ALABAMA BARRIER ISLAND RESTORATION ASSESSMENT

Monitoring and Adaptive Management Plan

April 20, 2020

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1.0 Introduction

Dauphin Island, Alabama, is a strategically important barrier island along the northern Gulf of Mexico. It serves as the only barrier island providing protection to much of the State of Alabama’s coastal natural resources. With an average elevation of 7.2 feet, Dauphin Island is highly susceptible to rising sea levels. The size of the system spans over 3500 acres of barrier island habitat including beach, dune, overwash fans, intertidal flats, intertidal wetlands, maritime forest, and freshwater ponds. In addition, Dauphin Island provides protection 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.

Dauphin Island and the remainder of the barrier islands fronting the Mississippi Sound have been historically losing surface area, 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 et al., 2008). Moreover, loss of barrier island area threatens the estuarine ecosystem of the Mississippi Sound and its resources 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 by the Deepwater Horizon (DWH) oil spill. Hurricanes Frederic, 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 as well as the merging of the Pelican/Sand Island complex to Dauphin Island. This pattern of island breaching and rollover as a function of hurricane passage, as well as the merging of the Pelican/Sand Island complex to Dauphin Island, has been documented several times in the historical survey record (Morton et al., 2008, Byrnes et al., 2010, Byrnes et al., 2012, Park et al., 2013). Breaches along the island prior to the most recent ones in 2004 and 2005 have been documented as closing naturally in response to sediment supplied from the Mobile Pass ebb-tidal delta, with large breach closures occurring on the order of decades. In addition, published reports (Morton et al., 2008, Byrnes et al., 2010) indicate that, historically, the western portion of the island has generally maintained its form through time by migrating landward.

Efforts to mitigate the impacts of these coastal hazards on the island date from 1904 when a rock revetment was put in place to protect Fort Gaines at the far eastern end of the island. Over time, other efforts include rock groins on the southeastern shore, a series of bulkheads along the northeastern side of the island, limited beneficial use 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. Most recent mitigation efforts include reorientation of the groin field into a breakwater configuration and pocket beach construction on the east end and dune construction along the western portion of the developed island. Furthermore, in response to the 2010 DWH oil spill, a major breach in the island, Katrina Cut, was closed with a temporary rubble mound structure to prevent oil migration into the Mississippi Sound.
Sea level rise, storms, oil spills, and development on the island and surrounding shorelines are primary stressors that continue to degrade and threaten further loss of the island habitats and threaten the ecological functioning of the Mississippi Sound and the Heron Bay wetlands on the mainland.

Restoration of Dauphin Island will help enhance, maintain, and protect important coastal habitat and living resources affected by these stressors. The goal of this work is to investigate viable options for the restoration of Dauphin Island as a sustainable barrier island to protect, enhance and restore resources on the island as well as the surrounding coastal resources the island supports. One of the main objectives for the Alabama Barrier Island Restoration Assessment is to evaluate potential restoration alternatives based on sound science, allowing science to guide development of sustainable restoration alternatives and exploring a 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, the island’s physical topography and bathymetry, and geologic and oceanographic factors. These factors play an important role in understanding how the island has evolved over time to the existing island feature and how the island might respond to restoration actions.

This feasibility-level monitoring and adaptive management (MAM) plan describes a programmatic monitoring design to evaluate progress towards meeting project goals and objectives, describes the organizational structure for the MAM process, identifies key uncertainties, provides potential adaptive management (AM) actions, and provides cost estimates that can be used to guide project planning, implementation, and performance monitoring. Many factors such as ecosystem dynamics, engineering applications, institutional requirements, and other key uncertainties can change and/or evolve over a project’s life. The MAM plan is a living document and will likely need to be revised upon availability of planning and engineering details regarding the suite of restoration measures included in the preferred restoration alternative. The revisions should consider updates to the goals and objectives, associated performance measures, monitoring design, and desired outcomes and specification of success criteria, interim targets, triggers, and adaptive management actions. Additionally, the plan should be regularly updated to reflect new monitoring and supporting information, as well as resolution of key uncertainties.

1.1 Introduction to Monitoring and Adaptive Management

Adaptive management is distinguished from traditional long-term monitoring in part through implementation of an organized, coherent, and documented decision process. Important aspects of the AM process lie in exploring alternative ways to meet management objectives, predicting the outcomes of alternatives based on the current state of knowledge, implementing one or more alternatives, and establishing a feedback mechanism whereby monitored conditions may be used to update the knowledge base and adjust management actions to refine and/or better achieve project goals and objectives. The definition of AM used for the Alabama Barrier Island Restoration Assessment is adopted from the National Research Council, Adaptive Management for Water Resources Project Planning, 2004:
“Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a “trial and error” process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.”

Learning from the AM experience is certainly not a new idea, but the purposeful and systematic pursuit of knowledge to address identified uncertainties has rarely been practiced. Adaptive management acknowledges the uncertainty about how ecological systems function and how they may respond to management actions. Nevertheless, AM is not a random trial-and-error process; it is not ad-hoc or simply reactionary. An essential element of AM is the development and execution of a monitoring and assessment program to analyze and understand responses of the system to implementation of the project.

The Alabama Barrier Island Restoration Assessment MAM program will be developed and used to:

- Allow scientists and managers to collaboratively design plans for managing complex and partially understood ecological systems.
- Reduce uncertainty over time.
  - Acknowledge, identify, and characterize risks and uncertainties.
  - Analyze uncertainties to identify key gaps in information and understanding.
- Implement systematic monitoring of outcomes and impacts.
  - Use scientific information obtained through continued monitoring to evaluate and manage uncertainties to achieve desired goals and objectives.
  - Explicitly state goals and measurable indicators of progress toward those goals.
  - Demonstrate to others that the project is meeting or exceeding performance goals and achieves “ecological success” (See Section 1.2).
  - Detect beneficial and detrimental system responses as early as possible to quantify the effects of these responses.
  - Evaluate hypotheses and performance measures and revise conceptual ecological models as appropriate.
- Incorporate an iterative approach to decision-making.
  - Develop feedback loops so that monitoring and assessment produce continuous and systematic learning that in turn is incorporated into subsequent decision-making.
  - Incorporate management flexibility in the design and implementation of programs or projects.
  - Implement projects and programs in phases to allow for course corrections based on new information.
- Provide a basis for identifying options for improvements in the design, construction and/or operation of Alabama Barrier Island Restoration Assessment projects and components through AM.
- Develop reports on the status and progress of the Alabama Barrier Island Restoration Assessment for the agencies involved, the public, and other stakeholders.
- Enhance predictive capability through improvements in simulation models before and after project construction.
- Provide information to summarize and develop lessons learned to optimize barrier island restoration strategies in the future.
- Ensure interagency collaboration and productive stakeholder participation. AM encourages defining agency objectives for stakeholder involvement, deciding upon a strategy for stakeholder involvement, clearly communicating this to the public, and maintaining long-term collaboration among stakeholders. Continued communication with key stakeholders helps identify and reduce socio-economic uncertainties, measure project progress towards objectives, and adaptively manage projects (Knight et al., 2008, Smith et al., 2009, Nkhata and Breen 2010).

Monitoring and Adaptive Management Process

The developed MAM program and process is complimentary to the U.S. Army Corps of Engineers (USACE) Project Life Cycle (planning, design, construction and operation and maintenance). The MAM process is not elaborate or duplicative and enhances activities that already take place. The basic process of MAM (Figure 1) was adapted from the DRAFT USACE Adaptive Management Technical Guide (USACE 2011) and includes:

**Planning** a program or project;

**Designing** the corresponding project;

**Building** the project (construction and implementation);

**Operating** and maintaining the project;

**Monitoring** and assessing the project performance;

**Continue** project implementation as originally designed or

**Adjust** the project if goals and objectives are not being achieved;

**Complete** project if goals and objectives and success criteria are achieved, or it is determined the project has successfully produced the desired outcomes

Project **termination** is possible if project goals and objectives are not being achieved and the decision is made to not adjust the project, or no adjustments are possible
Figure 1. Monitoring and Adaptive Management process for the USACE Civil Works.

1.2 Authorization for Monitoring and Adaptive Management

This feasibility-level monitoring and adaptive management plan is consistent with National Fish and Wildlife Foundation, Gulf Environmental Benefit Fund Monitoring and Adaptive Management Plan guidelines and consistent with the Water Resources Development Act guidance for U.S. Army Corps of Engineers projects.

1.2.1 Monitoring Plan Guidelines

- The plan should specify nature, duration, and periodicity of monitoring, disposition of monitoring and analysis, costs, and responsibilities.
- Scope and duration should include the minimum monitoring actions necessary to evaluate success.
- Success is determined by an evaluation of predicted outcomes compared to actual results.
- Monitoring should be continued until “ecological success” is documented by the project sponsor in consultation with Federal and State resource agencies, as appropriate.
- Monitoring can end sooner than planned, if success is determined.
- Monitoring costs should be included as part of the project cost.

1.2.2 Adaptive Management/Contingency Plan

- Adaptive management plan should be appropriately scoped to project scale.
- The rationale and cost of AM and anticipated adjustments should be reviewed as part of the decision document.
- Major changes needed to achieve ecological success that cannot be addressed through operational changes or the AM plan may be examined under other funding authorities.
1.3 Monitoring and Adaptive Management Framework

The MAM plan includes a Set-up Phase (Figure 2) and an Implementation Phase (Figure 3). The Set-up phase proceeds concurrently with the planning process. While planners are identifying problems and opportunities, inventorying and forecasting resource conditions, evaluating and comparing alternative formulations, and selecting a plan, the MAM plan for the project should be developed. In addition to items developed during the planning process, a conceptual ecological model (CEM) will be developed, uncertainties identified, and performance measures, desired outcomes, and summary monitoring designs established as guidance to MAM plan development. Upon selection of an alternative for construction, additional MAM details on success and decision criteria (i.e., targets, triggers and thresholds) should be developed.

While the AM Set-up phase includes planning, the implementation phase puts the MAM plans into action (Figure 3). Projects will be designed, constructed, monitored, and assessed to understand responses of the system to implementation of the project alternative relative to stated goals, objectives, targets and success criteria. A Program Team should decide whether to alter the project and implement AM actions to improve plan performance based on assessment results.

Baseline monitoring should begin during or proceeding the design phase, prior to project construction. Monitoring should also be conducted during construction. Unexpected detrimental events may alter the project site, requiring consideration of corrective measures. For example, a tropical cyclone impacting a project site or invasion of an exotic species may necessitate management actions. Decisions may be required on how to address changes in conditions. In addition, projects that are phased-in over a long period of time present a greater potential for changing baseline conditions due to construction methods, deviations from selected methods, or development of new information. Using an AM strategy in this situation may increase the chances of overall project success. Design changes during construction may warrant changes to the MAM plan.

After construction, the project will enter the iterative cycle of AM where monitoring data are used to assess impacts and evaluate project performance. The results from the monitoring assessment should guide decision-making. An operation and maintenance, repair, replacement, and rehabilitation (OMRR&R) manual (or equivalent) should clearly communicate the MAM plans and process, including monitoring parameters, frequency and duration of monitoring and assessment, decision criteria, and options for adjustment (if necessary) to increase project success.

Engagement with stakeholders throughout project planning and implementation phases is critical to developing and maintaining common understandings of the goals and objectives, expectations of results, and potential commitment of resources. All phases of the MAM process should be open, transparent, and accessible to stakeholders. Such interaction fosters the mutual understanding of decisions and events and appreciation of the time and patience required to fully realize the benefits of restoration projects and to manage unrealized expectations. A strong effort should be made to identify and engage all appropriate stakeholders. Project teams should continually seek to identify governmental and non-governmental organizations, groups and other interested parties who could affect, be affected by, and/or be able to contribute knowledge, data, and/or resources to project-related activities (e.g., planning, design, implementation, and monitoring).
Figure 2. Monitoring and Adaptive Management Program Framework Set-up Phase.

Figure 3. Implementation Phase of the Adaptive Management Program Framework.
2.0 Monitoring and Adaptive Management Planning

A feasibility-level MAM plan has been developed for the Alabama Barrier Island Restoration Assessment based on identified project goals and objectives, proposed restoration measures presented in the final report, and informed by a barrier island conceptual ecological model. The level of detail in the MAM plan is based on currently available programmatic project data and information developed as a part of this feasibility-level study of viable options for Dauphin Island restoration. Since this study is at the programmatic level, uncertainties remain concerning the exact project measures to be selected, project implementation, monitoring elements, and adaptive management opportunities. This MAM plan describes the types of monitoring and performance measures that could be used, but the MAM plan may need to be refined after an alternative is selected for construction. The MAM plan should then be implemented during pre-construction, project-construction, and post-construction phases and should be updated regularly to reflect new information, including important progress or resolution of recognized uncertainties, as well as any new uncertainties that might emerge during and following project construction. The actual scope of the final Alabama Barrier Island Restoration Assessment MAM plan should be based on project complexity, project uncertainties, the flexibility in potential management options, and the stage of project development. It is suggested that a MAM team be formed to develop the final MAM plan, including detailed cost estimates, monitoring protocols, and AM triggers, thresholds and actions.

2.1 Conceptual Ecological Model

As part of the MAM planning process, a CEM (Attachment 1) was developed to help explain the general functional relationships among the essential components of the barrier island ecosystem. CEMs are a means of:

1. simplifying complex ecological relationships by organizing information and clearly depicting system components and interactions;
2. integrating to more comprehensively implicit ecosystem dynamics;
3. identifying which attributes will show ecosystem response;
4. interpreting and tracking changes in restoration/management targets; and
5. communicating these findings in multiple formats.

This CEM assists with identifying aspects of the ecosystem where restoration measures can effect change. Specifically, the CEM identifies those major stressors, ecosystem drivers, and critical ecological processes and attributes of the natural system likely to respond to restoration measures. The Dauphin Island CEM developed for the Alabama Barrier Island Restoration Assessment was used in the development of this MAM plan to help identify and confirm objectives, identify problems and opportunities, uncertainties, and select important system attributes and performance measures to be considered for monitoring. The CEM represents the current understanding of these factors and should be updated and modified, as necessary, as new information becomes available to assist with further refining this MAM plan during project planning and implementation.

Factors identified for the Alabama Barrier Island Restoration Assessment are listed below and further detailed in Attachment 1. The numbers associated with the performance measures align with the same number identified with the attributes.
### Drivers
| D1: Coastal Geomorphic and Geological Processes | D3: Changing Global Climate Patterns |
| D2: Oceanographic & Atmospheric Processes | D4: Human Development & Expansions |

### Stressors
| ES1: Relative Sea Level Rise | ES6: Oil Spills |
| ES2: Altered Sediment & Nutrient Availability | ES7: Shoreline Protection Projects |
| ES3: Altered Hydrological Exchange & Circulation Patterns | ES8: Commercial & Recreational Use Activities |
| ES4: Island Morphological Changes | ES9: Navigation & Dredging Activities |
| ES5: Local Weather Disturbances & Storms | ES10: Habitat Restoration |

### Effects
| ES1: Groundwater Exchange | ES8: Bird Communities |
| ES2: Land Area & Elevation Change | ES9: Terrestrial Mammals |
| ES3: Sediment Budget & Transport | ES10: Vegetation Types |
| ES4: Buffer/Hazard Protection | ES11: Upper Trophic Level Marine Communities |
| ES5: Water Quality Dynamics | ES12: Fish & Shellfish Communities |
| ES6: Habitat Diversity | ES13: Reptiles & Amphibians |
| ES7: Benthic Communities |

### Attributes
| A1: Social Considerations |
| A2: Hydrological Processes |
| A3: Water Quality Constituents |
| A4: Island Morphology |
| A5: Substrate Characteristics |
| A6: Key Coastal & Marine Faunal Species |
| A7: Key Coastal & Marine Habitats |

### Performance Measures
| PM 1: Access to Recreational/Cultural Activities, Impacts to Properties |
| PM 2: Waves, Currents, Velocity, Tides, Groundwater |
| PM 3: Salinity, Temperature, Turbidity, Nutrients |
| PM 4: Elevation, Bathymetry, Slope, Width |
| PM 5: Grain Size, Color, Texture, Porosity |
| PM 6: Species Composition, Abundance, Biomass, Distribution |
| PM 7: Habitat Composition, Vegetation Distribution, Land/Water |
2.2 Goals and Objectives

The goal of the Alabama Barrier Island Restoration Assessment is to investigate viable options for the restoration of Dauphin Island as a sustainable barrier island to protect and restore island resources, including habitat and living coastal and marine resources, as well as protect the coastal resources of the Mississippi Sound/Mobile Bay and the southern portion of Mobile County, Alabama including the expansive Heron Bay wetlands. Some of the questions this study was designed to help answer include:

- 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 (20 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 (such as wave action and sand transport) support or degrade island resources over time?
- How should island restoration be configured (i.e., width, height) for resilience to winter and tropical storms?
- Would Dauphin Island withstand future storms if restored?
- Would restoration increase and/or conserve the habitats that support long-term living resources damaged by the DWH spill?
- Would successful restoration of the East End be different from the West End?
- What are the most feasible and cost-effective restoration alternatives that support a sustainable design?

The project objectives developed in this feasibility study were formulated by the State of Alabama Lands Division and the U.S. Army Corps of Engineers management team using scoping sessions with the public, directed stakeholder elicitations, and expert panels from academia, State and Federal partners, non-governmental organizations, and consultants. Objectives within existing natural resource management or restoration plans were also compiled and considered such as: the Dauphin Island Strategic Plan funded by the Town of Dauphin Island; the Alabama Coastal Comprehensive Plan; and plans prepared by the Mississippi-Alabama Sea Grant Consortium, the University of Southern Mississippi, the Alabama Department of Conservation and Natural Resources, the Dauphin Island Sea Lab and Mobile Bay National Estuary Program. The project objectives identified below were used to screen and select restoration measures for evaluation.

Project objectives

The overall planning objective of the project is to achieve long-term sustainability of Dauphin Island. In order to assess that fundamental objective, the following broad project objectives were identified:

Objective 1: Restore ecological function of Dauphin Island to support the coastal region by maximizing habitat and focal species.

Objective 2: Restore physical processes affecting morphology of Dauphin Island.

Objective 3: Minimize social impacts associated with impacted properties, infrastructure, human use, and cultural resources.

Objective 4: Minimize project costs.
These objectives may be refined upon the final identification of restoration actions to be included in the selected alternative.

### 2.3 Restoration Measures

The restoration measures considered for inclusion in a selected plan fall under four ecosystem restoration measure types: (1) Ebb Tidal Shoal; (2) Gulf Beach; (3) Back Barrier and Marsh Restoration; and (4) Land Acquisition. The details of individual measures are included in Table 1.

#### Table 1. Project Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
<th>Benefits</th>
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</thead>
<tbody>
<tr>
<td><strong>Ebb Tidal Shoal</strong></td>
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<tr>
<td>Pelican Island Southeast Nourishment</td>
<td>Place 4.5 million cubic yards (cy) of sand SE of existing Pelican Island. Supply sand to nearshore littoral system.</td>
<td>Create 240 acres of intertidal beach and barrier flat. Reduce loss of managed lands and piping plover critical habitat. Reduce wave energy and shoreline erosion along East End of Dauphin Island</td>
</tr>
<tr>
<td>Sand Island Platform Nourishment</td>
<td>Place 4.3 million cy of sand along Sand Island (-8 to -6 ft North American Vertical Datum (NAVD88)). Build up shoal system around Sand Island Lighthouse and supply sand to nearshore littoral system.</td>
<td>Create 127 acres of submerged offshore sand along ebb tidal shoal system. Directly feed Pelican Island and Sand Island shoals. Reduce shoal loss around Sand Island Lighthouse.</td>
</tr>
<tr>
<td><strong>Gulf Beach</strong></td>
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</tr>
<tr>
<td>East End Beach and Dune Restoration</td>
<td>Place 1.2 million cy of sand along shoreline to construct a beach and frontal dune (7 ft height x 25 ft width) with native vegetation. Install 3,200 ft of sand fencing.</td>
<td>Restore 35 acres of beach and dune habitat. Reduce loss of managed lands. Reduce storm risk to an additional 50 acres of beach, dune, woody vegetation, and freshwater lake habitats.</td>
</tr>
<tr>
<td>West End Beach and Dune Restoration (No Buyouts)</td>
<td>Place 4.2 million cy of sand along shoreline. Construct frontal dune (7 ft height x 25 ft width) with native vegetation. Install 14,000 ft of sand fencing.</td>
<td>Restore 200 acres of beach and dune habitat. Reduce loss of piping plover critical habitat. Reduce storm risk to an additional 100+ acres of beach, dune, intertidal flat, and intertidal marsh habitats.</td>
</tr>
<tr>
<td>West End Beach and Dune</td>
<td>Remove 225 residential structures.</td>
<td>Restore 200 acres of beach and dune habitat.</td>
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<tr>
<td>Measure</td>
<td>Description</td>
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<tr>
<td>Restoration (Voluntary Buyouts)</td>
<td>Place 3.1 million cy of sand along shoreline to construct a beach and frontal dune (5 ft height x 30 ft width) with native vegetation. Install 14,000 ft of sand fencing.</td>
<td>Reduce loss of piping plover critical habitat. Reduce storm risk to an additional 100+ acres of beach, dune, intertidal flat, and intertidal marsh habitats. Reduce storm damage to 225 residential structures.</td>
</tr>
<tr>
<td>West End Beach and Katrina Cut Beach and Dune Restoration (Voluntary Buyouts)</td>
<td>Remove 225 residential structures. Place 7.9 million cy of sand along shoreline to construct a beach and frontal dune (5 ft height x 30 ft width) with native vegetation. Install 14,000 ft of sand fencing.</td>
<td>Restore 450 acres of beach and dune habitat. Reduce loss of managed lands and piping plover critical habitat. Reduce storm risk to an additional 280+ acres of beach, dune, intertidal flat, and intertidal marsh habitats. Reduce storm damage to 225 residential structures.</td>
</tr>
<tr>
<td>Back Barrier and Marsh Restoration</td>
<td>Place 280,500 cy of material in the 31 abandoned 2010 borrow pits.</td>
<td>Restore intertidal and barrier flat habitat. Increase back barrier meadow and wetland habitats. Restore piping plover critical habitat. Provide platform for migration of intertidal marsh under rising sea level.</td>
</tr>
<tr>
<td>2010 Borrow Pits Restoration</td>
<td>Place 1.1 million cy of sand along lee of Katrina Cut Structure. Plant 1.6 million native marsh plants.</td>
<td>Restore 75 acres of intertidal marsh habitat. Reduce loss of managed lands and piping plover critical habitat.</td>
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<tr>
<td>Measure</td>
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<tr>
<td>Aloe Bay Beneficial Marsh Restoration</td>
<td>Place 34,000 cy of sediment along lee of DI within Aloe Bay. Plant 105,000 native marsh plants. Construct 1,900 ft low crested rubble mound or bioengineered breakwater.</td>
<td>Reduce lee side damage to Katrina Cut Structure.</td>
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<td>Restore 6 acres of intertidal marsh. Reduce lee side shoreline erosion in project area.</td>
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<tr>
<td>Graveline Bay Marsh Restoration</td>
<td>Place 162,000 cy of sediment along lee of DI within Graveline Bay. Plant 623,000 native marsh plants.</td>
<td>Restore 25 acres of intertidal marsh. Reduce lee side shoreline erosion in project area.</td>
</tr>
<tr>
<td>West End Back Barrier Herbaceous Dune Plant Restoration</td>
<td>Plant 120,000 native dune plants in historic vegetated dune footprint along developed West End. Install 19,000 ft of sand fencing.</td>
<td>Restore 21 acres of herbaceous dune habitat. Restore piping plover critical habitat. Rebuild island elevation.</td>
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<tr>
<td>Land Acquisition</td>
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<tr>
<td>West End Land Acquisition</td>
<td>Acquire approximately 720 acres of habitat west of Katrina Cut.</td>
<td>Conserve 720 acres of beach, dune, shrub, flat, and tidal pool habitats for various resident and migratory birds. Conserve critical habitat for piping plovers.</td>
</tr>
<tr>
<td>Mid-Island Land Acquisition and Management Phase I</td>
<td>Acquire approximately 10 acres of undeveloped beach and dune habitat located west of the public fishing pier. Enhance control of public access.</td>
<td>Conserve 10 acres of critical wintering habitat for resident and migratory birds. Reduce development risk.</td>
</tr>
<tr>
<td>U.S. Coast Guard Property Acquisition</td>
<td>Acquire approximately 7.5 acres of habitat.</td>
<td>Conserve 7.5 acres of scrub/shrub, dune, maritime forest, and beach habitats. Conserve habitat for resident and migratory birds. Enhance education through open laboratory use by Dauphin Island Sea Lab.</td>
</tr>
<tr>
<td>Dauphin Island 39 Parcel Property Acquisition: Parcel A – West End</td>
<td>Acquire approximately 518 acres on the west end of Dauphin Island along the Mississippi Sound.</td>
<td>Conserve 518 acres of habitat for shorebirds, fish, and marine invertebrates. Reduce development risk.</td>
</tr>
<tr>
<td>Dauphin Island 39 Parcel Property Acquisition:</td>
<td>Acquire approximately 340 acres of wetland and open water habitat south and west of the southern edge of Dauphin Island.</td>
<td>Conserve 340 acres of habitat for wading birds, waterfowl, fish, and marine invertebrates. Reduce development risk.</td>
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<tr>
<td>Measure</td>
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<tr>
<td>Parcel B – Graveline Bay</td>
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<tr>
<td>Dauphin Island 39 Parcel Property Acquisition: Parcel C – Aloe Bay</td>
<td>Acquire approximately 76 acres of shallow open water habitat in the Aloe Bay area of Mississippi Sound.</td>
<td>Conserve 76 acres of habitat for aquatic species.</td>
</tr>
<tr>
<td>Dauphin Island 39 Parcel Property Acquisition: Parcel D – Little Dauphin Island Bay</td>
<td>Acquire approximately 150 acres of shallow open water habitat in Little Dauphin Bay and Mississippi Sound.</td>
<td>Conserve 150 acres of habitat for aquatic species.</td>
</tr>
<tr>
<td>Dauphin Island 39 Acquisition: Parcel E – East End</td>
<td>Acquire approximately 4 acres of undeveloped land throughout the East End of Dauphin Island.</td>
<td>Conserve habitat for resident and migratory birds.</td>
</tr>
<tr>
<td>Tupelo Gum Swamp Land Acquisition</td>
<td>Acquire approximately 10 acres of gum swamp on Dauphin Island.</td>
<td>Conserve 10 acres of critical habitat for resident and migratory birds. Provide ecotourism opportunity by developing birding trails. Reduce development risk.</td>
</tr>
<tr>
<td>Gorgas Swamp Land Acquisition</td>
<td>Acquire approximately 10 acres of swamp.</td>
<td>Conserve 10 acres of critical habitat for resident and migratory birds. Provide ecotourism opportunity by developing birding trails. Reduce degradation from all-terrain vehicle traffic.</td>
</tr>
<tr>
<td>Steiner Property Acquisition</td>
<td>Acquire approximately 12 acres of undeveloped land.</td>
<td>Conserve 12 acres of critical habitat for migratory and wading birds and waterfowl. Provide ecotourism opportunity by developing birding trails. Reduce development risk.</td>
</tr>
</tbody>
</table>

### 2.4 Sources of Uncertainties

A fundamental tenet of AM is decision-making and achieving desired project outcomes in the face of uncertainties. The MAM program provides a framework for identifying, analyzing, and
managing uncertainties. Scientific uncertainties and technological challenges are inherent with any large-scale restoration project with the principal sources of uncertainty typically including (1) incomplete description and understanding of relevant ecosystem structure and function, (2) imprecise relationships between project management actions and corresponding outcomes, (3) engineering challenges in implementing project alternatives, and (4) ambiguous management and decision-making processes. It is important to determine the type of risk each uncertainty comprises and to discern what constitutes sufficient knowledge to proceed considering those risks.

Identified uncertainties associated with the restoration measures considered under this study include:

- Natural variability in ecological and physical processes (e.g., geomorphic variability and barrier island evolution).
- Life expectancy of the barrier island system without continued restoration and sand placement.
- The long-term fate of placed material.
- Climate-change variability, such as tropical cyclone frequency, intensity, and timing.
- Climate-change effects in redistributing sand placed as part of the project.
- Future rate of relative sea level rise (subsidence plus eustatic variability), how much sea level will rise at the barrier islands, whether the rate of rise will be relatively constant or accelerate and the island's response.
- Sediment utilization if storm impacts occur to historic and cultural resources.
- Borrow area impacts to sediment transport processes.
- Socio-economic and cultural, including effects on commercial and recreational activities, properties and infrastructure, and historic and cultural resources.

Climate change and rates of sea level rise are important scientific uncertainties for barrier island projects. These uncertainties were included in the forecast modeling of Dauphin Island by selecting three static sea-level increases (0.3 m, 0.5 m, and 1.0 m) derived from the USACE sea level change 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. The future sea level rise scenarios provide understanding of potential effects that can be incorporated into the planning, engineering and design, construction, operation and maintenance, and monitoring of selected alternatives. Ultimately, identifying and analyzing uncertainties and their associated risks allows the project team to discern what constitutes sufficient knowledge to proceed with a proposed course of action or how best to adaptively manage.

2.5 Rationale for Monitoring & AM Risk and Uncertainty Management

The primary reason for implementing AM is to increase the likelihood of achieving desired project outcomes given the uncertainties identified in Section 2.4. Adaptive management works best when it is tailored to the specific problem(s), designed to ensure accountability and enforceability, used to promote useful learning, and supported by sufficient funding (Doremus et al., 2011). Although all restoration projects should consider AM, there may be some projects or increments of project for which AM may not be applicable. AM is warranted when there are consequential decisions to be made, when there is an opportunity to apply learning, when the objectives of management are
clear, when the value of reducing uncertainty is high, and when a monitoring design can be put in place to reduce uncertainty (Williams et al., 2009). Adaptive management should not be used where or when there is a lack of flexibility in project designs and mistakes may be irreversible, when learning is unlikely on the relevant time scale, or where no opportunity exists to revise or reevaluate decisions (Doremus et al., 2011).

Once a selected plan is identified through the Alabama Barrier Island Restoration Assessment, an evaluation should determine if AM is applicable and would better enable the project to meet stated goals and objectives. Several questions will be considered to determine if AM could be applied to the project or a portion of the project:

1) Are the ecosystems to be restored sufficiently understood in terms of hydrology and ecology, and can project outcomes be accurately predicted given recognized natural and anthropogenic stressors?
2) Can the most effective project design and operation for achieving project goals and objectives be readily identified?
3) Are the measures for this restoration project performance well understood and agreed upon by all parties?
4) Can project management actions be adjusted in relation to monitoring results?

A ‘No’ answer to questions 1-3 and a ‘Yes’ answer to question 4 qualifies the project as a candidate that could benefit from AM.

3.0 Monitoring Plan

An effective monitoring program is required to determine if project outcomes are consistent with original project goals and objectives. The strength of a monitoring program developed to support AM lies in the establishment of feedback between continued project monitoring and corresponding project management. Consistent with the USACE Civil Works (CECW-PB) Memo dated 31 August 2009, the monitoring plan: “…includes the systemic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether Adaptive Management may be needed to attain project benefits.”

The elements proposed in this section include the elements that are typical for barrier island restoration project in the Gulf region. It is recommended that monitoring data collection occurs pre-construction, during construction, and post-construction monitoring to determine barrier island restoration success. Any additional monitoring that will be collected during construction by contractors as required by project plans and specifications that may support the monitoring proposed in the MAM plan should also be included or referenced when that information becomes available. Monitoring should continue until the trajectory of ecological and/or physical process changes as defined by project-specific objectives in the selected alternative meet the success criteria. It is anticipated that a 10-year post-construction monitoring period will be needed to determine if success criteria have been met. No further monitoring needs to be performed once success has been achieved.
Monitoring activities should utilize and leverage all existing data and monitoring guidance pertinent to developing a project-level MAM plan and evaluating the project. Integrating with existing monitoring efforts underway improves consistency in collection efforts and commonly reduces costs. Monitoring and research programs that could provide leveraging opportunities include:

- RESTORE Council Monitoring and Assessment Program, Monitoring Inventory and Baseline Assessments Compilation
- Natural Resources Damage Assessment, Monitoring and Adaptive Management Manual
- Gulf of Mexico Avian Monitoring Network, Strategic Avian Monitoring Guidelines
- National Academy of Science, “Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico” Report
- Dauphin Island Sea Lab, Alabama Center for Ecological Resilience
- U.S. Geological Survey (USGS) Barrier Island Evolution Research Project
- USGS Mississippi Water Science Center Data Collection
- National Park Service Inventory and Monitoring Program at Gulf Islands National Seashore
- Mississippi Coastal Improvements Project
- Louisiana Barrier Island Comprehensive Monitoring Program
- USACE National Coastal Mapping Program

3.1 Monitoring Plan Elements

Defining and assessing progress towards meeting project objectives are crucial components of the MAM program. Table 2 outlines the proposed performance measures, desired outcomes and minimum monitoring design that may be needed to measure restoration progress, determine ecological success and support the AM program should changes need to be made to improve project performance. This section identifies the potential performance measures associated with the current project objectives. The performance measures should be refined, using the CEM, and finalized once a construction project or restoration alternative is selected.

Table 2. Proposed Performance Measures, Desired Outcomes, and Monitoring Design

| Objective 1. Restore ecological function of Dauphin Island to support the coastal region by maximizing habitat and focal species. |
|---|---|
| (1) Measure Type(s): | Ebb Tidal Shoal; Gulf Beach; Back Barrier and Marsh Restoration; Land Acquisition |
| Performance Measure(s): | Habitat Composition, Vegetation Distribution and Land/Water |
| Desired Outcome: | Increase the habitat diversity and acreage of emergent and submerged habitats including barrier flats, beach, dune, intertidal flats, intertidal beach, intertidal marsh, woody vegetation, and woody wetlands. |
| Monitoring Design Summary: | High-resolution orthophotography and light detection and ranging (lidar) should be collected annually before and during construction, and at two additional times within a 10-year monitoring effort. These data should be used to map habitats using the same methodology and classification scheme used to develop the 2015 habitat map (Enwright et al., 2017, Enwright et al., 2019) for Dauphin Island, Little Dauphin Island, and Pelican Island. Field
investigations should be conducted to ground-truth various geomorphic and vegetation habitats in the field with corresponding signatures on orthophotography. Multitemporal satellite imagery (e.g., Sentinel-2 and Landsat 8) should be used to produce maps of water, sand, and vegetation for all available cloud-free available imagery for the entire MAM monitoring effort. These data should be used to understand changes in land/water and habitat dynamics before and after restoration measures are implemented.

<table>
<thead>
<tr>
<th>(2) Measure Type(s):</th>
<th>Gulf Beach; Land Acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Measure:</td>
<td>Nesting Shorebirds Distribution and Abundance</td>
</tr>
<tr>
<td>Desired Outcome:</td>
<td>Improve nesting potential in newly created habitats.</td>
</tr>
</tbody>
</table>

**Monitoring Design Summary:**
Trained bird monitors (observers) should conduct bird identification, counts, habitat use, behavior observations, and locational assessments of all observed solitary and colonial nesters, and winter migrants following the USFWS, Ecological Services Office, Jackson, Mississippi, non-breeding season survey guidelines, National Park Service guidelines (Byrne et al. 2009), or Florida Shorebird Alliance breeding bird protocol, or equivalent. At a minimum, monitoring (counts or relative abundance) should be conducted weekly or bi-weekly 1 year pre-, during, and 2 years post-construction after project equilibrium. Sampling interval/frequency should be consistent over all years. Nests should be monitored to minimize nest loss during construction of Gulf beach measures and also to evaluate changes in nesting effort by species over time. Tracking of emergent and submerged habitat types over a 10-year post-construction monitoring period will be used with any available data as identified through the Gulf of Mexico Avian Monitoring Network to help access nesting potential over time.

**Objective 2. Restore physical processes of Dauphin Island**

<table>
<thead>
<tr>
<th>(1) Measure Type(s):</th>
<th>Ebb Tidal Shoal; Gulf Beach; Back Barrier and Marsh Restoration; Land Acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Measure(s):</td>
<td>Elevation and Derived Geomorphic Profiles (slope, width, shoreline change)</td>
</tr>
<tr>
<td>Desired Outcome:</td>
<td>Net loss of Dauphin Island area benefiting from the measure should not be greater than the long-term average identified in Smith et al. (2018) over the 10-year monitoring period.</td>
</tr>
</tbody>
</table>

**Monitoring Design Summary:**
To capture changes, simultaneous near-vertical aerial imagery and lidar surveys should be acquired before and after construction and at two additional times over a 10-year post-construction monitoring period. To evaluate the effectiveness of the restoration design, measurements should be compared with previous measurements of historic shoreline change rates, foreshore slopes, elevations and volumetric changes within the system when combined with bathymetric surveys following approaches outlined in Smith et al. (2018) or equivalent.

| (2) Measure Type(s): | Ebb Tidal Shoal; Gulf Beach |
### Performance Measure: Bathymetry

**Desired Outcome:** Increase sediment availability for littoral transport along Dauphin Island.

**Monitoring Design Summary:** Bathymetric surveys of the nearshore should be collected at similar time intervals to island morphology and shoreline change to track the subaqueous movement of sand transported from the subaerial beach during initial beach adjustments toward dynamic equilibrium and in response to storm events. Single and multi-beam approaches should be used as outlined in DeWitt et al. (2017) and Flocks et al. (2018) or equivalent.

### Objective 3. Minimize social impacts associated with impacted properties, infrastructure, human use, and cultural resources

1. **Measure Type(s):** Ebb Tidal Shoal; Gulf Beach; Back Barrier and Marsh Restoration; Land Acquisition

   **Performance Measure:** Land/Water

   **Desired Outcome:** Emergent beach, dunes, marshes as well as shoal platforms continue to buffer public infrastructure and/or significant cultural resources such as the Sand Island Lighthouse.

   **Monitoring Design Summary:** Aerial imagery and lidar surveys should be acquired before and after project construction, and at two additional times over a 10-year monitoring period. Bathymetric surveys should also be collected as described in objective 2.

2. **Measure Type(s):** Ebb Tidal Shoal; Gulf Beach; Back Barrier, Marsh and Tidal Flat Restoration; Land Acquisition

   **Performance Measure:** Access or Direct Impact to Properties Based on Existing Types of Use (e.g., hunting, fishing, or other recreational use)

   **Desired Outcome:** Minimize impacts to public and private properties.

   **Monitoring Design Summary:** To be determined upon selection of restoration alternative.

### Objective 4. Minimize project costs

**Measure Type(s):** Ebb Tidal Shoal; Gulf Beach; Back Barrier and Marsh Restoration; Land Acquisition

**Performance Measure:** Project costs

**Desired Outcome:** Design, construct, and operate and maintain selected alternative within identified budget.

**Monitoring Design Summary:** To be determined upon selection of restoration alternative.

### 4.0 Assessment

The assessment phase of the implementation framework (Figure 3) compares the results of the monitoring efforts to the Alabama Barrier Island Restoration Assessment performance measures that reflect the goals and objectives of the restoration action.

This assessment process measures the progress of barrier island restoration in relation to the stated project goals and objectives, performance measures, and desired outcomes. The assessments
should continue through the life of the project or until it is decided that the project has successfully achieved (or cannot achieve) its goals and objectives.

4.1 Assessment Process

The MAM team should identify a combination of qualitative and quantitative methods for comparing the values of the performance measures produced by monitoring with the selected values of those measures that define criteria for decision-making.

Appropriate statistical comparisons (e.g., hypothesis testing, ANOVA, multivariate methods) should be used to summarize monitoring data and compare these data with stated metrics. Assessments should be documented as part of the project reporting and data management system.

A MAM team should collaborate with project managers and decision-makers to define significant differences between the values of monitored performance measures and the desired values that will constitute variances. Variances should be used to recommend AM actions, including (1) continuation of the project without modification, (2) project modifications, (3) consideration of new project features, or (4) termination of the project.

The CEM (Attachment 1) helps describe the linkages between stressors and performance measures and may be used to further define management actions based on monitored results. Assessments will help determine if the observed responses are attributable to restoration actions, and are either undesirable (e.g., are moving away from restoration goals) or in accordance with specified success criteria. If performance measures are not responding as desired or the stressor has not changed enough in the desired trajectory (for example, there is a reduction in important habitat), then AM considerations should be identified by a MAM team. If the stressor has changed as expected/desired and the performance measure has not, additional research may be necessary to understand why.

At this time, it is proposed that an initial project assessment be completed using pre-construction baseline data. Assessments are recommended to occur every 3 years and after acute events (e.g., tropical events) as necessary. Ultimately the determination of the frequency of assessment should be based on: (1) relevant temporal scales of the performance measures; (2) time required to obtain sufficient monitoring results and analysis for meaningful comparisons with the decision criteria; (3) consequences (ecological, socioeconomic, political, stakeholder) of variances with decision criteria; (4) logistical requirements to perform the assessment; (5) availability of the AM personnel; (6) funding; and (7) occurrence of acute events.

4.2 Documentation and Reporting

The performed assessments will be documented, and assessment results communicated to restoration management. This includes production of periodic reports that should measure progress towards project goals and objectives as characterized by the selected performance measures and decision criteria. The detailed reporting of monitoring results and AM evaluations should be in the form of an Assessment Report.
5.0 Data Management

Data management is a vital component of any long-term monitoring plan and the overall AM process. To maintain hydrological, biological, and physical data, the data must be stored, organized, and archived in an efficient and intuitive structure. All data collected should be analyzed for sensitivity and protected accordingly. Using a public and/or password-protected web interface, spatial and temporal aspects of applicable data types should be available for accessing restoration project progress and for use in AM decision-making. Each distinct data type collected should comply with its specific data format, delivery, and metadata standard. These standards were developed as a part of this study and are described in a Data Management Plan (DMP; Appendix A). The DMP is a living document and can be refined once a selected alternative is identified. Any new data types that are identified as a part of the selected alternative can be added to this DMP as well as additional details as appropriate, including information on data access, standardization, archival, and public release.

6.0 Adaptive Management and Decision-Making Processes

Scientific, technological, socio-economic, engineering, and institutional uncertainties are challenges inherent with any large-scale ecosystem restoration project, and are commonly the reason many programs rely on AM. However, many AM programs lack formalized decision structures to integrate learning about effectiveness of management actions and system dynamics and often utilize a “trial and error” approach to implementing corrective actions (NRC 2004, Rist et al., 2013). Formal AM, on the other hand, necessitates decision analytic models that explicitly address uncertainties to inform the iterative adjustment of actions through time. Structured Decision Making (SDM) is a collaborative process that includes stakeholders, managers and scientists to define management objectives, alternative actions, external drivers, predictive models, and quantitative methods for optimization and tradeoff analysis, which is used to identify optimal decisions and key uncertainties to be addressed through further gathering of information (Conroy and Peterson 2012, Gregory et al., 2012). This process has been used effectively to develop decision analytic models that can then be used to inform AM programs (Nichols et al., 2007, Conroy and Peterson 2012, Moore et al., 2013).

Under this study, SDM was used to determine objectives (Section 2.2) associated with the long-term sustainability and resiliency of the barrier island, its habitats, and the living and coastal marine resources and estuarine conditions it supports and to investigate the consequences of various alternatives for restoration of Dauphin Island. The SDM framework (Appendix I) provided a formal, transparent and replicable process for assessing tradeoffs among various restoration measure types (Ebb Tidal Shoal, Gulf Beach, Back Barrier and Marsh Restoration, and Land Acquisition) in optimally addressing the objectives. It also used modeling output to evaluate the major uncertainties associated with barrier island restoration, namely coastal storm frequency and intensity and sea level rise, and how the Dauphin Island system would respond to changes in climate and sea level over time. For example, this analysis helped decision-makers determine that a potential adaptive management action to account for these identified risks and uncertainties would be regular maintenance of intertidal marsh under accelerated sea level rise, especially under conditions of infrequent storms and low overwash depth (i.e., minimal elevation gain through sedimentation from overwash). Additional actions should be evaluated once a selected alternative is identified.
The monitoring plan should also be adaptively managed and adjusted as necessary based on any changes in management and stakeholder values. As part of the SDM framework, investigators identified habitat preferences for 44 species of value that are known to occupy Dauphin Island using a literature review and a non-metric multi-dimensional scaling (NMDS) model. Based on results, 11 proxy species represent the fauna that have strong habitat affinities on Dauphin Island: Seaside Sparrow, Reddish Egret, Oyster Catcher, Least Tern, Swainson’s Warbler, Loggerhead Shrike, Brown Pelican, Piping Plover, Loggerhead Sea Turtle, Bottlenose Dolphin, and Gulf Sturgeon. Once objectives are refined upon the final identification of restoration actions to be included in the selected alternative, additional proxy species other than nesting birds may be included in the monitoring plan.

Once the decision makers choose restoration measures or portfolios of measures, the iterative phase of AM will begin and monitoring of restoration outcomes will ensue to both determine if objectives are being met and/or if changes in restoration measures are needed. The monitoring design (previously described Section 3) provides data necessary to evaluate progress towards achieving project goals and objectives, and to compare against modeled sea level rise scenario outcomes. This should inform iterative decisions about future project adjustments that may be needed through AM. The assessment reports should be used by the project sponsors to evaluate project status and any potential adaptive management needs.

7.0 Lessons Learned

The MAM program should allow for lessons learned and provide information and or recommendations to other programs and or future projects. Monitoring results from the project should help refine modeling, design, and predictions of physical and ecological processes that may in turn inform design of future restoration projects.

The MAM program should compile lessons learned, best practices and experiences relevant to implementation of barrier island restoration, technical and organizational challenges, and monitoring and adaptive management approaches. Lessons and experiences should be clearly documented with recommendations so that they can be easily applied to future barrier island and ecosystem restoration programs and projects. Documenting the lessons learned ultimately aims to reduce recurring, technical or programmatic issues that negatively impact cost, schedule, restoration project performance and success.

Future potential projects that may benefit from lessons learned include operation and maintenance of Mobile Harbor Federal Navigation Channel and other state and local planning initiatives including the planning efforts in the State of Mississippi.

8.0 Costs

The MAM program establishes a feedback mechanism whereby monitored conditions should be used to adjust or refine construction and or maintenance actions to better achieve project goals and objectives. This MAM plan includes the minimum monitoring actions determined necessary to evaluate project success for the four restoration measure types and provide information to inform the AM program. For cost estimating purposes, a 10-year post-construction monitoring period was considered. Once ecological success has been established, monitoring would cease.
The budget estimate of 3% of total project cost was identified based on costs of similar programs, the risks and uncertainties of confronting climate change and sea level rise, and the potential need for adaptive management actions. The estimate includes the monitoring necessary to determine project success, data management, adaptive management, and overall MAM program management. Detailed cost estimates will need to be developed as additional information becomes available.

9.0 References


10.0 Attachment 1. Dauphin Island Conceptual Ecological Model