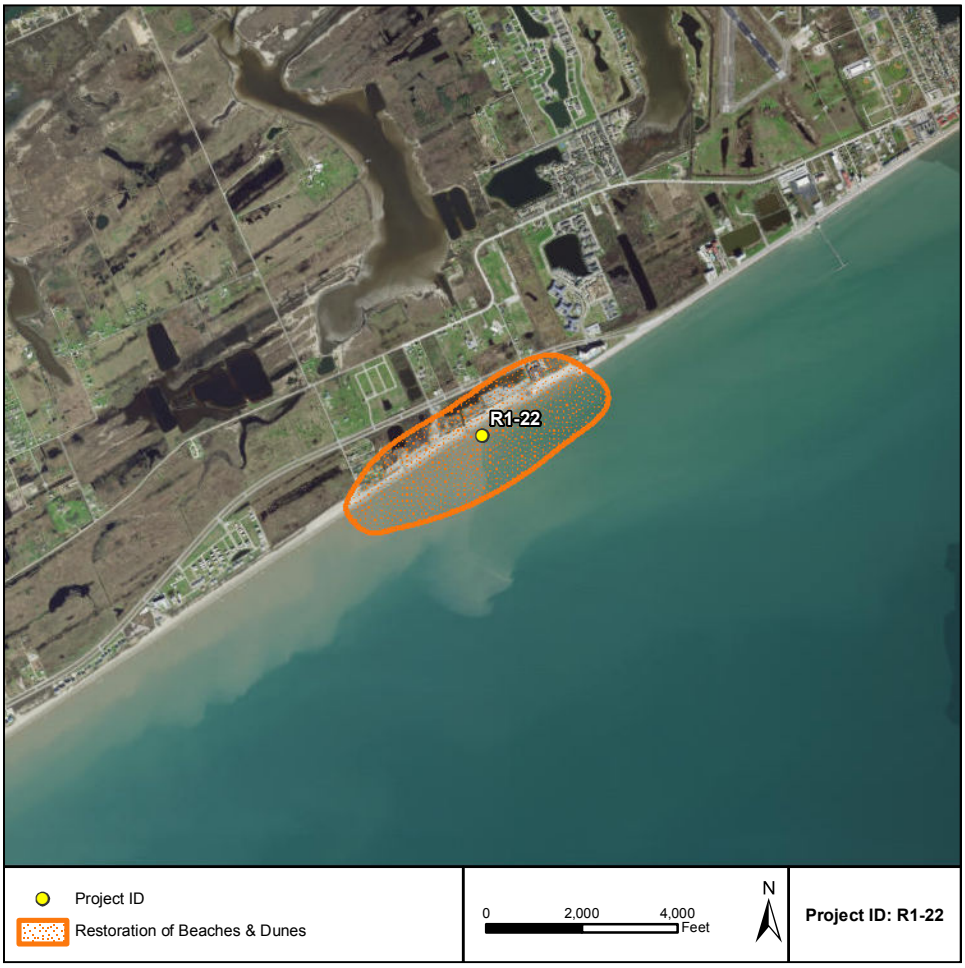
County: Galveston

Location:
Galveston Island from immediately West of the Seawall to 8 Mile Road



Estimated Project Cost:
$2,000,000 – $12,000,000

Applied Project Types:



Project Description:

The project will provide 1 mile of shoreline stabilization along the Gulf beach of Galveston's West End and create a feeder beach to passively nourish the shoreline from the Galveston Seawall to 8 Mile Road through natural transport..

Project Benefits:

The beach nourishment and protection of West Galveston Island, an area highly used by the public that generates important tourism benefits for the local economy, will preserve the recreational value for human use, as well as the natural habitat for wildlife. Recent nourishment efforts on Galveston Island were achieved through improved coordination of dredged materials between federal and state agencies. Continued coordination will keep costs feasible for this stretch of shoreline.

Project Need:

The West Galveston Island area experiences a long history of extreme erosion. Over the next 50 years, close to 60 acres are projected to erode based on historic rates without the project.

Follets Island Conservation Initiative

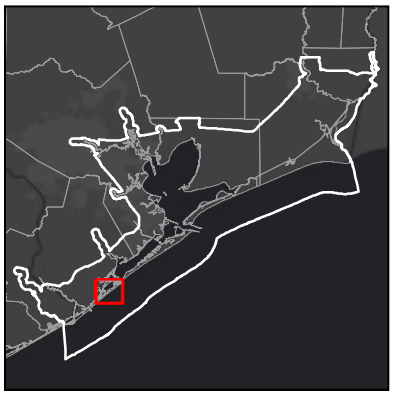
(Project ID R1-23)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Brazoria

Location:
Follets Island between San Luis Pass and Freeport



Estimated Project Cost:
$4,500,000 – $15,000,000

Applied Project Types:

Project Description:

The Follets Island Conservation Initiative is a partnership effort to acquire and protect 1,300 acres on the island and transfer title to the Texas Parks and Wildlife Department.

Project Benefits:

Follets Island helps protect the entire Galveston Bay estuary system, including Drum and Christmas Bays, from storm degradation, and allows the natural movement and restoration of habitats after storm events. Critically important wildlife habitats on the island include tall grass prairies, estuarine and freshwater wetlands, seagrass meadows, oyster reefs, mud flats, sand dunes and Gulf beaches, all of which create an ideal environment for Kemp's Ridley sea turtles, piping plovers, waterfowl, wading birds and shorebirds.

Project Need:

Development in this area will reduce the island's ability to attenuate coastal flood waters and stabilize after storm events. It is more economical to preserve land than to restore or recreate it later after developmental activities have taken place. Texas is ranked 4th in the nation for the highest wildlife-associated expenditures, and conserving lands contributes to the recreational well-being of the state.

Sabine Ranch Habitat Protection

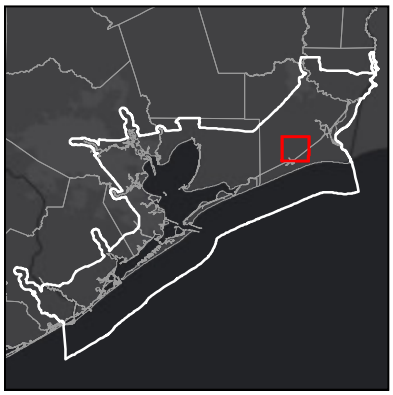
(Project ID R1-24)

Resiliency Strategy Addressed:

Freshwater Wetlands & Coastal Uplands Conservation

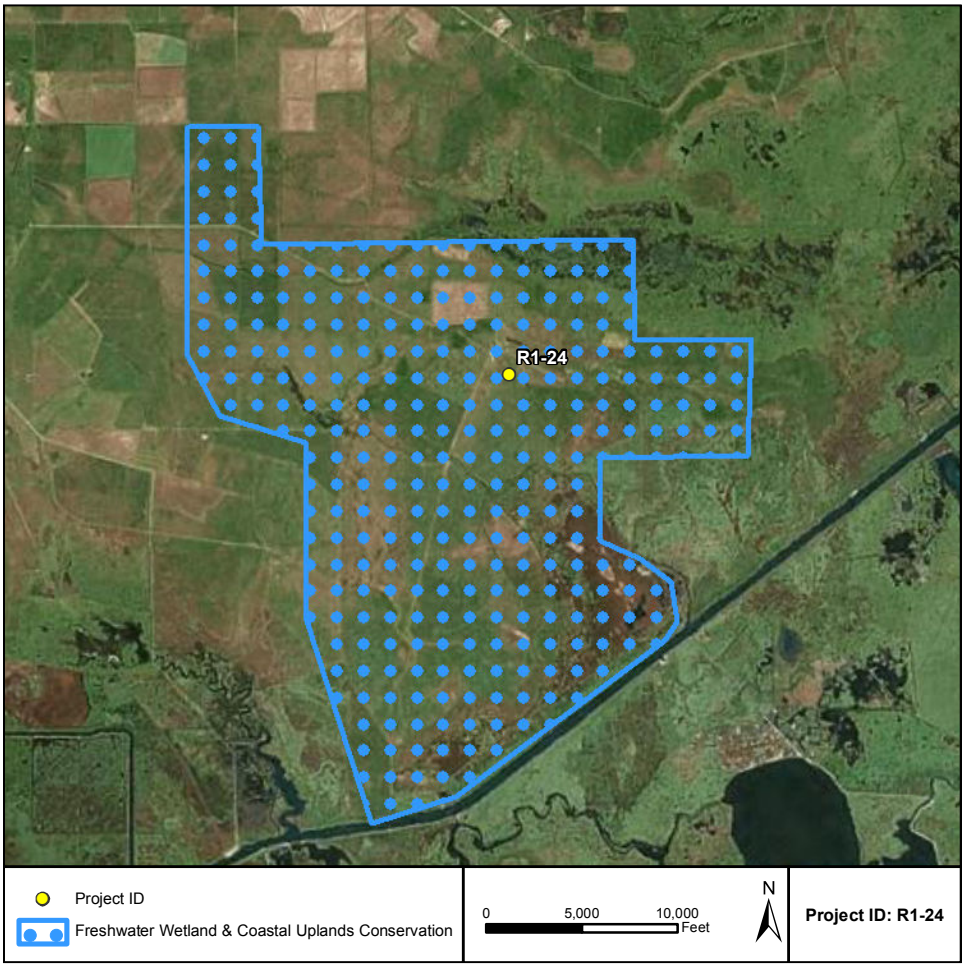
County: Jefferson

Location:
Sabine Ranch at the McFaddin National Wildlife Refuge, North of the GIWW



Estimated Project Cost:
$65,000,000 – $120,000,000

Applied Project Types:



Project Description:

Sabine Ranch is a critical 12,100 acre component of the largest remaining contiguous coastal freshwater marsh system in Texas. Protection of the Sabine Ranch, almost entirely within the McFaddin National Wildlife Refuge boundary, is a U.S. Fish and Wildlife Service (USFWS) top conservation priority for the upper Texas coast.

Project Benefits:

Sabine Ranch's central position within over 100,000 acres of federal and state protected beach and wetlands make the permanent protection of this coastal habitat critical to the entire complex. Conserving and restoring these lands will avert further losses of wetlands and biological diversity. Sabine Ranch's estuarine wetlands, coastal prairies and forested wetlands provide important habitat for 35 of the 48 avian species that are identified by USFWS as Species of Conservation Concern in the Gulf Prairies Bird Conservation Region.

Project Need:

Without action, the ecosystem health will continue to be threatened by coastal land loss, hydrological alterations, exotic species and contaminants. Protecting these habitats supports the state's $1.4 billion ecotourism industry and contributes to ecosystem services that provide benefits to water quality, nutrient cycling, nesting and nursery habitats, and recreation.

Galveston Bay Oyster Reef Planning & Restoration

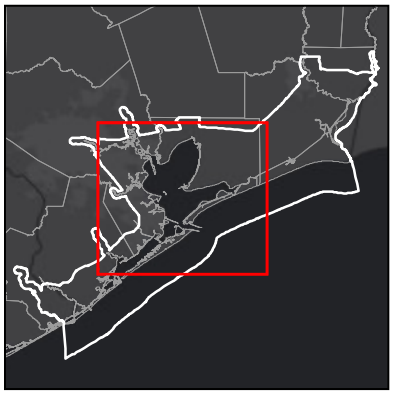
(Project ID R1-25)

Resiliency Strategy Addressed:

Oyster Reef Creation & Restoration

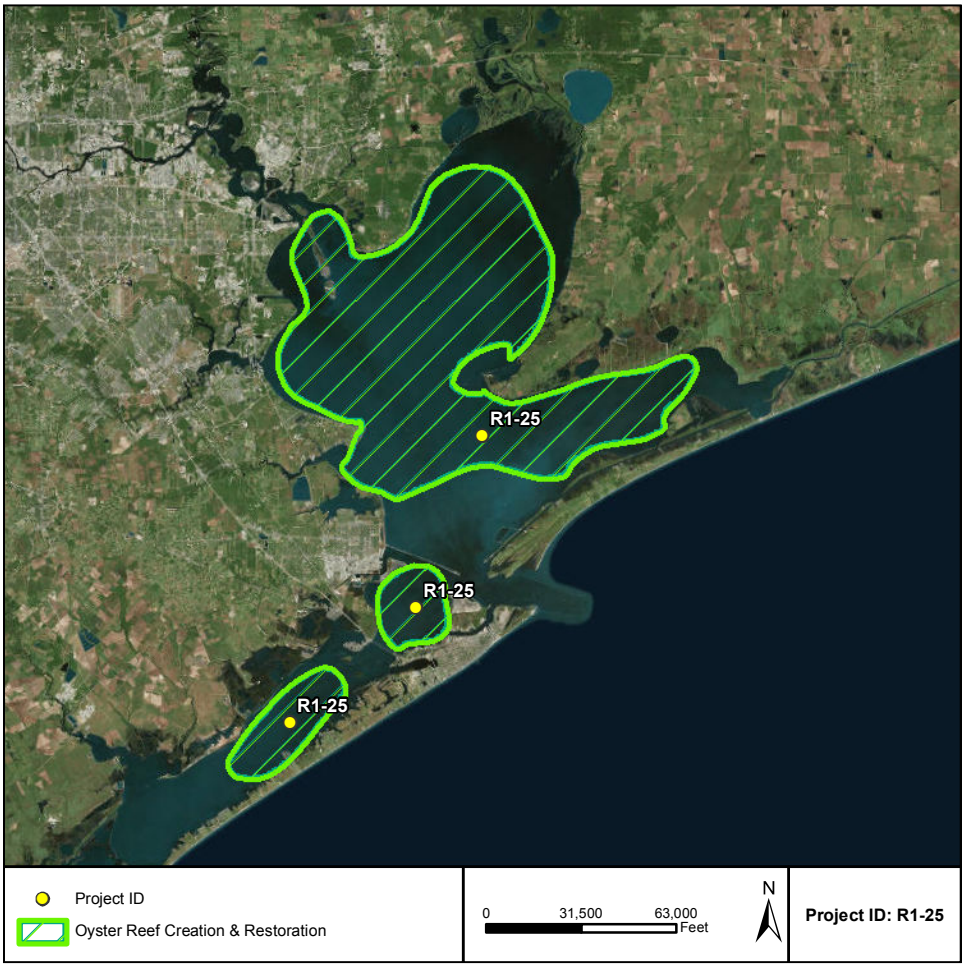
County: Galveston

Location:
Throughout the Galveston Bay System



Estimated Project Cost:
$5,000,000 – $60,000,000

Applied Project Types:



Project Description:

The project will restore Galveston Bay oyster reef habitats in response to large-scale impacts from Hurricane Ike and increased harvest pressures. The project will likely include a study to evaluate the best restoration locations to ensure high returns, as well as survey and monitoring efforts to catalog the extents and locations of existing reefs and success of various recruitment techniques.

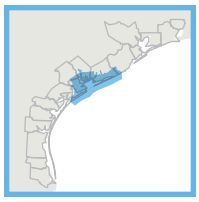
Project Benefits:

Oyster harvests are the third most valuable among the commercial fisheries in Texas, in both value and landings volume. Texas is the second largest oyster-producing state in the country, with more than 70 percent of its oysters coming from Galveston Bay. Notable benefits of oyster habitat creation are oyster harvest, water filtration, aquatic habitat diversity and shoreline protection by wave energy attenuation. The recreational value associated with species diversity of oyster reefs supports the state's $1 billion marine recreational fishing industry.

Project Need:

The existing oyster reefs in Galveston Bay are degraded by prior tropical storm events and persistent dredging activities that disturb sediment in adjacent bays. In 2008, Hurricane Ike destroyed up to 60 percent of the oyster habitat in Galveston Bay.

Region 2 Project Summaries



Counties:
Calhoun, Jackson, Matagorda, Victoria

Total Estimated Cost Range for Projects:
$145,500,000 - $304,500,000

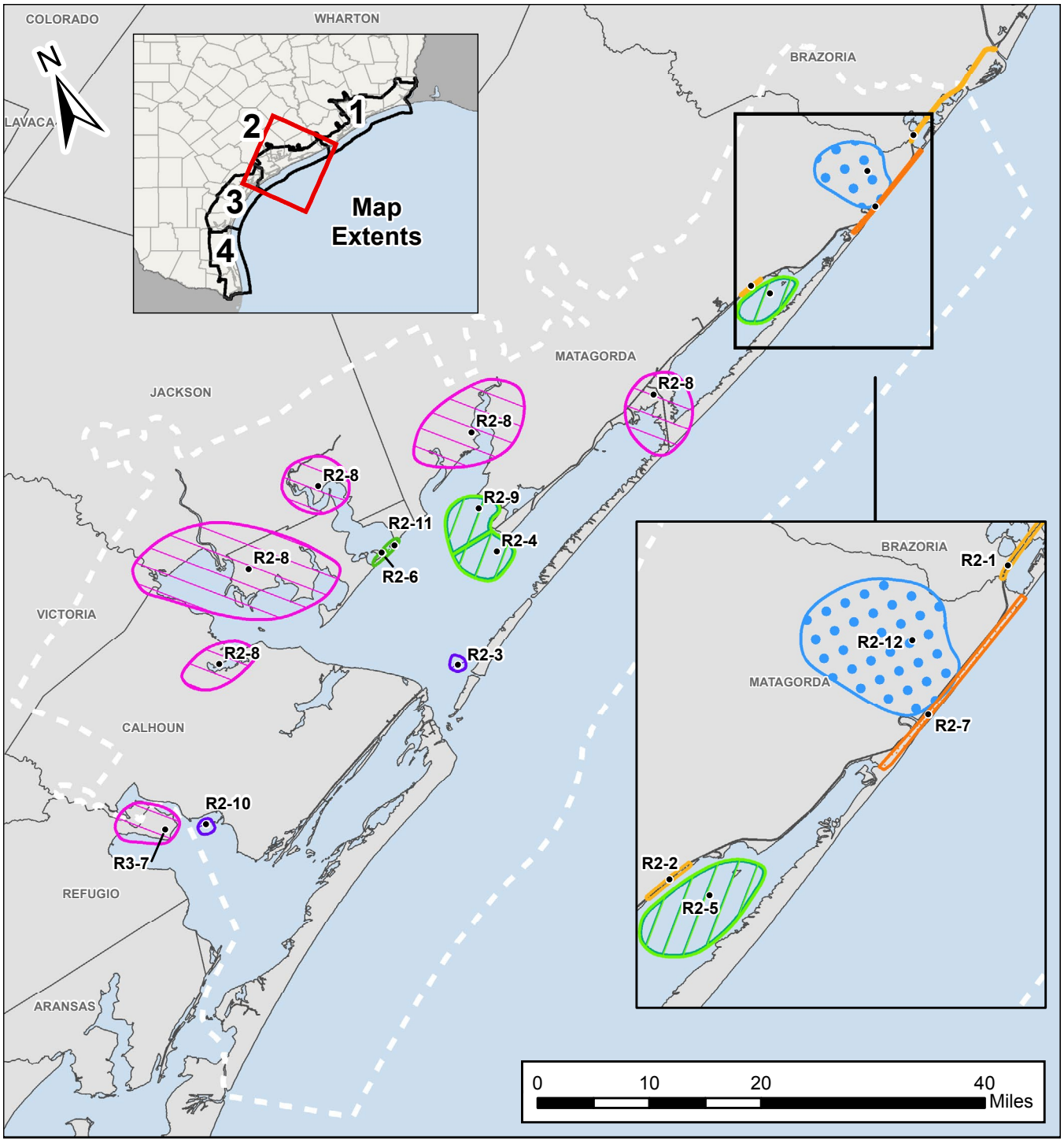
Priority Issues of Concern:

- Altered, Degraded or Lost Habitat
- Gulf Beach Erosion & Dune Degradation
- Coastal Resources Impacts
- Water Quality Impacts

Region 2 – Tier 1 Projects

ID	Tier 1 Projects	Project Type(s)*
R2-1	Brazos River to Cedar Lake Creek GIWW Stabilization	
R2-2	Boggy Cut GIWW Stabilization	
R2-3	Chester's Island Restoration	
R2-4	Half Moon Oyster Reef Restoration – Phase 3	
R2-5	Chinquapin Oyster Reef Restoration	
R2-6	Redfish Lake Living Shoreline	
R2-7	Sargent Beach & Dune Restoration	
R2-8	Matagorda Bay System Hydrologic Restoration Study	
R2-9	Oliver Point Oyster Reef Restoration	
R2-10	San Antonio Bay Rookery Island Restoration	
R2-11	Schicke Point Living Shoreline	
R2-12	Sargent Ranch Addition to San Bernard National Wildlife Refuge	

**Reference Figure 5.3 – Project Categorization – on page 65 for a listing and explanation of the project types addressed by the recommended Tier 1 projects.*



Resiliency Strategy Project Locations

- Restoration of Beaches & Dunes
- Bay Shoreline Stabilization & Estuarine Wetland Restoration (Living Shorelines)
- Rookery Island Creation & Restoration
- Stabilizing the GIWW
- Delta & Lagoon Restoration
- Freshwater Wetland & Coastal Uplands Conservation
- Oyster Reef Creation & Restoration

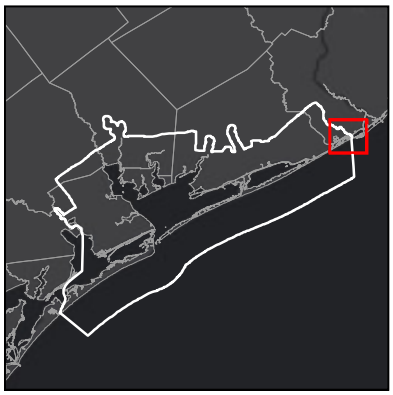
Brazos River to Cedar Lake Creek GIWW Stabilization *(Project ID R2-1)*

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

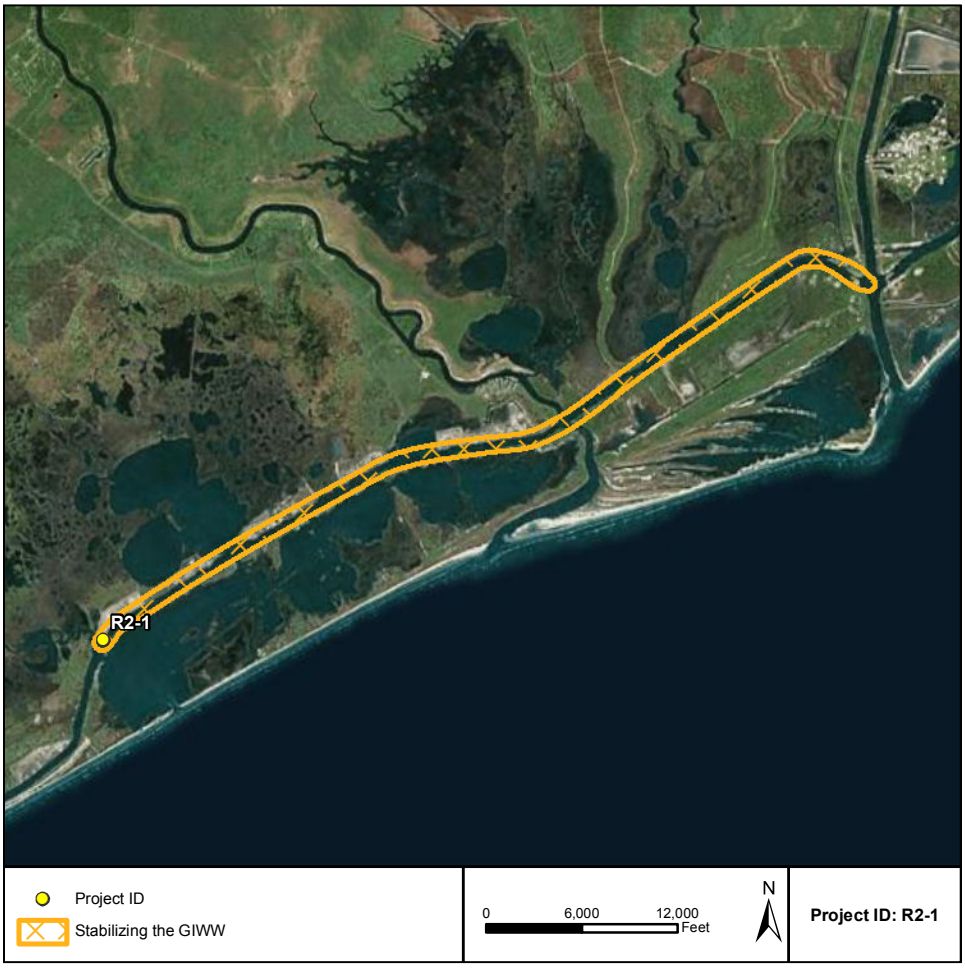
County: Brazoria

Location:
The GIWW from the Brazos River to Cedar Lake Creek



Estimated Project Cost:
$35,000,000 – $65,000,000

Applied Project Types:



Project Description:

The project will construct breakwaters or a living shoreline along approximately 20 miles of the GIWW, and will restore wetlands adjacent to the GIWW. Both sides of the GIWW require restoration, but restoring the southern side will provide some secondary benefits to the northern side. The proposed project methodology will be evaluated closely to avoid adverse impacts on water circulation patterns and oyster habitat within the lakes.

Project Benefits:

Stabilizing the banks of the GIWW promotes navigational safety and efficiency of barges that carry approximately 35 million tons of cargo across this segment of the GIWW yearly. It also protects estuaries from wakes that support commercial and recreational fisheries from saltwater intrusion by breach avoidance or repair.

Project Need:

Shoreline erosion along the GIWW is creating frequent shoaling in the channel and increasing erosion of adjacent, inland wetlands. The erosion of these barrier islands threatens not only the GIWW, but also reduces habitat to important and diverse aquatic and avian species.

Boggy Cut GIWW Stabilization

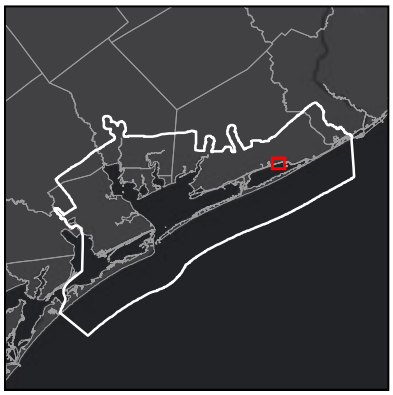
(Project ID R2-2)

Resiliency Strategy Addressed:

Stabilizing the Gulf Intracoastal Waterway

County: Matagorda

Location:
East Matagorda Bay,
South of Boggy Lake



Estimated Project Cost:
$4,500,000 – $13,000,000

Applied Project Types:

Project Description:

To mitigate erosion caused by wind, waves and ship wakes in the GIWW near Boggy Cut, the project proposes up to 20 miles of barrier island restoration, or construction of breakwaters and wetland restoration where island restoration is not feasible. The project may also include acquisition of private property adjacent to the GIWW, if willing sellers can be located, in an effort to restore coastal habitats and develop a more resilient coastline in the area.

Project Benefits:

These efforts will reduce wind and current impacts on navigation and mainland erosion that is produced by the long fetch length across the bay. As a result, cargo transport along the GIWW will be more sheltered and less exposed to navigational hazards. Stabilizing this section of the GIWW also will be a critical first step towards providing protection to the fringe wetlands and seagrass beds that serve as vegetative buffers to reduce storm surge, and vitalize the ecology of the bay.

Project Need:

If the project does not occur, erosion in this area will worsen, and the GIWW will be further exposed to breaching from the adjacent bay systems, lowering the efficiency of its use to transport cargo. Increased use of upland transport will transfer safety and environmental hazard risks to the general public and increase market prices. Loss of habitat also will occur if this project is not completed.

Chester's Island Restoration

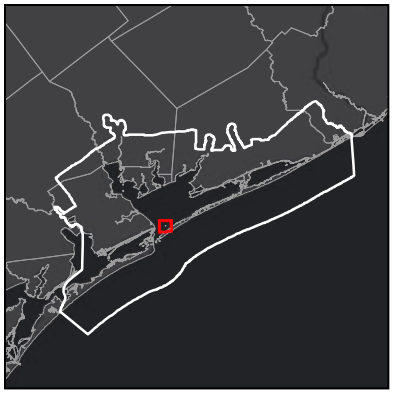
(Project ID R2-3)

Resiliency Strategy Addressed:

Rookery Island Creation & Restoration

County: Matagorda

Location:
Also known as Sundown Island, Located North of the Matagorda Ship Channel Jetties



Estimated Project Cost:
$1,500,000 – $5,000,000

Applied Project Types:

Project Description:

The project will slow the erosion of the rookery island and add 30 acres of land using nearshore breakwaters. Additional work may include invasive species control. Funding has been provided for a feasibility study and a nourishment template.

Project Benefits:

This project is designed and permitted, and identifies potential sites for beneficial use materials to be used to rebuild eroded land. The enhancement of this habitat is critical for the millions of migrating birds that fly through Texas semi-annually, and provides nesting area for colonial waterbirds.

Project Need:

High energy waves driven by wind, storms and passing ship wakes are causing accelerated erosion to multiple areas on the island. The U.S. Army Corps of Engineers created this island in the 1960's using dredged material from the Matagorda Ship Channel. Originally, the island provided 200 acres of rookery habitat, but is now less than 60 acres in size.

Half Moon Oyster Reef Restoration – Phase 3

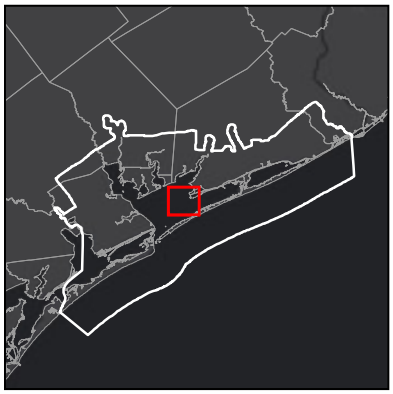
(Project ID R2-4)

Resiliency Strategy Addressed:

Oyster Reef Creation & Restoration

County: Matagorda

Location:
Matagorda Bay



Estimated Project Cost:
$2,000,000 – $5,000,000

Applied Project Types:

Project Description:

The project will restore 30 acres of reef habitat at Half Moon Oyster Reef in Matagorda Bay. The project is shovel-ready (designed, permitted and leased) and will support a high economic value, popular recreational fishing area.

Project Benefits:

The Nature Conservancy's 2016 study of 54 previously restored acres at Half Moon Reef showed that the oyster reef restoration caused recreational fishing activity to surge, resulting in an increase of $691,000 of the state's GDP per year and over $1.2 million in annual economic activity. Notable benefits of oyster habitat creation are oyster harvests, water filtration, aquatic habitat diversity and shoreline protection by wave energy attenuation.

Project Need:

Texas bay systems are experiencing ongoing degradation of oyster reefs due to coastal storms, over-harvesting, water quality impacts and commercial dredging. Scientists estimate that the Gulf of Mexico has seen close to 50 percent of its reefs depleted since the 19th century based on long-term historical data for the broader region[1]. This amounts to substantial ecological and economic losses for the state.

[1] *Shepard, C., Dumesnil, M. and S. Carlton. 2016. Half Moon Reef: Measuring the Recreational Fishing Benefits of a Restored Oyster Habitat. The Nature Conservancy and Texas Sea Grant. Available at: http://www.nature.org/media/texas/hmr_final_distribution.pdf (accessed Dec 29, 2016)*

Chinquapin Oyster Reef Restoration

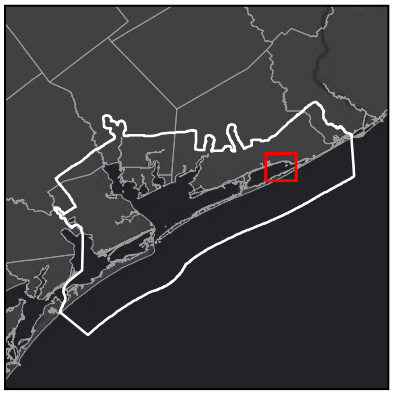
(Project ID R2-5)

Resiliency Strategy Addressed:

Oyster Reef Creation & Restoration

County: Matagorda

Location:
East Matagorda Bay



Estimated Project Cost:
$1,500,000 – $5,000,000

Applied Project Types:

Project Description:

The project involves approximately 10 acres of oyster reef restoration on the legacy Chinquapin Reef in East Matagorda Bay. The proximity of the reef to the GIWW will be considered during restoration planning.

Project Benefits:

The East Matagorda Bay oyster reefs are harvestable, a public resource and a popular fishing location. Improved water quality, increased recreational fishing opportunities, enhanced marine biodiversity and other ecosystem benefits are anticipated with a completed project. This oyster reef also could provide a level of erosion control for the adjacent GIWW barrier island system and northern shoreline.

Project Need:

Texas bay systems are experiencing ongoing degradation of oyster reefs due to coastal storms, over-harvesting, water quality impacts and commercial dredging. The Chinquapin oyster reefs have suffered losses of acreage in recent years, which could be tied to GIWW channel use and maintenance activities in the vicinity. A solution that restores these reefs, while acknowledging or improving the navigational issues, is needed to allow the reefs to regain stability.

Redfish Lake Living Shoreline

(Project ID R2-6)

Resiliency Strategy Addressed:

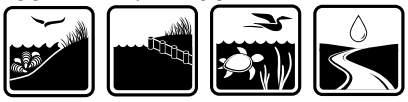
Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Calhoun

Location:
Redfish Lake, South of Carancahua Bay

Estimated Project Cost:
$5,000,000 – $15,000,000

Applied Project Types:



Project Description:

The project will rebuild and reconnect the breached bayside hook back to the peninsula with approximately 3 miles of living shoreline. There are depleted oyster reefs in this area, which may be able to be restored as part of the living shoreline. Healthy oyster reefs can create natural wave breaks due to the added elevation and structure of the reef, and can be incorporated into the living shoreline design for additional benefits.

Project Benefits:

The restoration of the protective barrier, oyster reefs, estuarine wetlands and seagrasses will preserve special aquatic sites, such as vegetated shallows. It will re-establish the original landform and salinity levels of the systems and prevent further associated habitat losses.

Project Need:

The peninsula typically separating Redfish Lake from Matagorda Bay is breached, causing saltwater intrusion into Redfish Lake that is degrading wetlands, seagrasses and other marine habitats in the area.

Sargent Beach & Dune Restoration

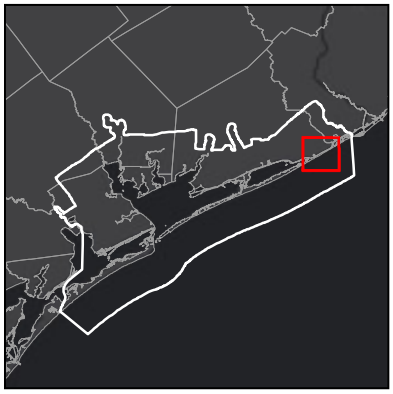
(Project ID R2-7)

Resiliency Strategy Addressed:

Restoration of Beaches & Dunes

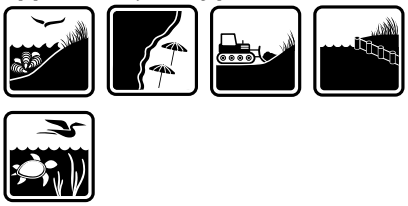
County: Matagorda

Location:
Sargent Beach Gulf Shoreline



Estimated Project Cost:
$45,000,000 – $80,000,000

Applied Project Types:



Project Description:

The project will nourish and restore approximately 8 miles of beach shoreline and dunes on Sargent Beach. This solution could include constructing groins or detached breakwaters to retain sediment on the beach to slow the natural processes of offshore transport. The nourishment efforts would primarily rely on sand sources that developed nearshore along the Brazos and San Bernard River deltas, with the additional possibility of a source offshore in the Colorado River Delta. A recommendation of phased 2-mile stretches of shoreline, focused on critical needs, is proposed to account for sediment and budget limitations, as opposed to addressing the full project length in a single phase of work.

Project Benefits:

Beach nourishment and construction of continuous dune systems in this area will provide coastal communities with the first line of defense from storm surge and flooding, and will enhance tourism and recreational value that beaches and beachfront amenities provide to the local and state economy. Protection of this land preserves its recreational value for human use and as habitat for wildlife.

Project Need:

Sargent Beach is a popular recreation area and was last re-nourished in 2013. Sargent Beach experiences high rates of erosion, some portions having an historical land loss rate of over 20 feet per year. If this project does not occur, an estimated 1,221 acres are projected to erode over the next 50 years. There also are anticipated significant, negative impacts on the local economy if the beach is not re-nourished and the groins to retain the sediment are not constructed.

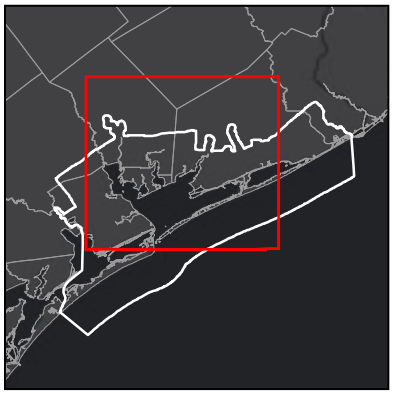
Matagorda Bay System Hydrologic Restoration Study *(Project ID R2-8)*

Resiliency Strategy Addressed:

Delta & Lagoon Restoration

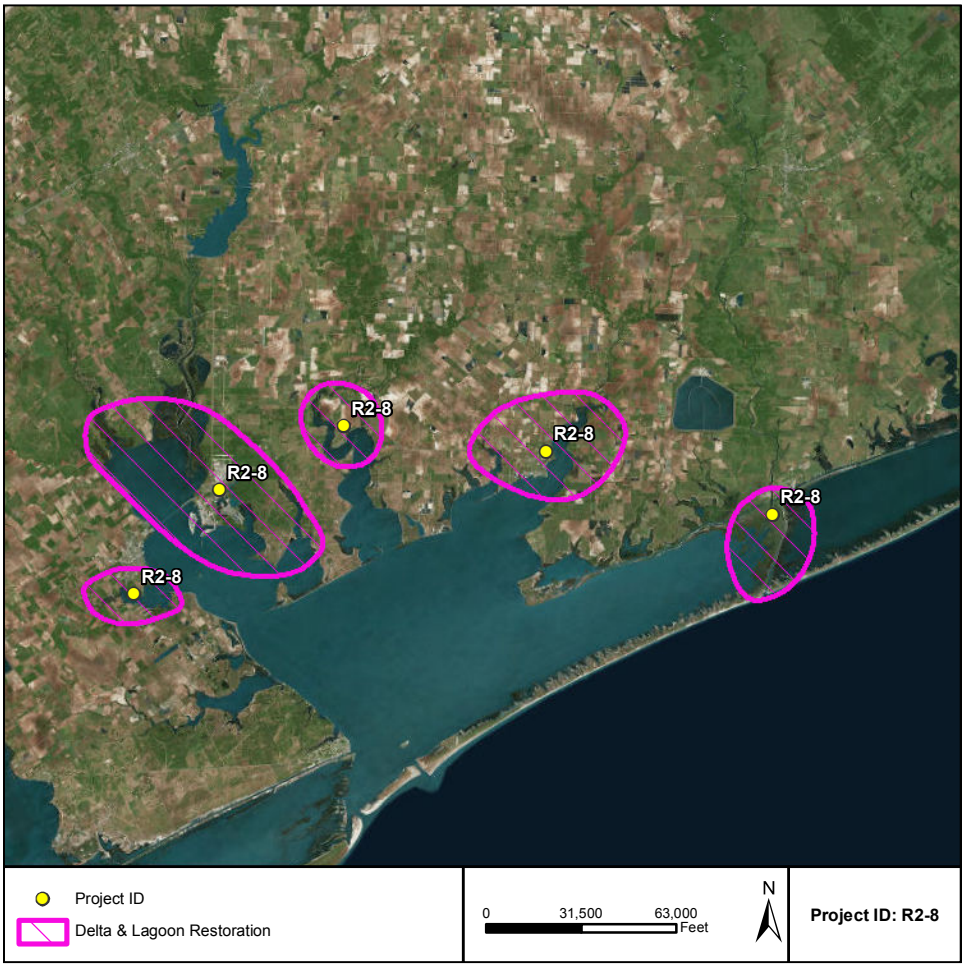
County: Matagorda

Location:
Matagorda Bay and its Minor Bays



Estimated Project Cost:
$1,000,000 – $5,000,000

Applied Project Types:



Project Description:

The project includes a study or adaptive management plan to develop a path towards restoring healthy inflows to the bays in order to meet environmental flow recommendations for the system. The adaptive management plan will identify how to best restore coastal ecosystems within the delta regime in a manner that is more resilient to freshwater inflow fluctuations.

Project Benefits:

Matagorda County has a large export economy dependent upon commercial fishing, and the Port of Palacios ranks fourth in the state in the value and weight of its commercial fishery landings. Providing additional habitat for commercially and recreationally valuable species will support the commercial and recreational fishing industries, and other recreational activities to help sustain economic diversity along the coast.

Project Need:

The Matagorda Bay System is experiencing losses of freshwater inflows from the Colorado River and Lavaca River, as well as numerous other small water bodies. This lack of freshwater inflows to Matagorda Bay and its minor bays is a systemic problem that has the potential to undermine the restoration of the rest of the area's coastal habitats, including fisheries and wetlands, by depleting nutrients needed by downstream ecosystems to maintain their functionalities.

Oliver Point Oyster Reef Restoration

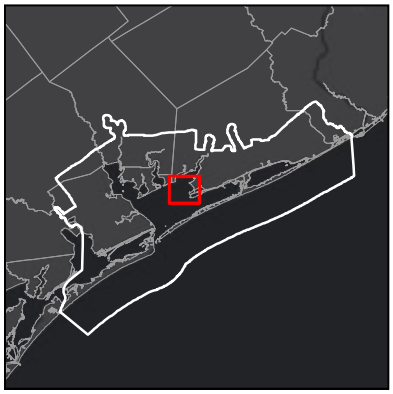
(Project ID R2-9)

Resiliency Strategy Addressed:

Oyster Reef Creation & Restoration

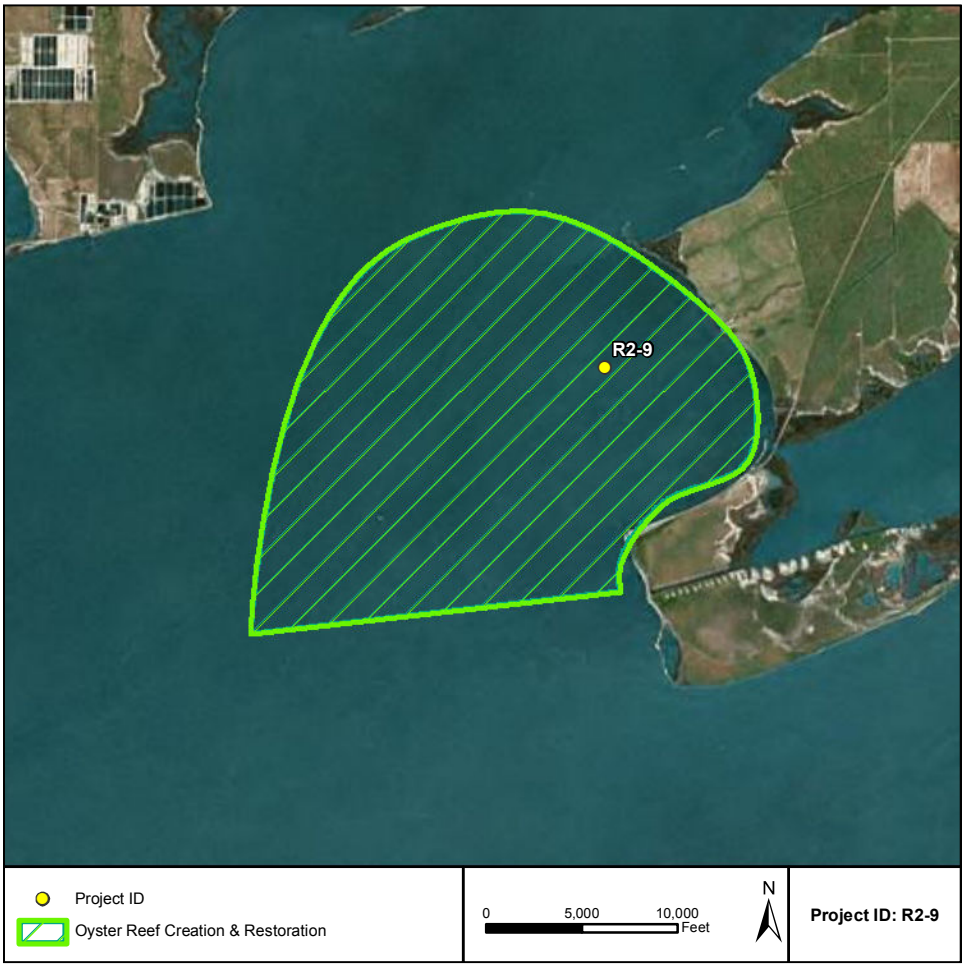
County: Matagorda

Location:
Oliver Point, at the convergence of Tres Palacios Bay and Matagorda Bay



Estimated Project Cost:
$1,500,000 – $5,000,000

Applied Project Types:



Project Description:

The project will restore the approximately 10 acres of the legacy Oliver Point Oyster Reef in Matagorda Bay.

Project Benefits:

Restored oyster reefs provide water quality benefits by filtering and reducing suspended sediments in bays, as well as erosion control benefits by attenuating wave energy. The Oliver Point Reef will help to stabilize the northern shoreline.

Project Need:

Texas bay systems are experiencing ongoing degradation of oyster reefs due to coastal storms, over-harvesting, water quality impacts and commercial dredging. The Oliver Point Oyster Reef has suffered significant losses of acreage in recent years, and restoring this reef is an important step towards improving water quality and stabilizing the shoreline at Oliver Point, while allowing harvesting.

San Antonio Bay Rookery Island Restoration

(Project ID R2-10)

Resiliency Strategy Addressed:

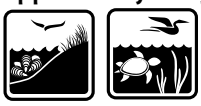
Rookery Island Creation & Restoration

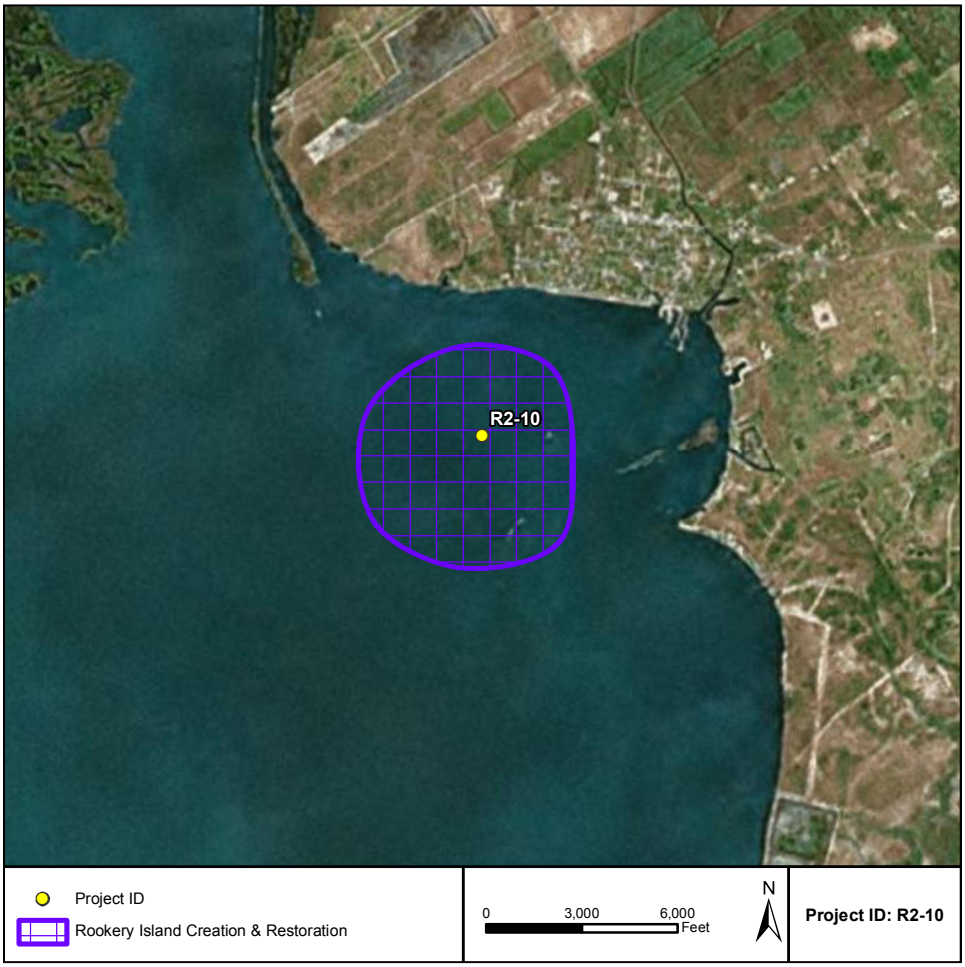
County: Calhoun

Location:
San Antonio Bay at Seadrift and Falcon Point Islands

Estimated Project Cost:
$6,000,000 – $19,000,000

Applied Project Types:





Project Description:

An initial site assessment of San Antonio Bay identified five locations of previously functioning rookery islands that are suitable for reconstruction. This project will restore an historical rookery island utilizing one or more of these locations.

Project Benefits:

This project will create an important colonial waterbird nesting area, and will enhance recreational activities such as birdwatching. This project, by boosting the ecotourism economy, also will help to diversify and strengthen Calhoun County's economy, which is currently heavily concentrated in one industry (chemical manufacturing), thereby building a more resilient local economy. Beneficial use of dredged material will be used from the adjacent channels, when possible, for reconstruction.

Project Need:

An inventory of rookery islands within San Antonio Bay shows that historical islands in this area have experienced extreme erosion or have been entirely submerged. The loss of suitable nesting habitat has led to a decline in herons, egrets, black skimmers and brown pelicans. This impacts the entire Texas Gulf coast rookery island chain and the local economy.

Schicke Point Living Shoreline

(Project ID R2-11)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

Counties: Calhoun, Matagorda

Location:
Schicke Point, at the convergence of Carancahua Bay and Matagorda Bay

Estimated Project Cost:
$2,500,000 – $7,500,000

Applied Project Types:

Project Description:

The project will provide shoreline protection to prevent further losses of estuarine wetlands from Schicke Point on the Matagorda Bay shoreline to the east. The protection method identified includes the construction of nearshore breakwaters to protect the wetland habitat and mitigate shoreline erosion. The project is already designed, permitted, and partially funded.

Project Benefits:

Protecting habitat for commercially and recreationally valuable species, with the creation of estuarine wetlands and living shorelines, supports the marine commercial and recreational fishing industries, and other recreational activities such as bird watching. With the completion of this project, the road that extends along the peninsula will remain protected, and will continue to serve as a functional evacuation route.

Project Need:

Schicke Point is experiencing persistent erosion of its important estuarine wetland habitat. If action is not taken, continued erosion will make Schicke Point more susceptible to breaching, which endangers its lone evacuation route.

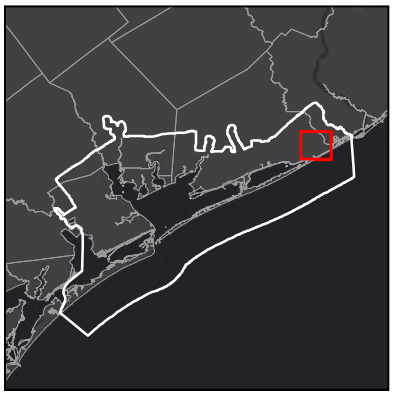
Sargent Ranch Addition to San Bernard National Wildlife Refuge *(Project ID R2-12)*

Resiliency Strategy Addressed:

Freshwater Wetlands & Coastal Uplands Conservation

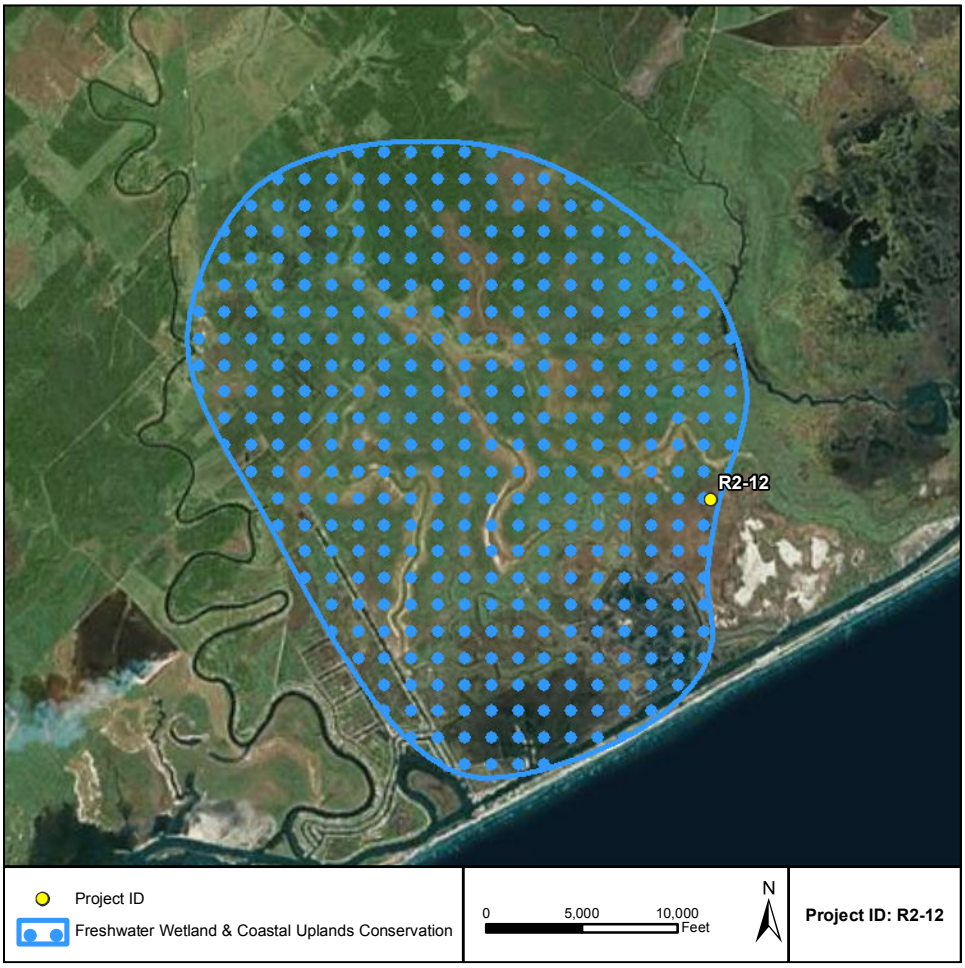
County: Matagorda

Location:
San Bernard National Wildlife Refuge, North of Sargent Beach



Estimated Project Cost:
$40,000,000 – $80,000,000

Applied Project Types:



Project Description:

The acquisition of Sargent Ranch, approximately 8,000 acres of habitat surrounded by the San Bernard National Wildlife Refuge, by the U.S. Fish and Wildlife Service.

Project Benefits:

The acquisition of Sargent Ranch will connect large portions of the refuge and make it possible to manage and protect important coastal dune and beach habitat for nesting sea turtles, piping plovers and a great diversity of waterfowl and water birds. The ranch stretches from the Gulf inland and includes beaches, dunes, prairies, extensive estuarine and freshwater wetlands, and Columbia Bottomland forests dominated by large old live oaks. The protection of the beach dunes also will improve the resiliency of this portion of the coast to storms and sea level rise, and allow the natural migration of wetlands and other habitats over time. Commercial fishing, recreational fishing and hunting, and ecotourism all benefit from the existence and preservation of breeding and nursery areas that support wildlife diversity. The expansion of the National Wildlife Refuge will further enhance the site by diversifying the ecological systems within it, presenting more opportunities to provide positive impacts on a wider range of species.

Project Need:

The acquisition of Sargent Ranch will complement the diverse habitat of the San Bernard National Wildlife Refuge, which provides vital habitat for migratory waterfowl and songbirds. Additionally, without acquisition of easements on the project site, it could undergo further development, which decreases the ecological resiliency in this region. Restoring or adding to the state's protected lands provides a variety of ecosystem services, contributes to the $262 million commercial fishing industry and the $1 billion marine recreational fishing industry, and supports the $1.4 billion ecotourism industry.

Region 3 Project Summaries

Counties:
Aransas, Kleberg, Nueces, Refugio, San Patricio

Total Estimated Cost Range for Projects:
$29,000,000 - $97,000,000

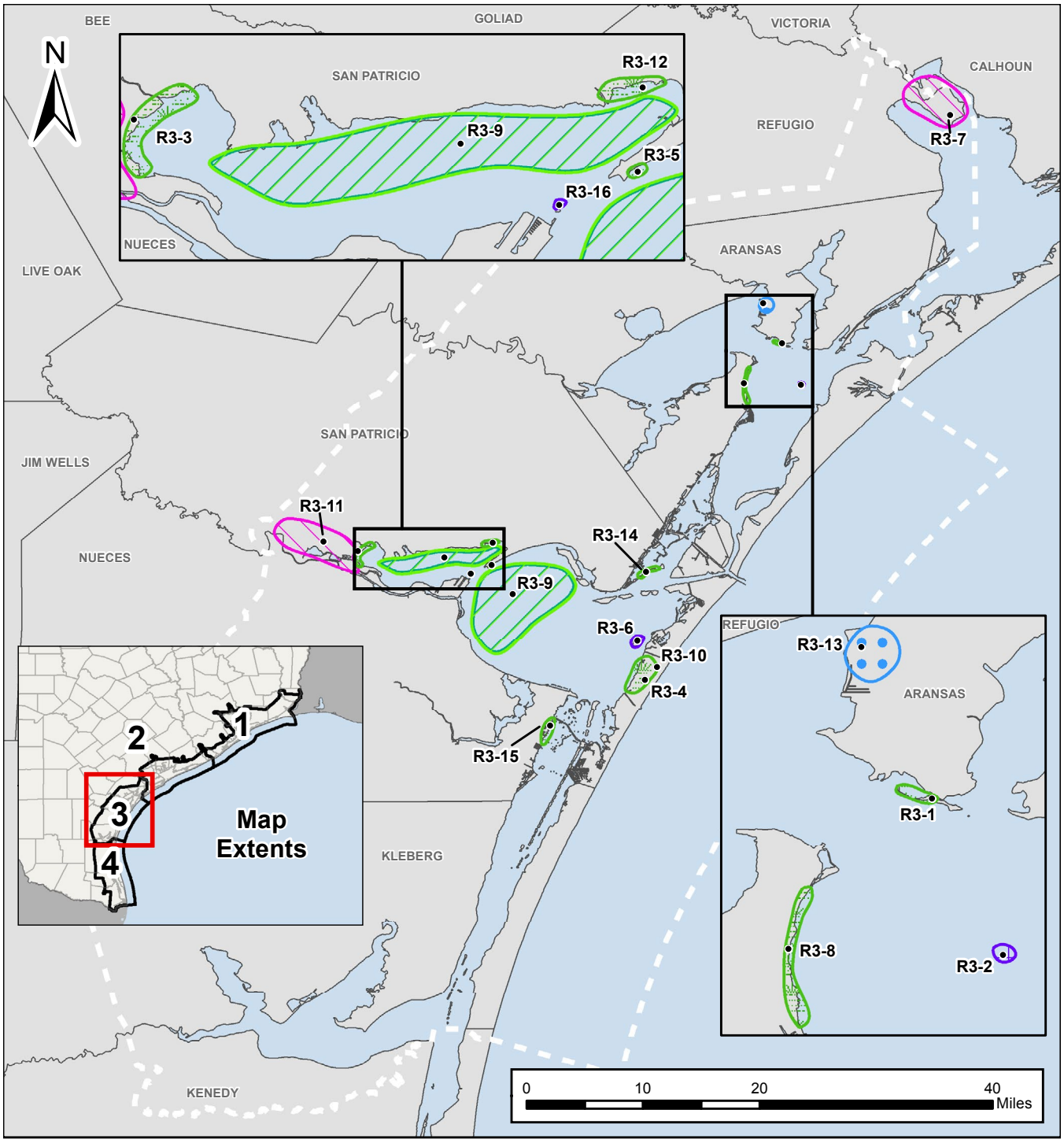
Priority Issues of Concern:

- Altered, Degraded or Lost Habitat
- Coastal Resources Impacts
- Gulf Beach Erosion & Dune Degradation
- Water Quality Impacts

Region 3 – Tier 1 Projects

ID	Tier 1 Projects	Project Type(s)*
R3-1	Goose Island State Park Living Shoreline	
R3-2	Long Reef Rookery Island Shoreline Stabilization	
R3-3	Nueces River Delta Shoreline Stabilization	
R3-4	Mustang Island State Park Acquisition	
R3-5	Indian Point Shoreline Protection	
R3-6	Shamrock Island Restoration – Phase 2	
R3-7	Guadalupe River Delta Estuary Restoration	
R3-8	Fulton Beach Road Living Shoreline	
R3-9	Corpus Christi & Nueces Bays Oyster Reef Restoration	
R3-10	Coastal Bend Gulf Barrier Island Conservation	
R3-11	Nueces County Hydrologic Restoration Study	
R3-12	Portland Living Shoreline	
R3-13	Shell Point Ranch Wetlands Protection	
R3-14	Dagger Island Living Shoreline	
R3-15	Flour Bluff Living Shoreline	
R3-16	Causeway Island Rookery Habitat Protection	

**Reference Figure 5.3 – Project Categorization – on page 65 for a listing and explanation of the project types addressed by the recommended Tier 1 projects.*



Resiliency Strategy Project Locations

- Bay Shoreline Stabilization & Estuarine Wetland Restoration (Living Shorelines)
- Rookery Island Creation & Restoration
- Delta & Lagoon Restoration
- Freshwater Wetland & Coastal Uplands Conservation
- Oyster Reef Creation & Restoration

Goose Island State Park Living Shoreline

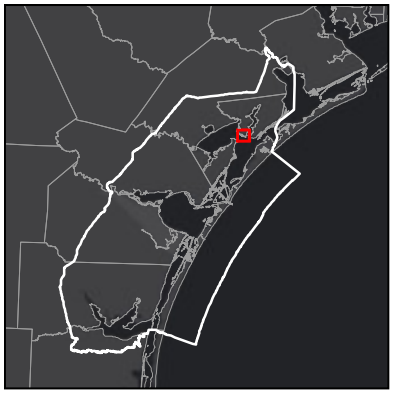
(Project ID R3-1)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Aransas

Location:
Goose Island State Park, at the convergence of Aransas Bay and St. Charles Bay



Estimated Project Cost:
$1,000,000 – $3,000,000

Applied Project Types:

Project Description:

The project will provide shoreline and habitat protection for the critical estuarine wetland habitat that makes up 25 acres of Goose Island State Park through the construction of 2,000 feet of living shoreline at the park's Big Tree unit. The project will include close to a quarter of an acre of restoration activities for the wetland habitat.

Project Benefits:

The project will protect a valuable area at Goose Island State Park, and may provide benefits to ongoing oyster reef restorations in nearby waters. Goose Island offers camping, fishing and birding along St. Charles and Aransas bays, and is home to one of the largest and oldest live oak trees in Texas, and the nation. This park supports ecotourism, a variety of recreational experiences and the local Aransas County economy, which has high employment in leisure and hospitality services. This project is a candidate for beneficial use of dredged material to create and restore the habitat periodically, and to mitigate relative sea level rise.

Project Need:

The shoreline at Goose Island State Park is eroding at a rate of approximately 1.7 feet per year since 1951, and is need of protection and restoration. Texas is ranked 4th in the nation for the highest wildlife-associated expenditures, and conserving lands at Goose Island State Park contributes to the economic and recreational well-being of the region and the state.

Long Reef Rookery Island Shoreline Stabilization

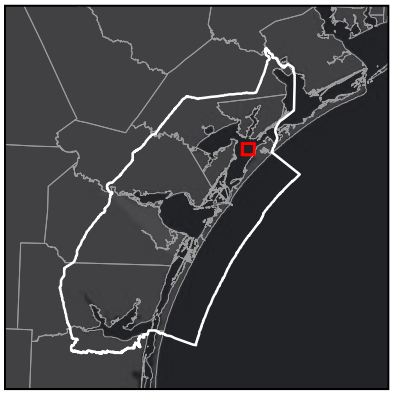
(Project ID R3-2)

Resiliency Strategy Addressed:

Rookery Island Creation & Restoration

County: Aransas

Location:
Aransas Bay, North of Big Island



Estimated Project Cost:
$1,000,000 – $3,000,000

Applied Project Types:

Project Description:

The project involves beneficial use placement of dredged material on the western tip of the Long Reef rookery island to raise its elevation, and installation of geotubes or other breakwaters and sediment retention structures.

Project Benefits:

Long Reef is a shell reef and dredge spoil island that is a popular fishing spot for trout and redfish, and valuable ground-nesting birding habitat for terns and skimmers. The local Aransas County economy has high employment in leisure and hospitality services catering to the tourism and ecotourism industries. Rookery island protection and creation supports the proliferation of avian and other specifies that contribute to the diversification of wildlife, thereby benefiting the ecotourism industry in the area. This project is a candidate for beneficial use of dredged material to create and restore the habitat periodically to mitigate relative sea level rise.

Project Need:

Shoreline stabilization is needed to prevent erosion to this island from wind waves and ship wakes from the GIWW. Only about 50 percent of the original island remains due to subsidence and erosion. Restoring the Texas rookery island system provides benefits to the state residents' and visitors' approximate annual 2 million birder trips.

Nueces River Delta Shoreline Stabilization

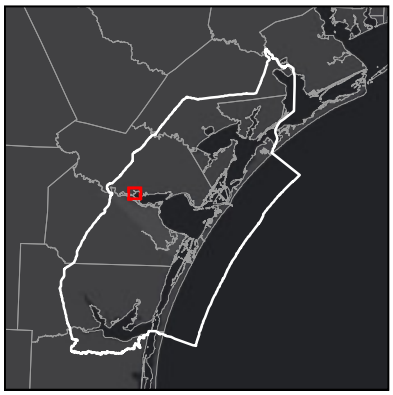
(Project ID R3-3)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

Counties: San Patricio, Nueces

Location:
The outfall of the Nueces River to Nueces Bay



Estimated Project Cost:
$3,000,000 – $8,000,000

Applied Project Types:

Project Description:

The project will include the construction of breakwaters along 2 miles of the Nueces River Delta to dissipate wave energy that is causing estuarine wetland losses. The GLO and the Coastal Bend Bays and Estuaries Program sponsored an alternatives analysis in 2014 for the feasibility, assessment and permitting of the shoreline protection structures.

Project Benefits:

This project will help protect thousands of acres of diverse coastal wetland and prairie habitat and living resources that lie behind the shoreline. Wetland preservation protects habitat for commercially and recreationally valuable species, which support the marine commercial and recreational fishing industries and other recreational activities, such as bird watching.

Project Need:

The westernmost shoreline of Nueces Bay at the Nueces River delta is rapidly eroding, with a documented erosion rate of 8.2 feet per year. According to the Coastal Bend Bays and Estuaries Program, the no-action scenario may lead to the complete collapse of Corpus Christi commercial and sport fisheries as the decline of nursery habitat irreparably damages the food web.

Mustang Island State Park Acquisition

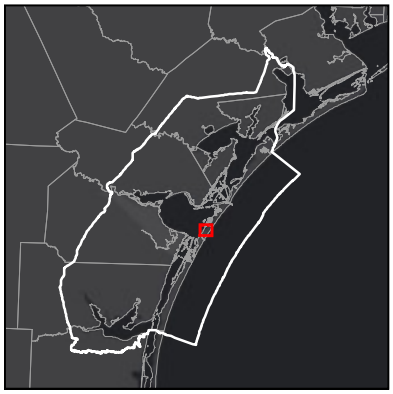
(Project ID R3-4)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

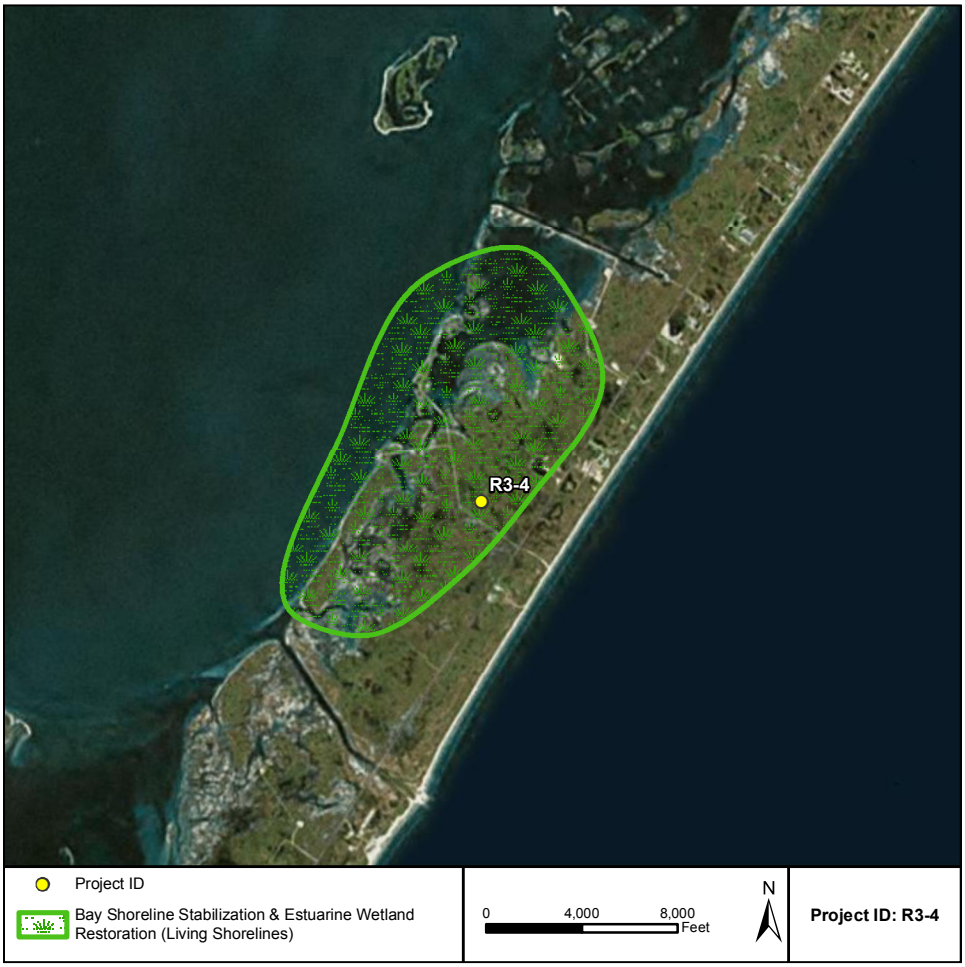
County: Nueces

Location:
Mustang Island,
Southeast of Corpus Christi Bay



Estimated Project Cost:
$3,000,000 – $10,000,000

Applied Project Types:



Project Description:

The project involves the acquisition of parts of Mustang Island and the protection of estuarine wetlands and coastal prairie dune and beachfront habitats. The proposed acquisition includes the Mustang Island State Park Conservation Initiative, which will create a contiguous 5,100 acre conservation area along the barrier island that will enhance the net biological value of the island.

Project Benefits:

The coastal dunes and wetlands are a first line of defense to protect the Corpus Christi Bay and mainland. The wetlands also will provide habitat for fish and wildlife. The preservation of multiple habitat types promotes diversity of wildlife and avian species, which provides benefits to ecotourism and other recreational activities. Dedicated land uses preclude development pressure that would otherwise put people and assets at risk from future storm events.

Project Need:

The coastal barrier island ecosystems on Mustang Island are unique and susceptible to human activity. Conservation of this area will avoid future economic damages or economic implications of needing to restore or re-create these ecosystems in the future. Texas is ranked 4th in the nation for the highest wildlife-associated expenditures, and conserving lands contributes to the economic and recreational well-being of the state.

Indian Point Shoreline Protection

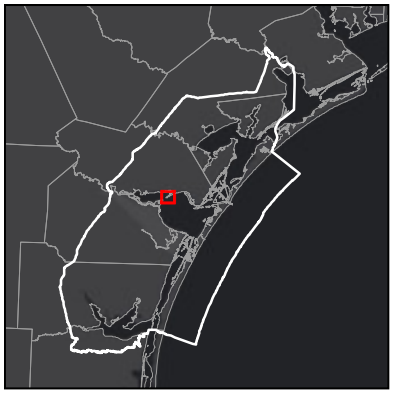
(Project ID R3-5)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: San Patricio

Location:
South of Highway 181, at the convergence of Nueces Bay and Corpus Christi Bay



Estimated Project Cost:
$500,000 – $2,000,000

Applied Project Types:

Project Description:

This project will protect over 50 acres of seagrass, wetlands and related habitat from shoreline erosion and retreat at Indian Point in Corpus Christi Bay by constructing an additional 1,760 linear feet of breakwaters for shoreline protection.

Project Benefits:

Protecting and restoring habitat for commercially and recreationally valuable species with the creation of estuarine wetlands and upland habitat supports the marine commercial and recreational fishing industries, and other recreational activities, such as bird watching. In particular, Indian Point is critical piping plover habitat.

Project Need:

Phase I of this project included the construction of approximately 1,040 linear feet of limestone revetment, which provides multiple benefits for stabilizing the shoreline. However, work is still needed in this area to prevent further erosion. In order to maximize the investment made in Phase I, the project should be taken to completion to ensure the existing wetlands, which are important to the Texas Birding Trail, are not further undermined by erosion. If Phase 2 does not occur erosion is still possible, as a significant portion is not protected and the area that is behind Phase I is subject to lesser protection due to northeastern exposure.

Shamrock Island Restoration – Phase 2

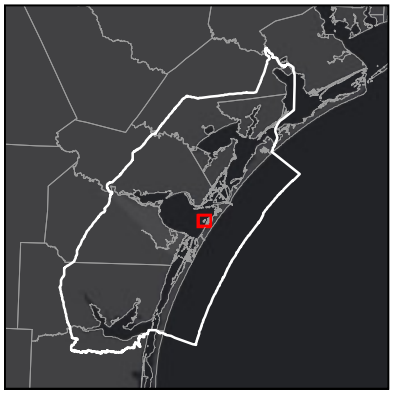
(Project ID R3-6)

Resiliency Strategy Addressed:

Rookery Island Creation & Restoration

County: Nueces

Location:
North of Shamrock Cove and Mustang Island



Estimated Project Cost:
$6,000,000 – $18,000,000

Applied Project Types:

Project Description:

This project involves installation of 900 feet of breakwaters, filling of a breach into one of the interior wetlands and lagoon, and installation of a feeder mound to help stabilize the breach fill around this rookery island.

Project Benefits:

Repairing the breach and adding breakwaters will protect approximately 2,000 linear feet of prime beach nesting habitat, 12 acres of estuarine wetlands, 14 acres of seagrass and 23 acres of upland nesting habitat from erosion. Improvements to the 150 acre rookery island will enhance the habitat of up to 21 bird species, including the reddish egret and white-faced ibis, which are listed as threatened in Texas. Preservation of diversified habitat encourages the growth of the ecotourism industry in Nueces County.

Project Need:

This project will restore an important rookery island in Region 3 and provide benefits to the birding populations in Texas, as well as the state's $1.4 billion ecotourism industry.

Guadalupe River Delta Estuary Restoration

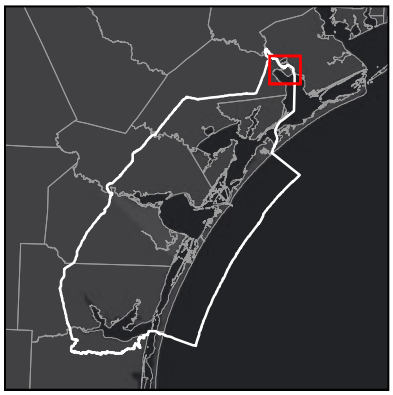
(Project ID R3-7)

Resiliency Strategy Addressed:

Delta & Lagoon Restoration

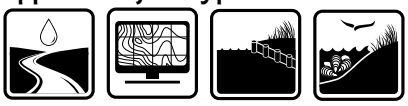
County: Refugio

Location:
The Mouth of the Guadalupe River in Northern San Antonio Bay



Estimated Project Cost:
$2,000,000 – $6,500,000

Applied Project Types:



Project Description:

The project involves restoration of river flows to the terminal end of the delta in addition to creating a living shoreline to guard against wind and wave erosion. Diversion of Traylor Cut to reconnect river flows will help mitigate erosion and maintain the functionality of the estuary.

Project Benefits:

Restoring the hydrology and inflows to the Guadalupe River Delta are key to stabilizing the vitality of the delta and realizing the full benefits throughout the corresponding bay system estuarine habitat and ecosystem services. Region 3 has a large employment base in leisure and hospitality services that caters to tourism, including ecotourism, and this project will support continued economic and ecological successes in the region.

Project Need:

The diversion of river flows through Traylor Cut depleted the quantity and quality of freshwater and nutrient inflows to the river delta, which are in critical need of restoration. Over the next 50 years, nearly 80 acres of the delta are projected to erode based on historic rates if this project does not occur.

Fulton Beach Road Living Shoreline

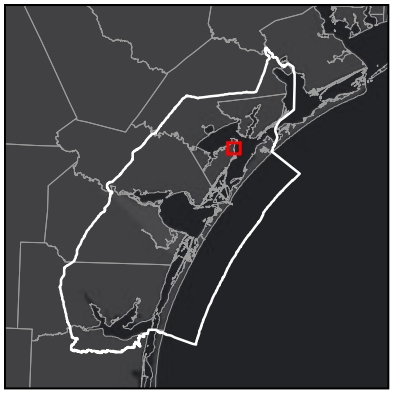
(Project ID R3-8)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Aransas

Location:
South of the Lyndon B. Johnson Causeway, at the convergence of Copano Bay with Aransas Bay



Estimated Project Cost:
$4,500,000 – $15,000,000

Applied Project Types:

Project Description:

The project will construct up to 4 miles of breakwaters along Fulton Beach in Aransas County. The project includes regrading and filling along the shoreline with vegetative plantings to establish a living shoreline system.

Project Benefits:

This project will protect Fulton Beach Road, as well as 70 acres of waterfront property. Protecting habitat for commercially and recreationally valuable spaces will support the coastal community and recreational industries, and thereby sustain economic diversity along the coast.

Project Need:

The 70 acres at risk of erosion along the project site have a cumulative value of $14 million. Additionally, this roadway is critical to the local communities as an evacuation route, which could be undermined or damaged if the erosion in this area is not controlled.

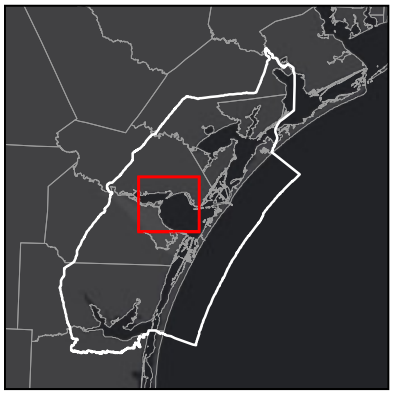
Corpus Christi & Nueces Bays Oyster Reef Restoration *(Project ID R3-9)*

Resiliency Strategy Addressed:

Oyster Reef Creation & Restoration

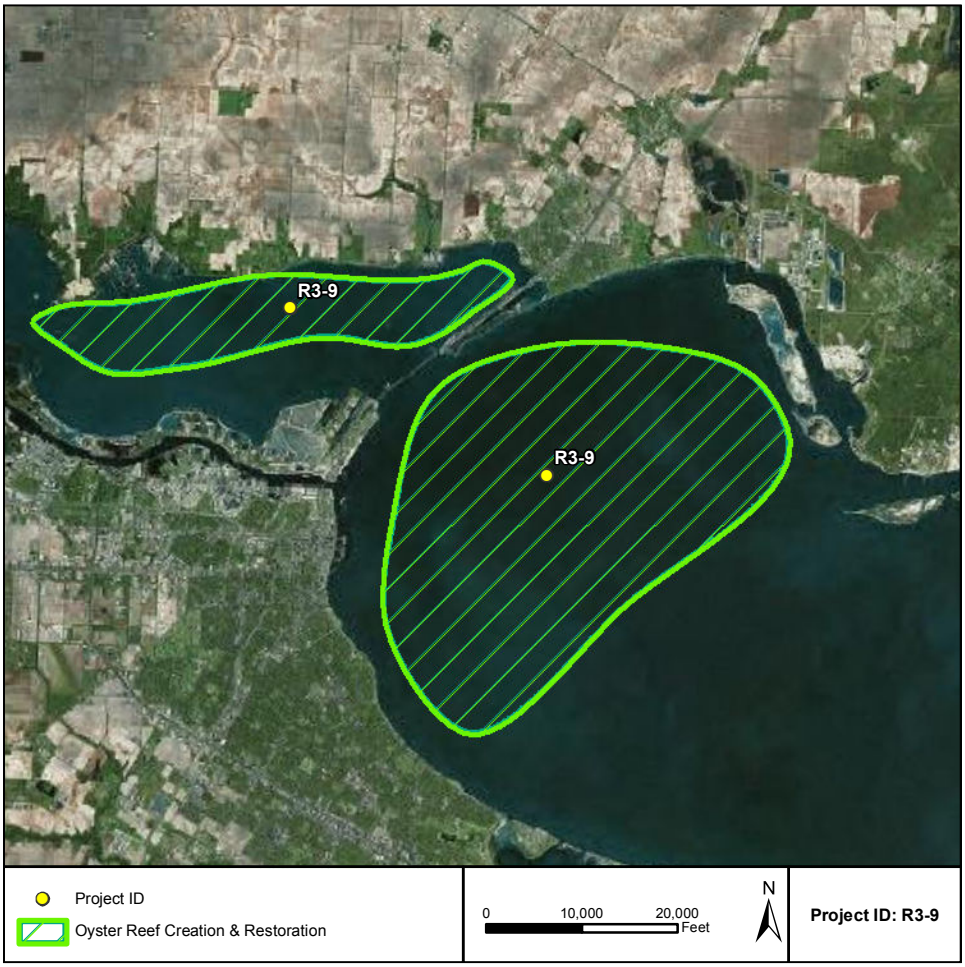
Counties: Nueces, San Patricio

Location:
Corpus Christi Bay and Nueces Bay



Estimated Project Cost:
$1,000,000 – $10,000,000

Applied Project Types:



Project Description:

This project will identify locations to restore degraded oyster reefs in Corpus Christi and Nueces bays. Restoration of reefs will likely occur in areas where there is evidence of previously existing reef (hard bottom, calcified bottom or shell remnants), but may also include the creation of new reefs.

Project Benefits:

Notable benefits of oyster habitat creation are oyster harvest, water filtration, aquatic habitat diversity and shoreline protection by wave energy attenuation. Restoration of oyster reefs supports the commercial and recreational fisheries in Texas, and helps sustain a diversified economy. The recreational value associated with species diversity of oyster reefs supports the state's $1 billion marine recreational fishing industry.

Project Need:

Nature-based and man-made impacts have degraded or reduced many of the reefs in Texas bays. This project will prioritize building vertical structures into the restoration of oyster reefs. Consideration will be given to the physical systems surrounding the proposed reef environments as well as the impacts of human activities to ensure the viability of creating or restoring reefs.

Coastal Bend Gulf Barrier Island Conservation

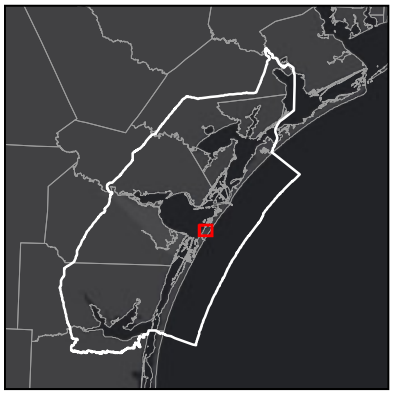
(Project ID R3-10)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Nueces

Location:
Mustang Island and North Padre Island



Estimated Project Cost:
$500,000 – $1,500,000

Applied Project Types:

Project Description:

The project proposes to acquire land, purchase development rights, and donate conservation easements to protect essential habitat on Mustang Island and North Padre Island.

Project Benefits:

Dedicated land use precludes development pressure that puts people at risk and avoids future losses from storm events. Preservation of multiple habitat types promotes diversity of wildlife, which contribute to ecotourism and other recreational activities. Open space land use is a preferred method to reduce risk to populations, as it prevents development in high risk areas, and these open space locations on Mustang Island and North Padre Island promote overall resiliency. Preference will be given to areas that have willing sellers and can be adjoined to existing preserves.

Project Need:

These barrier islands are home to critical habitats that are deteriorating, including tidal flats, beaches and dunes. It is far more economical to conserve coastal lands than to go through the expense of re-creating these lands in the future.

Nueces County Hydrologic Restoration Study

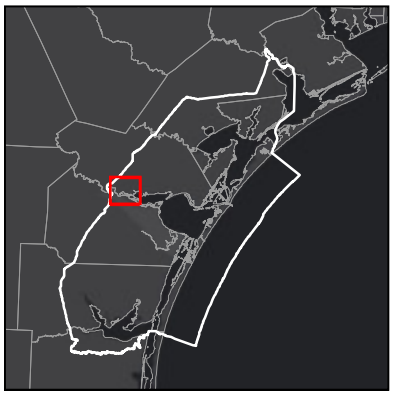
(Project ID R3-11)

Resiliency Strategy Addressed:

Delta & Lagoon Restoration

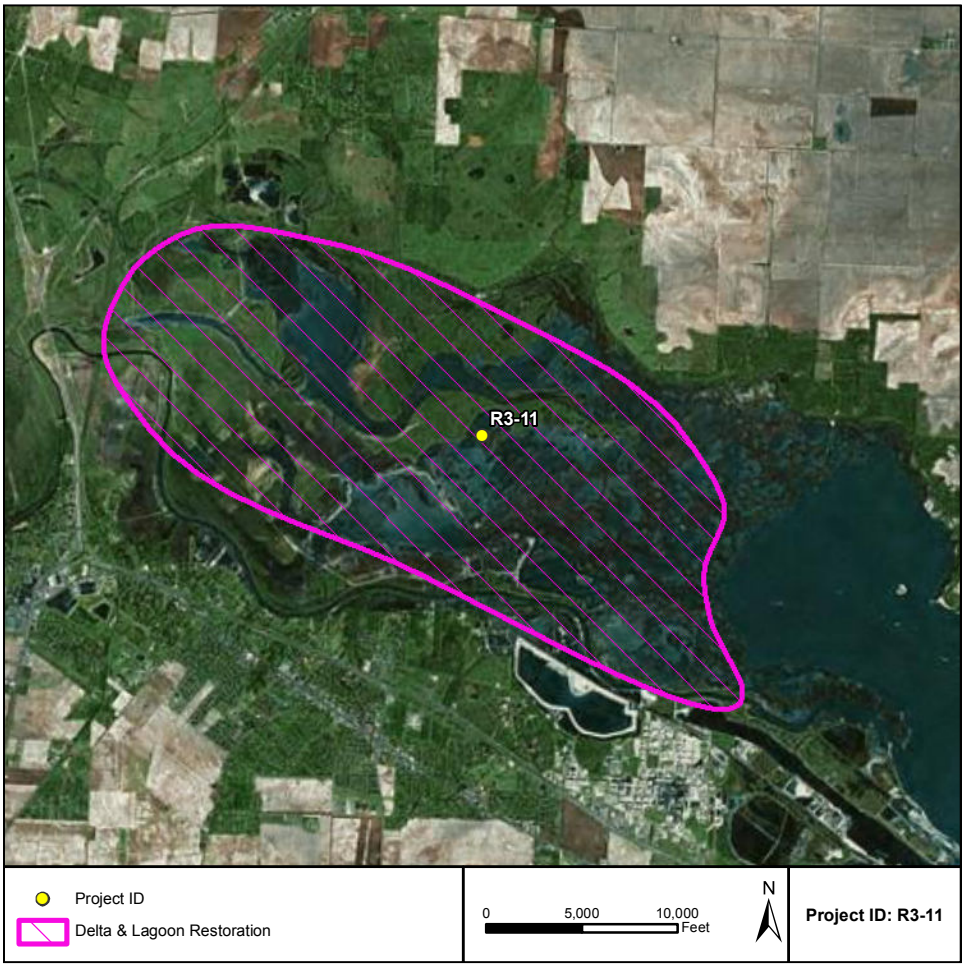
Counties: Nueces, San Patricio, Aransas

Location:
Throughout Nueces County



Estimated Project Cost:
$500,000 – $2,500,000

Applied Project Types:



Project Description:

An adaptive management plan and/or study will look at the interactions of the physical systems that affect the hydrology in Nueces County, as well as the stakeholder interactions in the region. The plan will identify how to best restore coastal ecosystems within the delta system in a manner that is more resilient to freshwater inflow fluctuations. This plan or study will be invaluable for long-term decision making for the mutual benefits of all of the county's residents and industries.

Project Benefits:

Restoring the freshwater and tidal inflows into the system can restore the ecological value to the area for commercially and recreationally important species, supporting the diversification and economic resilience of the coast.

Project Need:

The coastal systems throughout Nueces County are experiencing impaired quality and lower quantities of freshwater inflows to Nueces Bay and Corpus Christi Bay, possibly due to industrial and commercial upland developments. The water quality and quantity issues impact physical processes throughout the bays, and exacerbate degradation of coastal habitats.

Portland Living Shoreline

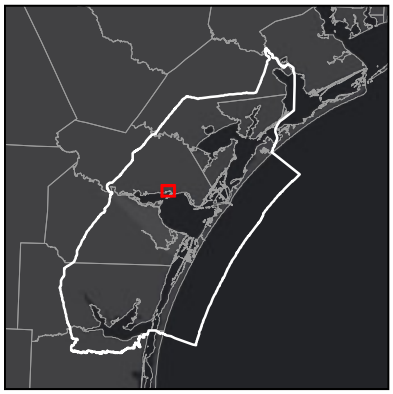
(Project ID R3-12)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

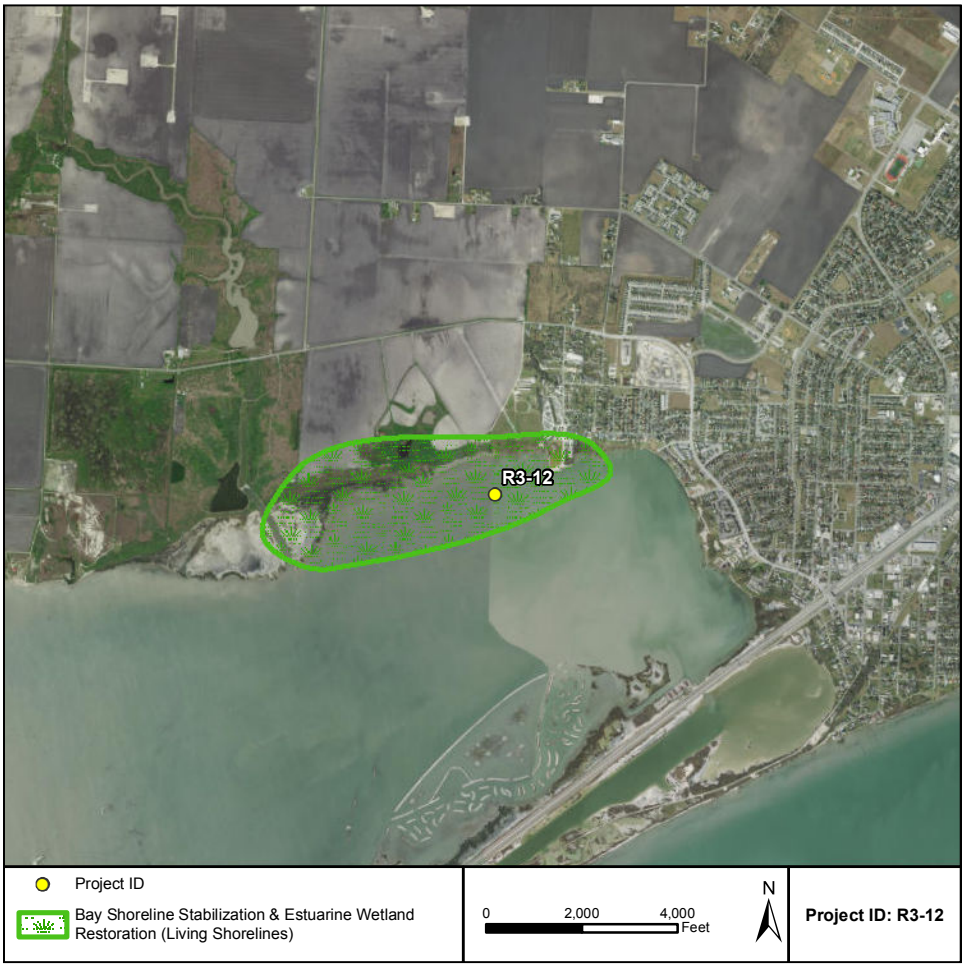
County: San Patricio

Location:
The Northeast Corner of Nueces Bay



Estimated Project Cost:
$1,000,000 – $3,500,000

Applied Project Types:



Project Description:

The project will create a living shoreline near southwest Portland to prevent shoreline erosion and enhance wetland habitats. This area of shoreline has degraded due to population growth and land use conversion, in addition to wind-driven erosion.

Project Benefits:

This project will protect the 5 acres of shoreline, and the roads, property, and infrastructure behind the shoreline, which would otherwise require relocation or abandonment based on current erosion trends. The project will also serve as an example of living shoreline techniques to increase coastal resiliency in a highly visible location for the public.

Project Need:

Over the next 50 years, 5 acres of shoreline are projected to erode based on historic shoreline retreat rates without the project.

Shell Point Ranch Wetlands Protection

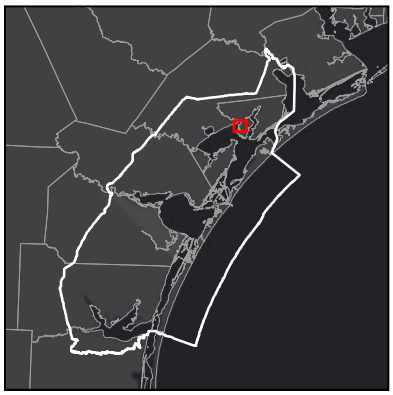
(Project ID R3-13)

Resiliency Strategy Addressed:

Freshwater Wetlands & Coastal Uplands Conservation

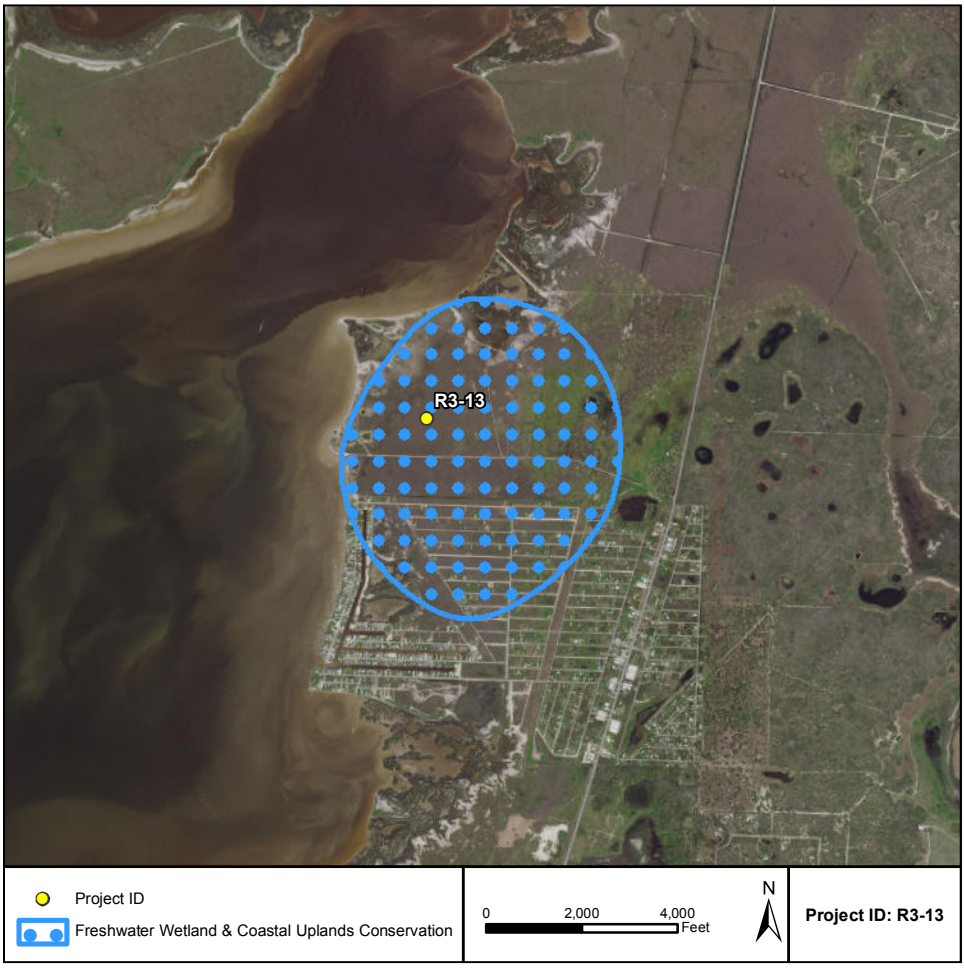
County: Aransas

Location:
On Copano Bay, North of Holiday Beach



Estimated Project Cost:
$2,000,000 – $5,000,000

Applied Project Types:



Project Description:

The acquisition of approximately 400 acres of coastal habitats that support coastal prairie, freshwater and estuarine wetlands, and the southernmost extents of Mima mounds at Shell Point Ranch.

Project Benefits:

The mosaic of habitats proposed for acquisition supports Mottled Duck and whooping cranes, in addition to other wildlife. The acquisition will also mitigate flooding and storm surge damage to the area.

Project Need:

Nearby development threatens upland prairie and wetlands, which are necessary for wildlife diversity. Open space is needed as wildlife habitat for species that contribute to ecotourism and other recreational activities.

Dagger Island Living Shoreline

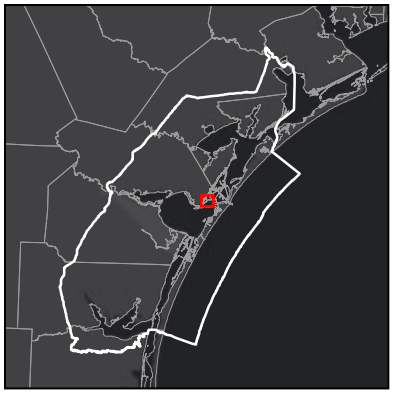
(Project ID R3-14)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Nueces

Location:
West of Ingleside, on the Southern Edge of Redfish Bay and just North of Corpus Christi Bay



Estimated Project Cost:
$1,000,000 – $2,500,000

Applied Project Types:

Project Description:

The project will eliminate or drastically reduce the rate of shoreline erosion and island migration by protecting the shoreline of Dagger Island, using up to 1 mile of nearshore breakwaters. The project will restore up to 30 acres of the island by coordinating with the Aransas Navigation District to beneficially use dredged material.

Project Benefits:

The project focuses on protecting shallow aquatic habitat, submerged aquatic vegetation, oyster reefs, estuarine wetlands, mangroves, seagrasses, tidal flats and associated uplands important for the health of the entire bay ecosystem. Protecting and restoring habitat for valuable species with the creation of wetlands and upland habitat supports bird watching and creates a nursery habitat for finfish. Restoration will contribute to the state's $262 million commercial fishing industry and $1 billion marine recreational fishing industry. This project is a candidate for beneficial use of dredged material to create and restore the habitat periodically to mitigate relative sea level rise.

Project Need:

The current rate of erosion, averaging between 1.3 feet and 5.6 feet per year, has breached in several areas and is showing adverse impacts on valuable habitats. Over the next 50 years, 27 acres are expected to erode based on historic rates if the project does not occur.

Flour Bluff Living Shoreline

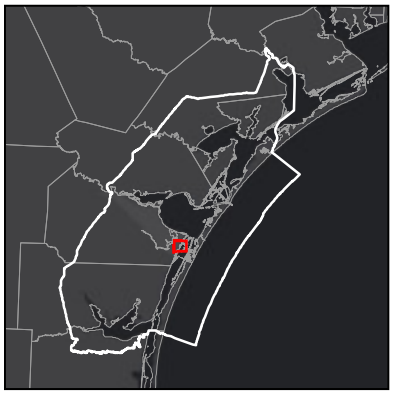
(Project ID R3-15)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

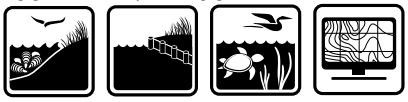
County: Nueces

Location:
West Corpus Christi Bay, at Flour Bluff



Estimated Project Cost:
$1,500,000 – $4,500,000

Applied Project Types:



Project Description:

This project will create approximately 1.5 miles of living shoreline to act as a buffer between Laguna Shores Road and the highly erosional shoreline of Laguna Madre, along the eastern shoreline of Flour Bluff.

Project Benefits:

Creating a living shoreline will help to attenuate wave energy and its erosive effects on Laguna Shores Road, thereby protecting roadways, houses and infrastructure in Corpus Christi. The project will be a collaborative opportunity for the City of Corpus Christi to pilot the inclusion of coastal resiliency considerations in the planning of transportation infrastructure projects.

Project Need:

Laguna Shores Road is vulnerable to erosion, flooding and washout from Laguna Madre. There is currently no buffer between the roadway and the Upper Laguna Madre.

Causeway Island Rookery Habitat Protection

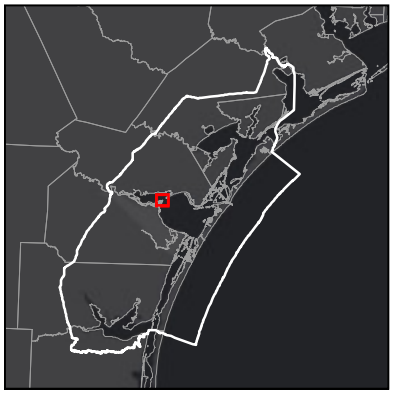
(Project ID R3-16)

Resiliency Strategy Addressed:

Rookery Island Creation & Restoration

County: Nueces

Location:
North of the
Corpus Christi Bay Causeway



Estimated Project Cost:
$500,000 – $2,000,000

Applied Project Types:

Project Description:

The project will replace failing geotubes with a 300-foot long hardened breakwater structure to retain sediment placed during recurring dredging events, which will protect the island from wind and wave erosion. The Coastal Bend Bays & Estuary Program has an ongoing partnership with the Port of Corpus Christi to beneficially place dredged materials on the island. The design for this project is already funded to create and restore the habitat periodically to mitigate relative sea level rise.

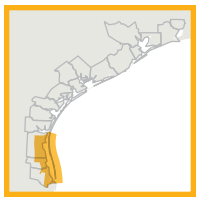
Project Benefits:

Causeway Island is currently 7 acres in size and serves as roosting and nesting habitat to support approximately 3,070 pairs of breeding colonial waterbirds per year, and harbors numerous threatened and priority avian species. This project provides avian habitat for recreational activities such as birdwatching and contributes to the growing ecotourism industry in Nueces County.

Project Need:

The erosion of the island's shoreline is causing the ongoing loss of critical rookery island habitat. Approximately 45 feet of shoreline eroded in 2014 alone, due to a failed geotube structure. Restoration of this island is imperative to avoid and prevent such dramatic land losses, which endanger bird populations and detract from the region's bird tourism industry.

Region 4 Project Summaries



Counties:
Cameron, Kenedy, Willacy

Total Estimated Cost Range for Projects:
$51,500,000 - $125,000,000

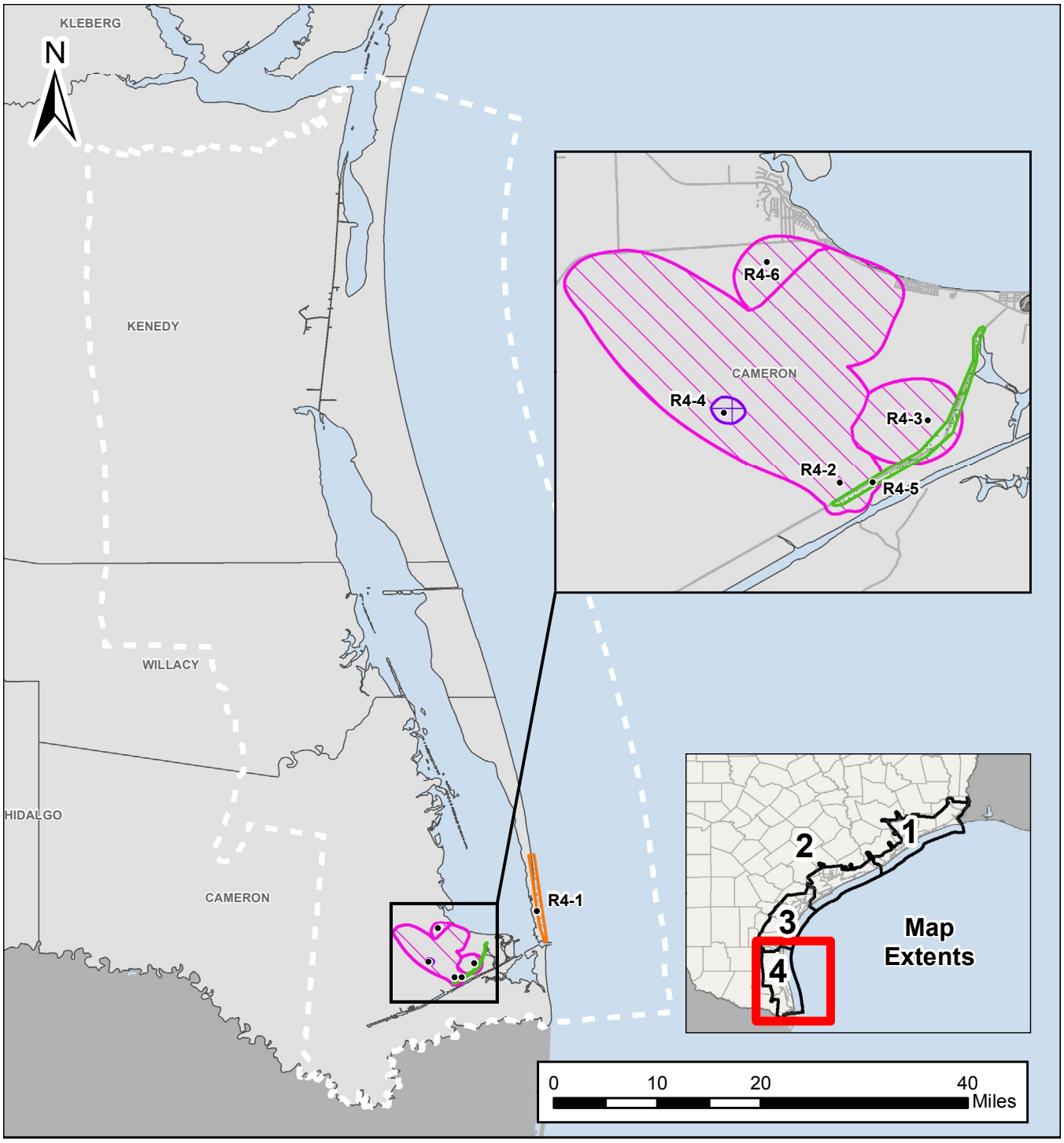
Priority Issues of Concern:

- Gulf Beach Erosion & Dune Degradation
- Altered, Degraded or Lost Habitat
- Water Quality Impacts
- Coastal Resources Impacts

Region 4 – Tier 1 Projects

ID	Tier 1 Projects	Project Type(s)*
R4-1	City of South Padre Island Gulf Shoreline Restoration	
R4-2	Bahia Grande Hydrologic Restoration	
R4-3	Paso Corvinas Wetlands & Hydrologic Restorations	
R4-4	Bird Island & Heron Island Restoration	
R4-5	Bahia Grande Living Shoreline	
R4-6	Laguna Heights Wetlands Acquisition	

**Reference Figure 5.3 – Project Categorization – on page 65 for a listing and explanation of the project types addressed by the recommended Tier 1 projects.*



Resiliency Strategy Project Locations

- Restoration of Beaches & Dunes
- Bay Shoreline Stabilization & Estuarine Wetland Restoration (Living Shorelines)
- Rookery Island Creation & Restoration
- Delta & Lagoon Restoration

City of South Padre Island Gulf Shoreline Restoration

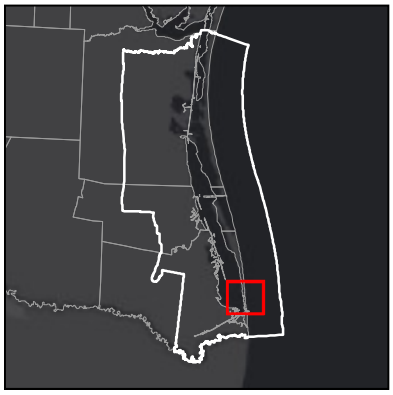
(Project ID R4-1)

Resiliency Strategy Addressed:

Restoration of Beaches & Dunes

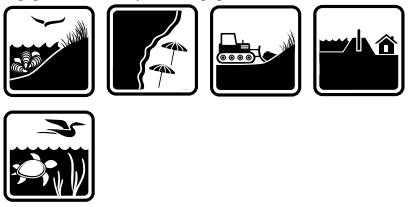
County: Cameron

Location:
The City of South Padre Island Gulf Shoreline



Estimated Project Cost:
$40,000,000 – $80,000,000

Applied Project Types:



Project Description:

This project will provide beach nourishment and dune restoration for up to 8 miles along the Town of South Padre Island's Gulf shoreline, primarily through the beneficial use of dredged materials from the adjacent ship channel. A recommendation of phased 1.5-mile stretches of shoreline, focused on critical needs, is proposed to account for sediment and budget limitations, as opposed to addressing the full project length in a single phase of work. This is a continuation of similar beach nourishment activities that have been undertaken in past years for the area.

Project Benefits:

The establishment of continuous dune systems provides the first line of defense from frequent coastal flooding. It is important to maintain these coastal features in order to support and protect the tourism communities and rebuild the natural habitats and protection offered by the coastline. The local economy is dependent upon the recreational value that beaches and beachfront amenities provide. The market appeal of nearby beaches and ocean views supports extensive development along the coast, which contributes to its overall market value.

Project Need:

This project is a continuation of similar beach nourishment activities that are necessary to help protect the community from the impacts of tropical storms and hurricanes. Additionally, the shoreline has experienced heavy and persistent erosion of its beaches and dunes, with some areas showing losses of 9 feet or more per year. Over the next 50 years, more than 100 acres are projected to erode based on historic rates without the project.

Bahia Grande Hydrologic Restoration

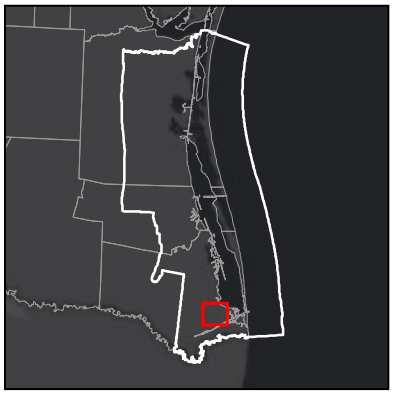
(Project ID R4-2)

Resiliency Strategy Addressed:

Delta & Lagoon Restoration

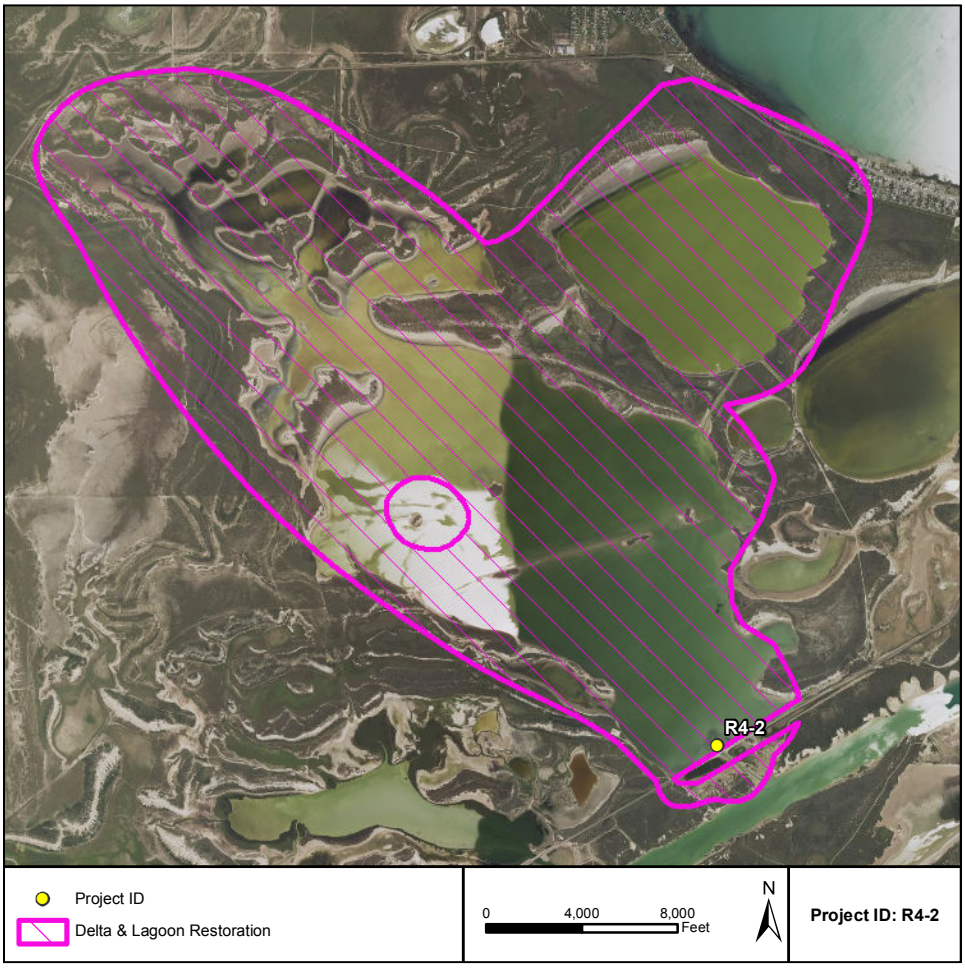
County: Cameron

Location:
The Bahia Grande



Estimated Project Cost:
$3,000,000 – $12,000,000

Applied Project Types:



Project Description:

This project will enhance the ecology of the Bahia Grande system by ensuring natural tidal flow and exchange. This will be accomplished by widening and deepening the existing inlet channel for tidal exchange to fully restore the natural biological functions of the wetlands.

Project Benefits:

This project will improve tidal flow into the Bahia Grande and its neighboring basins, and thereby regulate flow and salinity levels. This project will build on previous efforts, beginning in 2005, when a pilot channel was constructed that connected the Brownsville Ship Channel to the Bahia Grande, and in 2007, when two interior channels were cut that reconnected the larger basin to the Laguna Larga and the Little Laguna Madre.

Project Need:

If efforts are not taken to fully restore the hydrology of the Bahia Grande, there is an elevated risk of further wetland loss, fish kills, and loss of the finfish nursery and birding habitats. This will negatively impact Cameron County, which has a large export economy in commercial fishing and the Port of Brownsville-Port Isabel, which ranks first in value of commercial fishery landings and second in landings weight in Texas.

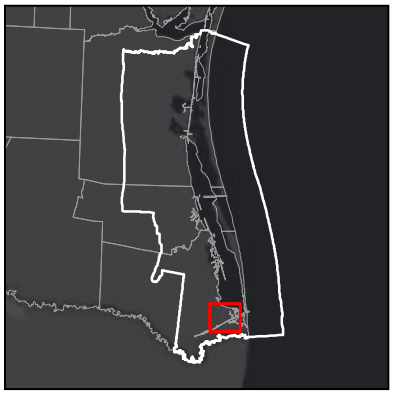
Paso Corvinas
Wetlands & Hydrologic Restorations *(Project ID R4-3)*

Resiliency Strategy Addressed:

Delta & Lagoon Restoration

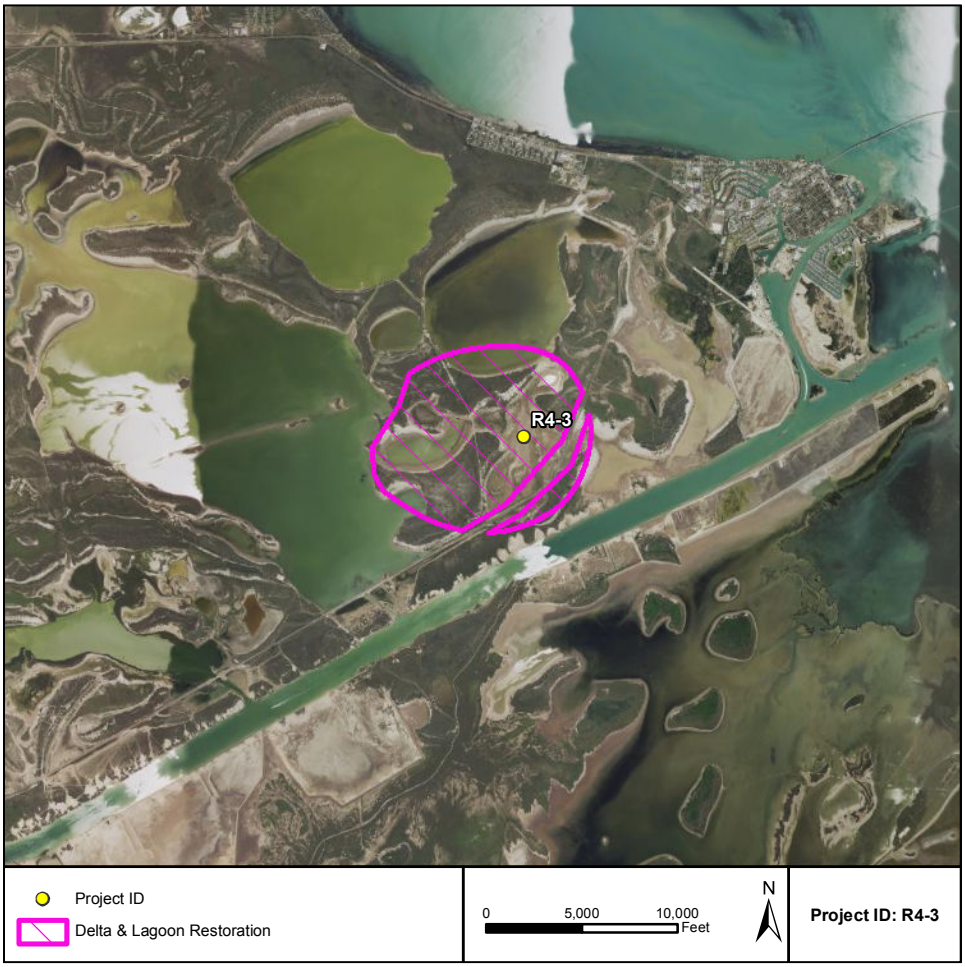
County: Cameron

Location:
The Bahia Grande and the Vadia Ancha



Estimated Project Cost:
$500,000 – $2,000,000

Applied Project Types:



Project Description:

The project will restore the wetland area near Paso Corvinas to its natural tidally-influenced condition by improving connectivity between the Bahia Grande and the Vadia Ancha, through the Paso Corvinas. This project also will remove accumulating sand bars that restrict the natural circulation between the Bahia Grande and Paso Corvinas. A hydrological study will be performed, followed by design and construction of the preferred restoration alternative.

Project Benefits:

Restoring circulation within this lagoon has the potential to generate widespread benefits to habitats and ecologies throughout, including wetlands, finfish and shellfish, bird populations and other wildlife.

Project Need:

If the connectivity of this system is not restored, there is a high risk of losing wetlands and habitat over time. The altered hydrology in the Bahia Grande system has been associated with fish kills, which impact Cameron County's large export economy in commercial fishing and the Port of Brownsville-Port Isabel, which ranks first in value of commercial fishery landings and second in landings weight in Texas.

Bird Island & Heron Island Restoration

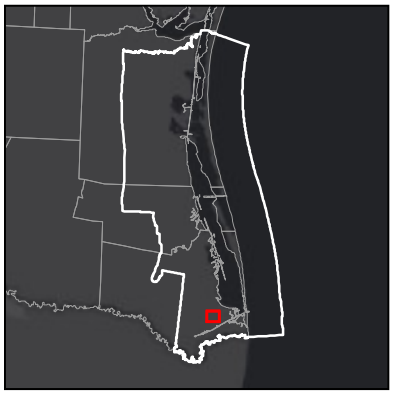
(Project ID R4-4)

Resiliency Strategy Addressed:

Rookery Island Creation & Restoration

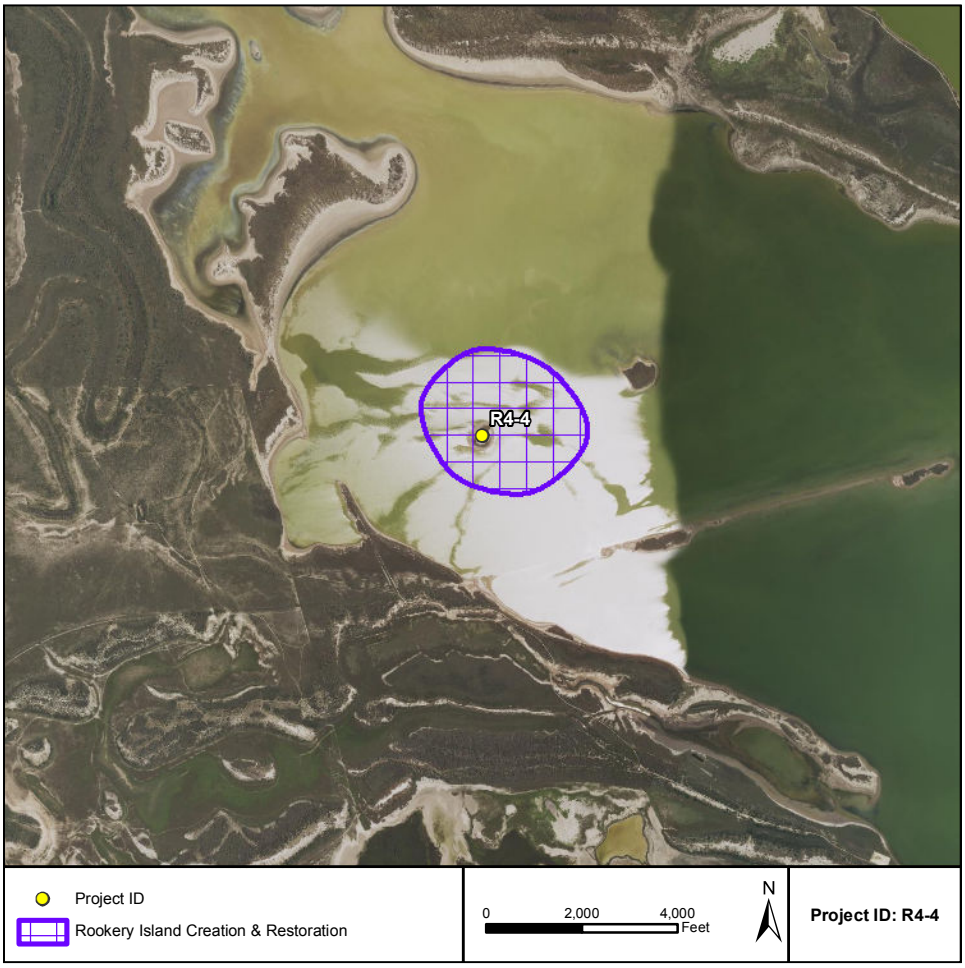
County: Cameron

Location:
The Bahia Grande



Estimated Project Cost:
$1,000,000 – $10,000,000

Applied Project Types:



Project Description:

The project will construct approximately 1 mile of breakwaters to control erosion and reduce the loss of critical bird habitat on Bird Island and Heron Island – two rookery islands located in the Bahia Grande. A feasibility study has already been funded to determine the most effective methods to protect these islands, and the final design of this project will build upon these efforts.

Project Benefits:

Bird Island and Heron Island provide refuge from predators for thousands of nesting terns, support populations of snowy egrets, reddish egrets, roseate spoonbills, gulls and osprey, and are critical habitat for the wintering piping plover, which is recognized as a threatened species. Rookery island restoration supports the proliferation of avian and other specifies that contribute to the diversification of wildlife in the Bahia Grande estuarine complex, and benefits the ecotourism economy.

Project Need:

Without this project, valuable rookery acreage will be lost to coastal erosion. A fully functioning rookery island system along the Texas coast is essential to maintain birding populations and support the state's $1.4 billion ecotourism industry.

Bahia Grande Living Shoreline

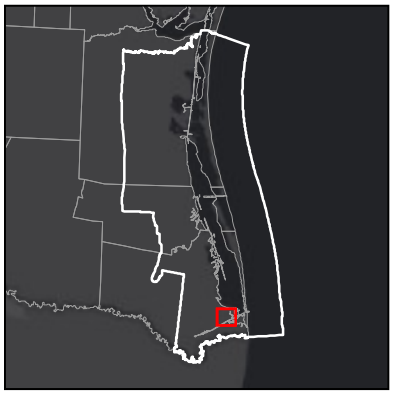
(Project ID R4-5)

Resiliency Strategy Addressed:

Bay Shoreline Stabilization & Estuarine Wetland Restoration

County: Cameron

Location:
The Bahia Grande



Estimated Project Cost:
$1,000,000 – $5,000,000

Applied Project Types:

Project Description:

The project will create a living shoreline near the inlet to the Bahia Grande using naturally-based, native materials. There may be opportunities to beneficially use material from maintenance dredging of the Brownsville Ship Channel.

Project Benefits:

This project will protect the Bahia Grande banks and shoreline from erosion due to vessel traffic, wind and increased tidal flow rates. Living shorelines are a resilient methodology proposed to combat bay shoreline erosion while promoting habitat restoration and creation. When fully restored, the 10,000 acres of wetlands in the Bahia Grande complex will enhance habitat for wildlife and fisheries, improve environmental conditions in surrounding communities, mitigate damage from tropical storms and hurricanes, provide opportunities for recreation and environmental education, and contribute to the local economy through increased nature tourism.

Project Need:

Shoreline erosion and scouring will continue or increase as a result of widening the inlet to the Bahia Grande, undermining its functionality. This project is a key component to ensure that inlet modifications to the Bahia Grande do not generate erosive conditions near the channel mouth and endanger vessel traffic.

Laguna Heights Wetlands Acquisition

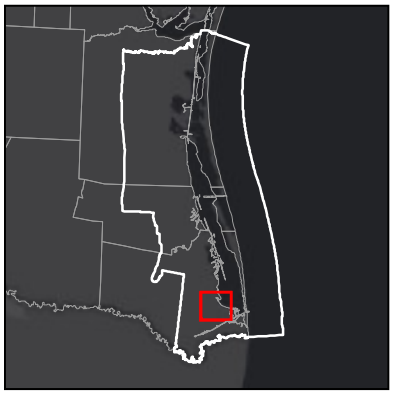
(Project ID R4-6)

Resiliency Strategy Addressed:

Delta & Lagoon Restoration

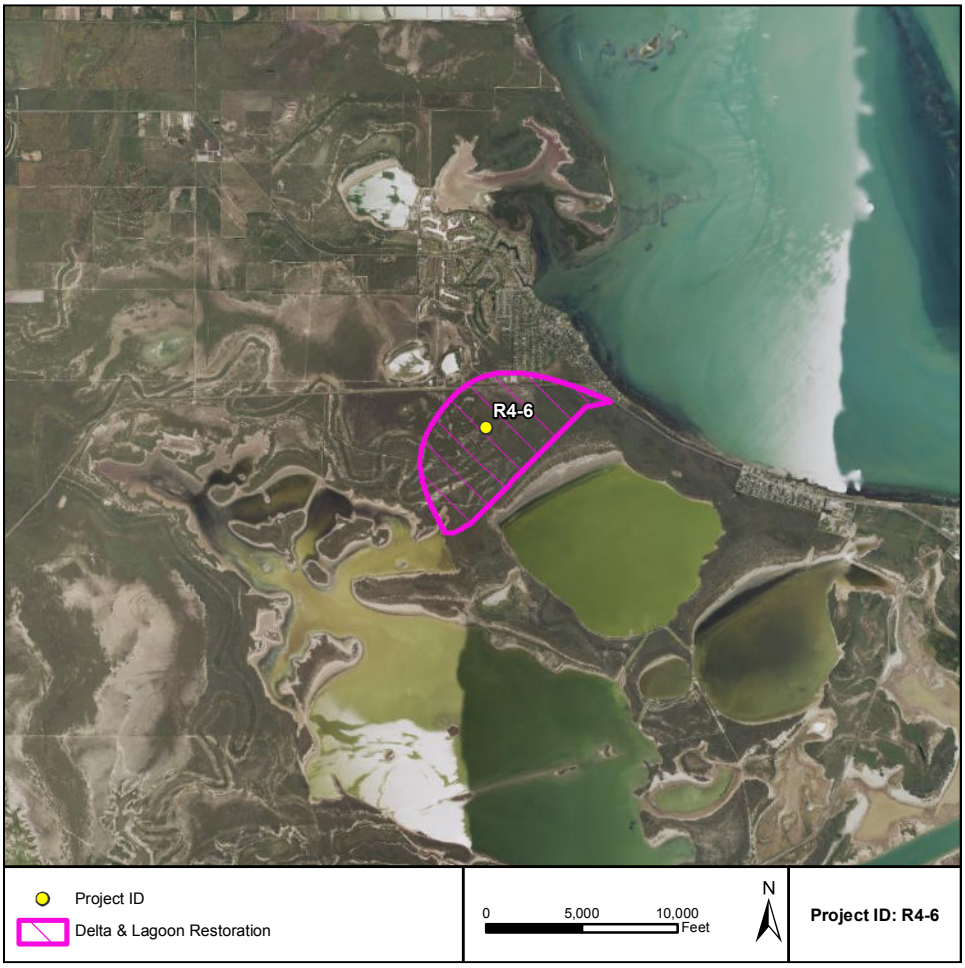
County: Cameron

Location:
Northeast of the Bahia Grande



Estimated Project Cost:
$6,000,000 – $16,000,000

Applied Project Types:



Project Description:

The project will protect wetland, coastal prairie and thornscrub habitat adjacent to the Bahia Grande unit of the Laguna Atascosa National Wildlife Refuge through the acquisition of the 1,400 acre Laguna Heights parcel.

Project Benefits:

When fully restored, the 10,000 acres of wetlands will enhance habitat for wildlife and fisheries, improve environmental conditions in surrounding communities, provide opportunities for recreation and environmental education, and contribute to the local economy through increased nature tourism. This project contributes to the Bahia Grande restoration, and the further expansion of ecotourism in the Rio Grande Valley.

Project Need:

Without the protection of this parcel, the shoreline of the Bahia Grande wetland complex will remain unprotected and subject to erosion. The maintenance of the functional value of the Bahia Grande wetland system, much of which has recently been restored, will be more challenging without this site serving that function. The adjacent habitats require restoration and protection to facilitate re-establishment of the hydrology and to regulate nutrient inflows throughout the Bahia Grande.

GLOSSARY

Accrete: The accumulation of sediment.

Abandoned structure/vessel: Derelict structures (e.g., piers, docks, pilings, debris, duck blinds, floating cabins) and vessels (e.g., boats, barges) that have been abandoned in coastal waters and on state-owned lands.

Attributes: Project-specific data that define the characteristics of a given project (e.g., location, cost, project type).

Barrier islands: Long, relatively narrow offshore deposits of sand and sediment that run parallel to the mainland along the coast. These landforms are separated from the mainland by shallow bays or lagoons.

Bays: Bodies of water that are partially enclosed by land, bounded on the Gulf side by barrier islands and peninsulas, and connected to the Gulf by passes and inlets.

Beach access: The right to use and enjoy the public beach, including the right of free and unrestricted ingress and egress to and from the public beach.[69]

Beach/dune system: The land from the line of mean low tide of the Gulf of Mexico to the landward limit of dune formation.[69]

Beach monitoring and maintenance: Tracking and collecting data to identify areas impacted and the amount of sand lost on engineered beaches during natural disasters. A Beach Monitoring and Maintenance Program is a prerequisite for the state to receive federal funding for the replacement of sand on engineered public beaches impacted by federally declared disasters, such as tropical storms and hurricanes.

Beach nourishment: The placement of beach-quality sediment on an eroded beach to restore it as a recreational beach, provide storm protection for upland property, maintain a restored beach by the replacement of sand, or serve other similar beneficial purposes.[i]

Beneficial use of dredged material: Refers to the use of sediments dredged, or dug, from the bottom of navigation channels in subsequent construction projects. Re-using dredged materials typically reduces the labor and expense that would be associated with completing the dredging and construction activities separately.

Bottomland hardwood forests: Forested areas adjacent to streambanks and floodplains; common tree species found in these forested areas include bald cypress, water tupelo, oaks, hickory, elm, green ash, red maple and black willow.

Brackish water: A mixture of freshwater and saltwater.

Breach: Erosion in estuaries, wetlands and marshes that changes ambient salinity gradients and land formations.

Breakwaters: Hard structures, typically built parallel to the shoreline, used to mitigate shoreline erosion.

Buffer areas: Undeveloped lands that protect coastal areas, inland habitats, and communities and infrastructure from flooding and storm surge.

Built environment: The man-made infrastructure and surroundings that support human activity (e.g., buildings, roads, channels, parks).

Bulkhead: A structure or partition built to retain or prevent the sliding of land. A secondary purpose is to protect the upland against damage from wave action.[69]

Chenier plains: Low-lying marshes and tidal flats with intermittent thin, linear sand ridges.

Coastal erosion: The loss of land, marshes, wetlands, beaches, or other coastal features within the coastal zone because of the actions of wind, waves, tides, storm surges, subsidence, or other forces.[i]

Coastal hazards: Issues that are putting the environmental and economic health of the coast at risk.

Coastal prairies: Large, open expanses of coastal upland with continuous, grassy vegetation and located immediately inland of coastal marshes.

Coastal resiliency: The ability of coastal resources and infrastructure to withstand and rebound from natural and human-induced disturbances.

Coastal resources: Living resources, including oysters, turtles, birds, fish, crabs and several endangered species that are sensitive to environmental changes.

i. Texas Natural Resources Code. 2015. NAT RES § 33.601. Available at: http://www.statutes.legis.state.tx.us/?link=NR (accessed Feb 28, 2017)

Coastal uplands: Coastal uplands are areas adjacent to coastal wetlands and can encompass various ecosystems, including swamps, bottomland hardwood forests, coastal prairies, live oak woodlands and thorny brush.

Coastal zone: The Texas Coastal Management Program boundary area that the GLO is required to regulate through state and federal laws.

Conservation: The practice of preserving habitat in its current condition.

Conservation easements: Dedicated conservation areas created by purchasing development rights to protect essential habitat.

Critical dune areas: Those portions of the beach/dune system as designated by the General Land Office that are located within 1,000 feet of mean high tide of the Gulf of Mexico that contain dunes and dune complexes that are essential to the protection of public beaches, submerged land, and state-owned land, such as public roads and coastal public lands, from nuisance, erosion, storm surge, and high wind and waves. Critical dune areas include, but are not limited to, the dunes that store sand in the beach/dune system to replenish eroding public beaches.[69]

Cultch: Shell, limestone, rubble, or other hard material that provides habitat for oyster colonization.

Current: The flow of water.

Deltas (Deltaic): Sediment deposits at the mouth of a river; over time, a complex of channels, sand bars and marshes may form.

Derelict structure/vessel: A structure or vessel that is inoperable or in a state of disrepair.

Deposition: The process in which sand and sediments settle out of, or are no longer suspended in, the water column.

Dike: See "levee."

Diversion: The process of rerouting a water body from its current course.

Dredged material: Sediments dredged, or dug, from the bottom of navigation channels in subsequent construction projects.

Drivers: Social, economic or natural, influences on the current conditions of the coast that are largely external to the coastal system and are instigated by need, including demand for food, health, clean water and energy.

Dune: An emergent mound, hill, or ridge of sand, either bare or vegetated, located on land bordering the waters of the Gulf of Mexico. Dunes are naturally formed by the windward transport of sediment, but can also be created via man-made vegetated mounds. Natural dunes are usually found adjacent to the uppermost limit of wave action and are usually marked by an abrupt change in slope landward of the dry beach. The term includes coppice mounds, foredunes, dunes comprising the foredune ridge, backdunes, and man-made vegetated mounds.[69]

Dune blowout: A breach in the dunes caused by wind erosion.[69]

Dune breach: A break or gap in the continuity of a dune caused by wind or water.[69]

Dune complex or dune area: Any emergent area adjacent to the waters of the Gulf of Mexico in which several types of dunes are found or in which dunes have been established by proper management of the area. In some portions of the Texas coast, dune complexes contain depressions known as swales.[69]

Dune restoration: The process of repairing or restoring dunes along the Gulf beach damaged by human activity or storms, for instance, through planting dune vegetation or nourishment.

Dune vegetation: Flora indigenous to natural dune complexes, and growing on naturally-formed dunes or man-made vegetated mounds on the Texas coast and can include coastal grasses and herbaceous and woody plants.[69]

Dune washover: A breach in or flattening of a dune system caused by waves and/or storm surge.

Ecosystem: An environmental system composed of living organisms and natural features.

Ecosystem service: Non-traditional economic factors that demonstrate the benefits (or services) provided by the environment that support, sustain and enrich human life.

Ecotourism: Environmentally responsible travel to natural areas, in order to enjoy and appreciate nature.[96]

Endangered species: Species of plants or animals that are at risk of extinction.

Engineered beach: A beach that has been nourished or constructed based on a design template.

Eroding areas: A portion of the shoreline which is experiencing an historical erosion rate of greater than two feet per year.[69]

Erosion: The wearing away of land or the removal of beach and/or dune sediments by wave action, tidal currents, wave currents, drainage, or wind. Erosion includes, but is not limited to, horizontal recession and scour and can be induced or aggravated by human activities.[69]

Estuaries: Bodies of water where freshwater from rivers and streams empties and mixes with saltwater from the Gulf of Mexico.

Estuarine wetlands: Wetlands that occur along the bay shorelines within an estuary or directly inland of beaches, dunes or barrier islands.

Extreme weather events: Weather events, such as floods and high surf, that take human life and damage property and coastal ecosystems.

Fee simple: A permanent and absolute acquisition of land rights.

Fetch: The distance over which a wind blows and generates water waves. The longer the fetch, the greater the potential for the formation of large and powerful waves, depending on the wind speed.

Fluvial: Of or related to rivers and streams.

Freshwater inflows: Freshwater that travels from rivers to coastal bays and estuaries, carrying sediments and nutrients downstream and regulating the salinity levels in coastal waters.

Freshwater wetlands: Areas that receive enough water to support grasses, such as cattails and bulrushes, or trees, such as cypress, with root systems that are often flooded with fresh water.

Fringing marsh: Narrow marsh areas located in and around bay shorelines.

Geotextile tubes (Geotubes): Tube-shaped erosion control devices constructed from woven geotextile (a highly durable, permeable and flexible material) filled with dredged material.

Groin: A rigid structure built out from a shore to protect the shoreline from erosion by trapping sand or to redirect a current from scouring a channel.

Groundwater: Water contained in the ground or soil, below the earth's surface.

Gulf: A large bay or inlet of the ocean, almost entirely surrounded by land. May also refer to the Gulf of Mexico.

Gulf Intracoastal Waterway (GIWW): A shallow draft channel used as a thoroughfare for barge and other commercial waterway traffic, connecting ports and navigation channels from Brownsville, Texas to Carrabelle, Florida.

Habitat alteration or conversion: The reduction or elimination of natural habitats through long-term natural processes or man-made disturbances (e.g., loss of marsh land to open water due to shoreline erosion).

Habitat degradation: The process wherein habitats do not experience a change in type, but lose a degree of their original functionality (e.g., the fragmentation of estuarine wetlands caused by a disconnection in the water circulation).

Hard structure: An erosion response structure such as a bulkhead, seawall, revetment, jetty, groin, or similar structure that is the functional equivalent of one of those structures.[i]

Hardened shoreline: Developing the existing shoreline with man-made, "hard" structures, such as seawalls, revetments, breakwaters and groins.

Harmful algal blooms: Excess growths of algae that can kill other aquatic life.

Hydrology: Hydrology refers to the dynamic processes of water moving within the environment, including the source, timing, amount and direction of water movement.

Hydrologic restoration: The process of restoring natural drainage patterns to remedy altered hydrology and improve the movement, distribution and quality of water.

Hypersaline: A condition wherein a body of water is saltier than most seawater.

IMPLAN: An economic Impact Analysis for Planning model used to identify short-term economic benefits.

i. Texas Natural Resources Code. 2015. NAT RES § 33.601. Available at: http://www.statutes.legis.state.tx.us/?link=NR (accessed Feb 28, 2017)

Induced economic impact: The change in purchases of goods and services due to a particular project at a household level (as opposed to industry level).

Inundation: Temporary or permanent coverage of an area with standing water.

Invasive species: Aquatic invasive species are plants and animals that evolved in one location and are introduced through a variety of means into another location.

Issue of Concern: Natural and human-induced disturbances which, if left unaddressed, will have or will continue to have adverse impacts on infrastructure, natural resources, economic activities, and the health and safety of Texas residents. Example Issues of Concern include altered, degraded or lost habitat and bay shoreline erosion.

Jetty: A large structure built perpendicular to the shoreline, typically at the outlet of a ship channel, to provide a protected passageway for ship traffic from ocean currents.

Lagoons: Protected areas of calm water, between the coast and the barrier beaches or islands, that receive little fresh water input. Lagoons may also be separated from the Gulf or bays by sand bars.

Land acquisition: Purchasing property to establish a dedicated land use for the preservation of wildlife habitat and preclude future land use development.

Levee: A compacted earthen embankment used to prevent coastal flooding.

Living shorelines: Shoreline stabilization measures that incorporate naturally-based solutions (e.g., vegetative plantings) and may include hard structures (e.g., revetments, breakwaters) to fully or partially reduce erosive wave forces along the coastline.

Longshore current: Currents that move parallel to the shoreline.

Longshore sediment transport: The movement of sand and sediment along the shoreline.

Mangroves (black/red): Coastal shrubs that grow in brackish waters.

Marsh: A wetland dominated by soft-stemmed vegetation, such as grasses or shrubs, specially adapted to saturated soil conditions.

Mean High Tide: Mean elevation of historical high tides.

Mima Mounds: Small earthen mounds found in Texas prairie habitat.

Mitigation: The effort to reduce impacts on natural and man-made systems.

Natural environment: Living and non-living differentiated from the built environment

Navigation channel: Man-made channel that is excavated deeper than the surrounding bay bottom to allow for transit of marine vessels.

Non-point source pollution: Water pollution caused by stormwater runoff from an array of sources (e.g., residential neighborhoods, commercial sites, agricultural fields).

Nuisance flooding: Flood events that occur multiple times annually due to high tide events, heavy rainfall or a combination of both scenarios.

Oyster beds or reefs: Submerged colonies of oysters found in nearshore rocky areas, bays and estuaries, and typically formed on a hardened substrate.

Peninsulas: Landforms that are separated from the mainland by shallow bays or lagoons and that run parallel to the mainland, while maintaining connectivity to the mainland.

Placement areas: Authorized locations to dispose of dredged material.

Pressures: Pressures are the human activities and natural processes, typically large-scale and long-term, which may lead to the development of Issues of Concern along the coast. Examples of coastal pressures include coastal resource consumption (e.g., oil and gas extraction, fishing), population growth, and relative sea level rise.

Programmatic model: An unbiased, repeatable and systematic method to calibrate relationships between anticipated physical and ecological benefits of projects in relation to the identified Issues of Concern.

Relative sea level rise: The combined impacts of land loss, due to both subsidence and sea level rise.

Resiliency Strategy: Category of restoration and protection measures for coastal resiliency. Collectively, the Resiliency Strategies and their proposed projects address the Issues and Concerns identified over the course of the planning process.

Restoration: The process of returning degraded, damaged, or destroyed areas to a fully functional, ecologically healthy state (or an approximation thereof) through the integrated application of planning, science and engineering principles.

Revetment: A structure built to prevent erosion of a shoreline through placement of stone or concrete directly on the shore. Constructing a revetment can involve reshaping the shoreline to create a more stable, gradual slope for placement of the materials.

Riverine: Of or related to rivers.

Riverine flooding: Flooding caused by a river overtopping its banks.

Rollover: The process where storm surge rushes over a barrier island or peninsula, carrying sand from the beaches and dunes and depositing it into the bay.

Rookery islands: Islands that provide foraging, roosting, cover and nesting habitats for colonial and migratory birds.

Runoff: The draining away of water and substances carried in it from the surface of an area of land, a building or structure, etc.

Salinity: The measure of salt content in a body of water.

Saltwater intrusion: The process of saltwater flowing into freshwater habitats and/or water bodies.

Sand source: Onshore or offshore sand deposits that may be mined and used to construct shoreline stabilization or beach nourishment projects.

Seagrass: A type of submerged aquatic vegetation that grows in saline environments.

Sea level rise: The increase in volume of water in the world's oceans, associated with thermal expansion of sea water and melting of glaciers, ice sheets and polar ice caps caused by increasing global atmospheric temperature.

Seawall: Coastal structures, typically designed to protect shorelines from direct impacts of waves and tides.

Sedimentation: The process of sand being deposited into bays, wetlands or other coastal environments.

Sediment deficit: A lack of sufficient natural material (e.g., sand), in quality and/or quantity, for shoreline stabilization or beach nourishment.

Sediment management: Coordinating and organizing the use and/or disposal of dredged material and other sediment sources to optimize use of available materials.

Shoreline advance: Areas of shoreline accretion resulting in the net movement of land seaward.

Shoreline stabilization (beach/bay): Methods used to mitigate shoreline erosion.

Siphons: Tubes used to convey liquid upwards from a reservoir and then down to a lower level of its own accord. Once the liquid has been conveyed into the tubes, typically by suction or immersion, flow continues unaided.

Social vulnerability: A measure of how at-risk a population is to suffer from consequences of an adverse event; also an indicator of how resilient a community will be if exposed to environmental or natural hazards.

Storm surge: The rise of water to atypically high levels (above high tide predictions) due to a storm.

Storm surge barriers: Coastal structures designed to reduce risks of damage from storm surge by reducing propagation of elevated waters and waves during severe weather.

Submerged aquatic vegetation: Grasses that grow beneath the water surface in bays and estuaries.

Subsidence: The sinking or downward settlement of land surface elevation. Groundwater pumping and petroleum extraction are common processes that contribute to land subsidence.

Surface water: Aboveground water from rivers, lakes, streams and wetlands, including floodwater and runoff.

Swamp: A forested, freshwater wetland that is typically inundated with water.

Tidal flats: Estuarine wetlands formed by mud deposits.

Vegetative plantings: Planting of native marsh grasses or other wetland plants.

Vessel wakes: Waves generated by movement of marine vessels.

Watershed: A land area where water entering it is drained by flow toward a common outlet distinct from adjacent areas.

Water quality: The chemical, physical, or biological composition of water.

Water quantity: The volume of water flowing to a particular area or estuary.

Wave attenuation: The reduction of wave energy, height or speed.

Wetlands: Naturally occurring or restored lands, such as marshes, swamps, or tidal flats, that are covered often intermittently with shallow water or have water saturated soil.

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