# Mustang Island Resilience Plan

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COASTAL BEND BAYS & ESTUARIES PROGRAM

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# Acronym List

| | |
|---|---|
| AIS | Automatic Identification System |
| BUDM | Beneficial Use of Dredged Material |
| CBBEP | Coastal Bend Bays & Estuaries Program |
| DMPA | Dredged Material Placement Area |
| EFH | Essential Fish Habitat |
| EPA | Environmental Protection Agency |
| ESA | Endangered Species Act |
| ESG | Environmental, Social, and Governance |
| GIS | Geographic Information Systems |
| GIWW | Gulf Intracoastal Waterway |
| GLO | Texas General Land Office |
| HD | Hydrodynamic (module in MIKE 21) |
| HRI | Harte Research Institute |
| MIKE | MIKE 21 Modeling Suite |
| MT | Mud Transport (module in MIKE 21) |
| NERR | Mission Aransas National Estuarine Research Reserve |
| NFWF | National Fish & Wildlife Federation |
| NMFS | National Marine Fisheries Service |
| NNW | North-Northwest |
| NOAA | National Oceanic and Atmospheric Administration |
| NWI | National Wetlands Inventory |
| RBFS | River Basin Flood Study |
| RSLR | Relative Sea Level Rise |
| SH | State Highway |
| SLR | Sea Level Rise |
| SSE | South-Southeast |
| SW | Spectral Wave (module in MIKE 21) |
| TCEQ | Texas Commission on Environmental Quality |
| TCRMP | Texas Coastal Resiliency Master Plan |
| TEXBUMP | Texas Beneficial Use Master Plan |
| TNC | The Nature Conservancy |
| TPWD | Texas Parks and Wildlife Department |
| USACE | U.S. Army Corps of Engineers |
| USDA | U.S. Department of Agriculture |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| UTMSI | University of Texas Marine Science Institute |
| WIS | Wave Information Study |

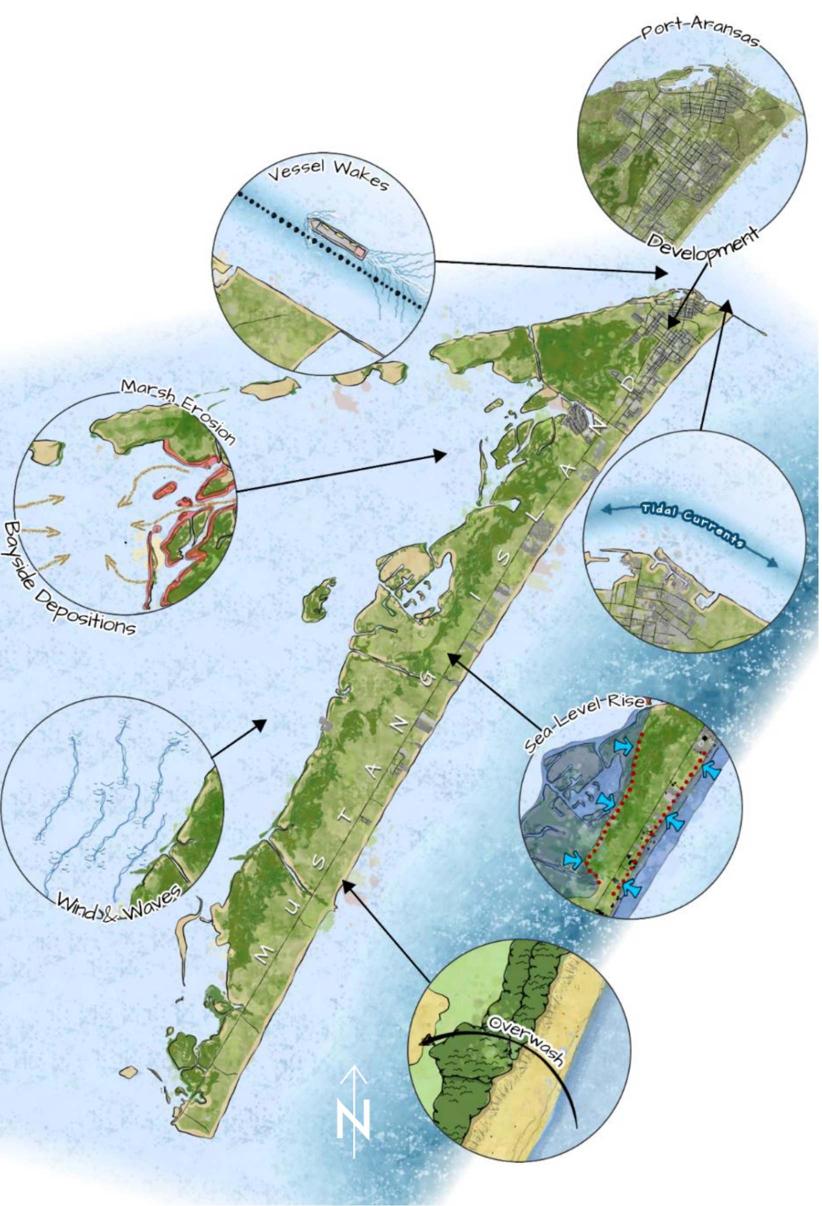
# Executive Summary

The wetlands on the backside of Mustang Island (Island) are experiencing rapid loss caused by habitat degradation and erosion driven by both human activities and underlying geologic instability. Increased tropical storm activity over the past decade has further reduced wetland health, extent, and cohesiveness. As the first line of defense against coastal hazards moving in from the Gulf of America, Mustang Island protects the communities and ecosystems surrounding Corpus Christi Bay. As protective wetland habitats decline, communities and infrastructure assets that exist on the Island, such as the City of Port Aransas and State Highway 361 (SH-361), face heightened risk.

Recognizing the urgency of these challenges, the Coastal Bend Bays & Estuaries Program (CBBEP) initiated development of the Mustang Island Resilience Plan (Resilience Plan). The Resilience Plan focuses on leveraging the Island's natural characteristics to improve long-term stability and resilience by protecting and enhancing backside habitats while supporting sustainable human use and ecological health.

The Resilience Plan outlines a suite of techniques to increase sediment retention and bolster the Island's natural defenses. These techniques were informed by a comprehensive assessment of the vulnerabilities driving long-term wetland loss. Initial resilience concepts were developed based on those vulnerabilities, refined through stakeholder input, and evaluated through hydrodynamic and sedimentation modeling. Modeling included with- and without-project scenarios, providing insight into how resilience projects could influence sedimentation patterns and habitat stability. The results aligned with stakeholder observations and supported the selected techniques.

Resilience techniques are organized into four categories based on the vulnerabilities they address:




1. **Wetland Stabilization**
2. **Wetland Health and Cohesion**
3. **Habitat Creation, Preservation, and Enhancement**
4. **Environmental Stewardship**

Each category includes multiple techniques that can be implemented to strengthen the Island's resilience. The Resilience Plan also outlines short-, mid-, and long-term actions to transition from planning to implementation.

Although conceived by CBBEP, the Resilience Plan is built around collaboration. Enhancing the resilience of Mustang Island requires coordinated action across the partner networks engaged throughout the Resilience Plan's development. Long-term resilience cannot be achieved by any single entity; collective effort is essential to supporting the Island's ability to adapt to changing conditions.

Ultimately, the Resilience Plan serves as a practical tool to guide collaborative decision-making, strengthen the long-term stability of Mustang Island, and address both the periodic impacts of major storm events and the ongoing trends that reduce the Island's capacity to recover. By aligning science-based solutions with community-driven priorities, the Resilience Plan provides a clear path toward a more stable, adaptable, and resilient Mustang Island.

# Introduction and Background

Mustang Island is a critical barrier island system along the Texas Coastal Bend, forming the interface between the Gulf of America (the Gulf) and the shallow waters of Corpus Christi Bay, while also serving as a growing tourist destination. Its bayside wetlands complement the Gulf beaches and dunes, providing essential protection from storm surge and wind-driven waves, supporting fisheries and wildlife habitat, and underpinning the region's recreation economy. These wetlands operate within a narrow range of elevation and sediment balance, making them highly productive, but also highly sensitive to disruption.

Over recent decades, the bayside wetlands of Mustang (Figure 1) Island have experienced persistent erosion and habitat loss, driven by a combination of natural processes, human alterations, and climate-driven change. Most notably, Hurricane Harvey produced approximately 6 to 10 feet of storm surge along the backside of the Island as it made landfall near Rockport in 2017. This led to significant wetland erosion at the Port Aransas Nature Preserve and intensified the sediment deficit to the south of the Island. Aside from hurricanes, other hazards such as Winter Storm Uri in 2021 create destabilizing forces along the Island through mortality of vital mangrove habitat that captures and stores incoming sediment. Shoreline hardening, dredged channels, altered sediment pathways, and constrained overwash corridors have modified how energy and sediment move, fragmenting the dynamic island system. At the same time, rising water levels, intensifying storms, and drought-driven hypersalinity are placing additional stress on wetlands that already exist near critical ecological thresholds.

Recognizing the importance of these wetlands and growing concern over their long-term stability, the Coastal Bend Bays & Estuaries Program (CBBEP) initiated the Mustang Island Resilience Plan (Resilience Plan). **The purpose of the Plan is to support informed, proactive management of the Island's bayside wetlands by identifying where vulnerabilities are most severe, understanding the processes that drive them, and outlining strategies to improve the system's ability to persist and adapt under future conditions.** Partners are encouraged to leverage this Plan as a resource that identifies needs along Mustang Island to support the implementation of restoration projects.

## Plan Framework: Assess, Advance, Adapt

This Plan is organized around three interconnected themes: **Assess, Adapt, and Advance**.

**Assess:** The Resilience Plan begins with a data-driven overview and vulnerability assessment that characterizes Mustang Island's wetland system, the pressures acting upon it, and where vulnerabilities concentrate today and under future conditions.

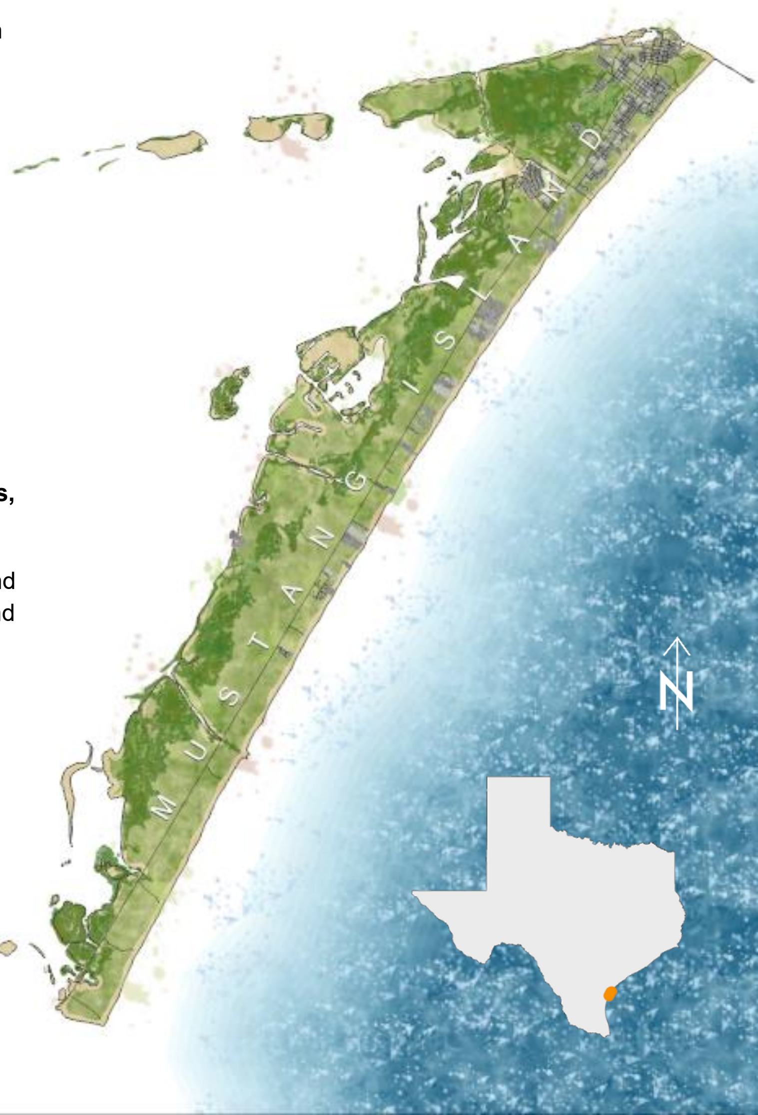
**Adapt:** Building on this assessment, the Resilience Plan identifies resilience techniques that strengthen natural processes, reduce destabilizing forces, and improve wetland stability and function across the Island.

**Advance:** Finally, the Resilience Plan provides implementation actions that emphasize adaptive management, recognizing that conditions will continue to change and that resilience depends on monitoring, learning, and adjusting over time.

## FROM UNDERSTANDING TO ACTION

Enhancing the resilience of Mustang Island starts with understanding how the system works and where it is most at risk. This Resilience Plan moves deliberately from assessment, to action, to adaptation to create a framework that supports both near-term decisions and long-term change.

Figure 1 Mustang Island



# Planning Framework

The Resilience Plan is grounded in the understanding that effective planning must be rooted in how the system functions alongside where impacts are observed. Rather than relying on a single dataset or model, the Resilience Plan integrates historical observations, spatial analyses, and numerical modeling to develop a process-based understanding of Mustang Island's wetland system. Using a combined data-driven and stakeholder informed approach provides a clearer understanding of how the system naturally functions, paired with an on-the-ground perspective of the overall impacts of the geological processes within the context of management priorities, restoration outcomes, and long-term sustainability of the Island. The graphic below (Figure 2) depicts the intricacies of the linkage between the data and modeling outcomes and the input from local and regional stakeholders. Throughout the planning process, stakeholders provided valuable insights that contextualized the modeling and analysis results, grounding them in the real changes observed on the Island and informing the development of coastal restoration techniques based on both demonstrated success and known shortcomings. More detail on the data-driven process and the stakeholder engagement process is discussed below.

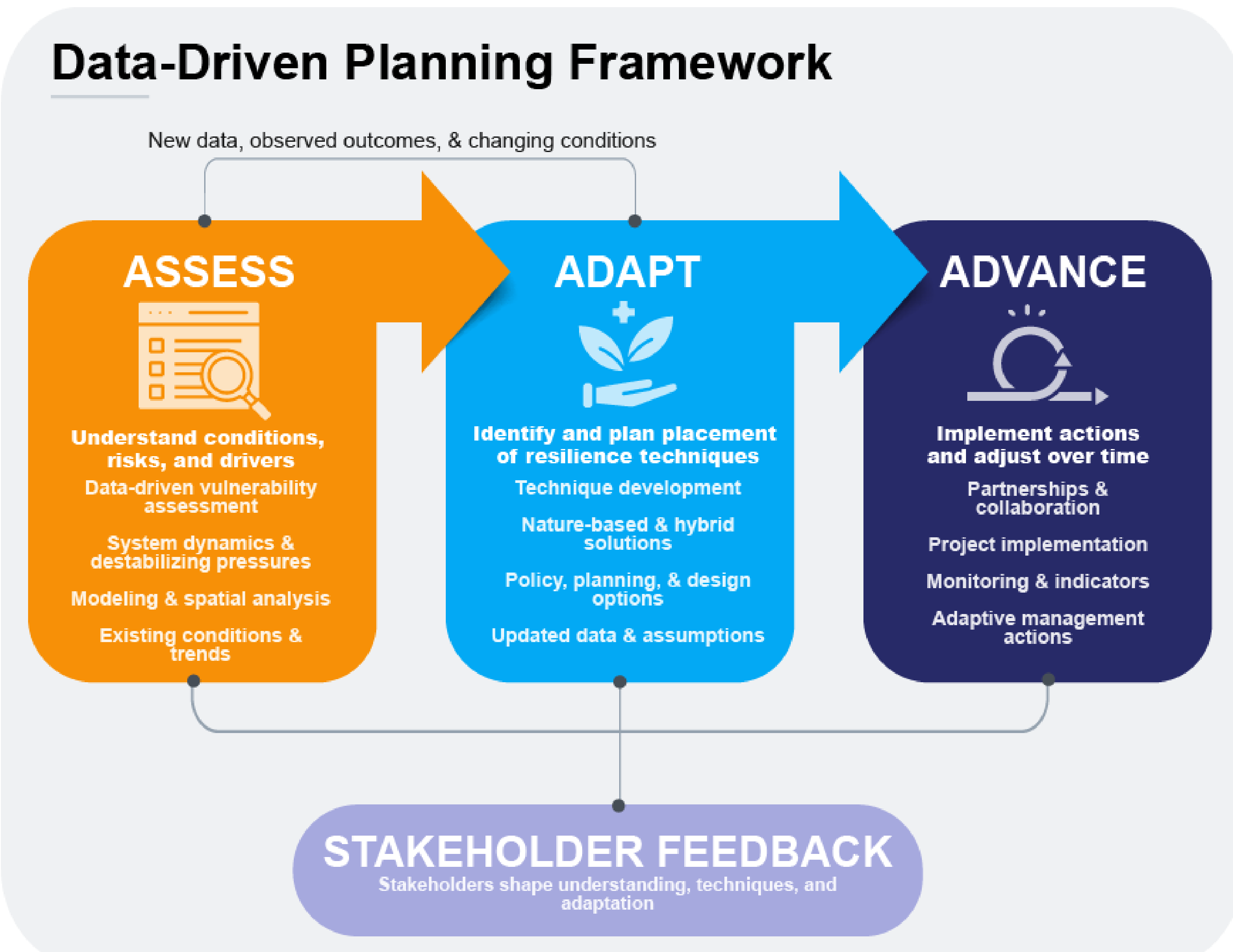



Figure 2 Mustang Island Resilience Plan planning framework

## Data-Driven Process

Barrier islands and their associated wetlands are dynamic and complex systems influenced by a combination of environmental and anthropogenic forces. Understanding the factors that drive change within these systems is essential for developing effective techniques to support their long-term stability. As part of the Resilience Plan, the conceptual modeling and analysis completed provide insight into the critical drivers affecting Mustang Island's wetland systems and identify actions that can mitigate future degradation. This foundational understanding guided subsequent technical analyses and stakeholder engagement throughout the planning process, providing results and data analysis that supported the development of short- and long-term solutions addressing the drivers of wetland loss across Mustang Island.

Identifying the most at-risk areas of Mustang Island requires a comprehensive understanding of the processes influencing the backside wetlands. This effort followed a framework (illustrated in Figure 3) that integrated a literature review, data collection, desktop analyses, sediment transport modeling, and existing regional models. Through this data analysis and modeling effort, sensitivity testing was completed to assess sediment capture, retention, or redirection and the relationship to physical constraints, the Island's geologic framework, and the feasibility of potential management actions. The analyses addressed key vulnerabilities such as sediment loss, subsidence, and the influence of engineered structures on wetland form and function.

**Overall, this analysis offers guidance for wetland restoration, resource management, and future development planning on Mustang Island. By synthesizing physical, ecological, and human-use dynamics, the work supports the Adapt phase to develop targeted techniques that enhance the long-term health and resilience of the Island's bayside wetland complexes.**

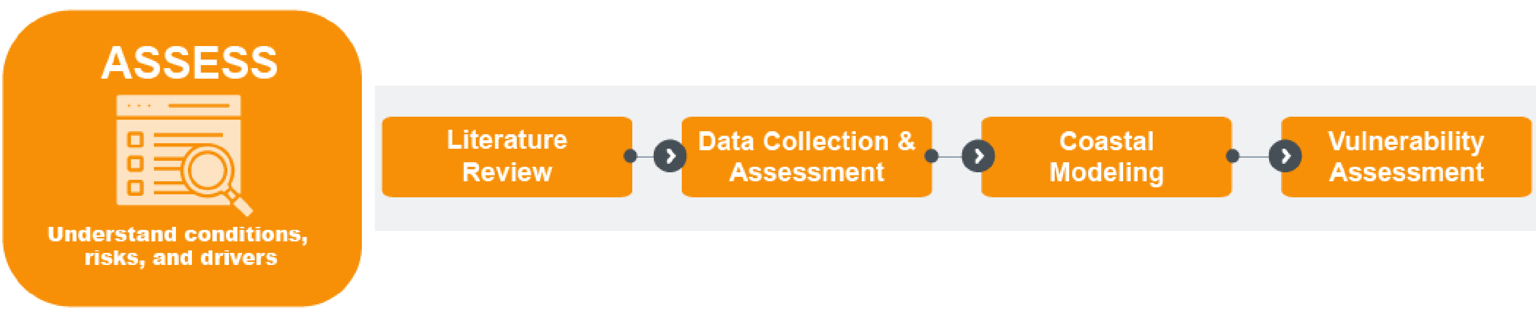
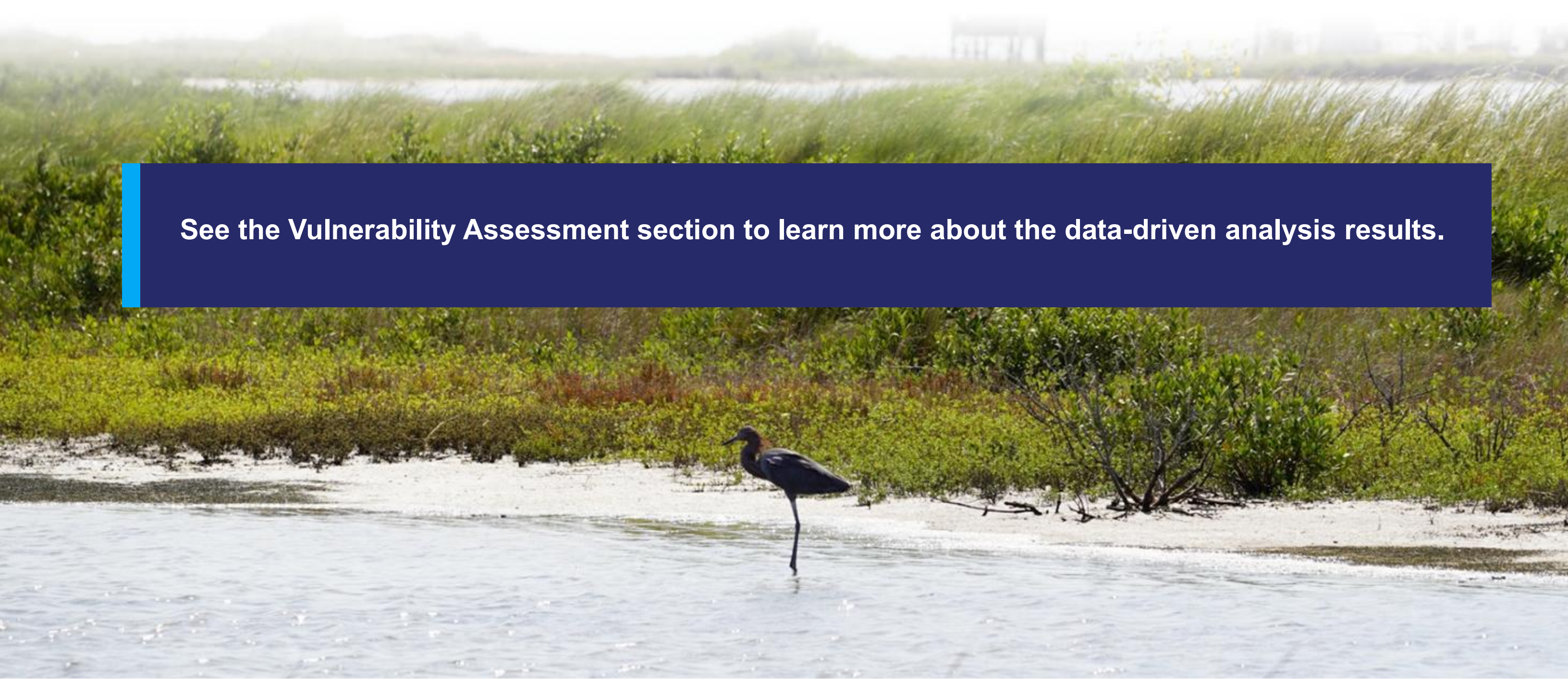



Figure 3 Data-driven process framework



**See the Vulnerability Assessment section to learn more about the data-driven analysis results.**

## Stakeholder Engagement Process

To achieve a Resilience Plan informed by local knowledge, CBBEP collaborated with a range of stakeholders, including state and local agencies, community organizations, and academic institutions. Throughout the development of the Resilience Plan, stakeholders were engaged through in-person and virtual meetings that provided updates on key milestones and opportunities for feedback.

Collaboration with these key stakeholders supports the development of recommended techniques and actions that are not only scientifically sound but also locally feasible considering land ownership and social expectations on the Island. By coupling an understanding of the Island's geologic formation with ongoing changes and social context, and actively engaging stakeholders throughout the process, the Resilience Plan identifies opportunities to address current challenges and proactively take action on future challenges. Beyond the project's completion, the Resilience Plan will serve as a tool for continued implementation of resiliency efforts along Mustang Island, while also serving as a model for other barrier islands throughout the state.

Development of the Resilience Plan began in 2024, and throughout the nearly two-year long effort, CBBEP hosted multiple virtual and in-person stakeholder meetings (Table 1).

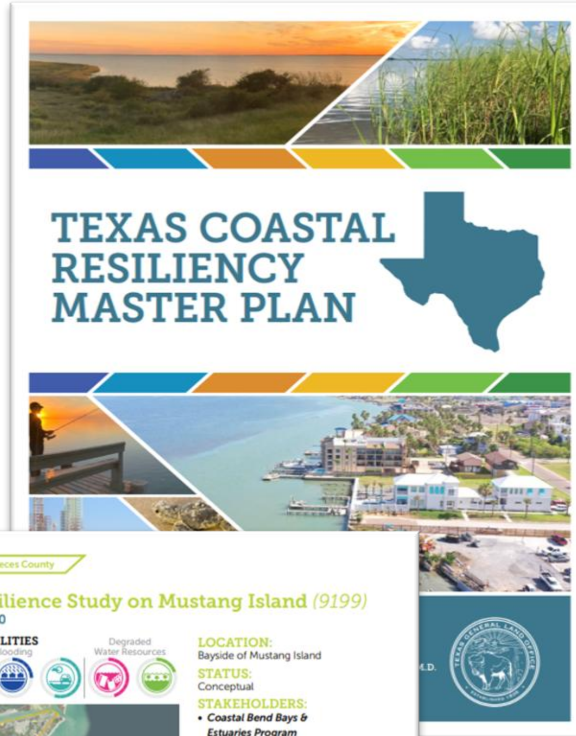
Table 1 Summary of stakeholder outreach meetings

| Meeting Date | Format | Topics Discussed | Attendee Organizations | Summary of Outcomes |
|---|---|---|---|---|
| **October 30, 2024** | Virtual | • Introduction to the Resilience Plan, its goals/objectives, and general timeline<br>• Outcomes of the literature review and overview of the modeling framework | • City of Port Aransas<br>• Harte Research Institute (HRI)<br>• Mission Aransas National Estuarine Research Reserve (Mission Aransas NERR)<br>• Mustang Island State Park<br>• National Marine Fisheries Service (NMFS)<br>• Nueces County Coastal Parks<br>• Texas Department of Transportation (TxDOT)<br>• Texas General Land Office (GLO)<br>• Texas Parks and Wildlife Department (TPWD)<br>• The Nature Conservancy (TNC)<br>• U.S. Fish and Wildlife Service (USFWS) | • Stakeholders discussed geomorphological influences on Mustang Island's resilience, referencing prior studies. AECOM emphasized integrating Holocene formation research and welcomed additional data to refine the modeling approach.<br>• Multiple tools and datasets were suggested to support the plan, including TPWD's marine geospatial modeling tool, GeoRED, and U.S. Department of Agriculture (USDA) bay-bottom mapping.<br>• Outlined a phased engagement strategy, with broader public involvement planned for future sessions. Stakeholders raised concerns about erosion, oil and gas infrastructure, and tidal impacts. |
| **May 15, 2025** | Virtual | • Outcomes of the conceptual modeling process and next steps<br>• Initial Resilience Concepts<br>• Preliminary Assessment | • Arcadis<br>• City of Port Aransas<br>• GLO<br>• HRI<br>• Mustang Island State Park (MISP)<br>• NMFS<br>• TPWD<br>• TxDOT<br>• USFWS | • Stakeholders raised concerns about the accuracy of National Oceanic and Atmospheric Administration (NOAA) and USFWS's National Wetlands Inventory (NWI) datasets used in the vulnerability assessment, noting gaps in coverage of higher marsh areas and outdated data. AECOM acknowledged these limitations and emphasized the need for improved spatial resolution and ground-truthing.<br>• Discussions explored the role of sediment transport (terrestrial and aeolian) in shoreline resilience. While full integration into modeling is complex, AECOM is considering these processes as boundary conditions. Stakeholders also debated habitat restoration strategies, including marsh mounds versus tidal flat recreation.<br>• TxDOT shared early-stage plans for SH-361 improvements, including sustainable infrastructure and recreational access. Stakeholders highlighted funding opportunities like the National Coastal Wetlands Grants and requested more information on living shoreline locations and oil and gas infrastructure. |
| **November 6, 2025** | In-Person | • Updates on hydrodynamic and sediment transport modeling<br>• Resilience concepts and strategies<br>• Implementation framework | • City of Port Aransas<br>• Coastal Bend Council of Governments (COG)<br>• GLO<br>• HRI<br>• Mission Aransas NERR<br>• TNC<br>• TPWD<br>• TxDOT<br>• University of Texas Marine Science Institute (UTMSI) | • Discussions focused on each resilience concept and the success or short-comings of each, in relation to the ongoing work or recent work completed on Mustang Island or within the region.<br>• Stakeholders provided suggestions on priority locations and which strategies to move forward into the final plan. |

| Meeting Date | Format | Topics Discussed | Attendee Organizations | Summary of Outcomes |
|---|---|---|---|---|
| **March 3, 2026** | In-Person | • Presentation of the final Mustang Island Resilience Plan | • Arcadis<br>• City of Port Aransas<br>• Coastal Bend COG<br>• GLO<br>• HRI<br>• MISP<br>• Port Aransas Nature Preserve<br>• Texas Commission on Environmental Quality (TCEQ)/RESTORE Council<br>• TNC<br>• TPWD<br>• TxDOT<br>• USFWS<br>• UTMSI | • Stakeholders emphasized the importance of clearly identifying priority resilience opportunity areas, particularly along SH-361 and near Fish Pass, to support a coordinated, system-wide approach to implementation and future funding and permitting efforts, as well as the incorporation of public access and recreational co-benefits.<br>• There was interest in the plan highlighting partnership networks and implementation capacity to demonstrate collaboration.<br>• Participants encouraged high-level consideration of funding pathways and implementation context, as well as acknowledgment of potential remediation and other restoration considerations, while maintaining flexibility in future project development.<br>• Stakeholders expressed support for a system-based implementation approach, including alignment with TCRMP, use of the stakeholder group beyond plan adoption, and recognition of monitoring and education roles for non-technical audience.<br>• Discussions included a desire to convene a working group to acknowledge longer-term regulatory and permitting considerations, including ecosystem-based management concepts and potential programmatic permitting, as a future step. |

# Connection to Statewide Resilience Efforts

This effort has been championed by CBBEP through local, regional, and statewide resilience planning frameworks. The conceptual project was included as a priority Tier 1 project in the 2023 Texas Coastal Resiliency Master Plan (TCRMP), and then later included in CBBEP's Fiscal Year 2024 Annual Work Plan. Inclusion in both planning documents has provided a platform through which the Resilience Plan could garner support and be prioritized for funding programs. While this Resilience Plan shares many goals with the TCRMP, it is not intended to replace the projects, actions, and strategies put forward by the TCRMP. Rather, CBBEP's Resilience Plan is intended to work in combination with and in support of the TCRMP's goal to create a more robust and resilient Texas coast.





Project Cutsheets | Region 3 | Nueces County

Bayside Wetland Resilience Study on Mustang Island *(9199)*

Estimated Project Cost: $1,000,000

ABILITY TO ADDRESS VULNERABILITIES

Land Change | Flooding | Degraded Water Resources

LOCATION:
Bayside of Mustang Island

STATUS:
Conceptual

STAKEHOLDERS:
- ***Coastal Bend Bays & Estuaries Program***
- Texas A&M University-Corpus Christi Conrad Blucher Institute
- Texas General Land Office
- Texas Parks & Wildlife Department
- The Nature Conservancy
- U.S. Fish and Wildlife Service
- Nueces County
- City of Port Aransas
- U.S. Army Corps of Engineers

ACTIONS:

PROJECT TYPE(S):
Studies, Policies, and Programs

Project Description

This project will preserve existing and enhance degraded wetlands on Mustang Island while making the island more resilient in the long-term by addressing chronic geomorphological concerns. A study is needed to determine the geological, geomorphic, and anthropogenic features or processes that could be preventing adequate sediment accretion and shoreline stabilization—such as soil formations, subsidence, lack of sufficient overwash to replenish soils, tidal impacts, or manmade structures impeding sediment transport. The results of such a study would inform the long-term management of the island and could include recommended solutions like sediment source, budgeting, and beneficial use of dredged material to support shoreline stabilization and wetland restoration and creation. The project would involve reviewing existing literature and relevant studies, performing an engineering assessment of present and anticipated future conditions of the island, and proposing recommended solutions.

Project Need

Mustang Island has experienced significant degradation of its coastal wetlands. This is thought to be due to underlying issues related to the geologic formation of the island, as well as coastal storm impacts and relative sea level rise. It is unlikely that a purely structural solution is sustainable long-term to address the problems across the island. Improving the long-term resilience of Mustang Island through the preservation and restoration of coastal wetlands can only be achieved by addressing the chronic geomorphological concerns.

POTENTIAL LOCAL BENEFITS

✓ Addressing Data Gaps | ✓ Support Funding Eligibility

**For more information on cost estimates and project benefits calculations, see page 132 of the 2023 Texas Coastal Resiliency Master Plan.*

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# Understanding Mustang Island's Wetland System and Vulnerabilities

## Regional Context

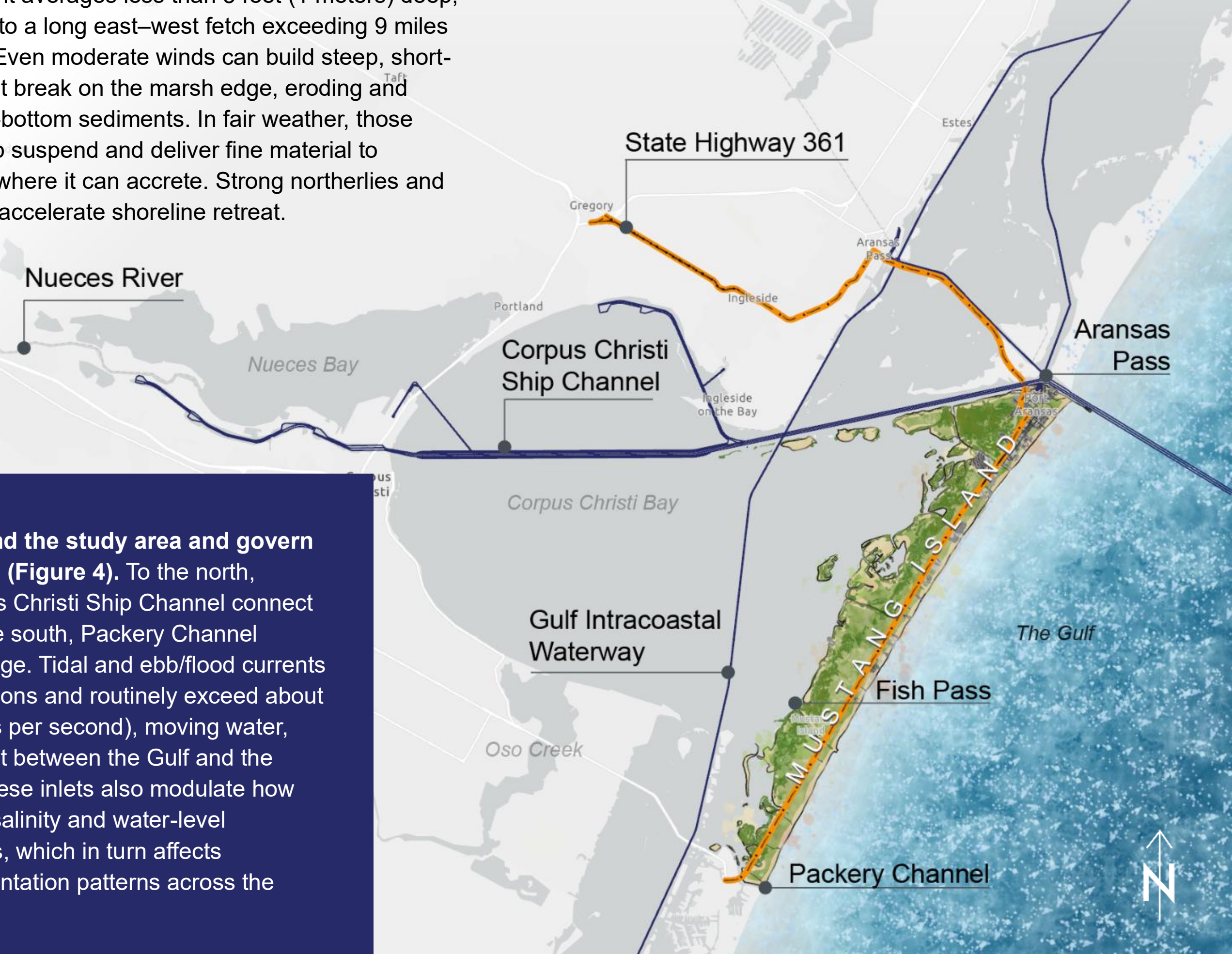
**Mustang Island functions as a linked system composed of three primary physical areas: the Gulf-facing shoreline and dune system, the Island interior and developed corridor, and the bayside wetlands and shallow flats**. While these areas are physically connected, each is shaped by different processes and stressors, and changes in one area can propagate across the system.

Along the Gulf-facing shoreline, waves, storms, and longshore sediment transport govern beach and dune dynamics. This ocean-facing coast is the Island's first line of defense during storm events and historically served as a sediment source for the rest of the Island through overwash during extreme water levels.

The interior of the Island, which includes dunes, roads, and developed areas, plays a critical role in mediating how sediment, water, and energy move between the Gulf and the bay. Infrastructure such as State Highway 361 (SH-361) and associated development can interrupt natural sediment pathways, limiting overwash and altering drainage patterns. As development expands, the interior increasingly acts as a barrier rather than a conduit between island sub-systems, but responsible development practices have the opportunity to mitigate many of these restrictions.

On the bayside, wetlands, tidal flats, and shallow subtidal areas form a low-energy but highly sensitive environment. These wetlands depend on a delicate balance between sediment supply, wave exposure, salinity, and water levels to maintain elevation and ecological function. In a micro-tidal setting, where daily tidal ranges are typically less than 1 foot (0.3 meters), even small changes in elevation, water level, or sediment delivery can shift wetlands from stable to degrading conditions. Corpus Christi Bay is characteristically shallow. Much of it averages less than 3 feet (1 meters) deep, yet it is exposed to a long east–west fetch exceeding 9 miles (15 kilometers). Even moderate winds can build steep, short-period waves that break on the marsh edge, eroding and remobilizing bay-bottom sediments. In fair weather, those same waves help suspend and deliver fine material to sheltered coves where it can accrete. Strong northerlies and tropical systems accelerate shoreline retreat.

Figure 4 Man-made features and waterbodies surrounding Mustang Island

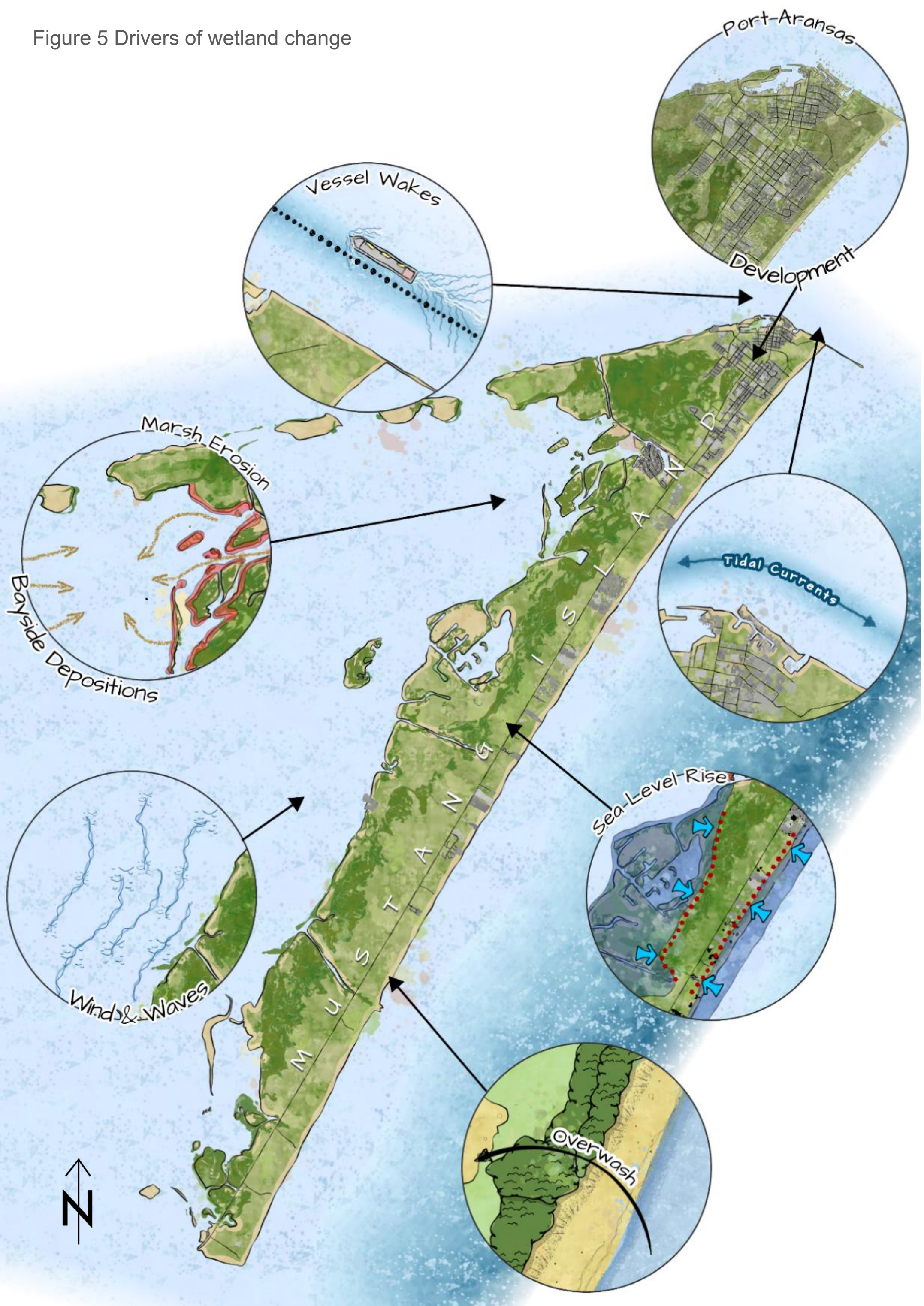



**Two engineered inlets bound the study area and govern much of its hydrodynamics (Figure 4).** To the north, Aransas Pass and the Corpus Christi Ship Channel connect the bay to the Gulf; and to the south, Packery Channel provides a secondary exchange. Tidal and ebb/flood currents focus through these constrictions and routinely exceed about 6 feet per second (1.8 meters per second), moving water, salt, and suspended sediment between the Gulf and the back-barrier environment. These inlets also modulate how quickly the system recovers salinity and water-level equilibrium after storm events, which in turn affects vegetation stress and sedimentation patterns across the bayside marshes and flats.

# System Dynamics & Drivers of Change

Understanding the Mustang Island system as a whole is critical to informing how best to enhance its resilience. Mustang Island's wetlands sit in a narrow elevation range where inches of water-level or sediment change can flip marshes from stable to eroding and/or drowning. In a micro-tidal setting such as Corpus Christi Bay, relatively small changes in any of these factors can shift wetlands from stable or accreting conditions toward erosion, fragmentation, or drowning. **Understanding how these pressures interact is critical to identifying vulnerabilities and what techniques are most likely to improve resilience.** Shallow, long-fetch bays and currents determine wave frequency and intensity and whether suspended sediments are delivered to rebuild or strip away marsh edges. Where shorelines are hardened, such as around Port Aransas, natural overwash and sediment exchange are cut off; while in less-developed reaches, intact corridors allow landward migration and recovery.

Figure 5 Drivers of wetland change




## Connected drivers of wetland change

Mustang Island's bayside wetlands respond to the combined effects of wind waves, vessel wakes, tidal currents, overwash, and rising water levels (Figure 5). These forces mobilize and redistribute sediment along the marsh edge and across the barrier, while human infrastructure locally concentrates energy and constrains sediment pathways. Where sediment delivery and connectivity are maintained, wetlands can accrete and persist; where pathways are restricted, erosion, ponding, and habitat loss accelerate. This system-scale perspective forms the basis for the vulnerability assessment and resilience techniques presented in this Plan.

Human land use varies markedly along Mustang Island, shaping distinct patterns of pressure and management opportunity. The northern end near Port Aransas is the most densely developed portion of the Island and contains hardened shorelines, particularly along the ship channel which can all constrain sediment exchange with bayside wetlands adjacent to the community. Progressing south, development transitions from residential communities to lower-intensity conservation and recreational uses, including Mustang Island State Park and the Cohn Preserve. However, SH-361 spans the full length of the Island and functions as a continuous linear barrier that modifies overwash and sediment connectivity even in less-developed areas. Roadway elevations, embankments, and associated infrastructure can limit storm-driven sediment transport from the Gulf-facing beach and dune system to interior wetlands. **This north-south gradient results in differing resilience challenges: an emphasis on retrofitting hardened edges and restoring exchange pathways in the north, and on protecting hydrologic connectivity, sediment delivery, and wetland migration corridors in the central and southern reaches.**

The dominant pressures acting on Mustang Island's bayside wetlands fall into four interrelated categories: Physical Degradation, Fragmentation and Flow Restrictions, Impending Habitat Loss, and Localized Disturbances. Each category represents a distinct pathway, illustrated in Figure 6, through which wetlands lose elevation, structural integrity, or adaptive capacity, though in practice these pressures often act together.

## Drivers Behind Wetland Change

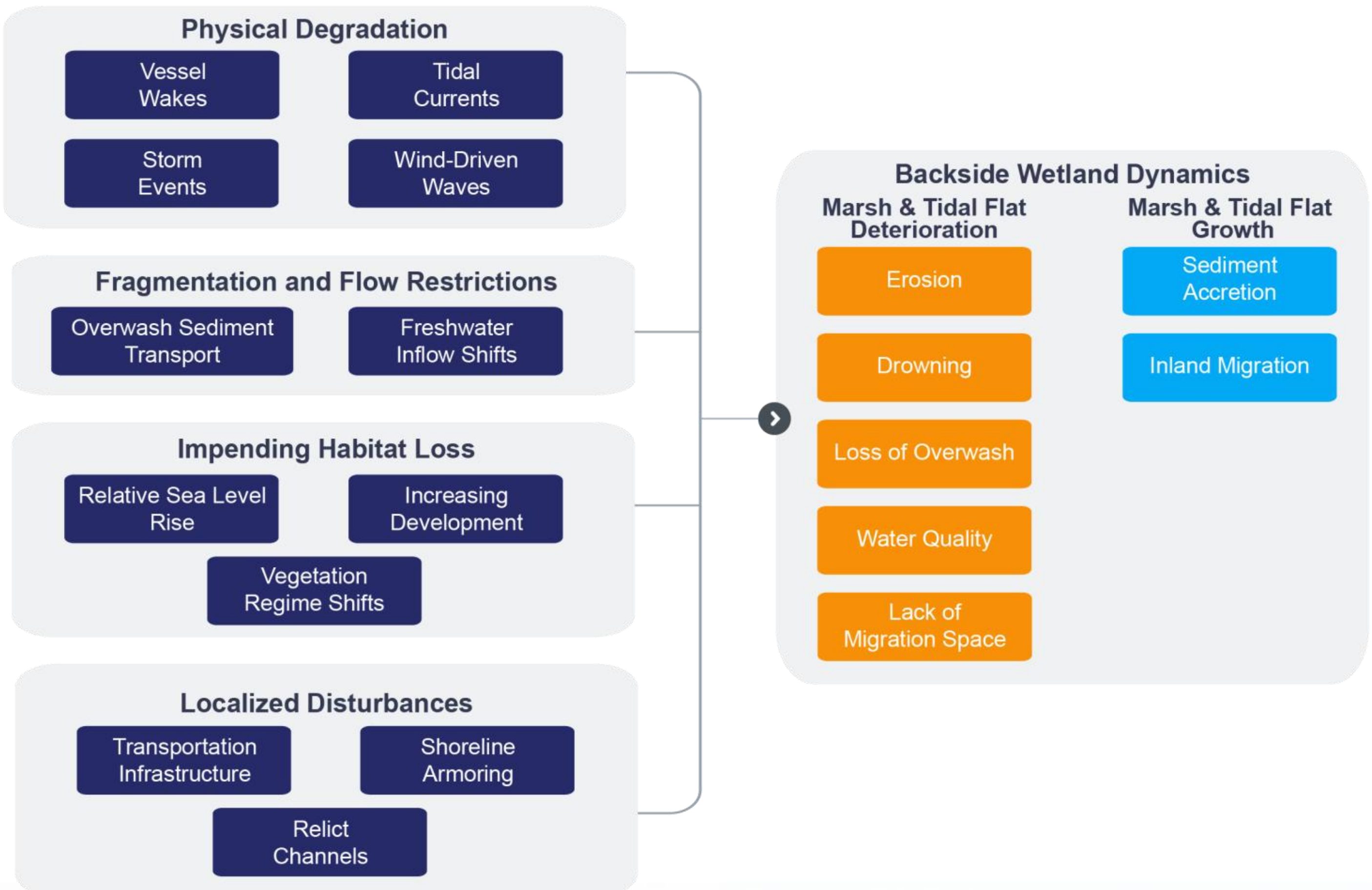



Figure 6 Diagram showing the drivers behind wetland dynamics that lead to change over time

# Physical Degradation

Physical degradation encompasses processes that directly erode marsh edges or destabilize the wetland platform through waves, currents, and flooding.

**Wind-driven waves generated across the long east-west fetch of Corpus Christi Bay are a primary driver of bayside erosion as this represents the typical conditions.** Shallow bay depths allow even moderate winds to produce steep, short-period waves that focus energy at the marsh toe, scouring cohesive peat and resuspending fine sediments.

**During strong northerlies associated with winter cold fronts and tropical systems, which represent more episodic conditions, water levels, long fetch alignment, and wave energy can increase substantially.** These events can accelerate shoreline retreat and often exceed the resistance of marsh vegetation in vulnerable areas.

**Tidal and inlet currents further concentrate erosive forces.** Engineered inlets at Aransas Pass (Corpus Christi Ship Channel) and Packery Channel focus the tidal prism into narrow corridors, where peak velocities regularly approach ~6 feet per second (1.8 meters per second). These flows propagate into the bay, mobilizing sand and undercutting marsh banks, creating localized erosion-accretion patterns near channel margins. They also control how quickly salinity and water levels equilibrate after storms, which can stress vegetation and ecology, and impact sedimentation patterns across the bayside platform.

**From 1937 to 2026, dozens of tropical cyclones and extreme wind events have passed within influence distance of Mustang Island (Figure 7), delivering episodic pulses of wave energy, storm surge, and strong currents.** In recent years, after a period of minimal storm impacts, major storms – including Hurricane Harvey in 2017 – have driven rapid change, particularly along the Island's bayside. Hurricane Harvey generated prolonged storm surge and elevated water levels that reworked shorelines, altered tidal exchange, and accelerated erosion in locations where sediment pathways were already constrained. Such events can reset shorelines, open or re-open breaches, and drive sediment landward through overwash.

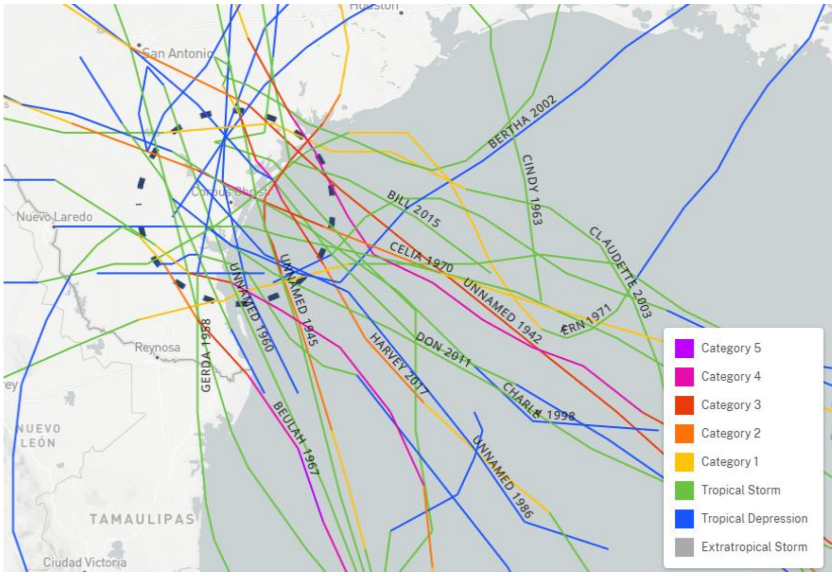



Figure 7 Historical hurricane tracks, 1937-2020 (NOAA, 2024)

**Vessel wakes from commercial and recreational traffic add a chronic, high-frequency energy source that compounds wind-driven erosion.** Unlike episodic storm events, repeated wake exposure delivers frequent, directional wave energy that can undercut marsh edges, prevent sediment from settling, and inhibit vegetation recovery, particularly along channel-adjacent wetlands with limited wave dissipation. While there is a general understanding of the extent of impact caused by commercial vessels, there is no data detailing the impact caused by recreational vessels.

## Fragmentation and Flow Restrictions

Fragmentation and flow restrictions occur where natural pathways for water and sediment delivery are interrupted, limiting the system's capacity to recover from disturbance.

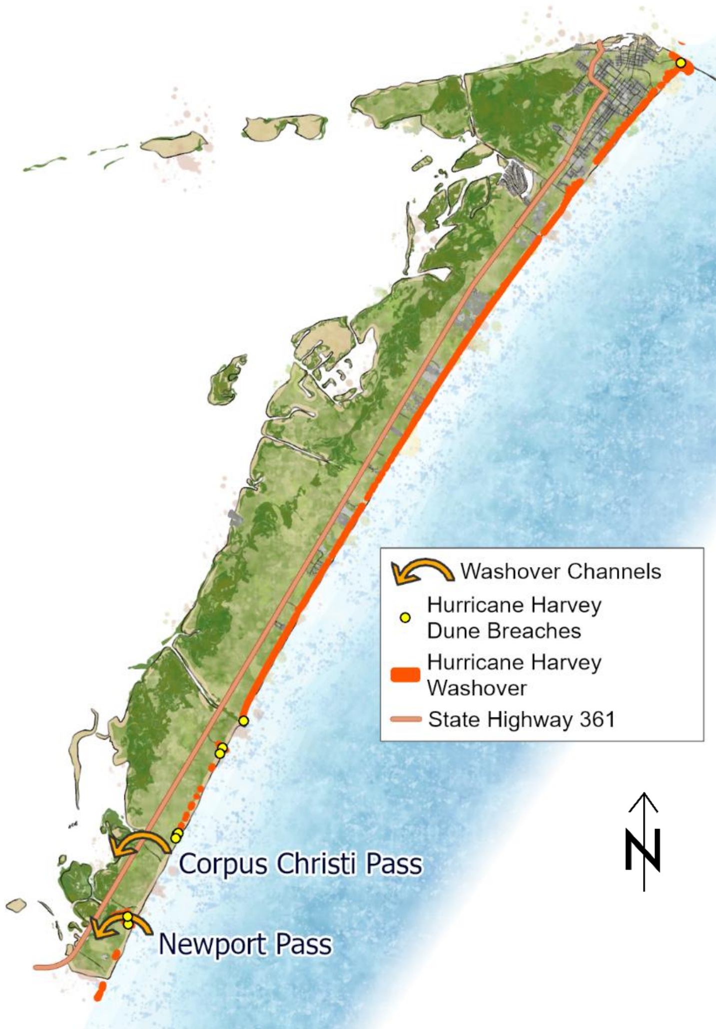
**Storm overwash is the primary mechanism by which beach and dune sand is delivered to the back-barrier, renewing marsh elevation and supporting long-term resilience.** While this process can erode and lower dune features during storm events, it also redistributes that sediment landward, providing a critical source of material for bayside wetlands (Figure 8). Overwash requires open, low-elevation corridors across the barrier. Infrastructure, such as SH-361 and adjacent development, locally constrain overwash pathways, reducing sediment delivery to bayside wetlands and increasing sediment starvation in some reaches. Historic overwash channels on Mustang Island include Newport Pass and Corpus Christi Pass (Figure 9).

**River-borne freshwater and sediment inputs provide an additional, though highly episodic, sediment source.** The Nueces River (and to a lesser extent Oso Creek) delivers freshwater, nutrients, and fine sediments during high-flow events. Because Mustang Island is located far downstream of the Nueces River mouth, these inputs are highly episodic and substantially attenuated by the time they reach the Island's bayside wetlands. High-flow periods deliver suspended sediments that can settle in low-energy areas and contribute to vertical marsh growth. However, upstream reservoirs and flow regulation reduce both the magnitude and frequency of sediment delivery, limiting the system's ability to replenish marsh substrates during non-storm conditions.

**Flow restrictions also influence salinity dynamics.** During droughts, reduced inflows can drive bay salinities into hypersaline ranges, stressing vegetation and the overall ecosystem, reducing below-ground biomass, and weakening marsh-edge cohesion. These conditions tighten the coupling between wave energy and erosion, increasing vulnerability even during moderate wind conditions.

Figure 8 Example of dune erosion in Port Aransas post-Hurricane Harvey

Figure 9 Historic washover channels and locations of dune breaches and washover from Hurricane Harvey (UT-BEG, 2025)



# Impending Habitat Loss

Impending habitat loss reflects long-term pressures that reduce the ability of wetlands to persist within a narrow elevation range.

**Sea level rise (SLR), particularly relative sea level rise (RSLR) which includes land subsidence in the region, is already compressing the vertical space occupied by marshes in this micro-tidal system and is expected to intensify over time (Figure 10)**. Increased inundation frequency and duration place greater demands on sediment accretion to maintain elevation. Where vertical accretion from overwash, riverine inputs, or local resuspension does not keep pace, low marsh transitions to tidal flat and, ultimately, open water.

**Land development further exacerbates this trajectory by limiting opportunities for landward migration.** Roads, developed uplands, and fixed infrastructure constrain the space available for wetlands to adjust to rising water levels, increasing the likelihood of long-term habitat loss.

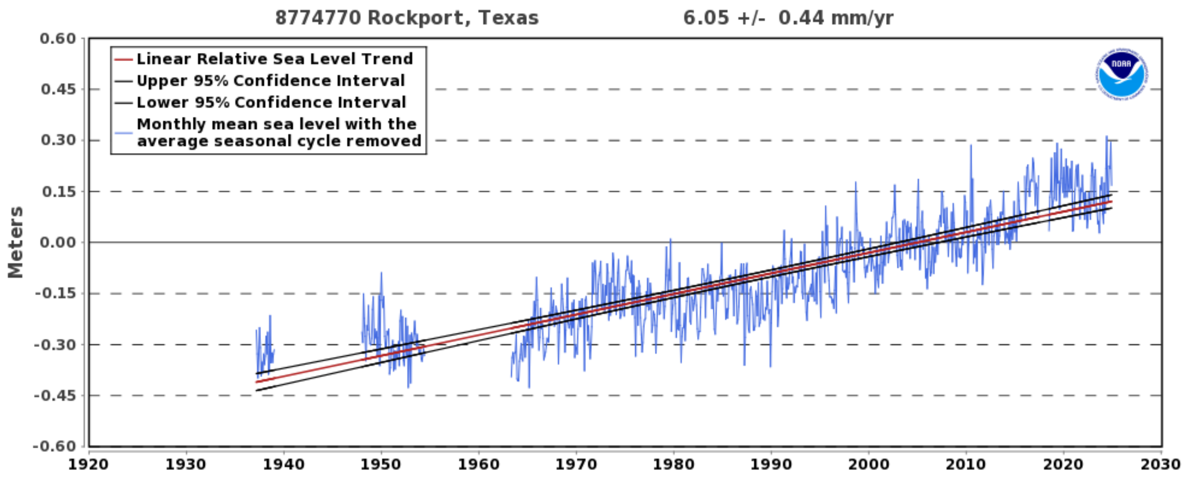



Figure 10 Relative sea level trend from the nearest tide gauge to Mustang Island in Rockport, Texas (NOAA, 2025)

**Hard freezes and vegetation regime shifts**

Events like Winter Storm Uri in 2021 caused widespread mangrove mortality across the Coastal Bend as a result of freezing temperatures. Loss of mangrove habitat temporarily removes a rough, flexible shrub layer that damps short-period waves and traps fine sediments at the marsh edge. In the years immediately following a dieback, exposed edges can retreat more quickly under typical wind conditions. Varying recovery trajectories can increase instability, with some stands resprouting and others transitioning toward a *Spartina*-dominated marsh with different drag characteristics and root cohesion. See the image below for an example of mangrove mortality at the Cohn Preserve following the winter storm.

## Localized Disturbances

Localized disturbances include direct human actions that alter wetland structure or function at specific sites. While often limited in spatial extent, these disturbances can have outsized effects when layered onto wetlands already stressed by physical degradation, fragmentation, or rising water levels.

**Transportation and marina infrastructure, including the SH-361 corridor, marina basins, and associated upland pads, introduce localized barriers to sediment and water movement.** Elevated roadbeds and developed pads channel overland flow through small culverts or storm drains, effectively blocking many overwash pathways that would otherwise deliver beach and dune sand to bayside wetlands during storm events. These constraints reduce sediment supply to interior marshes, increase ponding on the back-barrier platform. Although these features are spatially discrete, their placement can exert disproportionate influence on nearby wetlands by interrupting cross-barrier connectivity and compounding broader system-scale pressures.

**A network of historic oil-and-gas access channels and other relict dredge cuts intersect the marsh surface, particularly east of Shamrock Island near the Cohn Preserve (Figure 11).** These disturbances can cause environmental degradation, fragment hydrologic connectivity, and alter sediment redistribution at a local scale. Fish Pass, now largely shoaled, illustrates this dual effect: while the channel no longer functions as an active inlet, its remnant geometry continues to focus currents and wave energy, disrupting alongshore sediment continuity and promoting edge instability in central Mustang Island. The EPA's Brownfields Remediation program provides an opportunity to receive funding to address these disturbances.

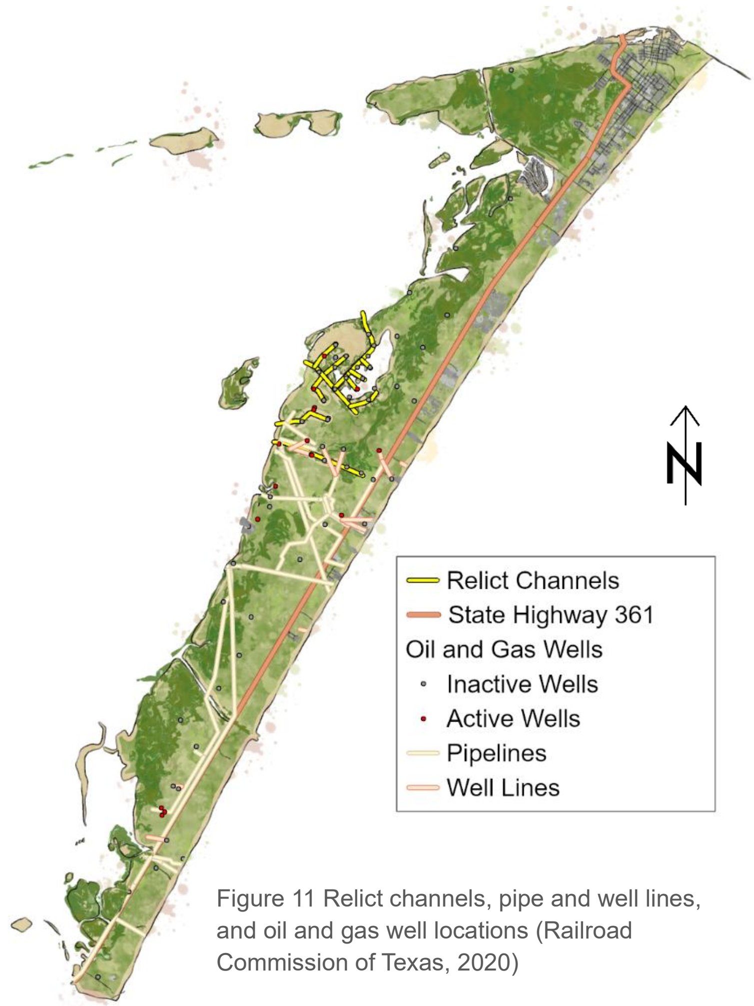



Figure 11 Relict channels, pipe and well lines, and oil and gas well locations (Railroad Commission of Texas, 2020)

**Navigation channels such as the Corpus Christi Ship Channel and the Gulf Intracoastal Waterway (GIWW) locally alter hydrodynamic and sediment transport conditions along Mustang Island's bayside wetlands.** Deepening and maintaining these corridors increase hydraulic conveyance and can modify current patterns that previously dispersed energy across adjacent shoals and flats. As a result, tidal energy and suspended sediments become focused within confined pathways, creating localized zones of enhanced erosion and deposition.

Where dredged material is placed outside local sediment transport pathways, those sediments are effectively removed from the system and no longer contribute to shoreline nourishment. Conversely, when beneficial use placements are aligned with modeled transport corridors, dredged material can shorten sediment travel distances and locally rebuild eroding margins. The influence of dredging on wetland stability is therefore highly dependent on placement location and design.

### KEY TAKEAWAYS

**These drivers are not uniformly "good" or "bad" -- their effect depends on balance.** Waves and currents shape inlets and shorelines but can outpace marsh recovery if sediment inputs lag. Overwash and river pulses supply the material needed to keep pace with rising waters but are intermittent. The resilience pathway for Mustang Island is therefore to dampen damaging energy where it concentrates while protecting and, where feasible, re-establishing sediment pathways (overwash corridors, feeder berms aligned with transport, and low-energy settling zones). Subsequent sections translate this process understanding into targeted techniques and monitoring triggers.

# Vulnerability Assessment

To understand why bayside wetlands on Mustang Island are changing and where vulnerabilities are most concentrated, the project team developed a data-driven vulnerability assessment grounded in multiple lines of evidence. Historical observations, spatial analyses, and modeling outputs were synthesized to identify the dominant processes shaping wetland condition across the Island, rather than relying on any single dataset or model. This section is divided into two areas of focus for the assessment, followed by a summary of key findings informed by each of the studies.

First is the data analysis that examines existing information across the various types of evidence. This builds an understanding of the system and its response to stressors, drawing on a range of sources compiled in this study to provide a holistic view of the Island. To support this assessment, the project team conducted a suite of data analyses to evaluate historical change, current system behavior, and potential future responses. These analyses draw on independent datasets and modeling approaches, including historical shoreline change, land cover trends, storm and water-level records, RSLR projections, and hydrodynamic and sediment transport modeling. This information is summarized in this report, but more detailed information on data sources and analysis can be found in the following supplement reports: (1) *Resilience Plan documents, Assessment of Current Literature, Data, and Models with Implications on Mustang Island*, and (2) *Mustang Island Resilience Plan - Modeling & Analysis Report*.

The second component of the vulnerability assessment is the development of new data through hydrodynamic modeling of Island sediment transport under typical conditions. This model is the result of a collaboration between the Resilience Plan and the GLO's River Basin Flood Study (RBFS). Under the RBFS, regional flood mitigation alternatives were evaluated for Mustang Island, including nature-based solutions focused on bayside wetlands to mitigate RSLR and storm surge conditions. For the RBFS, modeling was completed to inform the complex sediment transport mechanisms along Mustang Island and to inform long-term project costs and sediment needs. For the Resilience Plan, this information provided insight into the complex mechanisms that impact sediment transport along the Island and informed an understanding of vulnerabilities in the existing system, as well as the validity of potential techniques to enhance wetland stability and coverage.

Collectively, these efforts provide a process-based understanding of how waves, water levels, and sediment interact with bayside wetlands, and how human alterations and rising water levels modify those interactions. By integrating results across datasets, the analysis identifies consistent spatial patterns, dominant drivers of change, and areas where system behavior differs across Mustang Island.

# Data Analysis

The Resilience Plan draws on a suite of historical data analyses, landscape change datasets, and future projections to understand how bayside wetlands have responded to past disturbances and how they are likely to respond under future conditions. These analyses span shoreline change, land cover and development trends, storm history, RSLR, and habitat dynamics, and are grounded in both observational data and modeling frameworks.

Together, these datasets provide a multi-decadal perspective on how sediment supply, hydrologic connectivity, development, and water levels interact to shape wetland condition across the Island. Rather than relying on any single indicator, the analysis emphasizes convergence across datasets to identify persistent patterns, emerging vulnerabilities, and process-driven differences along Mustang Island. The primary data sources include:

- **Historical shoreline positions** (1937–2020; Figure 12) used to quantify long-term erosion and accretion patterns along bay-facing shorelines.
- **National land cover and wetland mapping datasets** used to evaluate changes in marshes, tidal flats, seagrasses, and developed land over multiple decades.
- **Storm history and water level records,** including hurricane tracks and tide gauge data, used to assess episodic disturbance and long-term RSLR.
- **Regional geohazard, land use change, and RSLR projections**, including outputs from the 2023 TCRMP used to evaluate future exposure to flooding, erosion, and wetland conversion.

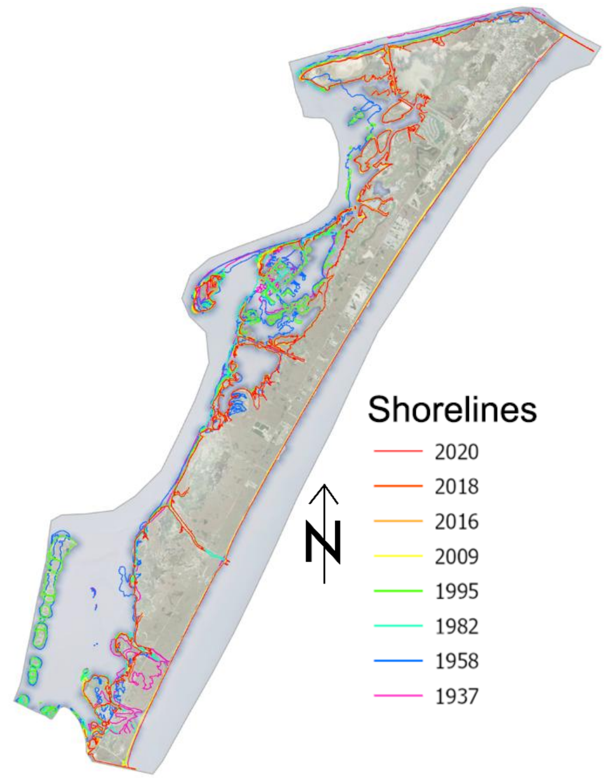


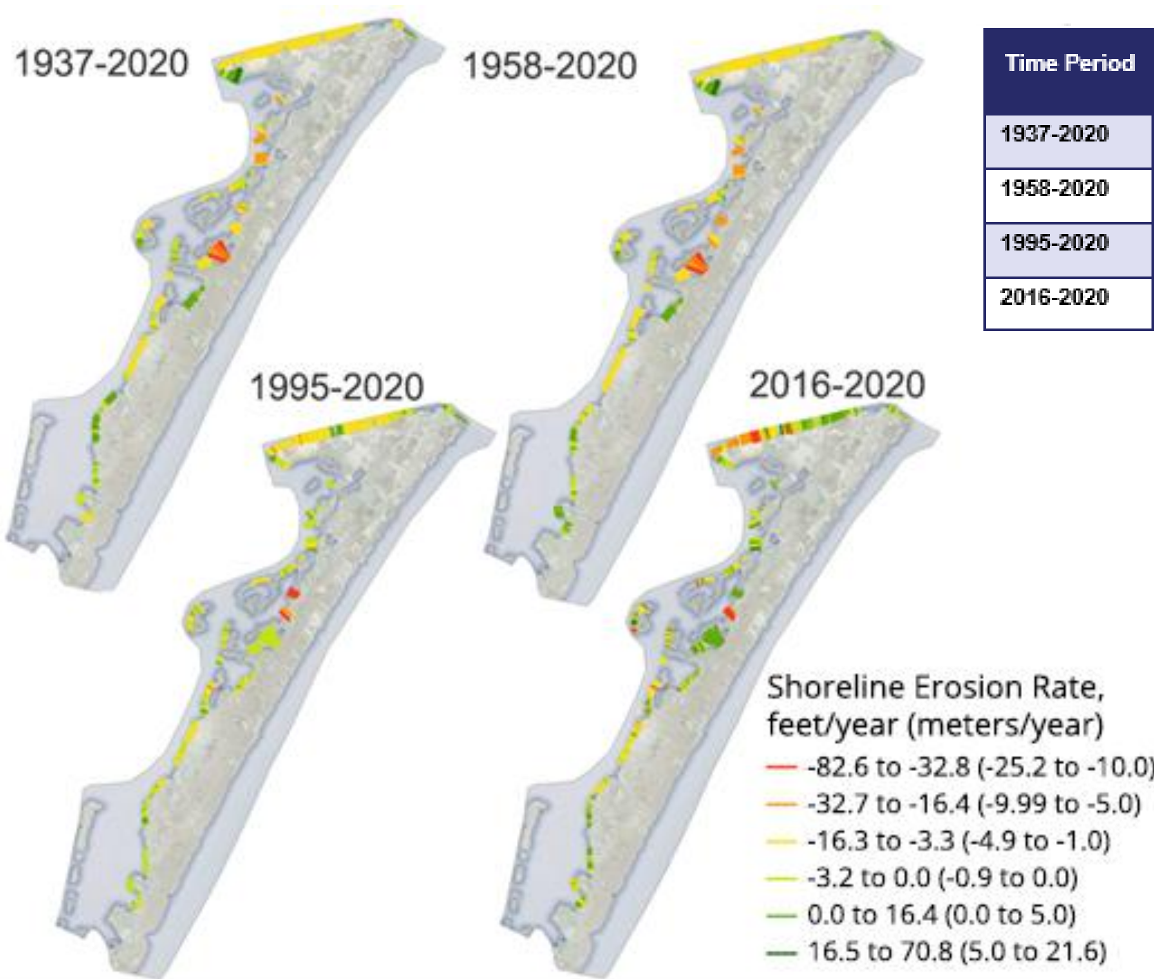

Figure 12 Historical shorelines used to analyze long-term shoreline change

### Historical Shoreline Change and Storm Influence

Historical shoreline change analysis indicates that Mustang Island's bay-facing shorelines have experienced persistent long-term erosion, with average erosion rates on the order of several feet per year over the past eight decades (Figure 13). Erosion rates are highest in the northern portion of the Island near Port Aransas, where shoreline armoring, navigation infrastructure, and dense development have altered natural sediment pathways and limited the capacity for recovery.

Central portions of the Island show more variable shoreline behavior, reflecting the combined influence of legacy dredged features, episodic storm impacts, and localized sediment redistribution. In the southern reaches near Packery Channel, shoreline change patterns reflect the influence of inlet dynamics and periodic dredging activities that modify sediment transport and deposition.

Storms play a defining role in shaping these patterns (Figure 14). While storms can facilitate sediment overwash and geomorphic resetting, their effects are strongly conditioned by existing development, infrastructure, and shoreline configuration. Major events, including Hurricane Harvey caused rapid shoreline retreat and interior wetland change, particularly in areas where storm surge and wave energy were not balanced by sediment delivery.




| Time Period | Average Erosion Rate, (feet/year) |
|---|---|
| 1937-2020 | -5.77 |
| 1958-2020 | -5.61 |
| 1995-2020 | -4.49 |
| 2016-2020 | -5.48 |

Figure 13 Shoreline change rates on Mustang Island over multiple timespans

## Land Cover Change, Development Pressure, and Habitat Shifts

Land cover analyses show that wetland change on Mustang Island has occurred alongside substantial increases in developed land over recent decades (Figure 15). Development expanded by more than one-third between the mid-1990s and 2016, primarily along SH-361, which spans nearly the full length of the Island. Wetland losses during this period were concentrated in areas adjacent to expanding development and transportation infrastructure, where overwash and sediment redistribution are most constrained.


Figure 14 Pre-Harvey shoreline (2016) over Post-Harvey imagery (2018) behind Port Aransas

At longer time scales, wetland mapping reveals that estuarine marshes expanded substantially between the 1950s and early 2000s, coinciding with post-drought recovery and shifts in hydrologic conditions (Figure 16). These gains were accompanied by a pronounced and persistent decline in tidal flats, suggesting a redistribution of habitat rather than uniform land gain. Seagrass coverage exhibited similar sensitivity to changing sediment and water quality conditions, with periods of expansion followed by decline.

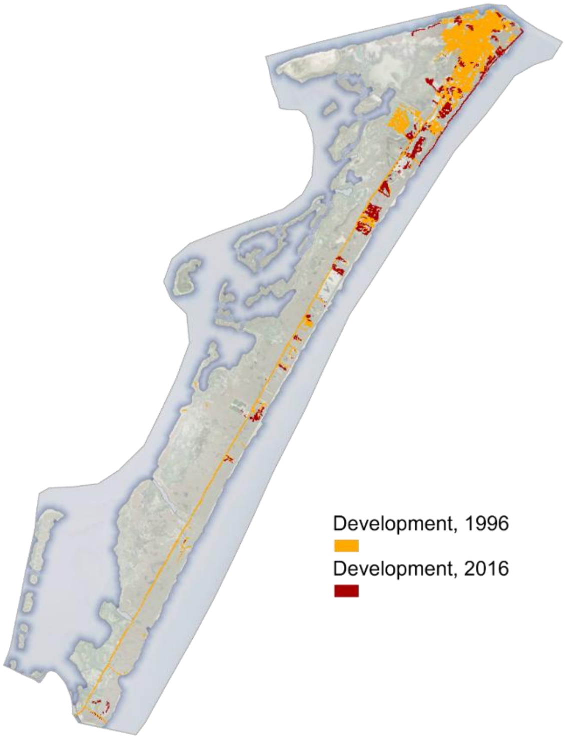



Figure 15 Developed land cover, 1996 and 2016 (NOAA, 2016)

## COASTAL SQUEEZE

As development expands along Mustang Island, particularly along the SH-361 corridor, wetlands are increasingly “squeezed” between rising water levels and fixed infrastructure. Barrier island wetlands depend on landward migration and sediment overwash to maintain elevation, but roads, buildings, and other barriers limit both pathways. As RSLR accelerates, this constraint reduces the ability of marshes to adapt, increasing the likelihood of conversion to tidal flats and open water rather than inland migration.

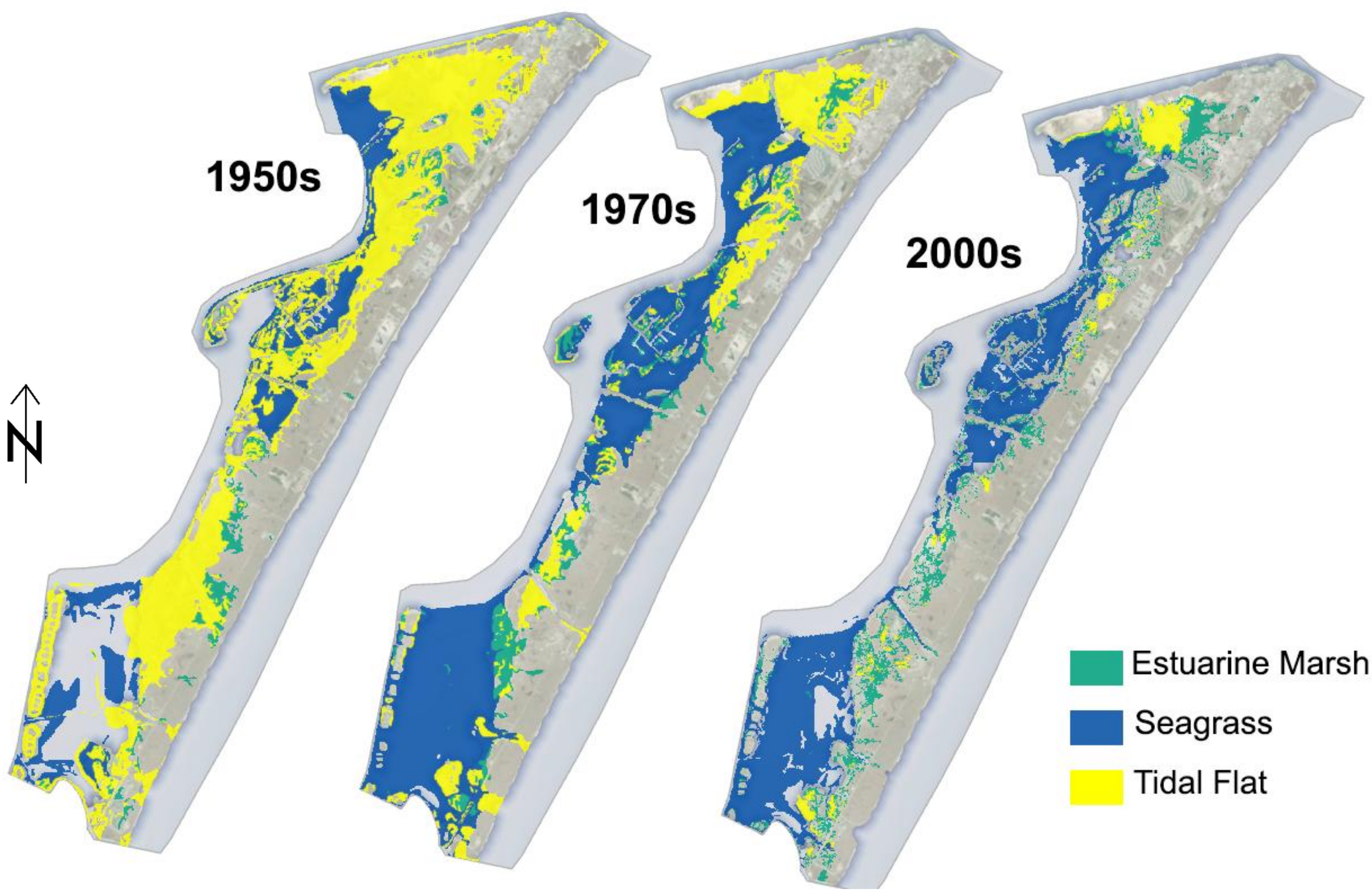



Figure 16 Historic coverage of estuarine marshes, seagrasses, and tidal flats from (Magolan et al., 2024)

## Sea Level Rise, Future Change, and Geohazard Exposure

Observed RSLR rates in the region are high and driven in part by subsidence, placing Mustang Island wetlands under increasing inundation stress. Regional modeling outputs from the TCRMP and complementary U.S. Geological Survey (USGS) analyses indicate that, under both moderate and high SLR scenarios, represented by NOAA's Intermediate-Low and Intermediate-High scenarios respectively, large portions of bayside wetlands are projected to transition to open water within this century, with some areas beginning as early as the 2030s (Figure 17; Figure 18).

Projected vulnerability is greatest in the northern and central portions of the Island, particularly near Port Aransas, Packery Channel, and the Fish Pass area, where low elevations, altered hydrology, and constrained sediment supply intersect. These findings are reinforced by geohazard assessments that identify extensive areas of Extreme and Imminent risk associated with storm surge, erosion, and wetland loss under future conditions (Figure 19).

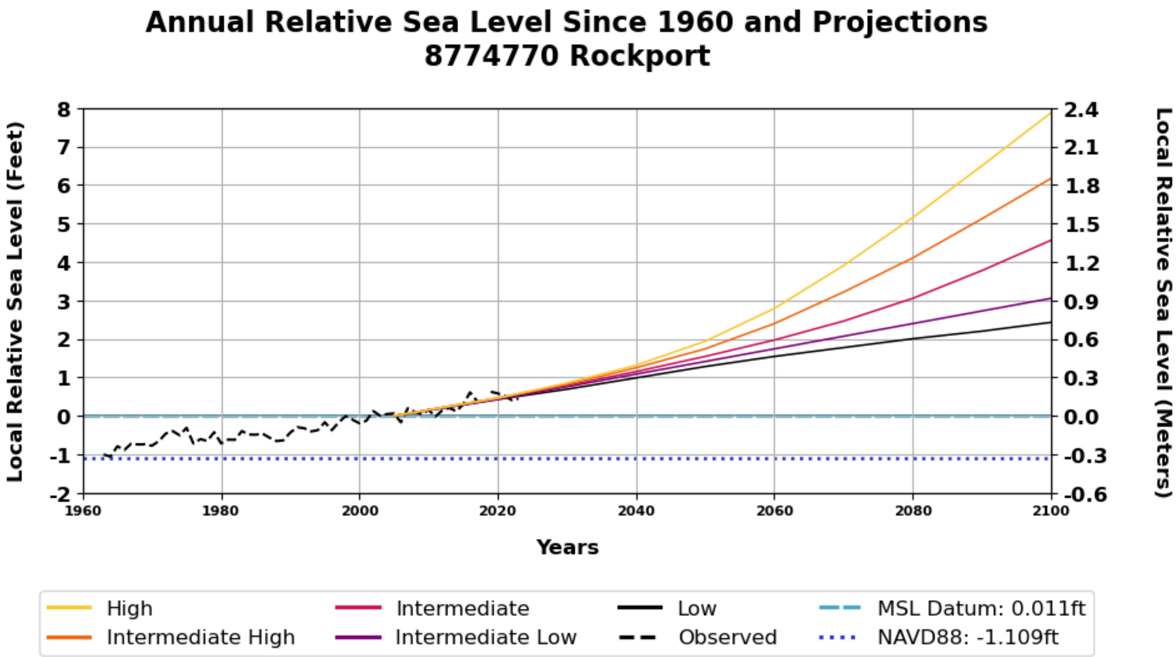



Figure 17 RSLR projections at the nearest tide gauge to Mustang Island in Rockport, Texas (NOAA, 2025)

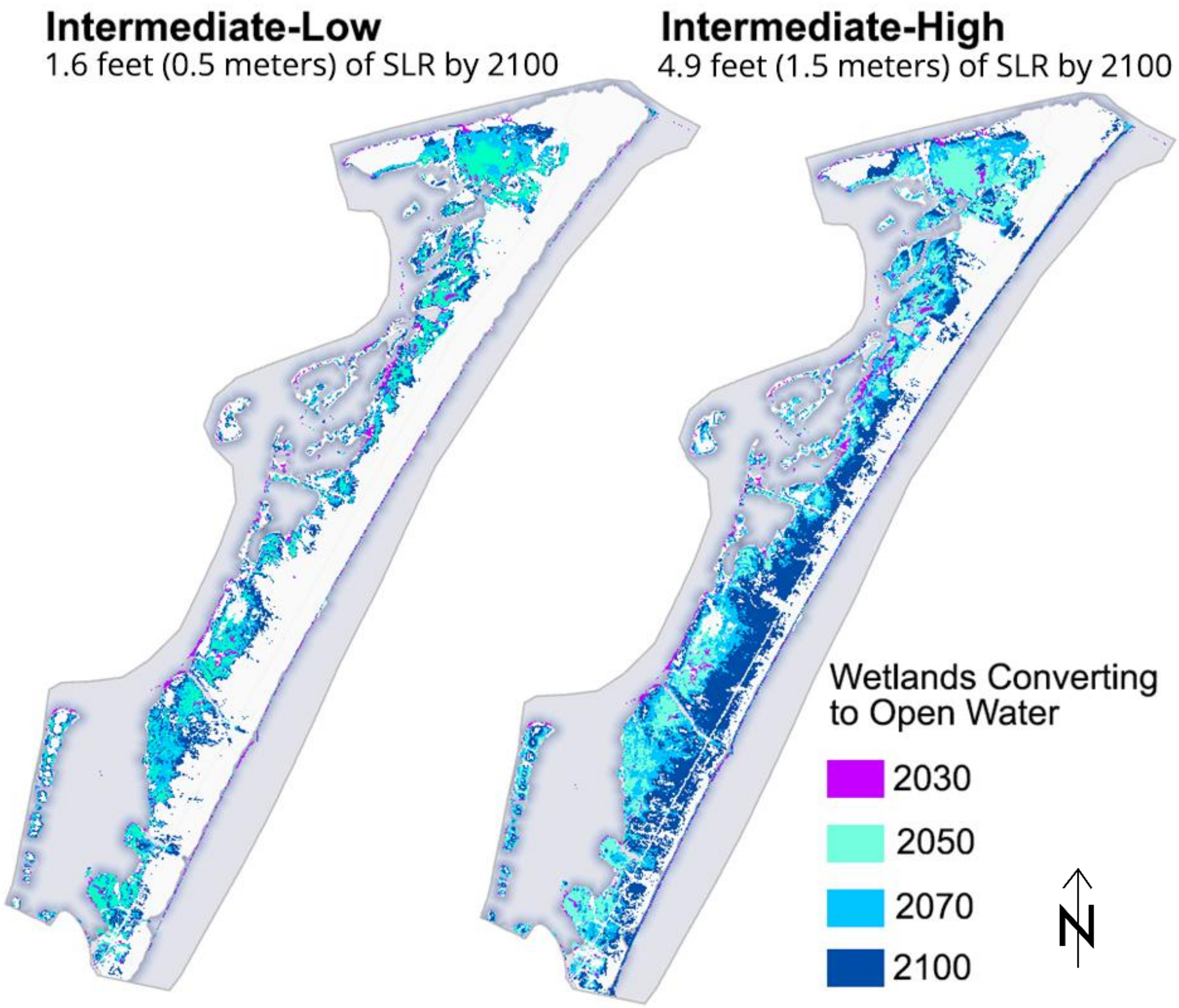



Figure 18 Wetlands converting to open water under 2 SLR Scenarios in 2030, 2050, 2070, and 2100 (Simons et al., 2025)

| Scenario | Intermediate-Low | Intermediate-High |
|---|---|---|
| **Year** | **Acres of Converting Wetlands** | **Acres of Converting Wetlands** |
| **2030** | 149,643.0 | 159,098.1 |
| **2050** | 314,027.8 | 388,389 |
| **2070** | 423,064.4 | 563,331.8 |
| **2100** | 269,227.5 | 500,424.2 |

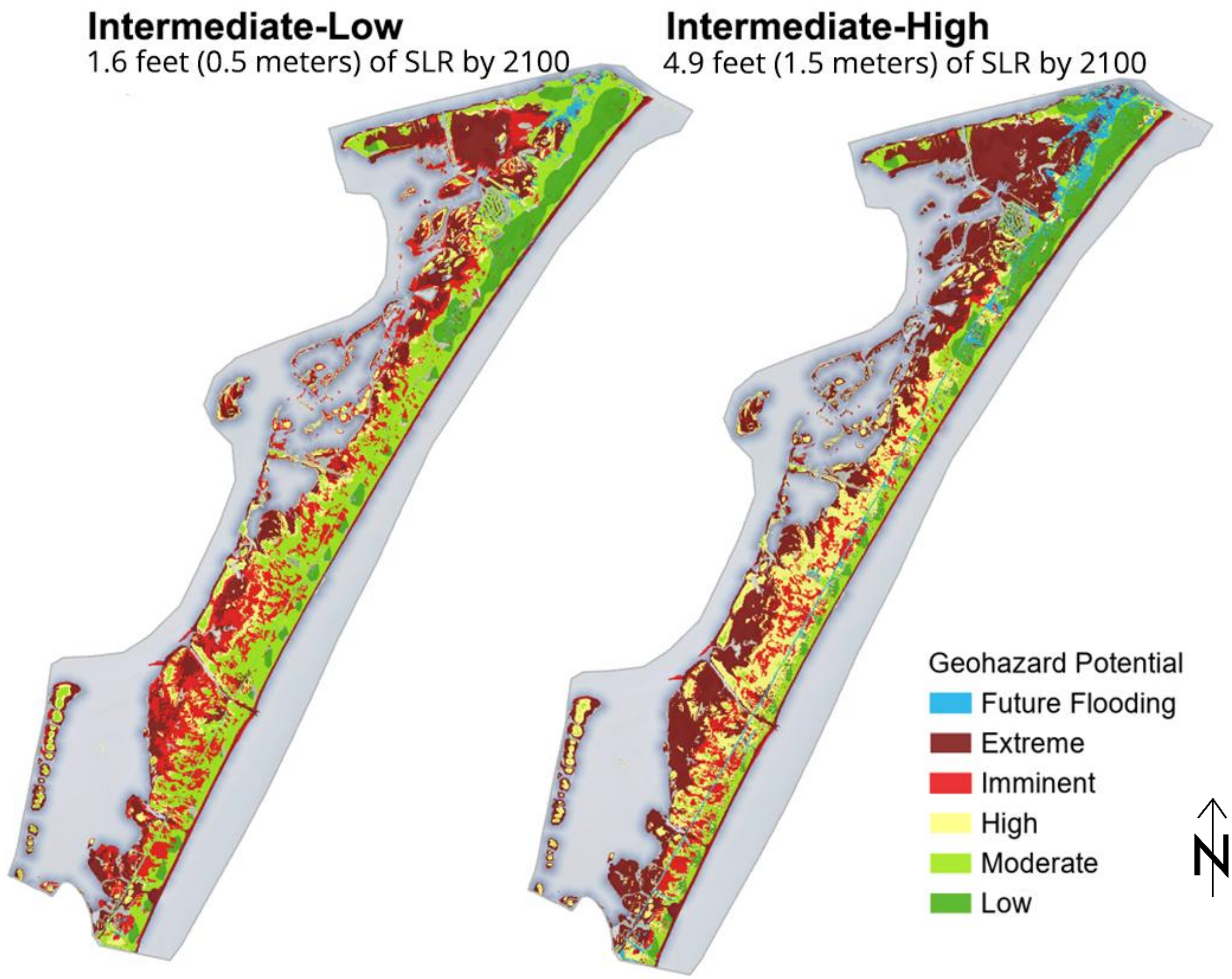
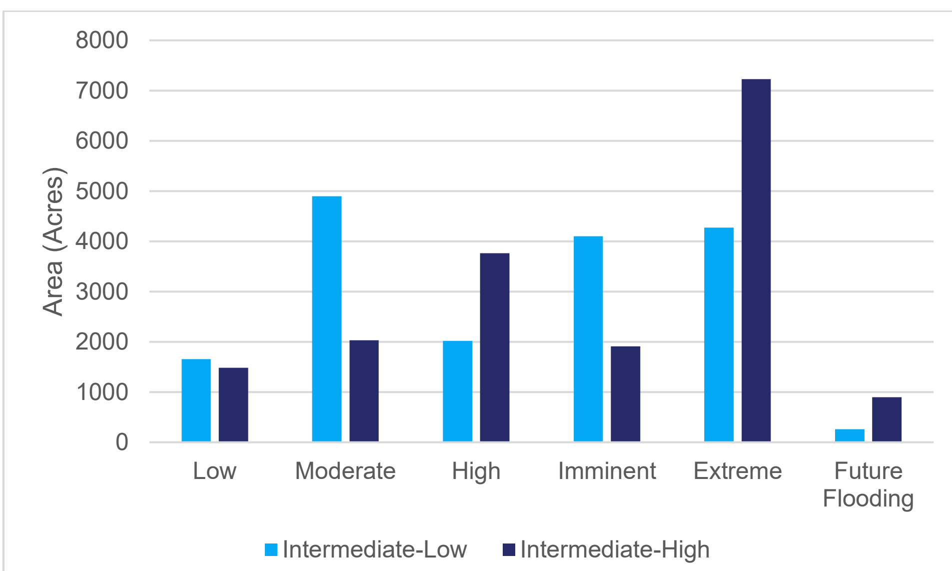



Figure 19 Geohazards potential for the Intermediate-Low and Intermediate High SLR scenarios (GLO, 2023)



## Habitat Stabilization and Disturbance Sensitivity

Mangroves play an important stabilizing role in portions of Mustang Island's wetland system by attenuating waves and retaining sediment. However, their distribution is uneven and concentrated primarily in the central and northern reaches (Figure 20). Freeze events, such as Winter Storm Uri (2021), have caused widespread mangrove mortality, temporarily reducing this stabilizing influence and increasing exposure to erosion and flooding until vegetation recovers.


Figure 20 Mangrove locations (NOAA, 2012)

# Coastal Modeling

As part of the RBFS, modeling was conducted to compare with- and without-project conditions along Mustang Island considering the bayside wetland complex and associated mitigation measures. With-project conditions were simulated and analyzed to understand the behavior of erosion and sediment transport processes along the back side of the Mustang Island's wetland complex and their response to feeder berms and shoreline stabilization techniques under typical conditions. **These conditions do not reflect how the Island responds to low-frequency events, which drive some of the significant erosion occurrences from tropical storms and hurricanes, this model assesses the response under the long-term conditions for general stability of the wetland system.**

To model the system, MIKE 21 FM was utilized, which integrates Hydrodynamic (HD), Spectral Wave (SW), and Mud Transport (MT) modules in a 2-D depth-averaged configuration, enabling dynamic feedback among water levels, currents, wave energy, and sediment transport. The model includes key features such as the Corpus Christi Ship Channel, GIWW, and Mustang Island. Water level boundary conditions incorporated tidal data from NOAA gauges offshore and at Rockport, offshore wave forcing from U.S. Army Corps of Engineers (USACE) Wave Information Study (WIS) stations, spatially varying wind forcing from NOAA High Resolution Rapid Refresh hindcasts, riverine inflows from USGS gages, and vegetation drag zones derived from the NWI wetland shapefiles footprints. Sediment conditions were input based on analysis of multiple studies and publicly available sediment sample analysis along Mustang Island.

## LIVING SHORELINES

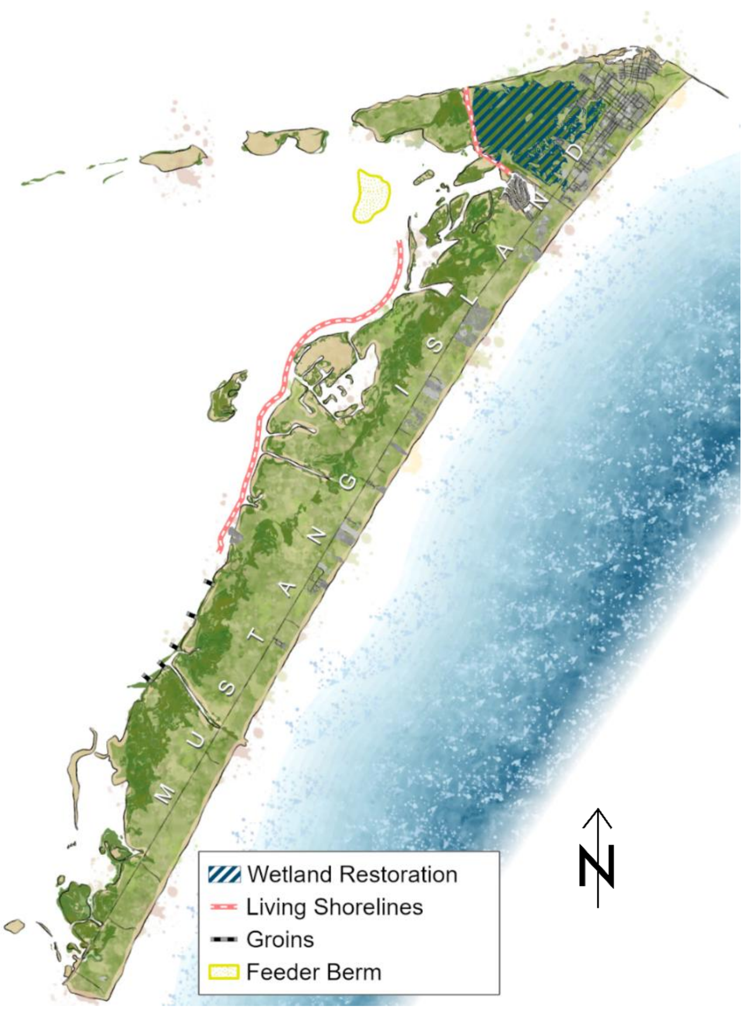
The GLO defines living shorelines as shoreline protection and stabilization features that incorporate substantial natural or nature-based elements to maintain shoreline ecosystem functions, sometimes combined with hard structural components such as rip rap. Living shorelines use natural or recycled materials and the strategic placement of plants and/or organic material to reduce erosion, protect property, create habitat, and enhance resiliency.

For more information, please refer to the GLO's *A Guide to Living Shorelines in Texas*: https://www.glo.texas.gov/sites/default/files/2025-01/guide-to-living-shorelines-in-texas.pdf

Two with-project scenarios (Figure 21) were developed that focused on protecting and restoring wetlands on the backside of Mustang Island. The first with-project scenario incorporated a sacrificial sediment feeder berm, living shoreline, and wetland restoration west of Port Aransas Nature Preserve. The second with-project scenario incorporated a larger living shoreline and wetland restoration component along the bayside toe of Mustang Island's wetlands east of Shamrock Island, as well as low elevation groins along the southern stretch. All alternatives incorporated into the two with-project scenarios were intended to improve the health and resiliency of Mustang Islands wetlands over time.

For the without-project (Figure 22) and two with-project scenarios, multiple simulations were conducted over a 5-year simulation period to understand the system's typical responses. Each scenario was simulated for this period under 0-foot, 3-foot, 4-foot, and 5-foot SLR conditions.

Figure 21 With-project modeling components




### Prevailing Sediment Transport Conditions

Sediment transport patterns are mostly consistent across varying SLR conditions. The dominant transport pattern is from the north to the south along the existing toe of the wetlands. Wind-generated waves from the north-northwest (NNW) direction appear to play a key role in driving the transport. Prevailing south-southeast (SSE) winds have a comparatively lesser erosional effect due to limited fetch distances and shallow water in the wetlands. In the northernmost part of Mustang Island, weaker transport patterns are observed compared to the mid and southern portions of the Island.

Analysis of the results indicates that the Corpus Christi Ship Channel and its spoil islands to the north and south provide greater protection during a NNW wind wave event, reducing transport processes that occurred before their construction. The mid-section of Mustang Island is more exposed to driving wind-wave forces from the NNW, and larger magnitudes of sediment transport can be observed mobilizing along the toe of the wetlands. Sediment is observed to follow the historical spit to Shamrock Island as it moves from north to south. As water levels increase under simulated SLR conditions, transport appears to shift across the spit in a southerly direction rather than along its alignment. South of Shamrock Island, the greatest sediment transport occurs along the toe of the existing wetlands. Some sediment is observed to deposit on the southernmost bay shoreline, and some passes south to enter the shallow Packery flats. Observations made from system wide results indicate that sediment recapture, or introduction of sediments to supplement the existing transport system would be most appropriate in the southern portions of the Mustang Island wetland system. Resilience projects in the northern section of Mustang Island are less likely to effectively re-capture sediment in the transport system due to the lower sediment load and transport occurring. The vegetation and shallow bathymetry at the toe of the existing wetlands reduced wave energy reaching the fragmented wetland areas behind.

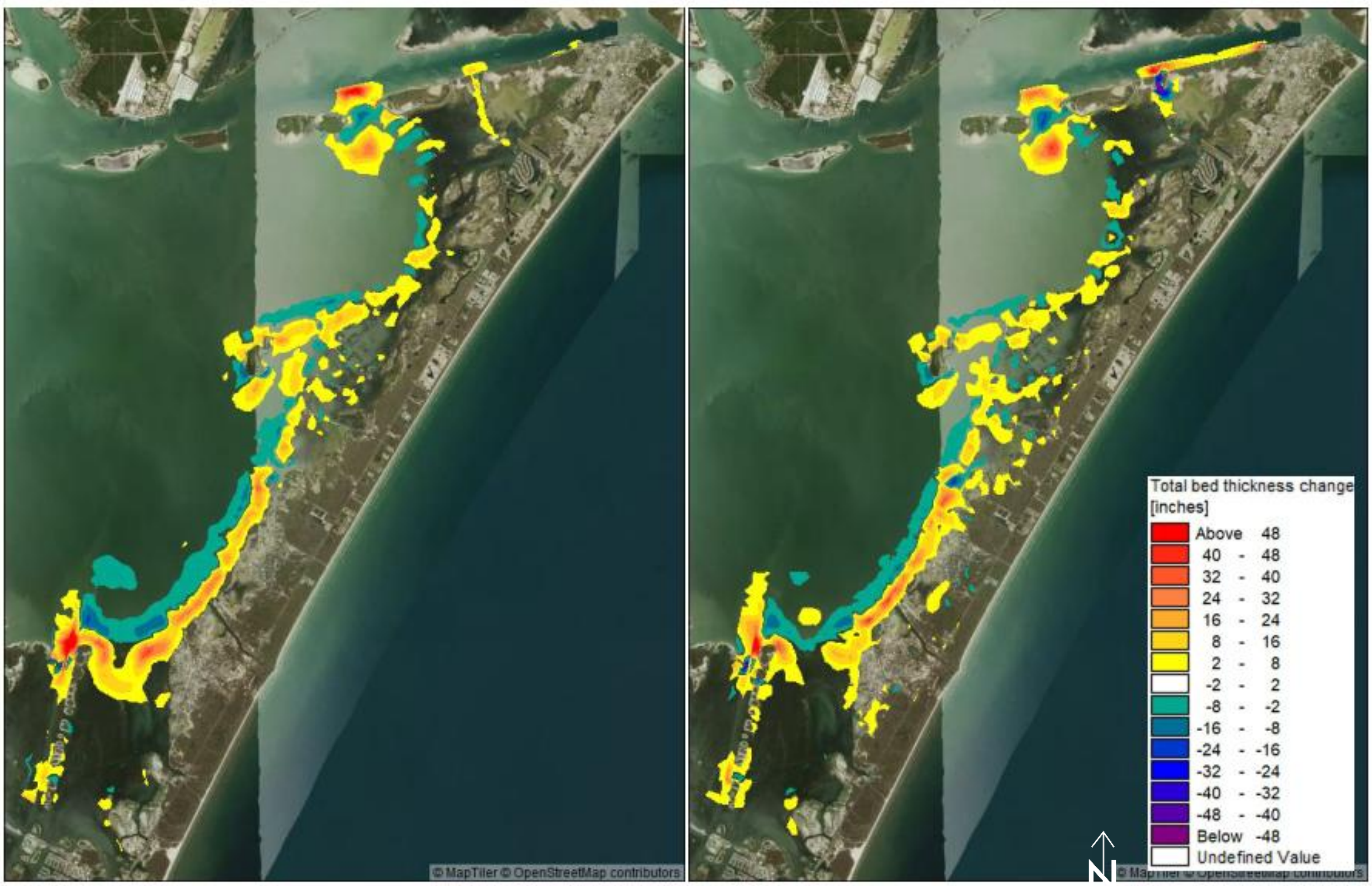



Figure 22 Total sediment accretion over a 5-year period in the Without-Project Scenario at current conditions (0-foot SLR) on the left and at 3-foot SLR on the right

## With-Project Sediment Response

Areas just west of the Port Aransas Nature Preserve were observed to be stable under typical conditions, and the living shoreline and wetland restoration components of the with-project scenario remain stable when simulated under various SLR conditions (Figure 23). With little sediment transport observed under the typical conditions, it is likely that long-term, these wetlands are more susceptible to degradation by drowning due to SLR than erosion. This indicates that for future resilience, wetland restoration projects such as the ones simulated here, would benefit from an increase in elevation in addition to only planting. The living shoreline component of this with-project condition could be reduced to a smaller scale from observed wave energy in simulation results. The area generally remains stable under without-project conditions, but the simulations do not include vessel wakes that would be present along the channel to the marina that would contribute to erosion if left unprotected.

The sediment feeder berm incorporated in this with-project scenario was intended to provide gradual nourishment into the fragmented wetlands to the east. However, little transport was observed in the results in that direction. The feeder berm was mostly affected by tidal flows between nearby spoil islands and sediment primarily moved in the north-south direction. With more protection from NNW wind wave events, a lack of west-east tidal movement, and generally lower magnitudes of sediment transport, sediment feeder berms are not recommended in the northern sections of Mustang Island.

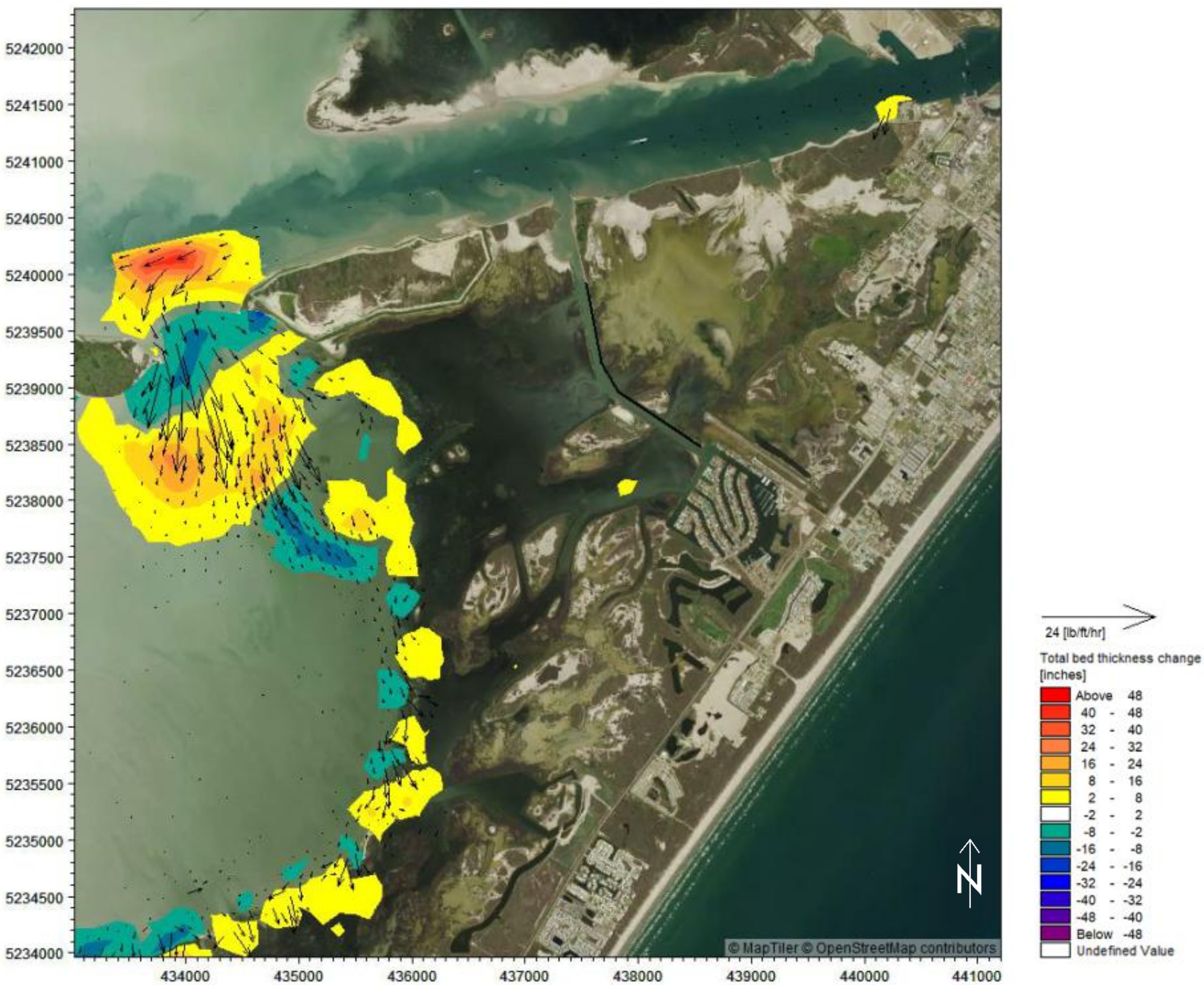



Figure 23 Wetlands behind the Port Aransas Nature Preserve and the adjacent living shoreline remain stable under typical conditions in the With-Project current condition (0-foot SLR) scenario

The living shoreline and wetland restoration components simulated along the middle of Mustangs Island's bayside wetlands were observed to stabilize erosion along the wetlands (Figure 24; Figure 25). Gaps in the breakwater and wetland restoration footprints led to sediment accretion into the existing wetlands behind, as well as along the toe of the living shoreline. This indicates potential for erosion stabilization and natural sediment capture along this portion of the system, providing increased resilience. Based on comparison of with- and without-project results, the northern portions of the living shoreline and wetland restoration would be recommended to be constructed first due to erosion observed in the area. This area also has a lower natural sediment budget, which may leave it more vulnerable than shorelines further south.

The groins simulated south of the living shoreline and wetland restoration footprints were observed to accrete sediment moving from north to south, indicating that this section of the shoreline can be stabilized with a different technique that focuses more on recapturing existing sediment. It is important to note that stabilizing the shoreline east of Shamrock Island would reduce sediment transport in the north to south direction, so stabilizing the southernmost bayside shorelines with groins first would allow them to capture more sediment before living shoreline construction on shorelines to the north.

Even though it was not included, results indicate that a sediment feeder berm may be more successful on the southern portion of Mustang Island's bayside shorelines. A much stronger directional natural transport system is observed along the southern shorelines of Mustang Island compared to the northern shorelines. A sediment feeder berm in this general area could provide additional sediment to the local budget to mitigate reduced transport associated with stabilizing shorelines north and south of Shamrock Island.

Figure 24 Zoomed-in map to the midsection of Mustang Island showing modeled groins and living shoreline

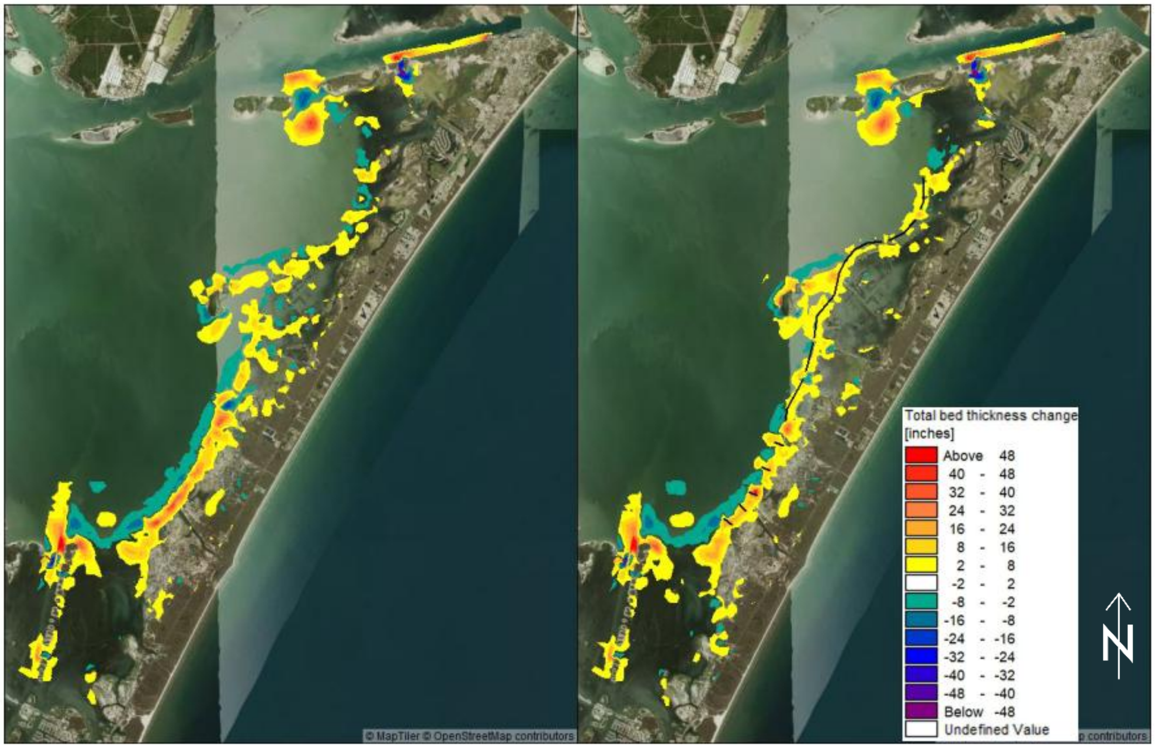



Figure 25 The With-Project current condition (0-foot SLR) scenario on the left compared to the With-Project 3-foot SLR scenario on the right indicates the breakwaters on the backside contribute to stability of the mid-Island wetlands.

## Model Limitations

The MIKE 21 simulations had several limitations and assumptions that should be acknowledged to provide context of the captured results.

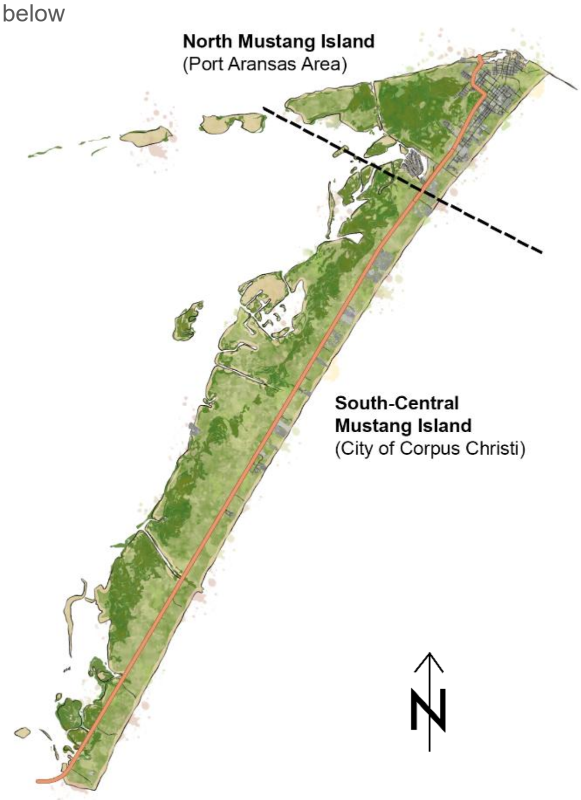
- Recreational and commercial vessel wakes were not incorporated into the model. Both types of vessel wakes are difficult to incorporate directly into the spectral wave model in MIKE21, and recreational traffic vessel traffic typically does not support Automatic Identification System (AIS) that allows for vessel position, speed, and heading tracking.
- Barrier island overwash transport of sediment was also excluded due to the complexity of accurately representing these processes across a system with variable terrain and development. It is documented that sediment overwash plays a role in nourishing wetlands behind barrier islands during significant surge or storm events, which were not simulated in this effort.
- The model resolution was not high enough to capture detailed marsh water circulation, which was not the main focus, and computational efficiency limits affected the overall resolution of the mesh.
- Salinity boundary condition data were obtained and evaluated, but were found to be inconsistently recorded with significant gaps and were not incorporated into the model. However, a significant portion of the sediment evaluated for transport was non-cohesive sediments, which reduces the salinity's chemical effects on non-cohesive transport processes.
- No wave data measurements were available within the bay domain to calibrate wind-generated waves against, but high-resolution spatially varying wind forcing was used to best represent conditions across the domain.
- Sediment transport calibration was constrained by limited measured data, so results should be interpreted as relative comparisons rather than absolute predictions.
- The simulations conducted are representative of typical conditions across various seasonal trends, and do not account for significant events like hurricanes and tropical storms that would be difficult to calibrate sediment transport processes to.

# Key Findings

## How Data Provides Insights into the Island System

**The vulnerability assessment finds that the wetland condition on Mustang Island is strongly controlled by sediment availability, hydrologic connectivity, and exposure to wave energy, with those factors varying across the bayside wetland complex. These differences are most evident between the more heavily modified and exposed northern reaches and the comparatively less developed, but still dynamically stressed, central and southern portions of the island, which are evaluated separately below (Figure 26).**

Figure 26 The division between the north and south-central reaches of the island used in the analysis below




Historical shoreline change data show persistent erosion along bayside shorelines, with higher rates in areas adjacent to development and engineered features. Land cover data indicate that wetland losses are closely associated with development, shoreline hardening, and infrastructure that limits sediment movement and overwash.

Sediment transport modeling further clarifies these patterns by identifying where sediment actively moves through the system and where it does not. The modeling shows that sediment transport along Mustang Island's bayside wetlands is directional and uneven, with stronger transport corridors in the central and southern portions of the Island and weaker transport in the north. These findings help explain why some wetlands exhibit greater capacity for recovery or stabilization, while others remain sediment-limited.

Storm and water level data demonstrate that Mustang Island's wetlands exist within a narrow elevation range and are highly sensitive to both episodic storm events and gradual increases in water levels. As relative sea level rises, wetlands require greater sediment input to maintain elevation. Where sediment supply or transport pathways are disrupted, wetlands become increasingly vulnerable to prolonged inundation and conversion to open water. Even more urgently, the wetlands can be substantially damaged by high-intensity erosional events from tropical storms and hurricanes and lack the capacity to recover, accelerating the overall degradation significantly.

The model results and data analysis also highlight the role of human alterations in shaping system behavior. Shoreline armoring, dredged channels, spoil placement, roads, and development influence how waves, water, and sediment interact with wetlands. In some locations, these features reduce local wave energy but also disrupt sediment pathways and hydrologic connectivity, which are critical for long-term wetland stability. The combined data indicate that vulnerability increases where multiple stressors overlap (such as limited sediment supply, altered hydrology, vessel traffic, and constrained landward migration), particularly in developed areas.

Rather than treating vulnerability as a static condition, this analysis focuses on the processes that generate it. Mapping sediment pathways, wave energy exposure, and elevation constraints reveals why wetlands respond differently across Mustang Island and provides a process-based foundation for interpreting both observed change and future projections. This knowledge allows for techniques and actions to be prioritized and catered to the unique needs of the Island.

## North Mustang Island

Northern Mustang Island, particularly around Port Aransas, has experienced some of the most extensive shoreline modification on the Island. Dense residential and commercial development, combined with widespread shoreline armoring such as bulkheads, seawalls, and revetments, has altered natural sediment movement and reduced hydrologic connectivity along bay-facing shorelines. These changes have limited the ability of sediment to naturally nourish wetlands and maintain shoreline stability.


Figure 27 City boundaries of Corpus Christi and Port Aransas

Land cover data show that wetland losses in this area closely follow patterns of urban expansion, with marshes replaced by impervious surfaces and hardened shorelines. This pattern reflects long-standing zoning and regulatory differences that allowed denser development in Port Aransas relative to other parts of Mustang Island (Figure 27).

Historical shoreline change analysis (1937–2020) indicates that bay-facing shorelines in northern Mustang Island erode at an average rate of approximately 7.6 feet per year (2.3 meters per year). Storm events have driven episodic but severe losses, particularly during hurricanes such as Celia (1970) and Harvey, when localized erosion exceeded 33 feet per year (10 meters per year). In many locations, post-storm recovery has been limited by shoreline armoring, which prevents sediment from re-entering the wetland system.

Coastal modeling results reinforce these observed patterns. Simulations indicate that sediment transport in the northern portion of Mustang Island is relatively weak compared to other parts of the Island. Existing features, including the Corpus Christi Ship Channel and adjacent spoil islands, reduce wave energy or limit sediment mobilization during dominant wind conditions. As a result, little sediment moves into fragmented wetlands behind the shoreline, even under elevated water levels associated with SLR.

Modeling further suggests that wetlands in the northern region are more vulnerable to long-term inundation and drowning than to continued lateral erosion. With limited sediment supply and weak transport pathways, wetlands in this area have little capacity to naturally build elevation in response to rising sea levels. This finding aligns with projected land loss patterns from regional sea level rise models, which indicate high conversion potential for low-lying marshes adjacent to developed areas.

### Implications for vulnerability:

In northern Mustang Island, vulnerability is driven by a combination of development pressure, hardened shorelines, limited sediment transport, and rising sea level. Modeling indicates that sediment-based techniques are unlikely to be effective in this region without active elevation enhancement. Long-term resilience will depend on strategic land use planning, wetland restoration approaches that incorporate elevation gain, and infrastructure designs that minimize further disruption to natural hydrologic processes.

# South/Central Mustang Island

The central and southern portions of Mustang Island, extending from Mustang Island State Park south to Packery Channel, exhibit a different vulnerability profile than the highly developed northern region. These areas fall largely under the jurisdiction of the City of Corpus Christi and Nueces County, where development restrictions and conservation-focused land management have limited intensive urban growth. Large contiguous wetland systems remain, supported by conservation lands such as Mustang Island State Park and the Cohn Preserve (Figure 28).

Historical shoreline change analysis (1937–2020) shows that bay-facing shorelines in this region erode at an average rate of approximately 5.6 feet per year (1.7 meters per year). Erosion is driven primarily by storms, natural sediment redistribution, and hydrodynamic changes associated with engineered features such as Packery Channel and legacy dredged passes, including Fish Pass.

Long-term ecological data indicate that wetlands in central and southern Mustang Island have undergone substantial shifts over time, including post-drought marsh expansion during the mid-to-late 20th century followed by more recent instability. These changes reflect the system's sensitivity to sediment supply, freshwater inflows, and storm-driven processes.

Existing washover channels and coastal modeling both indicate that the central and southern regions are the primary sediment transport corridor for Mustang Island. Simulations show strong, persistent north-to-south sediment movement along the toe of existing wetlands, driven largely by dominant wind-wave conditions. The magnitude of sediment transport increases southward, with the highest transport rates occurring south of Shamrock Island and approaching Packery Channel.

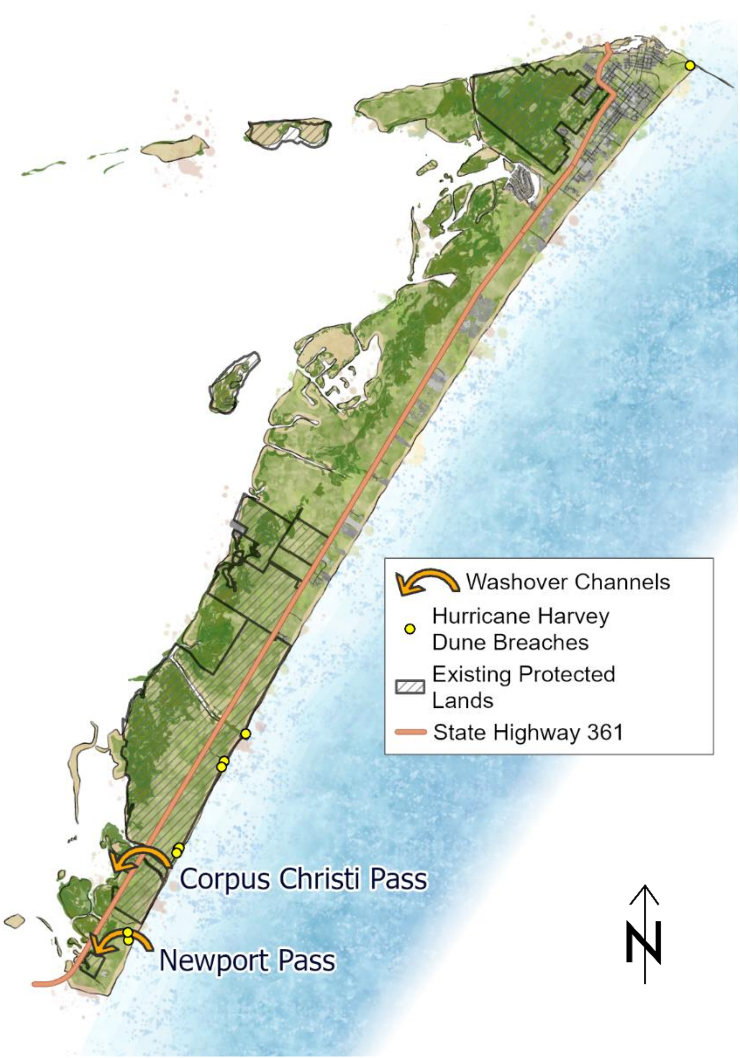
Model results indicate that this portion of the Island has a greater capacity to capture, redistribute, and retain sediment, particularly where natural or restored features interrupt transport pathways. Under SLR conditions, sediment movement becomes more diffuse, increasing the potential for sediment to enter wetlands when appropriate pathways and structures are present.

However, modeling also shows that storm exposure and altered hydrodynamics near Packery Channel continue to drive localized erosion, and recovery is constrained where sediment supply is disrupted. Without intervention, low-lying marshes in this region remain vulnerable to prolonged inundation and conversion to open water, consistent with RSLR projections and geohazard assessments.

## Implications for Vulnerability:

In central and southern Mustang Island, vulnerability is driven less by development pressure and more by sediment dynamics, storm exposure, and hydrologic disruption. Modeling indicates that this region offers the greatest opportunity for sediment-based resilience techniques, including actions that stabilize erosion while allowing natural sediment recapture. Maintaining hydrologic connectivity and carefully sequencing restoration actions will be critical to reducing long-term vulnerability.

Figure 28 South-Central Mustang Island has continuous tracts of protected land, the two primary washover channels on the island, as well as the majority of dunes that were breached during Hurricane Harvey



# Enhancing Resilience

Previous sections of the Resilience Plan describe the physical processes and human pressures that shape Mustang Island's wetlands and define where vulnerabilities emerge. This section shifts from understanding those dynamics and the need for resilience to how best to improve the Island's resilience based on these insights. Enhancing resilience is not about restoring wetlands to a fixed condition, but about reinforcing the natural processes that allow them to persist, adapt, and recover under changing environmental and development pressures.

**As illustrated in Figure 29 below, this section focuses on translating system understanding into actionable resilience techniques through stakeholder engagement, identification of resilience opportunities, technique development, and placement refinement.** The coastal resilience techniques that follow are organized within this framework and emphasize practical application, feasibility, and responsiveness to local conditions.


Figure 29 Process to identify resilience techniques

## Coastal Resilience Techniques

This section introduces formal recommendations to help wetlands, and the Island as a whole, maintain this balance by boosting natural stabilization mechanisms and minimizing the impacts of destabilizing ones. While this can include working within the wetland itself, successful implementation relies on efforts that extend far beyond the marsh's boundaries. It involves close collaboration among wetland scientists, engineers, land managers, local government, and residents who share a passion for safeguarding this important habitat and a willingness to sustain long-term investment.

Four overarching techniques have been identified in the Resilience Plan through which stakeholders can support Mustang Island's ability to maintain a healthy balance between its natural systems and communities.

- **Wetland Stabilization.** This technique comprises physical interventions that target erosion at the marsh edge, as well as policies that make implementation more efficient, cost-effective, and easier to replicate for future project needs.
- **Wetland Health and Cohesion.** This technique focuses on maintaining ideal conditions for growth within existing wetland complexes, including sediment supply, tidal connectivity, and water quality.
- **Habitat Creation, Preservation, and Enhancement.** This technique comprises actions that provide wetlands with the space they need to adapt to a range of potential future conditions.
- **Environmental Stewardship.** This technique focuses on improving communities' ability to live effectively alongside wetlands on Mustang Island, including improvements to public access, expansion of public awareness and engagement, and support for research that contributes to a more comprehensive understanding of wetland processes and needs.

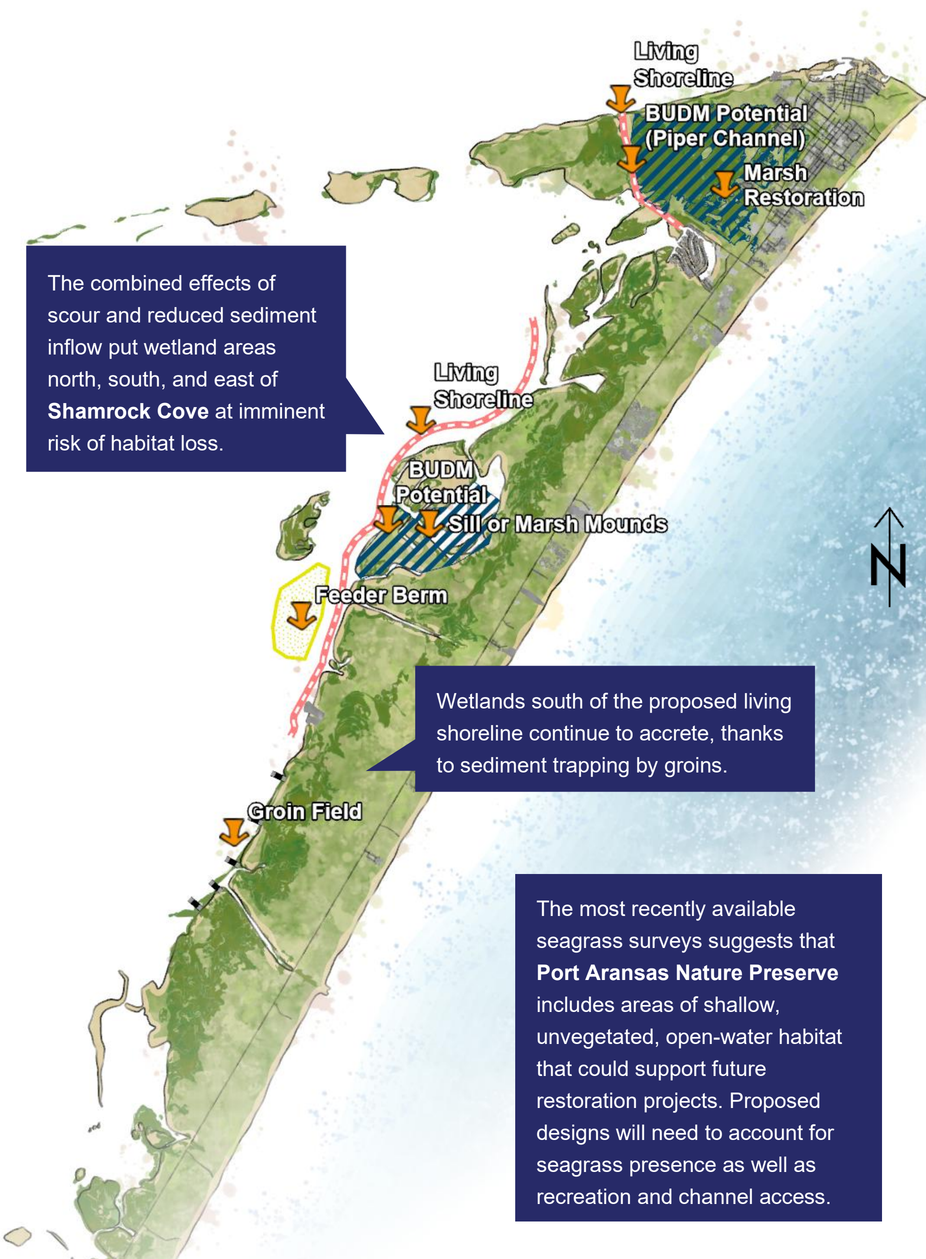
# Technique 1: Wetland Stabilization

Resilience begins at the marsh-bay interface, where the physical integrity of the wetland ecosystem is constantly under stress from waves, tidal currents, vessel wakes, and surge brought on by tropical systems. Healthy marshes maintain an equilibrium with these forces by capitalizing on sediment delivery processes and seasonal growth, slowly reclaiming lost ground and rebuilding it to support vegetation recruitment. However, an increase in the frequency or intensity of erosive forces can overwhelm a marsh's natural capacity for stabilization, leading to a loss of habitat extent over time.

Most engineered solutions to erosion confront these processes directly by building structures to reduce shoreline wave energy and by promoting sediment accretion behind the structure in calmer conditions, where new vegetation can take root. These are often constructed as living shorelines, with the structures supported by smooth cordgrass (*Spartina alterniflora*) or other marsh vegetation to provide a secondary buffer against waves. The Resilience Plan recommends a combination of living shorelines, groins, and marsh mounds installed at identified erosion hotspots on Mustang Island's bayside, as well as restoration of tidal flats that serve as wintering grounds for the endangered piping plover (*Charadrius melodus*) and nesting grounds for the snowy and Wilson's plovers (*Charadrius nivosus*; *Anarhynchus wilsonia*). All approaches rely on the timely placement of sediment compatible with the fine-grained, organic-rich soils already present within the marsh. For this reason, this technique also considers options to improve the availability of beneficial use of dredged material (BUDM) for resilience projects, thereby lowering costs.

**Install living shorelines at sites projected to experience severe marsh loss, and, where appropriate, boost sediment capture with groins or feeder berms.** Modeling suggests that living shorelines are effective solutions for managing erosion in bayside marshes adjacent to the Port Aransas Nature Preserve and Shamrock Island, both of which have high potential for land loss. These structures capture sediment traveling north-to-south along the Island's shoreline, tilting the overall sediment balance in the marsh's favor. Living shorelines can be paired with a series of groins or sediment-capture structures to avoid negative residual impacts on the sediment balance in the wetlands south of Shamrock Island. While modeling results did not favor the use of feeder berms near Port Aransas, the potential effectiveness of a feeder berm positioned adjacent to Shamrock Island has yet to be evaluated and should not be ruled out as a tertiary stabilization measure that could function in concert with living shorelines and groins.

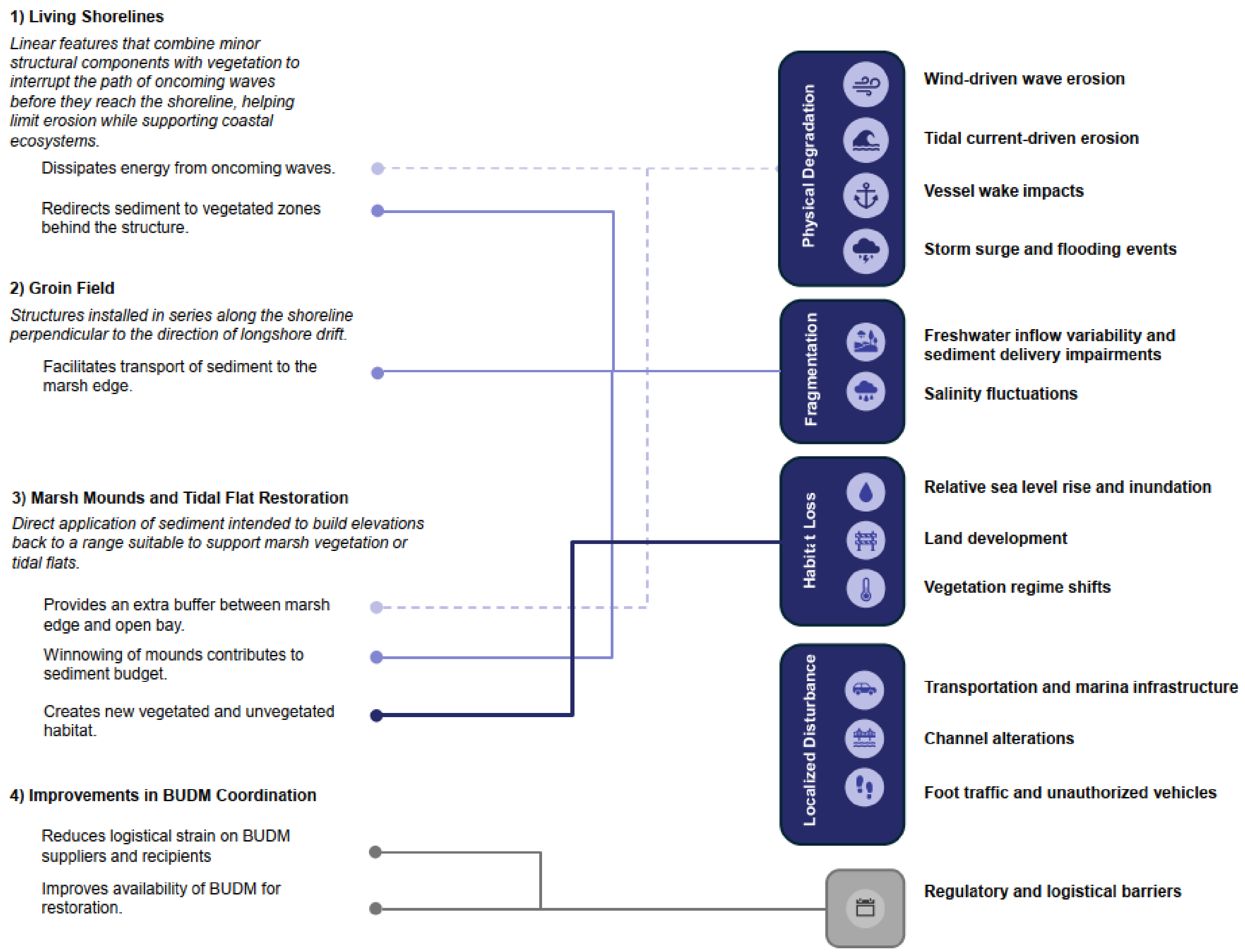
**Reclaim tidal flat and marsh habitat in sheltered open water areas.** Build elevations to a range that can support marsh vegetation ("marsh mounds") or algal flats ("tidal flat restoration") through direct BUDM placement within contained sites. The former solution has seen widespread use across the Texas coast, particularly on Galveston Island; the latter has fewer precedents but is included here in recognition of the steep loss and conversion of tidal flats that Mustang Island has experienced



since the 1950s. Marsh and tidal flat restorations are best performed on sheltered sites, suggesting that they could be placed shoreward of the living shorelines recommended under this technique.

**Form standing beneficial use agreements with the USACE, Port of Corpus Christi, and GIWW stakeholders.** Reduce logistical strain on BUDM suppliers and beneficiaries by establishing a consistent, replicable process for aligning resilience projects with maintenance dredge events. Ideally, permits and agreements should allow for recurring applications that support one or more restoration sites on the Island. Discussions could be mediated through existing stakeholder networks when applicable, such as beneficial use master planning or other working groups.

## How does Wetland Stabilization work within the ecosystem?




## CONSIDERING SEAGRASS IN DESIGN

Seagrass is a federally protected habitat critical for sustaining local marine life and fisheries. Much of the back-bay submerged habitat adjacent to Mustang Island's marshes supports seagrass. For this reason, engineers should take extreme care to place structures in areas with little to no seagrass presence, typically in deeper water between -3 and -6 ft NAVD88. However, this may require tradeoffs in cost and design effectiveness, and design teams often contend with uncertainty arising from data inaccuracies and seasonal variability in seagrass coverage. When seagrass impacts cannot be entirely avoided, they can be mitigated through use of turbidity curtains, thin-layer placement of sediment, and scheduling construction outside of peak productivity periods.

# Technique 2: Wetland Health and Cohesion

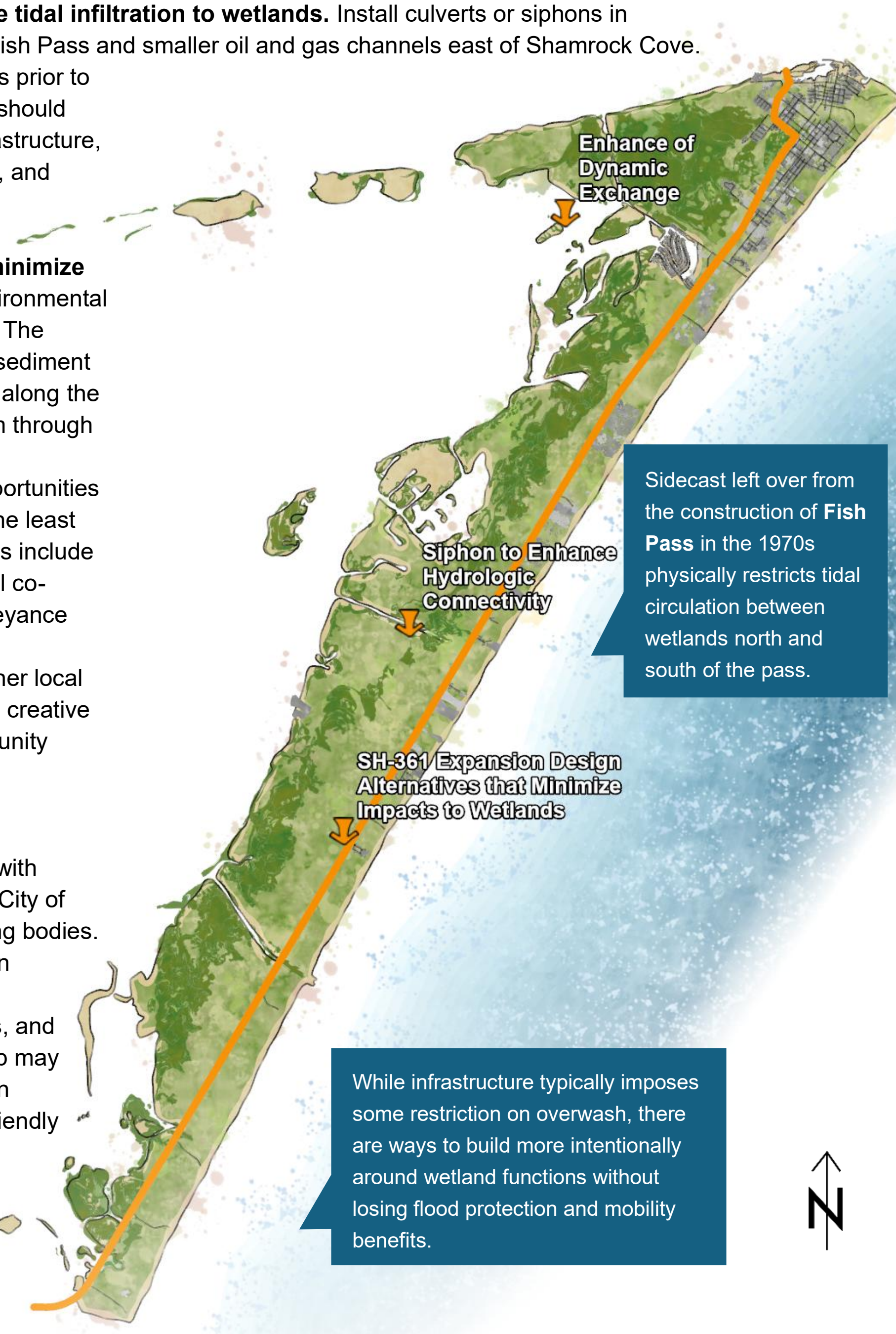
In the same way that many large cities feature complex intersections, unexpected dead-ends, and abrupt changes in street names due to centuries of overlapping development, the natural topography of Mustang Island's wetlands is overlaid by a network of cuts, access channels, roadways, and shoreline extensions as a result of anthropogenic activities. Features that today seem randomly distributed once served a purpose: some provided access to houses or marinas, some were cut as fish passages, and some, like the tangle of channels at the Island's midline, led to now-abandoned oil wells and pipelines.

Many features that inadvertently contribute to wetland fragmentation still have high value for the community in other facets of life – take, for example, SH-361, the Island's sole evacuation route and primary axis for travel by car. SH-361 may interfere with overwash processes that feed back-barrier wetlands, but transportation access is a necessity for communities on the Island, and we can consider ways to reduce its impact on the natural system. The future of Mustang Island's wetlands will be shaped by careful study of the Island's human footprint with an eye toward mutual benefit. If features no longer serve their original purpose, can they be altered or turned to a benefit? If features do serve a purpose, can they be enhanced without compromising the services they provide for the community?

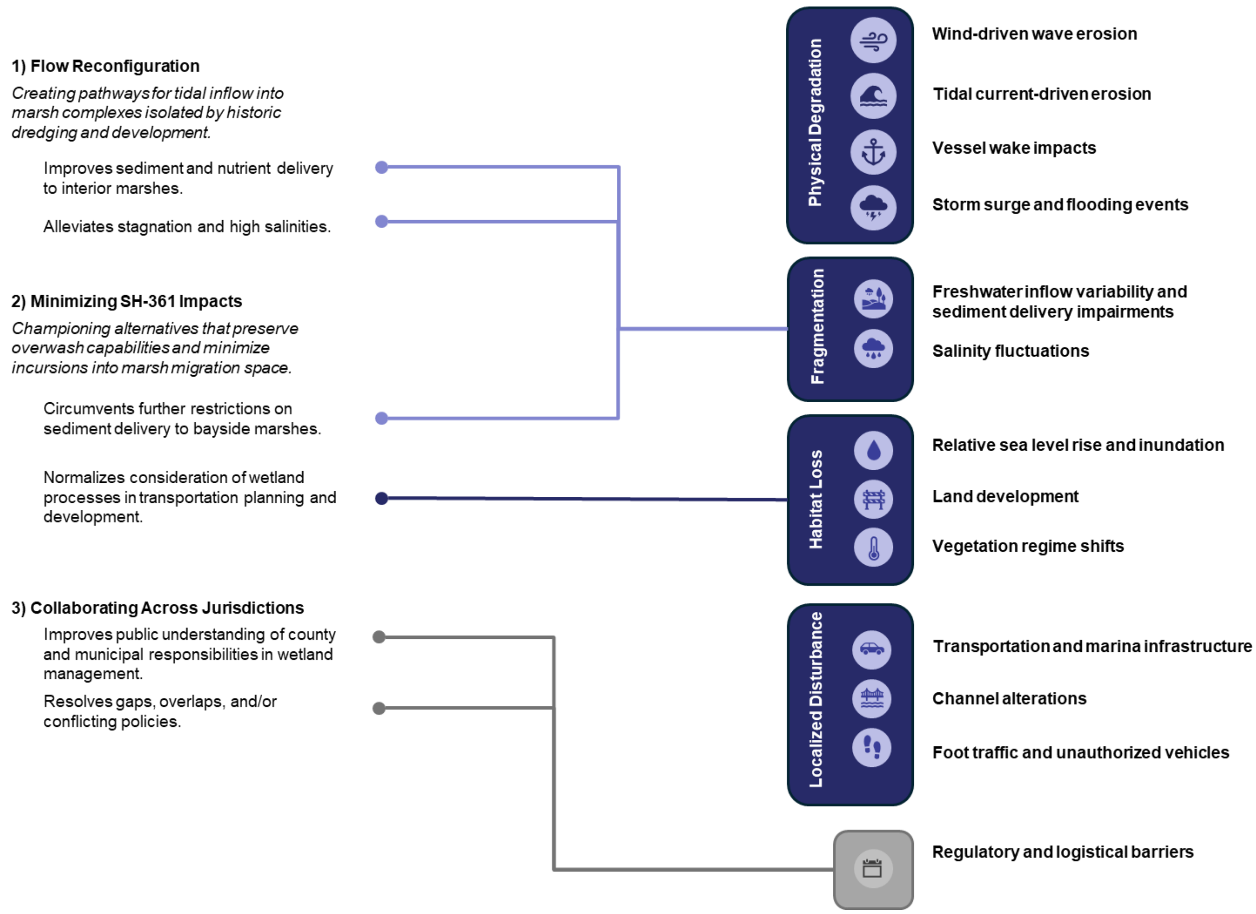
**Reconfigure flow in relict channels to maximize tidal infiltration to wetlands.** Install culverts or siphons in wetland areas isolated by historic cuts, including Fish Pass and smaller oil and gas channels east of Shamrock Cove. Remediation may be necessary for brownfield sites prior to restoration. Monitoring of tidal inflows and salinity should occur in tandem with management of relict oil infrastructure, including plugging of orphan wells, debris removal, and erosion control adjacent to pipelines.

**Advocate for SH-361 design alternatives that minimize impacts to wetlands.** TxDOT has initiated its environmental review process for a planned widening of SH-361. The expansion has the potential to continue impairing sediment overwash and to supplant upland migration space along the corridor. Engagement with the TxDOT design team through public forums and continued coordination with the Resilience Plan stakeholder group will provide opportunities to advocate for roadway geometries that impose the least restrictions on sediment transport. Potential options include enlarged culverts, bridge upsizing with recreational co-benefits, raised road segments, or sediment conveyance structures that mimic natural overwash. Building partnerships with CBBEP, TPWD, USACE, and other local representatives is another step towards identifying creative solutions that meet both environmental and community needs.

**Identify and close management gaps between jurisdictions.** Convene an annual working group with representatives from the City of Port Aransas, the City of Corpus Christi, Nueces County, and local permitting bodies. The working group could define each party's role in community development and governance, identify opportunities for alignment, develop best practices, and resolve policy gaps or overlaps. The working group may also explore opportunities for coordination between regulatory bodies, such as incentivizing wetland-friendly alternatives in urban planning and development.



## How does Wetland Health and Cohesion work within the ecosystem?




## SEDIMENT MATCHMAKING

In order to encourage vegetation growth and minimize shocks to the ecosystem, engineers test any externally-sourced sediment to make sure it contains similar characteristics to sediment in the marsh. This typically includes measuring grain size, chemical composition, and the percentage of organic content, as well as screening for contaminants. Sediment characteristics must also be tailored to the project and site of interest. For example, marsh mounds in highly exposed sites would require sand with a large grain size so that the sediment is not swept away post-construction. Note that there are other project types, such as a feeder berms, where resuspension of sediment is a desired feature of the project.

# Technique 3: Habitat Creation, Preservation, and Enhancement

When faced with conditions that challenge their survival, wetlands seek an evacuation route. Competing land uses tend to limit the availability of undisturbed, contiguous habitat that would enable marsh migration. Instead, vegetation is "squeezed" between the waterline below and an uneven patchwork of roads, buildings, and infrastructure above.

Proactive development for marsh migration is best achieved through collaboration between governments, developers, and individual landowners. These parties are fundamentally their own decision-makers with their own responsibilities, needs, priorities, and perspectives on wetland environments. For this reason, it is important to embrace a spectrum of solutions that reflect what can realistically be achieved within a given property or parcel.

**Prioritize land acquisition to conserve and protect connected habitat corridors.** Conservation of undeveloped habitat areas increases the land available for future marsh migration, protects vital habitat corridors, and provides additional storm buffering to developed areas, particularly when these lands are adjacent to existing protected areas. However, opportunities to acquire land adjacent to already protected lands are infrequent, often arise suddenly, and require swift action. Identifying priority lands that would support the long-term conservation needs of Mustang Island can better position stakeholders or groups of stakeholders to pursue acquisition if and when these lands become available.

**Leverage Resilience Plan baseline data in landowner outreach.** A clear, long-term vision for land acquisitions or easements strengthens funding proposals and provides landowners with context for understanding why a given tract or parcel is of high conservation priority. Datasets informing the Resilience Plan provide a backdrop for current trends in land loss and future storm impacts, which can guide future acquisition strategy and contextualize decision-making.

**Encourage built-in consideration of wetland protections in municipal development planning.** The City of Corpus Christi's Padre/Mustang Island Area Development Plan (2021) includes several actions supporting conservation-focused development. Engagement with city representatives will further encourage the City of Corpus Christi, Nueces County, and the City of Port Aransas to create or expand policies that incentivize preservation of overwash corridors and marsh habitat through use of buffer zones, as well as embracing alternatives to impervious surfaces (e.g., rain gardens, permeable pavement, and pocket parks). The Resilience Plan can serve as a platform to improve understanding of the municipal advantages of taking proactive action.

**Offer technical support for landowner and public engagement.** Within existing partner networks, continue to provide a communication channel that enables organizations to step into community engagement roles when one partner's capacity is limited.


Bay-facing tracts on central Mustang Island face less intense development pressure compared to tracts in Port Aransas, which in turn can influence short- and long-term conservation goals. Conservation can be difficult in areas of greater development pressure with higher land value and smaller parcels, but should still be considered and pursued where possible.

**Adopt nature-based solutions over traditional shoreline armoring when site conditions allow.** Encourage use of green and hybrid stabilization measures at low-energy residential sites to prevent further restrictions to overwash and sediment transport. Identify opportunities to use locally sourced materials or have community-led installations to emphasize local stewardship and connection to the natural system.

## How does Habitat Creation, Preservation, and Enhancement work within the ecosystem?

**1) Land Acquisition for Conservation**

*Identify and prioritize potential land acquisition opportunities for unprotected, undeveloped lands adjacent to existing protected lands to protect habitat corridors.*

- Enables stakeholders to act quickly in the pursuit of priority lands if and when they become available.

**2) Landowner Outreach and Communications**

*Drawing on MIRP baseline data to contextualize how acquisitions and wetland-friendly development policies contribute to long-term resilience.*

- Enables systematic preservation of wetland habitat and migration space in a manner that is sensitive to changing conditions.
- Provides overarching narrative for resilience priorities.

**3) Wetland-sensitive Development Policies**

*Encouraging developers to preserve overwash corridors and celebrate wetland features in residential designs.*

- Minimizes further restrictions on sediment delivery.
- Minimizes incursions on marsh migration space.
- Strengthens communities' personal connections and sense of responsibility for wetland habitats.
- Reduces regulatory uncertainty and potential conflict by incorporating wetland-sensitive approaches early in the development process.

**4) Technical Support for Public Engagement**

*Offer staffing and resources to support public engagement through retailers, tourism centers, and municipalities.*

- Expand public engagement where capacity is limited.

**5) Nature-based Solutions for Shoreline Armoring**

*Encourage use of green and hybrid stabilization measures in heavily-developed areas.*

**Physical Degradation**

- Wind-driven wave erosion
- Tidal current-driven erosion
- Vessel wake impacts
- Storm surge and flooding events

**Fragmentation**

- Freshwater inflow variability and sediment delivery impairments
- Salinity fluctuations

**Habitat Loss**

- Relative sea level rise and inundation
- Land development
- Vegetation regime shifts

**Localized Disturbance**

- Transportation and marina infrastructure
- Channel alterations
- Foot traffic and unauthorized vehicles

**Regulatory and logistical barriers**

# Technique 4: Environmental Stewardship

Mustang Island encapsulates a broad range of coastal habitats along its 18-mile stretch. The natural beauty of the Island attracts thousands of visitors each year and provides ample recreational opportunities for the residents that call the Island home. However, with increased public access to the habitats on the Island, also comes increased residual impacts caused by irresponsible access and misuse of natural resources. Direct impact from human activity, including driving over sensitive tidal flats and recreational boating activity scarring seagrass beds, contributes to the increased loss of these vital habitats.

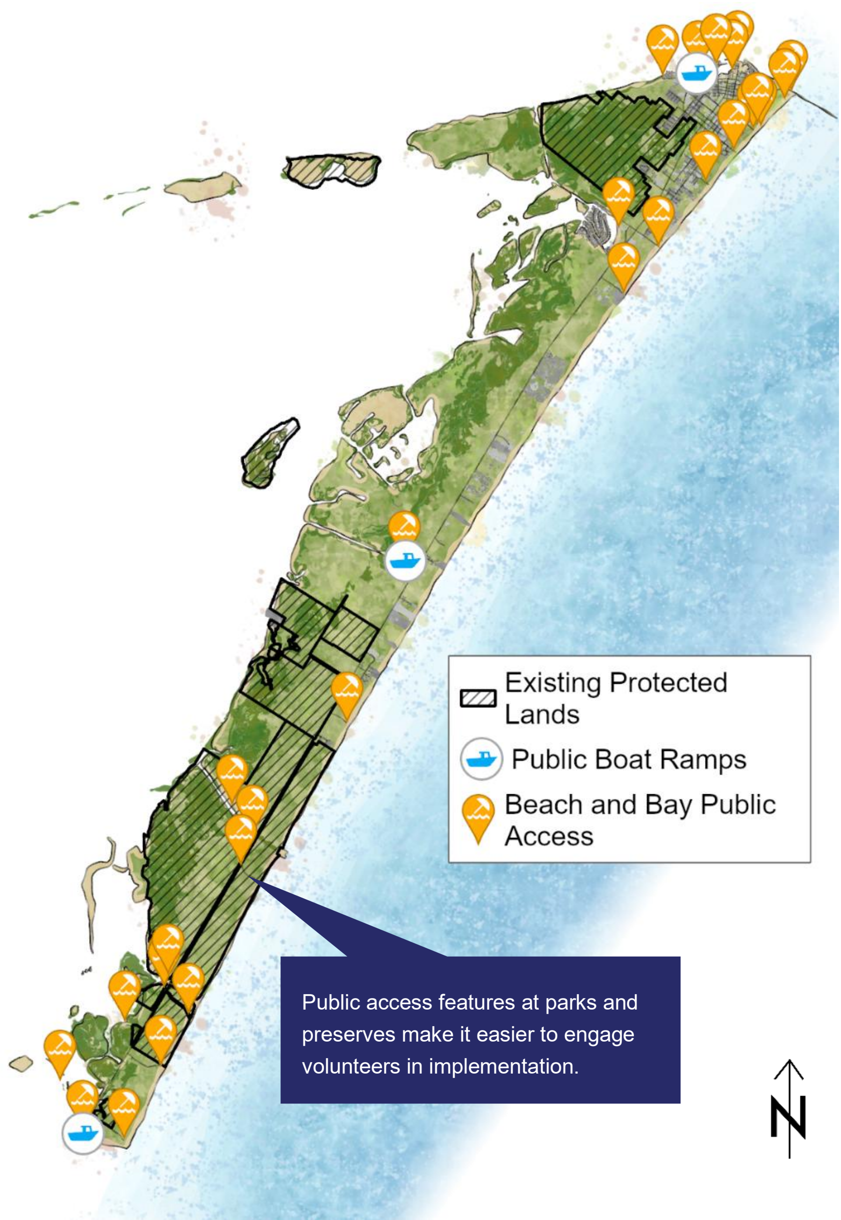
Park and preserve managers are the curators of responsible public interaction with the habitats along Mustang Island. Educational programs, volunteer plantings, bird counts, site walks, and community meetings bring into focus the complexity of an ecosystem that might otherwise fade into the background of day-to-day life. Visitors develop a personal relationship with wetlands through these programs, and this is an economic driver through eco-tourism. As that relationship deepens, it increases the likelihood that an individual will embrace a role in advancing resilience work, whether in science, art, policy, or education.

Mustang Island benefits from many programs that harness momentum at the individual level for the mutual benefit of wetlands and people. By establishing multiple pathways for involvement, encouraging responsible public access, and focusing on data gaps, everyone can play a role in shaping the future of wetland ecosystems.

**Use ongoing restoration projects as teaching examples for responsible public use.** Public access is a necessary consideration for all engineered solutions in this plan. Eco-tourism is an economic driver for the area and is an important aspect of everyday life on the Island. However, without demonstrating public access that sustains the health of the habitat, rather than contributing to its demise, these additional benefits provided by the wetlands will diminish over time. Stakeholders should draw on project examples to showcase real-time wetland processes and demonstrate their sensitivity to human interference. Engagement through social media to highlight the importance of wetland habitats is recommended, modeling after similar campaigns by Visit Port Aransas.

**Engage existing research, volunteer, and education programs to fill data gaps.** To the extent that knowledge gaps surrounding sediment budgets, shoreline change, seagrass presence, and habitat shifts can be enriched through local collaboration, that research should consider roles for community-led partnerships and citizen science initiatives.

**Regularly check for alignment of partner goals and initiatives.** All partners active in the implementation of the Resilience Plan should maintain awareness of planning review cycles locally (e.g., CBBEP's Coastal Bend Bays Plan, the City of Corpus Christi's Comprehensive Plan) and regionally (e.g. TCRMP, Ducks Unlimited's Texas Beneficial Use Master Plan [TEXBUMP]) and communicate needs, opportunities, and concerns as they arise.



## How does Environmental Stewardship work within the ecosystem?

**1) Educational Campaigns / Responsible Public Use**

*Using real-time examples of wetland processes as educational tools.*

- Strengthens communities' personal connections and sense of responsibility for wetland habitats.
- Promotes awareness of public access best practices.

**2) Pivot Research and Volunteer Programs to Address Data Gaps**

*Leveraging student and volunteer engagement to improve scientific documentation of Mustang Island's wetlands.*

- Fills gaps in baseline understanding of wetland processes.
- Supports training of future wetland scientists and advocates.

**3) Local and Regional Planning Alignments**

*Establishing communication pathways with groups engaged in local and regional planning*

- Strengthens partner relationships
- Provides opportunities for data-sharing and collaboration
- Enables MIRP to act on statewide funding priorities

**Physical Degradation**

- Wind-driven wave erosion
- Tidal current-driven erosion
- Vessel wake impacts
- Storm surge and flooding events

**Fragmentation**

- Freshwater inflow variability and sediment delivery impairments
- Salinity fluctuations

**Habitat Loss**

- Relative sea level rise and inundation
- Land development
- Vegetation regime shifts

**Localized Disturbance**

- Transportation and marina infrastructure
- Channel alterations
- Foot traffic and unauthorized vehicles

**Regulatory and logistical barriers**

# Implementation

The Resilience Plan is intended to be an action-oriented, adaptive framework that translates a data-driven understanding of system dynamics and vulnerability into strategically targeted actions spanning one or more resilience techniques. Because Mustang Island's bayside wetlands are shaped by evolving physical conditions, land use, and climate stressors, implementation is designed to be phased, flexible, and responsive to new information.

Implementation actions are organized across three planning horizons (short-term, mid-term, and long-term) to reflect differences in readiness, data availability, permitting complexity, and anticipated system change. Across all phases, implementation is informed by continued data collection, monitoring, and stakeholder engagement, promoting that actions remain aligned with on-the-ground conditions and community priorities (Figure 30).


Figure 30 Implementation process for advancing techniques

## Short-Term Actions (0-5 Years): Targeted Early Interventions and Early Wins

Short-term actions focus on high-priority vulnerabilities where existing data, stakeholder consensus, and implementation pathways already support near-term progress. These actions are intended to stabilize vulnerable wetlands, preserve critical sediment pathways, and reduce concentrated energy where impacts are most acute. Short-term implementation emphasizes learning by doing, allowing early projects to inform design refinements, performance expectations, and permitting approaches for subsequent phases.

Table 2 describes typical short-term implementation actions that can be started following publication of the Resilience Plan.

Table 2 Short-term implementation actions

| Implementation Action | Activities | Applicable Techniques and Priority Areas | Priority Area | Potential Partners Involved |
|---|---|---|---|---|
| **Pilot-scale or site-specific nature-based and hybrid shoreline stabilization projects in areas experiencing active erosion** | • Site identification (prioritized locations within the Resilience Plan)<br>• Permitting<br>• Site design<br>• Construction | • Wetland Stabilization<br>• Wetland Health and Cohesion | Shoreline areas north of Shamrock Island to mitigate high erosion areas and monitor for residual impacts downdrift; Pilot technique for nature-based groin field north of Fish Pass | CBBEP, USACE, GLO, TPWD, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Federal Resource Agencies, Local Governments, Industry & Utilities (adjacent property), Private Landowners (adjacent property) |
| **Identify potential funding opportunities for projects that support implementation of the Resilience Plan** | • Develop phased approach to implementing strategies identified in the Resilience Plan<br>• Collaborate with funding partners on available funding opportunities for identified approaches<br>• Review GLO's Funding Program Resiliency Design Guide for additional funding programs<br>• Explore other funding strategies (e.g., spill impact dollars, mitigation) | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | Phased approach to implementing living shorelines behind Port Aransas Nature Preserve and on the backside of Mustang Island north of Shamrock Cove | CBBEP, GLO, USFWS, TPWD, TCEQ, Federal Resource Agencies |
| **BUDM where sediment sources and transport pathways are well understood** | • Form local BUDM coordination working group<br>• Establish a plan to utilize local BUDM for wetland restoration or sediment management<br>• Identify a potential short-term placement area to stockpile material<br>• Site identification (prioritized locations within the Resilience Plan)<br>• Seagrass studies or monitoring<br>• Permitting<br>• Site design | • Wetland Stabilization<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | Piper Channel and marsh north of Wilson's cut; BUDM at Port Aransas Nature Preserve provides opportunity for educating public on benefits of using fill to restore marsh | CBBEP, USACE, Port of Corpus Christi Authority, Ducks Unlimited |
| **Targeted backfilling or modification of legacy cuts and relict channels that concentrate wave energy or fragment hydrology** | • Site identification (prioritized locations within the Resilience Plan)<br>• BUDM coordination<br>• Design of hydrologic modification structures<br>• Seagrass studies or monitoring<br>• Permitting | • Wetland Health and Cohesion | Relict channels and oil and gas infrastructure within and adjacent to the Cohn Preserve | CBBEP, GLO, USACE, TPWD, Local Governments, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Local Academia, Federal Resource Agencies |

| Implementation Action | Activities | Applicable Techniques and Priority Areas | Priority Area | Potential Partners Involved |
|---|---|---|---|---|
| **Protection of existing overwash and sediment corridors, including avoidance of new barriers in high-functioning areas** | • Form coordination group with local governments (Port Aransas, Corpus Christi, Nueces County)<br>• Pilot zoning program for City of Port Aransas and expand City of Corpus Christi's Program<br>• Network with/outreach to developers to bridge gap between resource needs and continued development<br>• Engage in design and environmental review of SH-361 expansion | • Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | SH-361 expansion; Preserve existing unprotected county land | CBBEP, TPWD, TxDOT, Local Governments |
| **Establishment of baseline monitoring for elevation change, shoreline position, vegetation condition, and hydrodynamics** | • Develop standard monitoring metrics to track the system's health<br>• Outline monitoring plan and responsibilities<br>• Establish key habitat indicators to promote early predictors of system health | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | Formation of citizen science groups can support annual monitoring efforts | CBBEP, GLO, Local Academia, TPWD, TNC, Audubon, Coastal NGOs, Federal Resource Agencies, Port of Corpus Christi Authority |
| **Collaborate to identify and mitigate gaps in management of natural resources and advocate for policies that make project implementation easier** | • Convene working groups for BUDM, planned developments, and local governments<br>• Draft educational materials and plan for public outreach campaigns<br>• Identify educational opportunities in site designs<br>• Establish host site for Resilience Plan and supporting data<br>• Define land acquisition strategy and connections to the Resilience Plan data<br>• Establish a working group to continue discussions on regulatory framework updates and development of policies that are more responsive to changing conditions | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Prevention, and Enhancement<br>• Environmental Stewardship | Engage with new or planned developments to build connections for future coordination on opportunities to integrate natural features in land development designs; Work with regulatory agencies to develop new permitting frameworks that recognize benefit trade-offs in restoration projects | CBBEP, TPWD, TxDOT, Local Governments, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Local Academia, Industry & Utilities, Private Landowners/HOAs/Tourism & Recreation |

## Mid-Term Actions (5-15 Years): Scaling and System Connectivity

Mid-term actions build on lessons from early projects and focus on scaling interventions and restoring system connectivity at larger spatial extents. This phase emphasizes coordinated sediment management, improved cross-barrier connectivity, and integration of resilience strategies into broader planning and infrastructure decisions. Mid-term implementation shifts from individual projects toward system-scale resilience, allowing benefits to persist beyond isolated sites.

Representative mid-term actions are detailed in Table 3**.**

Table 3 Mid-term implementation actions

| Implementation Action | Activities | Applicable Techniques | Potential Partners Involved |
|---|---|---|---|
| **Expansion of feeder berms, marsh mounds, and sediment placement templates aligned with modeled transport corridors** | • Leverage outcomes and lessons learned from pilot-scale or site-specific projects and knowledge of sediment transport corridors to expand nature-based shoreline stabilization and sediment capture<br>• Perform Island-wide hydrodynamic assessment to track success of implemented projects | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | CBBEP, USACE, GLO, TPWD, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Federal Resource Agencies, Local Governments, Port of Corpus Christi Authority, Industry & Utilities (adjacent property), Private Landowners (adjacent property) |
| **Strategic modification of transportation or marina infrastructure to improve sediment and water exchange (e.g., culvert retrofits, sediment pass-through windows)** | • Highlight successful project examples in urban development<br>• Identify priority locations from updated hydrodynamic assessment that are still lacking in sediment and/or water exchange | • Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement | CBBEP, GLO, USACE, TPWD, TxDOT, Local Governments, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Local Academia, Federal Resource Agencies |
| **Integration of resilience priorities into maintenance dredging and navigation planning** | • Enact the plan developed by the BUDM coordination working group<br>• Target aligning project planning phases with maintenance dredge cycles | • Wetland Stabilization<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | CBBEP, Port of Corpus Christi Authority, USACE, Ducks Unlimited |
| **Protection or creation of landward migration space where feasible, through land use planning or conservation mechanisms** | • Establish larger roles for City of Port Aransas, City of Corpus Christi, and Nueces County in Resilience Plan implementation<br>• Review of policy changes that have reduced development pressure<br>• Pursue priority land acquisitions | • Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | CBBEP, GLO, TPWD, TxDOT, Local Governments, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Local Academia, Industry & Utilities, Private Landowners/HOAs/Tourism & Recreation |

| Implementation Action | Activities | Applicable Techniques | Potential Partners Involved |
|---|---|---|---|
| **Refinement of monitoring programs to track performance thresholds and detect emerging vulnerabilities** | • Review data from monitoring events to identify early trends<br>• Evaluate and refine monitoring metrics<br>• Define adaptive management triggers<br>• Leverage lessons learned from previously implemented projects to capture additional monitoring needs | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement | CBBEP, GLO, Local Academia, TPWD, TNC, Audubon, Coastal NGOs, Federal Resource Agencies, Port of Corpus Christi Authority |

## Long-Term Actions (15+ Years): Adaptation Under Changing Conditions

Long-term actions address structural and climatic shifts that are expected to intensify over time, including RSLR, altered storm regimes, and long-term sediment deficits. These actions are inherently adaptive and may evolve as conditions and priorities change. Rather than prescribing fixed outcomes, long-term implementation focuses on maintaining system function and flexibility in the face of uncertainty.

Long-term implementation considerations are included in Table 4.

Table 4 Long-term implementation actions

| Implementation Action | Activities | Applicable Techniques | Potential Partners Involved |
|---|---|---|---|
| **Periodic reassessment of vulnerability using updated data, models, and observed trends** | • Define timeline for reassessment<br>• Establish process for including updated data, models, and trends | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement | CBBEP, GLO, Local Academia, TPWD, TNC, Audubon, Coastal NGOs, Federal Resource Agencies |
| **Adjustment of sediment management strategies to account for changing shoreline configurations and transport dynamics** | • Continue leveraging lessons learned from iterations of shoreline stabilization and sediment management projects<br>• Identify additional hotspots for strategy implementation following reassessment of vulnerabilities and data | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement | CBBEP, GLO, USACE, Port of Corpus Christi Authority, TPWD, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Federal Resource Agencies |
| **Planned retreat, realignment, or redesign of infrastructure where maintaining current configurations becomes infeasible** | • Apply retrofits to SH-361 and continue looking for additional opportunities to minimize impact to sediment transport<br>• Resolve policy gaps and overlaps between local, regional, and state policy<br>• Review zoning programs<br>• Assess conservation measures adopted | • Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | CBBEP, GLO, TPWD, TxDOT, Local Governments, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Local Academia, Industry & Utilities, Private Landowners/HOAs/Tourism & Recreation |

| Implementation Action | Activities | Applicable Techniques | Potential Partners Involved |
|---|---|---|---|
| **Long-term habitat transitions and acceptance of managed change in certain areas** | • Continue pursuing priority land acquisitions, as applicable and available<br>• Continue coordination across jurisdictions to establish policies that reduce development pressure on already conserved land<br>• Continue monitoring for health of conserved lands and implement strategies as needed to reduce impacts | • Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement<br>• Environmental Stewardship | CBBEP, GLO, TPWD, Local Governments, TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs, Local Academia, Federal Resource Agencies |
| **Continued refinement of adaptive management triggers tied to monitoring results** | • Adjust adaptive management triggers as the landscape and habitats change<br>• Review monitoring plan and update to reflect existing habitats and related monitoring metrics | • Wetland Stabilization<br>• Wetland Health and Cohesion<br>• Habitat Creation, Preservation, and Enhancement | CBBEP, GLO, Local Academia, TPWD, TNC, Audubon, Coastal NGOs, Federal Resource Agencies |

## Data, Monitoring, and Adaptive Management

Adaptive management refers to the process of repeatedly tailoring one's approach based on observed performance. As wetlands respond to changing conditions in the bay, the Resilience Plan should respond in kind by revisiting priorities, assessing project performance, and strengthening relationships between partners.

**Establish an adaptive review cycle for the Resilience Plan.** Convene stakeholders every two years (in line with CBBEP reporting timeline) to compare monitoring results against model projects and realign priorities as needed.

**Embrace flexibility in design.** Define performance indicators for engineered projects, which may include shoreline change rates, marsh accretion rates, water levels, salinities, and vegetation health. Set thresholds that trigger design tweaks or maintenance.

**Promote data-sharing and transparency.** Host all GIS layers, monitoring data, and as-built drawings on a shared CBBEP portal to streamline permitting, analysis, and community outreach, and to enable partners to incorporate findings into project narratives.

**Gain visibility through project performance stories.** Use monitoring data and indicators (e.g., berm longevity, habitat gains) to compete for TEXBUMP, National Fish & Wildlife Federation (NFWF), and RESTORE grants to sustain the Resilience Plan and associated efforts in the long term.

# Partner Roles in Implementation

Successful implementation will require coordination among multiple agencies, stakeholders, and partners. While specific implementing entities may vary by project, collaboration across local, regional, and state partners is essential to align sediment management, infrastructure planning, habitat conservation, and community goals.

Stakeholder engagement remains central throughout implementation, supporting transparency, shared understanding of tradeoffs, and long-term stewardship of Mustang Island's bayside wetlands. Table 5 discusses each stakeholder, their potential roles in maintaining Mustang Island's resilience, the benefits they provide to the organization through sediment management, and their coordination priorities. In addition, many partners listed in the table below also have the capability to provide funding for project implementation through programs such as those listed in the GLO's *Funding Programs Resiliency Design Guide*: glo.texas.gov/crmp.

Table 5 Mustang Island Resilience Plan stakeholders' implementation role

| Stakeholder(s) | Potential Role | Benefits | Coordination Priorities |
|---|---|---|---|
| **CBBEP** | Lead partner for Mustang Island Resilience Plan development and implementation; convene regional partners and stakeholder engagement; co-funding; stewardship and monitoring. | Enhanced regional visibility and leadership in coastal resilience; ability to pilot and scale innovative restoration techniques; improved habitat and community outcomes; leverage for NFWF/RESTORE; volunteer science. | Support project development and design for priority features; facilitate stakeholder engagement and technical working groups; oversee monitoring, reporting, and adaptive management; align implementation with regional and state resilience strategies; coordinate with TPWD, GLO, USFWS, and local governments for permitting, funding, and outreach. |
| **GLO** | Program leadership; lead for state-owned submerged land; funding alignment; policy integration (CMP, BUDM); technical support for sediment management, flood mitigation, and land acquisition. | Progress toward CMP objectives; scalable NBS template; visible BUDM outcomes. | Prioritize Resilience Plan sites in annual work plans; coordinate on any required submerged lands lease agreements; align DMPA/BUDM placement windows with build seasons; pursue joint determinations and permitting pathways; collaborate on grant applications and reporting; facilitate data sharing and technical review; coordinate sediment management and resilience efforts. |
| **USFWS** | Habitat conservation and restoration; technical guidance on marsh, seagrass, and rookery habitat; Endangered Species Act (ESA) and Essential Fish Habitat (EFH) consultations; funding partner for habitat restoration and monitoring. | Improved habitat outcomes and bird rookery gains; enhanced compliance with federal regulatory requirements; support for NBS and living shorelines | Early and streamlined consultations on project design; concurrence on standardized restoration details; input on monitoring and adaptive management; collaboration with state and local partners for habitat protection. |
| **TPWD (Coastal Fisheries, State Parks, Redfish Bay SSA)** | Resource stewardship; seagrass and essential fish habitat (EFH) concurrence; site access. | Marsh/seagrass protection; rookery habitat gains; improved EFH outcomes. | Seagrass avoidance/mitigation parameters; seasonal work windows; signage/enforcement support for living shorelines. |
| **TCEQ** | Regulatory agency for water quality, permitting, and environmental compliance; oversight of stormwater, wetlands, and pollution prevention; technical review and permitting for resilience projects; funding through RESTORE Act. | Streamlined permitting for NBS; improved water quality and reduced pollution risks; enhanced regulatory alignment and compliance; participation in statewide resilience and environmental stewardship initiatives. | Early engagement in permitting and technical review; alignment of monitoring metrics with state water quality standards; coordination with GLO, USFWS, and local governments. |

| Stakeholder(s) | Potential Role | Benefits | Coordination Priorities |
|---|---|---|---|
| **USACE (Galveston District) & GIWW Program** | Dredging program; navigation channel management; beneficial use placements, permitting. | Reduced disposal costs via BUDM; extended Dredged Material Placement Area (DMPA) life; fewer shoaling hotspots; Engineering with Nature-aligned outcomes. | Annual placement agreements; sediment volume/quality forecasts; shared as-built surveys and sediment budget tracking, regulatory alignment. |
| **Port of Corpus Christi Authority & Bar Pilots / Terminal Operators** | Navigation operations; data and access; potential cost-share. | Improved navigation reliability; reduced weather downtime; environmental, social, and governance (ESG)/permitting advantages. | Cost-sharing for feeder berms/rookery modules; AIS/traffic and wake data sharing; coordinated access for instrument deployment. |
| **TxDOT (SH-361 Corridor)** | Corridor design and retrofits that preserve overwash and tidal exchange. | Lower overtopping/closure risk; fewer emergency repairs; resilient-design credit. | Incorporate sediment-pass windows/culverts at modeled corridors; coordinate elevations and hydraulics during 30% design milestones. |
| **Local Governments (Port Aransas, Corpus Christi, Nueces County)** | Local governance and policy; zoning/setbacks; site access and communications. | Back-bay flood risk reduction; stabilized shorelines; tourism/recreation uplift; property value support. | Adopt sediment-corridor overlays and setbacks; community outreach/education. |
| **TNC, Audubon, Ducks Unlimited, Coastal Bend NGOs** | Habitat implementation partners; co-funding; stewardship and monitoring. | Habitat acres and rookery gains; leverage for NFWF/RESTORE; volunteer science. | Co-sponsor grants; secure easements/access; adopt-a-site stewardship and long-term monitoring. |
| **Local Academia (UTMSI, HRI/Texas A&M University – Corpus Christi, University of Texas – Bureau of Economic Geology)** | Monitoring, analysis, and independent technical review. | Fundable applied research; student training; long-term datasets and publications. | Memorandum of Understanding for Unmanned Aerial Vehicle/LiDAR cadence, vegetation plots, and Acoustic Doppler Current Profiler; data sharing; Quality checks for model updates. |
| **Industry & Utilities (pipelines, power/water, marinas, oil & gas infrastructure [Texas Railroad Commission])** | Adjacent asset coordination; shoreline treatment integration; oversight of oil/gas infrastructure, plugging orphan wells, and remediation of legacy sites; incident reporting and support for erosion control near pipelines and wells. | Lower outage risk; stabilized embankments; non-traditional co-benefits; enhanced compliance and risk mitigation; participation in resilience pilot projects and remediation efforts. | Easements/Right-of-Entry for construction and sensors; cost-share for adjacent living shorelines; incident reporting for wake/scour; coordination with TCEQ and GLO for permitting and remediation; collaboration on sediment management and infrastructure resilience. |
| **Private Landowners/ HOAs & Tourism/ Recreation (guides, outfitters)** | Access, easements, and shoreline stewardship. | Shoreline protection; amenity uplift; potential insurance/credit benefits; “living shoreline” branding. | Participation in voluntary buyouts/easements; adoption of living shoreline standards; coordinated monitoring access. |

| Stakeholder(s) | Potential Role | Benefits | Coordination Priorities |
| --- | --- | --- | --- |
| **Federal Resource Agencies (NOAA NMFS, Environmental Protection Agency (EPA) Region 6, Texas Historical Commission)** | Consultations (EFH/Endangered Species Act (ESA)/Section 106), EPA Brownfield Program, design and monitoring feedback. | EFH/ESA offsets; bird habitat gains; water-quality co-benefits; improved Section 7 outcomes. | Early, batched consultations; concurrence on standardized details; input on monitoring design. |

# Conclusion

The Mustang Island barrier system is a vital component of the overall resilience of the Corpus Christi Bay region. Without the protection provided by the wetlands on the backside of the Island, surrounding communities and public assets would be increasingly vulnerable to tropical storms, RSLR, storm surge, and other impacts. Equally important is the Island's own dependence on healthy, preserved wetlands to maintain long-term stability. The loss of these habitats would also diminish many of the defining qualities that make Mustang Island unique, from the wildlife that attracts visitors and recreational users to the natural scenery that offers a sense of peace and connection to the coast.

To help these features endure for current and future generations, proactive measures are needed to allow the Island to adapt to changing conditions and strengthen its ability to respond to both acute storm events and the long-term trends that continue to erode its resilience. The Resilience Plan presented here issues this call to action and represents the first step toward building a more resilient Mustang Island through close collaboration among all who have a vested interest in the Island, whether that is to preserve its natural habitats, improve community resilience, or sustain the economic drivers that depend on its health. Meaningful progress will require every partner to take part. Together, these collective efforts can safeguard the future of Mustang Island and support a protected, vibrant, and resilient landscape for decades to come.