FINAL ALABAMA BARRIER ISLAND RESTORATION ASSESSMENT REPORT

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May 2020

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Final Alabama Barrier Island Restoration Assessment Report

1. Executive Summary

Historical and recent hurricanes and man-made disasters such as Hurricanes Ivan (2004), Katrina (2005), Isaac (2012), and the Deepwater Horizon (DWH) oil spill (2010) have caused substantial ecological changes on Dauphin Island, Alabama. These events coupled with residential and commercial development on the barrier island and the surrounding area since the 1950s have resulted in the loss, degradation, and/or encroachment of natural habitats, including wetlands, seagrasses, oyster reefs, beach/dune habitats, and maritime forest. Climatic events, including sea level change (SLC) and coastal storms, continue to erode, degrade, and threaten further loss of these habitats as well as threaten the ecological function of the Mississippi Sound and Heron Bay wetlands on the Alabama mainland. Given the influences on these valuable resources and the species that rely on them, there is a need to protect, restore, and enhance ecological resiliency and function of the island.

This report describes the comprehensive work completed by the U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (USACE) under a grant from the National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund (Alabama Barrier Island Restoration Assessment; project identifier 45719). This project was a multidisciplinary effort that involved data management, documentation of historical data and baseline conditions, modeling to evaluate various restoration measures, and the development of a monitoring and adaptive management plan. Numerous data collection efforts and data analyses were conducted to determine historical change and baseline conditions. Specifically, these included the collection of: (1) bathymetric surveys; (2) physical characteristics of sediments; (3) water quality data; and (4) vegetation surveys. Analyses to understand baseline conditions included: (1) Gulf and back-barrier shoreline change; (2) decadal seafloor change; (3) sediment characterization; and (4) habitat coverage.

The team utilized the results of the data collection and analyses efforts to develop a suite of models to evaluate how Dauphin Island may change in response to various SLC and storm (frequency and intensity) risks, and how proposed restoration measures may influence those changes. Restoration measures were grouped into four categories (ebb tidal shoal; Gulf beach; back-barrier and marsh restoration; and land acquisitions) and evaluated under two paired SLC and "storminess" (ST) conditions (ST2SL1 and ST3SL3). The ST2SL1 future condition scenario was determined to be reasonable with approximately a 50% probability of storminess occurrence combined with the historic SLC projection at Dauphin Island. The ST3SL3 future condition scenario was selected as it represented a "worst case" set of energetic conditions with a higher SLC projection to influence island evolution. The measures were evaluated using a suite of hydrodynamic, morphologic, water quality, and habitat models to document project performance and total project costs (i.e., initial construction and future operations & maintenance) over a 20- and 50-year life cycle.

The morphologic model results provided insights into elevation, shoreline, and volumetric changes, as well as, breaching potential for the various plausible future conditions. A predictive habitat model showed how the coverage and distribution of habitat types changed for the various restoration measures and potential future island configurations. The habitat modeling effort also applied accretion assumptions to explore how the rate of SLC can influence intertidal marsh habitats and/or marsh restoration measures. Based on literature review, the team assumed that intertidal marsh would tend to keep pace with SLC for scenarios with increases of up to 1 cm/yr, whereas intertidal marsh was often converted to intertidal flat or open water for scenarios of greater than 1 cm/yr. Water quality model results were coupled with a habitat suitability index model to highlight how changing abiotic conditions could impact seagrass and oysters, namely breaching near Katrina Cut. Finally, all model results were analyzed in a structured-decision-making framework to evaluate tradeoffs such as benefits to marine and coastal resources, sustainability, social acceptance, and cost. Table 1 presents the highest ranking restoration measures and their costs, per restoration measure category, based on the structured-decision-making tool.

Table 1: Alabama Barrier Island Restoration Structured-Decision-Making Results.

MEASURE	**Initial Construction Cost ($ million)**	**20-year O&M Cost ($ million)**	**50-year O&M Cost ($ million)**
Ebb Tidal Shoal Measures			
Pelican Island Southeast Nourishment	$72.9 - $79.4	$3.0	$8.5
Gulf Beach Measures			
East End Beach and Dune Restoration	$28.2 - $35.2	$5.8 - $7.9	$23.8 – $32.5
Back-Barrier and Marsh Restoration Measures			
Marsh Habitat Restoration Behind Katrina Cut	$28.5 - $35.9	-	-
Aloe Bay Beneficial Use Marsh Restoration	$4.4 - $5.0	-	-
Land Acquisition Measures			
Dauphin Island 39 Parcel Property Acquisition: Parcel B – Graveline Bay	$0.4	-	-

In summary, Dauphin Island plays an important role in the protection of the State of Alabama's coastal natural resources, and similar to its neighboring islands in Mississippi, serves as the first line of defense in reducing storm impacts to the mainland coast. Collectively, the results of this study demonstrate that restoration measures have the potential to enhance the ecological resiliency and structure of the island. However, risks associated with hazards from extreme storms in the area will continue to grow with increases in SLC for which the island's structure, habitats, and species are sensitive to. While no measure will eliminate the hazard, these science-based assessments suggest the implementation of various measures, combined with a targeted monitoring and adaptive management strategy, could enhance the islands ability to absorb, adapt, and recover to potential future events over the next several decades.

2. Background

The USGS and USACE, at the request of the State of Alabama, prepared and submitted a proposal to the NFWF to fund a feasibility-like study to investigate sustainable restoration options for Dauphin Island through the Gulf Environmental Benefit Fund. Per NFWF, the objectives of potential restoration options were to promote ecological benefits and ensure the sustainability of the barrier island feature. The proposal, as approved by NFWF on 30 April 2015, included nine interrelated tasks. This comprehensive report and accompanying appendices are the product of those efforts.

Dauphin Island is a strategically significant barrier island along the northern Gulf of Mexico coast. It serves as the only barrier island providing protection to much of the state of Alabama's coastal natural resources (Figure 1). With an average elevation of 7.2 feet, Dauphin Island is highly susceptible to rising SLC. The size of the system spans over 3,500 acres of barrier island habitat including beach, dune, overwash fans, intertidal flats, wetlands, maritime forest, and freshwater ponds and lakes. In addition, Dauphin Island provides shelter to approximately one-third of the Mississippi Sound and estuarine habitats including oyster reefs, marshes, and seagrasses. It serves as one of the most important bird sanctuaries in the Southeast and supports an important recreational and commercial fishing industry.

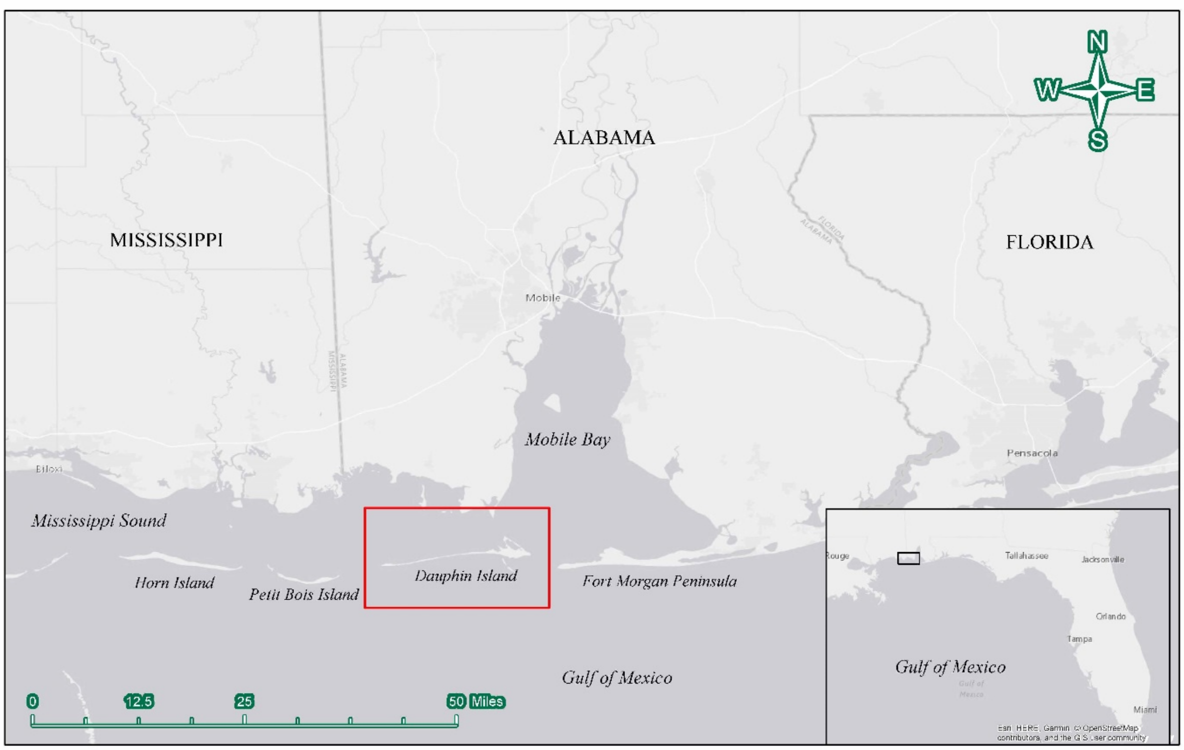


Figure 1: Dauphin Island Location Map

Dauphin Island and the remainder of the barrier islands fronting the Mississippi Sound have been historically eroding and their capacity to protect mainland natural resources and infrastructure is diminishing (Byrnes et al., 2010). Rising sea level, severe and frequent storms, and engineering activities all threaten the sustained subaerial presence (Twichell et al., 2013, Byrnes et al., 2012, Morton, 2008). Moreover, loss of barrier island area threatens the estuarine ecosystem goods and services of Mississippi Sound and exposes the mainland coast and its associated wetlands and coastal habitats to increasing saltwater intrusion and damage from future storms and storm surges (USACE, 2009).

Dauphin Island has been severely impacted by repeated extreme events over the past several decades, most recently Hurricanes Ivan, Katrina, and Isaac, and the DWH oil spill. Hurricanes Frederic (1979), Ivan, and Katrina caused some of the most substantial morphological changes since major residential development on the island. Changes from these storms include island lowering, rollover, and breaching along the western portion of Dauphin Island and the merging of the Pelican/Sand Island complex to Dauphin Island. These island changes have been documented several times in the historical survey record (Morton, 2008, Byrnes et al., 2010, Byrnes et al., 2012, Park et al., 2013). Breaching prior to Hurricane Katrina has been documented to close naturally in response to sediment supplied from the Mobile Pass ebb-tidal delta, with large breach closures occurring on order of decades. In addition, published reports (Morton, 2008, Byrnes et al., 2010) indicate that, historically, the western portion of the island has been able to generally maintain its form through time by migrating landward.

Efforts to mitigate impacts of coastal hazards on the island date back to 1894 when a rock revetment was constructed on the far eastern end of the island to protect Fort Gaines. Over time, other efforts included rock groins on the southeastern shore, a series of bulkheads along the north eastern side of the island, limited beneficial use of the sandy material on the southeastern shore, riprap protection at the fishing pier to the west, and construction of two emergency protective berms on the west end funded by the Federal Emergency Management Agency (FEMA) following Hurricane Georges, Tropical Storm Isadore, and Hurricanes Ivan and Katrina. More recent mitigation efforts have included the reorientation of the groin field into a breakwater configuration with a pocket beach construction on the east end and dune construction along the western portion of the developed island. Additionally, in response to the 2010 DWH oil spill, a major breach in the island (i.e., Katrina Cut) was closed with a temporary rubble mound structure to prevent oil migration into the Mississippi Sound.

Climatic events, disasters (such as the DHW oil spill), and development on the island continue to degrade habitats and threaten the ecological integrity of the Mississippi Sound and the Heron Bay wetlands on the mainland. Therefore, the goal of this work was to investigate viable and sustainable options to enhance and restore the resources on the island and in the surrounding coastal environments (e.g., marshes, seagrasses, and oysters). One of the main objectives was to evaluate all restoration measures based on sound principles of physical, ecological, and decision science, allowing the science to guide the development of sustainable restoration actions while, exploring a wide range of restoration possibilities. The likelihood of restoration success can be maximized by ensuring that restoration plans include an understanding of the island's historical evolution as well as the, physical topographic, bathymetric, geologic, and oceanographic setting. These factors play an important role in understanding how the island has evolved over time to the existing island feature and will govern its future response.

2.1. Study Purpose, Goals, and Objectives

The overall purpose of this study was to investigate sustainable restoration options through a feasibility-like study based on science and technical expertise that provides the ability to effectively evaluate the natural resource benefits and impacts of restoration measures. The study includes modeling the island to evaluate: (1) beneficial use options and other sand placement activities; and (2) other resilient and sustainable island restoration options in support of critical habitats and resources.

The goal of this study was to investigate viable options for the restoration of Dauphin Island as a sustainable barrier island to enhance and restore island resources and the surrounding coastal resources. Some of the questions this study was designed to help answer are:

- Is restoration of Dauphin Island feasible? For example, can the habitats and living resources that depend on it be increased and sustained over a longer period of time (e.g., 50 years) with the appropriate amount of financial resources invested in island restoration?
- Is there a feasible option to support beneficial use of dredged material to aid in restoration of Dauphin Island?
- Would natural processes (e.g., wave action and sand transport) support or degrade island resources over time?
- How should island restoration be configured via restoration design (i.e., width, height) for resilience to winter and tropical storms?
- Would Dauphin Island withstand future storms with and without various restoration measures?
- Would restoration increase and/or conserve the habitats that support long-term living resources damaged by the DWH oil spill?
- Would successful restoration of the east end be different from the west end?
- What are the most feasible and cost-effective restoration options that support a sustainable design?

The results of this study support existing natural resource management and restoration plans prepared by a number of stakeholders such as: (1) the Dauphin Island Strategic Plan funded by the Town of Dauphin Island; (2) the plan developed by the Mississippi-Alabama Sea Grant Consortium and the University of Southern Mississippi; and (3) plans prepared by the Alabama Department of Conservation and Natural Resources, the Dauphin Island Sea Lab, and the Mobile Bay National Estuary Program. The tools and measures developed through this study advance many aspects of barrier island management and strategic recommendations from these plans including: (1) protecting all natural and cultural resources by determining their capacity in light of resource vulnerability; (2) protective measures to preserve wetland ecosystems; (3) understanding the importance of, and relationships between, the Dauphin Island complex of Sand Island Shoals, Pelican Island, and Little Dauphin Island; (4) developing a better island-wide understanding for the extent of what is called the "west end" of Dauphin Island, and what it represents to the island in terms of resources; and (5) identifying best ways to seek beach stabilization through beach and dune restoration.

2.2. Scope of Work

The scope of work for this study covered tasks necessary to evaluate feasibility level alternatives capable of increasing the resiliency and sustainability of Dauphin Island, Alabama. The study was divided into nine separate tasks. These tasks included:

1. Updating Baseline Conditions and Trends
2. Collecting Field Data, which included:
    a. Bathymetric and Geophysical Surveys
    b. Tidal Current Measurements
    c. Wave Measurement
    d. Sediment Distribution Data and Conditions
    e. Water Quality Data and Conditions
3. Data Analysis of Dauphin Island Shorelines and Habitats
4. Updating the Sediment Budget Analysis and Calculating Volumetric Changes
5. Modeling of Coastal Processes, which included:
    a. Hydrodynamic and Morphological Changes
    b. Life-Cycle Structure Response for the Katrina Cut Rubble Mound
    c. Water Quality Changes
    d. Habitat Changes
6. Alternative Formulation, Evaluation, and Cost Estimating
7. Monitoring and Adaptive Management
8. Reporting (Interim and Final Reports)
9. Project Management

3. Products

Tasks 1-5 were generally concerned with amassing scientific information necessary to make informed decisions including field data collection, analysis, and modeling. Task 6 utilized information collected during the previous tasks to formulate alternative actions that met the goal of restoring Dauphin Island to a sustainable barrier island. Task 6 also included development of tools to assess the consequences of each restoration measure relative to natural resource benefits and the impact to coastal resiliency. Task 7 provided a monitoring and adaptive management plan (MAM) to employ for any implemented actions. The MAM plan is intended to provide a guide to the types of monitoring (data collection) necessary to evaluate the success of implemented restoration measures and propose adaptive options for areas of uncertainty with regards to the conservation and restoration objectives. Tasks 8 and 9 consisted of report development (i.e., the interim report and final report) and project management, respectively. A brief summary of each task (subtask) is provided below.

3.1. Task 1 – Update Baseline Conditions and Trends

This task consisted of three subtasks (Data Compilation, Database Management, and Tool Development) focused on data standardization and organization and development of software tools to aid in the management and visualization of the data pertaining to the study. The effort included the use of legacy or baseline data and any data collected specifically for this study. The software applications developed for the study include a project team file/data sharing “sandbox”, online data catalog, and interactive web mapping application. The data catalog and mapping applications are publicly available at https://gom.usgs.gov/DauphinIsland/Default.aspx (Figure 2). Project-related reports are also available at: https://gom.usgs.gov/DauphinIsland/Reports.aspx.

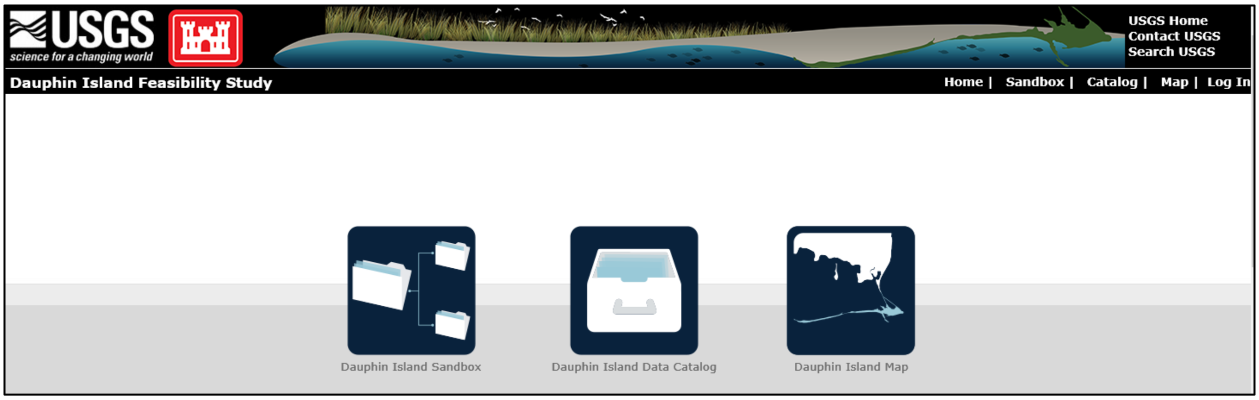


Figure 2: Alabama Barrier Island Restoration Assessment Online Software Suite (Project Team file/data sharing Sandbox, Data Catalog, and Interactive Web Mapping Application)

3.1.1. Task 1.1 – Data Compilation

The data compilation portion of this study focused on providing a centralized repository of past and present Dauphin Island-related data. Baseline and legacy datasets were compiled, attributed, and cataloged. The cataloged data were transformed into a customized database-driven online searchable data catalog that can be queried by data type, title, data steward, or data collection dates. For publicly available data, the data catalog record links to the data's existing location. For data collected by USGS during the course of the study, the data catalog record links to the persistent URL for the peer-reviewed data often being an official digital object identifier (doi) link. All other study data is housed within the catalog and can be downloaded from the specific catalog record. The data catalog includes data of the following data types: currents, digital elevation, hydrographic, aerial/imagery, land cover, Light Detection and Ranging (LiDAR), map, meteorologic, multibeam bathymetry, publication, sediment, shoreline, side scan sonar, tides, topography, vegetation, wave, and winds. Over 130 Dauphin Island-related records are included in the data catalog which is located at: https://gom.usgs.gov/DauphinIsland/Catalog.aspx.

3.1.2. Task 1.2 – Database Development

The Data Management Team (DMT) developed a Data Management Plan (DMP) documenting study data details including file formats, visualization strategies, and final dissemination locations. A custom web mapping application was also developed for visualizing and sharing the spatial and tabular data collected as part of this study. This included information from four water quality gages, two wave gage stations, sediment sample locations, acoustic Doppler current profiler (ADCP) transect and observational point data, habitat data, historic/current shoreline, and 2015 LiDAR and bathymetry. Users can select which datasets to download and/or review. A list of the data that has been integrated in the database is provided in Table 2. The web mapping application is located at: https://gom.usgs.gov/DauphinIsland/Viewer/Map.aspx. The DMP (Appendix A) prescribes the data delivery format, organizational strategies, internal data sharing strategy, archival processes, and product dissemination methods.

Table 2: Alabama Barrier Island Restoration Assessment web-enabled datasets.

Data Type	Location Count	Observation Count
Water Quality	4	305 observations (2015 and 2016) including depth, DO, PH, Specific Conductivity, Salinity, Temperature, and Nutrients
Wave Gage	2	Aquadopp (2015) 13,801 observations AWAC (2015) 17,498 observations
Acoustic Doppler Current Profiles (ADCP)	62 transects	741,034 point observations (2015) along transects
Sediment Samples	303	Sediment texture characterized into 10 classes (2015)
Habitat Data	1	1 Dataset (2015) including 19 Habitat Classifications
Shoreline (Satellite-derived)	1	7 Datasets (1984, 1990, 2000, 2005, 2006, 2010, 2015)
Shoreline (LiDAR-derived)	1	14 Datasets (1998, 2001, May 2004, September 2004, 2005, March 2006, September 2006, 2007, June 2008, September 2008, 2010, 2012, 2013, and 2014)
Shoreline (Aerial-derived)	1	10 Datasets (1940, 1952, 1960, 1974, 1985, 1989, 1992, 1997, 2006, 2015)
LiDAR and Bathymetry	1	1 Merged Dataset (2015)

3.1.3. Task 1.3 – Tool Development

By web-enabling the study data, the DMT was able to integrate spatial data visualizations with dynamic charting of tabular values for applicable datasets. For example, dynamic charts can be created and viewed for all water quality parameters observed at each station by time period. Acoustic Doppler Current Profiler (ADCP) data visualizations were also enhanced allowing the user to not only view the data by transect but allowing the user to drill down into the specific observation points of the line if desired. Once at the point level, the user has the option to view the dynamic graph of velocity values over depth at that location. To support the project team during the study, the DMT also implemented the Dauphin Island sandbox, a digital repository with an online interface, where information was shared for project-specific tasks. The sandbox was a secure central location allowing multiple project team members across various states and agencies to engage in productive collaboration. The sandbox provided ample storage for both document and data files being mapped to a large capacity data storage device allowing for big data tasks to upload and store preliminary project data. The DMT supported the development, expansion, and maintenance of the sandbox, data catalog, and mapping application providing user guidance and assistance as needed.

3.2. Task 2 – Field Data Collection

Field data collected during this study included: (1) bathymetric and geologic surveys; (2) wave and current measurements; (3) sediment distribution information; and (4) water quality data. This information was used to update baseline conditions and provide a primary source of data for model development and validation. Details of each of the data collection efforts are described in in sections 3.2.1 through 3.2.5.

3.2.1. Task 2.1 – Bathymetric and Geologic Surveys

The seafloor around Dauphin Island is highly dynamic. Thus, updated bathymetric data was necessary to adequately characterize the morphology and habitat types, model oceanographic and sedimentologic processes, and provide accurate information for coastal management. The team developed a comprehensive, high-resolution bathymetric digital elevation model (DEM) around the island using single-beam bathymetry acoustic sensors in shallow waters (~1–10 feet), and multibeam acoustic sensors in deeper waters (~9–50 feet). Figure 3 shows the survey extents for the single-beam and multibeam bathymetry surveys. The DEM was integrated with LiDAR elevation data of the island to provide a complete up-to-date topobathymetric DEM. Quality assurance and quality control (QA/QC) of the various datasets was completed and analysis of the DEM generated depth measurements and actual soundings collected during the sediment distribution survey indicate good correlation. These data are available to the public through USGS Data Series publications and at https://gom.usgs.gov/DauphinIsland/Default.aspx.

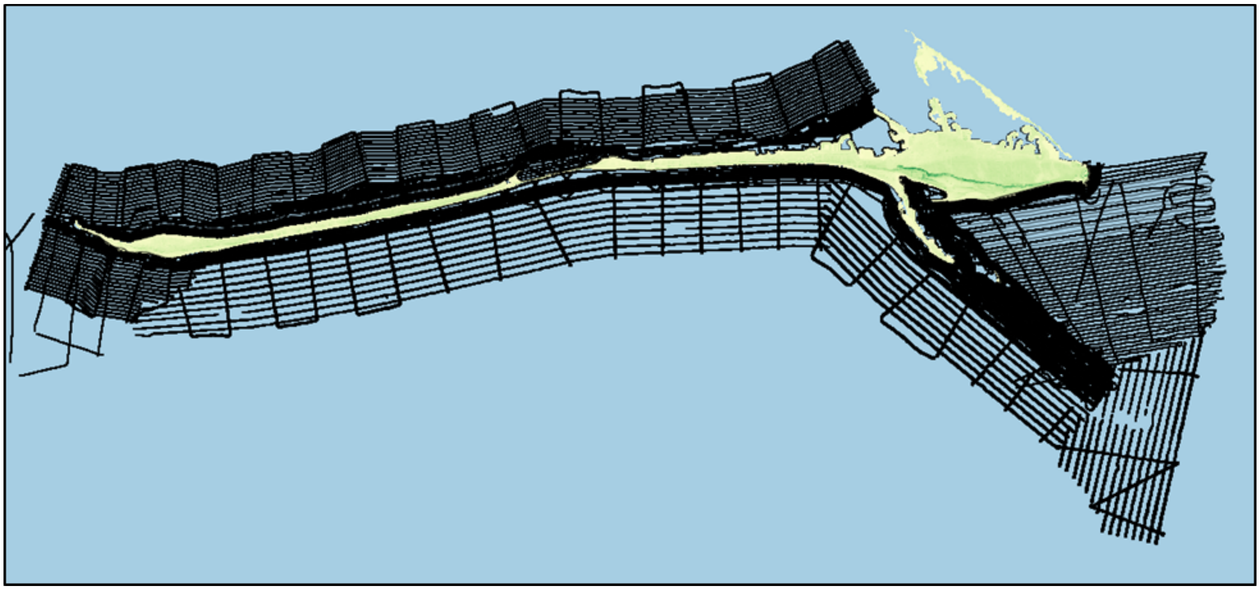


Figure 3: Trackline map showing the final 2015 single-beam and multibeam coverages around Dauphin Island

3.2.2. Task 2.2 – Tidal Current Measurements

Tidal currents are an important parameter for understanding the hydraulics of the nearshore system. Roving acoustic Doppler current profiler (ADCP) measurements were taken across Pass aux Herons, Mobile Pass, and Petit Bois Pass during spring tides on August 26, 2015 and again on December 9, 2015. The transect locations are shown in Figure 4 and are available on the web mapping application located at: https://gom.usgs.gov/DauphinIsland/Viewer/Map.aspx. The post-processed datasets were utilized for calibration and validation of the suite of numerical models developed for the study (as described in Section 3.5). The Petit Bois Pass, Pass aux Herons, and Mobile Pass ebb tide velocity magnitude plots generated from the roving ADCP surveys conducted on August 26, 2015 near the peak of a spring tide indicated a strong flow through Mobile Pass during ebb tide with notably smaller flows through Pass aux Herons and Petit Bois Pass. A similar pattern was observed in the velocity magnitude plots for Petit Bois Pass, Pass aux Herons, and Mobile Pass flood tide conditions collected on December 9, 2015 near the peak of a spring tide. These plots and the ADCP data are available to the public as a USACE Engineer Research and Development Center (ERDC) Letter Report located in Appendix B and available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

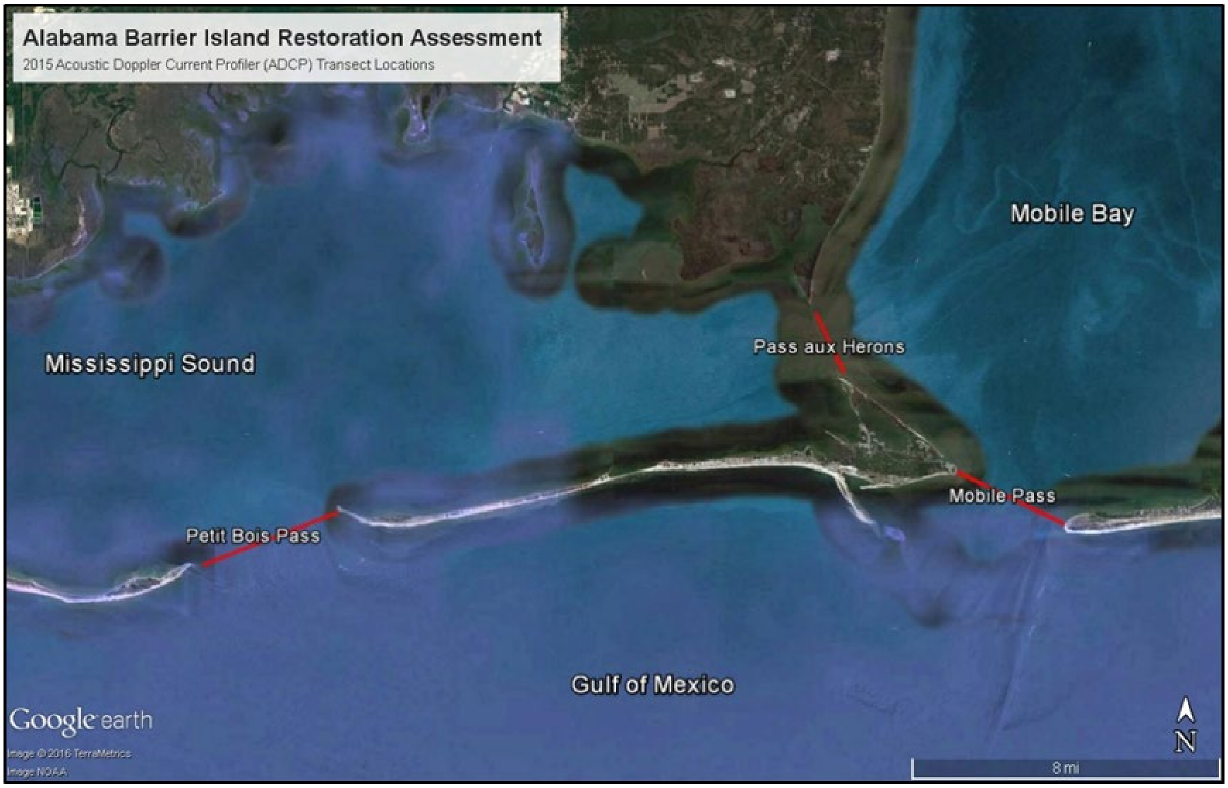


Figure 4: Acoustic Doppler current profiler (ADCP) transect locations (August and December 2015).

3.2.3. Task 2.3 – Wave Measurements

Waves are important coastal processes because they cause a shear at the seabed that can readily mobilize sediment and make it available for transport. In addition, breaking waves generate mean cross- and alongshore currents in the surf zone that also transport sediment. In order to accurately model currents driven by breaking waves, sediment transport, and shoreline morphology, wave measurements were collected during both ebb and flood conditions for the passes affecting the island. Two directional wave gage and current profilers were deployed in June 2015 to record measurements of waves, surface water elevations, and currents through August and November 2015. The gage locations are shown in Figure 5 and are available on the web mapping application located at: https://gom.usgs.gov/DauphinIsland/Viewer/Map.aspx. The post-processed datasets were utilized for numerical model calibration and validation of the suite of numerical models developed for the study (see Section 3.5).

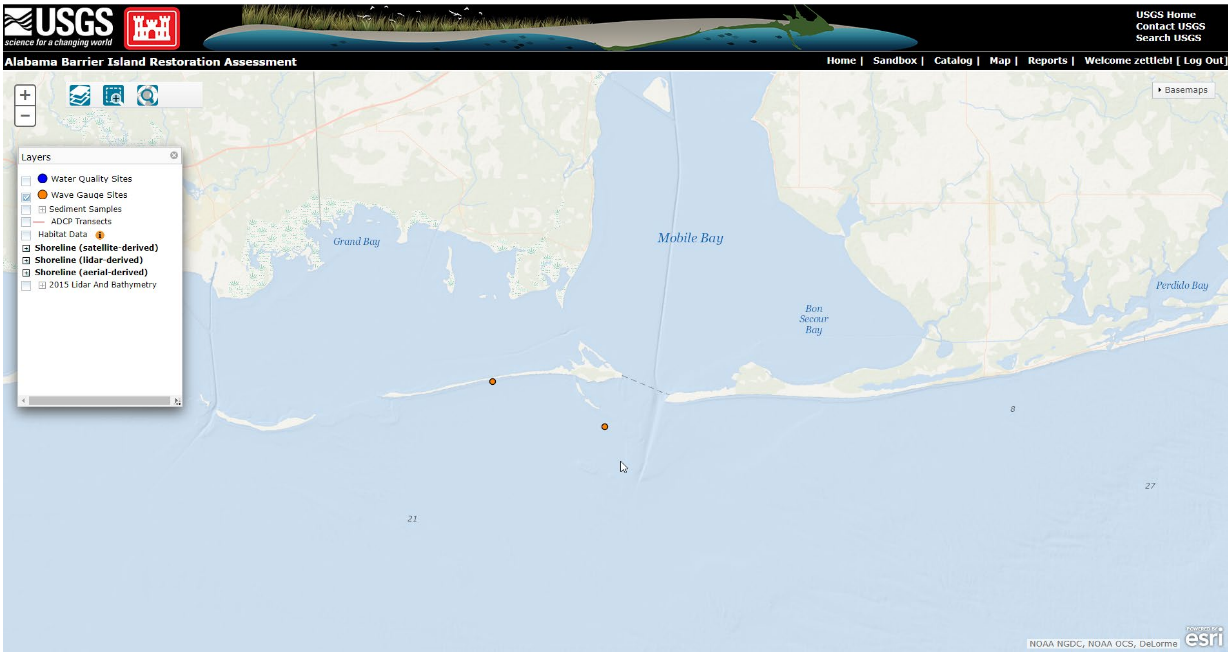


Figure 5: Wave Gage Locations.

Wave and currents were measured in the vicinity of the Mobile Pass ebb tidal shoal and Katrina Cut (Figure 5) using current profiler and directional wave systems. A bottom-mounted Nortek Aquadopp (specialized for shallow depths near Katrina Cut) and an Acoustic Wave and Currents (AWAC) profiler (near Mobile Pass ebb tidal shoal) were used. Both gages were initially deployed on June 20, 2015 with a second AWAC being redeployed on August 31, 2015 after the original gage was lost and not recovered. The Aquadopp recorded until August 23, 2015 at which time the gage became buried and could not be recovered. Processed full spectra directional wave data, wave height, wave period, wave direction, sea surface elevation, and current velocities data were generated along with the raw data and are stored in the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

Plots of significant wave height, period, and direction from the Aquadopp located just south of Katrina Cut during the time period of June 20, 2015 to August 23, 2015 and the AWAC located southwest of the Mobile Pass ebb tidal shoal during the time period of September 1, 2015 to November 1, 2015 indicated waves were primarily out of the south and southeast with significant wave heights rarely exceeding 1 meter. Wave periods were rarely greater than 4 seconds at the Aquadopp south of Katrina Cut. Wave conditions as recorded from the AWAC near the Mobile Pass ebb tidal shoal indicate more energetic conditions, with the strongest waves recorded out of the south and southeast with waves reaching heights of 1.5 to 2.5 meters with wave periods reaching 6 seconds. These plots are available to the public in the USACE ERDC Letter Report located in Appendix B and available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.2.4. Task 2.4 – Sediment Distribution Data and Conditions

Sampling for the sediment distribution was completed in August 2015. A total of 303 sediment samples (Figure 6) were collected from subaqueous and subaerial environments. The samples were analyzed for several bulk sediment parameters, including: (1) organic matter determined by loss-on-ignition; (2) bulk density; (3) water content; and (4) detailed grain size. Characterization of sediment texture, including detailed grain size metrics, within coastal-zone environments was obtained in order to evaluate relationships among sediment-transport patterns, alongshore variability, and geotechnical properties that influence the development of shoreline nourishment and restoration approaches. The sediment characterization is also important for inclusion in the numerical models to inform anticipated coastal-system response to storm events (see Section 3.5).

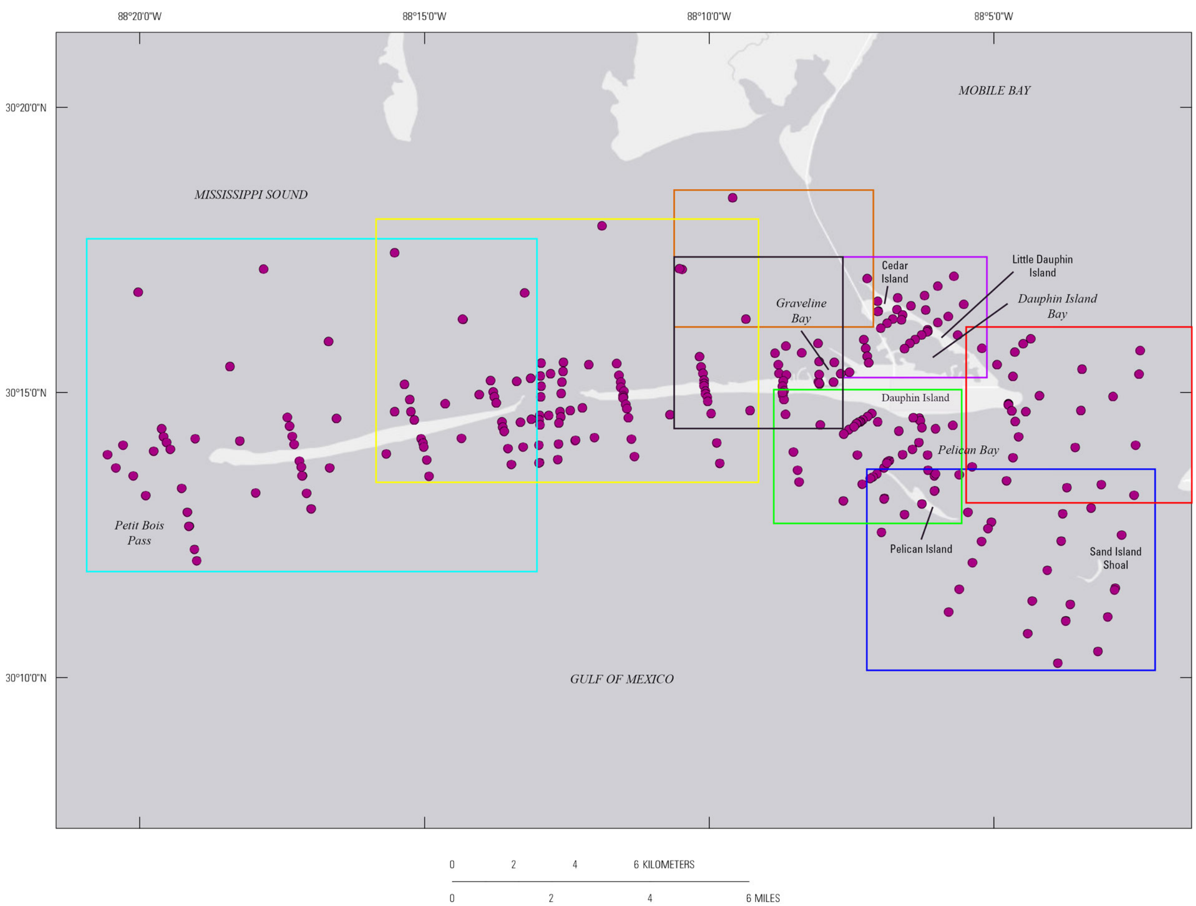


Figure 6: Sediment Sample Locations.

The results of the sediment distribution analysis indicate the sub-aerial portions of east and west ends of Dauphin Island are dominated by well sorted medium to coarse sand (Folk Classification) highlighting the sand-rich nature of the study area. The sand on the surface is associated with a combination of Pleistocene highs and tidal deltas. Offshore of the central portion of the island is fine-grained and has a similar median grain size as portions of Mississippi Sound. Further information is available to the public in a USGS Data Series report available at https://pubs.er.usgs.gov/publication/ds1046 and at the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.2.5. Task 2.5 – Water Quality Data and Conditions

Water quality samples were collected from 3 depths (i.e., near top, middle depth, and near bottom) at 4 discrete locations over eight sampling periods ranging from July 2015 – June 2016. Sampling frequency was approximately monthly, but flexible enough to capture the effects of various river inflow conditions. The eight sampling trips included both “high flow” and “low flow” events during the year duration of the data collection effort, thus encompassing a range of water quality conditions. The water samples were analyzed for nutrients, chlorophyll, salinity, carbon, and other field parameters. The dataset complemented existing datasets and helped to refine the water quality models developed for the study. All data are publicly available in the USGS National Water Information System (NWIS) online database at the following link: https://nwis.waterdata.usgs.gov/favicon.ico. The water quality sample locations (Figure 7) and charted data are also available on the web mapping application located at: https://gom.usgs.gov/DauphinIsland/Viewer/Map.aspx. A chart depicting the results of a selected parameter is available for each station on the web mapping application.

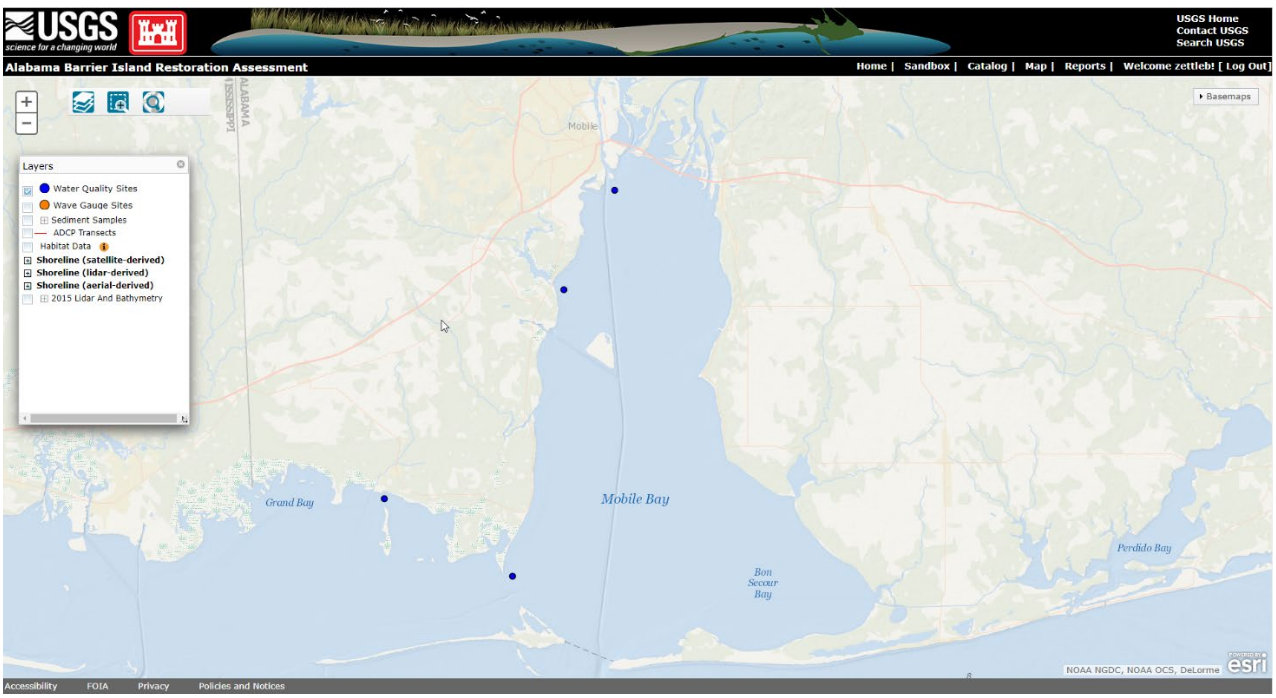


Figure 7: Water Quality Sample Locations

3.3. Task 3 – Data Analyses of Dauphin Island Shorelines and Habitats

Data analyses of Dauphin Island shorelines and habitats provided the basis for assessing short-term and long-term shoreline change, island width change, and baseline information for vegetated communities along the island. Subtasks included mapping historical shorelines and contemporary habitat coverage. The habitats assessed were deemed important to identified species and ecosystem endpoints to help support evaluation of restoration alternatives. The results of these analyses were helpful in characterizing the existing conditions of the study area and served as a basis for comparison for future no-action and restoration measures of the island and for the development of a landscape-position-based habitat prediction model (section 3.5.4).

Further details of each of the subtasks are discussed below in Sections 3.3.1 through 3.3.2.

3.3.1. Tasks 3.1 and 3.2 – Gulf Facing and Estuarine Shorelines and Environments

The purpose of this task was to extract ocean-facing and estuarine shoreline positions from aerial imagery, satellite imagery, and LiDAR surveys in order to quantify short-term and long-term shoreline change and changes in island position and width. These data and analyses are intended to aid in establishing island-scale sediment budgets and validate numerical models of morphologic change. In addition to these observations of horizontal shoreline position, back-barrier marsh cores were collected to understand vertical accretion/erosion of marsh environments. The reporting of these two tasks has been combined to reflect that the ocean-facing and estuarine shorelines are interconnected (e.g., storm overwash) and the analysis of them as one system provides a more comprehensive understanding of island evolution and dynamics.

Historical aerial imagery was reviewed and errors associated with georeferenced imagery were corrected to ensure accurate uncertainty estimates in computed shoreline change rates. The final shoreline change analysis included an island-wide assessment, but also addressed spatial and temporal differences. For instance, the analysis included a comparison of east/west island shoreline change rates and pre/post-breach shoreline change rates. This evaluation helps to better understand island dynamics and the role extreme storms play in dictating changes. Shoreline change rates using the three data sources were computed at 270 cross-shore transects spaced 100 meters apart along the entire length of the island. The analysis suggests that Dauphin Island and Little Dauphin Island have experienced erosion of both the open-ocean and back-barrier shorelines over the last 75 years, resulting in a decrease in the width of the islands. The imagery analysis does not provide the information needed to fully link shoreline change with volumetric gains or losses of island sediment. However, these data clearly demonstrate that cross-barrier transport, which is critical to the maintenance of the island, has been limited. Overall, a disequilibrium between oceanic shoreline erosion and back-barrier progradation has resulted in a decreasing island width trend over the last 75 years. The historical shoreline data and analyses were released as a USGS Data Release, an Open-File Report, and Data Series. The shoreline change assessment is documented in Open-File Report 2018–1170 (Appendix D). All of the geographic information system data files (i.e., shapefiles) representing the various shoreline derivations (satellite-derived, LiDAR-derived, and aerial-derived) are available to the public on the web mapping application located at: https://gom.usgs.gov/DauphinIsland/Viewer/Map.aspx.

The back-barrier marsh core data and analysis highlights the vertical flux and history of modern peat accumulation in the Graveline Bay and Little Dauphin Island marshes. The analysis determined that Cedar Island and Little Dauphin Island exhibit a fining upward trend from the sandy shoreline to marsh shoreline, consistent with washover-dominated (unidirectional) sediment transport. In contrast, along a Spartina marsh island between Graveline Bay and Dauphin Island, the USGS determined the marsh exhibits sediment textures and accretion rates that favor strong bidirectional sediment inputs. The assessment of organic and inorganic sediment accumulation rates and temporal changes in accumulation rates over multiple decades at multiple locations across the island is documented in Open-File Report 2017-1165 available at https://pubs.usgs.gov/of/2017/1165/index.html.

3.3.2. Task 3.3 – Habitat Mapping

The objective of the habitat mapping task was to develop an accurate baseline habitat map using high-resolution aerial stereo color-infrared photography and other ancillary data (e.g., past aerial and multi-temporal satellite imagery, LiDAR, bathymetry, soils, and ancillary data collected by other tasks). The habitat map serves as a baseline for evaluating and predicting changes caused by gradual coastal processes, potential future episodic events, and potential restoration actions. The data used to build the habitat map were collected in 2015, thus the habitat map represents the 2015 condition. Nineteen (19) custom habitat classifications were developed for Dauphin Island based on the review of various other barrier island mapping efforts and field observations. The 19 habitat classifications descriptions and the percentage of the mapped area they represent is provided in Table 3.

Table 3: Dauphin Island Baseline Habitat Classification (2015).

Habitat	Description	Percent of Total Habitat on Dauphin Island (2015)
Dune, bare	Dunes are supratidal features developed via Aeolian processes. Dunes are often found above water levels during storms and have a well-defined relative elevation (i.e., upper slope or ridge). Dune, bare includes dunes that have less than 10 percent vegetation cover.	0.18
Dune, herbaceous	Dune, herbaceous includes low-elevation dunes with sparse to dense herbaceous vegetation coverage. Herbaceous vegetation cover should generally be greater than or equal to about 10 percent. See the Dune, bare class for a general description of dune features.	1.97
Dune, wooded	Dune, woody includes relatively immobile secondary dunes that support sparse vegetation coverage by shrubs. Compared to the other dune classes, these dunes are typically found at higher elevations and further from the shoreline. Woody vegetation cover should generally be greater than or equal to about 30 percent. See the Dune, bare class for a general description of dune features.	0.40
Meadow	Meadow includes areas with sparse to dense herbaceous vegetation located above extreme high water springs found leading up to primary dunes and on the barrier flat (i.e., backslope of dunes). Vegetation coverage should be generally greater than 30 percent.	6.50
Unvegetated barrier flat	Unvegetated barrier flat includes flat or gently sloping unvegetated or sparsely vegetated areas (i.e., less than 30 percent cover) above extreme high water springs that are located on the backslope of dunes, unvegetated washover fans, unvegetated open developed areas, and estuarine shorelines where salinity is less than 30 parts per thousand (ppt).	1.90
Scrub/shrub	Scrub/shrub includes areas where woody vegetation height is greater than about 0.5 m, but less than 6 m. Woody vegetation coverage should generally be greater than 30 percent.	0.85
Forest	Forest includes upland areas where woody vegetation height is greater than 6 m. Woody vegetation coverage is generally greater than 30 percent.	5.27
Forested wetland	Forested wetland includes all nontidal wetlands dominated by woody vegetation with a height greater than or equal to 6 m. Woody vegetation coverage should generally be greater than 30 percent.	0.11
Intertidal	Intertidal beach includes bare or sparsely vegetated areas along the	0.34

beach	ocean-facing side of the island found between extreme low water springs and extreme high water springs that are adjacent to high-energy shorelines which occasionally experience salinity that is greater than or equal to 30 ppt.	
Beach	Beach includes bare or sparsely vegetated area that is upslope of the intertidal beach zone and marine open water. These habitats occasionally experience inundation by marine water at a concentration of greater than or equal to 30 ppt and also include shorelines with high wave energy.	1.52
Intertidal flat	Intertidal flat includes all tidal wetlands (i.e., wetlands found above extreme low water springs and below extreme high water springs) adjacent to estuarine open water (i.e., water with salinity due to ocean-derived salts that would rarely be above 30 ppt) and along shorelines with low wave energy with vegetation cover of less than 30 percent.	0.99
Intertidal marsh	Intertidal marsh includes all tidal wetlands (i.e., wetlands that are found above extreme low water springs and below extreme high water springs) with 30 percent or greater areal cover by erect, rooted, herbaceous hydrophytes.	2.20
Seagrass	Seagrass includes any combination of patchy or continuous submerged vegetation (i.e., seagrasses, oligohaline grasses, attached macroalgae, and drift macroalgae) that covers 10 to 100 percent of the substrate. Areas mapped as seagrass were predominately obtained from 2015 generalized seagrass maps developed by Barry Vittor and Associates, Inc.	1.71
Oyster reef	Oyster reef includes subtidal and intertidal estuarine areas that are dominated by ridge-like or mound-like structures formed by the colonization and growth of extensive exoskeleton-building sessile invertebrates. Areas mapped as oyster reef were obtained from 1968 survey data (May, 1971) and oyster leases obtained from the State of Alabama.	5.56
Shoreline protection	Shoreline protection includes areas that have any material used to protect shorelines from erosion.	0.05
Developed	Developed includes areas dominated by constructed materials (i.e., transportation infrastructure, and residential and commercial areas).	2.18
Open water, fresh	Open water, fresh includes all areas of nontidal open water (i.e., isolated low-lying areas that are not influenced from tides associated with extreme high water spring tides). These open water areas generally have less than 30 percent cover of vegetation.	0.09
Open water, estuarine	Open water, estuarine includes all areas of tidal open water and estuarine water of the back-barrier side of the island (i.e., water bodies that receive regular inundation from tides). These areas rarely have salinity greater than 30 ppt. These open water areas generally have less than 30 percent cover of vegetation.	44.15
Open water, marine	Open water, marine includes all areas of marine open water found offshore of the ocean-facing side of the island. These areas are found along high-energy coastlines and/or occasionally experience salinity levels greater than or equal to 30 ppt.	24.10

Figure 8 and Figure 9 illustrate the baseline habitat map created with the 2015 data. The methodology and full detail of the results of the baseline habitat mapping have been documented in [USGS Open-File Report 2017–1083](https://doi.org/10.3133/ofr20171083) (Appendix E) and the baseline habitat map is available to the public on the web mapping application located at: https://gom.usgs.gov/DauphinIsland/Viewer/Map.aspx. The habitat mapping approach was also published in a peer-reviewed journal article in *Progress in Physical Geography* (Enwright et al., 2019a).

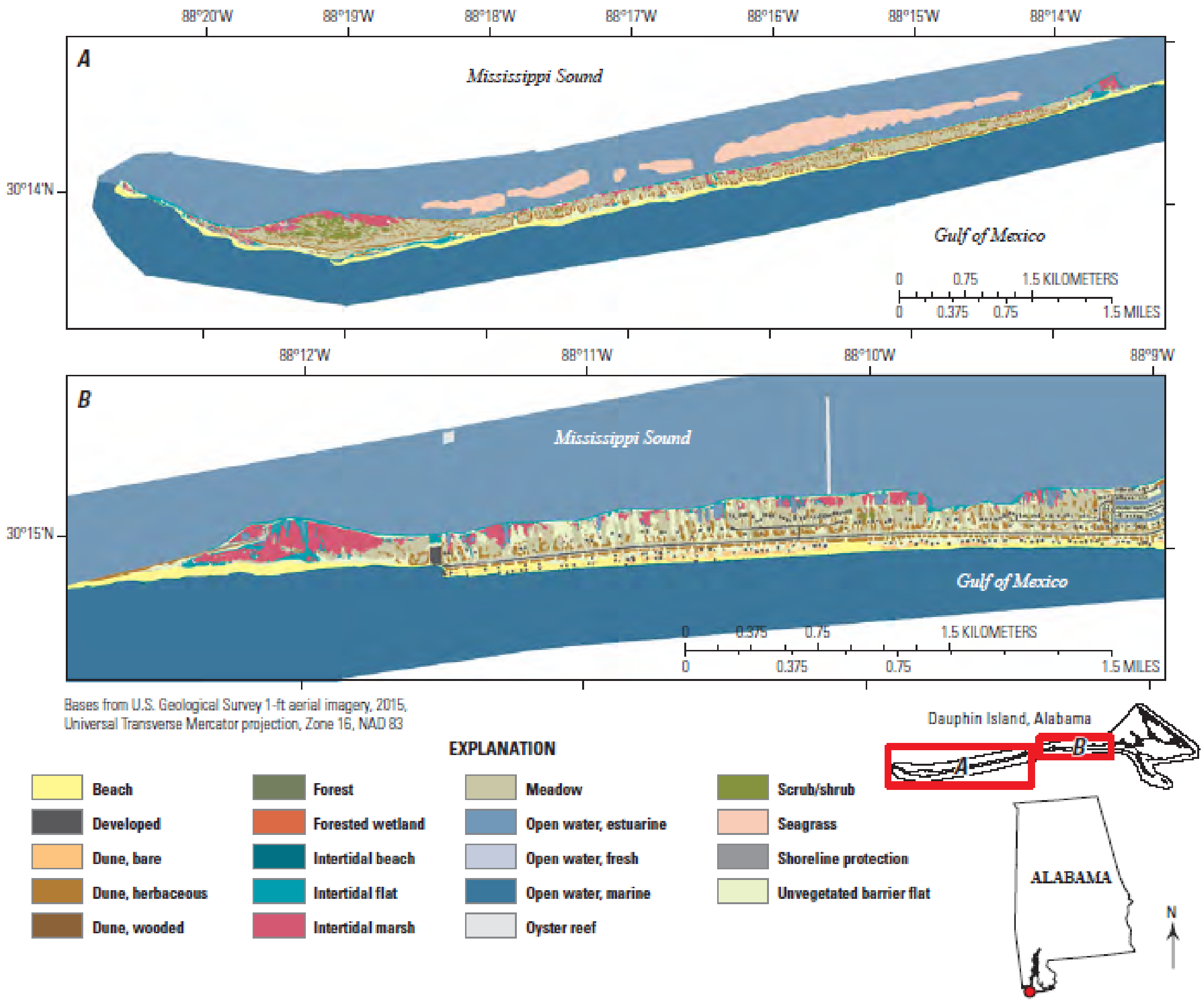


Figure 8: Baseline habitat map for the western two-thirds of Dauphin Island, Alabama, 2015.

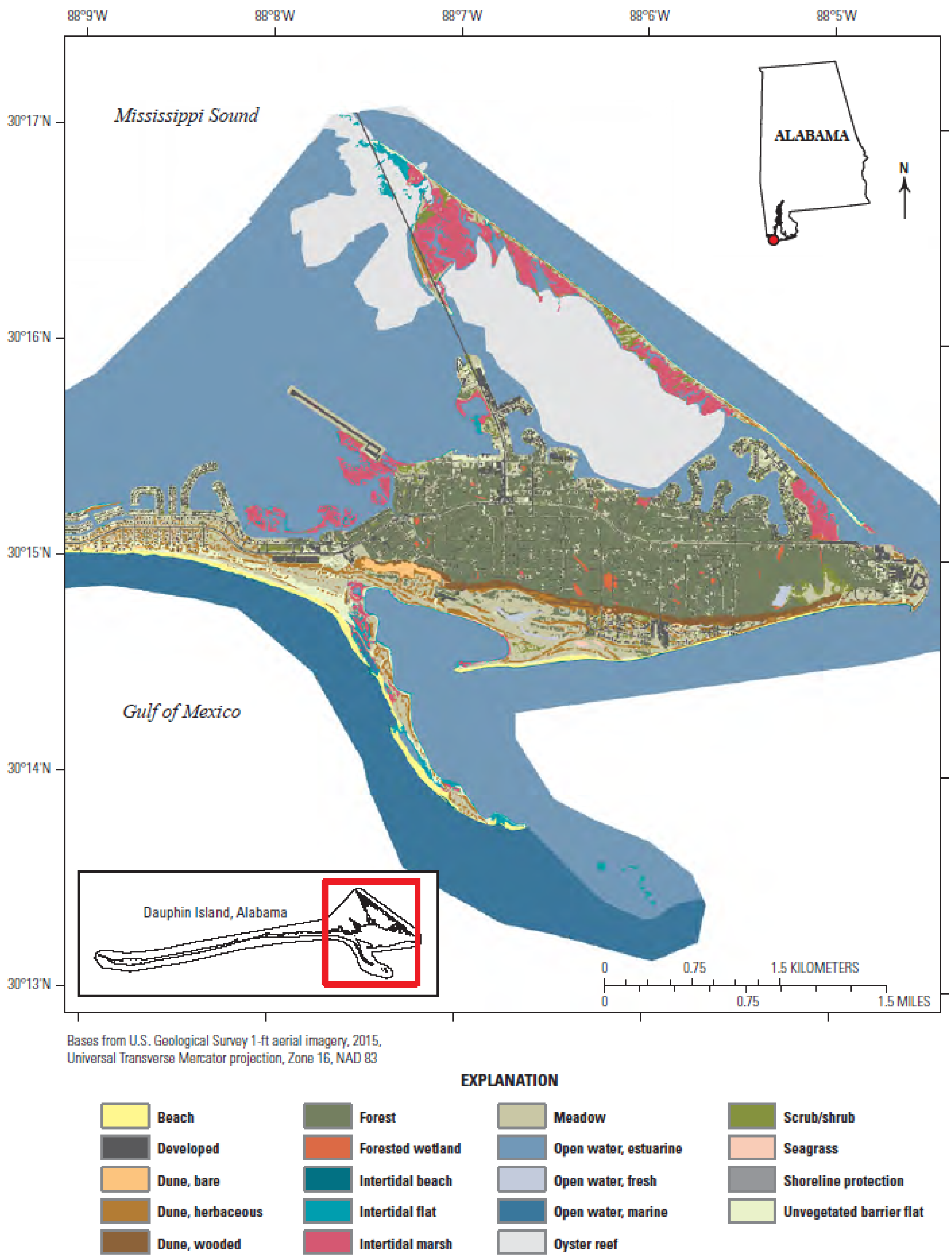


Figure 9: Baseline habitat map for eastern one-third of Dauphin Island, Alabama, 2015.

3.4. Task 4 – Existing Bathymetric and Volumetric Change Analysis

As part of this study, an analysis of multi-decadal seafloor change of the western ebb tidal shoal and the nearshore area around Dauphin Island, Alabama during periods of intense (1987–2006) and non-intense tropical storms (2006–2015) was conducted by the USGS. The bathymetric datasets documented in Flocks et al. (2017) and Appendix C were used to describe recent era (i.e. 1987–2015) sediment gains and losses in the nearshore areas of Dauphin Island and Mobile Pass. In addition, the USACE integrated these datasets into an updated sediment budget of the system using the sediment budget analysis system (SBAS) (Rosati and Kraus 2001; Dopsovic et al., 2002) to quantify transport of littoral sediments, both natural and man induced, into and out of the region covering the time periods from 1985/88 to 2010/16. The time periods considered contain good spatial survey coverage for the study area and extend the temporal time period beyond the 1917/20 to 1986/2002 period previously considered in Byrnes et al. (2010).

The analysis found that the seafloor around Dauphin Island is spatially and temporally dynamic, with specific areas changing elevation at different rates in response to morphology and oceanographic conditions. Bathymetric change was analyzed over two time periods (1987–2006 and 2006–2015) and compared to the long term (1987–2015). The first time interval (1987–2006) corresponds to a period of frequent and intense storm impacts with 12 tropical storms passing near the island, 4 of them severe. During this time, episodic erosion and rapid transport of the seafloor sediments appeared to be the dominant process affecting elevation. In contrast, only two tropical storms passed by Dauphin Island during the second time interval (2006–2015). During this period, normal east-to-west littoral sediment transport, driven by a prevailing southeast wave climate, appears to be the main process of seafloor change. The analyses further determined that the magnitudes of transport rates vary over the time periods evaluated in response to the dominant forces of strong tidal currents, prevailing waves, and the frequency of episodic events impacting the study area. The direction of sediment transport was found to only have slight variations, primarily in response to the merging of Pelican Island to Dauphin Island.

The analyses conducted by the USGS and USACE confirmed, as with Byrnes et al., (2010), that the geomorphologic features identified in the study respond differently over the stormy and non-stormy time periods, which can be quantified through variations in transport rates and associated erosion and accretion within the nearshore regions. During the time period analyzed, the most erosion in the study area, in terms of volume and persistence, occurred along the central and western shoreface of Dauphin Island, both on the gulf and sound sides, with reduced net erosion occurring during the non-storm period.

The assessment of sea floor changes around Dauphin Island over the period of 1987 to 2015 is documented in Open-File Report 2017–1112 available at https://pubs.er.usgs.gov/publication/ofr20171112 . The results of the sediment budget analysis are available to the public in the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx. Both of these analyses can also be found in Appendix C.

3.5. Task 5 – Modeling

A suite of numerical models were developed for Dauphin Island to provide a quantitative understanding of the processes governing the past and present Dauphin Island barrier system, including the nearshore region adjacent to the barrier island complex. Figure 10 illustrates the integrated modeling framework utilized and how the various models inform each other. The development of the numerical modeling tools (i.e., hydrodynamic, water quality, sediment transport, morphologic, and habitat change models) was intended to support the evaluation of restoration measures. Summaries of each of the modeling components are discussed in sections 3.5.1 through 3.5.4. Details about the model development and results can be found in Appendices F–I.

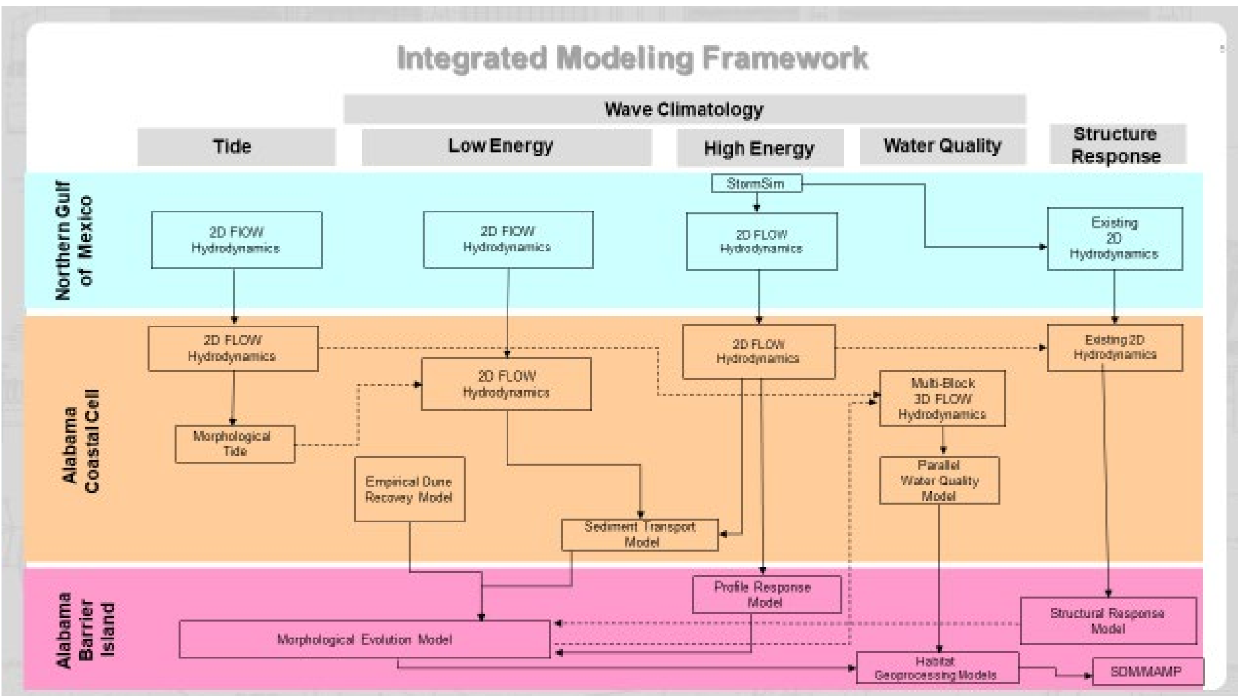


Figure 10: Integrated Modeling Framework Logic-diagram.

3.5.1. Task 5.1 – Hydrodynamic & Morphological Change Modeling

Forecasting barrier island evolution provides decision makers the ability to assess the resiliency of coastal environments to future climate change conditions. Specifically, it allows evaluation of how existing habitats are impacted from various storm and SLC scenarios, along with a suite of restoration measures. A coupled hydrodynamic and morphologic model framework was developed to hindcast and forecast the evolution of Dauphin Island over decadal time scales. The coupled model framework used validated models for long-term alongshore sediment transport (Delft 3D; Deltares, 2019), short-term storm induced impacts (XBeach; Roelvink et al., 2009), and dune building and recovery (empirical dune growth model; Mickey et al., 2020). The framework was comprised of multiple nested domains and individual models that, when coupled together, simulate the dominant processes that dictate how the island evolves. This includes littoral sediment transport processes, the island response to large storms (e.g., dune erosion and overwash), and beach and dune recovery that occurs during non-storm conditions. The model framework was calibrated/validated by hindcasting the island evolution between 1998 and 2013 and compared to 15 LiDAR surveys collected during that time period. Based on the results of the no-action (i.e., the future condition of the island if no restoration measures are implemented) simulations, restoration measures were developed and incorporated into the present day island configuration in order to simulate the island response in the future over various time periods and conditions. Hydrodynamic and morphologic outputs (i.e., footprint/elevations and wave and flow characteristics) from this model framework were passed to the water quality, structural response (i.e., for the Katrina Cut structure), and habitat modeling efforts at varying time intervals. Details regarding this modeling effort methodology can be found in USGS Open-File Report 2019-1139 and the modeling results can be found in USGS Open-File Report 2020–1001 (Appendix F). A copy of both reports is also available to the public on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.5.1.1. Sea Level Projections and Forecast Storm-Set Generation

In order to quantify the uncertainty in alternative response under varying conditions, the team utilized various levels of storminess and SLC. The following subsections describe the development of the SLC and storminess scenarios.

3.5.1.1.1. Sea Level Change

There is variability and uncertainty associated with the predicted global and local SLC rates (Intergovernmental Panel on Climate Change, 2014). Therefore, based on USACE guidance (ER 1100-2-8162), the modeling team considered several SLC scenarios in the barrier island forecast modeling. Historic rates from the Dauphin Island, Alabama, NOAA tide station 8735180 (1966–2017) were used as the lower bound SLC rate. Predictions of future sea level due to intermediate and high rates of SLC were developed in accordance with USACE guidance by extension of rate Curve 1 and Curve 3, respectively, from the National Research Council's 1987 report "Responding to Changes in Sea Level: Engineering Implications." (Mickey et al., 2020).

Data from NOAA tide station 8735180, show the relative rate of SLC was approximately 3.61 millimeters per year (mm/yr) (mm/yr; 95 % confidence error is +/-0.59 mm/yr). These data were used in conjunction the USACE SLC curve calculator ([version] 2017.55) for low, intermediate and high curves to develop projections for the relative rise in SL at Dauphin Island over the next 50 years. The projected relative rise in SL by 2070 varies from 0.3 meters in 2070 (using the current low rate) to 1 m in 2070 (using the current high rate; Figure 11).

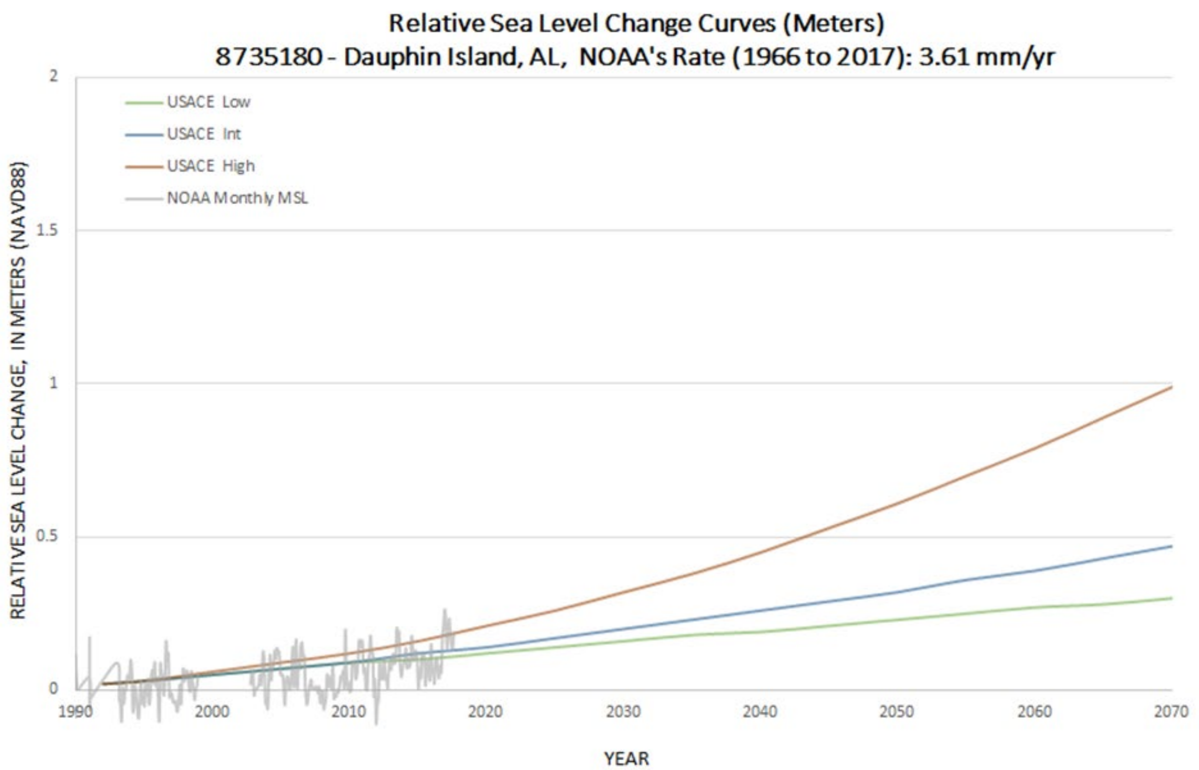


Figure 11: Projected relative sea-level change at Dauphin Island, Alabama, using data from the NOAA tide gage 8735180 and USACE SLC curve calculator.

The modeling and management teams selected three static SLC (SL1–SL3) to apply as boundary conditions to the model forecast runs. The three cases (SL1, SL2, and SL3) represented increases of the modeled offshore mean sea level by 0.3 m, 0.5 m, and 1 m, respectively. These future SLC scenarios were derived from the USACE SLC curve calculator ([version] 2017.55) for, low, intermediate, and high curves and the National Oceanic and Atmospheric Administration (NOAA) 1966 to 2017 local relative sea-level trends that are reported for the Dauphin Island tide station 8735180 depicted in Figure 11 (Mickey et al., 2020). A detailed description of the SLC methodology is available in USGS Open-File Report 2020–1001 (Appendix F) and a copy of the report is also available to the public on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.5.1.1.2. Coastal Storm Variability

The modeling and management teams use the term “storminess” to refer to the variation in storm frequency and intensity over a 10-year period. The level of storminess can result in significant variation in island geomorphic response, and influences restoration measure design, evolution, and benefits. The team developed a computationally efficient method for characterizing storminess and selecting representative storm sequences so that multiple levels of storminess could be used to predict Dauphin Island’s evolution and response to restoration measures. This method utilized a 1D proxy model (CA1D) to reduce the potential variability in storminess to four representative storm sequences. CA1D simulated the response of a representative island profile to 1,000 different realizations of storm sequences with realistic recurrence rates for the

Dauphin Island area. Four storminess bins (Low, Medium, High, and Extreme) were then identified based on the integrated island response over the 10-year period for each realization. These storminess scenarios included: (1) ST1, the low storminess bin, was characterized by limited change to the 1D island profile and included a lower frequency and intensity of storms; (2) ST2, the medium storminess bin, was characterized by island overwash and dune recovery; (3) ST3, the high storminess bin, was characterized by repeated island overwash and rollover; and (4) ST4, the extreme storminess bin, was characterized by island inundation and included six storms over the ten-year period with four of those storms being high intensity (maximum total water level over 4 m). A single representative storm sequence was chosen for each of the storminess bins. When combined with the three sea-level (SL) values, a total of 12 potential future combinations of sea level and storminess were generated to capture the range of future climatological forcing variability at Dauphin Island (Mickey et al., 2020). A detailed description of the storminess variability methodology is available in USGS Open-File Report 2020–1001 (Appendix F) and a copy of the report is also available to the public on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.5.1.2. No-Action Model Results

In order to understand how the island might change over time if no restoration actions are employed, a no-action alternative was simulated. The no-action alternative was represented by the 2015 DEM with no restoration measure or potential cumulative regional projects including changes to the Mobile Harbor Channel were applied. Modeling of the no-action alternative allowed the team to evaluate which island habitat features were vulnerable to degradation or loss in the future under the suite of potential SLC and storminess scenarios simulated. Thus, it provided insight into restoration measure formulation, and served as a comparative condition for the various restoration measure simulations. The four storm simulation scenarios (ST1–ST4) were combined with the three static sea-level increases (SL1–SL3) to produce a total of 12 forecast scenarios that were simulated for the no-action alternative using the coupled model framework.

The final (year 10) island configuration results of the 12 forecast scenarios for the no-action alternative are shown in Figure 12. This matrix of island configurations shows the possible conditions that could occur under the suite of potential SLC and storminess scenarios simulated. These results indicated that increases in storminess (frequency and strength) and increases in SLC, both independently and in combination, contribute to increased island degradation and loss of habitat (Mickey et al., 2020, Enwright et al., 2020).

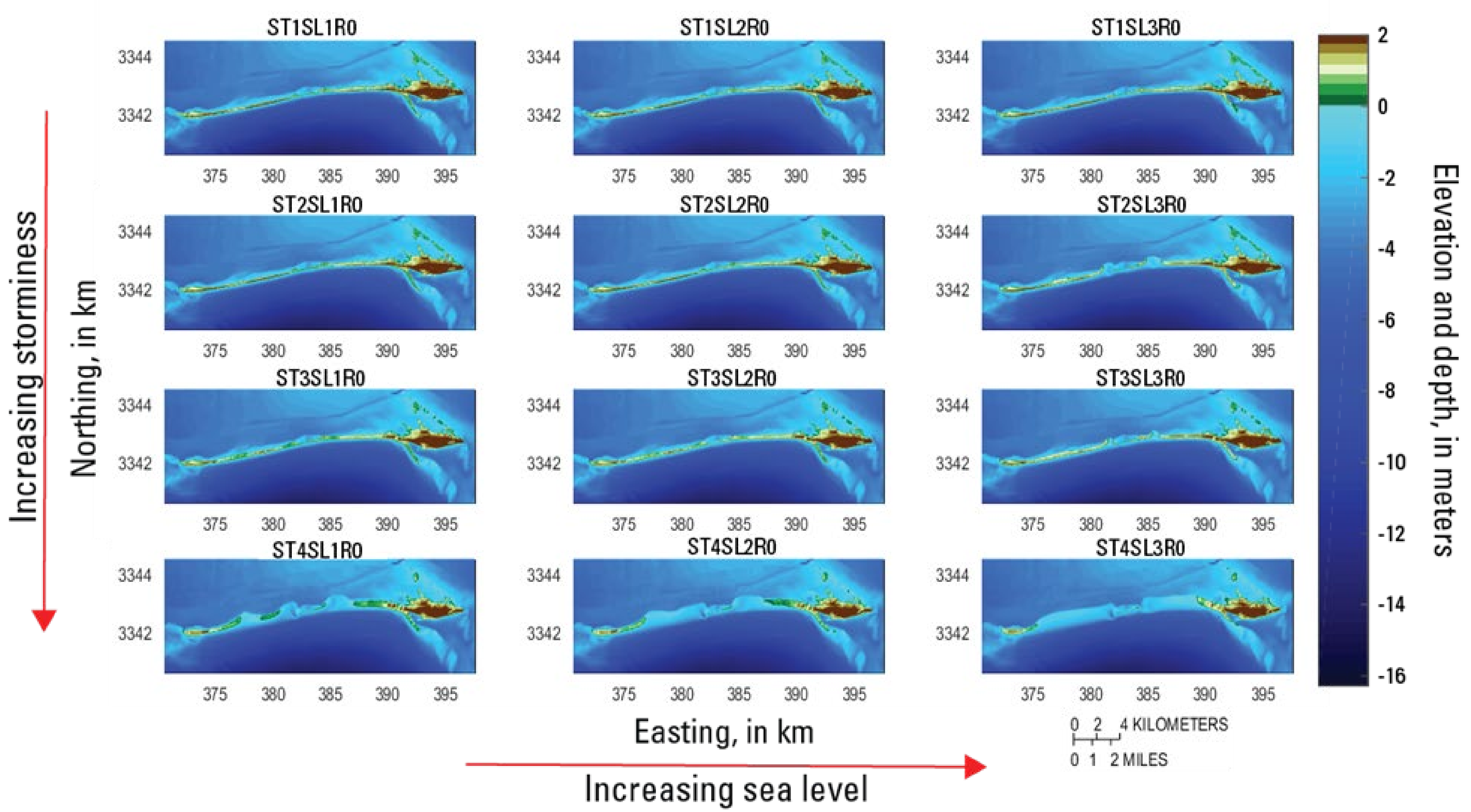


Figure 12: Final island configurations from the 12 no-action simulation scenarios.

Based on the results of the no-action morphological modeling alternative simulations (Figure 12) and habitat modeling simulations (see Section 3.5.4) restoration measures were developed to address increased potential for island breaching, loss of island width, and loss of the Pelican Island complex. A more detailed description of the no-action morphological modeling methodology and results is available in USGS Open-File Report 2020–1001 (Appendix F) and a copy of the report is also available to the public on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.5.2. Task 5.2 – Life-Cycle Structure Response Modeling

Life-cycle structure response modeling was performed on the Katrina Cut rubble mound structure to determine damage, wave transmission, and reliability computations within the context of the decadal modeling framework used for the barrier island evolution modeling. Hydrodynamic and morphological change modeling outputs for the no-action and those restoration measures located in the vicinity of the Katrina Cut structure were also incorporated into the analysis to determine potential effects on structure response. As described previously, the Katrina Cut structure was designed as a temporary structure to address environmental concerns related to the DWH oil spill. As such, damage to the rubble mound structure would be expected to continue as it becomes exposed to hydrodynamic loading caused by tropical storm events.

The performance of the Katrina Cut rubble mound structure was evaluated using a reliability-based probabilistic approach. Given the temporary nature of the structure, this level of performance was defined as damage indicative of breaching of the rubble mound structure. Structure response assessment was based on storminess conditions and SLC scenarios consistent with those described in Section 3.5.1. A comprehensive characterization of structure response was conducted to determine the effect of a beach in front of the structure and to understand the effects of various forcing, SLC, and structure crest height conditions through a sensitivity analysis of damage progression. The effects of restoration measures on structure response were considered by incorporating the output of the morphological modeling for each measure, along with the 10-year storminess and SLC scenarios that coincide with the barrier island evolution modeling. Significant overtopping of the Katrina Cut structure is expected since it is a low crested structure. A sensitivity analysis to determine wave transmission in the lee of the structure was performed to determine mean maximum transmitted wave heights, along with an assessment of the effect of restoration measures that could affect wave transmission.

The analysis found progressive damage and reduced reliability of the structure with increased storm and sea level conditions. The analysis further determined that the presence of a beach in front of the structure has played a significant role in dissipating wave energy, reducing damage, and increasing reliability of the structure. Beach loss associated with the highest storminess and SLC conditions would leave the structure vulnerable to breaching. The wave transmission analysis for the various configurations resulted in wave transmission increasing with storminess and SLC. Restoration measures that increase the sea floor elevation behind the Katrina Cut structure can create shallow conditions that reduce transmitted wave heights.

Details regarding the methodology and results of the Life-Cycle Structure Response Modeling of the Katrina cut structure, including damage progression are documented in an ERDC technical report (Appendix G) available at http://dx.doi.org/10.21079/11681/36236 and on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.5.3. Task 5.3 – Water Quality Modeling

In an effort to understand the existing conditions within Mississippi Sound and to quantify the relative changes in the water quality and flushing capacity resulting from future possible island configurations, an existing Geophysical Scale Transport Modeling System (GSMB) that includes a framework of hydrodynamic and water quality models was updated to expand simulation time, forcing conditions, and parameters. The GSMB includes CH3D-MB (Luong and Chapman, 2009), which is the multi-block (MB) version of CH3D-WES (Chapman et al., 1996, Chapman et al., 2009) and a parallel water quality module, CE-QUAL-ICM (Cerco and Cole, 1994, Bunch et al., 2003). The hydrodynamic model, CH3D–WES, provided hydrodynamic flux across grid cell boundaries to the water quality model (CE–QUAL–ICM). CH3D–WES also computed salinity, surface elevation, velocity, diffusivity, and bottom shear stress. Eutrophication processes were computed by the CE–QUAL–ICM eutrophication model. The CE–QUAL–ICM model incorporated 24 state variables in the water column including physical variables; multiple algal groups; 2 zooplankton groups; and multiple forms of carbon, nitrogen, phosphorus, and silica. Extensive calibration and validation of the models to time periods where there are observed data for the water quality constituents of concern were conducted to ensure salinity and temperature variation demonstrate self-consistency and reliability in both the hydrodynamic and water quality models.

These tools were used to investigate potential changes in water quality resulting from probable future island conditions. Because of limits of computational expense, water quality model was not developed for each specific restoration measure. Instead, four general model conditions were utilized based on the results of the geomorphic modeling simulations. Those four conditions included: (1) the baseline 2015 geomorphology conditions with no island breaching; (2) a single breach west of the Katrina Cut structure; (3) breaching on either side of the Katrina Cut structure and along Little Dauphin Island and Pelican Island; and (4) breaching on either side of the Katrina Cut structure but no breaching along Little Dauphin Island and Pelican Island.

The three breach scenarios simulated in the hydrodynamic modeling all point to changed water quality conditions compared to the baseline (2015). Water temperature, total suspended solids (TSS), salinity, and dissolved oxygen (DO) changes were primarily localized around Katrina Cut and generally more towards the west and north of Dauphin Island. Changes from breaches in Little Dauphin Island and Pelican Island remained local and did not extend into the broader Mississippi sound and Mobile Bay systems.

Details regarding the development, calibration, validation, and results of the water quality modeling are documented in an ERDC Letter Report (Appendix H) available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.5.4. Task 5.4 – Habitat Modeling

In order to quantify changes to habitats from proposed restoration measures and under a no-action scenario, the project delivery team created a habitat model that was linked to the geomorphological model outputs (DEMs) and water quality model outputs. The habitat model focuses on habitat types broadly linked to important species found on Dauphin Island (e.g., beach, dune, intertidal marsh, and woody vegetation) with an emphasis on habitats utilized by species that were injured by the DWH oil spill. For various potential future island configurations for Dauphin Island, the team predicted coverage of habitat types using a spatially explicit habitat model based on landscape-position-information extracted from the hydrodynamic and geomorphic model outputs. The habitat modeling team also developed and used habitat suitability index (HSI) models to forecast habitat suitability for oysters and seagrasses under various future conditions.

The initial step in the habitat modeling effort was to develop a baseline habitat map to better understand current conditions and understand the relationship between landscape position and contemporary barrier island habitats (as discussed in Section 3.3.2). The next step in developing the predictive habitat model for Dauphin Island required the development of geocomputational models for each tidal regime (i.e., subtidal, intertidal, supratidal/upland) to predict barrier island habitats from landscape position information, including elevation, relative topography, and distance from shore using machine learning algorithms, including K-nearest neighbor and random forest to predict the habitat type based on the landscape position information (Enwright et al., 2019b). The predictive habitat model utilized generalized habitat classes from the geomorphology-based habitat classification scheme that was developed for the 2015 baseline habitat map discussed in Section 3.3.2. The generalizations of the mapping classification scheme involved combining habitat classes that occupy the same geomorphic setting but are regulated by factors not included in the model, such as disturbance and habitat succession. The changes included combining meadow and unvegetated barrier flat habitats into a single habitat class (Barrier flat), combining dunes with various vegetative states into a single class (Dune), and combining forest and scrub/shrub into a single habitat class (Woody vegetation). Therefore, the predictive habitat model utilized 12 habitat classifications rather than the 19 habitat classifications utilized in the 2015 baseline habitat map depicted above. This predictive model was applied to various geomorphological model outputs (DEMs) to predict habitat coverage for each restoration measure. The predictive habitat model also assumes there will be no change to developed areas and that developed areas would remain constant regardless of morphologic change. This underlying assumption was based on historical trends at Dauphin Island indicating land is not typically abandoned after storm events (i.e., structures are rebuilt after damage) and currently undeveloped areas have remained that way over the past several decades.

The predictive habitat model accounts for the ability of intertidal marshes to adapt to increasing SLC through vertical and/or horizontal adjustments to position in the landscape by combining the intertidal marsh habitat model with two assumptions regarding the potential for vertical elevation adjustments, erosion, and sedimentation. Based on literature review, the modeling team determined the threshold rate of increasing SLC for marsh persistence was 1 cm/yr. Therefore, the two marsh accretion assumptions were: (1) the elevation of existing marshes would adjust to keep up with SLC at rates of as much as 1 cm/yr (i.e., cumulative accretion in marshes would be the same as the cumulative SLC); and (2) marsh accretion would not occur once the SLC rate exceeded 1 cm/yr. The USACE SLC curve calculator ([version] 2017.55) was again used to determine how the rate of SLC influenced these assumptions for the intermediate and high SLC curves. Based on the two assumptions, the USACE high curve only had accretion through 2022 due to a rapid SLC rate, whereas intertidal marshes kept pace with SLC through accretion for nearly the entirety of the USACE intermediate curve. In other words, intertidal marsh habitat is sensitive to which SLC rate is considered. The habitat modeling team accounted for accretion by applying a “marsh mask” to the results of the geomorphic simulations prior to running the habitat model. The marsh mask is a spatially explicit layer based on the areas predicted as intertidal marsh for the baseline habitat model (i.e., modeled habitat for 2015). Prior to running the habitat model based on the results of the ST2SL1 and ST3SL3 geomorphic simulations, the elevation under the marsh mask was adjusted to represent marsh accretion. This feature reduces the risk of overestimating the loss of intertidal marsh habitat that would occur through the application of a static SLC.

In order to forecast future habitat conditions, the predictive model was loosely coupled with the decadal hydrodynamic model outputs from Task 5.1 (Section 3.5.1) for two paired potential storminess and SLC conditions (ST2SL1 and ST3SL3). These were the same model scenarios used to simulate the restoration measures developed by the project team. The ST2SL1 future condition scenario was determined to be the most representative of design conditions and the ST3SL3 future condition scenario was selected as it represented a “worst case” set of energetic conditions to influence island evolution (Mickey et al., 2020).

In addition to the predictive habitat model, a spatially explicit oyster HSI model driven by water quality variables was developed for the estuarine waters near Dauphin Island, Alabama. The HSI assessed how habitat suitability for oysters changes for two paired potential storminess and SLC conditions (ST2SL1 and ST3SL3) and a variety of restoration measures including beach and dune restoration, marsh restoration, placement of sand in the littoral zone, and the no-action measure. The HSI model was developed based on previous oyster HSI models, reviewed by experts, and calibrated and validated using oyster data and water quality data from the Mississippi Sound (Appendix I). The model included salinity, temperature, TSS, DO, and depth as they are key factors regulating oyster growth and survival. The model does not consider substrate and other biophysical parameters, but may be adapted to include them in the future if data becomes available. The goal of the HSI model was to evaluate how potential future conditions with and without restoration influenced habitat suitability for oysters based on these water quality parameters.

A spatially explicit seagrass HSI model was also developed for the estuarine waters near Dauphin Island, Alabama. This model assessed how habitat suitability for seagrass changes two paired potential storminess and SLC conditions (ST2SL1 and ST3SL3) and a variety of restoration measures including beach and dune restoration, marsh restoration, placement of sand in the littoral zone, and a no-action alternative. The HSI model was developed based on previous seagrass HSI models, reviewed by experts, and calibrated and validated using and seagrass data and water quality data from the Mississippi Sound. Along the Mississippi Sound and coastal Alabama, Halodule wrightii (shoal grass) is the dominant species (>62 percent) of seagrass communities due to its rapid growth and tolerance to a wide range of salinity regimes. Therefore shoal grass was selected as the focal species for the HSI. Shoal grass and other seagrass species are highly susceptible to changes in water quality variables (e.g., salinity and turbidity [TSS]), geomorphological variables (e.g., water depth), and hydrodynamic variables (e.g., exposure to wind waves). Therefore, these parameters were utilized in the seagrass HSI model. The goal of the HSI model was to evaluate how potential future conditions with and without restoration influenced habitat suitability for seagrasses based on these parameters.

Additional details regarding the development of the habitat model and the oyster and seagrass HSI models is provided in USGS Open-File Report 2020–1003 (Appendix I), and is also available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.5.4.1. No-Action Habitat Model and HSI Results

For comparison purposes, a 2015 baseline habitat map was produced using the landscape-position-information model (Figure 13; Enwright et al., 2019b). This was needed to ensure the habitat coverage is compared using the same methodology (i.e., modeled habitat vs. produced via remote sensing) and because the predictive habitat model uses a generalized set of habitat classifications compared to the full suite used in the 2015 baseline habitat. This map and the future no-action map served as baselines for determining how the simulated future conditions and/or restoration measures influenced habitat conditions for island configurations under the two paired scenarios (i.e., ST2SL1 and ST3SL3). For each scenario, a predicted habitat map was produced for year 0, year 5, and year 10 using both the USACE SLC high and intermediate curves.

Figure 14 illustrates the habitat model results for Year 10 of the future no-action scenario under ST2SL1 for both the high (H) and intermediate (I) SLC curves. In these simulations, there was a general reduction in the width of the island between Katrina Cut and Pelican Island with a commensurate reduction in beach, dune, and barrier flat habitats as compared to the baseline condition. Woody vegetation and barrier flat habitats along Little Dauphin Island were converted to intertidal flat, marsh, and water (estuarine) habitats also in this future scenario as breaches occur. Pelican Island also experienced breaching and corresponding conversion of beach, dune, and barrier flat habitats to open water (marine) habitat. The maps also illustrate how intertidal marsh habitat responded to the varying SLC rate assumptions through upslope tidal saline wetland migration. As expected, intertidal marsh from the 2015 baseline habitat map (Figure 13) kept pace with SLC under the USACE intermediate curve (Figure 14I), whereas intertidal marsh often converted to intertidal flat or water (estuarine) under the USACE high curve (Figure 14H).

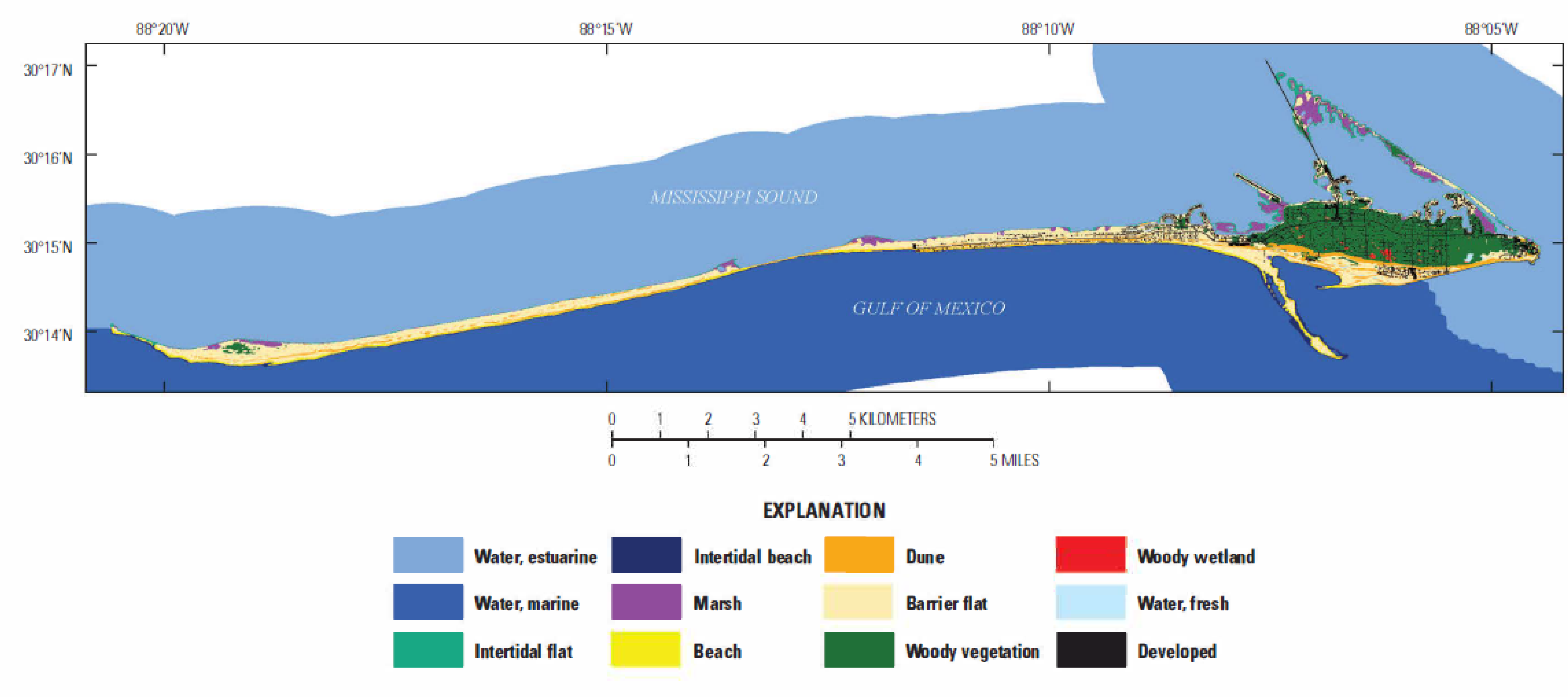


Figure 13: Predictive habitat model results for the Baseline 2015 modeled TBDEM.

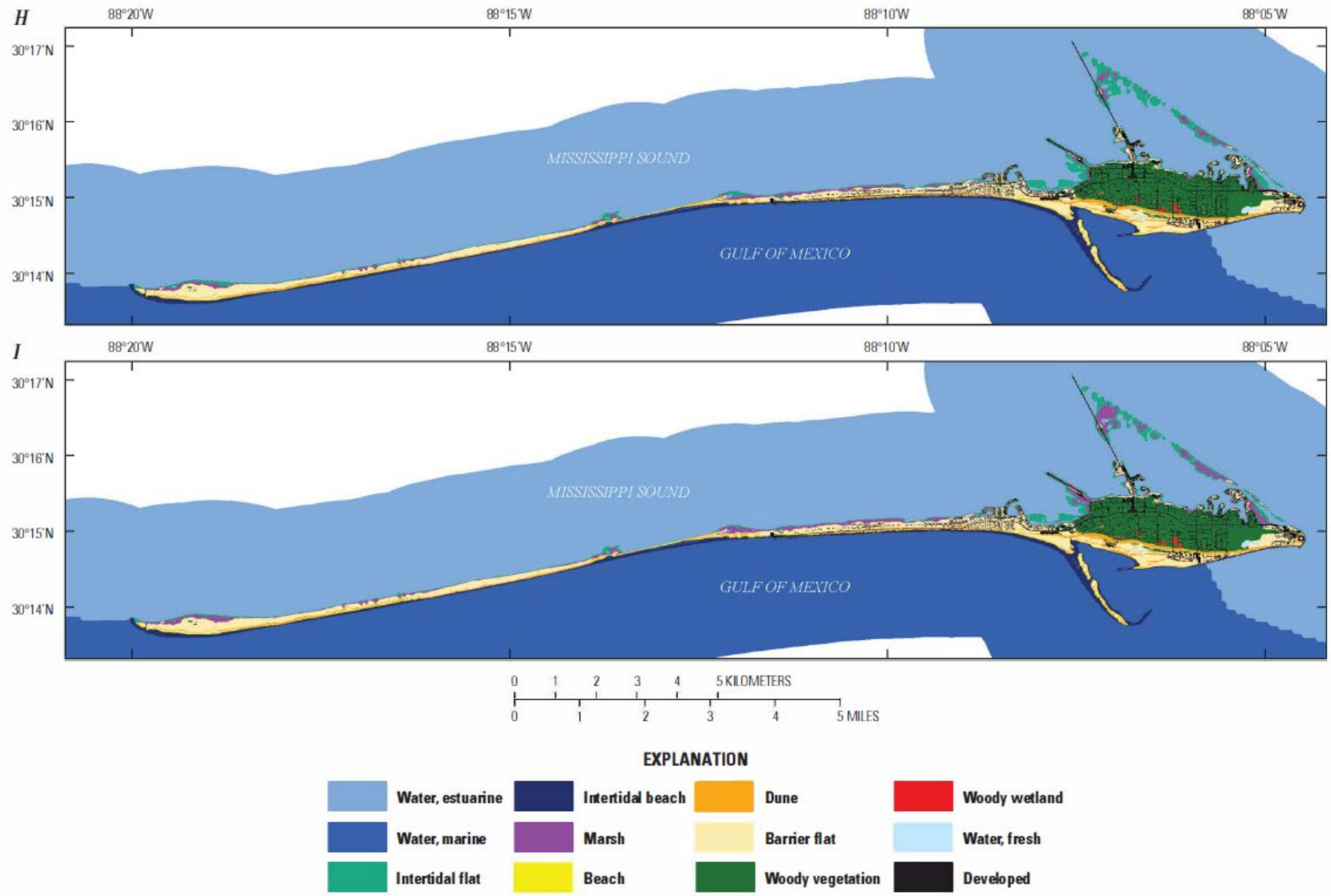


Figure 14: Predictive habitat model results for Year 10 of the future no-action scenario under ST2SL1 for both the high (H) and intermediate (I) USACE SLC curves.

Table 4 illustrates the areal coverage for the baseline and future with no-action habitat model results for the ST2SL1 scenario for both the high (H) and intermediate (I) SLC rates and the percent change between year 10 for ST2SL1 to the baseline results. Developed habitat is not included in the table as it is assumed to be constant. The results for the two scenarios are similar with decreases in the aerial coverage of marine water, beach, dune, barrier flat, and woody vegetation. However, the high SLC rate simulation also resulted in a decrease in the aerial coverage of intertidal marsh habitat as it could not keep pace with the SLC and converted to intertidal flat or water.

Figure 15 illustrates the habitat model results for Year 10 of the future no-action scenario under ST3SL3 for both the high (H) and intermediate (I) USACE SLC rates. In this more extreme future storminess and SLC simulation there are significant breaches to the east and west of Katrina Cut and along Pelican Island and Little Dauphin Island. The simulation also resulted in a significant reduction in the amount of subaerial habitat for the main island, with many developed areas now occurring in open water or intertidal flat habitats. The upslope migration of marsh habitat is evident under both the high (H) and intermediate (I) USACE SLC rates where many areas that were barrier flat or woody vegetation in the baseline habitat map now appear to be converted to intertidal marsh. Large portions of these areas also occurred in developed habitat. Rare habitats, such as water (fresh) and woody wetland, are almost completely lost under this scenario. Table 5 illustrates areal coverage for the baseline and future with no-action habitat model results for the ST3SL3 for both the high (H) and intermediate (I) SLC rates and the percent change between year 10 of ST3SL3 to the baseline results.

Table 4: Areal coverage for the baseline and future with no-action habitat model results for the ST2SL1 for both the high (H) and intermediate (I) SLC rates and the percent change between year 10 for ST2SL1 to the baseline results. The red values represent a percent decrease in the areal coverage of that habitat. [ha, hectare; WE, water, estuarine; WM, water, marine; IF, intertidal flat; IB, intertidal beach; IM, intertidal marsh; B, beach; D, dune; BF, barrier flat; WV, woody vegetation; WW, woody wetland; WF, water, fresh; TBDEM, topobathymetric digital elevation model; --, not applicable; Y, year].

ST2SL1 (H)												
Restoration measure	**Year**	**Areal coverage (ha) by habitat class**										
		WE	WM	IF	IB	IM	B	D	BF	WV	WW	WF
2015 modeled TBDEM	--	10,674.00	11,204.10	84.17	65.3	115.86	95.28	128.39	501.99	356.61	6.35	5.62
Future without action (R0)	Y0	10,701.40	11,215.80	156.23	101.79	115.05	98.05	100.49	417.98	317.24	8.23	6.09
	Y5	10,794.50	11,108.10	184.04	163.56	100.07	73.22	106.12	384.52	310.86	6.71	6.56
	Y10	10,794.40	11,116.30	188.24	171	99.39	59.94	108	377.06	309.73	6.69	7.47
Percent change Y10 to Baseline		1.13	0.78	123.64	161.87	14.22	37.09	15.88	24.89	13.15	5.35	32.92

ST2SL1 (I)												
Restoration measure	**Year**	**Areal coverage (ha) by habitat class**										
		WE	WM	IF	IB	IM	B	D	BF	WV	WW	WF
2015 modeled TBDEM	--	10,674.00	11,204.10	84.17	65.3	115.86	95.28	128.39	501.99	356.61	6.35	5.62
Future without action (R0)	Y0	10,699.10	11,215.70	99.9	101.86	174.09	98.12	100.69	417.39	317.08	8.24	6.07
	Y5	10,794.20	11,108.20	138.94	162.68	145.16	73.08	99.95	391.44	310.89	7.2	6.53
	Y10	10,793.70	11,116.30	147.51	170.91	139.64	60.47	107.98	378.1	309.33	6.84	7.47
Percent change Y10 to Baseline		1.12	0.78	75.25	161.73	20.52	36.53	15.90	24.68	13.26	7.72	32.92

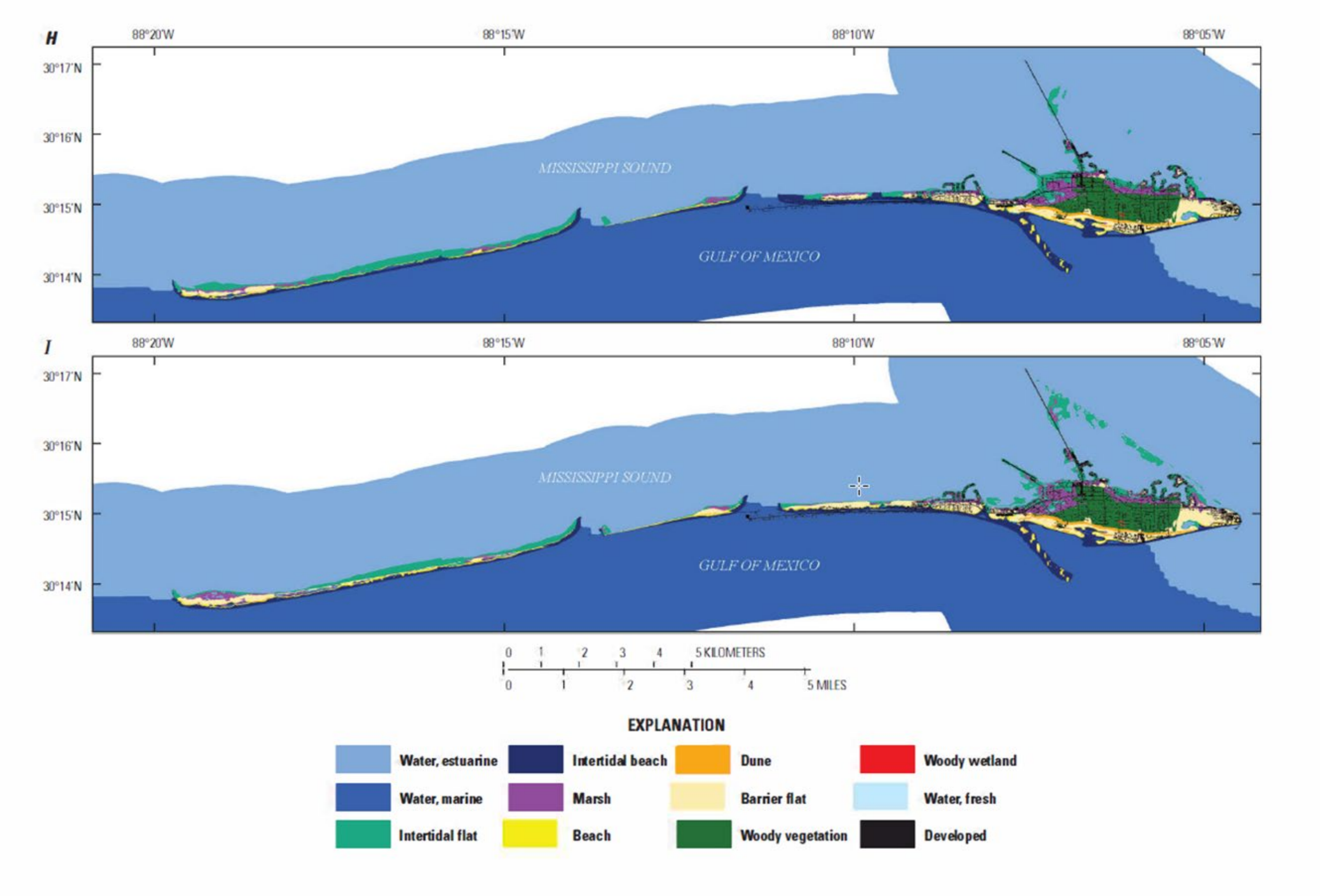


Figure 15: Predictive habitat model results for Year 10 of the future no-action scenario under ST3SL3 for both the high (H) and intermediate (I) USACE SLC curves.

Table 5: Areal coverage for the baseline and future with no-action habitat model results for the ST3SL3 for both the high (H) and intermediate (I) SLC rates and the percent change between year 10 of ST3SL3 to the baseline results. The red values represent a percent decrease in the areal coverage of that habitat. [ha, hectare; WE, water, estuarine; WM, water, marine; IF, intertidal flat; IB, intertidal beach; IM, intertidal marsh; B, beach; D, dune; BF, barrier flat; WV, woody vegetation; WW, woody wetland; WF, water, fresh; TBDEM, topobathymetric digital elevation model; --, not applicable; Y, year].

ST3SL3 (H)												
Restoration measure	**Year**	**Areal coverage (ha) by habitat class**										
		WE	WM	IF	IB	IM	B	D	BF	WV	WW	WF
2015 modeled TBDEM	--	10,674.00	11,204.10	84.17	65.3	115.86	95.28	128.39	501.99	356.61	6.35	5.62
Future without action (R0)	Y0	10,867.50	11,251.60	267.82	209.9	137.51	65.9	59.33	163.92	208.32	2.9	3.57
	Y5	10,926.00	11,220.80	232.04	267.19	129.56	63.23	41.61	151.45	200.61	2.47	3.3
	Y10	10,846.90	11,336.50	272.86	241.79	113.53	62.88	32.13	155.39	175.48	0.77	0
Percent change Y10 to Baseline		1.62	1.18	224.18	270.28	2.01	34.01	74.97	69.05	50.79	87.87	100.00

ST3SL3 (I)												
Restoration measure	**Year**	**Areal coverage (ha) by habitat class**										
		WE	WM	IF	IB	IM	B	D	BF	WV	WW	WF
2015 modeled TBDEM	--	10,674.00	11,204.10	84.17	65.3	115.86	95.28	128.39	501.99	356.61	6.35	5.62
Future without action (R0)	Y0	10,854.90	11,266.30	126.66	196.38	286.38	66.42	59.31	167.18	208.22	2.93	3.57
	Y5	10,877.00	11,215.00	228.27	214.16	175.79	84.77	41.76	194.98	200.72	2.47	3.42
	Y10	10,775.20	11,334.70	275.65	223.13	142.58	78.96	32.63	198.72	175.77	0.85	0.12
Percent change Y10 to Baseline		0.95	1.17	227.49	241.70	23.06	17.13	74.59	60.41	50.71	86.61	97.86

In addition to the predictive habitat model, the habitat modeling team also developed HSI models to forecast habitat suitability for oysters and seagrasses for the two paired storminess and SLC future conditions (ST2SL1 and ST3SL3). Figure 16 (Wang et al., 2020a) shows the distribution of oyster habitat suitability for year 10 of the no-action scenario under ST2SL1 (Figure 16A) and ST3SL3 (Figure 16B). The ST2SL1 oyster HSI distribution was very similar to the baseline oyster HSI distribution (not pictured). However, under the ST3SL3 future conditions there is a significant reduction in the "highly suitable" areas as compared to the baseline. Most of these changes occur in the back-barrier areas in the Mississippi Sound north of Dauphin Island due to the breaching of the island near Katrina Cut resulting in increased water depth and salinity.

Figure 17 (Wang et al., 2020b) shows the distribution of seagrass habitat suitability for year 10 of the no-action scenario under both ST2SL1 (Figure 17A) and ST3SL3 (Figure 17B). Compared to HSI distribution under the baseline condition (not pictured), the ST2SL1 (Figure 17A) scenario generally maintains the same pattern and distribution of suitability but does have a slight reduction in the seagrass suitable areas. However, under the ST3SL3 (Figure 17B) scenario, the amount of suitable seagrass habitat was significantly reduced and fragmented as compared to the baseline or the ST2SL1 scenarios. This is likely attributable to the increased water depth and increased salinity in the back-barrier areas due to island breaching under this scenario.

Additional details regarding the results of the habitat modeling and oyster and seagrass HSI modeling efforts of the no-action and various restoration measures are provided in USGS Open-File Report 2020–1003 (Appendix I) and is also available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

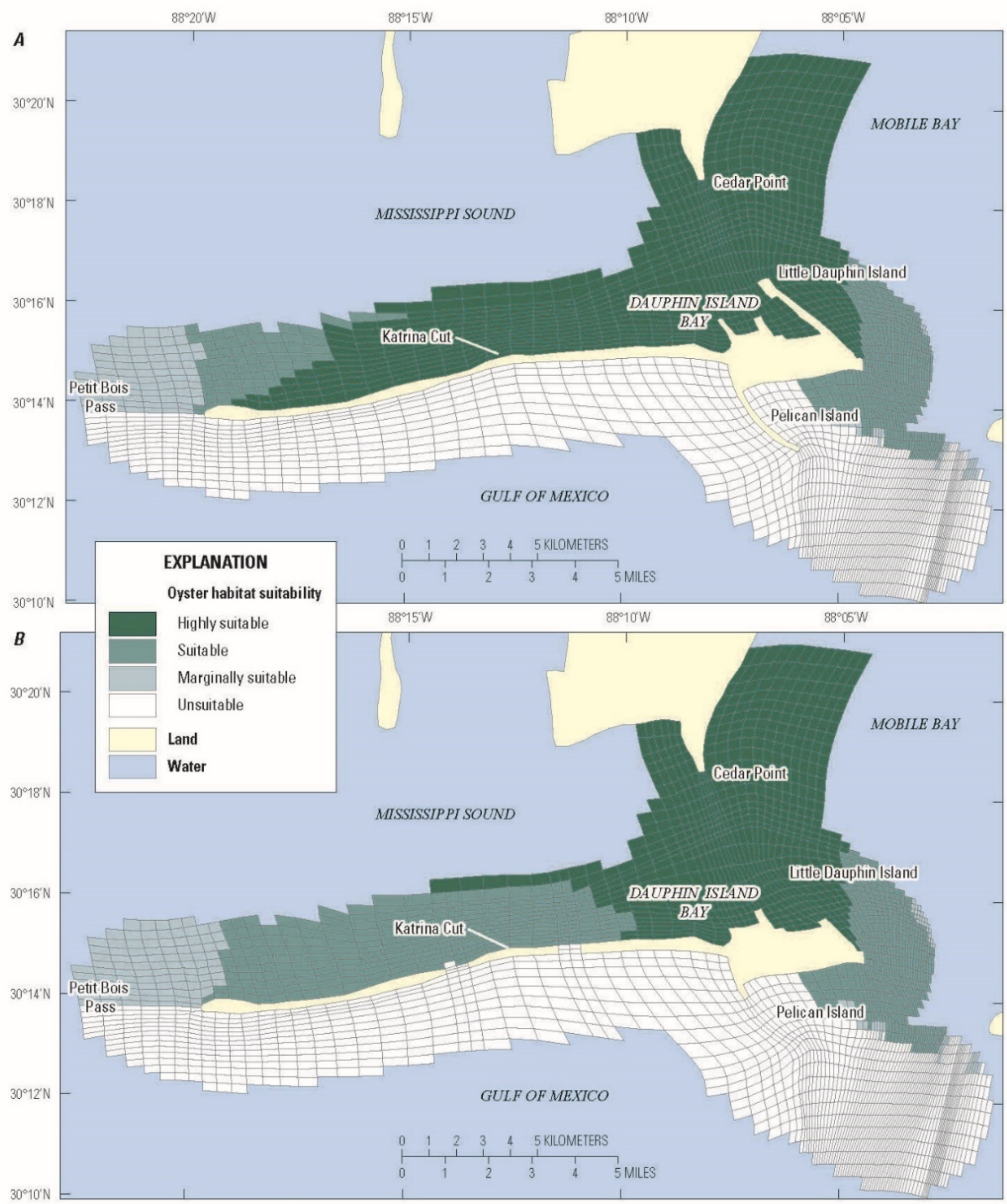


Figure 16: Year 10 oyster HSI distribution for the no-action scenario under both ST2SL1 (A) and ST3SL3 (B).

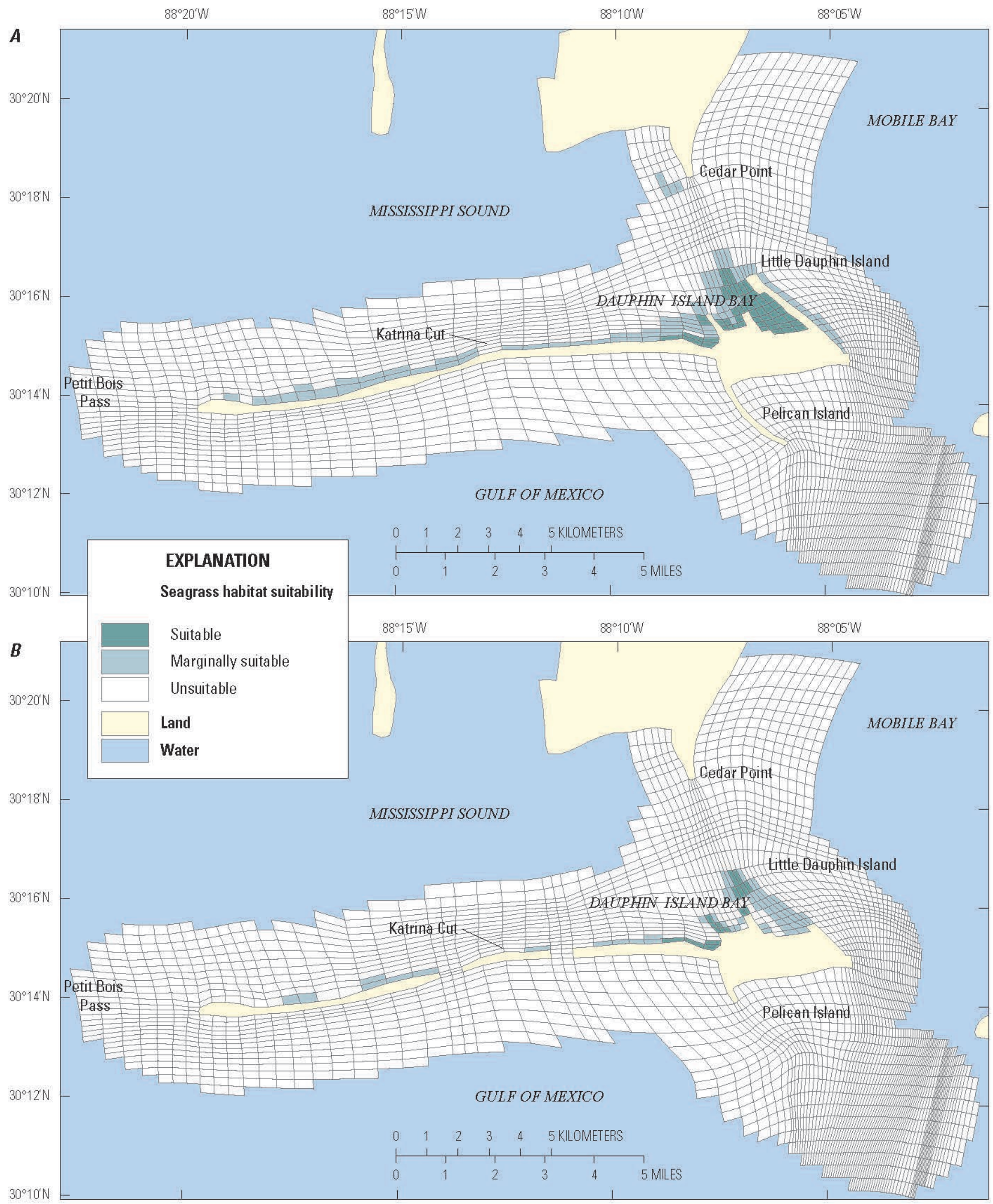


Figure 17: Year 10 seagrass HSI distribution for the no-action scenario under both ST2SL1 (A) and ST3SL3 (B).

3.6. Task 6 – Alternative Evaluations

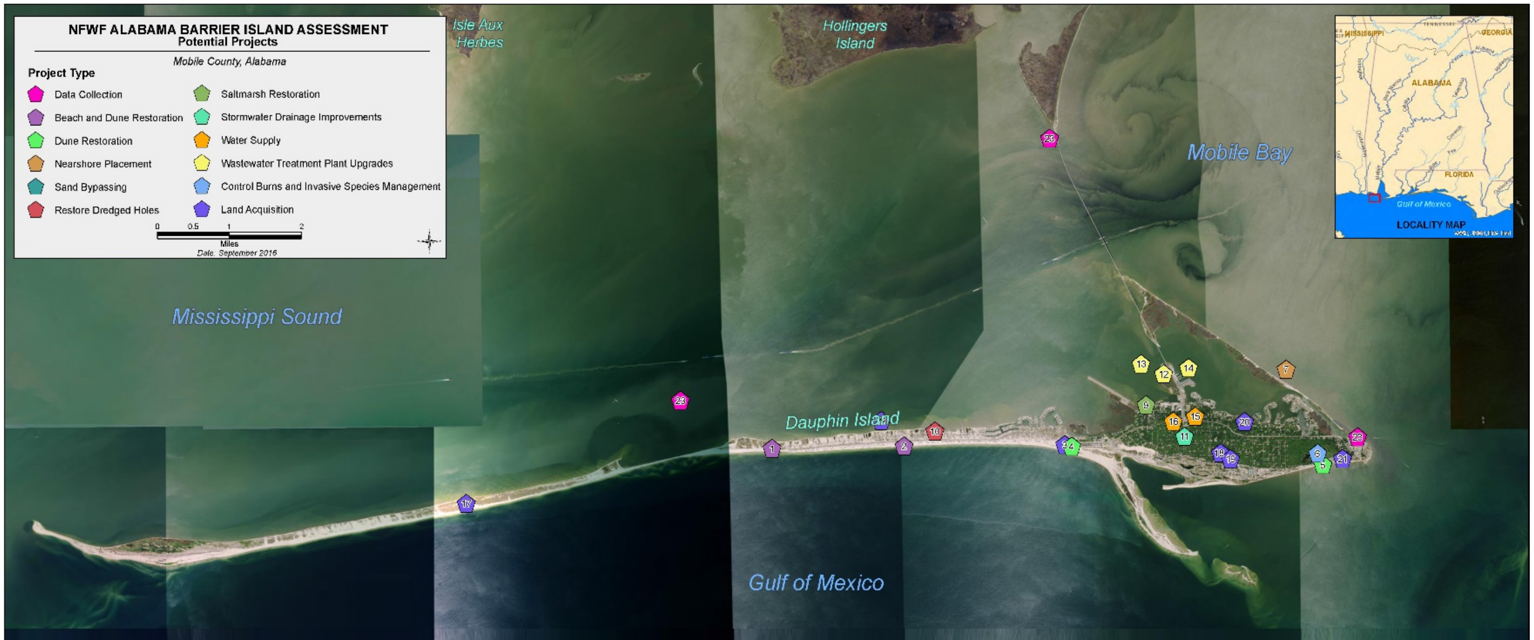
The overarching goal of the Alabama Barrier Island Restoration Assessment was to investigate viable options for restoration of natural and nature-based features along Dauphin Island that can increase island sustainability and restore vital habitats for species affected by the DWH oil spill. Restoration measures to achieve this goal were formulated based on science and technical expertise. These measures were evaluated using the modeling tools and products, including decadal hydrodynamic and morphologic, water quality, and habitat modeling developed as part of this study (i.e., Tasks 1–5). Collectively, these products helped to determine how various measures may affect the habitat composition, sustainability, and resiliency of Dauphin Island under varying potential future scenarios. Details on the alternative formulation and evaluation process, the assessment tools utilized to determine how well each measure meets restoration objectives, and the costs of the restoration measures are provided in the following sections.

3.6.1. Task 6.1 – Alternative Formulation and Evaluation

The alternative formulation and evaluation task consisted of two basic components. The first (Task 6.1a) was the identification of viable measures that could be implemented in the short-term without needing detailed analysis to meet restoration objectives of NFWF and State of Alabama (these are called "interim projects" for the purposes of this report). This effort was led by the USACE through close coordination with the State and supported by the USGS and a panel of eight experts (known as the Evaluation Support Panel) with firsthand knowledge of Dauphin Island. The second (Task 6.1b) was to identify longer-term, more comprehensive restoration measures that were formulated and evaluated using technical expertise and the tools developed as part of this study.

A detailed description of the interim projects developed under Task 6.1a is documented in Appendix A of the 2017 Interim Report (USGS et al., 2017). A copy of the interim report is available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx. For ready reference, the locations, names, and a brief description of the 27 projects, including the project types, benefits, and costs (as estimated by project proponents) are shown in Figure 18.

In order to identify longer-term, more comprehensive restoration measures, the project delivery team evaluated the various model results for the future no-action scenarios (as discussed in Section 3.5) to understand how SLC and climate change might influence the geomorphology, water quality, and habitat composition on and around the island. Potential restoration measures, influenced by the interim project evaluations and model results, were developed to address the study objectives of restoring Dauphin Island to a sustainable barrier island and enhancing or restoring the island and surrounding coastal resources for species affected by the DWH oil spill. Section 3.6.2 describes the restoration measures formulated and the results of the model simulations used in their evaluations. These model results served as inputs to the alternative assessment tool, developed as part of Task 6.2 (see Section 3.6.3), which evaluated combinations of restoration measures and other factors to identify potential restoration alternatives.



Id	Project Name	Project Type	Benefits	Cost
1	Dauphin Island Public Beach and Dune Restoration	Beach and Dune Restoration	Restoration to reduce breaching potential and increase protection of habitat for a variety of unique plant and animal assemblages.	$10,000,000
2	West End Beach and Dune Restoration	Beach and Dune Restoration	Restoration to reduce breaching potetnial and increase protection of habitat for a variatety of unique plant and animal assemlages.	$61,501,000
3	Mid-Island Land Acquisition and Management - Phase I	Land Acquisition	Conservation of coastal barrier beach and dune habitat for variety of unique plant and animal assemblages including neotropical birds and wintering migratory species.	$2,500,000
4	Mid-Island Land Acquisition and Management - Phase II	Land Acquisition	Public access to natural resources.	$1,000,000
5	Dauphin Island Audubon Bird Sanctuary Shoreline Restoration & Management	Dune Restoration	Increase protection and habitat for a variety of unique plant and animal assemblages.	$445,650
6	Dauphin Island Audubon Bird Sanctuary Shoreline Restoration & Management	Control Burns and Invasive Species Management	Increase in heathly maritime forrest and beach and dune habitiat types.	$1,079,350
7	Little Dauphin Island Nearshore Placement	Nearshore Placement	Increased sediment supply to Little Dauphin Island complex. Subaerial and subtidal habitats benefiting various wildlife including aquatic and avian species.	$2,850,000
8	Improved Bypassing of Beach Sands Dredged from the Mobile Ship Channel	Sand Bypassing	Increased sediment supply to Sand/Pelican complex. Subaerial and subtidal habitats benefiting various wildlife including aquatic and avian species.	$3,960,000
9	Aloe Bay Beneficial Use Restoration	Saltmarsh Restoration	Restore nursery habitat for aquatic and avian wildlife.	$2,445,000
10	Fill Borrow Pits Dug in 2010 to Protect Against Oil Spill Damage	Restore Dredged Holes	Reduce potential for island breaching and potential associated impacts in the Mississippi Sound. Restore Subaerial and subtidal habitats.	$5,600,000
11	Stormwater Quality Rehabilitation Project	Stormwater Drainage Improvements	Improve the overall health of the estuaries in and around Dauphin Island including fishery and shellfish habitats.	$500,000
12	Aloe Bay/Mississippi Sound Water Quality Enhancement Project - Phase I	Wastewater Treatment Plant Upgrades	Improve the overall health of the estuaries in and around Dauphin Island including fishery and shellfish habitats.	$10,050,000
13	Aloe Bay/Mississippi Sound Water Quality Enhancement Project - Phase II	Wastewater Treatment Plant Upgrades	Improve the overall health of the estuaries in and around Dauphin Island including fishery and shellfish habitats.	$13,050,000
14	Dauphin Island Wastewater Collection System Rehabilitation	Wastewater Treatment Plant Upgrades	Improve the overall health of the estuaries in and around Dauphin Island including fishery and shellfish habitats.	$3,145,000
15	Dauphin Island Water Supply Aquifer Improvements	Water Supply	Reduce the impact on existing water aquifers.	$1,842,000
16	Dauphin Island Water Supply Elevated Storage Tank	Water Supply	Provide adequate water supply to the island.	$3,428,000
17	West End Land Acquisition	Land Acquisition	Conservation of coastal barrier resource land that provides stop over habitat for neotropical birds and critical wintering habitat for migtratory species.	$10,000,000
18	Tupelo Gum Swamp Land Acquisition	Land Acquisition	Conservation of migratory bird habitat that includes brackish ponds that become rich sand flats during low tide, rich interior wetlands and maritime forest.	$700,000
19	Gorgas Swamp Land Acquisition	Land Acquisition	Conservation of migratory bird habitat that includes brackish ponds that become rich sand flats during low tide, rich interior wetlands and maritime forest.	$700,000
20	Steiner Property Acquisition	Land Acquisition	Conservation of migratory bird habitat that includes brackish ponds that become rich sand flats during low tide, rich interior wetlands, and maritime forest.	$600,000
21	US Coast Guard Property Disposal / Acquisition	Land Acquisition	Conservation of coastal barrier beach, dune and shurb habitat that act as buffer to adjacent maritime forests.	$2,500,000
22a	Dauphin Island 39 Parcel Property Acquisition - West End	Land Acquisition	Conservation of coastal barrier back beach, washover fans, and island platform.	$900,000
22b	Dauphin Island 39 Parcel Property Acquisition - Graveline Bay	Land Acquisition	Conservation of marsh and nearshore coastal bay bottoms.	$400,000
22c	Dauphin Island 39 Parcel Property Acquisition - Aloe Bay	Land Acquisition	Conservation of nearshore coastal bay bottoms.	$100,000
22d	Dauphin Island 39 Parcel Property Acquisition - Little Dauphin Island and Bay	Land Acquisition	Conservation of coastal barrier beach, dune and shurb habitat that act as buffer to adjacent marsh and bay systems.	$200,000
22e	Dauphin Island 39 Parcel Property Acquisition - East End	Land Acquisition	Conservation of coastal barrier habitat.	$620,000
23	Dauphin Island Management Support System	Data Collection	Better realization of current and future habitat management efforts.	$1,141,000

Figure 18: Potential Interim Projects Considered by the USACE, State of Alabama, and Evaluation Support Panel.

3.6.2. Formulation and Evaluation of Restoration Measures

The project team evaluated the hydrodynamic, morphological change, water quality, life-cycle structure response (i.e., of the Katrina Cut structure), and habitat model results of the no-action future conditions, and considered the Interim Report project recommendations, to develop potential restoration measures. Descriptions of the measures developed to meet the study objectives are provided below. These consisted of restoration measures on the ebb tidal shoal south of Dauphin Island, Gulf beach restoration measures, back-barrier and marsh restoration measures, and land acquisitions for conservation. These measures were evaluated using the models previously described in section 3.5 and/or the alternative assessment tool described in section 3.6.3. The tool computed an overall utility score for each of the measures as a function of how well they satisfied the restoration objectives associated with social, fiscal, and conservation values on Dauphin Island.

Two storminess and SLC conditions (ST2SL1 and ST3SL3, as described in section 3.5) were used to evaluate the performance of the restoration measures. The ST2SL1 future condition scenario represents the medium storminess bin (characterized by island overwash and dune recovery) and historical SLC rates. The ST3SL3 future condition scenario represents the high storminess bin (i.e., characterized by repeated island overwash and rollover) and USACE high rates of SLC. This scenario represents a more energetic or "worst case" set of conditions to influence island evolution (Mickey et al., 2020).

The following sections detail how the restoration measures, which vary in scale, location, and design, may affect the habitat composition, sustainability, and resiliency of Dauphin Island under these potential future scenarios. Rough Order of Magnitude (ROM) cost estimates were prepared for the various restoration measures formulated, including costs for final engineering and design, initial construction, operation and maintenance, any land acquisitions, and contingencies. Monitoring and adaptive management costs were calculated as three percent of the total estimated cost based on other barrier island work in the region. However, these MAM costs will need to be refined once the measures are fully developed and will vary based on the complexity of the final measure. Summaries of these costs are provided in the restoration measure descriptions below.

3.6.2.1. Ebb Tidal Shoal Restoration Measures

The general intent of the ebb tidal shoal measures was to determine if sand dredged from the Mobile Harbor Bar Channel could be feasibly and beneficially used, supplemented with sand from other sources, to enhance sediment transport in the area, create sustainable habitat, and provide protection to areas along the eastern end of Dauphin Island. These measures were particularly focused on restoration of historical footprints of Pelican and Sand Islands. Descriptions of the measures, including their benefits, performance, costs, and utility score are provided in the following sections.

3.6.2.1.1. Pelican Island Southeast Nourishment

Description: The Pelican Island Southeast Nourishment measure would serve to supply sand to the nearshore littoral system while enhancing important habitat that is found naturally along the ephemeral, subaerial sand deposit. In addition to supplying a direct source of sand in the littoral system near Pelican Island, this measure would provide additional storm damage reduction to beaches located leeward of the island along Dauphin Island's eastern end. The measure would also increase piping plover critical habitats and undeveloped lands covered under the Coastal Barrier Resources Act.

The Pelican Island measure would place an estimated 4.5 million cubic yards at a target elevation of +4.5 feet North American Vertical Datum of 1988 (NAVD88) southeast of the existing Pelican Island along the general 1985 island shoreline position (Figure 19). Estimates of fill quantities are based on 2015/2016 USACE and USGS topographic and bathymetric surveys and account for historic volumetric change rates observed for the area based on 2010 to 2016 surveys.

Potential sources of sand for initial construction include borrow areas located within the Mobile ebb tidal shoal system (Sand Island Beneficial Use Area (SIBUA)), relic sand deposits located just offshore of Petit Bois Pass, and upland sources located within dredge material sites along the Alabama-Tombigbee river system (Figure 20 and Figure 21). Borrow sources for future nourishments include sand dredged from Mobile Harbor Bar Channel during routine maintenance activities. These sources are assumed to be compatible with the native beach materials on the island; therefore, volume estimates for initial construction and future nourishment efforts do not include an overfill factor.

Figure 19. Pelican Island Southeast Nourishment Measure.

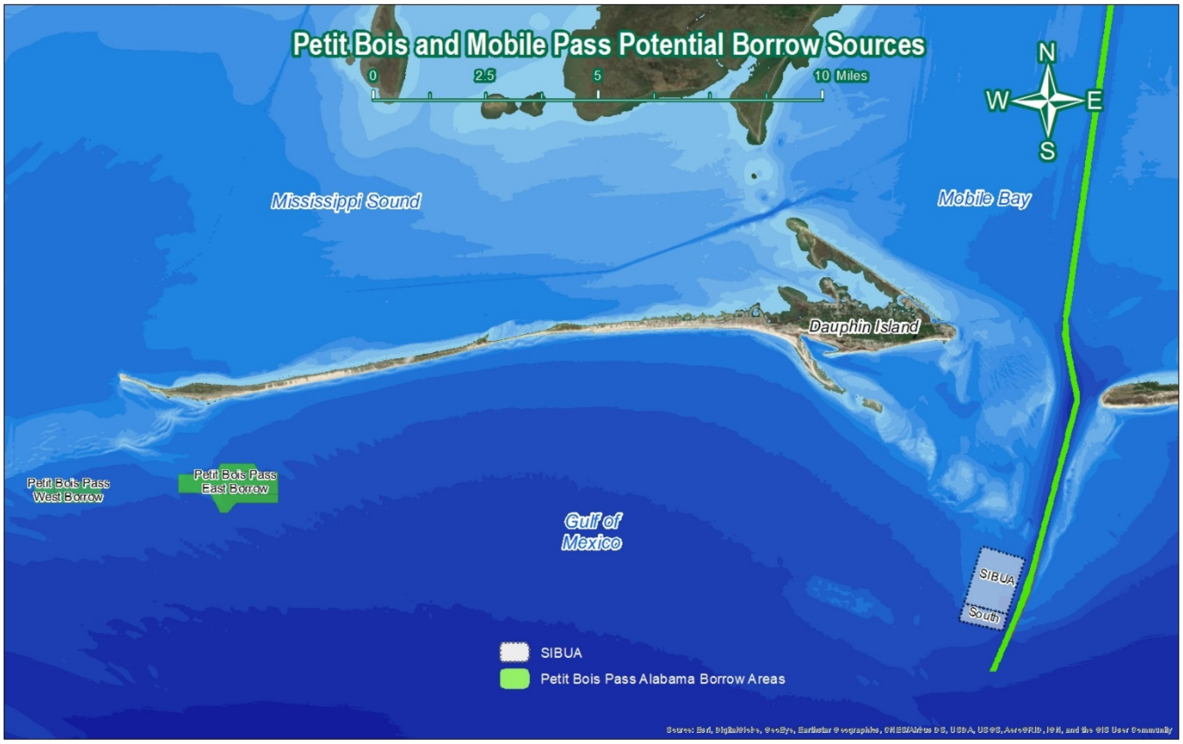


Figure 20. Petit Bois Pass Relic Sand Deposits and Mobile Ebb Tidal Shoal (SIBUA) Borrow Sources.

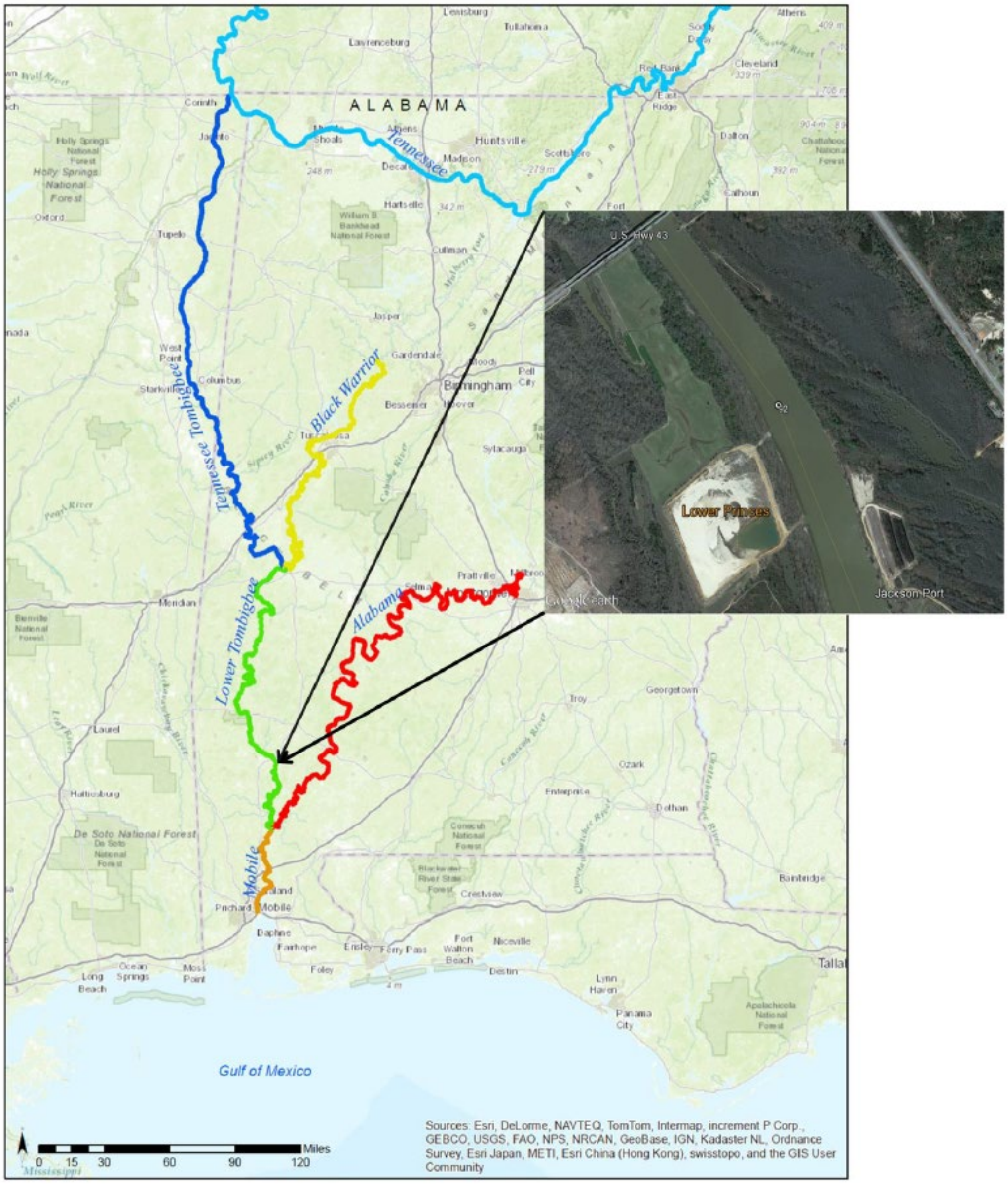


Figure 21. Alabama-Tombigbee River Sand Borrow Sources.

Benefits: The measure provides an estimated 240 acres of intertidal beach and barrier flat habitat offshore of Dauphin Island along the ebb tidal shoal system. In addition to the direct habitat and species benefits, the measure generates secondary benefits of risk reduction to hazards associated with storms along the east end of Dauphin Island through a reduction in wave energy and shoreline erosion. For comparison, shoreline erosion was reduced over 1.5 miles by approximately 52% and 41% between the proposed restoration measure and future no-action scenario for the ST2SL1 and ST3SL3 10-year model simulations respectively.

Performance: Under low SLC and moderate storm conditions (i.e., ST2SL1), the measure is estimated to maintain sufficient volumes and island elevation and width to prevent projected losses of over 138 acres of intertidal beach and barrier flat habitats when compared to the no-action case. At 10 years, it is estimated that roughly 30% of the fill volume (approximately 1.35 million cubic yards of sand) would be transported to the lee and along the Gulf-side requiring nourishments on an estimated average 10-year interval to maintain maximum benefits over a 50-year project life. Results from the USGS morphological change modeling, detailed in Appendix F, indicate that the majority of the changes (i.e., compared to the simulation of the future no-action case) were in the areas surrounding Pelican Island where the sand was placed. During the 10-year model simulation, there was no noticeable change in the rates of sediment transport from Pelican Island to Dauphin Island. Nor were there significant documented differences in the patterns or magnitude of erosion or deposition around the main portions of Dauphin Island. As stated above, the primary benefit seen from this measure is the reduction in shoreline erosion along Dauphin Island's east end.

Under high SLC rates and storm conditions (i.e., ST3SL3), most of the subaerial features were eroded with only about 70 acres of intertidal beach located above the significant submerged sand deposits after 10 years. During the 10 year simulation material is predominantly transported to the lee of Pelican Island through increased island overwash and breaching. To maintain subaerial benefits, this measure would require adaptive management measures of increased berm height that would result in increased future nourishment volume needs should SLC occur at the higher rates.

Cost: The estimates for initial construction costs range from \$72.9 to \$119.0 million, depending on the borrow source used (i.e., Mobile Harbor Bar Channel, Petit Bois Pass relic sand deposits, or upland sources along the Alabama-Tombigbee River). To maintain maximum benefits, nourishments would be needed on an estimated 10-year average cycles. Estimates of total present value cost for nourishments over a 20-year and 50-year project life-cycle (i.e., future operations and maintenance (O&M) costs) are presented in Table 6 and assume the use of sand dredged from Mobile Harbor Bar Channel during routine maintenance activities. The summary of costs for this restoration measure to include MAM are provided in Table 6 below and further details are provided in Appendix K.

Table 6. Present Value Costs for the Pelican Island Southeast Nourishment Measure.

Borrow Source Options	**Initial Construction Cost (\$ million)**	**20-Year O&M Costs (\$ million)**	**50-Year O&M Costs (\$ million)**
Option 1 – Mobile Ebb Tidal Shoal	\$79.4	-	-
Option 2 – Petit Bois Pass Relic Sand Deposits	\$72.9	-	-
Option 3 – Alabama-Tombigbee River Sand	\$119.0	-	-
Option 1 – Mobile Harbor Bar Channel	-	\$3.0	\$8.5
Monitoring and Adaptive Management (*3% of initial project costs*)	\$2.2 - \$3.6	-	-

Utility Score: The utility scores for the various options range from 211.9 to 221.9.

3.6.2.1.2. Sand Island Platform Nourishment and Sand Bypassing

Description: The Sand Island Platform Nourishment and Sand Bypassing measure would serve to build up the shoal system around the Sand Island Lighthouse and supply sediment to the nearshore littoral system along regions of the submerged ephemeral sand deposits of Pelican and Sand Islands.

This measure would place an estimated 4.3 million cubic yards at target elevations of -8 to -6 feet NAVD88 within regions located along the general 1847-50 Sand Island shoreline position (Figure 22). In addition the measure includes the simulation of bypassing of dredge material from the Mobile Harbor Bar Channel every 2 years to maintain the initial placement volume and footprint. Estimates of initial fill quantities are based on 2015/2016 USACE and USGS topographic and bathymetric surveys and account for historic volumetric change rates observed for the area based on 2010 to 2016 surveys.

Potential sources of sand for initial construction include the Mobile Harbor Bar Channel, borrow areas located within the Mobile ebb tidal shoal system, relic sand deposits located just offshore of Petit Bois Pass, and upland sources located within dredge material sites along the Alabama-Tombigbee river system (as shown in Figure 20 and Figure 21). Borrow sources for future nourishments include sand dredged from Mobile Harbor Bar Channel estimated at approximately every 2 years during routine maintenance activities. These sources are assumed to be compatible with the native beach materials on the islands and shoals; therefore, volume estimates for initial construction and future nourishment efforts do not include an overfill factor.

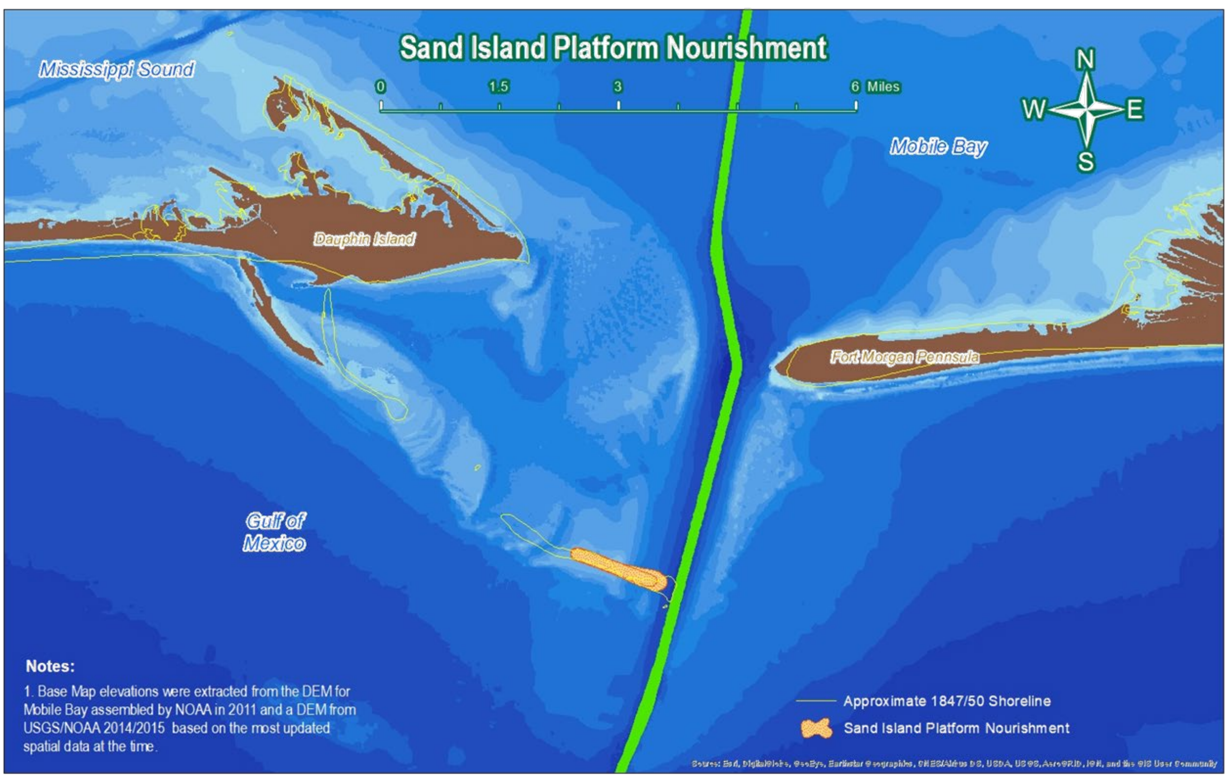


Figure 22. Sand Island Platform Nourishment

Benefits: The measure provides an estimated 127 acres of submerged offshore sand deposits along the ebb tidal shoal system, and a direct source of sediment to the Pelican Island and Sand Island submerged ephemeral sand deposits. The movement of the sand towards Pelican Island was fairly localized during the 10-year model simulations (for both the ST2SL1 and ST3SL3 scenarios), indicating that sediment transport processes on the ebb tidal shoal are multi-decadal in time scale and are heavily influenced by highly energetic storm events. It is estimated that only about a third of the bypassed material would be transported out of the site on a two-year cycle, based on the simulated transport rates of approximately 178,000 cubic yards per year and the estimated annualized dredge volume from the Mobile Harbor Bar Channel of approximately 525,000 cubic yards per year since the last bar channel deepening in 1990. Over the 10-year model simulation period there were no significant increases in sediment transport or direct or secondary subaerial habitat benefits identified.

Performance: Under low SLC and moderate storm conditions (i.e., ST2SL1) for the 10-year model simulation, roughly 31% (net erosion of approximately 178,000 cubic yard per year) of the placed fill was transported to the northwest along the Pelican and Sand Island submerged ephemeral shoals. Under higher SLC and storms (i.e., ST3SL3) the rate of sediment transport from the sites over the 10-year simulation period was reduced to an average rate of approximately 131,000 cubic yards per year. This reduction in transport rate during simulations was believed to driven by differences in water levels between the scenarios that would reduce wave-bottom interaction in this area resulting in less erosion.

Cost: The estimates for initial construction costs range from $82.0 to $103.1 million, depending on the borrow source used (i.e., Mobile ebb tidal shoal, Petit Bois Pass relic sand deposits, or upland sources along the Alabama-Tombigbee River). To maintain maximum benefits, nourishments would be needed on an estimated 2-3 year average cycle. Estimates of total present value cost for nourishments over a 20-year and 50-year project life-cycle (i.e., future O&M costs) are presented in Table 7 and assume the use of sand dredged from Mobile Harbor Bar Channel during routine maintenance activities every 2 years. The summary of costs for this restoration measure to include MAM are provided in Table 7 below and further details are provided in Appendix K.

Table 7. Present Value Costs for the Sand Island Platform Nourishment Measure

Borrow Source Options	**Initial Construction Cost ($ million)**	**20-Year O&M Costs ($ million)**	**50-Year O&M Costs ($ million)**
Option 1 – Mobile Ebb Tidal Shoal, Mobile Harbor Bar Channel, and Alabama-Tombigbee River Sand	$103.1	-	-
Option 2 – Petit Bois Pass Relic Sand Deposits	$82.0	-	-
Option 1 – Mobile Harbor Bar Channel	-	$10.4	$29.7
Monitoring and Adaptive Management (*3% of initial project costs*)	$2.5 - $3.1	-	-

Utility Score: The utility scores for the various options range from 206.7 to 216.7.

3.6.2.2. Gulf Beach Restoration Measures

The Gulf beach measures formulated for the east and west ends of Dauphin Island were primarily intended to create and restore beach and dune habitat, while reducing possible damages to existing habitats landward on the island (e.g., herbaceous and wooded dunes, freshwater ponds, maritime forest, etc.). These measures were also evaluated to determine if they reduced the risk of island breaching in the future under the storminess and SLC scenarios simulated. Descriptions of the measures, including their benefits, performance, costs, and utility scores are provided in the following sections.

3.6.2.2.1. East End Beach and Dune Restoration

Description: The proposed East End Beach and Dune Restoration measure would restore vital habitat that has been lost along the east end of Dauphin Island and provide additional storm damage reduction to existing herbaceous and wooded dunes located landward of the proposed footprint, primarily along the Dauphin Island Audubon Bird Sanctuary. The eastern portion of the island exhibits some of the oldest and most extensive manmade and natural coastal storm risk management measures found along the island today, including a groin field on the eastern end that was first built in 1894 to protect Fort Gaines. In 1897, a seawall was incorporated and in 1909 additional groins were added along the shoreline southwest of the seawall. To mitigate extensive erosion, the 8 westernmost detached groins were reoriented in 2015 and 2016 into segmented breakwaters with an approximate 320,000 cubic yards of sand placed along the landward shoreline as part of the Coastal Impact Assistance Program (CIAP) East End Shoreline Restoration Project. Based on 3 years of post-construction monitoring, this project has performed well with over 80% of the volume remaining (Douglass, 2020). The natural and nature-based measures found along the east end of the island include maritime forest and extensive primary and secondary dune systems that peak in elevations of over +40 feet NAVD88.

The East End Beach and Dune Restoration measure would place an estimated 1.2 million cubic yards of sand along the shoreline at a natural berm elevation of approximately +5.5 feet NAVD88 to extend the 2016 CIAP East End Shoreline Restoration Project approximately 3,600 feet to the west (Figure 23). Additionally, the measure includes construction of a frontal dune at an elevation of +12 feet NAVD88 and width of 25 feet along a 4,800 foot stretch of the coast, to slightly overlap with and extend eastward of where the natural extensive high dune system currently ends. The dunes would be vegetated with approximately 50,400 native dune plants (Bitter Panicum, Sea Oats, and Gulf Bluestem) that are robust in helping stabilize dunes and incorporate roughly 3,200 feet of sand fencing.

Figure 23. East End Beach and Dune Restoration Measure

The design follows standard coastal engineering principles of including a design section and advanced fill. The design section contains the sand placed to achieve the project purpose and benefits and the advanced fill is the additional sand placed to sustain the beach between nourishment events. Estimates of fill quantities are based on a translated profile from the 2015/2016 USACE and USGS topographic and bathymetric surveys and account for continued averaged background erosion rates of approximately 8.5 feet per year based on USGS long-term weighted linear regression shoreline change rates (1940–2015) as documented in Appendix D.

Potential sources of sand for initial construction include borrow areas located within the Mobile ebb tidal shoal system, relic sand deposits located just offshore of Petit Bois Pass, and upland sources located within dredge material sites along the Alabama-Tombigbee river system (Figure 20 and Figure 21). Borrow sources for future nourishments include the sources previously referenced and potential sand dredged from Mobile Harbor Bar Channel during routine maintenance activities. These sources are assumed to be compatible with the native beach materials on the island; therefore, volume estimates for initial construction and future nourishment efforts do not include an overfill factor.

Benefits: The measure provides an estimated 35 acres of restored beach and dune habitat along the east end of the island. In addition to the direct habitat and species benefits, the measure generates secondary benefits of risk reduction to hazards associated with storms and rising seas to over 50 acres of existing beach, dune, woody vegetation, and freshwater lakes and ponds when compared to the no-action case. These habitats are critical in providing wave dissipation, stabilization to the shoreline, soil retention, ground-water storage, and shelter for the fresh water ponds and marsh that naturally occur behind the beach and dunes and within the maritime forest.

These habitat systems also provide ecosystem services, such as water purification, carbon sequestration, wildlife habitat, and biodiversity.

Performance: In the past twenty years, the beaches at the east end of Dauphin Island have experienced some of the most dramatic shoreline recession seen in the United States (Douglass et al., 1999). While beach and dune nourishment would not eliminate shoreline loss or reduce the shoreline recession rates, it would reduce loss of existing landward beach, dune, and maritime forest habitats under rising sea levels. Under low SLC and moderate storm conditions (i.e., ST2SL1), the measure is estimated to maintain sufficient dune and beach elevation and width to prevent projected losses of over 40 acres of existing beach, dune, and woody vegetation when compared to the no-action case. At 10 years, it is estimated that over 70% of the fill volume would be transported primarily westward out of the project footprint requiring nourishments on an estimated average 7-year interval to maintain maximum benefits over a 50-year project life. Under high SLC rates and storm conditions (i.e., ST3SL3), less than 30% of the east end measure's fill is estimated to remain within the project footprint after 5 years indicating the measure is highly sensitive to sea levels and storm intensity, with reduced life expectancy of the fill by more than 50%. Despite the higher volume loss, the measure is estimated to prevent losses of over 50 acres of existing beach, dune, woody vegetation, and freshwater lakes and ponds under the simulated higher rates of SLC and storms when compared to the no-action case. To maintain benefits this measure would require adaptive management measures of increased dune and berm height that would result in increased volume needs should SLC at the higher rates of documented scientific projections.

Cost: The estimates for initial construction costs range from $28.2 to $35.2 million, depending on the borrow source used (i.e., Mobile ebb tidal shoal, Petit Bois Pass relic sand deposits, or upland sources along the Alabama-Tombigbee River). To maintain maximum benefits, nourishments would be needed on an estimated 7-year average cycles. Estimates of total present value cost for nourishments over a 20-year and 50-year project life-cycle (i.e., future O&M costs) are presented in Table 8. Differences in O&M costs within the assumed project life-cycles are dependent on the borrow source used. The summary of costs for this restoration measure to include MAM are provided in Table 8 below and further details are provided in Appendix K.

Table 8. Present Value Costs for the East End Beach and Dune Restoration Measure.

Borrow Source Options	**Initial Construction Cost ($ million)**	**20-Year O&M Costs ($ million)**	**50-Year O&M Costs ($ million)**
Option 1 – Mobile Ebb Tidal Shoal	$28.2	-	-
Option 2 – Petit Bois Pass Relic Sand Deposits	$29.8	-	-
Option 3 – Alabama-Tombigbee River Sand	$35.2	-	-
Option 1 – Mobile Harbor Bar Channel	-	$5.8	$23.8
Option 2 - Petit Bois Pass Relic Sand Deposits	-	$5.8	$23.8
Option 3 – Alabama-Tombigbee River Sand	-	$7.9	$32.5
Monitoring and Adaptive Management (*3% of initial project costs*)	$0.9 - $1.1	-	-

Utility Score: The utility score for all the options was 301.1.

3.6.2.2.2. West End Beach and Dune Restoration (No Buyouts)

Description: The West End Beach and Dune Restoration measure with no buyouts would restore vital beach and dune habitat that has been extensively lost along the west end of Dauphin Island, Alabama over the past three decades. The western portion of the island is highly susceptible to storm impacts due to its low elevation, narrow width, lack of dune features, and no shielding from Pelican Island or existence of maritime forest that are found naturally on the east end (CP&E and SCE, 2011). This segment is highly susceptible to overwash and loss of sand across the island, especially in regions that lack a near continuous herbaceous dune system, which are naturally found along the undeveloped regions of the island to the west of Katrina Cut as documented in (Enwright et. al, 2015). These breaks in the dunes and vegetative barrier flats provide regions where sand from the Gulf shoreline is transferred onto and across the island into the adjacent Mississippi Sound during energetic overtopping storm events.

While no extensive existing manmade or natural and nature-based coastal storm risk management measures are found along the western developed portions of island today, there are documented historic attempts at abating the Gulf shoreline loss and frequent inundation. These efforts include two Federal Emergency Management Agency (FEMA) emergency berms that were constructed in 2000 and 2007 following Hurricane Georges in 1998 and Hurricanes Ivan and Katrina in 2004 and 2005. In addition, two shore parallel sand dunes were placed along the shoreline and Bienville Boulevard right-of-way in 2010 in response to the Deepwater Horizon oil spill. Outside of these efforts, home owners on the far western Gulf shoreline have constructed bulkheads in an attempt to reduce the erosion of their property and undermining their homes. These bulkheads have been exposed overtime and currently act as groin features, trapping sand on their updrift side with shoreline offsets on the downdrift side.

The West End Beach and Dune Restoration (No Buyouts) measure generally follows the recommended design laid out in the 2011 Town of Dauphin Island Beach and Barrier Island Restoration Project. It consists of the placement of an estimated 4.6 million cubic yards of sand along the shoreline at a natural berm elevation of approximately +5.5 feet NAVD88 to widen the natural beach for a length of approximately 4 miles along the developed stretch of coast (Figure 24). Additionally, the measure includes construction of a frontal dune at an elevation +12 feet NAVD88 and width of 25 feet, seaward of existing structures. The dunes would be vegetated with approximately 221,000 native dune plants (Bitter Panicum, Sea Oats, and Gulf Bluestem) that are robust in helping stabilize dunes. Roughly 14,000 feet of sand fencing would also be incorporated to further capture windblown sand and promote additional dune growth.

Figure 24. West End Beach and Dune Restoration (No Buyouts) Measure.

The design follows standard coastal engineering principles of including a design section and advanced fill. The design section contains the sand placed to achieve the project purpose and benefits and the advanced fill is the additional sand placed to sustain the beach between nourishment events. Estimates of fill quantities are based on a translated profile from the 2015/2016 USACE and USGS topographic and bathymetric surveys and account for continued averaged background erosion rates of approximately 7.8 feet per year based on 2018 USGS mid-term weighted linear regression shoreline change rates (1998–2015), as documented in Appendix D.

Potential sources of sand for initial construction and nourishments include borrow areas located within the Mobile ebb tidal shoal system and relic sand deposits located just offshore of Petit Bois Pass, as shown in Figure 20. These sources are assumed to be compatible with the native beach materials on the island; therefore, volume estimates for initial construction and future nourishment efforts do not include an overfill factor.

Benefits: The measure provides nearly 200 acres of restored beach and dune habitat along the populated west end of the island. In addition to the direct habitat and species benefits, the measure reduces the potential for island breaching on the eastern side of the Katrina Cut structure and generates secondary benefits of risk reduction to hazards associated with storms and increasing SLC to over 100 acres of beaches, dunes, barrier island flats, and intertidal marsh when compared to the no-action case. These habitats are critical in providing wave dissipation, stabilization to the shoreline, soil retention, and shelter for the marsh and meadows that naturally occur behind the beach and dunes. These habitat systems also provide ecosystem services, such as water purification, carbon sequestration, wildlife habitat, and biodiversity.

Performance: The west end of Dauphin Island has experienced dramatic shoreline recession as well frequent overwash events that have lowered the elevation of the island and resulted in numerous documented breaches. Decadal shoreline change analysis conducted by Smith et al., 2018, as detailed in Appendix D, documents that the west developed segment of the island has been able to generally maintain or increase width, through migration of the barrier footprint northward a few tens of meters as a result of island washover events, during the period between 1997 and 2006. However, from shoreline datasets between 2006 and 2015, the USGS determined that erosion on both the back-barrier and open-ocean shorelines has been reducing the gain from this earlier period. While beach and dune nourishment would not eliminate shoreline loss or reduce the shoreline recession rates, it would reduce loss of landward beach, dune, barrier flats, and intertidal marsh habitats under rising sea levels.

Under low SLC and moderate storm conditions (i.e., ST2SL1), the West End Beach and Dune Restoration (No Buyouts) measure is estimated to maintain sufficient fill volume and sustain dune and beach elevation and width to prevent projected losses of over 100 acres of beach, dune, barrier flats and marsh habitat when compared to the no-action case. At 10 years, it is estimated that roughly 40% of the fill volume would be transported primarily westward out of the project footprint, requiring nourishments on an estimated average 10-year interval to maintain maximum benefits over a 50-year project life. Similar to the future no-action conditions (see Section 3.5.1.2), no breaching occurred on the west end during model simulations of the ST2SL1 scenario.

Under high SLC and storm conditions (i.e., ST3SL3), only 30% of the West End Beach and Dune Restoration (No Buyouts) measure's fill is estimated to remain within the project footprint after 5 years. This indicates the measure is highly sensitive to rates of SLC and storm intensity, with reduced life expectancy of the fill by more than 50%. Breaching was observed during the ST3SL3 model simulation for this restoration measure, but only on the western side of the Katrina Cut structure (breaching occurred on both sides of the structure in the ST3SL3 future no-action simulation). Despite the higher volume loss and island breaching, the measure is estimated to still prevent losses of over 100 acres of beach, dune, barrier flats, and marsh habitat under the simulated higher rates of sea level and storms when compared to the no-action case. This is primarily due to the redistribution of the fill material along the island to expand the various habitat features. To maintain benefits, this measure would require adaptive management measures of increased dune and berm height that would result in increased volume needs should SLC at the higher rates of documented scientific projections.

Cost: The estimates for initial construction costs range from $73.0 to $78.7 million, depending on the borrow source used (i.e., Mobile ebb tidal shoal and/or Petit Bois Pass relic sand deposits). To maintain maximum benefits, nourishments would be needed on an estimated 10-year average cycle. Estimates of total present value cost for nourishments over a 20-year and 50-year project life-cycle (i.e., future O&M costs) are estimated at $51.9 and $148.7 million respectively. The summary of costs for this restoration measure are provided in Table 9 below and further details are provided in Appendix K.

Table 9. Present Value Costs for the West End Beach and Dune Restoration (No Buyouts) Measure

Borrow Source Options	Initial Construction Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)
Option 1 – Mobile Ebb Tidal Shoal and Petit Bois Pass Relic Sand Deposits	$78.7	-	-
Option 2 – Petit Bois Pass Relic Sand Deposits	$73.0	-	-
Option 1 – Petit Bois Pass Relic Sand Deposits	-	$52.0	$148.7
Monitoring and Adaptive Management (*3% of initial project costs*)	$2.2 - $2.4	-	-

Utility Score: The utility score for all the options was 229.2.

3.6.2.2.3. West End Beach and Dune Restoration (with Voluntary Buyouts)

Description: The West End Beach and Dune Restoration (with Voluntary Buyouts) measure is a modification of the West End Beach and Dune Restoration (No Buyouts) measure described in the previous section. The focus of this measure was to evaluate whether or not buying out (voluntary) 225 properties south of Bienville Boulevard and shifting the beach and dune design northward would result in a more resilient island feature. As with the previous measure, this measure would restore vital beach and dune habitat that has been extensively lost along the west end of Dauphin Island, Alabama over the past 3 decades.

This measure seeks to restore island width and dune alignments to conditions near those that were present in the 1950s along the western developed segment of the island based on georeferenced aerial photography from Smith et al. (2018). The removal of structures would allow to naturally set back the dunes away from the receding shoreline and placement in regions observed in aerial photography from the 1950 and 1970s.

The measure would place an estimated 3.1 million cubic yards of sand along the shoreline at a natural berm elevation of approximately +5.5 feet NAVD88 to widen the natural beach for a distance of approximately 4 miles along the developed stretch of coast (Figure 25). Additionally, the measure would include construction of a frontal dune at an elevation +10 feet NAVD88 and a width of 30 feet just south of Bienville Boulevard. The dunes would be vegetated with approximately 231,000 native dune plants (Bitter Panicum, Sea Oats, and Gulf Bluestem) that are robust in helping stabilize dunes. Roughly 14,000 feet of sand fencing would also be incorporated to further capture windblown sand and promote additional dune growth.

Figure 25. West End Beach and Dune Restoration (with Voluntary Buyouts) Measure.

The design follows standard coastal engineering principles of including a design section and advanced fill. The design section contains the sand placed to achieve the project purpose and benefits and the advanced fill is the additional sand placed to sustain the beach between nourishment events. Estimates of fill quantities are based on a translated profile from the 2015/2016 USACE and USGS topographic and bathymetric surveys and account for continued averaged background erosion rates of approximately 7.8 feet per year based on Smith et al. (2018) mid-term weighted linear regression shoreline change rates (1998–2015), as documented in Appendix D.

Potential sources of sand for initial construction and nourishments include borrow areas located within the Mobile ebb tidal shoal system and relic sand deposits located just offshore of Petit Bois Pass, as shown in Figure 20. These sources are assumed to be compatible with the native beach materials on the island; therefore, volume estimates for initial construction and future nourishment efforts do not include an overfill factor.

Benefits: Similar to the benefits of the previous measure (see Section 3.6.2.2.2), the West End Beach and Dune Restoration (with Voluntary Buyouts) measure provides nearly 200 acres of restored beach and dune habitat along the populated west end of the island. Additionally, it reduces the potential for island breaching on the eastern side of the Katrina Cut structure and it provides additional storm damage reduction benefits from the acquisition and removal of 225 residential structures along some of the most vulnerable segments of the island. It also generates secondary benefits of risk reduction to hazards associated with storms and rising seas to over 100 acres of beaches, dunes, barrier island flats, and intertidal marsh when compared to the no-action case. These habitats are critical in providing wave dissipation, stabilization to the shoreline, soil retention, and shelter for the marsh and meadows that naturally occur behind the beach and dunes. These habitat systems also provide ecosystem services, such as water purification, carbon sequestration, wildlife habitat, and biodiversity.

Performance: As discussed previously, the west end of Dauphin Island has experienced dramatic shoreline recession as well a frequent overwash events that have lowered the elevation of the island and resulted in numerous documented island breaches. While beach and dune nourishment would not eliminate shoreline loss or reduce the shoreline recession rates, it would reduce loss of existing landward beach, dune, barrier flats, and intertidal marsh habitats under rising sea levels. Under low SLC and moderate storm conditions (i.e., ST2SL1), the measure is estimated to maintain sufficient fill volume and sustain dune and beach elevation and width to prevent projected losses of over 84 acres of beach, dune, barrier flats, and marsh habitat when compared to the no-action case. At 10 years, it is estimated that roughly 40% of the fill volume would be transported primarily westward out of the project footprint requiring nourishments on an estimated average 10-year interval to maintain maximum benefits over a 50-year project life.

Under high sea level rates and storm conditions (i.e., ST3SL3), less than 10% of the west end measure's fill is estimated to remain within the project footprint after 5 years, indicating the measure is highly sensitive to rates of sea level and storm intensity, with reduced life expectancy of the fill by more than 50%. Despite the higher fill volume loss from the template, the measure is estimated to prevent losses of over 100 acres of beach, dune, barrier flats and marsh habitat compared to the future no-action case under the simulated higher rates of sea level and storms. This is primarily due to the redistribution of the fill material along the island to expand the various habitat features. To maintain benefits this measure would require adaptive management measures of increased dune and berm height that would result in increased volume needs should SLC at the higher rates of documented scientific projections.

In contrast to the previous measure (i.e., West End Beach and Dune Restoration without Buyouts), this measure does not perform substantially different with respect to the prevention of habitat acreage loss but would require much higher initial costs associated with the voluntary acquisitions of the 225 residential properties located in the project footprint.

Cost: The estimates for initial construction costs range from \$52.7 to \$57.5 million, depending on the borrow source used (i.e., Mobile ebb tidal shoal and/or Petit Bois Pass relic sand deposits). The purchase of the 225 residential properties adds an additional \$90.2 million on to each option. To maintain maximum benefits, nourishments would be needed on an estimated 10-year average cycle. Estimates of total present value cost for nourishments over a 20-year and 50-year project life-cycle (i.e., future O&M costs) are estimated at \$52.0 and \$148.5 million respectively. The summary of costs for this restoration measure are provided in Table 10 and further details are provided in Appendix K.

Table 10. Present Value Costs for the West End Beach and Dune Restoration (with Voluntary Buyouts) Measure.

Borrow Source Options	Initial Construction Cost ($ million)	Real Estate Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)
Option 1 – Mobile Ebb Tidal Shoal and Petit Bois Pass Relic Sand Deposits	$57.5	$90.2	-	-
Option 2 – Petit Bois Pass Relic Sand Deposits	$52.7	$90.2	-	-
Option 1 – Petit Bois Pass Relic Sand Deposits	-	-	$52.0	$148.5
Monitoring and Adaptive Management (*3% of initial project costs*)	$1.6 - $1.7	-	-	-

Utility Score: The utility score for all the options was 213.4.

3.6.2.2.4. West End and Katrina Cut Beach and Dune Restoration (with Voluntary Buyouts)

Description: The West End and Katrina Cut Beach and Dune Restoration (with Voluntary Buyouts) measure is a modification of West End Beach and Dune Restoration (with Voluntary Buyouts) measure described previously in Section 3.6.2.2.3. This measure would restore vital beach and dune habitat that has been extensively lost along the west end of Dauphin Island over the past 3 decades. The intent of extending the restoration footprint west of Katrina Cut was to determine any performance changes to the Katrina Cut rubble mound structure, as well as, to evaluate reduced breaching potential along the west side of the structure that was still observed in the other west end measures simulated.

This measure seeks to restore island width and dune alignments to conditions near those that were present in the 1950s along the western developed segment of the island eastward roughly 4,000 feet westward. The removal of structures would allow the ability to set the dunes back away from the receding shoreline and placement in regions observed in aerial photography from the 1950 and 1970s.

The measure would place an estimated 7.9 million cubic yards of sand along the shoreline at a natural berm elevation of approximately +5.5 feet NAVD88 to widen the natural beach approximately 6 miles along west end (Figure 26). Additionally, the measure would include construction of a frontal dune at an elevation of +10 feet NAVD88 and a width of 30 feet. The dune would be located just seaward of Bienville Boulevard and the Katrina Cut structure where it would ultimately tie into the natural near continuous herbaceous dune system to the west. The dunes would be vegetated with approximately 358,600 native dune plants (Bitter Panicum, Sea Oats, and Gulf Bluestem) that are robust in helping stabilize dunes. In addition, roughly 21,700 feet of sand fencing would be incorporated to further capture windblown sand and promote additional dune growth.

Figure 26. West End and Katrina Cut Beach and Dune Restoration (with Voluntary Buyouts) Measure.

The design follows standard coastal engineering principles of including a design section and advanced fill. The design section contains the sand placed to achieve the project purpose and benefits and the advanced fill is the additional sand placed to sustain the beach between nourishment events. Estimates of fill quantities are based on a translated profile from the 2015/2016 USACE and USGS topographic and bathymetric surveys and account for continued averaged background erosion rates of 7.8 feet per year based on Smith et al. (2018) mid-term weighted linear regression shoreline change rates (1998–2015), as documented in Appendix D.

Potential sources of sand for initial construction and nourishments include borrow areas located within the Mobile ebb tidal shoal system and relic sand deposits located just offshore of Petit Bois Pass (Figure 20). These sources are assumed to be compatible with the native beach materials on the island; therefore, volume estimates for initial construction and future nourishment efforts do not include an overfill factor.

Benefits: The measure provides nearly 450 acres of restored beach and dune habitat along the populated west end of the island and reduces the potential for island breaching on the eastern and western sides of the Katrina Cut structure. Additional benefits include increase structure reliability and reduced overtopping and wave transmission across the Katerina Cut rubble mound structure. The measure also provides storm damage reduction benefits through the acquisition and removal of 225 residential structures along some of the most vulnerable segments of the island and generates secondary benefits of risk reduction to hazards associated with storms and rising seas to over 280 acres of beaches, dunes, barrier island flats, and intertidal marsh as compared to the no-action case. These habitats are critical in providing wave dissipation, stabilization to the shoreline, soil retention, and shelter for the marsh and meadows that naturally occur behind the beach and dunes. These habitat systems also provide ecosystem services, such as water purification, carbon sequestration, wildlife habitat, and biodiversity.

Performance: As discussed previously in Sections 3.6.2.2.2 and 3.6.2.2.3, the west end of Dauphin Island has experienced dramatic shoreline recession and frequent overwash events that have lowered the elevation of the island and resulted in numerous documented breaches. While beach and dune nourishment would not eliminate shoreline loss or reduce the shoreline recession rates, it would reduce loss of existing landward beach, dune, barrier flats, and intertidal marsh habitats under rising sea levels. Under low SLC and moderate storm conditions (i.e., ST2SL1), the measure is estimated to maintain sufficient fill volume and sustain dune and beach elevation and width to prevent projected losses of over 280 acres of beach, dune, barrier flats and marsh habitat when compared to the no-action case. At 10 years, it is estimated that roughly 30% of the fill volume would be transported primarily westward out of the project footprint requiring nourishments on an estimated average 10-year interval to maintain maximum benefits over a 50-year project life. Under high SLC and storm conditions (i.e., ST3SL3), over 40% of the west end measure's fill is estimated to remain within the project footprint after 5 years indicating the measure is sensitive to rates of sea level and storm intensity, with reduced life expectancy of the fill by more than 50%. Despite the higher volume loss, the measure is estimated to prevent losses of roughly 260 acres of beach, dune, barrier flats and marsh habitat as well as an additional 80 acres of prevented loss to intertidal beach and flats under the simulated higher rates of sea level and storms when compared to the no-action case. This is primarily due to the redistribution of the fill material along the island to expand the various habitat features. To maintain benefits, this measure would require adaptive management measures of increased dune and berm height that would result in increased volume needs should SLC at the higher rates of documented scientific projections.

Cost: The estimates for initial construction costs range from \$116.2 to \$120.8 million, depending on the borrow source used (i.e., SIBUA-South and/or Petit Bois Pass relic sand deposits). The purchase of the 225 residential properties adds an additional \$90.2 million on to each option. To maintain maximum benefits, nourishments would be needed on an estimated 10-year average cycle. Estimates of total present value cost for nourishments over a 20-year and 50-year project life-cycle (i.e., future O&M costs) are estimated to range from \$84.4 to \$453.0 million dependent on assumed project life-cycle and borrow location. The summary of costs for this restoration measure are provided in Table 11 and further details are provided in Appendix K.

Since the study objective was to restore vital habitats for species affected by the DWH oil spill, the team did not explicitly model a West End and Katrina Cut Beach and Dune Restoration (No Buyouts) measure. However, the performance is expected to be similar between the two measures. The No Buyouts measure would have an increased initial construction cost of approximately 25% and decreased overall cost of approximately \$90 million due to the removal of the costs to acquire the 225 residential properties.

Table 11. Present Value Costs for the West End and Katrina Cut Beach and Dune Restoration (with Voluntary Buyouts) Measure.

Borrow Source Options	Initial Construction Cost ($ million)	Real Estate Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)
Option 1 – SIBUA-South and Petit Bois Pass Relic Sand Deposits	$120.8	$90.2	-	-
Option 2 – Petit Bois Pass Relic Sand Deposits	$116.2	$90.2	-	-
Option 1 – Petit Bois Pass Relic Sand Deposits[1]	-	-	$84.4	$241.2
Option 2 – Alabama-Tombigbee Waterway	-	-	$158.4	$453.0
Monitoring and Adaptive Management (*3% of initial project costs*)	$3.5 - $3.6	-	-	-
	[1]Depending on borrow area options used for initial construction Borrow area Petit Bois Pass may not contain sufficient quantities for nourishment needs over a 50-year life cycle.			

Utility Score: The utility score for all the options was 231.1.

3.6.2.2.5. Katrina Cut Structure Removal

Description: During Hurricane Ivan in 2004, a narrow breach formed in the unpopulated western segment of Dauphin Island approximately a mile and half west of Bienville Boulevard. The area substantially widened to just over a mile during Hurricane Katrina in 2005, with additional widening during Hurricanes Gustav and Ike in 2008. To address concerns of oil migration through the cut following the 2010 DWH oil spill, the Alabama Department of Environmental Management (ADEM) contracted with Thompson Engineering for the design and construction management of a temporary structure across what has become known as Katrina Cut to protect the Mississippi Sound. Construction of a rubble mound structure started in 2010 with final closure completed in April 2011. According to permit files, the structure was built with a sand-filled geotextile core armored by Alabama Department of Transportation (ALDOT) Class 5 riprap and supported by a structural geogrid. The constructed crest elevation of the armor layer was +7 feet NAVD88 with a crest width of approximately 20 feet and side slopes of 1 vertical and 2 horizontal (IV:2H). Field inspections and surveys conducted by the USACE, Mobile District in 2016 confirmed that structural damage has occurred over time at several locations including structure lowering along multiple reaches to include areas of the structure over existing pipeline infrastructure. Life-cycle structural response modeling conducted by Gonzalez et al. (2020), as detailed in Appendix G, confirmed that the structure is under-designed for the hydrodynamic conditions expected at the site, which leaves it susceptible to further structural damage and breaching with intense storms and rising seas. The analysis further determined that the steady accumulation of sand in front of the structure has played a significant role in dissipating wave energy and protecting the structure. Morphologic change modeling performed by the USGS, as detailed in Appendix F, indicated that sand would continue to exist in front of the structure under lower sea levels and average storms conditions (ST2SL1); however, the modeling predicted breaching of the island on either side of the structure and loss of beach with increased storms and higher sea levels, leaving the structure vulnerable.

The intent of the Katrina Cut Structure Removal measure was to determine if removal of the structure altered (in a positive or negative way) future island evolution and the likelihood of future island breaching. The proposed measure would involve the excavation of an estimated 230,000 tons of ALDOT Class 5 riprap and grade A stone along approximately 7,300 feet of the island's north shoreline (Figure 27). This rock could be sold or leveraged in use with other restoration efforts that require reef structures in the area.

Figure 27. Katrina Cut Structure Removal Measure.

Benefits: Removal of the Katrina Cut structural would restore 27 acres of back-barrier flats and nearshore tidal areas including intertidal beach and flats, which are vital piping plover critical habitat elements that have been lost along the west end of the island due primarily to development and island erosion, including breaching. The measure would slightly reduce the breaching potential on adjacent public and private lands, but would not eliminate all breaching potential in this location. While breaching occurs, it is a natural process for which several studies have suggested play an important role in maintaining barrier island width (Kraft, 1971, Kraft et. al, 1979, Smith et al., 2018). To investigate this further, the USGS conducted morphological modeling sensitivity assessments, as documented in Appendix F, using a sand berm only option in the footprint of the current structure. Results indicate that an approximately 3.5 km wide breach could occur in the Katrina Cut area under the higher storm and SLC scenario (i.e., ST3SL3) with the sand berm only option (Mickey et al., 2020). Compared to the no-action case, the simulated breaching is located in the region where the structure would be removed. This would allow for more deposition in the back-bay regions behind the structure, which has been documented in scientific literature to add to the sustainability of barrier islands.

Performance: The measure is simulated to perform similar to the no-action case in which sand accumulation and no significant breaching is expected during the lower sea level change and average storms events (ST2SL1). Under the higher rates of storminess and SLC (i.e., ST3SL3), breaching occurs in the center of the removed structure (instead of on the eastern and western ends); however, no significant differences in land losses were observed between the two scenarios. In summary, there is no real difference in island breaching potential by removing the structure but there are potential habitat benefits due to future deposition of material in the lee of the structure.

Cost: The initial construction cost estimate for this measure is $7.7 million and is estimated to require no maintenance under low sea level and average storm conditions (e.g., ST2SL1). Under higher storm intensity and frequency with rising seas (e.g., ST3SL3), the area is susceptible to breaching, which will drive future decisions as to whether to allow the area to naturally heal or enact measures that would artificially close the breach in an effort to balance impacts and benefits to aquatic habitats such as oyster reefs and seagrasses. The summary of costs for this restoration measure are provided in Table 12 and further details are provided in Appendix K.

Table 12. Present Value Costs for the Katrina Cut Structure Measure.

Borrow Source Options	Initial Construction Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)
Structure Removal	$7.7	-	-
Monitoring and Adaptive Management (*3% of initial project costs*)	$0.2	-	-

Utility Score: The utility score for this measure was 195.9.

3.6.2.3. Back-Barrier and Marsh Restoration Measures

The general intent of these natural and nature based restoration measures was to determine if back-barrier and marsh restoration actions could be viably created and sustained to enhance the important ecosystems and diverse habitats supported by these areas. These measures can also serve as buffers to inland habitats during higher frequency, less intense coastal storm events. Descriptions of the various measures, as well as their benefits, performance, cost, and utility score are described in the following sections.

3.6.2.3.1. 2010 Borrow Pits Restoration

Description: This measure consists of filling borrow pits located on the north side of Dauphin Island that were excavated during the 2010 DWH oil spill along the developed segment of the west end. The sand was used to construct two sand dunes, referred to as berms, along the island. One dune ran shore-parallel at the water's edge and the other ran parallel to Bienville Boulevard. These dunes were intended to act as barriers to the oil that might come ashore with the intention that the Town could remove oil from the constructed dunes much easier than from the natural beach and back-barrier habitats.

This measure would restore approximately 31 acres of back-barrier flats by filling existing holes excavated from various private properties along the north side of the island with an estimated 285,000 cubic yards of material (Figure 28). No permit records or surveys existed that could be used to estimate the exact quantity or depth that the material was excavated; therefore, quantities were estimated based on USACE 2016 topographic and bathymetric LiDAR surveys with an assumed maximum excavation depth of 10 feet in the areas with no survey coverage.

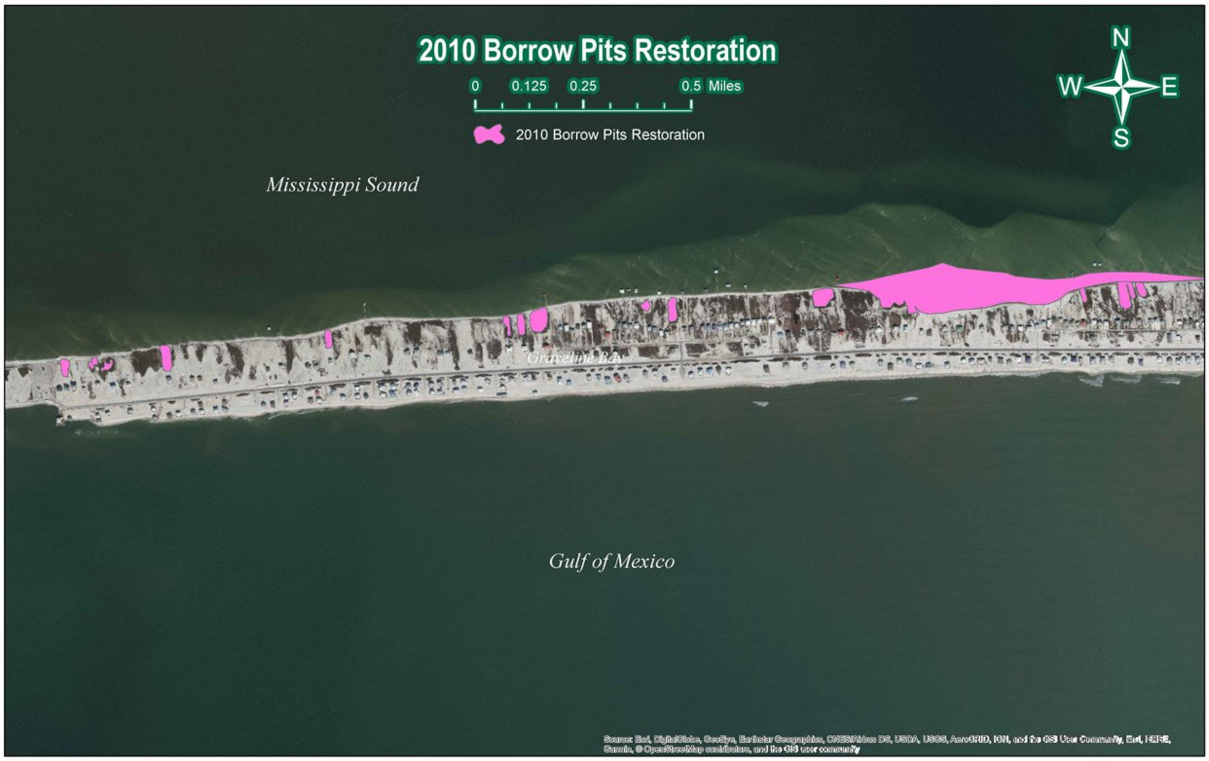


Figure 28. 2010 Borrow Pit Restoration Measure.

Potential sources of sand for initial construction and nourishments include the beneficial use of dredged material from the Dauphin Island Village Channel or excavated material from approved upland areas truck-hauled to the site (Figure 29). These sources are assumed to be compatible with the native beach materials on the island; therefore, volume estimates for initial construction and future nourishment efforts do not include an overfill factor.

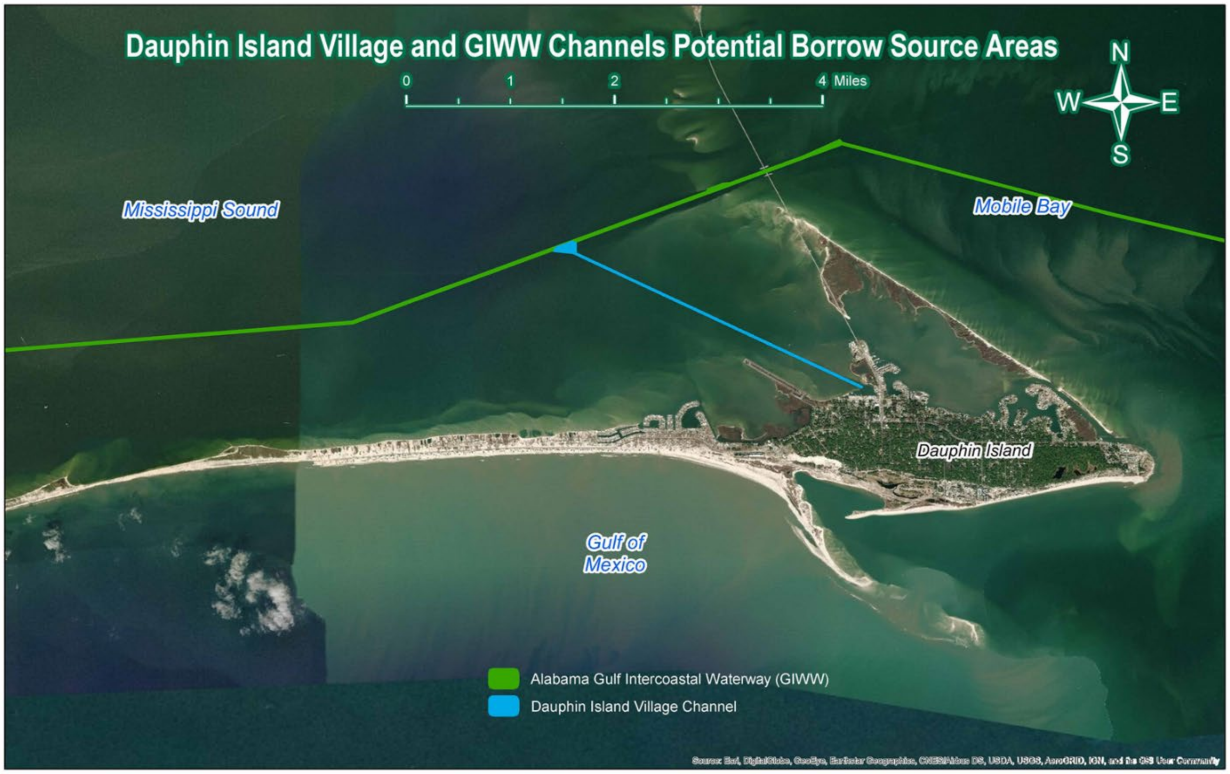


Figure 29. Dauphin Island Village Channel and GIWW Borrow Sources.

Benefits: Island elevation and width are critical to overall barrier island stability, thus restoring back-bay regions dredged during the DWH oil spill is a vital component to reducing the vulnerably of island to lowering and/or breaching along the developed west end. USGS geomorphic and habitat modeling that simulated higher storm and sea level (ST3SL3) conditions indicated island lowering across the entire island in the region of the eastern most dug pits over the 10-year simulation. Simulations conducted with rising seas and intense storms indicate this area converts from beach, dune, and barrier flats to intertidal beach and intertidal flats. In addition, restoration of the near shore areas and island shoreline provides for increased habitat area for back-barrier meadow and wetlands and provide a platform for intertidal marsh migration with rising sea levels.

Performance: Under low SLC and moderate storm conditions (i.e., ST2SL1), the measure is estimated to maintain sufficient fill volume to sustain back-barrier elevation and width within the majority of the 31 areas of restored intertidal and barrier flats. Under high SLC and storm conditions (i.e., ST3SL3), much of these restored barrier flats are convert to intertidal marsh with rising sea levels. Based on these finding no maintenance of this measure was deemed necessary.

Cost: The estimates for construction costs range from $5.1 to $6.4 million, depending on the borrow source used (i.e., Dauphin Island Village Channel or upland source). No long-term maintenance cost outside of 3 percent total project costs for monitoring and adaptive management are included. The summary of costs for this restoration measure are provided in Table 13 and further details are provided in Appendix K.

Table 13. Present Value Costs for the 2010 Borrow Pits Restoration Measure

Borrow Source Options	Initial Construction Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)
Option 1 Dauphin Island Village Channel	$5.2	-	-
Option 2 Upland Source	$6.4	-	-
Monitoring and Adaptive Management (3% of initial project costs)	$0.2	-	-

Utility Score: The utility score for all the options was 206.8.

3.6.2.3.2. Marsh Habitat Restoration Behind Katrina Cut

Description: The Marsh Habitat Restoration Behind Katrina Cut measure would restore back-bay habitat behind the structure with intertidal marsh, which has been lost along the leeside of Dauphin Island. Marshes are important ecosystems found along Dauphin Island, Alabama. These ecosystems provide not only diverse habitat, but also can buffer the island and inland habitats during higher frequency less intense coastal storm events. Eroding shorelines and development along the island in the 1950s and 1960s have resulted in significant losses of saltwater marsh habitat along in the back-bay regions.

The Katrina Cut marsh measure would restore approximately 75 acres of intertidal marsh and tidal flats along the lee side of the Katrina cut structure (Figure 30). The area would be filled with an estimated 1.1 million cubic yards of sand and planted with approximately 1.6 million marsh plant species (Juncus roemarianus and Spartina alterniflora) that are native to the back-bay marsh systems.

Potential sources of sand for initial construction include relic sand deposits located just offshore of Petit Bois Pass and upland sources located within dredge material sites along the Alabama-Tombigbee river system (Figure 20 and Figure 21). These sources are assumed to be acceptable for marsh restoration.

Figure 30. Marsh Habitat Restoration behind Katrina Cut.

Benefits: Intertidal marshes provide numerous important ecosystem services including storm surge reduction, wave attenuation, erosion control to the mainland, habitat for fish and wildlife, carbon sequestration, water catchment and purification, recreation, and tourism (Barbier et al., 2011, Feagin et al., 2010, Sallenger, 2000). In addition, based on findings in the life structural response modeling (Appendix G), marsh behind the structure reduces potential lee side damage to the rubble mound structure during overtopping events.

Performance: Habitat assessments and modeling conducted by the USGS assumed intertidal marsh tended to keep pace with sea level for habitat predictions for scenarios with the intermediate curve, whereas intertidal marsh was often converted to intertidal flat or open water for habitat predictions for scenarios with the high SLC curve (see Section 3.5.4 for additional details on this assessment). Under low SLC and moderate storm conditions (i.e., ST2SL1), the measure is estimated to maintain sufficient fill volume to sustain marsh elevation and width within the majority of the 75 acres of restored marsh. The modeling results, however, indicated that areas restored under the marsh restoration measure were converted to intertidal flat under the scenario with faster sea level increases, which indicates that regular nourishment may be necessary to maintain marsh restoration areas, especially if storm frequency is low and overwash depth is low (i.e., minimal elevation gain through sedimentation from overwash). Based on the measure's performance under the lower rates of SLC and moderate storm conditions, no maintenance was assumed for this measure. However, monitoring and adaptive management would be recommended to monitor SLC and marsh accretion rates.

Cost: The initial construction cost estimate for this measure range between $28.5 and $41.2 million depending on the source of fill material. No long-term maintenance cost outside of 3 percent total project costs for monitoring and adaptive management are included. The summary of costs for this restoration measure are provided in Table 14 and further details are provided in Appendix K.

Table 14. Present Value Costs for the Marsh Habitat Restoration Behind Katrina Cut Measure

Borrow Source Options	Initial Construction Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)
Option 1 – Petit Bois Pass	$28.5	-	-
Option 2 – Alabama-Tombigbee Waterway	$41.2	-	-
Option 3 – Upland sources	$35.9	-	-
Adaptive Management and Monitoring (*3% of initial project costs*)	$1.1	-	-

Utility Score: The utility score for all the options ranged from 214.8 to 224.8.

3.6.2.3.3. Aloe Bay Beneficial Use Marsh Restoration

Description: The Aloe Bay Beneficial Use Marsh Restoration measure would restore intertidal marsh that has been lost along the leeside of Dauphin, Island within Aloe Bay. Marshes are important ecosystems found along Dauphin Island, Alabama. These ecosystems provide not only diverse habitat but can also buffer the island and inland habitats during higher frequency less intense coastal storm events. Eroding shorelines and development along the island in the 1950s and 1960s have resulted in significant losses of saltwater marsh habitat along in the back-bay regions.

This measure would restore approximately 6 acres of intertidal marsh. The area would be filled with an estimated 34,000 cubic yards of sediment and planted with approximately 105,000 Juncus roemarianus and Spartina alterniflora plant species that are native to the back-bay marsh systems (Figure 31). In addition, the measure would incorporate approximately 1,900 linear feet of low crested rubble mound or a bio-engineered breakwater system and a terminal groin at the east end to retain sediment within the marsh construction template. The shore parallel breakwater structures would function to reduce shoreline erosion and wave energy in its lee.

The potential source of sand for initial construction would be material dredged from the Dauphin Island Village Chanel (Figure 29). This source is assumed to have suitable sediments for marsh restoration.

Figure 31. Aloe Bay Beneficial Use Marsh Restoration.

Benefits: Intertidal marshes provide numerous important ecosystem services including storm surge reduction, wave attenuation, erosion control to the mainland, habitat for fish and wildlife, carbon sequestration, water catchment and purification, recreation, and tourism (Barbier et al., 2011; Feagin et al., 2010, Sallenger, 2000).

Performance: Habitat assessments and modeling conducted by Enwright et al., (2020) assumed intertidal marsh tended to keep pace with sea level for habitat predictions for scenarios with the intermediate curve, whereas intertidal marsh was often converted to intertidal flat or open water for habitat predictions for scenarios with the high SLC curve (see Section 3.5.4 for further details on this assessment). Under low SLC and moderate storm conditions (i.e., ST2SL1), the measure is estimated to maintain sufficient fill volume to sustain marsh elevation and width within the majority of the 6 acres of restored marsh. The modeling results, however, indicated that areas restored under the marsh restoration measure were converted to intertidal flat under the scenario with faster sea level increases, which indicates that regular nourishment may be necessary to maintain marsh restoration areas, especially if storm frequency is low and overwash depth is low (i.e., minimal elevation gain through sedimentation from overwash). Based on the measure's performance under the lower rates of SLC and moderate storm conditions no maintenance was assumed for this measure. However, monitoring and adaptive management would be recommended to monitor SLC and marsh accretion rates.

Cost: The initial construction cost estimates for this measure range between \$4.4 and \$5.0 million depending on the material used in the construction of the offshore breakwater. No long-term maintenance cost outside of 3 percent total project costs for monitoring and adaptive management are included. The summary of costs for this restoration measure are provided in Table 15 and further details are provided in Appendix K.

Table 15. Present Value Costs for the Aloe Bay Beneficial Use Marsh Restoration Measure.

Borrow Source Options	Initial Construction Cost (\$ million)	20-Year O&M Costs (\$ million)	50-Year O&M Costs (\$ million)
Option 1 – Low Crested Rubble Mound	\$4.4	-	-
Option 2 – Bioengineered Breakwater System	\$5.0	-	-
Adaptive Management and Monitoring (*3% of initial project costs*)	\$0.15	-	-

Utility Score: The utility score for all the options was 224.8.

3.6.2.3.4. Graveline Bay Marsh Restoration

Description: The Graveline Bay Marsh Restoration measure would restore intertidal marsh that has been lost along the leeside of Dauphin Island within Graveline Bay. Marshes are important ecosystems found along Dauphin Island, Alabama. These ecosystems provide not only diverse habitat, but also can buffer the island and inland habitats during higher frequency less intense coastal storm events. Eroding shorelines and development along the island in the 1950s and 1960s have resulted in significant losses of intertidal marsh habitat along in the back-bay regions. Within Graveline Bay, it is estimated from digitalized shoreline data that as much as 40% of the marsh habitat has been lost since the 1950s.

This measure would restore approximately 25 acres of intertidal marsh. The area would be filled with an estimated 162,000 cubic yards of material and planted with approximately 623,000 marsh plant species (Spartina alterniflora) that are native to the back-bay marsh systems (Figure 32). The potential sources of sand for initial construction include beneficial use of dredge material from the Dauphin Island Village Chanel or the Gulf Intracoastal Waterway (GIWW; Figure 29). The small boat channel in the lee of the Graveline marsh is the assumed source for spray application of sediment over the marshes for future maintenance. This source is assumed to have suitable sediments for marsh restoration.

Figure 32. Graveline Bay Marsh Restoration.

Benefits: Intertidal marsh, provide numerous important ecosystem services including storm surge reduction, wave attenuation, erosion control to the mainland, habitat for fish and wildlife, carbon sequestration, water catchment and purification, recreation, and tourism (Barbier et al., 2011; Feagin et al., 2010; Sallenger, 2000).

Performance: Habitat assessments and modeling conducted by the USGS determined much of the 25 acres of restored intertidal marsh within Graveline Bay would be converted to intertidal flat habitat by year 10 under the low SLC and moderate storm simulation (i.e., ST2SL1). Based on this, maintenance of the entire marsh complex with a hydraulic spray application of dredged sediments of approximately 70,000 cubic yards of sediment was assumed every 10 years. In addition, monitoring and adaptive management would be recommended to monitor SLC and marsh accretion rates and adjust maintenance of the marsh as necessary.

Cost: The initial construction cost estimate for this measure is $6.9 million. To maintain maximum benefits, nourishments would be needed on an estimated 10-year average cycle. Estimates of total present value cost for nourishments over a 50-year project life-cycle (i.e., future O&M costs) is estimated at $50.4 million. The high cost of O&M relative to initial construction is due to the need for spray application of material over the entire marsh platform, not just the newly created marsh, to keep up with SLC. This application method is extensively more expensive than typical hydraulic dredging and placement of material. The summary of costs for this restoration measure are provided in Table 16 and further details are provided in Appendix K.

Table 16. Present Value Costs for the Graveline Bay Marsh Restoration.

Borrow Source Options	Initial Construction Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)
Graveline Bay Marsh Restoration	$5.4	-	-
Maintenance – Spray Application	-	$17.6	$30.9
Adaptive Management and Monitoring (3% of initial project costs)	$0.2	-	-

Utility Score: The utility score for this measure was 209.8.

3.6.2.3.5. West End Back-Barrier Herbaceous Dune Plant Restoration

Description: The intent of the Dauphin Island back barrier herbaceous dune planting measure is to repopulate the back-barrier segment along the developed west end in area where vegetated dunes existed based on georeferenced aerial photography from Smith et al. (2018), from the 1940s, 1950s, and 1970. The overall goal of this measure is plant vegetation along the right-of-way of Bienville Boulevard, where possible, in a scheme that will accumulate sand and promote natural dune rebuilding.

Based on habitat assessments conducted by the USGS, as documented in Appendix I, woody vegetation followed by beach and dunes continue to be some of the highest impacted habitat types under the low sea level and moderate storm conditions (i.e., ST2SL1) along the western portion of the island with predicted average losses of 50% and greater in these habitat types. This measure would vegetate approximately 21 acres with roughly 120,000 native dune plants (Bitter Panicum, Sea Oats, and Gulf Bluestem) that are robust in helping stabilize dunes (Figure 33). In addition, roughly 19,000 feet of sand fencing would be incorporated to further capture windblown sand and promote additional dune growth.

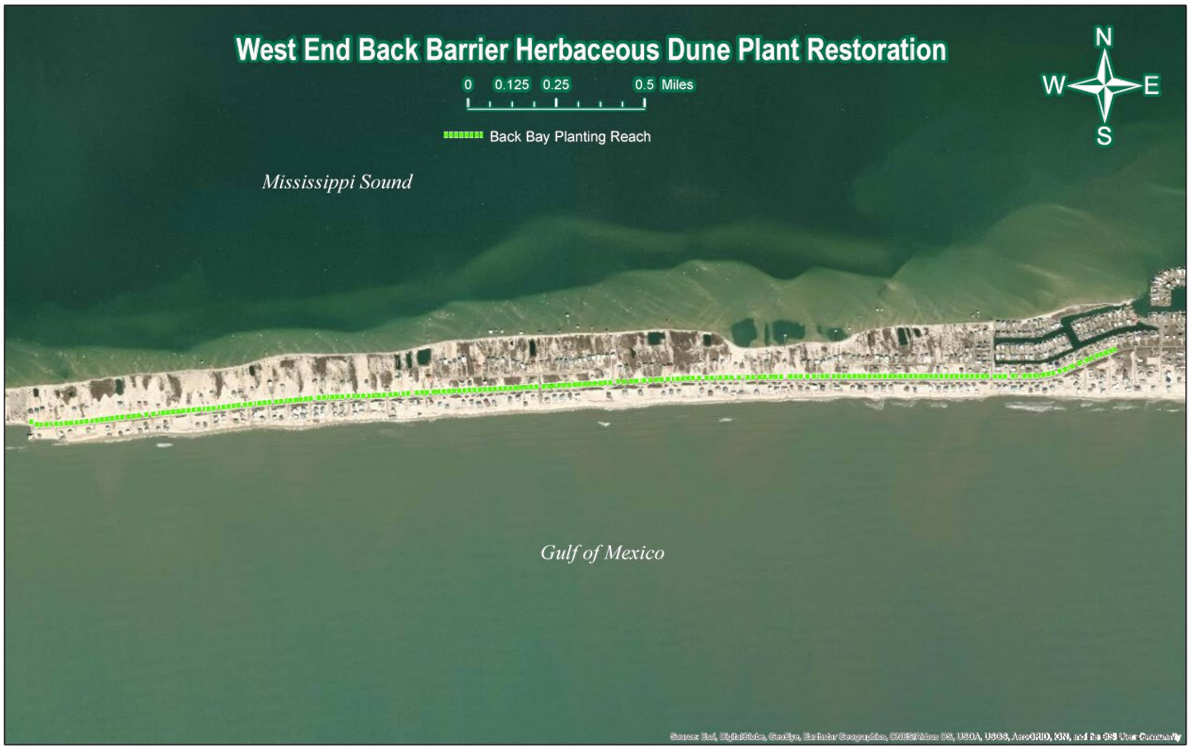


Figure 33. West End Back-Barrier Herbaceous Dune Plant Restoration Measure.

Performance: Since no analysis or modeling tools specifically account for the positive effects of vegetation on dune performance (FHA, 2019), this measure was not incorporated into the morphological or habitat modeling framework. However, in most published studies, dune vegetation substantially decreases dune erosion and retreat rates (Figlus et al., 2014). Dunes with sand fencing and vegetation trap and stabilize sand, leading to increases in dune volume and dune height over time. Bryant et al. (2018) conducted physical modeling of vegetated dunes in the laboratory, which showed that the combination of belowground and aboveground vegetation biomass reduced the loss of dune volume by a factor of three when compared to an unvegetated dune during a wave over washing event.

Benefits: The measure provides 21 acres of restored back-bay herbaceous dune habitat along the west end of the island. In addition to the direct habitat and species benefits, the measure generates secondary benefits of risk reduction to hazards associated with storms and rising seas. Given time the sand fence and vegetation will accumulate sand and begin to rebuild island elevation. These systems are effective at reducing wave runup, overtopping, and overwashing (Gralher et al., 2012, Kim et al., 2016, Kobayashi et al., 2013, Silva et al., 2016), which are hazards that threaten habitat and island resilience.

Costs: The estimates for initial construction costs are $1.5 million. No long-term maintenance cost outside of 3 percent total project costs for monitoring and adaptive management are included. The summary of costs for this restoration measure are provided in Table 17 and further details are provided in Appendix K.

Table 17. Present Value Costs for the West End Backbarrier Herbaceous Dune Plant Restoration.

Borrow Source Options	Initial Construction Cost ($ million)	20-Year O & M Costs ($ million)	50-Year O & M Costs ($ million)
West End Backbarrier Herbaceous Dune Plant Restoration	$1.5	-	-
Adaptive Management and Monitoring (*3% of initial project costs*)	$0.1	-	-

Utility Score: The utility score for this measure was 182.0.

3.6.2.4. Land Acquisition Measures

The Interim Report identified numerous land acquisitions intended to serve as important habitat conservation and protection actions. The project team determined that 11 of the land acquisitions identified in the Interim Report should be further evaluated as potential restoration measures to be considered individually or in combination with other measures. These 11 land acquisitions are all primarily identified for their conservation value. The Interim Report grouped each of the interim projects into one of three groups based on the results of evaluations conducted by a multi-agency support panel. "Group 1" projects were those projects that most strongly satisfied the evaluation criteria. Land acquisitions identified as "Group 2" projects were less clear in the benefits they would provide. This was generally because these land acquisitions were considered too fragmented to substantially provide a benefit to the ecosystem, or because they were thought to already provide their highest ecological capacity and that was unlikely to change. None of the 11 land acquisitions evaluated in this final report were identified as "Group 3" projects.

A method for further assessing the performance of the individual land acquisitions via a Land Conservation Utility score was developed as part of the structured decision-making alternative assessment tool developed for this study, as described in Section 3.6.3 and Appendix J. The Land Conservation Utility score considers development risk, the scarcity of the predominant habitat on the parcel, the amount of land, and connectivity to other conservation lands to inform an overall score. The higher the overall score the higher the utility of the land acquisition. Descriptions of the land acquisitions, their benefits, cost, and their performance based on their Land Conservation Utility score are provided in the sections below.

3.6.2.4.1. West End Land Acquisition (Interim Project ID #17)

Description: The proposed project consists of the acquisition and conservation of approximately 720 acres west of Katrina Cut (Figure 34). The purpose of this project would be the conservation of this unique habitat and its maintenance as a critical habitat for a variety of birds. This project alone and, in combination, with other similar opportunities on Dauphin Island would maintain a network of quality avian stop habitats for a number of species, including the Federally endangered Piping Plover as well as various species of shorebirds, gulls, terns, and waterfowl. This acquisition was designated a Group 2 project in the Interim Report because the west end is achieving significant environmental benefits in its current state and because of the unknown cost associated with conservation. In addition, development of this area is not imminent because of the status as an Undeveloped Coastal Barrier (Coastal Barrier Resources Act status) and the cost of possible development.

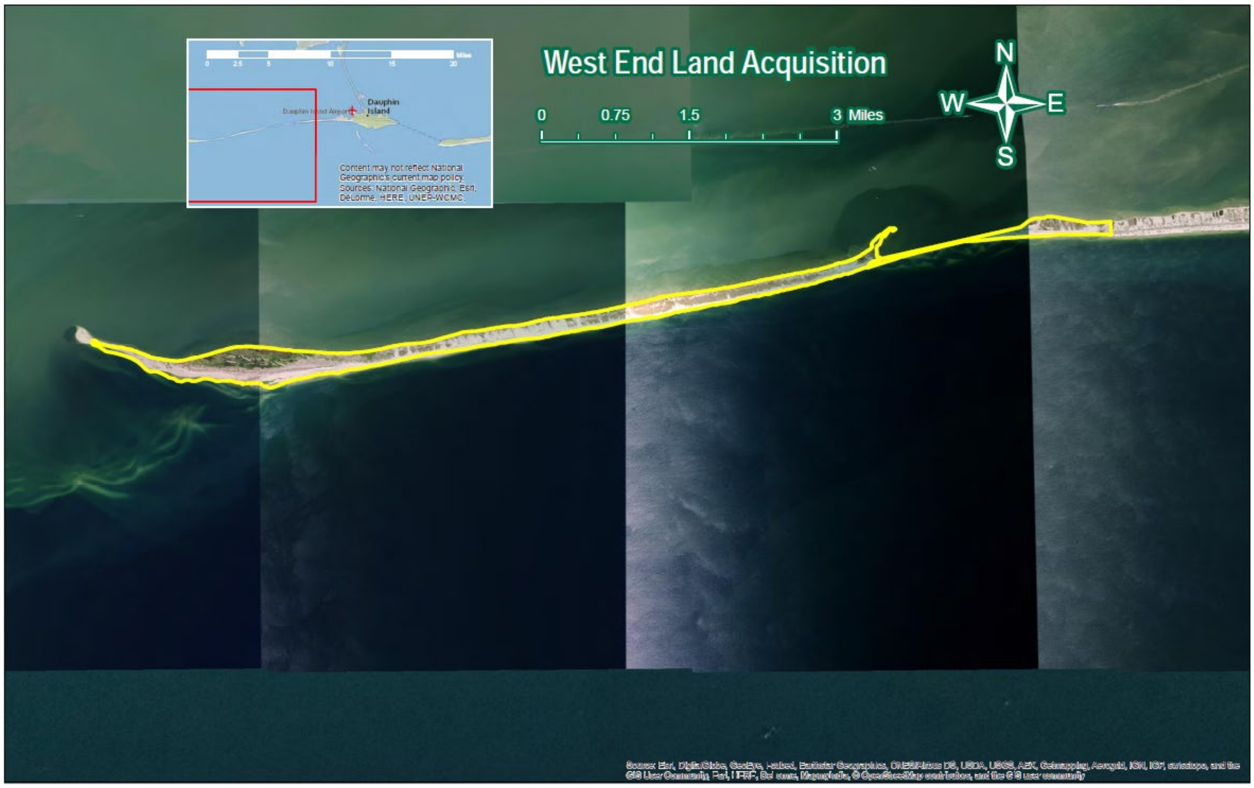


Figure 34. West End Land Acquisition.

Benefits: The undeveloped west end of Dauphin Island has been recognized by the American Bird Conservancy as a Globally Important Bird Area in the Southeast Coastal Plain Bird Conservation Region. The west end is used as a primary staging area during migration of numerous migratory birds and is designated piping plover critical habitat by the United States Fish and Wildlife Service. This approximate 720 acres of undeveloped barrier island contains a variety of habitats including beach, dune, shrub, flats and tidal pools that provide primary constituent elements for wintering piping plover. The beach and dunes are also prime habitat for nesting of various bird species including the Least Tern and Snowy and Wilson's Plover. The entire area provides critical habitat migrants, wading birds, waterfowl, and small vertebrates. The project would also promote the economic value of ecotourism in Dauphin Island, coastal Alabama and the state through involvement in the Alabama Coastal Birding Trail.

Conservation Utility Score: The overall conservation utility score for the West End land acquisition is 100.0.

Cost: The estimated land acquisition cost as submitted by the Mobile Baykeeper in the Alabama Coastal Restoration Portal (https://www.alabamacoastalrestoration.org/Projects), and vetted by USACE real estate staff, is $10 million with an O&M cost of $5,000 per year.

3.6.2.4.2. Mid-Island Land Acquisition and Management Phase I (Interim Project ID #3)

Description: The proposed project consists of the acquisition and conservation of approximately 10 acres of undeveloped beach and dune habitat located west of the public fishing pier (Figure 35) and includes the provision of enhanced controlled public access. This acquisition was considered a Group 1 project in the Interim Report.

Figure 35. Mid-Island Land Acquisition and Management Phase 1.

Benefits: This property serves as a critical wintering area for both resident and migratory avian species and is located directly adjacent to designated critical habitat for Piping Plover. Specifically, the Gulf front property is located south of Bienville Boulevard between the condos located on the east side of the property and Ponce De Leon Court on the west. This acreage is some of the last remaining beach habitat in this area of the island and is vulnerable to disturbance and or development. The management goal for the Gulf-front property is to preserve, protect, and increase the natural habitat and their ecosystem functions.

Conservation Utility Score: The overall conservation utility score for the Mid-Island land acquisition and management Phase I is 23.0.

Cost: The estimated land acquisition cost, as determined by USACE real estate staff, is approximately $2.5 million and there are no estimated O&M costs.

3.6.2.4.3. U.S. Coast Guard Property Acquisition (Interim Project ID #21)

Description: The U.S. Coast Guard (USCG) operated a recreational facility on the southeastern side of Dauphin Island until the housing facilities were destroyed by hurricanes in 2005–2007. The property is no longer needed by the USCG and is in the process of being disposed by the General Services Administration (GSA) Public Building Service. The approximately 7.5-acre parcel (Figure 36) which fronts the Gulf of Mexico is bounded on the east by the Dauphin Island Sea Lab (DISL), on the west by the Dauphin Island Bird Sanctuary, and on the north by the Dauphin Island Park and Beach Board Campground. The DISL is interested in acquiring the site through a public benefit conveyance to use for education and wildlife conservation. This acquisition was considered a Group 2 project in the Interim Report because of the uncertain timing of the GSA process for disposal of excess property.

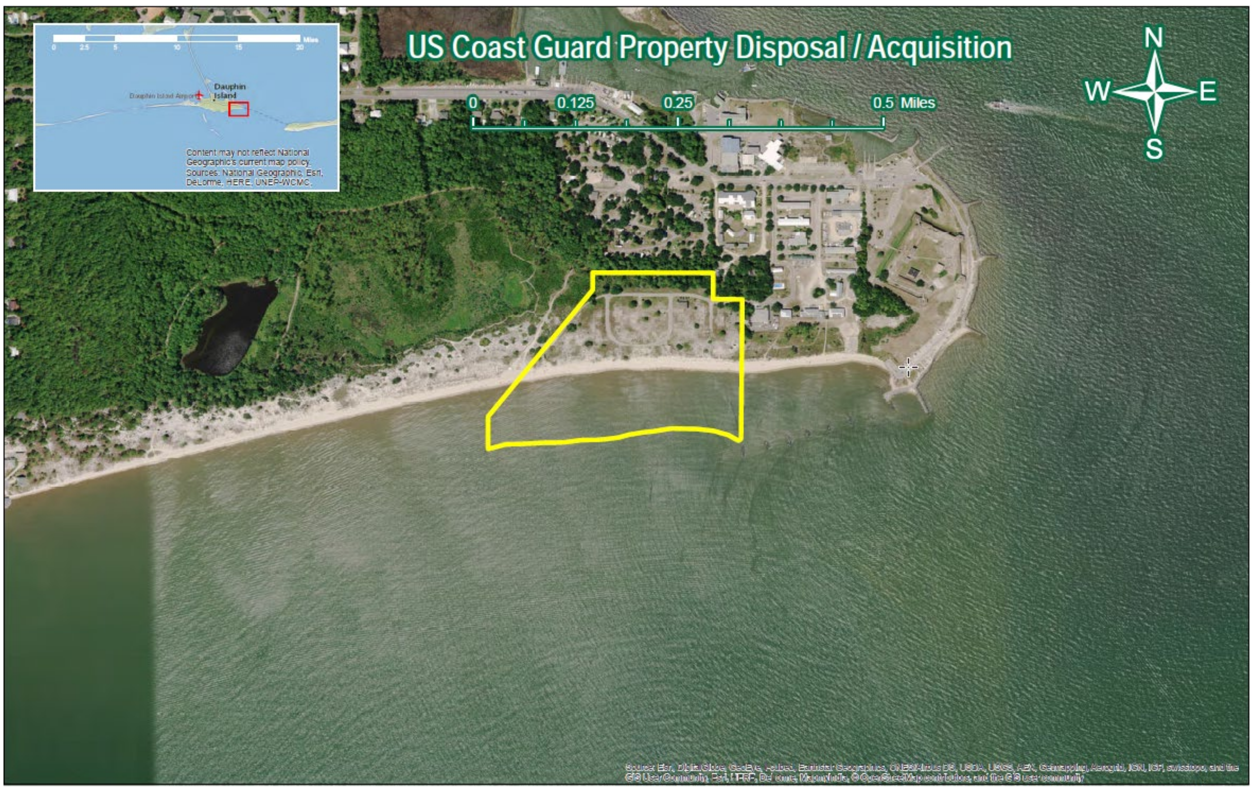


Figure 36. U.S. Coast Guard Property Acquisition Location.

Benefits: Conservation of the 7.5 acres of scrub/shrub, dune, maritime forest, and beach habitats would provide significant benefit to resident avian species, neo-tropical migrants from South America, and small vertebrates. Significant educational benefits would also be gained through the use of the area as an open laboratory supporting the educational mission of the DISL, which includes K–12 and higher education.

Conservation Utility Score: The overall conservation utility score for the USCG property acquisition is 8.7.

Cost: The estimated land acquisition cost, as determined by USACE real estate staff, is $2.5

million and there are no estimated O&M costs.

3.6.2.4.4. Dauphin Island 39 Parcel Property Acquisition: Parcel A – West End (Interim Project ID #22a)

Description: This project consists of the acquisition of approximately 518 acres on the west end of Dauphin Island along the Mississippi Sound as shown in Figure 37. The majority of this acreage is open water within the Mississippi Sound which is devoid of vegetative habitats. The remainder encompasses approximately 87 acres of the north side of the island beginning at St. Stephen Street and extending west to the end of Bienville Boulevard. These areas are characterized as overwash sand abutting residential properties. Some of the areas are vegetated with low dune vegetation and others are ponds created to obtain sand during the DWH oil spill. This acquisition was considered a Group 2 project in the Interim Report because of the uncertainty associated with the benefits that would accrue, above what is currently provided, due to conservation.

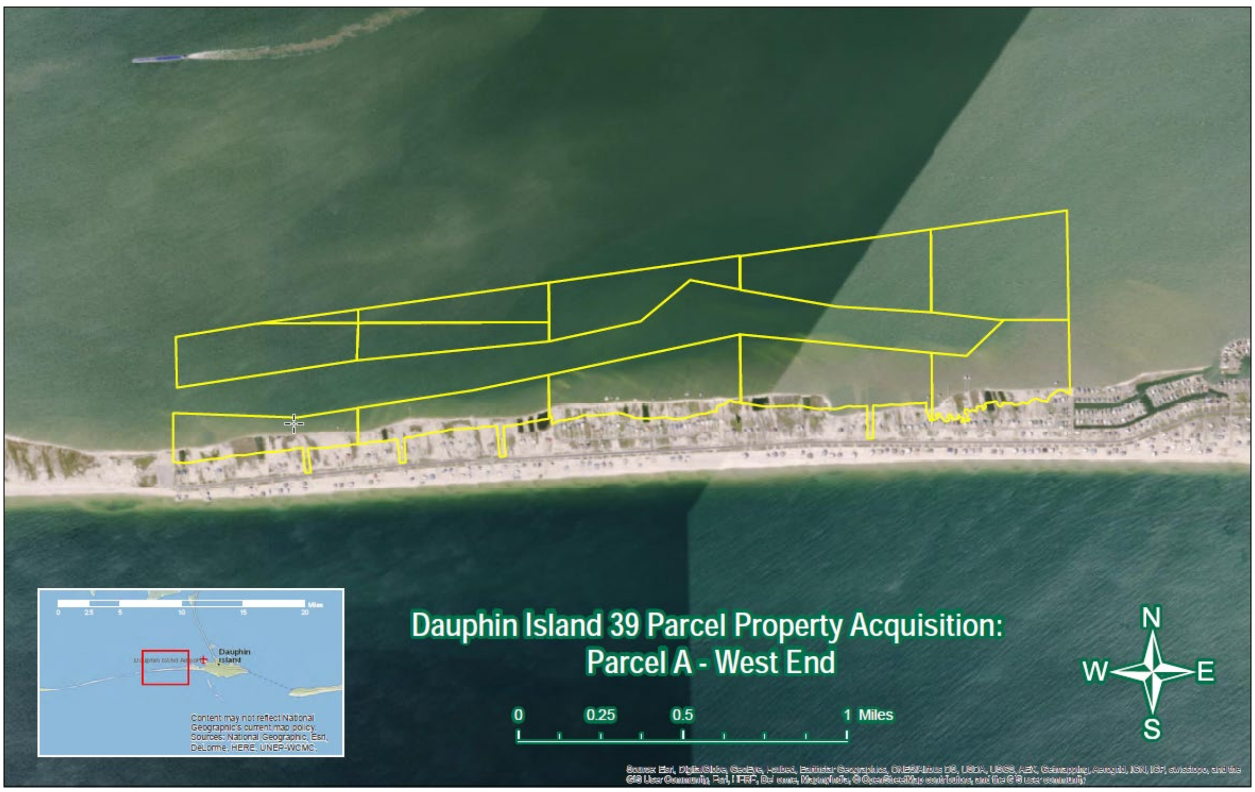


Figure 37. Dauphin Island 39 Parcel Property Acquisition: Parcel A – West End Location.

Benefits: This acquisition is part of a total of 39 parcels proposed for sale representing a broad diversity of significant bottomland, shoreline, wetland, dune, and forested habitat strategically located on Dauphin Island. Many of these properties provide essential habitat for shorebirds including the Semipalmated Sandpiper and the Piping Plover. In addition, many of the areas provide essential habitat for the production and survival of fish, shellfish, and crab. Their conservation for ecological and environmental preservation and use for seafood and tourism applications represents a unique and important opportunity to preserve, protect, and promote

Dauphin Island's unique natural habitat, seafood, and tourism resources.

Conservation Utility Score: The overall conservation utility score for the Dauphin Island 39 parcel property acquisition: parcel A – west end is 104.7.

Cost: The estimated land acquisition cost, as developed by USACE real estate staff, is approximately $900,000 and there are no estimated O&M costs.

3.6.2.4.5. Dauphin Island 39 Parcel Property Acquisition: Parcel B – Graveline Bay (Interim Project ID #22b)

Description: The Graveline Bay acquisition area includes 6 parcels comprising 340 acres of wetland and open water habitat south and west of the southern edge of the Dauphin Island Airport runway to the vicinity of Pineda Street (Figure 38). No residential or commercial properties are included in this area. The eastern and southern property portions contain significant unimpacted intertidal wetlands and intertidal flats that are essential habitat for the production and survival of fish, shellfish, and crabs. In addition, the wetlands provide habitat for wading birds and waterfowl. This acquisition was considered a Group 2 project in the Interim Report because of the uncertainty associated with the benefits that would accrue, above what is currently provided, due to conservation.

Figure 38. Dauphin Island 39 Parcel Property Acquisition: Parcel B – Graveline Bay Location.

Benefits: This acquisition is part of a total of 39 parcels proposed for sale representing a broad diversity of significant bottomland, shoreline, wetland, dune, and forested habitat strategically located on this barrier island. Their conservation for ecological and environmental preservation represents a unique and important opportunity to preserve, protect, and promote Dauphin Island's unique natural habitat and seafood and tourism resources.

Conservation Utility Score: The overall conservation utility score for the Dauphin Island 39 parcel property acquisition: parcel B – Graveline Bay is 142.2.

Cost: The estimated land acquisition cost, as developed by USACE real estate staff, is approximately $400,000 and there are no estimated O&M costs.

3.6.2.4.6. Dauphin Island 39 Parcel Property Acquisition: Parcel C – Aloe Bay (Interim Project ID #22c)

Description: This project consists of the acquisition of approximately 76 acres of shallow open water habitat in the Aloe Bay area of Mississippi Sound adjacent and north east of the Dauphin Island Airport runway (Figure 39). This acquisition was considered a Group 2 project in the Interim Report because of the uncertainty associated with the benefits that would accrue, above what is currently provided, due to conservation.

Figure 39. Dauphin Island 39 Parcel Property Acquisition: Parcel C – Aloe Bay Location.

Benefits: This area serves as habitat for numerous aquatic species including fish, shellfish, and crab.

Conservation Utility Score: The overall conservation utility score for the Dauphin Island 39 parcel property acquisition: parcel C – Aloe Bay is 100.9.

Cost: The estimated land acquisition cost, as developed by USACE real estate staff, is approximately $100,000 and there are no estimated O&M costs.

3.6.2.4.7. Dauphin Island 39 Parcel Property Acquisition: Parcel D – Little Dauphin Island Bay (Interim Project ID #22d)

Description: This project consists of the acquisition of approximately 150 acres of shallow open water habitat in the in Little Dauphin Bay and Mississippi Sound including a portion of the disposal area for maintenance of the federally authorized Government Cut Channel (Figure 40). This portion of the property is maintained against erosion through the routine placement of this material. This acquisition was considered a Group 2 project in the Interim Report because of the uncertainty associated with the benefits that would accrue, above what is currently provided, due to conservation.

Figure 40. Dauphin Island 39 Parcel Property Acquisition: Parcel D – Little Dauphin Island Bay Location.

Benefits: This area serves as habitat for numerous aquatic species including fish, shellfish, and crab.

Conservation Utility Score: The overall conservation utility score for the Dauphin Island 39 parcel property acquisition: parcel D – Little Dauphin Island Bay is 117.4.

Cost: The estimated land acquisition cost, as developed by USACE real estate staff, is approximately $200,000 and there are no estimated O&M costs.

3.6.2.4.8. Dauphin Island 39 Acquisition: Parcel E – East End (Interim Project ID #22e)

Description: This project consist of the acquisition of five separate parcels of undeveloped land on the east end of the island, comprising approximately 4 acres total (Figure 41). Four of the properties are located in the commercial area of the island north of Bienville Blvd. The fifth property is located on the north side of the main dune system in the vicinity of the golf course. This acquisition was considered a Group 2 project in the Interim Report because of concern as to the best use of the four parcels in the commercial area and the uncertainty associated with the benefits that would accrue, above what is currently provided, due to conservation.

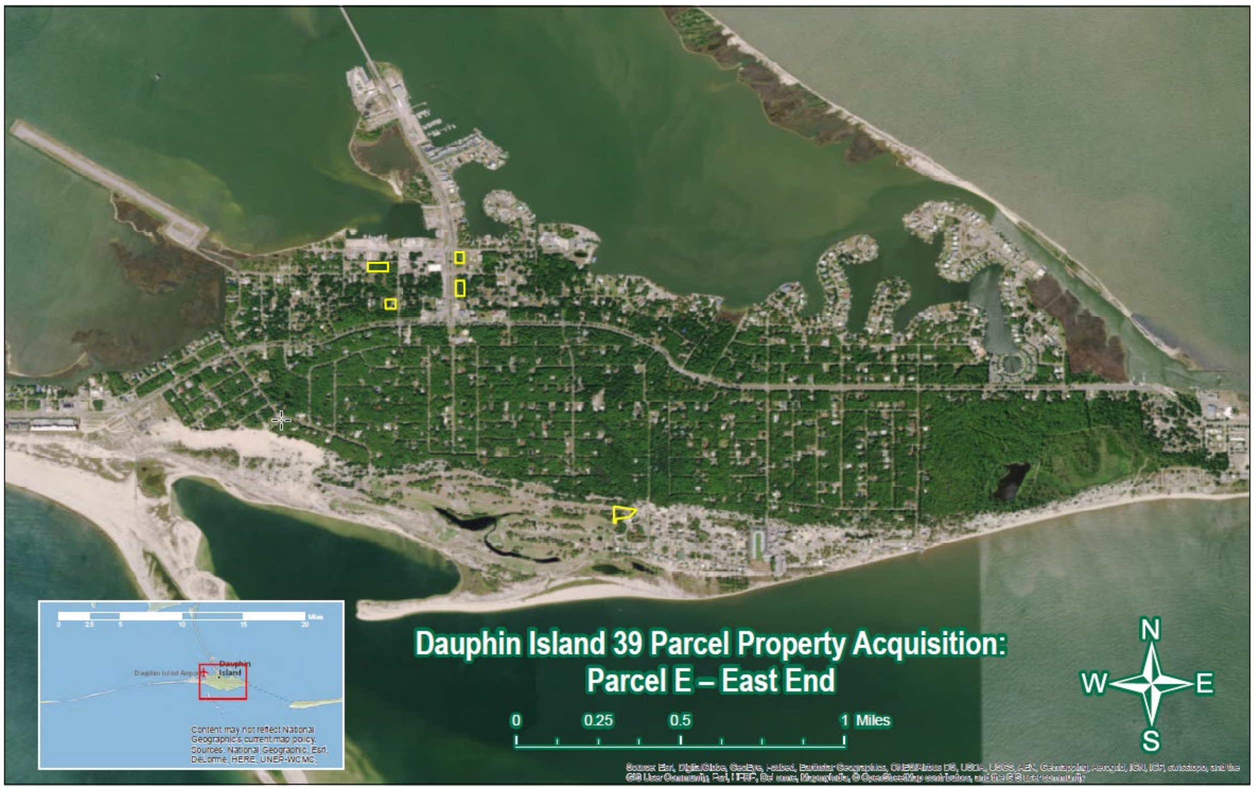


Figure 41. Dauphin Island 39 Parcel Property Acquisition: Parcel E – East End Location.

Benefits: This fifth parcel has the ability to provide habitat to resident and migratory avian species and small vertebrates. The other four parcels are in a commercial area and provide minimal habitat benefits.

Conservation Utility Score: The overall conservation utility score for the Dauphin Island 39 parcel property acquisition: parcel E – East End is 81.5.

Costs: The estimated land acquisition cost, as developed by USACE real estate staff, is approximately $620,000 and there are no estimated O&M costs.

3.6.2.4.9. Tupelo Gum Swamp Land Acquisition (Interim Project ID #18)

Description: The proposed project consists of the acquisition and conservation of up to 10 acres of gum swamp located within the center of the widest part of Dauphin Island. This "Tupelo Gum Swamp" is located between several dead-end roads branching off Iberville Drive and Hernando Street on the widest part of the island south of Bienville Boulevard (Figure 42). Twenty platted lots total approximately 10 acres containing substantial wetlands populated by tupelo gum trees, saw palmetto, and pines interspersed with ponded freshwater wetlands. Since 2001, the Dauphin Island Bird Sanctuary has acquired four of the twenty lots. These remaining lots are vulnerable to developmental of residential structures. This acquisition was considered a Group 1 project in the Interim Report.

Figure 42. Tupelo Gum Swamp Land Acquisition Location.

Benefits: This project would conserve and maintain critical habitat for resident and migratory avian species while providing an ecotourism opportunity through the development of a birding trail along the existing right-of-way. Dauphin Island has been identified by The National Audubon Society as a Globally Important Birding area. At least 348 species have been reported on the island including residents and neo-tropical migrants. The location of the island on the Gulf Flyway and the first/last land mass encountered by migrating species to and from South America make the various habitats on the island critical features in maintaining the existence of a number of avian species.

Conservation Utility Score: The overall conservation utility score for the Tupelo Gum Swamp land acquisition is 92.4.

Cost: The estimated land acquisition cost, as determined by USACE real estate staff, is approximately $700,000 and there are no estimated O&M costs.

3.6.2.4.10. Gorgas Swamp Land Acquisition (Interim Project ID #19)

Description: The proposed project consists of the acquisition and conservation of approximately 10 acres identified as the "Gorgas Swamp" (Figure 43). This swath of wetlands east of the Tupelo Gum Swamp (Project ID #18) is centered on Gen. Gorgas Street between the main dunes and Gen. Gaines Place. Twenty platted lots totaling approximately 10 acres contain substantial wetlands populated predominately by tupelo gum trees. To date, three of the 20 lots have been purchased for conservation by the Dauphin Island Bird Sanctuary. Currently, this area is being destroyed by excessive all-terrain vehicle traffic, which compacts the soil, generating ruts and gullies that serve to drain the water off the surface thus interrupting the hydrologic cycle that is critical to maintenance of this unique habitat. This acquisition was considered a Group 1 project in the Interim Report.

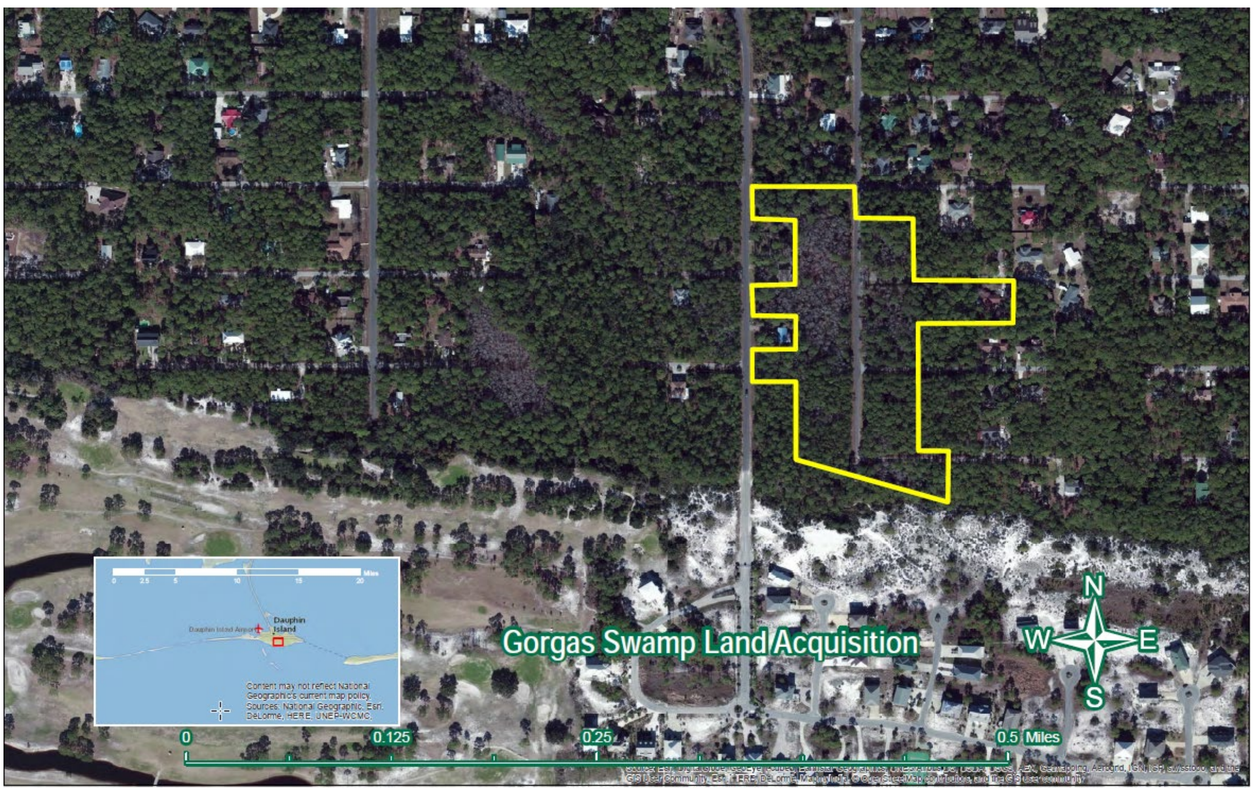


Figure 43. Gorgas Swamp Land Acquisition Location.

Benefits: This project would conserve and maintain critical habitat for resident and migratory avian species while providing an ecotourism opportunity through the development of confined birding trails. Dauphin Island has been identified by The National Audubon Society as a Globally Important Birding area. At least 348 species have been reported on the island including residents and neo-tropical migrants. The location of the island on the Gulf Flyway and the first/last land mass encountered by migrating species to and from South America make the various habitats on the island critical features in maintaining the existence of a number of avian species.

Conservation Utility Score: The overall conservation utility score for the Gorgas Swamp land acquisition is 90.2.

Cost: The estimated land acquisition cost, as determined by USACE real estate staff, is approximately $700,000. Minimal costs (estimated to be less than $5,000) for gates and/or signage would be required to curtail continued all-terrain vehicle use and associated damage.

3.6.2.4.11. Steiner Property Acquisition (Interim Project ID #20)

Description: The Steiner Property is a parcel left largely untouched during the initial development of the island in the 1950s. The property consists of a swath of wetlands on the north side of Bienville Boulevard between Grant and Fort Conde Streets and runs northward with the northern boundary being the main portion of Dauphin Island Bay (Figure 44). Only two lots on the entire property have been developed and five parcels have been purchased for conservation by the Dauphin Island Bird Sanctuary. The remaining acreage is at jeopardy for development especially the area adjacent to Dauphin Island Bay. This acquisition was considered a Group 1 project in the Interim Report.

Figure 44. Steiner Property Acquisition Location.

Benefits: Implementation of this project would provide for the conservation and management of approximately 12 acres of critical habitat for neotropical migrants, wading birds, and waterfowl. In addition, the acquisition of the land could provide an ecotourism opportunity through the development of confined birding trails. The habitat types consist primarily of forested area, scrub/shrub, intertidal marsh, and a small portion of meadow, intertidal flat, and open-water. Maritime forest, scrub/shrub, and intertidal marsh provides extensive habitat for migrant and resident birds including waterfowl. The meadow, intertidal marsh and intertidal flats provide additional habitat for birds, fish and shellfish/oysters. Dauphin Island has been identified by The National Audubon Society as a Globally Important Birding area. At least 348 species have been reported on the island including residents and neo-tropical migrants. The location of the island on the Gulf Flyway and the first/last land mass encountered by migrating species to and from South America make the various habitats on the island critical features in maintaining the existence of a number of avian species.

Conservation Utility Score: The overall conservation utility score for the Steiner property acquisition is 92.4.

Cost: The estimated land acquisition cost, as determined by USACE real estate staff, is approximately $600,000 and there are no estimated O&M costs.

3.6.3. Task 6.2 – Alternative Assessment Tool Development

The purpose of this task was to develop a decision analysis tool to quantify the consequences of the restoration measures developed in Task 6.1 and provide a transparent assessment of the tradeoffs among the restoration strategies. A structured decision-making framework was applied to predict the consequences of various measures for restoration to ensure island sustainability and protection of natural resources and ecosystem integrity. The decision analysis required integration of technical expertise, model results, and appropriate stakeholder objectives to determine the optimal measure or sets of measures for restoration of Dauphin Island. The integrated technical modeling efforts quantified multiple areas of uncertainty associated with restoration design and costs of measures. The decision analysis facilitated a process for evaluating the consequences of implementing each measure on multiple stakeholder objectives by incorporating those technical data into the decision support tool. The ultimate goal of the decision analysis was to determine the consequences of restoration actions on a suite of stakeholder objectives.

The decision analysis followed the basic steps outlined by Clemen (1996): 1) formed hypothesized relations between restoration alternatives and system response; 2) constructed a basic model outlining these hypotheses; 3) parameterized the model; 4) determined the optimal decision from the model results; and 5) conducted sensitivity analysis to determine which components of the model had the greatest influence on the decision. A Bayesian Belief Network (Netica 1.12 Norsys Software 1998) and consequent decision support model were developed using this structure for the various structural restoration measures (Figure 45) and the land acquisition (non-structural) options (Figure 46). The tool quantifies uncertainty regarding the response of the system to restoration actions and our understanding of system dynamics (hypotheses, or model output) relative to predicted responses in order to identify the optimal restoration measure or land acquisition.

The blue box in Figure 45 identifies the utility scores for the various restoration measures. The restoration measures that had the highest utility were those that most satisfied the complex multiple stakeholder objectives associated with social, fiscal and conservation values on Dauphin Island. Of the proposed structural measures, the East End Beach and Dune Restoration ranked the highest of the Gulf beach restoration actions; the Pelican Island Southeast Nourishment ranked the highest for the ebb-tidal shoal measures; and the Marsh Habitat Restoration Behind Katrina Cut and Aloe Bay Beneficial Use Marsh Restoration (both had same utility score) ranked the highest for the back-barrier and marsh creation measures. The results presented demonstrate the optimal decision when comparing the measures against one another in order to evaluate tradeoffs. However, selection of restoration measures could also involve portfolios of measures and their impact on meeting stakeholder objectives, but the outcomes associated with implementation of multiple measures are not necessarily additive. Additional value might be realized from synergistic relations among measures, based on landscape ecology principles of patch size, proximity to similar protected habitat types, and connectivity (Irwin et al., 2020). In addition, the decision analysis may be used in the set-up phase of adaptive management where the probability distributions associated with each model can be updated through monitoring the physical performance of implemented restoration measures and the associated outcomes of measured state variables (e.g., habitat, water quality, or faunal population response).

Figure 46 illustrates the Bayesian Belief Network (Netica 1.12 Norsys Software 1998) for the land acquisition measures. The land acquisition utility was informed by different metrics than the restoration measures network. The blue box identifies the utility scores for the various non-structural measures. The land purchase that had the highest utility score was the Dauphin Island 39 parcel property acquisition: parcel B – Graveline Bay.

Table 18 is a summary of all the restoration measures and land acquisitions evaluated. It provides a ready reference to the individual rankings, construction costs, O&M costs, and MAM costs organized by measure category.

A detailed description of the methodology, application, and results of the alternative assessment tool is available in the report provided in Appendix J and is also available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

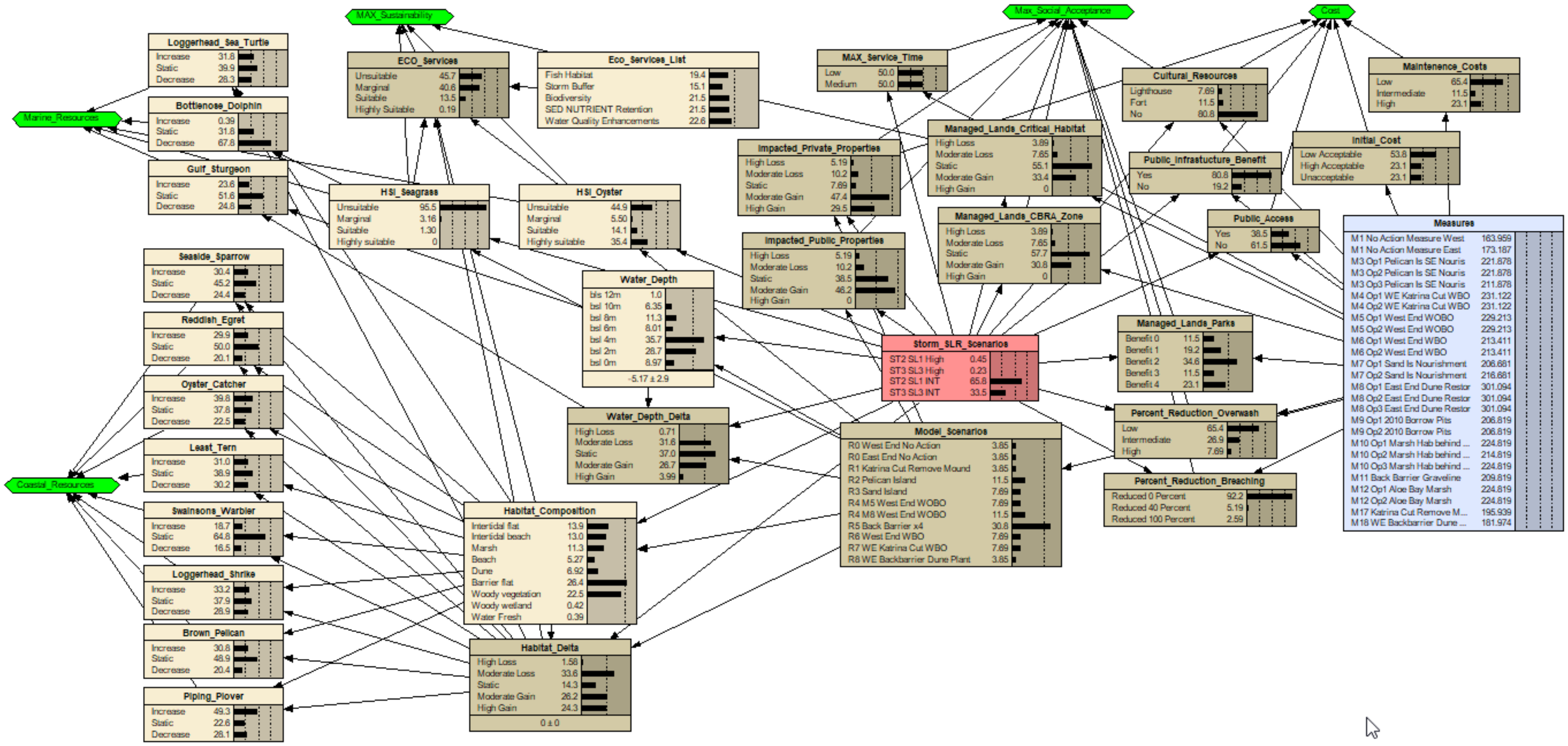


Figure 45. Dauphin Island Restoration Measures Bayesian Belief Network

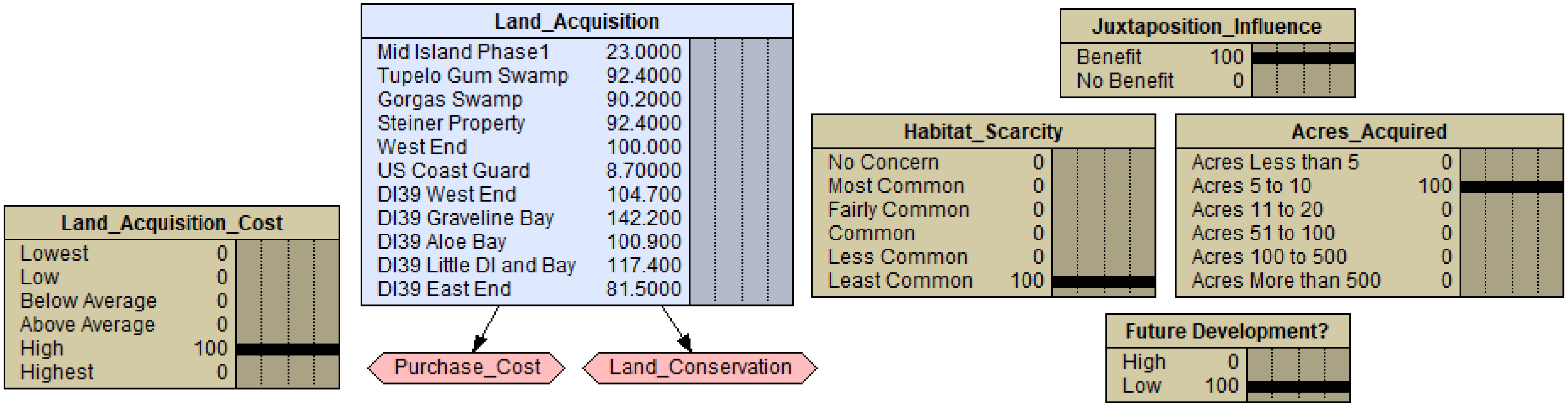


Figure 46. Dauphin Island Land Acquisition Bayesian Belief Network

Table 18. Summary of Utility Scores and Costs for the Restoration Measures.

MEASURE	Utility Score	Initial Construction Cost ($ million)	20-Year O&M Costs ($ million)	50-Year O&M Costs ($ million)	MAM Costs – 3% Initial Construction Cost ($ million)
Ebb Tidal Shoal Measures					
Pelican Island Southeast Nourishment Opt-1	221.9	$79.4	$3.0	$8.5	$2.4
Pelican Island Southeast Nourishment Opt-2	221.9	$72.9	$3.0	$8.5	$2.2
Pelican Island Southeast Nourishment Opt-3	211.9	$119.0	$3.0	$8.5	$3.6
Sand Island Platform Nourishment and Sand Bypassing Opt-1	206.7	$103.1	$10.4	$29.7	$3.1
Sand Island Platform Nourishment and Sand Bypassing Opt-2	216.7	$82.0	$10.4	$29.7	$2.5
Gulf Beach Measures					
East End Beach and Dune Restoration Opt-1	301.1	$28.2	$5.8 - $7.9	$23.8 - $32.5	$0.9
East End Beach and Dune Restoration Opt-2	301.1	$29.8	$5.8 - $7.9	$23.8 - $32.5	$0.9
East End Beach and Dune Restoration Opt-3	301.1	$35.2	$5.8 - $7.9	$23.8 - $32.5	$1.1
West End Beach and Dune Restoration (No Buyouts) Opt-1	229.2	$78.7	$52.0	$148.7	$2.4
West End Beach and Dune Restoration (No Buyouts) Opt-2	229.2	$73.0	$52.0	$148.7	$2.2
West End Beach and Dune Restoration (Voluntary Buyouts) Opt-1	213.4	$57.5 + $90.2 for Real Estate	$52.0	$148.5	$1.7
West End Beach and Dune Restoration (Voluntary Buyouts) Opt-2	213.4	$52.7 + $90.2 for Real Estate	$52.0	$148.5	$1.6
West End and Katrina Cut Beach and Dune Restoration (Voluntary Buyouts) Opt-1	231.1	$120.8 + $90.2 for Real Estate	$84.4 - $158.4	$241.2 - $453.0	$3.6

West End and Katrina Cut Beach and Dune Restoration (Voluntary Buyouts) Opt-2	231.1	$116.2 + $90.2 for Real Estate	$84.4 - $158.4	$241.2 - $453.0	$3.5
Katrina Cut Structure Removal	195.9	$7.7	-	-	$0.2
Back-Barrier and Marsh Restoration Measures					
2010 Borrow Pits Restoration Opt-1	206.8	$5.2	-	-	$0.2
2010 Borrow Pits Restoration Opt-2	206.8	$6.4	-	-	$0.2
Marsh Habitat Restoration Behind Katrina Cut Opt-1	224.8	$28.5	-	-	$0.9
Marsh Habitat Restoration Behind Katrina Cut Opt-2	214.8	$41.2	-	-	$1.2
Marsh Habitat Restoration Behind Katrina Cut Opt-3	224.8	$35.9	-	-	$1.1
Aloe Bay Beneficial Use Marsh Restoration Opt-1	224.8	$4.4	-	-	$0.1
Aloe Bay Beneficial Use Marsh Restoration Opt-2	224.8	$5.0	-	-	$0.2
Graveline Bay Marsh Restoration	209.8	$5.4	$17.6	$30.9	$0.2
West End Back-Barrier Herbaceous Dune Plant Restoration	182.0	$1.5	-	-	$0.05
Land Acquisition Measures					
West End Land Acquisition	100.0	$10.0	$0.1	$0.25	-
Mid-Island Land Acquisition and Management Phase I	23.0	$2.5	-	-	-
U.S. Coast Guard Property Acquisition	8.7	$2.5	-	-	-
Dauphin Island 39 Parcel Property Acquisition: Parcel A – West End	104.7	$0.9	-	-	-
Dauphin Island 39 Parcel Property Acquisition: Parcel B – Graveline Bay	142.2	$0.4	-	-	-
Dauphin Island 39 Parcel Property Acquisition: Parcel C – Aloe Bay	100.9	$0.1	-	-	-

Dauphin Island 39 Parcel Property Acquisition: Parcel D – Little Dauphin Island Bay	117.4	$0.2	-	-	-
Dauphin Island 39 Acquisition: Parcel E – East End	81.5	$0.62	-	-	-
Tupelo Gum Swamp Land Acquisition	92.4	$0.7	-	-	-
Gorgas Swamp Land Acquisition	90.2	$0.7	$0.005	-	-
Steiner Property Acquisition	92.4	$0.6	-	-	-

3.6.4. Task 6.3 – Cost Estimating

Rough Order of Magnitude (ROM) cost estimates were prepared for the various restoration measures formulated, including costs for final engineering and design, initial construction, operation and maintenance, any land acquisitions, and contingencies. Summaries of these costs are provided in the restoration measure descriptions previously discussed. All cost estimates are documented and provided with a cost estimate narrative in Appendix K and is also available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

3.7. Task 7 – Monitoring and Adaptive Management (MAM)

A feasibility/planning level MAM plan has been developed consistent with the Monitoring and Adaptive Management Plan requirements of the GEBF as well as the Water Resources Development Act of 2007 Section 2039. Once specific restoration measures have been implemented, a MAM plan will be used to determine if they are meeting the intended conservation and/or restoration objectives, and if not, whether adaptive management actions may be warranted. The MAM plan guidance is provided in Appendix L and is also available on the database developed for this study at https://gom.usgs.gov/DauphinIsland/Default.aspx.

4. Summary and Conclusions

The goal of this study was to investigate viable options for the restoration of Dauphin Island that can increase island sustainability and restore vital habitats for species affected by the DWH oil spill. A range of potential sea level change (SLC) and future storm scenarios were developed for the island and a suite of predictive models (i.e., hydrodynamic, morphologic, life-cycle structure response (for the Katrina Cut structure), water quality, and habitat) were used to evaluate future conditions (i.e., with and without restoration actions). The future without restoration (i.e., no-action) conditions were evaluated to determine which island habitat features were vulnerable to degradation or loss under the various SLC and storminess scenarios. Results indicate that increases in storminess (frequency and strength) and SLC, both independently and in combination, contribute to increased island degradation and loss of habitat (Mickey et al., 2020, Enwright et al., 2020). Woody vegetation, beach, barrier flat, and dune habitats continue to be some of the highest impacted habitat types under lower SLC and moderate storm conditions. Along the western portion of the island, predicted average losses of 50% and greater occur in these habitat types and these losses are exacerbated under more extreme future conditions.

The no-action modeling results demonstrated an increased potential for island breaching (around Katrina Cut, Pelican Island, and Little Dauphin Island), loss of island width, loss of the Pelican Island complex, and commensurate loss of vital habitats (i.e., beach, dune, marsh, etc.). Therefore, potential restoration measures covering a wide variety of techniques were developed and grouped into four categories (ebb tidal shoal; Gulf beach; back-barrier and marsh restoration; and land acquisitions). These measures were evaluated using the suite of predictive models to document project performance and total project costs (i.e., initial construction and future operations & maintenance) over a 20- and 50-year life cycle. The morphologic model results provided insights into breaching, elevation changes, and shoreline changes for the various potential future conditions. The life-cycle structure analysis evaluated the long-term performance of the Katrina Cut rubble mound structure. A predictive habitat model using landscape-position-information extracted from the morphological model outputs showed how the coverage and distribution of habitat types changed for the various restoration measures and potential future island configurations. The habitat modeling effort also applied accretion assumptions to explore how the rate of SLC can influence intertidal marsh habitats and/or marsh restoration measures. Additionally, water quality model outputs for four general scenarios were coupled with a habitat suitability index model to highlight how changing abiotic conditions could impact seagrass and oysters, namely breaching near Katrina Cut. Those four scenarios included: (1) the baseline 2015 geomorphology conditions with no island breaching; (2) a single breach west of the Katrina Cut structure; (3) breaching on either side of the Katrina Cut structure and along Little Dauphin Island and Pelican Island; and (4) breaching on either side of the Katrina Cut structure but no breaching along Little Dauphin Island and Pelican Island. Under the low sea level and moderate storm conditions (i.e., ST2SL1), seagrass habitat generally maintains the same pattern and distribution of suitability but does have a slight reduction in the suitable areas. However, under the more extreme future conditions (i.e., ST3SL3), the amount of suitable seagrass habitat was significantly reduced and fragmented as compared to the no-action or the ST2SL1 scenarios. This is likely attributable to the increased water depth and increased salinity in the back-barrier areas due to island breaching under this scenario (Enwright et al., 2020, Wang et al., 2020a, and Wang et al., 2020b).

Finally, all model results were analyzed in a structured-decision-making framework to determine the extent in which each measure met restoration objectives (via an overall utility score – the higher the score, the better the measure met the objectives) under two future condition storminess and SLC scenarios (i.e., ST2SL1 and ST3SL3). The ST2SL1 future condition represented a reasonable design condition (approximately 50% probability of storminess occurrence with the historic SLC projection at Dauphin Island) and the ST3SL3 scenario was selected as a “worst case” set of energetic conditions with a higher SLC projection to influence island evolution. The general intent and results of these evaluations per restoration category are discussed below, followed by a discussion of habitat suitability

Ebb Tidal Shoal Restoration Measures:

The intent of the ebb tidal shoal restoration measures was to determine if material from the Mobile Harbor Bar Channel could be feasibly and beneficially used, supplemented with sand from other sources, to enhance sediment transport in the area, create sustainable habitat, and provide protection to areas along the eastern end of Dauphin Island. Two specific measures were evaluated. The first (i.e., Pelican Island Southeast Nourishment) focused on restoring the Pelican Island to its general 1985 shoreline position and the second (i.e., Sand Island Platform Nourishment and Sand Bypassing) was aimed at re-establishing the Sand Island platform to elevations of -8 to -6 feet NAVD88 within regions along the general 1847-1850 Sand Island shoreline position. Of the two options, the Pelican Island Southeast Nourishment better met restoration objectives resulting in a higher utility score (see Table 18 for results). This was predominately due to the direct subaerial habitat benefits created from this measure and the risk reduction it provided to the eastern end of Dauphin Island by reducing future shoreline erosion. However, increases in the rates of sediment transport from Sand and Pelican Islands to Dauphin Island, as predicted by the morphological modeling simulations (for both the ST2SL1 and

ST3SL3 scenarios), were minimal for both measures, indicating the ebb tidal shoal system is not sediment starved, but energy limited instead. Sediment transport processes on the ebb tidal shoal are multi-decadal in time scale and are heavily influenced by highly energetic storm events. The rates of transport, even in these shallower, more dynamic areas, is significantly less than the rate material is dredged from the navigation channel and deposited on the ebb tidal shoal as part of routine maintenance dredging activities.

The Pelican Island Southeast Nourishment measure would place an estimated 4.5 million cubic yards at a target elevation of +4.5 feet North American Vertical Datum of 1988 (NAVD88) southeast of the existing Pelican Island. Potential sources of sand for initial construction include borrow areas located within the Mobile ebb tidal shoal system, relic sand deposits located just offshore of Petit Bois Pass, and upland sources located within dredge material sites along the Alabama-Tombigbee river system (as shown in Figure 20 and Figure 21). Borrow sources for future nourishments include sand dredged from Mobile Harbor Bar Channel during routine maintenance activities.

The initial construction cost, in present value dollars, for the Pelican Island Southeast Restoration measure is estimated at $72.9 million - $79.4 million (depending on the material borrow source used). Future O&M costs range from $3.0 million to $8.5 million for the 20- and 50-year lifecycles, respectively, and monitoring and adaptive management costs were estimated at 3% of the initial construction cost.

Gulf Beach Restoration Measures:

The Gulf beach measures formulated for the east and west ends of Dauphin Island were primarily intended to create and restore beach and dune habitat, while reducing possible damages to existing habitats landward on the island (e.g., herbaceous and wooded dunes, freshwater ponds, maritime forest, etc.). These measures were also evaluated to determine if they reduced the risk of island breaching in the future under the storminess and SLC scenarios simulated. Four measures were evaluated to determine their performance and total project costs over a 20- and 50-year life-cycle. The first measure focused on restoration of the eastern end of the island (i.e., the East End Beach and Dune Restoration measure) and the other three focused on west end restoration (i.e., West End Beach and Dune Restoration (No Buyouts) measure; West End Beach and Dune Restoration (with Voluntary Buyouts) measure; and West End and Katrina Cut Beach and Dune Restoration (with Voluntary Buyouts) measure). All four measures consisted of a beach berm and dune design with vegetative plantings. Sand to initially construct these measures could come from a combination of sources located within the Mobile ebb tidal shoal system, relic sand deposits located just offshore of Petit Bois Pass, and upland sources located within dredge material sites along the Alabama-Tombigbee river system (as shown in Figure 20 and Figure 21). Material for future nourishments, as needed, could come from these same sources with the addition of the Mobile Harbor Bar Channel for future nourishments of the east end restoration project.

Of the four measures, the East End Beach and Dune Restoration measure had the highest overall utility score (see Table 18 for results). This is primarily due to the direct habitat and species benefits it would create plus the risk reduction to future SLC and storm hazards it would provide for the existing herbaceous and wooded dunes and fresh water lakes and ponds along, and on, the Dauphin Island Audubon Bird Sanctuary. The measure would place an estimated 1.2 million cubic yards of sand along the shoreline at a natural berm elevation of approximately +5.5 feet NAVD88 to extend the 2016 CIAP East End Shoreline Restoration Project approximately 3,600 feet to the west (see Figure 23). Additionally, the measure includes construction of a frontal dune at an elevation of +12 feet NAVD88 and width of 25 feet along a 4,800 foot stretch of the coast, to slightly overlap with and extend eastward of where the natural extensive high dune system currently ends. The dunes would be vegetated with approximately 50,400 native dune plants that are robust in helping stabilize dunes and incorporate roughly 3,200 feet of sand fencing. The initial construction cost for this measure ranges from $28.2 million to $35.2 million (depending on the material borrow source used) in net present value dollars. Future O&M costs range from $5.8 million to $32.5 million for the 20- and 50-year lifecycles, respectively, and future monitoring and adaptive management costs were estimated at 3% of the initial construction cost.

Although the west end restoration measures had lower utility scores, they would provide valuable direct beach and dune habitat benefits, as well as, reduce the potential for future island breaching around the Katrina Cut structure. Both the West End Beach and Dune Restoration (No Buyouts) and West End Beach and Dune (with Voluntary Buyouts) measures prevented the breaching on the eastern side of the structure for the ST3SL3 scenario (breaching occurred on both sides of the structure for the no-action case). Of the two, the Voluntary Buyouts measure did not perform substantially different with respect to the prevention of habitat acreage loss but would require much higher initial costs associated with the voluntary acquisitions of the 225 residential properties (approximately $90 million) located in the project footprint. The West End and Katrina Cut Beach and Dune (with Voluntary Buyouts) measure would further reduce the potential for breaching around the Katrina Cut structure (e.g., no breaching was observed for the ST3SL3 simulation). This measure had the highest utility score of the three west end measures, although it was substantially more expensive due to the increased volume of material needed to construct and maintain the project. Initial construction costs for these measures range from $52.7 million to $120.8 million with future O&M costs ranging from $52.0 million to $453.0 million for the 20- and 50-year lifecycles respectively. Future monitoring and adaptive management costs were estimated at 3% of the initial construction costs.

Since the study objective was to restore vital habitats for species affected by the DWH oil spill, the team did not explicitly model a West End and Katrina Cut Beach and Dune Restoration (No Buyouts) measure. However, the performance is expected to be similar between the two measures. The No Buyouts measure would have an increased initial construction cost of approximately 25% and decreased overall cost of approximately $90 million due to the removal of the costs to acquire the 225 residential properties.

Back-Barrier and Marsh Restoration Measures:

The general intent of these restoration measures was to determine if back-barrier and marsh restoration actions could be viably created and sustained to enhance these important ecosystems and diverse habitats supported by these areas. These measures can also serve as buffers to inland habitats during higher frequency, less intense coastal storm events. Overall, five back-barrier and marsh restoration measures were developed and evaluated at different locations along the north side of the Dauphin Island. These included (1) filling the borrow pits dug in 2010 to construct berms after the DWH oil spill; (2) marsh creation behind the Katrina Cut structure; (3) marsh restoration in Aloe Bay; (4) marsh restoration in Graveline Bay; and (5) creation of a back-barrier herbaceous dune system along the right-of-way of Bienville Boulevard. Of these five measures, the Katrina Cut and Aloe Bay marsh restoration measures tied for the highest utility score, followed by the restoration of the Graveline Bay Marsh and filling of the holes dug in 2010 after the DWH oil spill. The back-barrier dune system creation measure was the lowest scoring of the five measures.

The Marsh Habitat Restoration behind Katrina Cut measure would create approximately 75 acres of back-bay, intertidal marsh habitat behind the structure which has been lost along the leeside of Dauphin Island due to eroding shorelines and development since the 1950s and 1960s. The area would be filled with an estimated 1.1 million cubic yards of sand and planted with approximately 1.6 million marsh plant species that are native to the back-bay marsh systems. Potential sources of sand for initial construction include relic sand deposits located just offshore of Petit Bois Pass and upland sources located within dredge material sites along the Alabama-Tombigbee river system (as shown in Figure 20 and Figure 21). The initial construction cost ranges from $28.5 million to $35.9 million (depending on the material borrow source used) in present value dollars. There would be no anticipated future O&M costs and monitoring and adaptive management costs were estimated at 3% of the initial construction cost.

The Aloe Bay Beneficial Use Marsh Restoration measure would restore approximately 6 acres of intertidal marsh that has been lost along the leeside of Dauphin Island within Aloe Bay. The area would be filled with an estimated 34,000 cubic yards of sediment and planted with approximately 105,000 plant species that are native to the back-bay marsh systems. In addition, the measure would incorporate approximately 1,900 linear feet of low crested rubble mound or a bio-engineered breakwater system and a terminal groin at the east end to retain sediment within the marsh construction template. The shore parallel breakwater structures would function to reduce shoreline erosion and wave energy in its lee. The potential source of sand for initial construction would be material dredged from the Dauphin Island Village Chanel (see Figure 29). The initial construction cost ranges from $4.4M to $5.0M (depending on the breakwater system used) in present value dollars. There would be no anticipated future O&M costs and monitoring and adaptive management costs were estimated at 3% of the initial construction cost.

Land Acquisitions for Conservation:

The Interim Report for this study (USGS et al., 2017) identified numerous land acquisitions intended to serve as important habitat conservation and protection actions. Of those, 11 were identified to be further considered individually or in combination with other measures as part of this Final Report. These 11 land acquisitions were primarily identified for their conservation value. The Interim Report grouped each of them into one of three groups based on the results of evaluations conducted by a multi-agency support panel. “Group 1” acquisitions were those that most strongly satisfied the evaluation criteria for conservation values. “Group 2” acquisitions were less clear in the benefits they would provide. This was generally because they were considered too fragmented to substantially provide a benefit to the ecosystem, or because they were thought to already provide their highest ecological capacity and that was unlikely to change. “Group 3” acquisitions were those that had no, or minimal, conservation value and were not further considered in study. None of the 11 land acquisitions evaluated in this final report were identified as “Group 3” acquisitions.

Each land acquisition was evaluated using the structured-decision-making alternative assessment tool (as described in Section 3.6.3) and assigned a Land Conservation Utility Score. The score was a function of development risk, the scarcity of the predominant habitat on the parcel, the amount of land, and connectivity to other conservation lands to inform an overall score. The higher the overall score the higher the utility of the land acquisition. Of the 11 land acquisitions considered, the Dauphin Island 39 Parcel Property Acquisition: Parcel B – Graveline Bay had the highest utility score followed by Dauphin Island 39 Parcel Property Acquisition: Parcel D – Little Dauphin Island Bay. The scores for all 11 land acquisitions are shown in Table 18.

The Graveline Bay acquisition area includes 6 parcels comprising 340 acres of wetland and open water habitat south and west of the southern edge of the Dauphin Island Airport runway to the vicinity of Pineda Street (see Figure 38). No residential or commercial properties are included in this area. The eastern and southern property portions contain significant unimpacted intertidal wetlands and intertidal flats that are essential habitat for the production and survival of fish, shellfish, and crabs. In addition, the wetlands provide habitat for wading birds and waterfowl. The acquisition cost for this property was estimated at $400,000 and there are no estimated O&M costs.

The Little Dauphin Island Bay land acquisition consists of approximately 150 acres of shallow open water habitat in Little Dauphin Bay and Mississippi Sound including a portion of the disposal area for maintenance of the federally authorized Government Cut Channel (see Figure 40). This area serves as habitat for numerous aquatic species including fish, shellfish, and crab and the acquisition cost for this property was estimated at $200,000 and there are no estimated O&M costs.

In summary the risks associated with hazards from coastal storms in the area will continue to grow with SLC. The extensive modeling efforts and analyses show the sensitivity of the island’s structure, habitats, and species to rising seas and severe and frequent coastal storms. While no measure will eliminate the hazards, these science-based assessments suggest various individual measures or combinations of measures, paired with strategic monitoring and adaptive management plans, could enhance the ability of Dauphin Island to absorb, adapt, and recover to potential future events over the next several decades.

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