# MISSISSIPPI COASTAL IMPROVEMENTS PROGRAM

## Comprehensive Barrier Island Restoration

## Monitoring and Adaptive Management Plan

July 31, 2018

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## 1.0 Introduction

The Mississippi barrier islands are dynamic coastal landforms that form the first line of defense for the Mississippi mainland coast against the wave energy of the Gulf of Mexico. The Mississippi barrier islands are experiencing changes in both island geomorphology (land area and habitat) and physical processes (erosion and accretion) due to frequent intense storms, rise in relative sea level, and changes in sediment supply (associated with inlet hydraulics, channel configuration, and shoal dynamics) (Byrnes et al., 2012). The loss of these barrier islands potentially both threatens the highly productive Mississippi Sound estuarine ecosystem, and exposes the Mississippi Gulf Coast mainland, and its associated wetland habitats, to increasing damages from saltwater intrusion and tropical storms.

Hurricane Camille (1969) caused extensive land loss on the barrier islands, splitting Ship Island into two smaller islands and reducing overall elevation. Little natural recovery occurred in the years leading up to 2005 when Hurricane Katrina caused widespread damage along the Mississippi Gulf Coast. The opinion has been repeatedly expressed by the public that the damage done to the mainland by Hurricane Katrina was exacerbated by the reduction in barrier island extent and elevation associated with Hurricane Camille, especially the opening of the "Camille Cut", which now separates East and West Ship islands. In 2009, in response to the Department of Defense Appropriation Act of 2006 (P.L. 109-148), the U.S. Army Corps of Engineers (USACE), Mobile District, in conjunction with other Federal and State agencies, developed the Mississippi Coastal Improvement Program (MsCIP) to reduce future storm damage along the Mississippi Gulf Coast. Restoring the natural ability of the Mississippi barrier island system to reduce the impact of hurricanes traversing the Mississippi Gulf coast became the primary goal of the Comprehensive Plan. The centerpiece of the plan is the USACE, Mobile District proposal to restore sediment to the system, in order to preserve and protect the Mississippi barrier islands and, subsequently, the Mississippi Sound and the Mississippi mainland.

A key feature of this plan is the implementation of a Monitoring and Adaptive Management (MAM) Program before, during, and after project construction, which will be used to evaluate the effectiveness of the restoration of a portion of the Mississippi barrier islands and altered placement of dredged-material disposal at Horn Island Pass in improving regional conditions. This plan will allow the USACE, Mobile District to assess restoration progress relative to both short- and long-term effects to the barrier island system. Furthermore, through the use of adaptive management (AM) principles, this monitoring plan will provide the information necessary for adjusting project activities, if necessary, in order to better meet project goals and objectives, and will, ultimately, provide the basis for improving future project design and the management of coastal resources.

This MAM Plan, designed to best evaluate progress towards meeting project goals and objectives, describes the organizational structure for the MAM process, identifies key uncertainties, provides potential AM actions, and provides time and cost estimates; all of which will be used to guide project planning, implementation, and performance. Due to their highly variable nature and/or the scientific uncertainty of possible responses, several key factors, such as ecosystem dynamics, engineering applications, and institutional requirements, are likely to change and/or evolve over the project's life. For this reason, the MAM Plan is designed as a living document, and will be regularly updated to reflect the new information and insights acquired through the monitoring and/or management processes. This iterative approach is expected to improve the identification and resolution of key uncertainties, elucidate lessons learned, and develop new and effective processes for coastal resource management.

## 1.1 Introduction to Monitoring and Adaptive Management

Adaptive management is distinguished from traditional long-term monitoring through, in part, the implementation of an organized, coherent, and documented decision process. Distinguishing aspects of the AM process include exploring alternative processes for meeting 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 MsCIP program 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 associated with the processes associated with ecological systems and their response to management actions. It is important to emphasize that AM is not a random trial-and-error process, and that it is not simply ad-hoc, reactive responses to changed conditions. Rather, as an organized and flexible set of decision-making processes, a central feature of AM is the development and execution of a monitoring and assessment program designed to analyze and understand responses of the system to implementation activities.

The MsCIP 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
  - Risks and uncertainties will be acknowledged, identified, and characterized
  - Uncertainties will be analyzed and exploited to identify key gaps in information and understanding
- Implement systematic monitoring of outcomes and impacts
  - Scientific information obtained through ongoing monitoring processes will be used to evaluate and manage uncertainties to achieve the desired goals and objectives
  - Goals and measurable indicators of progress toward those goals will be explicitly stated
  - Monitoring results will be used to demonstrate that the project is meeting or exceeding. performance goals and achieves "ecological success" as required by USACE (See Section 1.2)
  - Beneficial and detrimental system responses will be detected and identified as early as possible as a means of quantifying the effects of these responses

  - Hypotheses and performance measures will be evaluated and used to revise conceptual ecological models, as appropriate
- Incorporate an iterative approach to decision-making
  - The monitoring data will be used to influence future management decisions
  - Feedback loops will be developed so that monitoring and assessments produce continuous and systematic learning, which, in turn, will be incorporated into subsequent planning and decisions
  - Management flexibility will be incorporated in the design and implementation of programs or projects
  - Projects and programs will be implemented in phases to allow for course corrections based on new information
- Use AM to provide a basis for identifying options for improving the design, construction and/or operation of MsCIP projects and components
- Develop reports on the status and progress of the MsCIP Barrier Island Restoration for the agencies involved, the public, Congress, and stakeholders
- Enhance predictive capability through improvements in simulation models before and after project construction
- Provide information that summarizes and develops 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, including strategizing that involvement, clearly communicating with the public, and establishing 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 USACE Project Life Cycle (planning, design, construction and operation and maintenance). The MAM process is not elaborate or duplicative, but rather enhances previously existing activities. The basic process of MAM for USACE projects (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

**Terminate** Project, if project goals and objectives are not being achieved and the decision is made not to adjust the project or no adjustments are possible

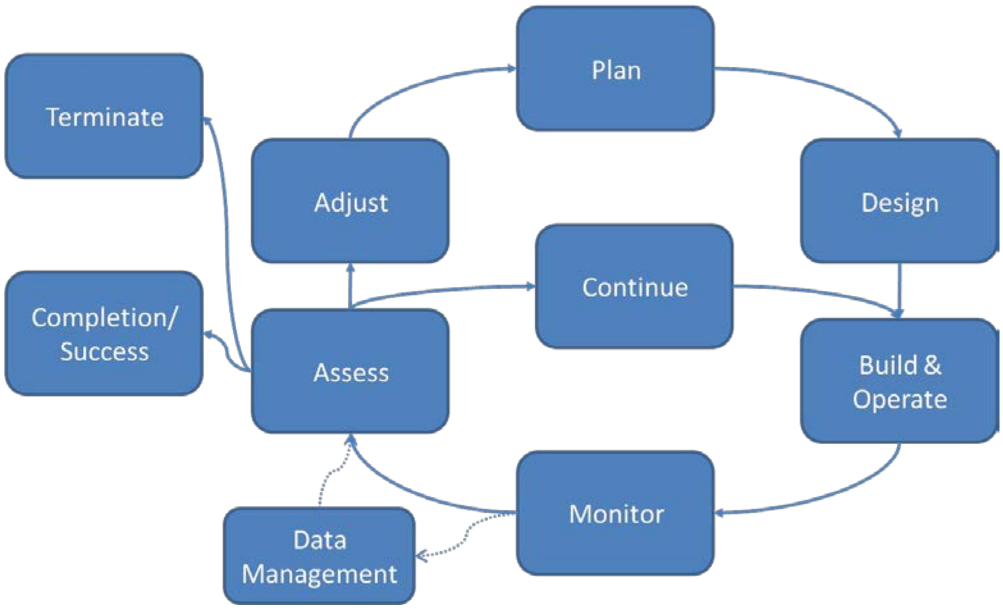


**Figure 1.** Monitoring and Adaptive Management process for the USACE Civil Works.

### 1.2 Authorization for Monitoring and Adaptive Management

Section 2039 of the Water Resources Development Act (WRDA) of 2007 and Implementation guidance for Section 2039, in the form of a CECW-PB Memo dated 31 August 2009, require ecosystem restoration projects to develop a plan for monitoring the success of the ecosystem restoration and to develop an AM Plan (contingency plan). See Appendix B.

#### 1.2.1 Monitoring Plan

- The plan must specify the 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 actual results compared to predicted outcomes
- Monitoring plan has been reviewed during Agency Technical Review (ATR)
- Monitoring will be continued until "ecological success" is documented by the USACE in consultation with federal and state resource agencies
- Monitoring costs must be included as part of the project cost and cannot increase the federal cost beyond the authorized dollar limit. Monitoring can end sooner if success is determined
- Funding for monitoring beyond 10 years post-construction is a 100% non-MsCIP responsibility

### 1.2.2 Adaptive Management/Contingency Plan

- The adaptive management plan must be appropriately scoped to project scale
- The rationale and cost of AM and anticipated adjustments will be reviewed as part of the decision document
- Significant changes needed to achieve ecological success that can't be addressed through operational changes or the AM plan may be examined under other authorities
- Costly AM plans may lead to re-evaluation of the project

## 1.3 Program Structure for Implementation of Monitoring & Adaptive Management

The management structure of the MAM program associated with MsCIP includes several components, namely the Program Management Team, Adaptive Management and Monitoring Oversight Committee, the Technical Advisory Group (TAG), Data Management, the Regional Science and Leadership Group (RSLG), and stakeholders. The program implementation establishes communication lines that facilitate coordination between these interlinking management groups.

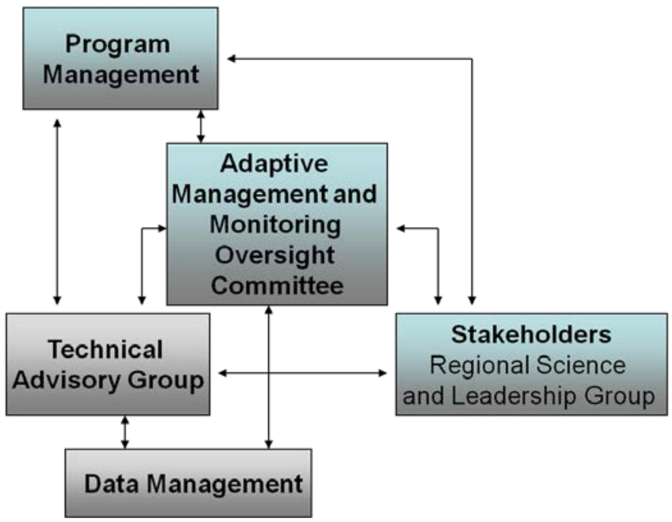


**Figure 2.** Program Structure for MsCIP Monitoring and Adaptive Management.

### 1.3.1 Program Management Team

The MsCIP Program Management Team consists of senior leaders from the USACE, Mobile District, the Mississippi Departments of Marine Resources (MDMR) and Environmental Quality (MDEQ), and the National Park Service (NPS) (Appendix C). The Program Management Team will vet MAM program issues, and consider recommendations for AM or monitoring actions from the Adaptive Management and Monitoring Program Oversight Committee, the Technical Advisory Group, the Data Management Team and the Regional Science and Leadership Group. The Program Management Team will make determinations of whether monitoring or AM actions are required. In accordance with Section 2039 of the 2007 Water Resources Development Act, the Program Management team will coordinate with the USACE Mobile District Commander and the South Atlantic Division (SAD) Commander once a determination has been made that operational and/or structural changes (AM) may be needed to ensure that the ecosystem restoration project meets specified success criteria. Likewise, the Program Management Team will coordinate with the USACE District Commander and the SAD

Commander for final determination that project success has been achieved and to cease monitoring efforts.

### 1.3.2 Adaptive Management and Monitoring Oversight Committee

The Adaptive Management and Monitoring Program Oversight Committee consists of MsCIP project and resource managers from the USACE, USGS, and NPS. The Adaptive Management and Monitoring Program Oversight Committee will report to the MsCIP Program Management team, and provide progress reports as necessary on the status of monitoring efforts and project results. A list of these team members is provided in Appendix C. The Committee will:

- Provide recommendations regarding the need for AM actions to better meet expected restoration goals and objectives
- Identify additional monitoring or AM program requirements and set priorities for the TAG, as needed
- Work with the TAG to establish the MAM program and to develop and coordinate the individual MAM plans
- Be responsible for administrating the implementation of AM, monitoring and assessment processes detailed in the MAM Plan
- Ensure that the monitoring data and assessments being produced are properly used to determine project success and to inform future decision-making
- Lead the effort to compile lessons learned from the MAM program, and to assist the Program Management Team in making the best possible decisions regarding future design and implementation strategies
- Coordinate with other Gulf of Mexico/regional restoration efforts including, but not limited to, Revived Economies of the Gulf Coast States Act (RESTORE Act), Natural Resource Damage Assessment (NRDA), Louisiana Coastal Area (LCA), and Alabama and Louisiana State Planning Efforts

### 1.3.3 Technical Advisory Group

Technical Advisory Group Members

The TAG is divided into Official and Reach-back members. The Official TAG members will be responsible for producing the MAM Plan. A subset of the Official Team is a core team that will be responsible for initially drafting work products and sending draft products to the rest of the Official Team for review, as well as providing comments and additional input as necessary. Reach-back members are a potential technical-expert resource that will be brought in as necessary to support Core and Official team members. A list of TAG members is provided in Appendix C.

The TAG will be involved in the pre-construction, during construction, and post-construction MAM activities. The purpose of the TAG is to bring together the necessary technical experts to develop the monitoring and assessment protocols required to determine whether performance measures have been met and ecological success has been achieved. During pre-construction, the TAG will:

- Document the methods, procedures, and monitoring sampling design necessary to evaluate ecological success
- Develop alternative AM processes that could be implemented if the project is not performing as expected

- Coordinate with, and leverage other monitoring efforts where possible (i.e. US Geological Survey [USGS] Barrier Island Evolution Research [BIER] Project), to reduce MsCIP monitoring costs and design an approach consistent with other ongoing monitoring efforts
- Develop a conceptual ecological model (CEM) for the Barrier Island Ecosystem (using existing information where possible), including development of performance measures, success criteria, and triggers which will be used to evaluate project performance. The developed CEM is further described in Section 2.1.1 and presented in Appendix F. Success criteria and triggers have been identified and included in Section 3 and 6
- Develop the specific details of the protocols for processing, analyzing, and summarizing the data collected through the MAM Plan
- Develop the methodology for evaluating project restoration progress and determining if AM is needed; this includes the identification of alternative AM actions, should contingency plan(s) be needed

In addition to the pre-construction planning activities, the TAG will:

- Be involved, both during and post-construction, as activities under the MAM plans are implemented and the project is monitored and assessed, in developing an understanding of the responses of the system to project implementation, especially as related to the established performance measures
- Work with the Adaptive Management and Monitoring Oversight Committee to ensure that all monitoring data collection, processing, and analysis are consistent and in accordance with protocols developed in the MAM Plan. More specifically, the TAG will be responsible for actual project performance assessment and interpreting that performance on the basis of data analyses
- Produce periodic reports that measure progress towards project goals and objectives, and make recommendations to the Adaptive Management and Monitoring Oversight Committee and Program Management Team to improve MAM Plan performance

### 1.3.4 Data Management Team

A list of Data Management Team members is provided in Appendix C.

A Data Management Team has been developed to facilitate the management of data and information available for, and developed by, the MsCIP program. This includes data collected directly for the MsCIP program and by outside agencies and organizations in support of the program, including historical datasets, ongoing monitoring collections and new data collections generated from the MAM program. The Data Management Team has representation on the TAG and will develop the data standards for inclusion in the MAM Plan (Section 4.0). The Data Management Team will:

- Develop and provide the decision-support tools necessary to compare historical trends and management strategies with MsCIP project restoration
- Incorporate transparency into data and information delivery and visualizations, and facilitate determinations of restoration progress, adjustments to restoration strategies as needed, and demonstrations of lessons learned

### 1.3.5 Regional Science and Leadership Group

The RSLG is a multi-agency and multi-disciplinary group of federal and state resource agencies and stakeholders who are involved in the MsCIP program. The members of the Program Management Team, the Adaptive Management and Monitoring Oversight Committee, TAG, and the Data Management Team will also participate on the RSLG, which will

- Provide peer review on project monitoring results
- Review MAM deliverables produced by the Adaptive Management and Monitoring Oversight Committee, TAG and the Data Management Team

The broad membership of the RSLG aims to facilitate coordination with other regional restoration efforts (such as Resources and Ecosystems Sustainability, Tourist Opportunities and RESTORE Act, NRDA, etc.). A list of RSLG members is provided in Appendix C.

## 2.0 Monitoring and Adaptive Management Planning

An interagency team with members from the USACE, Mobile District, NPS, MDEQ, MDMR, US Fish and Wildlife Service (USFWS), USGS, and Applied Coastal Research and Engineering developed the MAM Plan for the comprehensive barrier island restoration component of MsCIP. The actual scope of the MsCIP MAM Plan is based on project complexity, project uncertainties, flexibility in potential management options, and the stage of project development. The MAM Plan will be implemented during all project phases (pre-construction, during construction, and post-construction), and will be updated regularly to reflect new information, including significant progress or resolution of recognized uncertainties, as well as any new uncertainties that might emerge during and following project construction.

### 2.1 Monitoring and Adaptive Management Program Set-up Phase

The MAM Program includes a Set-up Phase (Figure 3) and an Implementation Phase (Section 2.2), with the Set-up Phase proceeding concurrently with the planning process. The MAM Plan for the project will be developed while planners are identifying problems and opportunities, inventorying and forecasting resource conditions, evaluating and comparing alternative formulations, and selecting a plan. In addition to items developed during the planning process, a CEM will be developed, uncertainties will be identified, and performance measures, targets, and other decision criteria (including AM triggers) will be established.

Engagement with stakeholders throughout the project planning and implementation phases is a critical element in developing and maintaining common understandings of the goals and objectives, expectations of results, and potential commitment of resources. All phases of the MAM process must be open, transparent, and accessible to stakeholders. Such interactions foster the mutual understanding of events and appreciation of the time and patience required to fully realize the benefits of restoration projects, and to manage unrealized expectations. It is essential that strong efforts be made to identify and engage all appropriate stakeholders. Project teams should continually seek to identify governmental and non-governmental organizations, groups and all 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).

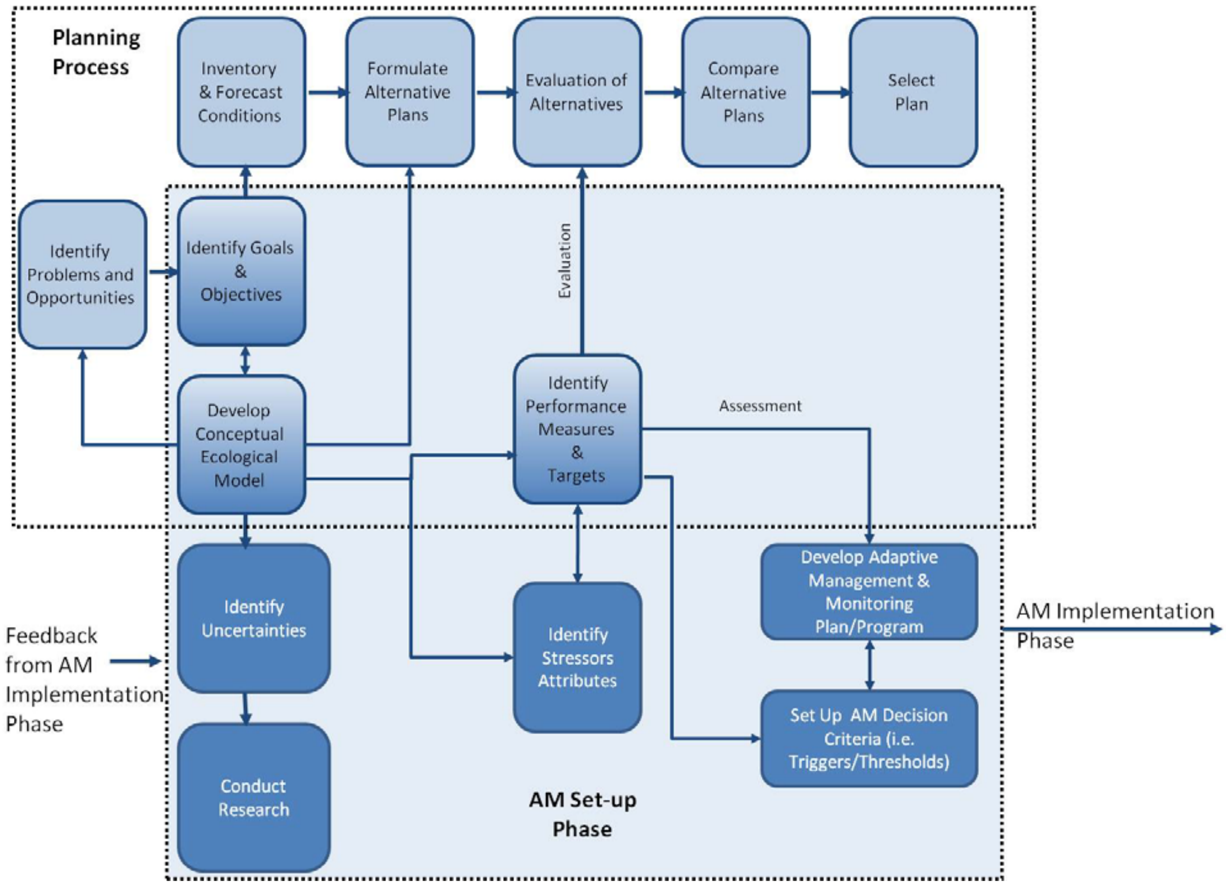


**Figure 3.** Monitoring and Adaptive Management Program Set-up Phase.

### 2.1.1 Conceptual Ecological Model

As part of the monitoring and AM planning process, a CEM (Appendix F) 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
(5) Communicating these findings in multiple formats

The MsCIP MAM program CEM assists with the identification of those aspects where the project can effect change. Specifically, the CEM identifies the major stressors, ecosystem drivers, and critical thresholds of ecological processes and attributes of the natural system most likely to respond to restoration features. The barrier island CEM, together with a structured decision analysis process described in Section 6, will be used to help confirm objectives, identify problems, opportunities, and uncertainties, and select attributes to be used as performance measures for monitoring. The CEM represents the current understanding of these factors and will be updated and modified, as new information becomes available, to assist with developing monitoring and AM during project planning and implementation phases.

Factors identified for the MsCIP Barrier Island project are listed below and further detailed in Appendix F.

**Drivers**

D1: Coastal Processes
D2: Acute Events
D3: Anthropogenic Activities

**Stressors**

S1: Littoral Sediment Transport
S2: Relative Sea Level
S3: Current and Tides
S4: Winds and Waves
S5: Storms
S6: Restoration
S7: Oil Spills
S8: Channel Dredging/Placement
S9: Human Use
S10: Cultural Resources

**Effects**

E1: Land Loss/Gain
E2: Biological Composition (community or species change)
E3: Elevation Change
E4: Habitat Alteration
E5: Altered Sediment Transport
E6: Altered Circulation

**Attribute**

A1: Habitat Cover of Emergent and Submerged Land
A2: Habitat Diversity of Emergent and Submerged Land
A3: Species of Concern
A4: Island Morphology
A5: Water Quality
A6: Cultural Resources

**Performance Measures**

PM1: Shoreline/Island Response (Subaerial, subaqueous)
PM 2: Water Circulation
PM 3: Habitat Composition and Utilization
PM 4: Sedimentation/Shoaling
PM 5: Species Diversity, Abundance and Distribution
PM 6: Salinity, Turbidity, Dissolved Oxygen

### 2.1.2 Goals and Objectives

In accordance with specific authorizations, prior reports, and collaborative interactions with stakeholders, the USACE, Mobile District defines restoration goals to achieve or resolve the identified problems, needs, opportunities, and agreed upon desired future conditions. The goals and objectives developed for project planning play a crucial role after project implementation in evaluating constructed project performance, reducing uncertainty, improving AM actions, and determining project success. Therefore, it is important to develop clear, measurable, and agreed-upon goals and objectives at the outset. To be useful for the MAM Program, project objectives, consistent with Engineering Regulation 1105-2-100, Planning Guidance Notebook, and including assessment and decision making, should be specific, measureable, and applicable over a specific time frame.

The overarching goal of barrier island restoration for MsCIP is environmental sustainability. This includes sustaining cultural resources and estuarine habitat in the Mississippi Sound by restoring barrier island habitat and natural sediment transport quantities to the levels reached prior to breaching and inlet formation along Ship Island.

The objectives for barrier island restoration for MsCIP are to:

- Maintain the estuarine ecosystem and resources of the Mississippi Sound
- Preserve the natural and cultural resources of the Mississippi barrier islands
- Restore the barrier islands physical structure to reduce storm damage impacts on the mainland coast of Mississippi
- Enhance the long-term littoral drift system for the Mississippi barrier islands

### 2.1.3 Restoration Actions

From west to east, the naturally-formed islands of the Mississippi Barrier Island system are Cat Island, West Ship Island, East Ship Island, Horn Island, Petit Bois Island, and Dauphin Island (Figure 4). Major inlets within the island system are Ship Island Pass, Little Dog Keys Pass, Dog Keys Pass, Horn Island Pass, and Petit Bois Pass. Sand Island (Disposal Area 10) was artificially created by the placement of littoral sand dredged from Horn Island Pass.

The USACE, Mobile District proposes to restore a portion of the Mississippi barrier islands through the placement of sand at, and adjacent to, Camille Cut to connect East and West Ship islands, and the augmentation of sediment to the updrift system along East Ship Island.

Additional sand has been placed on the northern shore of West Ship Island around Fort Massachusetts, and beach restoration is planned for Cat Island. Additionally, future placement of dredged material adjacent to Horn Island Pass will be located to enhance the natural transport of dredged material to Horn Island.


**Figure 4.** Project Area Map.

<u>Ship Island Restoration</u>

The Ship Island restoration component will be constructed in five phases. The first four phases will consist of dredging and placement activities, while the fifth phase will consist of dune planting on the newly restored Ship Island. Phases 3 and 4 will run concurrently and be completed at different locations (i.e., East Ship Island and Camille Cut, respectively). Phase 5 will commence upon completion of all other phases. It is estimated that the five phases will be completed over a period of 2.5 years. Individual phases are detailed below.

- Phase 1 consists of the placement of approximately 6.0 million cubic yards (mcy) of sand to construct the initial berm across Camille Cut, and approximately 0.9 mcy for a portion of the berm on East Ship Island. The East Ship Island berm, constructed adjacent to the Camille Cut berm along the west end of the southern shoreline of East Ship Island, will serve as a feeder source for Camille Cut until the remaining portion of the East Ship Island berm is constructed during Phase 3. It is estimated that Phase 1 will take 15 months to complete.
- Phase 2 consists of the placement of approximately 6.3 mcy of sand to raise and widen the fill at Camille Cut. Work under Phase 2 is expected to begin immediately upon completion of Phase 1, and is estimated to take approximately one year.
- Phase 3 consists of restoring the southern shoreline of East Ship Island. Approximately 5.0 mcy of sand will be placed to extend and expand the initial East Ship Island berm, constructed in Phase 1, and complete the restoration of the southern shoreline of East Ship Island. It is estimated that Phase 3 would be completed over a period of approximately eight months.
- Phase 4 consists of placing approximately 1.1 mcy of sand in the interior portion of the Camille Cut berm. The work is estimated to take approximately five months. In order to

facilitate establishment of dune vegetation, finer grain sized material from the Ship Island borrow area will be used as a cap on the Camille Cut fill section.

- Phase 5 consists of vegetating the Camille Cut restoration berm to restore stable dune habitat. The newly created island segment will be planted with such native dune vegetation as currently exists in adjacent coastal habitats. Selected species will include sea oats (*Uniola paniculata*), gulf bluestem (*Schizachyrium maritimum*), and/or other grasses and forbs. It is estimated the construction of Phase 5 will be completed in seven months.

<u>Cat Island Restoration</u>

The portion of restored Cat Island was acquired by BP following the Deepwater Horizon incident to facilitate the clean-up. Restoration work at Cat Island was accomplished under a separate contract, with the construction preceding the Ship Island Restoration efforts.

Restoration work at Cat Island, conducted from July through October 2017, consisted of the placement of slightly >2 mcy of sand along the eastern shoreline. The material was pumped onto the beach and shaped using land-based equipment. The construction profile is expected to adjust rapidly through the erosion of the upper profile, thereby mimicking the natural nearshore profile reaching equilibrium. The total equilibrated fill area encompasses approximately 305 acres. The planting with native dune vegetation finishing on November 15, 2017, and the turbidity barrier was removed on December 7, 2017.

### 2.1.4 Uncertainties

A fundamental aspect of AM is the ability to improve the decision-making process and achieve desired project outcomes in the face of uncertainties. The MAM Program provides a framework for identifying, analyzing, and managing uncertainties for the MsCIP Barrier Island Restoration program. Scientific uncertainties and technological challenges are inherent with any large-scale restoration project. Principal sources of uncertainty typically include (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 both determine the type of risk generated by each uncertainty and to decide what information is required to manage those risks.

Identified uncertainties associated with the restoration of the Mississippi barrier islands include:

- Natural variability in ecological and physical processes
- Geomorphic variability and barrier island evolution
- Life expectancy of the barrier island system without restoration
- The long-term fate of placed material
- Climate change variability, such as the frequency, intensity, and timing of tropical cyclones
- The effects of climate change on the redistribution of emplaced sand
- Relative sea level rise (subsidence plus eustatic variability)
  - Height of relative sea level rise at the barrier islands
  - Constant vs accelerating rate of rise
  - Island response to increasing sea level

- Gulf sturgeon population utilization of adjacent passes after closure of Camille Cut
- Bird species utilization of existing low-lying spits on the west and east tips for feeding, resting, and roosting after fill placement at Camille Cut and East Ship Island
- Projected recovery time and recruitment for benthic invertebrates
- Effectiveness of protection of existing submerged aquatic vegetation (SAV) and wetland habitat in the lee of East Ship and Camille Cut after restoration
- Water quality variability (e.g., salinity) in the lee of East Ship and Camille Cut after restoration
- Sediment utilization if impacts occur to historic and cultural resources from storms
- Borrow area impacts to sediment transport processes
- The hydrology of West and East Ship islands
  Potential effects on wetlands and island hydrology from the placement of sediment

Ultimately, identifying and analyzing uncertainties and their associated risks allows the project team to determine what constitutes sufficient knowledge to proceed with a proposed course of action and how best to adaptively manage. The project team has evaluated these uncertainties and the risks, and determined they are outweighed by the potential benefits of moving ahead. This list will be updated and the project re-evaluated as additional information is received and existing uncertainties and risks are minimized, or new uncertainties arise,

### 2.1.5 Performance Measures, Decision Criteria, Success Criteria and Adaptive Management Triggers

**Performance Measures (PM),** are commonly used in AM frameworks as indicators of progress toward a goal, objective, or target, and the desired outcomes of program and project implementation (Fischenich et al., 2012) as a means of assessing project outcomes and modify project performance. The CEM, by identifying potential stressors and drivers, provides a context for monitoring and tracking these goals and objectives, as funds allow. The selection of performance measures is determined by project goals and objectives. PMs should:

(1) Be measurable

(2) Have a relatively strong degree of predictability (*i.e.*, targets specified by predictive models or by best professional judgment)

(3) Be sensitive enough to change in response to project implementation

(4) Verify progress and evaluate hypotheses through monitoring and assessment (Fischenich et al., 2012)

See Section 3.1 for the performance measures developed through the MAM planning process, including the justifications for their selection.

Restoration targets for each performance measure are used to develop thresholds that serve as **Decision Criteria** to determine whether restoration success has been met (see "Success Criteria" description) or adjustments are needed (see "AM Triggers" description). Decision Criteria are specific values of monitored parameters used in evaluating program and project performance. These criteria can be based on reference sites, predicted values, or as comparison to historical conditions. They can be qualitative or quantitative, based on the nature of the performance measure and the level of information necessary to make a decision. The management options in response to the criteria can be adjusted over time as resource conditions change and understanding evolves.

- **AM Triggers** are thresholds that are used to determine the need for a corrective action. These criteria are used to determine if monitoring results support continued implementation of the project as designed, or if AM actions should be undertaken. AM triggers should be developed for performance measures, so that performance hypotheses about project outcomes can be evaluated to determine if management measure adjustments are needed (Fischenich et al., 2012).

- **Success Criteria** are used to assess project performance and the trajectory of ecological progress. Ultimately, success criteria will be used to help determine when ecological success has been achieved and determine whether monitoring may cease prior to the projected ten year post-construction monitoring period. Project success criteria have been identified based on the project objectives and performance measures, and are included in Section 3 of this plan.

- **Interim Targets** were developed concurrently with the success criteria and are included in Section 3. Interim targets are a means for evaluating progress towards meeting the success criteria over a shorter time scale, with an earlier date used to evaluate the trend of restoration progress; e.g. the expected progress at year 3 or year 5 if restoration is progressing as planned. The inability to meet an interim target indicates that AM actions could be needed to adjust the project.

## 2.2 Monitoring and Adaptive Management Program Implementation Phase

While the AM Set-up phase includes planning, the Implementation phase sets the MAM Plans into action (Figure 5). Projects will be designed, constructed, monitored, and assessed relative to stated hypotheses and evaluated relative to established Performance Measures, and Decision Criteria (AM Triggers, Success Criteria and Interim Targets). The Program Team will decide whether to alter the project and implement AM actions to improve plan performance based on assessment results.

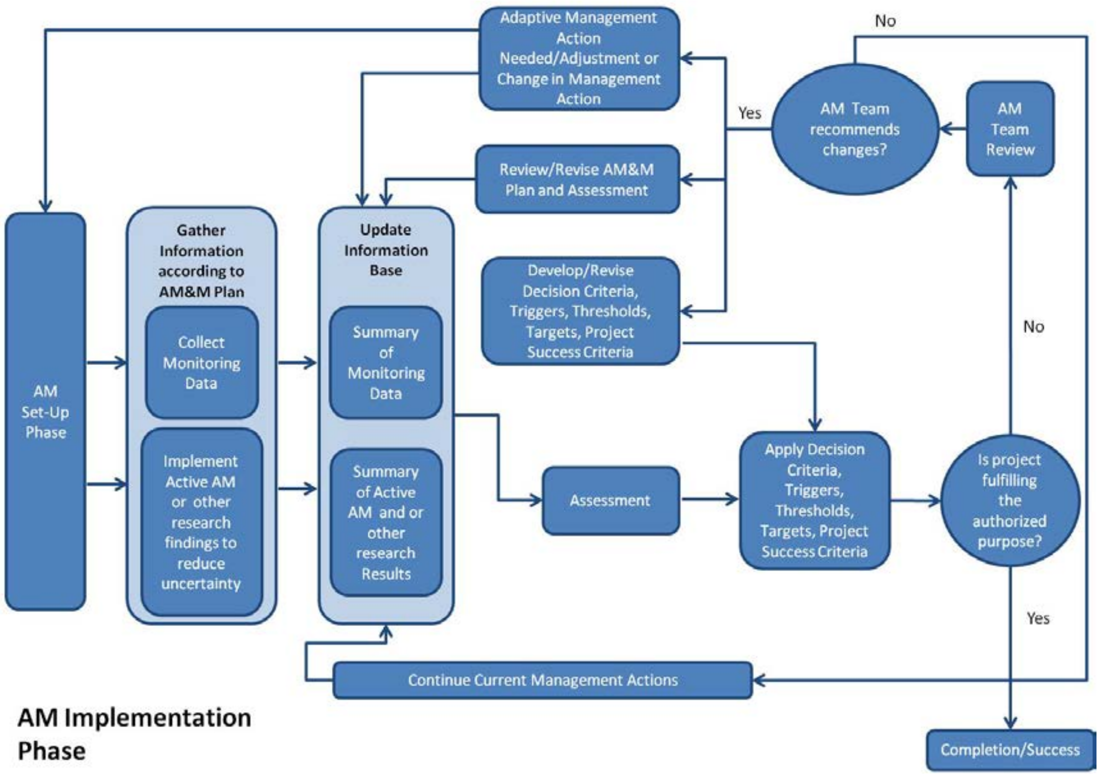


**Figure 5.** Implementation Phase of the Adaptive Management Framework.

Baseline monitoring should begin during or proceeding the design phase, prior to project construction. Monitoring will 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. A decision will be required on how to address changes in conditions. 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 such situations may increase the chances of overall project success. Design changes during construction may require changes to the MAM Plan.

After construction, the project will enter the iterative cycle of AM where monitoring data is used to assess impacts and gain an understanding of project performance. The results from the monitoring assessment will guide decision-making (Figure 1). The Operation and Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) manuals should clearly communicate the MAM Plan's processes including: monitoring parameters, frequency and duration of monitoring and assessment, performance measures, decision criteria, and options for adjustment (if necessary) to increase project success.

The results of the monitoring program will be used to assess system responses for evaluation of overall project performance, and assemble Assessment Reports as outlined in the MAM Plan (Section 5).

## 2.3 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 2.1.4. 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 are required to consider AM, there may be some projects or components 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., 2007, 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).

The MsCIP Barrier Island Restoration Project was evaluated to determine if AM was applicable and, if so, would better enable the project to meet stated goals and objectives. The following questions were considered in determining whether AM could be applied to the project, or a portion of the project:

1) Are the target ecosystems sufficiently understood in terms of hydrology and ecology, and can project outcomes be accurately predicted, given recognized natural and anthropogenic stressors?

   A: Partially. There has been extensive data collection, analyses, and numerical modeling conducted as part of the MsCIP Barrier Island Program, which, along with additional existing information, have been used to support the engineering and design components of the restoration project. Data analyses and numerical modeling have provided the information needed to improve the understanding of the site's coastal processes, geomorphology, and ecology to produce reasonable estimates of project performance. Physical data collection, analyses, and predictive modeling already conducted under the MsCIP Barrier Island Program includes geophysical and geotechnical investigations, including bathymetric and sediment budget assessments, and wave, current, circulation, sediment transport and water quality modeling. Baseline ecological data collection and analyses have been conducted on submerged aquatic vegetation, benthic infauna, gulf sturgeon, shorebird, and sea turtles. However, limited information exists on beach invertebrate communities and the hydrology of wetlands on East and West Ship islands.

   There will always remain uncertainties related to climate change and sea level rise, and the associated response of the barrier islands.

2) Can the most effective project design and operation for achieving project goals and objectives be readily identified?

   A: Yes. The design and optimization process relied on extensive data collection, analyses, and numerical modeling. Furthermore, the Main Report/Supplementary Environmental Impact Statement (SEIS), and all appendices and supporting documentation are subject to ATR conducted by a regional and national team of experts. Post-construction, the MAM process will be used to measure restoration progress towards meeting the goals and objectives over time.

As evidenced by a recently completed project within Gulf Islands National Seashore (i.e., 2012 West Ship Island, north shore sand replenishment project), achieving desired conditions will vary over time due to the dynamic nature of these systems.

3) Are the measures for this restoration project performance well understood and agreed upon by all parties?

   A: Yes, the ultimate goal to restore compatible sand to Ship Island and augment the existing sand transport system is well understood and agreed upon by all parties. It is also understood that once placed, the material should be transported to the islands by natural coastal processes, and this performance measured as part of the MAM Program.

   Specific performance measures and desired outcomes for measuring restoration progress are being drafted as part of the MAM Plan by the interagency TAG, based on the overall goals and objectives of the MsCIP Barrier Island Restoration Program, and the stressors and attributes identified in the CEM. Performance measures and success criteria will be coordinated and vetted through the MAM process by members of the TAG, Oversight Committee, Program Management Team, and the RSLG.

4) Can project management actions be adjusted in relation to monitoring results?

   A: Yes, however, given the design criteria, logistics associated with dredging operations, and timing for placement of sand, there is limited flexibility for AM and adjustment in relation to monitoring results once construction has started. The project design was developed to meet certain criteria (i.e. design life, sand compatibility, minimal impacts to Gulfport Navigation Channel, etc.). Components that are not flexible include the upper amounts of fill quantities, costs, and modifications to a contract once awarded. However, construction will be conducted in phases under separate construction contracts, allowing for small modifications between phases. Any proposed changes in relation to monitoring results to borrow sites, placement areas, etc., would need to be implemented on short notice in order to limit potential delays that could impact project success. Potential AM triggers and actions under the MsCIP and recommendations that can be made to other programs and or agencies are further described in Sections 5 and 6.

A lack of complete understanding in response to question 1, 2 or 3 and a “YES” answer to question 4 qualifies the project as a candidate that could benefit from AM. Based on the TAG and Oversight Committee discussions, and the identified project uncertainties, needs, and opportunities, the MsCIP MAM program was developed to:

- Reduce uncertainty over time
- Implement monitoring to determine progress towards meeting ecological success
- Determine long-term cumulative impacts of restoration actions
- Develop feedback loops so that monitoring and assessments produce continuous and systematic learning, that in turn is incorporated into subsequent rounds of decision-making through AM
- Develop reports on the status and progress of the restoration for the agencies involved, the public, Congress, and 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.

## 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.*"

Pre-construction/baseline data and monitoring during and post-construction will be utilized to determine barrier island restoration success and avoid impacts to threatened and endangered (T&E) species. This plan includes the monitoring actions necessary to evaluate success within the project area as well as the monitoring procedures necessary for T&E species compliance, as required in the Biological Opinions (BO) issued for the project. Additional monitoring will be collected during construction by the contractor as required by project plans and any specifications that support the monitoring proposed in the MAM Plan (i.e. turbidity monitoring and grain size testing); detailed procedures are not included within the MAM Plan.

Post-construction monitoring is scheduled to begin after completion of Ship Island the sand placement associated with Phase 1 construction. Post-construction monitoring procedures on Cat Island will commence upon completion of sand placement on that island, as described in Section 2.1.3. Although Section 2039 of WRDA 2007 allows for a ten year cost-shared monitoring plan post-construction, ten years of monitoring may not be required. Monitoring will continue until the trajectory of ecological change and/or other measures of project success, as defined by project-specific objectives, are achieved. Once ecological success has been achieved, a determination will be made as to whether further monitoring is required. Any additional monitoring required past the ten year time frame will be a non-MsCIP responsibility.

The MAM Plan is a living document with the proposed monitoring elements based on currently available information. As such, it will be updated to incorporate monitoring-acquired and/or other new information, lessons learned, the resolution of key uncertainties, and the identification of novel conditions.

Currently, the MAM plan focuses on the MsCIP Barrier Island restoration actions at Ship Island and Cat Island (described in Section 2.1.3), but will be modified as necessary to include data collection for additional future project components.

Data collected by MsCIP partners, not necessarily under MsCIP funding, will be leveraged wherever possible. Additional data will be collected as part of MsCIP (1) if required, or (2) only if scientifically defensible to achieve a complete dataset with which to compare post-restoration success and avoid impacts to T&E species. Appendix E presents the supplementary datasets that have been compiled for baseline information, to be used in conjunction with the monitoring proposed under the MAM plan.

Other monitoring and programs with which we will coordinate include the:

- USGS BIER Project

- Louisiana Barrier Island Comprehensive Monitoring (BICM) Program
- USGS Mississippi Water Science Center Data Collection
- NPS Inventory and Monitoring Program at Gulf Islands National Seashore
- Baseline samples, collected under various oil spill response programs (e.g. NRDA, Pollution Removal Funding Authorizations [PRFA]) related to the Deepwater Horizon spill of April 20, 2010 will be used to augment baseline data and monitoring efforts funded under the MsCIP program
- NFWF Gulf Environmental Benefit Fund, Alabama Barrier Island Restoration Assessment

### 3.1 Objectives, Performance Measures, Desired Outcomes, and Monitoring Designs

In accordance with the MAM planning approach outline in Section 2.0, this section identifies the performance measures and desired outcomes needed to evaluate whether or not we are meeting the desired project objectives. The performance measure includes specific feature(s) to be monitored to determine project performance. Additional details regarding the proposed monitoring designs are provided in Appendix D. Protocols outlining how the data will be assessed and analyzed are provided in Appendix G. Details regarding the manner in which the monitoring data will be used to influence future management decisions, including triggers and potential adaptive management actions, are included in Section 6 and Table 1. Success criteria and interim targets have been developed for the performance measures and are included under each of the objectives below.

**Objective 1- Maintain the estuarine ecosystem and resources of the Mississippi Sound.**

a. **Performance Measure- Flow patterns at Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass:** East and West Ship islands, separated by Camille Cut, are flanked by Ship Island Pass to the west and Little Dog Keys Pass and Dog Keys Pass to the east. Current flows through these passes and through Camille Cut affect the estuarine ecosystem and resources of Mississippi Sound. This estuarine ecosystem is expected to adjust to changing flow patterns once Camille Cut is closed. It is anticipated that minimal flow pattern changes will occur within Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass after closure of Camille Cut.

   **Monitoring Purpose:** Record flow patterns at Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass to evaluate overall circulation changes after closure of Camille Cut. The monitoring is being conducted for the Ship Island Restoration component and will provide the supporting information required to measure progress against success criteria.

   **Monitoring Design Summary:** To document changes and assess whether closure of Camille Cut impacts overall circulation in the sound adjacent to the island, Acoustic Doppler Current Profiler (ADCP) transects should be monitored at each pass – one prior to, and one after the closure of Camille Cut. Current measurements at each transect should be measured for at least one tidal cycle. Pre- and post-closure data should be collected at the same time of year for similar tidal conditions. Additional details regarding the monitoring procedure can be found in Appendix D2.

   **Desired Outcome:** Minimal changes to overall circulation patterns in the Mississippi Sound after sediment placement along Ship Island and the filling of Camille Cut.

   **Success Criteria:** An assessment of changes in currents through Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass will be made within the first year after construction. Changes in flows measured from the pre- and one year post-construction surveys through the three passes are within the range of simulated change.

**Interim Target:** N/A

**AM Trigger:** Flows having similar tidal, river and wind conditions exceed predicted values through Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass.

b. **Performance Measure- Water Quality:** East and West Ship islands, separated by Camille Cut, are flanked by Ship Island Pass to the west and Little Dog Keys Pass and Dog Keys Pass to the east. Current flows through these passes and through Camille Cut affect circulation patterns and water quality in the Mississippi Sound. It is anticipated that minimal changes in water quality in the system will occur after implementation of the Ship Island component and the closure of Camille Cut.

**Monitoring Purpose:** To monitor water quality parameters, as long-term indicators of change due to the Ship Island Restoration Component and the closure of Camille Cut. The long-term responses will be used to perform a strength of evidence approach to evaluate project success. The monitoring will provide the supporting information required to measure progress against success criteria and understand the other biological responses including Gulf sturgeon and SAV.

**Monitoring Design Summary:** Before, during, and after Ship Island construction discrete water quality measurements will be taken at four water quality stations located north, south, and west of Ship Island and three control sites in the lee of Cat, Horn and Petit Bois islands. Primary water quality parameters will be continuously monitored (time series) at USGS East Ship Island Light (ID #301527088521500) near the proposed work area, and at USGS Gulfport Light monitoring station (ID #301912088583300). Weather permitting, water quality sites will be sampled every six to eight weeks, for a minimum of six samples per year pre-construction, and will continue for a minimum of two years post-construction. Additional details regarding the monitoring procedure can be found in Appendix D2.

Turbidity curtains will be installed and turbidity measurements collected within seagrass beds located north of East and West Ship islands and around Cat Island during critical construction periods for both the Ship Island and Cat Island restoration components.

**Desired Outcome:** Maintain current estuarine conditions in Mississippi Sound for primary water quality parameters (e.g., salinity, turbidity, dissolved oxygen, temperature, and light within seagrass beds) leeward of West and East Ship Island.

**Success Criteria:** Changes in the important water quality parameters, measured for a period of up to two years following the closure of Camille Cut are within the range of historic variability, and compare to changes observed at control stations.

**Interim Target:**The levels of the important water quality parameters mentioned above measured over a year following the closure of Camille Cut are within the range of the historic variability, and compare to changes observed at control stations.

**AM Trigger:**
The levels of the important water quality parameters mentioned above exceed predicted values and are outside of the range of historic variability.

c. **Performance Measure-** Submerged Aquatic Vegetation Coverage: Seagrasses and SAV provide critical spawning, nursery, refuge, and feeding habitat for recreational and commercial marine species. Areal coverage and distribution of SAV around the barrier islands has declined significantly since 1969 (Moncreiff, 2007), with a high of approximately 13,000 acres reduced to 3,614 acres in 2010 (USACE 2014; Appendix H). Although there is the potential for temporary impacts to SAV during construction, it is anticipated there will be an increase in SAV after the closure of Camille Cut.

**Monitoring Purpose:** Document SAV distribution, acreage and condition over time at Cat Island and Ship Island, and evaluate effects of changing circulation and sedimentation patterns on and around Ship Island.

**Monitoring Design Summary:** Aerial imagery mapping of SAV will be conducted within the technical framework established by the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP), following methods described in Appendix H of the 2014 Draft Supplemental Environmental Impact Statement (USACE 2014). Aerial imagery will be collected in the summer before and after project construction, and a minimum of three additional surveys before the end of the ten year monitoring. The post-construction surveys will be timed to correspond with U.S. National Park Service SAV monitoring surveys, scheduled to occur every three years beginning in 2019. When possible, coincident topobathymetric Light Detection and Ranging (lidar) will be collected. Digital orthophotographs will be created, boundaries of SAV signatures digitized, and classifications field verified.

SAV condition indicators (percent cover, species composition and canopy height), and stressors (water transparency, depth, temperature, salinity, DO, and pH) will be measured within 0.25 $m^2$ quadrats following Tier II rapid assessment methodologies adapted from Dunton et al. (2010) and Neckles et al. (2012), as used by the NPS Gulf Islands National Seashore (GUIS) in surveys conducted in 2011, 2012, and 2013. Existing GUIS Ship Island ground surveys may be extended into potential SAV areas on the north side of Camille Cut by adding five to seven sampling locations to the existing 18 stations used in the repeated measures design. These surveys will be conducted in conjunction with GUIS surveys for a period of up to nine years. Additional details regarding the monitoring procedure can be found in Appendix D3.

Additional turbidity monitoring will be collected during construction by the contractor as required by project plans and specifications. This data will be used to support the monitoring proposed in this MAM plan (i.e. turbidity monitoring and grain size testing); detailed procedures are not included within the MAM.

**Desired Outcome:** Increase in total acreage of SAV on Ship Island as compared to the pre-construction period 2010-2014.

**Success Criteria:** Ten years post-construction total SAV acreage, distribution, condition and species composition on Ship Island are similar to the pre-construction period.

**Interim Target:** three year post-construction, maintain 2014 pre-construction SAV distribution.

**AM Trigger:** Reduction in SAV cover and condition six years post-construction on Ship Island associated with the closure of Camille cut

d. **Performance Measure- Benthic and Infaunal Species:** The bottom sediments present in the tidal passes and beaches of the barrier islands and shallow waters adjacent to the barrier islands provides habitat for multiple benthic and infaunal species that are important food sources for shorebirds and Gulf sturgeon. Previous benthic macroinfauna community studies found that, due to the dynamic nature of these systems and the exposure to frequent disturbances (e.g., sediment disposal, storm action, and maritime activity), taxa richness and densities varied significantly by location, and that the common species tended to be either disruption-tolerant, or capable of rapidly recolonizing disturbed areas (USACE, 2009; Rakocinski et al., 1990, 1993, 1998; Wilber et al., 2007). It is anticipated that benthic and infaunal communities will be displaced in the short-term due to the dredging and placement of dredged material associated with construction.

**Monitoring Purpose:** Document the density and diversity of benthic and infaunal communities on and around Ship Island and Cat Island prior to and after construction in order to evaluate the post-construction reestablishment of benthic populations at placement sites and determine the suitability of placement areas for feeding habitat for Gulf sturgeon and shorebirds. This monitoring will provide supplementary information needed for the compliance monitoring of Gulf sturgeon and shorebirds, as required in the BOs issued for the project.

**Monitoring Design Summary:** Benthic macroinfauna community sampling will follow methods described in Appendix I of the 2014 Draft Supplemental Environmental Impact Statement (USACE, 2014). Pre-construction baseline benthic community surveys were collected in the 2010 (summer and fall) and 2011 (spring) at borrow, placement, and reference sites. Additional sites were surveyed to support Gulf sturgeon monitoring (fall, 2011) and shorebird monitoring (winter, 2015). Post-construction sampling will be conducted at the sites previously surveyed in 2010, 2011, and 2015, with the exception of borrow sites, which will not be sampled post-construction. If, after the closure of Camille Cut locational change occur in regards to sturgeon and shorebird feeding locations, new sites may potentially be sampled. Sand placement will be surveyed approximately two years after the completion of construction at Cat Island, and two years after the completion of construction on Ship Island. Benthic surveys for shorebird feeding sites will be conducted during the winter approximately two years after completion of construction. Post-construction benthic sampling for sturgeon feeding sites are scheduled to be sampled in the fall and spring beginning six months after completion of the closure of Camille Cut. Additional details regarding the monitoring procedure can be found in Appendix D3, in the Benthic and Infaunal species, Gulf sturgeon, and Shorebirds sections.

Additional monitoring, based on grain size analysis collected as part of the construction activities, will be used to support the benthic monitoring proposed in this MAM Plan. This additional monitoring conducted during construction will be detailed in the Plans and Specifications; detailed procedures are not included within this MAM.

**Desired Outcome:** Re-establish benthic and infaunal species population densities and diversity to pre-construction baseline levels post-construction for placement, and shorebird and sturgeon feeding sites.

**Success Criteria:** The re-establishment of benthic and infaunal species post-construction will occur when the average biomass level within the project area is at least 70% of the pre-project average biomass level. This success criteria will be evaluated approximately three years post-construction.

**Interim Target:** A short-term evaluation of benthic and infaunal species re-establishment will be collected six months after as part of the Gulf sturgeon benthic prey assessment. Maintain suitable shorebird foraging habitat acreage five years after the completion of the closure of Camille Cut.

**AM Trigger:** Success criteria not met by five years post-sand placement

e. **Performance Measure- Gulf Sturgeon:** The Gulf sturgeon, *Acipenser o. desotoi*, occurs in Gulf of Mexico drainages from Tampa Bay westward to the Mississippi River. This subspecies is listed as threatened under the Endangered Species Act and is also state-listed as endangered in Mississippi, with the principal reasons for population declines being habitat loss due to dams, commercial fishing, and general water quality deterioration (USFWS and Gulf States Marine Fisheries Commission, 1995). In Mississippi, the Gulf sturgeon historically occurred in the Pascagoula, Pearl, and Mississippi Rivers. Critical habitat for Gulf sturgeon was designated in 2003, and includes the entire Mississippi Sound to one mile south of the Mississippi barrier islands within the northern Gulf of Mexico. Several studies have noted the occurrence of Gulf sturgeon in barrier island passes (Rogillio et al. 2007; Ross et al. 2009) and with the closure of Camille Cut, it is anticipated that Gulf sturgeon will redistribute and utilize adjacent passes.

**Monitoring Purpose:** Compliance monitoring to document Gulf sturgeon critical habitat utilization over time at Ship and Dog Keys Pass and determine whether Ship Island restoration and filling Camille Cut has an impact on Gulf sturgeon utilization of these habitat features.

**Monitoring Design Summary:** To assess habitat utilization, monitoring of Gulf sturgeon will be conducted at Ship Island and Dog Keys Pass using acoustical tagging techniques before (baseline), during construction after the filling of Camille Cut (post-fill), and post-construction (after completion of all phases of construction). The approach will be evaluated at multiple levels: (1) an initial assessment to determine the relative occurrence of Gulf sturgeon within the project area (e.g., specific zones; seasonal timing); (2) a secondary assessment will address occupancy patterns of Gulf sturgeon within identified project areas to evaluate potential changes in occupancy patterns between years and project zones; and a (3) benthic assessment to develop a relationship between Gulf sturgeon and benthos. Data collection started in 2011 and will be conducted during and after construction. Monitoring for Gulf sturgeon also will be evaluated in conjunction with benthic and infaunal species sampling described within Performance Measure 1d to develop a surrogate to predict favorable Gulf sturgeon habitat. Additional details regarding the monitoring procedure can be found in Appendix D3.

**Desired Outcome:** Maintain suitable Gulf sturgeon habitat in the vicinity of Ship Islands.

**Success Criteria:** Two years post-construction occupancy values fall within two standard deviations of pre-construction values
AND
No significant change in post-construction benthos community assessments as compared to the pre-construction assessment.

**Interim Target:** Immediately (< **s**ix months) post-construction track potential movement of Gulf sturgeon shift to other surrounding habitat zones.

**AM Trigger:** Reduction in Gulf sturgeon habitat usage and occupancy patterns within the Ship and Horn Island System.

**<u>Objective 2- Preserve the natural and cultural resources of the Mississippi barrier islands.</u>**

a. **Performance Measure- Habitat Composition:** The Mississippi barrier islands contain over 50 unique categories of terrestrial and aquatic habitats, as previously classified under the National Wetlands Inventory (NWI). Changes in terrestrial and submerged vegetation communities and geomorphic features such as tidal flats, beaches, and bars occur naturally over time, but both large events, such as Hurricane Katrina, and restoration efforts, such as MsCIP, can greatly change the islands' morphology and the habitats they support.

**Monitoring Purpose:** Document changes in habitat diversity and acreage of emergent/submerged habitats over time and use these data with supporting datasets (bathymetry and topography, shorebird and sea turtle nesting, Gulf sturgeon distribution, benthic/infaunal density, and SAV cover) to develop relationships between emergent and submerged habitat types and habitat utilization on Ship Island and Cat Island. This monitoring will be used to measure project performance as a success criterion.

**Monitoring Design Summary:** Lidar (topobathymetric lidar when possible), satellite and orthophotography data will be used. High resolution aerial photography will be used to map emergent and submerged habitats on Ship Island and Cat Island using the technical framework established by the USFWS National Wetlands Inventory (NWI) Classification of Wetlands and Deepwater Habitats (Cowardin., 1979). Aerial photography will be collected annually before, during, and for two years post-construction. A minimum of two additional collections will be conducted within the following eight years; exact dates will be determined by the construction schedule and the temporal correlation of survey requirements across the program.
Orthophotography acquired during lidar missions will also be analyzed and mapped as part of this monitoring effort. Field investigations will be conducted to ground-truth various

geomorphic and vegetation habitats in the field with corresponding signatures on aerial photography. Topobathymetric lidar will be conducted when possible. Additionally, moderate resolution Landsat Multi-Spectral Scanner and Thematic Mapper satellite imagery will be used to increase the number of datasets available to assess historic and post-construction geomorphic landform evolution and land area change trends, and to help discern normal environmental variability present at the time of acquisition of the orthophotography. Additional details regarding the monitoring procedure can be found in Appendix D3.

**Desired Outcome:** Increase the habitat diversity and acreage of emergent and submerged habitats over time, including beach and dune, intertidal flats, wetlands, and upland/scrub shrub.

**Success Criteria:** Ten years following the completion of construction on Ship Island the success criteria is that loss of emergent habitat relative to project completion acreage is less than the historical land loss rate. The assessment will include analyses of loss rates of habitat above mean sea level and mean high water using analyses of the change in areal coverage for habitat maps, satellite imagery, and lidar datasets. The land loss rate will come from either literature, such as Morton (2007), or recent satellite-based land change analyses such as Couvillion (2017). Acreage will be determined from the habitat mapping effort conducted immediately after project completion.

AND

Maintain habitat diversity of emergent and submerged habitats over time, including beach and dune, intertidal flats, wetlands, and upland/scrub shrub.

**Interim Target:** Habitat mapping is scheduled to be conducted at regular intervals post-construction and success criteria will be assessed at each interval

**AM Trigger:** Loss of emergent habitat within ten years greater than the historical land loss rate. Ten years post- construction a reduction in acreage of wetlands on Ship Island due to overwash and sand burial, compared to historical data.

b. **Performance Measure- T&E Shorebirds:** The Mississippi barrier island beaches are listed as critical habitat for the threatened Piping plover (*Charadrius melodus*) and are important habitats for the Red knot (*Calidris canutus*). These species are protected pursuant to the Endangered Species Act (ESA) and Migratory Bird Treaty Act, and therefore potential impacts associated with barrier island construction activities must be avoided.

**Monitoring Purpose:** Compliance monitoring to document the number of T&E shorebirds using Ship Island and Cat Island to determine any impacts pursuant to the ESA.

**Monitoring Design Summary:** Trained bird monitors (observers) will use U.S. Fish and Wildlife Service, Ecological Services Office, Jackson Mississippi, Non-breeding season survey guidelines to conduct bird identification, counts, habitat use, behavior observations, and locational assessments of Piping Plover and Red Knot. Monitoring will be conducted weekly on Ship Island (East and West) and Cat Island to cover migration/mid-winter seasons and will be conducted before, during, and for at least two years following the completion of planting on Ship Island. Post-construction monitoring will occur every other week. In addition to Piping Plover and Red Knot, all observed solitary and colonial nesters and all other winter migrants will be included in the shorebird surveys. Long-term shorebird monitoring data, collected by the NPS on GUIS, Mississippi, will be utilized, as appropriate, upon availability. Additional details regarding the monitoring procedures can be found in Appendix D3.

The benthic sampling conducted under Performance Measure 1d will be used to correlate T&E Shorebirds and benthic prey species at shorebird feeding sites previously surveyed in 2010, 2011, and 2015, and at new locations where feeding occurs after the closure of Camille Cut.

**Desired Outcome:** Maintain T&E shorebirds habitat on Ship Island and Cat Island post-construction, as compared to the pre-construction baseline.

**Success Criteria:** Ten years following the completion of planting on Ship Island maintain or increase the pre-construction acreage of suitable shorebird foraging habitat, as evaluated by habitat mapping.
AND
Provide suitable benthic habitat five years post-construction.

**Interim Target:** Maintain suitable shorebird foraging habitat acreage five years post-construction. The total number of acres of suitable nesting habitat will be determined by habitat mapping based on pre-construction conditions.

**AM Trigger:**
Reduction of suitable shorebird foraging habitat after closure of Camille Cut

c. **Performance Measure- Nesting Birds:** The Mississippi barrier islands and shorelines provide feeding, nesting, resting, and wintering habitat for numerous resident and migratory bird species (MDMR 2010). The project area serves as an important migration corridor and stopover habitat for birds migrating to and from tropical wintering areas. It is anticipated that the project will enhance island morphology and diversity of habitats supporting solitary and colonial nesters and winter migrants.

**Monitoring Purpose:** Assess utilization of newly created beach and shoreline habitats by nesting shorebirds. This monitoring will be used to measure project performance as a success criterion.

**Monitoring Design Summary:** Trained bird monitors (observers) will use the USFWS, Ecological Services Office, Jackson, Mississippi, Non-breeding season survey guidelines to conduct bird identification, counts, habitat use, behavior observations, and locational assessments of all observed solitary and colonial nesters, and winter migrants. To cover nesting seasons, monitoring will be conducted daily during construction activities on Ship Island (East and West) and Cat Island during March through September. Long-term shorebird monitoring data collected by the NPS on GUIS, Mississippi, will be utilized, as appropriate, upon availability. Tracking of emergent and submerged habitat types over the ten year post-construction monitoring period will be used with any available NPS data to help access nesting potential over time. Additional details regarding the monitoring procedures can be found in Appendix D3.

**Desired Outcome:** Post-construction improve nesting potential in newly created habitats.

**Success Criteria:** Ten years post-construction maintain or increase suitable acres of nesting habitat as compared to the pre-construction acreage. This will be evaluated by habitat mapping.

**Interim Target:** Five years post-construction maintain suitable acres of nesting habitat as evaluated by habitat mapping efforts

**AM Trigger:** Loss of nesting habitat (acres) for solitary and colonial nesting shorebirds as evaluated by habitat mapping efforts. The total number of acres of suitable nesting habitat will be determined by habitat mapping based on pre-construction conditions.

d. **Performance Measure- Sea Turtles:** The Mississippi barrier island beaches are sometimes used for nesting by five species of endangered and threatened sea turtles: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), and Kemp's Ridley (*Lepidochelys kempii*). These species are protected pursuant to the ESA and therefore, potential negative impacts associated with barrier island construction activities must be avoided.

**Monitoring Purpose:** Compliance monitoring to document the changes to the amount of habitat conducive to sea turtle nesting relative to the baseline conditions and determine any negative impacts pursuant to the ESA.

**Monitoring Design Summary:** Sea turtle monitors (observers) will be used to conduct sea turtle identification, counts, locational assessments and the identification of turtle crawls and nest sites, marking of nests, and Global Positioning System (GPS) locations on beaches of Ship Island and Cat Island following U.S. Fish and Wildlife Service, Ecological Services Office survey guidelines. Monitoring will be conducted from April 15 to November 30 both during and post-construction. No pre-project surveys will be required if project construction activities are initiated between November 30 and April 15. If the project construction is initiated between April 15 and November 30, daily pre-project surveys will begin at least 100 days prior to the project starting or by April 15, whichever is later. Post-construction weekly sea turtle monitoring shall continue for two full nesting and hatching seasons (April 15th thru November 30th), after the end of construction. In addition, the shear resistance of the beach sediments at Ship Island and Cat Island, Mississippi will be measured pre- and post-construction using a dynamic cone penetrometer testing (DCP) apparatus, since sediment shear resistance is an important factor in sea turtle nesting. Further details regarding the monitoring procedure can be found in Appendix D3.

**Desired Outcome:** Establish suitable habitat for sea turtles post-construction.

**Success Criteria:** Ten years following the completion of planting on Ship Island maintain or increase suitable acreage of sea turtle habitat, as compared to the pre-construction acreage. Sea turtle habitat is defined as upper beach habitat at three feet or higher. The total number

of suitable acres will be determined by habitat mapping based on pre-construction conditions
AND
The development of an evaluation formula, driven by improved understanding of the changes in penetration resistance over the monitoring period, such that no further consultations with Fish and Wildlife Service are needed
AND
Compliance with terms and conditions set forth in the Biological Opinions

**Interim Target:** Five years following the completion of the planting on Ship Island maintain suitable acres of turtle habitat as evaluated by habitat mapping efforts.

**AM Triggers:** Loss of habitat (acreage) for sea turtle as evaluated by habitat mapping efforts. The total number of suitable acres will be determined by habitat mapping based on pre-construction conditions. Compaction tests do not meet requirements for suitable turtle hatching.

e. **Performance Measure- Cultural Resources:** Cultural resources are archeological and architectural resources known to occur within the project area and are listed in, eligible, or potentially eligible, for listing in the National Register of Historic Places (NRHP). They are important historical and cultural features of the country's national heritage. Construction will be conducted in a manner to avoid impacts to cultural resources, with subsequent monitoring documenting the area surrounding all cultural resources.

**Monitoring Purpose:** Identify resources prior to construction. Document areal island extent surrounding cultural resources eligible, or potentially eligible, for nomination to the NRHP, and coordinate any needed actions based on monitoring results. The monitoring will provide supporting information to assess potential exposure of cultural resources to erosive forces as Ship Island and Cat Island evolve over time. Monitor dredge locations to ensure that submerged avoidance areas are not disturbed.

**Monitoring Design Summary:** Monitoring will ensure that all previously identified eligible, or potentially cultural resources are avoided. Additionally, a monitor trained in recognizing cultural material that may be inadvertently discovered during construction will identify such material so that the material/site can be evaluated before construction resumes in order to prevent further destruction to the cultural resource. Continued post-construction monitoring by NPS archaeologists will assess erosion to sites. Possible negative impacts to the borrow areas will be monitored using RECENTPAST, a real-time remotely-accessed map showing culturally-sensitive areas which will be integrated with the DQMS data on the dredges, to ensure avoidance of the collection of dredge material in culturally-sensitive areas. Datum stakes will be placed around cultural resources to monitor vertical and horizontal movement of placed material as lidar and aerial photography is made available. National Park Service (NPS) archaeologists will continue to monitor post-construction erosion around cultural resources.

**Desired Outcome:** Emergent land continues to surround cultural resources.

**Success Criteria:** Ten years following the completion of all construction activities the success criteria is no appreciable loss of listed, eligible, or potentially eligible cultural resources due to erosion or construction, as determined by aerial mapping and baseline conditions. No potential submerged cultural resources are impacted by dredging or placement activities.

**Interim Target:** Five years following the completion of all construction activities no appreciable loss of listed, eligible, or potentially eligible cultural resources due to erosion or construction based on aerial mapping and baseline conditions.

**AM Trigger:** An inadvertent discovery made during construction
OR
Increase exposure or disturbance to resources eligible for nomination to the NRHP.

**<u>Objective 3- Restore the barrier islands structure to reduce storm damage impacts on the mainland coast of Mississippi.</u>**

a. **Performance Measure- Island morphology and shoreline change:** The ability of the Mississippi barrier island system to limit storm impacts to mainland beaches depends upon the islands' ability to maintain sufficient width and elevation. Beach erosion and overtopping along East Ship Island and changes in inlet shoal and channel morphology within Little Dog Keys and Dog Keys passes endanger the longevity of East Ship Island, which could result in complete degradation of the island within the next 10 to 20 years (Byrnes et al., 2012). Restoration along Camille Cut and East Ship Island will increase island width and elevation to augment natural sediment transport quantities reduced by the breaching and inlet formation along Ship Island. Once sand placements reflecting the design templates are complete, it is anticipated that adjustments in shoreline change and subaerial island morphology will occur.

   **Monitoring Purpose:** Document island elevations, shoreline change rates, and areal island extents of Ship and Cat islands. The monitoring at Ship Island will be used to measure project performance against the success criteria and to identify breaches that would be used as AM decision criteria under the AM Plan (Section 6). The monitoring will also provide supplementary information to increase understanding of the responses of such biological and physical performance measures as circulation and habitat availability.

   **Monitoring Design Summary:** To capture changes, simultaneous near-vertical aerial imagery and lidar surveys will be acquired before and after construction and three additional times during the ten year monitoring effort. To evaluate the effectiveness of the restoration design, measurements will be compared with previous measurements of historic shoreline change rates, foreshore slopes, elevations and volumetric changes within the system when combined with bathymetric surveys. Additional details regarding the monitoring procedure can be found in D1.

   **Desired Outcome:** Net loss of original Ship Island restoration surface area should be less than an average of 3% per year over the ten year monitoring period.

**Success Criteria:** Net loss of original island restoration surface area is not greater than an average of 3% per year over the ten year monitoring period.

**Interim Target:** Net loss of original island restoration surface area should be less than 15% over the five year monitoring period.

**AM Trigger:** Net loss of original island restoration surface area is greater than an average of 3% per year over the ten year monitoring period. Land loss along Ship Island exceeds 50% of the original restoration area over the ten year monitoring period.
A storm(s) significantly impacts the project before and/or during construction

b. **Performance Measure- Wave Reduction Leeward of Ship Island:** One of the expected benefits of filling Camille Cut is the reduction in Gulf of Mexico wave energy impacting mainland beaches in Harrison County, Mississippi. Wave measurements at locations seaward and soundward of Camille Cut are required to directly measure the extent of the attenuation of wave energy from the Gulf of Mexico after Camille Cut has been closed. Additionally, wave measurements will provide a valuable data set for verifying wave prediction models used for the nearshore and estuarine system surrounding Ship Island.

**Monitoring Purpose:** Assess wave attenuation in the lee of Ship Island. The monitoring will provide the information required to measure progress against success criteria.

**Monitoring Design Summary:** Deployment of three wave gages prior to and for a period up to two years after construction to measure wave height, period, direction, and water level seaward and soundward will provide quantitative data necessary for the evaluation of the degree to which the Camille Cut closure reduced wave energy leeward of Ship Island. Additional details regarding the monitoring procedure can be found in Appendix D1.

**Desired Outcome:** Reduce wave heights in the lee of Ship Island.

**Success Criteria:** Reduced wave height leeward of Ship Island relative to pre-construction baseline conditions during the five years post-construction monitoring period.

**Interim Target:** None

**AM Triggers:** No reduced wave attenuation north of Ship Island after the closure of Camille Cut to limit mainland beach damages

**<u>Objective 4 - Enhance the long-term littoral drift system for the Mississippi barrier islands.</u>**

a. **Performance Measure- Restore Sediment to the Barrier Island System**: Based on littoral sand transport estimates along East and West Ship Island and long-term sediment budget estimates for the Mississippi barrier islands (Byrnes et al., 2013), Dog Keys Pass and Little Dog Keys Pass have been a sand sink throughout the historical record, resulting in limited sand movement from Horn Island to East Ship Island. The result has been rapid shoreline recession and chronic beach erosion along East Ship Island, resulting in significant island area losses and habitat degradation. Presently, the island is in a highly degraded state and is expected to become a shoal within the next decade without island restoration. If the island is left to naturally degrade, valuable wetlands, sea turtle nesting habitat, and shorebird foraging and nesting habitat will be lost and wave and current energy from the Gulf of Mexico are expected to negatively impact estuarine habitats in the lee of the island, water quality, and mainland beach sustainability. As such, island restoration with sand from outside the Ship Island littoral transport system has been designed to augment the natural littoral transport system and create both subaerial and subaqueous habitat within the barrier island system.

**Monitoring Purpose:** Verify sand restoration volumes are adequate for enhancing sand supply to the littoral transport system to help maintain Ship Island. The monitoring will provide the information required to measure progress against success criteria.

**Monitoring Design Summary:** Measurements of the subaerial and subaqueous portions of the beach will be conducted to track sand movement and monitor island elevation changes throughout the monitoring effort. Simultaneous aerial imagery and lidar surveys will be collected before and after construction and two times during the ten year monitoring effort to verify that restored sand volumes were adequate to maintain Ship Island. Bathymetric surveys of the nearshore will be collected at similar time intervals to track the subaqueous movement of sand transported from the subaerial beach during beach adjustments resulting from dynamic equilibrium processes and in response to storm events. Additional details regarding the monitoring procedure can be found in Appendix D1.

**Desired Outcome:** Increase sediment availability for littoral transport along the barrier islands.

**Success Criteria:** Increase sediment availability for littoral transport along the barrier islands measured over a five and ten year period.

**Interim Target:** Increase sediment availability for littoral transport along the barrier islands measured over a five year period.

**AM Trigger:** During the initial construction phases, the sand material placed at Ship Island placement is removed at rates higher rates than expected, due to unexpectedly strong longshore transport.

b. **Performance Measure- Sedimentation/Shoaling:** Ship Island Pass exists along the western end of Ship Island and encompasses the federally maintained Gulfport Ship Channel. Water depths within the channel are generally 40 feet or less. Long-term dredging records show large annual variability in maintenance dredging quantities. However, long-term annualized dredging requirements for Ship Island Pass are on the order of 156,000 $yd^3/yr$. Analysis indicates that the restoration of the littoral sediment transport system and changes to local currents resulting from the closing of Camille Cut could potentially result in increased sedimentation in the Ship Island Pass, especially during hurricanes. However, increased sedimentation over what would naturally occur with the westward growth of Ship Island is expected to be minimal.

**Monitoring Purpose:** Verify sedimentation and shoaling that could impact dredging operations and maintenance costs. The monitoring will provide the information required to evaluate achieving the success criteria.

**Monitoring Design Summary:** Bathymetric surveys of the Gulfport Ship Channel (Ship Island Pass) will be collected and evaluated to verify whether or not average sedimentation and shoaling rates increase beyond the historical variability, as determined by average annual maintenance dredging.

**NOTE:** Surveys will continue to be collected by the USACE Operations & Maintenance (O&M) program. The TAG will assess the shoaling rates and compare them to historical rates as well as using other nearshore bathymetric surveys collected as part of the restoration of sediment to the barrier island system performance measure to determine if an increase in channel shoaling/sedimentation is associated with the Camille Cut and East Ship Island restoration.

**Desired Outcome:** Minimal impact to navigation channel dredging operations and maintenance at Ship Island Pass.

**Success Criteria:** No increase over natural variability in average annual maintenance dredging during the five and ten year periods with Ship Island Pass.

**Interim Target:** Shoaling rates in the Ship Island Pass navigation channel remain within the range of natural variability and average annual maintenance dredging per year over a five year period is unchanged compared to baseline values.

**AM Trigger:** Average shoaling rates in the navigation channel increase to be outside the range of natural variability and average annual maintenance dredging costs increase over the ten year monitoring period compared to baseline values

c. **Performance Measure- Dredged material placement within Horn Island littoral system:** Horn Island Pass is approximately 3.5 miles wide, encompasses the Pascagoula Ship Channel, and is located between Horn Island to the west and Petit Bois Island to the east. Dredging activities within Horn Island Pass have intercepted west-directed littoral sand transport, some of which has not been placed in the littoral zone west of the channel (Byrnes et al., 2013). A substantial portion of maintenance dredging sand has been placed in Disposal Area 10 (DA-10). This disposal area is located far north on the shoal complex in an area of limited wave energy, insufficiently strong to drive sediment to the west. This was resulted in limiting sediment transport to eastern Horn Island.

Based on sediment transport and budget information developed as part of the MsCIP, proposed modifications to maintenance dredging practices are being implemented to redirect placement of maintenance dredging sand to a more active portion of the littoral drift system west of the channel. Modification of USACE dredged material placement practice is expected to improve current practices and enhance the natural transport of sand to Horn Island.

**Monitoring Purpose:** Verify that sand placement west of Horn Island Pass has been relocated to a more active portion of the littoral transport system for bypassing material downdrift to Horn Island. The monitoring will provide the information required to measure progress against the success criteria.

**Monitoring Design Summary:** To ensure that the modified maintenance dredging placement practice is achieving its desired outcome, bathymetric surveys will be conducted before and after sand is relocated to the new dredged material placement site adjacent to Horn Island. In addition, at least two extended surveys within Horn Island Pass will be conducted during the ten year monitoring period. A sand transport study, being conducted using sand tracer technology with an associated monitoring program, will provide insight into the fate of dredged material placed within the Horn Island and DA-10 Littoral Zone Placement site. This information will assist in verifying the optimum placement zone for future dredging/placement operations. Additional details regarding the monitoring procedure can be found in Appendix D1.

**Desired Outcome:** Effective placement of dredged material from Horn Island Pass to downdrift beaches of Horn Island.

**Success Criteria:** Increase sediment availability for littoral transport along the barrier islands measured over a five and ten year period at Horn Island Pass.

**Interim Target:** Increase sediment availability for littoral transport along the barrier islands measured over a five year period at Horn Island Pass.

**AM Trigger:** No improved sediment transport of placed dredged material from Horn Island Pass toward Horn Island. Sediment flux is not increased to Horn Island.

## 4.0 Data Management

Data management is a vital component of any long-term monitoring plan and the associated AM process. To maintain hydrological, biological, and physical data, the data must be stored, organized, and archived in an efficient and intuitive structure. The data management role will be shared by USACE, Mobile District and USGS, who, together will form the MsCIP Data Management Team. All data collected will be analyzed for sensitivity and protected accordingly. Using a public and/or password protected web interface, spatial and temporal aspects of applicable data types will be available for accessing restoration project progress and for use in AM decision-making. Each distinct data type collected must comply with its specific data format, delivery, and metadata standard. These standards will be prescribed by the Data Management Team and managed by the Adaptive Management and Monitoring Program Oversight Committee. Over-arching MsCIP data management concepts and data type details can be found outlined in the MsCIP Data Management Plan (Appendix E).

Topics included in the data management plan include:

- Applicability
- Public Release
- Coordination

- Standardization
- Provider
- Data Access
- Data Format
- Metadata
- Archival
- Transparency

## 5.0 Assessment

The assessment phase of the implementation framework (Figure 5) compares the results of the monitoring efforts to the MsCIP barrier island 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. The assessments will 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. The following assessments planned under the MsCIP and described in Appendix G.

- Morphology, Shoreline Change
- Sediment Transport
- Sedimentation, Shoaling
- Dredged Material Placement
- Flow Patterns
- Wave Attenuation
- Water Quality
- Habitat Composition
- Benthic Infauna
- SAV Acreage and Distribution
- SAV Condition and Composition
- SAV Turbidity, Depth and Substrate
- SAV Long-term Trends
- Gulf Sturgeon Habitat Area
- Gulf Sturgeon Occupancy
- Gulf Sturgeon Foraging Habitat
- Sea Turtle Habitat Suitability Model
- Sea Turtle Sediment Shear Strength
- Sea Turtle Suitable Nesting Habitat from Habitat Mapping
- Sea Turtle Historical Habitat
- Shorebirds Benthic Foraging Habitat
- Shorebirds Critical Habitat Mapping
- Shorebirds Habitat Utilization Modeling
- Shorebirds Historical Habitat
- Shorebird Habitat Change Mapping
- Cultural Resources

The CEM (Section 2.1.1; Appendix F) helps describe the linkages between stressors and Performance Measures and may be used to further define management actions based on the monitored results. The assessments will help determine if the observed responses are:

1) attributable to sediment placement by MsCIP; and 2) undesirable (e.g., are moving away from restoration goals) vs. in accordance with specified Success Criteria. If Performance Measures are not responding as desired, or the stressor has not changed enough in the desired direction (for example, there is an increase in wave heights in the lee of Ship Island), then recommendations should be made for modifications to the project (both within the authority of MsCIP and outside

of MsCIP) (see section 5.2). If the stressor has changed as expected/desired and the Performance Measure has not, additional research may be necessary to understand why.

### 5.1 Variance

The TAG will refer to a combination of formal predictive models along with their own professional judgment when comparing the values of the Performance Measures detected by monitoring with the corresponding pre-defined Decision Criteria (Performance Measures, Success Criteria, Triggers and thresholds). This group will collaborate with project managers and decision-makers to define magnitudes of difference (e.g., statistical differences, significance levels) between the values of monitored Performance Measures and the desired values (i.e., Decision Criterion) that will constitute variances from the desired outcomes. Comparisons between monitoring results and project performance will require characterization of historical and current spatial-temporal variability that define baseline conditions. Variances (or their absence) will be used to recommend one the following actions:

- Continuation of the project without modification
- Determine that more data are required and continue (or modify) monitoring
- Identify and implement active design or a remedial AM action through the MsCIP
- Identify and recommended remedial AM action outside of the MsCIP
- Modify project goals and objectives (this option would only be considered as a last resort and upon careful consideration by, and consensus of, the Program Management Team).
- Successful close-out of the barrier island restoration project and lessons learned.

Appropriate statistical comparisons (e.g., hypothesis testing, ANOVA, multivariate methods, etc.) will be used to summarize monitoring data and compare these data with the decision criteria. These continued assessments will be documented as part of the project reporting and data management protocols

### 5.2 Frequency of Assessments

An initial project assessment will be completed using pre-construction baseline data. There will be post-construction project assessments during the post-construction period; however, the level of detail will depend on the timescale of expected responses, and frequency of data collection. At this time it is proposed that assessments will occur every three years after the pre-construction baseline assessment and after acute events, as necessary. Ultimately the determination of the frequency of assessment will be based on:

- Relevant temporal scales of the performance measures
- Time required to obtain sufficient monitoring results and analysis for meaningful comparisons with the Decision Criteria
- Consequences (ecological, socioeconomic, political, stakeholder) of variances with Decision Criteria
- Logistical requirements to perform the assessment
- Availability of the AM personnel
- Funding
- Occurrence of acute events

### 5.3 Reporting

The TAG will document each of the performed assessments and communicate the results of its deliberations to the RSLG, Oversight Committee managers and Program Management Team. The TAG will produce periodic reports that will measure progress towards project goals and objectives as characterized by the selected Performance Measures and Decision Criteria. The reporting of monitoring results and AM evaluations will be in the form of Assessment Reports that include a high level of detail, and a science- and management-friendly summary document.

## 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. Because of inherent uncertainty and the inability to develop courses of actions optimal to all possible future scenarios, the USACE and other natural resource management agencies have increasingly committed to address uncertainties using AM (NRC 2004; Convertino et al., 2013; Rist et al., 2013). The monitoring design (previously described in Section 3) provides the feedback necessary to not only determine progress towards achieving project goals and objectives, but to also address uncertainty and inform the iterative decisions driving the potential future project adjustments.

A distinction is often made between “passive” and “active” adaptive management. While there is considerable variability in the use of these terms, the main difference between passive and active adaptive management is the degree to which management objectives treat uncertainty and learning, and the formalization of decisions (Fischenich et al., 2012; Williams and Brown, 2012). Active AM formally pursues the reduction of uncertainty and learning to determine the cause-and-effect relationships between management actions and environmental responses. In active AM a range of management choices are explored at decision points and the best alternative is applied (NRC, 2004). AM can also be passive, in which case uncertainty is recognized and selected performance measures are monitored, but the project is implemented and focused on evaluating outcomes rather than resolving uncertainties, in these cases learning is a byproduct (NRC, 2004; Fischenich et al., 2012; Williams and Brown, 2012). Traditionally, passive AM has been planned and implemented for restoration projects. Whether passive or active, AM is an evolving process involving learning (the accumulation of understanding over time), and adaptation (the adjustment of management over time), that lead to a better understanding of the resource system and better management based on that understanding (Williams and Brown., 2012).

The development of the AM program for the MsCIP program included both traditional passive AM planning and identification of corrective actions that could be implemented post-construction, should monitoring data indicate the project is not performing as expected (Section 6.1), as well as implementation of a more active, formal AM program through the incorporation of Structured Decision Making (SDM, Section 6.2). Since the barrier island restoration is being implemented (previously described in Section 2.1.3) in a highly dynamic system, a formal decision analysis tool was developed to provide a framework to guide AM decisions that could arise at critical decision points during construction.

### 6.1 Adaptive Management Actions

As previously indicated in Section 2.3, there is limited flexibility for traditional AM post-construction since the MsCIP barrier island restoration, once implemented, does not contain plans for modification or renourishment. The AM actions (contingency/corrective) identified in Table 1 are proposed to be implemented if the Success Criteria (presented in Section 3.1) are not met within the specified timeframes. It should be noted that in some cases, due to the limited authority of the MsCIP barrier island restoration and the design criteria, some corrective actions may be implemented under the MsCIP, whereas the MsCIP would make recommendations for an action that would have to be implemented by other programs and/or agencies, in other cases.

**Table 1.** Potential Adaptive Management Response Options

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
|---|---|---|---|---|---|
| Flow patterns at Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass | Changes in flows measured from the pre- and one year post- construction surveys through the three passes are within the range of simulated changes. | Flows having similar tidal, river and wind conditions exceed predicted values through Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass. | N/A | N/A | N/A |
| Water Quality | Changes in primary water quality parameters (salinity, turbidity, dissolved oxygen, temperature, and light within seagrass beds), measured for a period of up to two years post-construction are within the range of historic variability and compare to changes observed at control stations. | The levels of the primary water quality parameters (salinity, turbidity, dissolved oxygen and temperature, and light within seagrass beds) exceed predicted values and are outside of the range of historic variability. | The levels of the primary water quality parameters (salinity, turbidity, dissolved oxygen, temperature, and light within seagrass beds) measured over a year following the closure of Camille Cut are within the range of the historic variability, and compare to changes observed at control stations | N/A | N/A |
| Submerged Aquatic Vegetation (SAV) coverage | Ten years post-construction total SAV acreage, distribution, condition and species composition on Ship Island is similar to the pre-construction period 2010-2014. | Reduction in SAV cover and condition six years post- construction on Ship Island associated with the closure of Camille cut. | Three year post-construction, maintain 2014 pre-construction SAV distribution. | Restore seagrass habitat in suitable areas. Potential methods include plantings in areas conducive for SAV establishment. | MsCIP action may be required if it is determined that the negative impacts are associated with the construction of Ship Island |

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
|---|---|---|---|---|---|
| Benthic and Infaunal Species | The re-establishment of benthic and infaunal species post-construction will occur when the average biomass is within the project area is at least 70% of the pre-project average biomass level. (applies to shorebird and sturgeon feeding sites and placement sites) | Success criteria not met by five years | A short-term evaluation of benthic and infaunal species re-establishment will be collected six months post-construction as part of the Gulf sturgeon benthic prey assessment. Maintain suitable shorebird foraging habitat acreage five years after the completion of the closure of Camille Cut. | Should prey biomass not meet the success criteria, then additional benthic surveys will be conducted until the success criterion is met. | MsCIP would conduct the additional benthic surveys needed to meet success criterion. |
| Gulf sturgeon | Two years post-construction occupancy values fall within two standard deviations of pre-construction values<br>AND<br>No significant change in post-construction benthos community assessments as compared to the pre-construction assessment. | Reduction in Gulf sturgeon habitat usage and occupancy patterns within the Ship and Horn Island System. | Six months post-construction track potential movement of Gulf sturgeon shift to other surrounding habitat zones. | Additional Gulf sturgeon monitoring will be implemented until success criteria are met (See scenarios A-D in Appendix D3i) | MsCIP would conduct additional Gulf sturgeon monitoring until success criteria are met. |

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
|---|---|---|---|---|---|
| Habitat Composition | Ten years following the completion of construction on Ship Island the loss of emergent habitat relative to project completion acreage is less than the historical land loss rate. The land loss rate will come from either literature, such as Morton (2007), or recent satellite-based land change analyses by Couvillion (2017). Acreage will be determined from the habitat mapping effort conducted immediately after project completion.<br>AND<br>Maintain habitat diversity of emergent and submerged habitats over time, including beach and dune, intertidal flats, wetlands, and upland/scrub shrub. | Loss of emergent habitat within ten years greater than the historical land loss rate.<br>------------------------<br>Ten years post- construction a reduction in acreage of wetlands on Ship Island due to overwash and sand burial, compared to historical data. | Habitat mapping is scheduled to be conducted at regular intervals post-construction and success criteria will be assessed at each interval | Additional sand placement on the island to restore emergent land.<br>----------------------<br>Restore wetlands lost from overwash or sand burial. | Not within the current MsCIP Authorization. If implemented, action would require either additional authorization or action by outside agency.<br>------------------------<br>Not within the current MsCIP Authorization. If implemented, action would require either additional authorization or action by outside agency. |
| T&E Shorebirds | Ten years post-construction maintain or increase the pre-construction acreage of suitable shorebird foraging | Reduction of suitable shorebird foraging habitat after closure of Camille Cut. | Maintain suitable shorebird foraging habitat acreage five years post-construction. The total number of acres of suitable nesting habitat will be determined | If closing of Camille Cut adversely affects the low-lying spits on the western and eastern tips of the island that provide sufficient habitat for key indicator bird species, recommendations to | MSCIP would re-consult with the USFWS to determine if further actions are necessary. |

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
|---|---|---|---|---|---|
| | habitat, as evaluated by habitat mapping efforts.<br>AND<br>Provide suitable benthic habitat five years post-construction. | | by habitat mapping based on pre-construction conditions. | construct lower lying areas within the restoration template in the lee or at the ends of the project during one of the later project construction phases may be made. | |
| Nesting Birds | Ten years post-construction maintain or increase suitable acres of nesting as compared to the pre-construction acreage as evaluated by habitat mapping efforts. | Loss of nesting habitat (acres) for solitary and colonial nesting shorebirds as evaluated by habitat mapping efforts. The total number of acres of suitable nesting habitat will be determined by habitat mapping based on pre-construction conditions. | Five years post-construction maintain suitable acres of nesting habitat as evaluated by habitat mapping efforts. | Additional sand placement on the island to create suitable nesting habitat. | Not within the current MsCIP Authorization. If implemented, action would require either additional authorization or action by outside agency. |
| Sea Turtles | Ten years following the completion of planting on Ship Island maintain or increase suitable acreage of sea turtle habitat, as compared to the pre-construction acreage. Sea turtle habitat is defined as upper beach habitat at three feet or higher. The total | Loss of habitat (acreage) for sea turtle as evaluated by habitat mapping efforts. The total number of suitable acres will be determined by habitat mapping based on pre-construction conditions.<br>------------------------------- | Five years following the completion of the planting on Ship Island maintain suitable acres of turtle habitat as evaluated by habitat mapping efforts. | Creation of additional suitable habitat.<br>---------------------------------<br>Tilling will occur as required by the Biological Opinion. | MsCIP would re-consult with the USFWS to determine if further actions are necessary.<br>-------------------------<br>MsCIP would re-consult with the USFWS to determine if further actions are necessary |

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
| --- | --- | --- | --- | --- | --- |
| | number of suitable acres will be determined by habitat mapping based on pre-construction conditions<br>AND<br>The development of an evaluation formula, driven by improved understanding of the changes in penetration resistance over the monitoring period, such that no further consultations with Fish and Wildlife Service are needed<br>AND<br>Compliance with terms and conditions set forth in the Biological Opinions. | Compaction tests do not meet requirements for suitable turtle hatching | | | |
| Cultural Resources | Ten years following the completion of all construction activities the success criterion is no appreciable loss of listed, | An inadvertent discovery made during construction<br>---------------------------------<br>Increase exposure or disturbance to resources | Five years following the completion of all construction activities no appreciable loss of listed, eligible, or potentially eligible cultural resources due to | The purpose of this monitoring is to ensure compliance with Section 106 of the National Historic Preservation Act of 1966. During construction all | MsCIP Actions are required during the construction period only.<br><br>------------------------------------ |

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
|---|---|---|---|---|---|
| | eligible, or potentially eligible cultural resources due to erosion or construction, as determined by aerial mapping and baseline conditions. No potential submerged cultural resources are impacted by dredging or placement activities. | eligible for nomination to the National Register of Historic Places. | erosion or construction based on aerial mapping and baseline conditions. | actions will fall within these requirements along with the Inadvertent Discoveries Plan. | No actions will be conducted under the MsCIP program post- construction. |
| Island morphology and shoreline change | Net loss of original island restoration surface area is not greater than an average of 3% per year over the ten year monitoring period. | Net loss of original island restoration surface area is greater than an average of 3% per year over the ten year monitoring period.<br>---------------------------------<br>Land loss along Ship Island exceeds 50% of the original restoration area over the ten year monitoring period.<br>---------------------------------<br>A storm(s) significantly impacts the project before and/or during construction | Net loss of original island restoration surface area should be less than an average of 15 over the five year monitoring period. | Additional sand placement on the island.<br>----------------------------------------<br>Additional sand placement on the island.<br>---------------------------------------<br>If a storm(s) significantly impacts the project before and/or during construction and requires additional sand fill, additional construction actions may be | Not within the current MsCIP Authorization. If implemented, action would require either additional authorization or action by outside agency.<br>-----------------------------------<br>Not within the current MsCIP Authorization. If implemented, action would require either additional authorization or action by outside agency.<br>-----------------------------------<br>MsCIP Action. See Section 6.2 for recommended actions; SDM was specifically used to evaluate decisions on how to respond to potential storm-induced damages. |

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
|---|---|---|---|---|---|
| | | | | necessary to maintain island integrity and meet the project objectives. | |
| Wave Reduction Leeward of Ship Island | Reduced wave height leeward of Ship Island relative to pre-construction baseline conditions during the five years post-construction monitoring period. | No reduced wave attenuation north of Ship Island after the closure of Camille Cut. | N/A | N/A | N/A |
| Restore Sediment to the Barrier Island System | Increase sediment availability for littoral transport along the barrier islands measured over a five and ten year period. | During the initial construction phases, the sand material placed at Ship Island placement is removed at rates higher rates than expected, due to unexpectedly strong longshore transport. | Increase sediment availability for littoral transport along the barrier islands measured over a five year period. | If material at Ship Island placement in the initial phases reveals higher longshore transport rates, then additional sand could be placed updrift in later construction phases. These revisions would be limited to the coordinated template and additional coordination would be required. | MsCIP Action. See Section 6.2 for recommended actions; SDM was specifically used to evaluate decisions on how to respond to increased longshore transport rates. |

| Performance Measure Indicator | Success Criteria | AM Trigger | Interim Target | Potential Response Option | Responsibility (MsCIP or outside agency) |
|---|---|---|---|---|---|
| Dredged Material Placement within Horn Island littoral system. | Increase sediment availability for littoral transport along the barrier islands measured over a five and ten year period at Horn Island Pass. | No improved sediment transport of placed dredged material from Horn Island Pass towards Horn Island. Sediment flux is not increased to Horn Island. | Increase sediment availability for littoral transport along the barrier islands measured over a five year period at Horn Island Pass. | If dredged material removed from Horn Island Pass and placed west of the channel is not migrating toward Horn Island at rates higher than disposal quantities and/or is migrating back toward the channel, recommendations outside of the MsCIP for revisions to future placements may be made. | Not within the current MsCIP Authorization. MsCIP could make recommendations for revisions to future Horn Island placements |
| Sedimentation/ Shoaling | No increase over natural variability in average annual maintenance dredging during the five and ten year periods with Ship Island Pass. | Average shoaling rates in the navigation channel increase to be outside the range of natural variability and average annual maintenance dredging costs increase over the ten year monitoring period compared to baseline values. | Shoaling rates in the Ship Island Pass navigation channel remain within the range of natural variability and average annual maintenance dredging per year over a five year period is unchanged compared to baseline values. | Recommendation to limit sediment from depositing in the Ship Island Pass navigation channel may be investigated (i.e. groins, sediment basins, backpassing sediment to nearshore etc.).<br>or<br>If suitable sand is available to be dredged from the Ship Island Pass navigation channel, MsCIP could recommend the future back passing to benefit the overall Ship Island system, if such action would not adversely impact the existing navigation project | Not within the current MsCIP Authorization, if implemented, action would be required by outside agency |

## 6.2 Structured Decision Making

Many AM programs employed in large restoration projects include a formal monitoring program, but lack formalized decision structures designed to integrate learning concerning the 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 the use of decision analytic models that explicitly address uncertainties to inform the iterative adjustment of actions through time. SDM is a collaborative process that includes both stakeholders and scientists to better define management objectives, alternative actions, external drivers, predictive models, and quantitative methods for optimization, and tradeoff analysis, in order to identify optimal decisions and the key uncertainties to be addressed (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 the MsCIP program, SDM was applied to the Barrier Island Restoration on Ship Island to provide a formal, transparent, and replicable process for analyzing decisions regarding the reparation of any storm-related damages that may arise during island construction.

Typically, the design template for barrier island restoration is based on a number of assumptions that, if met, should provide a specified island structure and longevity. This, however, does not take into account the possibility of unexpected conditions arising during construction in such highly dynamic systems. In developing the AM plan for the MsCIP project, we looked to directly incorporate the scientific uncertainties and technological challenges inherent with large-scale barrier island restoration into the AM planning through the use of SDM in order to create an AM decision framework that could be used to actively guide construction decisions for barrier island restoration on East and West Ship islands and help determine the relationships between environmental conditions and management actions.

### 6.2.1 Decision Model Development Summary - PrOACT Process

SDM was applied to four phases of Barrier Island Restoration at Ship Island to set up a decision process that can be quickly and effectively implemented during project construction to make decisions should either the restored berm incur damages or the environmental dynamics change. SDM was conducted through a collaborative decision analysis with a diverse team of stakeholders representing multidisciplinary expertise in barrier island ecosystems. Participants represented subject-matter experts, decision makers, and stakeholders who preserve, manage, or restore barrier islands across the Gulf of Mexico region (Appendix C). Specifically, we followed a SDM framework that includes an assessment of Problems, Objectives, Alternatives, Consequences, and Tradeoffs (PrOACT) (Hammond et al., 1999; Runge et al., 2011) and, through a series of webinars and rapid-prototyping workshops, used expert judgment to identify and link objectives, performance measures, consequences, trade-offs and uncertainties associated with the construction of the Barrier Island Restoration at Ship Island. This formal process analyzed decisions at key decision points by breaking the problems, potential scenarios and solutions into components that were weighed through a transparent and replicable process. Expert elicitations, predictive models, and quantitative analysis were incorporated into a Bayesian decision network model (decision support tool) to represent the probabilistic relationships between storm impacts on the constructed island footprint (i.e., breaching, narrowing, and/or lowering) and consequences for restoration objectives, including mitigation of shoaling, wave attenuation, avoiding loss of habitat for sea turtles, shorebirds, and Gulf sturgeon, maintaining salinity levels in Mississippi Sound, and preserving funds for subsequent MsCIP restoration projects.

The initial prototype decision (Decision Question 1) framework was developed at a workshop in November 2013. Results from this workshop were then used in a subsequent series of webinars and workshops through June 2014 to refine the decision questions and consider additional objectives for Ship Island construction and restoration, which were included in Decision Question 2. The results of the SDM effort and the decision tool are the product of this iterative process and illustrate the crucial uncertainties affecting the optimal choices for the construction and performance of the MsCIP Barrier Island Restoration Project. A summary of the process and results are presented in this Chapter.

***Problem Definition***

The group developed decision questions, including the spatial and temporal dimensions of the problem and any relevant legal or regulatory issues, that formed the conceptual foundation for SDM application. The decisions questions that were developed for the project were:

<u>Decision Question 1</u>

How can MsCIP partners optimize decision making relative to Ship Island restoration and the benefits, including the use of monitoring and adaptive management practices, given sand limitations and the uncertainties related to the financial budget, storm impacts, and system response? If a storm impacts the constructed berm, or longshore sediment transport is greater than expected, should the MsCIP partners repair a major breach in the berm or address increased longshore sediment transport by offsetting sediment placement given the funding and sand limitations?

<u>Decision Question 2</u>

When should MsCIP partners repair weakening events (i.e., lowering or minor puncturing of the fill), if needed, within the Ship Island template to maximize the benefits, including the use of monitoring and adaptive management practices, during construction, given the uncertainties in storm impacts and system response? How should potential minor mid-construction damage be handled?

***Objectives***

The next step was to identify a set of fundamental objectives to guide decision-making. The selected fundamental objectives were:

- Gulfport Harbor Channel Shoaling
    - Do not exceed historic shoaling rates of the Gulfport Harbor navigation channel

- Wave Attenuation
    - Increase wave height attenuation between Gulf of Mexico and Mississippi Sound

- Ecological integrity of Mississippi Sound
    - Maximize shallow sandy acreage for Gulf sturgeon feeding habitat
    - Maintain pre-construction salinity levels in Mississippi Sound

- Ecological integrity of Shoreline
    - Minimize loss of upper beach habitat for sea turtles
    - Maximize swash zone habitat for shorebird feeding

- Maximize leftover funding for other high priority MsCIP projects
    - The MsCIP Management Team identified several high priority MsCIP projects that it would like to implement if funding were available after the implementation of the Barrier Island Restoration Project. Approximately $39,000,000 would be needed to implement these high priority projects, so this minimum cost was included as a consideration in the decision model in cases where decisions would reduce available funding.

***Alternative strategies***

Once the objectives were identified, the next step was to identify alternative management actions that could be combined into strategies for achieving these fundamental objectives. The participants identified alternative management actions and alternative strategies for sediment placement decisions during each phase of Ship Island construction. Implementation of any given alternative strategy was dependent on the drivers, including the longshore transport rate (LST) (included only in Decision Question 1), storm inundation, available sediment, and remaining funding. The alternative management strategies identified were as follows:

<u>Decision Question 1</u>

- Phases 1-4: If there is a major breach to the Camille Cut berm after initial construction and strengthening in Phases 1 and 2, should it be repaired?
- Phase 3: If longshore sediment transport is greater than expected, should sediment placement be offset with additional sand placement to account for the increased rate?

Decision Question 2

- Phase 1: If there are minor damages (lowering and/or narrowing) to the Camille Cut berm behind construction during Phase 1, should they be repaired at the end of Phase 1 (Sooner option) or during Phase 2 (Later option)?
- Phase 2 decision: If there are minor damages (lowering and/or narrowing) to the Camille Cut berm behind construction during Phase 2, should they be repaired at the end of Phase 2 (Sooner option) or during Phase 4 (Later option)?
- Phase 3 decision: If the nourished area of East Ship Island is lowered to less than 3-foot elevation over at least 50% of its surface area, then should this be repaired at the end of Phase 3 (Repair option), or not repaired at all (No Repair option)?
- Phase 4 decision: If the Camille Cut berm is lowered below the template during Phase 4 construction, should this be repaired at the end of Phase 4 (Repair) or not (No Repair)? If the decision is to repair, should those repairs be made with coarser sand (more expensive) or finer sand (less expensive)?

***Consequences***

In order to predict and evaluate consequences of alternative management strategies, the SDM team began by using influence diagrams to link the strategies to each of the fundamental objectives, while explicitly considering the external effects. The influence diagrams developed are presented in Figures 6-8. For Decision Question 1, which focused on whether or not to fix a major breach and/or offset increased longshore transport, the diagram aggregated the fundamental objectives into Mississippi Sound conditions, near-shore conditions and island habitat. These fundamental objectives represent biophysical processes and functions of the Barrier Island restoration on the Ship Island project. Some of the management actions that could be taken to influence the fundamental objectives are shown in the hexagon in Figure 6 and are associated with the management of sediment within the designed construction template of Ship Island. Each of the actions would require a decision that is dependent upon available sediment quantity and quality, available budget, and consideration of storm impacts during construction. Availability of suitable sediment, storm occurrence, and budget limitations were identified as important drivers to include in the decision frameworks that would impact the success of the fundamental objectives.

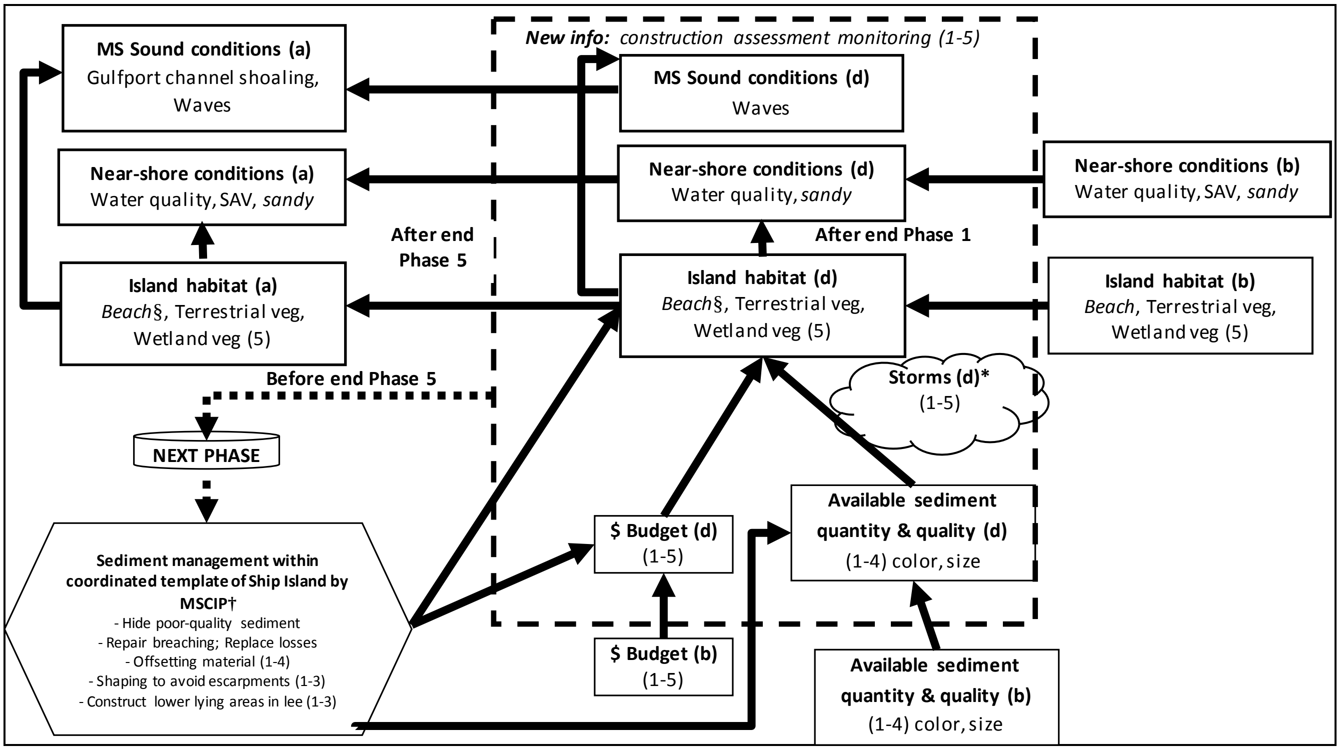


**Figure 6.** Decision Question 1 Influence Diagram. This conceptual model represents timing of external drivers, constraints, and ultimate outcomes regarding linked decisions related to sediment placement within the coordinated template of Ship Island under authority of the Barrier Island Restoration Project administered by the USACE MsCIP**.** The hexagon represents decisions and rectangles represent objectives. Numbers in parentheses represent phases of construction; letters in parentheses represent before (b) or during (d) construction. **†**Actions will avoid exceeding allowed take of threatened and endangered species (i.e., Gulf sturgeon and sea turtles). *Storms impact every objective, SAV = submerged aquatic vegetation.

For Decision Question 2, the influence diagrams were developed further to include a temporal component and the phases on construction, and include a broader range of decisions to be made regarding potential damages (lowering, narrowing and minor breaching). Each of the actions would require a decision that is dependent upon storm impacts during construction, costs to fix damages, available sediment quantity, available budget, and sediment quality.

Damages in early phases could be repaired immediately or they could be repaired during subsequent phases as part of scheduled sand placement in the future phases. The decision to make immediate repairs would require additional cost for remobilization, while leaving the berm damaged and weakened until future phase repair increases the risk of additional damage, potentially increasing future costs. For damage in Phase 4, there was also the choice of the use of finer or coarser sand. The finer-grain material is less stable, but, being more readily available, is a less expensive alternative. The condition of Ship Island restoration at the end of the phase depends on the occurrence of storms or unrepaired damage in prior phases and possible repair (at a sand and money cost) of narrowing, lowering, or breaching. The availability of suitable sediment, storms and budget were identified as important drivers to include in the decision frameworks that would impact the success of the fundamental objectives.

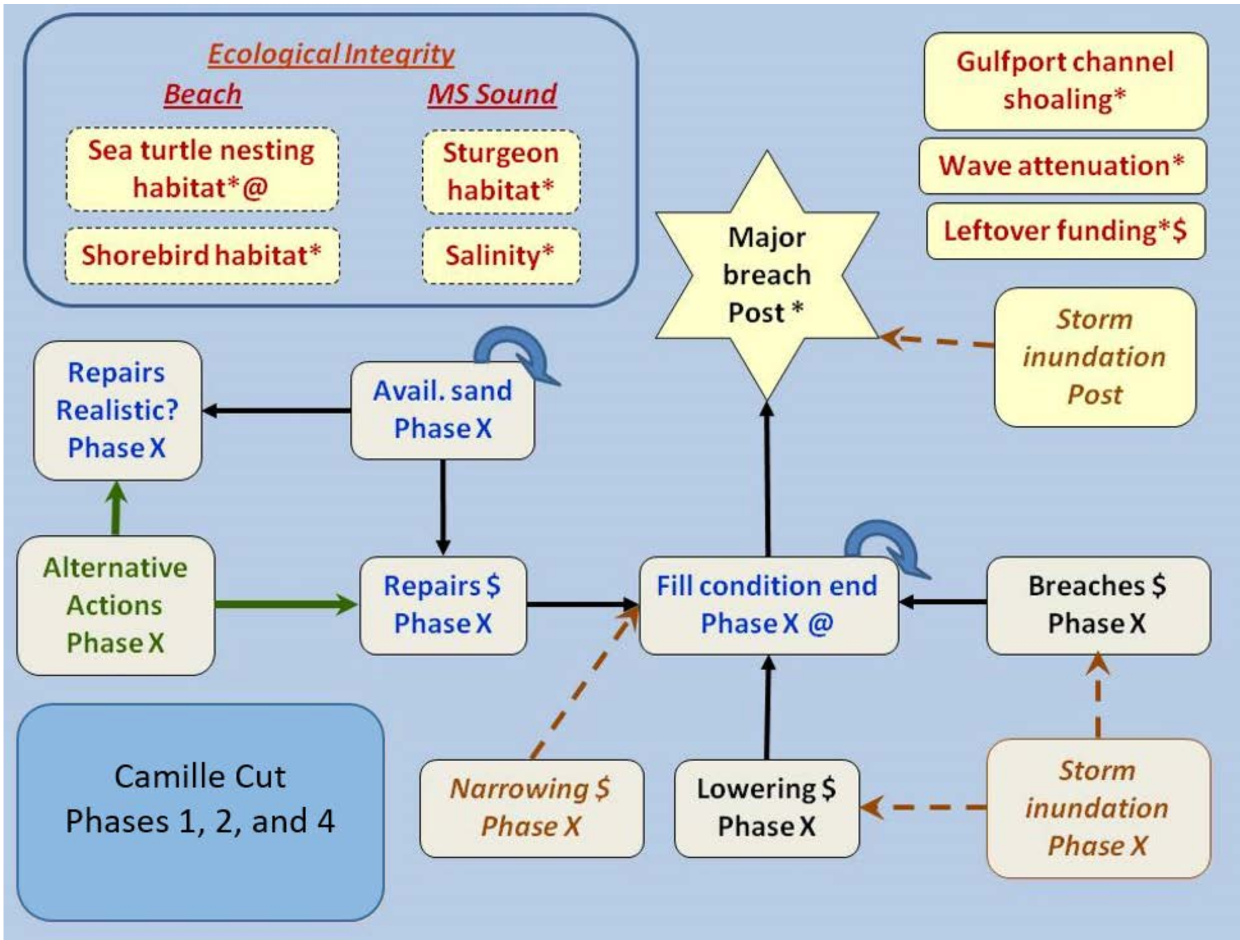


**Figure 7.** Decision Question 2 Influence Diagram Phases 1, 2, 4. Phase X refers to Phases 1, 2, and 4, except "Avail. sand", which is relevant only for Phases 2 and 4. Circular arrows, which are only pertinent to Phases 2 and 4, indicate that these factors are contingent on their levels during the previous phase. Gray boxes are factors occurring during construction, and yellow boxes are factors occurring post-construction. Red text indicates fundamental objectives, brown text and dashed arrows indicate external drivers. Blue text indicates intermediate drivers not needing to be informed with elicited probabilities. Bold black text indicates intermediate drivers that would need to be informed by elicited probabilities. In some cases, linkages between factors are indicated with symbols, with linkage between specific boxes marked by the appearance of the same symbol: asterisk (*), "at" (@), and dollar ($).

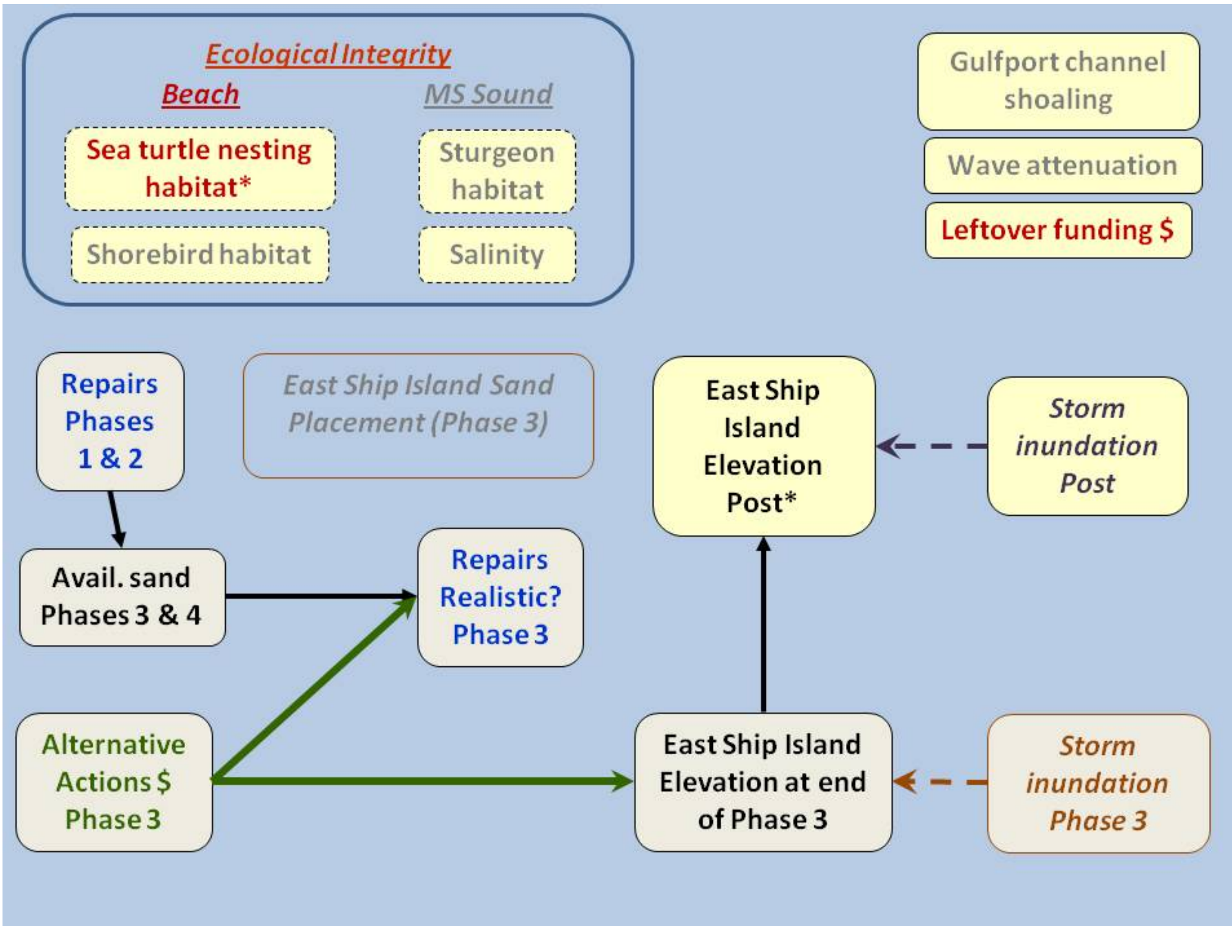


**Figure 8.** Decision Question 2 Influence Diagram-Phase 3. Gray boxes are factors occurring during construction, and yellow boxes are factors occurring post-construction. Red text indicates fundamental objectives, brown text and dashed arrows indicate external drivers. Blue text indicates intermediate drivers not needing to be informed with elicited probabilities. Black text indicates intermediate drivers that would need to be informed by elicited probabilities. In some cases, linkages between factors are indicated with symbols, with linkage between specific boxes marked by the appearance of the same symbol: asterisk (*), “at” (@), and dollar ($).

The developed influence diagrams subsequently were converted to Bayesian Decision Network (BDN) models using the Netica software program (Norsys Software Corp: Vancouver BC, Canada) to represent probabilistic relationships. In general, the BDN is organized as a collection of linked nodes that take one of three forms: 1) decision nodes that distinguish between alternative management strategies; 2) stochastic nodes that quantify intermediate outcomes (i.e., means objectives) and ultimate outcomes (i.e., fundamental objectives) along with external drivers; and 3) a utility node that represents how managers and decision makers value all possible outcomes in terms of the fundamental objectives. The BDN is particularly valuable for predicting the consequences of alternative management strategies, because uncertainties (e.g., sediment availability, budget, and storm impacts) are propagated explicitly through the model.

To parameterize the BDN model and assign probabilities in Netica, the group assigned measureable attributes to the objectives and used quantitative methods for making predictions about the effects of management actions on the objectives. When literature-based predictions, existing data and/or predictive modeling results were unavailable, the group used rapid expert elicitation approaches to parameterize the BDNs (Kuhnert et al. 2010). During the elicitation, decision makers, stakeholders and workshop participants were asked to quantify their values regarding the possible outcomes of the fundamental objectives on a 0-100 scale, with 0 being the worst possible outcome and 100 being the best possible outcome, providing their expert judgment and supporting rationale (based on data, experience and values). The resulting BDN models developed decision frameworks that tied various potential future scenarios to management actions and the resulting effects on the fundamental objectives.

***Optimization, Tradeoffs and the Identification of optimal management strategies***

As the final step in the PrOACT sequence, a tradeoff and sensitivity analysis was conducted on resulting BDNs for Decision Questions 1 and 2. Often a decision maker would like to know whether an optimal decision would change if assumptions within the decision model are changed, or if new information is discovered. Sensitivity analyses were conducted to evaluate the robustness of an optimal decision (expected utility), i.e. whether it changes when assumptions are altered regarding external drivers, predicted consequences, and/or trade-offs between objectives. Netica allowed the team to conduct the multi-attribute perturbation analyses to identify which of the stochastic nodes or combinations of nodes were driving optimal decision-making.

***Summary and Conclusions***

Under the SDM process the team developed two prototypes through an iterative process to formalize AM decisions that may be needed during construction to better ensure that project objectives and success criteria are met. Decision Question 1 addressed decisions regarding whether or not to repair a major breach and/or offset longshore transport, while Decision Question 2 addressed decisions regarding the management of minor breaches, lowering and or narrowing that could occur in each phase, while tracking sand and expenditures through the phases and decisions. Using expert elicitation from the team we identified the expected consequences and tradeoffs of potential actions (repairs or offsetting future placement to adjust for LST) that could be needed to ensure the integrity of the constructed Ship Island template, while minimizing impacts on the fundamental objectives (mitigation of shoaling, wave attenuation, avoiding loss of habitat for sea turtles, shorebirds, and Gulf sturgeon, maintaining salinity levels in Mississippi Sound, and preserving funds for subsequent MsCIP restoration projects). Overall, the results from the BDN models determined that while sand supply could be a limiting factor in making optimal decisions, the available budget was not. For the examined scenarios there was sufficient funding, but possibly insufficient sand, if multiple repairs are required, due to the fact that the maximum amount of sand that can be placed is limited by the project's authorization.

The optimal decision identified from the BDN in Decision Question 1 was to always repair a major breach as long as there was available sand. Under scenarios with both limited funding and sand, the optimal decision was to repair the breach, but not offset material in future phases to account for increased LST. Under a scenario with sufficient funding and sand, the optimal decision was to fix the major breach and offset material to address LST. However, the benefit of this strategy was only slightly more beneficial (<2%) than not offsetting to address LST. A sensitivity analysis was run to evaluate the strategy optimality regarding the uncertainty associated with predicted outcomes of the fundamental objectives and selected drivers. The uncertainties associated with the Gulfport Harbor navigation channel, shoaling, Gulf sturgeon habitat, upper beach habitat, salinity in Mississippi Sound, storm inundation, major breaching post construction and funding for Phase 5 plantings did not change the optimal decision. The only fundamental objective affected was wave attenuation, which was only affected to a small degree. When the likelihood of decreased wave attenuation was adjusted, the expected utility outcome was increased by <1%; this was not a large enough difference to change the optimal decision, but does illustrate the importance of including monitoring for wave attenuation in the MAM plan.

The Decision Question 2 framework helped determine optimal decisions related to repair of minor damages and identification of scenarios that might result in a shortage of sand in later phases. Furthermore, Decision Question 2 helps guide decisions regarding MsCIP's ability to reserve funding to implement subsequent high priority MsCIP projects without impacting the fundamental objectives or integrity of the constructed Barrier Island Restoration project at Ship Island. The model showed that the optimal decisions for Phases 1 and 2 are to repair minor damages at the end of each phase rather than waiting until the next phase. A bigger breach was determined to be up to three times as likely if the repairs to the damages were delayed until Phase 2, rather than at the end of Phase 1. Similarly, according to the decision model, a major breach has no chance of occurring if minor damages are repaired in Phase 2, and a bigger breach is up to 43 times as likely to occur in later phases if the repairs are not made in Phase 2. The optimal decision during Phase 3 depended on two primary factors: whether the available sand limit has been exceeded, and whether the threshold of funding needed to implement subsequent high priority MsCIP projects had been reached. When sand is available to repair damages to Phase 3, but doing so would not leave enough funds to implement the high priority projects, the optimal decision was to consider not repairing the lowered sections, since the BDN model did not show negative impacts to the fundamental objectives. Most of the fundamental objectives were predicted to have similar outcomes regardless of whether or not a repair was made in Phase 3. Sea-turtle nesting habitat was the only fundamental objective that was shown to be potentially impacted, with the model showing an up to a 5% greater probability of nesting habitat loss if the minor damages were not repaired. Based on the loss of ability to pay for additional MsCIP projects resulting from performing the repairs, it was determined that the potentially minor impacts to the sea turtle fundamental objective habitat did not outweigh the benefits of implementing the additional MsCIP projects. The Phase 4 decision also took the cost of using fine (less costly) vs. coarse grain (more expensive) sand into consideration. Consistent with the results from the previous phases, it was determined that a major breach is >20 times as likely to form if damages are left unrepaired than if they are repaired, depending on the type and extent of damage. The optimal decision was to complete repairs with coarser sand, if funding was available. If the cost of repairing with courser sands would not leave enough funding left for additional MsCIP projects, finer sand would be considered. When the cost-savings threshold would be crossed by the coarser sand, but not the finer sand repair, then the optimal decision is to use finer sand. In cases where the use of finer sand is not suitable a decision would need to be made to determine if the repair is needed. In cases where the fundamental objectives are not impacted (as shown by some scenarios in the BDN), the optimal decision may be to consider not repairing, due to the negligible impacts on the fundamental objectives.

Tables 2-5 summarize the recommended actions based on the BDN.

**Table 2.** Phase 1 Example Scenarios

| **Major Breach (> 670 KCY) during Phase 1** | **Narrowing or lowering < 90 KCY during Phase 1** | **Bigger breach (> 90 KCY) during Phase 1** | **Is sand still available within the 22 MCY limit for the entire project?** | **Recommended Action** |
|---|---|---|---|---|
| Yes | -- | -- | Yes | Repair damages in Phase 1 |
| -- | -- | Yes | Yes | Repair damages in Phase 1 |
| -- | Yes | -- | Yes | repair damages in Phase 1 |
| Yes | -- | -- | No | Do not repair |
| -- | -- | Yes | No | Do not repair |
| -- | Yes | -- | No | Do not repair |

**Table 3.** Phase 2 Example Scenarios

| **Major Breach (> 670 KCY) during Phase 2** | **Narrowing or lowering < 90 KCY during Phase 2** | **Bigger breach (> 90 KCY) during Phase 2** | **Is sand still available within the 22 MCY limit for the entire project?** | **Recommended Action** |
|---|---|---|---|---|
| Yes | -- | -- | Yes | Repair damages in Phase 2 |
| -- | Yes | -- | Yes | Repair damages in Phase 2 |
| -- | -- | Yes | Yes | Repair damages in Phase 2 |
| Yes | -- | -- | No | Do not repair |
| -- | Yes | -- | No | Do not repair |
| -- | -- | Yes | No | Do not repair |

**Table 4.** Phase 3 Example Scenarios

| **Major Breach (> 670 KCY) during Phase 3** | **More than or equal to 50% of the Berm is lowered to 3ft or less** | **Was more than $39M available for other MsCIP projects before damages discovered?** | **Is sand still available within 22 MCY limit for the entire project?** | **Would at least $39M be available for other MsCIP projects if repair done?** | **Recommended Action** |
|---|---|---|---|---|---|
| Yes | -- | -- | Yes | Yes or No | Repair in Phase 3 |
| Yes | -- | -- | No | -- | Do not repair |
| -- | Yes | No | Yes | -- | Repair lowered areas in Phase 3 |
| -- | Yes | Yes | Yes | Yes | Repair lowered areas in Phase 3 |
| -- | Yes | Yes | Yes | No | Consider not repairing (fundamental objectives are expected not to be significantly impacted) |
| -- | Yes | -- | No | -- | Do not repair |
| -- | No | -- | -- | -- | Do not repair |

**Table 5.** Phase 4 Example Scenarios

| **Major Breach (> 670 KCY) during Phase 4** | **Narrowing or lowering < 90 KCY during Phase 4** | **Bigger breach (> 90 KCY) during Phase 4** | **Is sand still available within 22 MCY limit for the entire project?** | **> $39M available for other MsCIP projects before damages discovere** | **≥ $39M be available for other MsCIP projects if repair done with** | **Berm is lowered to ≤ 6ft or less & narrowed to ≤200ft** | **Berm is lowered to 4ft or less & narrowed to 500ft or less** | **≥$39M be available for other MsCIP projects if repair done with fine** | **Recommended Action** |
|---|---|---|---|---|---|---|---|---|---|
| Yes | -- | -- | Yes | -- | -- | -- | -- | -- | Repair damages in Phase 4 |
| Yes | -- | -- | No | -- | -- | -- | -- | -- | Do not Repair |
| -- | Yes | -- | Yes | No | -- | -- | -- | -- | Repair with Coarse Sand |
| -- | -- | Yes | Yes | Yes | Yes | -- | -- | -- | Repair with Coarse Sand |
| -- | Yes | -- | Yes | Yes | Yes | -- | -- | -- | Repair with Coarse Sand |
| -- | Yes | -- | Yes | Yes | No | -- | -- | Yes | Repair damages in Phase 4 with Fine sand |
| -- | Yes | -- | Yes | Yes | No | Yes | No | No | Repair damages in Phase 4 with Coarse Sand |
| -- | Yes | -- | Yes | Yes | No | No | No | No | Consider not repairing (fundamental |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | objectives are not expected to be significantly impacted) |
| -- | Yes | -- | Yes | No | -- | -- | -- | -- | Repair with Coarse Sand |
| -- | Yes | -- | Yes | Yes | No | | Yes | No | Repair with Coarse Sand |
| -- | -- | Yes | No | -- | -- | -- | -- | -- | Do not Repair |
| -- | Yes | -- | No | -- | -- | -- | -- | -- | Do not Repair |
| -- | Yes | -- | Yes | -- | Yes | -- | -- | -- | Repair with Coarse Sand |

### 6.3 Adaptive Management Decision Making Process

For both the AM actions outlined in Section 6.1 and the optimal decisions determined by the SDM framework in Section 6.2, a formal process will be followed for recommendation and implementation of an AM action. The MAM program structure (Section 1.3, Figure 2) establishes lines of communication that facilitates coordination between Program Management, Adaptive Management and Monitoring Oversight Committee, TAG, and the RSLG. Based on during-construction data, MAM plan monitoring results, Assessment Reports and outlined AM actions and SDM framework, the TAG will submit specific AM recommendations to the Oversight Committee. The TAG will investigate and further refine any recommended AM action for Oversight Committee presentation to the Program Management Team. During project implementation and operation, it will ultimately be up to the District Commander in coordination with the NPS and other agencies to make changes under AM for the MsCIP Program, or to make a recommendation to an outside agency or program to improve performance.

## 7.0 Lessons Learned

Although there will be limited opportunities for AM actions through the MsCIP, the MAM program will allow for lessons learned and provide information and/or recommendations to other programs and or future projects. Monitoring results from the project will help refine modeling, design, and predictions of physical and ecological processes that will in turn inform the design of future restoration projects. The barrier island decision question framework developed as part of the SDM process (Section 6) will also provide collaborative problem solving and stakeholder engagement tools that will be used to adjust future adaptive management decisions.

The Adaptive Management and Monitoring Oversight Committee will develop and 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 will be clearly documented with recommendations so that they can be easily applied to future barrier island and ecosystem restoration programs and projects. The ultimate aims of the documentation of the lessons learned is to reduce recurring, technical or programmatic issues that negatively impact the cost, schedule, performance and success of restoration projects.

Future potential projects that may benefit from lessons learned include O&M of Gulfport and Pascagoula Harbor Federal Navigation Channels, future local plans for restoring Dauphin Island in Alabama, potential expansion proposed by the Port for Gulfport, and other state and local planning initiatives, including planning efforts in the State of Alabama.

## 8.0 Costs

Costs associated with implementing this MAM Program were estimated based on available data and may be revised as additional information becomes available. Section 2039 of the WRDA 2007 allows monitoring for up to ten years post-construction. For cost estimation purposes, this ten-year monitoring timeframe was assumed for all performance measures. The need for additional monitoring to determine the project’s ecological success will be assessed at the end of the 10-year cost-shared period. Any additional monitoring would be a 100-percent non-MsCIP responsibility.

The MAM program establishes a feedback mechanism whereby monitored conditions will be used to adjust or refine construction and/or maintenance actions to better achieve project goals and objectives.

As previously indicated, there will be limited opportunities for AM actions through the MsCIP. At this time, it is not recommended that separate funding for AM contingency actions be included for the activities described in Section 6.1, as these potential AM actions are already expected to be covered in the construction or O&M costs, if needed. AM program, planning and management costs have been estimated.

Table 6 presents the breakdown of the estimated project costs for MAM between pre-construction, during construction and post-construction. These costs include the cost of planning and management, data collection, T&E species compliance monitoring, data assessment and evaluation, data management and the adaptive management program. These proposed MAM Plan elements and associated costs will continue to be evaluated to ensure that they include the minimum elements necessary to evaluated project success, meet required compliance monitoring and conduct adaptive management actions.

**Table 6-** Estimated MAM Costs for the MsCIP Barrier Island Restoration

| | **Pre-Construction** | **During Construction** | **Post-Construction** |
|---|---|---|---|
| Planning and Management | $900,000.00 | $860,000.00 | $2,590,000.00 |
| Currents/Waves | $650,000.00 | $570,000.00 | $150,000.00 |
| Habitat Classifications/ Land:Water | $130,000.00 | $210,000.00 | $430,000.00 |
| Surveys | $440,000.00 | $340,000.00 | $810,000.00 |
| Water Quality | $190,000.00 | $320,000.00 | $140,000.00 |
| Submerged Aquatic Vegetation | $120,000.00 | $80,000.00 | $350,000.00 |
| Compliance: Shorebirds | $280,000.00 | $1,590,000.00* | $760,000.00 |
| Compliance: Sea Turtles | $110,000.00 | $300,000.00* | $580,000.00 |
| Compliance: Sturgeon | $1,540,000.00 | $1,340,000.00 | $380,000.00 |
| Compliance: Benthic | $820,000.00 | --- | $220,000.00 |
| Data Management | $440,000.00 | $570,000.00 | $930,000.00 |
| Assessment and Reporting | $260,000.00 | $1,590,000.00 | $2,910,000.00 |
| Post storm surveys (Contingency) | ---- | $110,000.00 | $120,000.00 |

*monitoring will be included in construction contract

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   - ii. Water Quality
3. Biological
   - i. Gulf Sturgeon
   - ii. Shorebirds
   - iii. Habitat Composition/Habitat Mapping
   - iv. Sea Turtles
   - v. Benthic and Infaunal species
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## Appendix A.  Acronym List

# Appendix A- Acronym List

| | |
|---|---|
| ADCP | Acoustic Doppler Current Profile |
| AM | Adaptive Management |
| ATR | Agency Technical Review |
| AWAC | Acoustic Wave and Current profilers |
| BBN | Bayesian Belief Net |
| CEM | Conceptual Ecological Model |
| CIR | Color-infrared |
| DA-10 | Disposal Area #10/Sand Island |
| DEM | Digital Elevation model |
| DMC | Digital Mapping Camera |
| DO | Dissolved Oxygen |
| EM | Engineering Manual |
| ER | Engineering Regulation |
| GIS | Geographic Information Systems |
| GPS | Global Positioning System |
| GUIS | National Park Service Gulf Islands National Seashore |
| HQUSACE | Headquarters United States Army Corps of Engineers |
| IEPR | Independent External Peer Review |
| LCA | Louisiana Coastal Area |
| LiDAR | Light Detection and Ranging |
| MAM | Monitoring & Adaptive Management |

| | |
|---|---|
| Mcy | Million Cubic Yards |
| MsCIP | Mississippi Coastal Improvements Project |
| MDEQ | Mississippi Department of Environmental Quality |
| MDMR | Mississippi Department of Marine Resources |
| mNDWI | Normalized Difference Water Index |
| NEPA | National Environmental Policy Act |
| NPS | National Park Service |
| NRDA | National Resources Damage Assessment |
| NRHP | National Register of Historic Places |
| NWI | National Wetlands Inventory |
| O&M | Operation and Maintenance |
| PAR | Photosynthetically Active Radiation |
| PM | Performance Measure |
| PPA | Project Partnership Agreement |
| PPCP | Primary Project Control Points |
| RSLG | Regional Science and Leadership Group |
| RSME | Root Mean Square Error |
| SAV | Submerged Aquatic Vegetation |
| SDM | Structured Decision Making |
| TAG | Technical Advisory Group |
| T&E | Threatened and Endangered Species |
| TM | Thematic Mapper |
| TOC | Total Organic Carbon |

| | |
|---|---|
| USACE | United States Army Corps of Engineers |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| UTM | Universal Transverse Mercator |
| WRDA | Water Resources Development Act |

## Appendix B. Implementation Guidance for Section 2039 of WRDA 2007

**DEPARTMENT OF THE ARMY**
**U.S. ARMY CORPS OF ENGINEERS**
**441 G STREET NW**
**WASHINGTON, D.C. 20314-1000**

CECW-PB

31 AUG 2009

MEMORANDUM FOR COMMANDERS, MAJOR SUBORDINATE COMMANDS

SUBJECT: Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007) – Monitoring Ecosystem Restoration

1. Section 2039 of WRDA 2007 directs the Secretary to ensure that when conducting a feasibility study for a project (or component of a project) for ecosystem restoration that the recommended project includes a plan for monitoring the success of the ecosystem restoration. The monitoring plan shall include a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring as well as specify that monitoring will continue until such time as the Secretary determines that the success criteria have been met. Within a period of ten years from completion of construction of an ecosystem restoration project, monitoring shall be a cost-shared project cost. Any additional monitoring required beyond ten years will be a non-Federal responsibility. A copy of Section 2039 is enclosed.

2. Applicability. This guidance applies to specifically authorized projects or components of projects as well as to those ecosystem restoration projects initiated under the Continuing Authority Program (CAP) or other programmatic authorities.

3. Guidance.

a. Monitoring includes the systematic 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. Development of a monitoring plan will be initiated during the plan formulation process for ecosystem restoration projects or component of a project and should focus on key indicators of project performance.

b. The monitoring plan must be described in the decision document and must include the rationale for monitoring, including key project specific parameters to be measured and how the parameters relate to achieving the desired outcomes or making a decision about the next phase of the project, the intended use(s) of the information obtained and the nature of the monitoring including duration and/or periodicity, and the disposition of the information and analysis as well as the cost of the monitoring plan, the party responsible for carrying out the monitoring plan and a project closeout plan. Monitoring plans need not be complex but the scope and duration should include the minimum monitoring actions necessary to evaluate success. The appropriateness of a monitoring plan will be reviewed as part of the decision document review including agency technical review (ATR) and independent external peer review (IEPR), as necessary. The estimated cost of the proposed monitoring program will be included in the project cost estimate and cost-shared accordingly.

c. Upon completion of the construction of the ecosystem restoration project (or component of a project), monitoring for ecological success will be initiated. Monitoring will be continued until ecological success is determined. Once ecological success has been documented by the District Engineer in consultation with the Federal and State resources agencies, and a determination has been made by the Division Commander that ecological success has been achieved (may be less than ten years), no further monitoring will be required. Ecological success will be documented through an evaluation of the predicted outcomes as measured against the actual results. The law allows for but does not require a 10 year cost shared monitoring plan. Necessary monitoring for a period not to exceed 10 years will be considered a project cost and will be cost shared as a project construction cost and funded under Construction. Costs for monitoring beyond a 10 year period will be a non-Federal responsibility. Financial and implementation responsibilities for the monitoring plan will be identified in the Project Partnership Agreement. For CAP projects, or for those projects that may be authorized with an explicit dollar cap, any cost shared monitoring costs cannot increase the Federal cost beyond the authorized project limit of the CAP or other authority under which the project is being considered.

d. Contingency Plan (Adaptive Management). An adaptive management plan (i.e., a contingency plan) will be developed for all ecosystem restoration projects. The adaptive management plan must be appropriately scoped to the scale of the project. If the need for a specified adjustment is anticipated due to high uncertainty in achieving the desired outputs/results, the nature and cost of such actions should be explicitly described in the decision document for the project. The reasonableness and the cost of the adaptive management plan will be reviewed as part of the decision document. Costly adaptive management plans may indicate the need to reevaluate the formulation of the ecosystem restoration project. The information generated by the monitoring plan will be used by the District in consultation with the Federal and State resources agencies and the MSC to guide decisions on operational or structural changes (adaptive management) that may be needed to ensure that the ecosystem restoration project meets the success criteria. The adaptive management plan cost should be shown in the 06 feature code of the cost estimate.

If the results of the monitoring program support the need for physical modifications to the project, the cost of the changes will be cost shared with the non-Federal sponsor and must be concurred in by the non-Federal sponsor. The appropriate HQUSACE RIT should be advised at such time that it is determined a modification to a project is required. Any changes to the adaptive management plan approved in the decision document must be coordinated with HQUSACE at the earliest possible opportunity. If a needed change is not part of the approved adaptive management plan and is determined by HQUSACE to be a deficiency correction the annual budget guidance to initiate a study for such corrections should be followed. Significant changes to the project required to achieve ecological success and which cannot be appropriately addressed through operational changes or through the approved adaptive management plan may need to be examined under other authorities, such as Section 216, River and Harbor and Flood Control Act of 1970.

4. This guidance is effective immediately and will be incorporated into ER 1105-2-100 upon the next revision.

FOR THE COMMANDER:

Encl

THEODORE BROWN, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works

DISTRIBUTION:
COMMANDER, GREAT LAKES AND OHIO RIVER DIVISION
COMMANDER, MISSISSIPPI VALLEY DIVISION
COMMANDER, NORTH ATLANTIC DIVISION
COMMANDER, NORTHWESTERN DIVISION
COMMANDER, PACIFIC OCEAN DIVISION
COMMANDER, SOUTH ATLANTIC DIVISION
COMMANDER, SOUTH PACIFIC DIVISION
COMMANDER, SOUTHWESTERN DIVISION
CECW-LRD
CECW-MVD
CECW-NWD
CECW-SAD
CECW-NAD
CECW-SAD
CECW-POD
CECW-SPD
CECW-NWD
CECC-G

## *SEC. 2039. MONITORING ECOSYSTEM RESTORATION.*

*(a) In General- In conducting a feasibility study for a project (or a component of a project) for ecosystem restoration, the Secretary shall ensure that the recommended project includes, as an integral part of the project, a plan for monitoring the success of the ecosystem restoration.*

*(b) Monitoring Plan- The monitoring plan shall--*

*(1) include a description of the monitoring activities to be carried out, the criteria for ecosystem restoration success, and the estimated cost and duration of the monitoring; and*

*(2) specify that the monitoring shall continue until such time as the Secretary determines that the criteria for ecosystem restoration success will be met.*

*(c) Cost Share- For a period of 10 years from completion of construction of a project (or a component of a project) for ecosystem restoration, the Secretary shall consider the cost of carrying out the monitoring as a project cost. If the monitoring plan under subsection (b) requires monitoring beyond the 10-year period, the cost of monitoring shall be a non-Federal responsibility.*

## Charge from Congress

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-SAD

15 SEP 2009

SUBJECT: Mississippi Coastal Improvements Program, Hancock, Harrison, and Jackson Counties, Mississippi, Comprehensive Plan Report

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my final report on water resources improvements associated with hurricane and storm damage risk reduction and ecosystem restoration in the coastal counties of Hancock, Harrison, and Jackson, Mississippi. It is accompanied by the report of the district and division engineers. These reports are a final response to authorizing legislation contained in the Department of Defense Appropriation Act of 2006 (P.L. 109-148), dated 30 December 2005. The study authorization states, in part, the following:

> *"... the Secretary shall conduct an analysis and design for comprehensive improvements or modifications to existing improvements in the coastal area of Mississippi in the interest of hurricane and storm damage reduction, prevention of saltwater intrusion, preservation of fish and wildlife, prevention of erosion, and other related water resource purposes at full Federal expense; Provided further, that the Secretary shall recommend a cost-effective project, but shall not perform an incremental benefit-cost analysis to identify the recommended project, and shall not make project recommendations based upon maximizing net national economic development benefits; Provided further, that interim recommendations for near term improvements shall be provided within 6 months of enactment of this act with final recommendations within 24 months of this enactment."*

l. <u>Barrier Island Restoration</u>. This project element consists of the placement of approximately 22 million cubic yards of sand within the National Park Service's Gulf Islands National Seashore, Mississippi unit. Approximately 13 million cubic yards of sand would be used to close a gap between East Ship Island and West Ship Island, originally opened by Hurricane Camille, through the construction of a low level dune system. The remaining 9 million cubic yards of sand would be placed in the littoral zones at the eastern ends of Ship and Petit Bois Islands. This would result in the restoration of 1,150 acres of critical coastal zone habitats. In accordance with the requests of the National Park Service, the closure of the Ship Island gap and placement of sand into the littoral zones would be undertaken only once, and would not be nourished or otherwise maintained in the

## Appendix C.  Monitoring & AM Program and Structured Decision Making Team Members

| MSCIP Monitoring and Adaptive Management Teams | |
|---|---|
| | |
| **Name** | **Agency** |
| **Program Management Team** | |
| Susan Rees | USACE |
| Tom Smith | USACE |
| Gary Rikard | MDEQ |
| Jamie Miller | MDMR |
| Dan Brown | NPS |
| Sherri Fields | NPS |
| | |
| **Adaptive Management and Monitoring Oversight Committee** | |
| Justin McDonald | USACE |
| Brian Zettle | USACE |
| Tomma Barnes | USGS |
| Steve McCoy | NPS |
| Jennifer Jacobson | USACE |
| | |
| **Technical Advisory Group** | |

| Official Team Members (Core Members are in Bold) | |
|---|---|
| **Michelle Meyers** | **USGS** |
| **Brian Zettle** | **USACE** |
| Mark Byrnes | Consultant |
| **Soupy Dalyander** | **USGS** |
| **Elizabeth Godsey** | **USACE** |
| Cheryl Hughes | USACE |
| Jeff Clark | MSDMR |
| Ronald Hobgood | USACE- Cultural |
| Scott Mize | USGS/MSWSC |
| Jolene Williams | NPS |
| Christina Hunnicutt | USGS |
| Mike Miner | BOEM |
| Paul Necaise | FWS |
| Mark Ford | NPS |
| Martha Segura | NPS |
| **Additional technical experts that are contacted as needed are listed below** | |
| Ray Chapman | ERDC- Water Quality |
| Andy Coleman | Turtles-IMMS |

| | |
|---|---|
| Jim Flocks | USGS-Geomorphology |
| Nicholas Enwright | USGS-Habitat Mapping |
| Kristen Hart | Turtles-USGS |
| Hardin Waddle | Birds/Benthic-USGS |
| Nate Lovelace | Project Management Navigation-USACE |
| Scott Mize | USGS-Benthics |
| Mark Peterson | Sturgeon-USM |
| Eve Eisemann | SAV-ERDC |
| Todd Slack | Sturgeon-ERDC |
| Steve Underwood | Consultant |
| Mary Bryant | USACE-CEERD-CHL |
| Jacqueline Wittmann | USACE |
| Nick Winstead | MMNS |
| Mark Woodrey | Birds -Grand Bay NERR |

| | |
|---|---|
| Barry Vittor | SAV, Benthic Species-Consultant |
| Alison Sleath Grzegorzewski | USACE-CEERD-CHL |
| Dena Dickerson | USACE-ERDC |
| | |
| **Data Management Team** | |
| Clint Padgett | USACE |
| Craig Conzelmann | USGS |
| Cheryl Hughes | USACE |
| Christina Hunnicutt | USGS |
| Dave Hill | USACE |
| Christopher Barrow | NPS |
| Joesph Givhan | USACE-OC |
| Reach back as needed with other regional data management systems | |

| **Regional Science and Leadership Group** | |
|---|---|
| Steve McCoy | NPS |
| David Barnes | MDEQ |
| Brian Zettle | USACE |

| | |
|---|---|
| Cheryl Hughes | USACE |
| Christopher Barrow | NPS |
| Dan Brown | NPS |
| Mark Byrnes | Applied Coastal |
| Ray Chapman | ERDC- Water Quality |
| Jeff Clark | MSDMR |
| Andy Coleman | Turtles-IMMS |
| Melissa Collins | Birds/Benthic-USGS |
| Craig Conzelmann | USGS |
| John Cornelison | NPS |
| Soupy Dalyander | USGS |
| Nicholas Enwright | USGS |
| Michelle Fischer | USGS/NWRC |
| Ronald Hobgood | USACE |
| Sherri Fields | NPS |
| Mike FitzHarris | MsCIP |
| Jim Flocks | USGS |
| Mark Ford | NPS |
| Joesph Givhan | USACE |

| | |
|---|---|
| Elizabeth Godsey | USACE |
| Kristen Hart | USGS |
| Ryan Hendren | NMFS |
| Matthew Hicks | USGS/MSWSC |
| Dave Hill | USACE |
| Christina Hunnicutt | USGS |
| Jennifer Jacobson | USACE |
| Ntale Kajumba | EPA |
| Jack Kindinger | USGS |
| Barb Kleiss | USACE |
| Darin Lee | LA CPRA |
| Nate Lovelace | USACE |
| Chris Macon | USACE |
| Justin McDonald | USACE |
| Michelle Meyers | USGS/NWRC |
| Jamie Miller | MDMR |
| Mike Miner | BOEM |
| Paul Necaise | FWS |
| Clint Padgett | USACE |
| Larry Parson | USACE |

| | |
|---|---|
| Mark Peterson | USM |
| George Ramseur | DMR |
| Richard Rebich | USGS |
| Susan Rees | USACE |
| Gary Rikard | MDEQ |
| Julie Rosati | USACE |
| Martha Segura | NPS |
| Eve Eisemann | ERDC |
| Todd Slack | ERDC |
| Tom Smith | USACE |
| Brian Spears | USFWS |
| Tomma Barnes | USGS |
| Barry Bunch | ERDC |
| John Tirpak | GCPO LCC |
| Steve Underwood | Applied Coastal |
| Barry Vittor | Consultant |
| Jacqueline Wittmann | USACE |
| Jolene Williams | NPS/GUIS |
| Nick Winstead | MMNS |

| | |
|---|---|
| Mark Woodrey | Grand Bay NERR |
| Jennifer Wozencraft | USACE |
| Steve Wright | NPS |
| Heather Young | NMFS |
| Michael Andres | USM |
| Linda York | NPS |

| **Structured Decision Making (SDM) Core Team** | | |
|---|---|---|
| Greg Steyer | USGS | Team Coordinator/Project Management |
| Mark Byrnes | Applied Coastal | Scientist |
| P. Soupy Dylander | USGS | Scientist |
| Mark Ford | NPS | Scientist |
| Elizabeth Godsey | USACE | MsCIP Decision Maker/Technical Advisor |
| Elise Irwin | USGS | SDM Co-Coach |
| Ayse Karanci | North Carolina state University | SDM Coaching Apprentice |
| Linda Barnett | USACE | MsCIP Technical |
| Darin Lee | CPRA | LCA OM&M Decision Maker, In-Kind |
| Nate Lovelace | USACE | USACE |

| | | |
|---|---|---|
| Brady Mattsson | BOKU Institute of Zoology | SDM Coaching, Technical |
| Justin McDonald | USACE | MsCIP Decision Maker/Technical, In-Kind |
| Michelle Meyers | USGS | Adaptive Mangement Liaison/Technical/Project Management |

## Appendix D. Monitoring Procedures

### D. Monitoring Procedures

1. Physical –Survey Data
2. Hydrological Data
    i. Wave, Currents, Circulation
    ii. Water Quality
3. Biological
    i. Gulf Sturgeon
    ii. Shorebirds
    iii. Habitat Composition/Habitat Mapping
    iv. Sea Turtles
    v. Benthic and Infaunal species
    vi. Submerged Aquatic Vegetation
4. Cultural

# APPENDIX D - MONITORING PROCEDURES

The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate ecological success and inform the adaptive management program.

## 1 PHYSICAL- SURVEY DATA

A combination of bathymetric and lidar surveys will be used to determine the cross-shore profile, shoreline position, and sand volumes for East and West Ship islands and Cat Island. One pre-construction lidar and bathymetric survey will be conducted, as the standards for future changes in island dimensions along with historical topographic, bathymetric, and shoreline data compiled in Byrnes et al. (2012). Four lidar surveys and two bathymetric surveys will be conducted within the first 10 years post-construction in the vicinity of Ship Island and Ship Island Pass to develop elevation models for comparison of subaerial and subaqueous elevation and to quantify volumetric changes. Similar data will be collected at Cat Island. Additionally, two bathymetric surveys will be conducted within the first 10 years within Horn Island Pass to compare subaqueous volumetric changes and movement of dredged material placed in the littoral zone west of the Pascagoula Federal Navigation Channel.

Lidar surveys will be conducted as per methods detailed by Heidemann et al. (2012) and in compliance with USACE EM-1110-1-1000 for Photogrammetric Mapping, USACE EM -1110-1-1002 Survey Markers and Monumentation, USACE EM -1110-1-1003 NAVSTAR Global Positioning System Surveying, USACE EM -1110-1-1004 Deformation Monitoring and Control Surveying, USACE EM -1110-1-1005 Topographic Surveying, USACE EM -1110-2-1003 Hydrographic Surveying, and USACE EM -1110-1-2909 Geospatial Data and System, Tri-Services A/E/C CADD Standards, Tri-Services Spatial Data Standards, and Related Spatial Data Products. Lidar surveys will cover the complete island shoreline and extend inland approximately 1 km to cover the whole island, including the shallow shoals to the north. The resulting data will provide a density of approximately 1 elevation point per square meter, accurate to approximately +/- 15 cm (RMSE) vertical elevation and +/- 1.5m (RSME) horizontal position.

Bathymetric survey methodology should include a combination of single-beam and swath or multi-beam sensors (for the rest of the discussion the term swath refers to either swath or multi-beam sensors). Within the project areas, bathymetric coverage should be extensive enough to capture the area of active littoral transport under normal oceanographic conditions (non-storm processes). To capture the area of active littoral transport on the Gulf and Sound sides of placement areas, bathymetric surveys should extend to water depths identified as the long-term seaward limit for significant sand transport in the MsCIP sediment budget (Byrnes et al., 2013). This distance can be defined through the examination of previously collected geophysical data. Real Time Kinematic (RTK) shall be utilized for horizontal and vertical positioning of all hydrographic data acquisition. All project surveying and mapping shall be in strict compliance with EM 1110-2-6056, Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums. Specifically, all Primary Project Control Points (PPCP) and all project survey mapping shall be referenced to NAVD88. In addition, all PPCP shall be tied to the National Spatial Reference System.

For single beam coverage shore perpendicular tracklines should be spaced 1 km apart across the study areas which extend to water depths identified as the long-term seaward limit for significant sand transport in the MsCIP sediment budget (Byrnes et al., 2013). The use of single beam systems for shore-perpendicular transects will be used to ensure reproducibility in different oceanographic conditions. Two shore-parallel single-beam tie-lines should be obtained across the shore-perpendicular transects on both the Gulf and Sound sides to provide cross-track error estimates. Water depths less than one meter should be measured using single beam systems. A survey grid should be designed to cover the study area with trackline spacing not to exceed 328 feet where possible. Trackline spacing in areas of significant elevation change should be reduced as much as possible to ensure data represent the bathymetry accurately. The seaward portion of the study area, defined by the1 m water depth contour should be measured by near-total swath or multibeam coverage. Near-total coverage can be defined as measurements covering a minimum of 80% of the study area. Project design and construction surveyed points (including, easting, northing, and elevation for each point) will be collected along cross-section lines within the fill portion of Camille Cut and the nearshore area of East Ship Island with shore-perpendicular spacing not to exceed 200 feet within the immediate fill template and 500 feet elsewhere. In addition, cross-lines shall be run every 1,000 to 2,000 feet. The easting and northing values will be relative to the State Plane Coordinate System, Mississippi East zone, NAD 1983 in U.S. survey feet. This data will supplement bathymetric data collected as part of the MAM.

In addition, District bathymetric surveys are routinely conducted for the navigation channels (including the Pascagoula and Gulfport channels) by the USACE, Operations Division. These surveys will supplement bathymetric data collected as part of the MAM to assess channel shoaling rates to infer transport rates from the west end of Ship Island.

## PASCAGOULA HARBOR – DISPOSAL AREA 10 LITTORAL ZONE PLACEMENT

## SAND TRANSPORT STUDY

### DESCRIPTION

The scope of work for this task is for the completion of a sand transport study for the Pascagoula Harbor – Disposal Area 10 Littoral Zone Placement Site (see Figure 1) using sand tracer technology and monitoring. The current Disposal Area 10 Littoral Zone Placement was identified through review of historical bathymetric changes and dredging operations and costs. The objective of the proposed study is to provide insight into the fate of dredged material placed within the Disposal Area 10 Littoral Zone Placement site to assist in verifying the optimum placement zone for future dredging/placement operations. Specific objectives of this study include:

1. Identifying if sand within the placement site is transported toward Horn Island and if so, at what size fractions and at what rates (for normal tidal and storm conditions).

2. Identifying if sand within the placement site is transported back toward the Pascagoula Harbor Federal navigation channel and if so, at what size fractions and at what rates (for normal tidal and storm conditions).
3. Identifying if sand within the placement site is transported offshore of the placement site and if so, at what size fractions and at what rates (for normal tidal and storm conditions).

The Mobile District will provide two field personnel to assist with the background sampling, mixing, and release of the sand tracer. Additional before and after dredge placement surveys will also be provided.

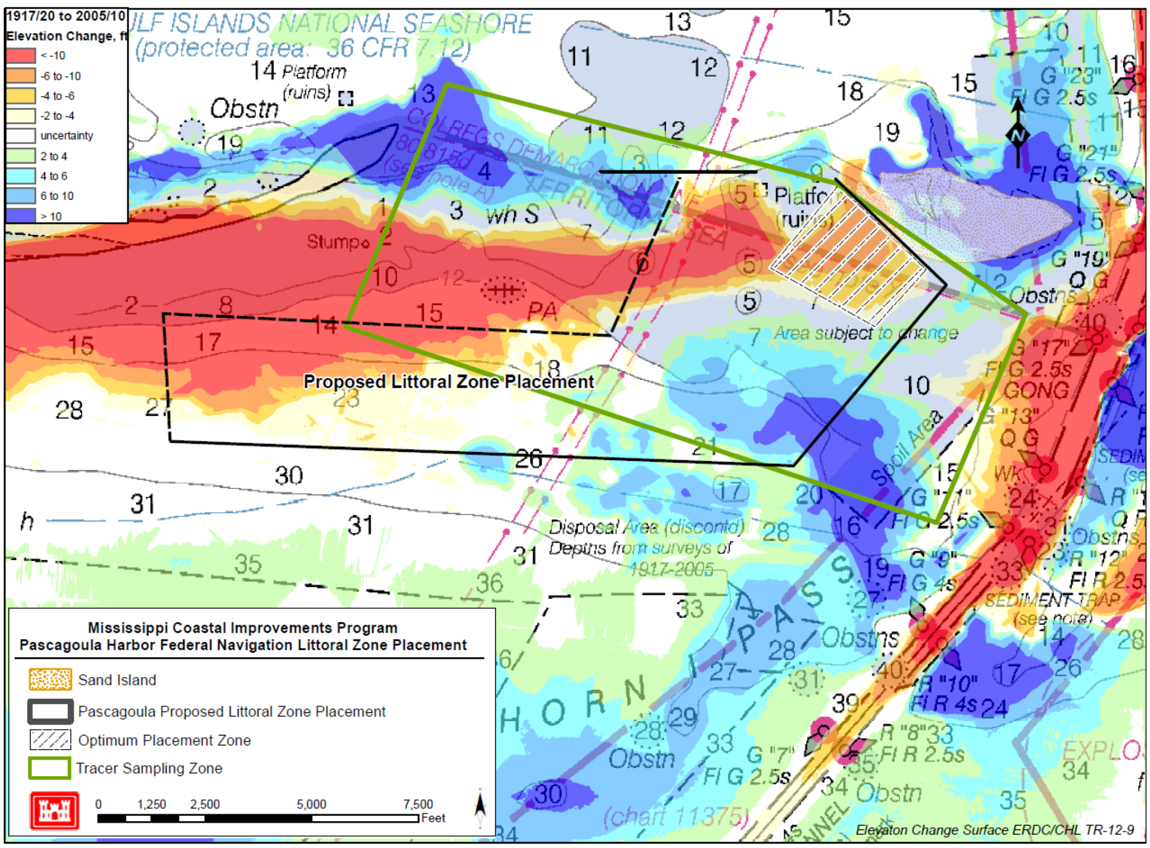


**Figure 1:** Pascagoula Harbor – Disposal Area 10 Littoral Zone Placement Site

Task 1: Approval/Permits for the Tracer Release:

Obtain all necessary approval/permits for the tracer release prior to mobilizing to the site for background sampling collection and placement. This includes but is not limited to a Special Use Permit from the United States National Park Service.

Task 2: Sand Tracer Background Collection, Manufacturing and Release:

i. Tracer Manufacturing: Provide an artificial fluorescent tracer that mimics the physical properties of sand from the Pascagoula Harbor Navigation Chanel placed at the Disposal Area 10 Littoral Zone Placement Site. Specifically, the tracer particle shall be a Barium sulphate filled polymer to adjust the density to SG 2.65, such as EcoTrace or equivalent. Sufficient tracer as approved by the Contracting Officer shall be manufactured to allow sediment tracing for 12-18 months (as required).

ii. Background Sampling: Collect background samples from an agreed sampling area (approximately 30 samples). The locations of the samples will be determined through coordination with the Mobile District Coastal Engineer POC and PAE.

iii. Tracer Release: Mix one color of tracer with native sediment and release via dissolving bags within the Disposal Area 10 Littoral Zone Optimized Placement Site (see Figure 1) following the placement of the dredged material at DA 10. A second color tracer shall be released via dissolving bags in the southeast portion of the Disposal Area 10 Littoral Zone Placement Site to compare the dispersal and deposition of material from the different locations within the site. The tracer shall be earth tone in color (i.e black, green and/or blue), and the quantity shall be limited to no greater than 3.5 cubic feet per site unless otherwise approved by the USACE. The locations for the placement of tracer shall be fully coordinated with the Mobile District Coastal Engineer POC and PAE prior to deployment. The current operation and maintenance dredge cycle for the Pascagoula Harbor Entrance channel is scheduled for January 2016.

Task 2: Sand Tracer Sampling and Evaluation:

i. Standard Operating Procedure: Develop a Standard Operating Procedures for tracer sampling and sub-sampling. The sampling procedure shall be submitted the Mobile District Coastal Engineer POC for approval prior to the collection of any samples. Grab sampling shall be conducted with a spring-loaded grab (similar to a Shipek grab) such that consistent samples can be taken. Vessels utilized to release samples shall be equipped with davit, Hiab, A-frame or similar and with a hydraulic winch strong enough to operate the grab. The vessel shall also be equipped with a navigational positioning system and have sufficient draft, capacity, and deck space to deploy the sand tracer.

Ensure that proper field and office quality control procedures are implemented and monitored, including adherence to accuracy standards and compliance with minimum technical standards.

ii. Sampling Location: Collect tracer samples from an agreed sampling area (approximately 75-80 samples over a sampling area of roughly 3.5 square miles). To provide more accurate data in areas of specific interest, such as close to the release site, the navigation channel, and eastern tip of Horn Island; initial sampling shall be weighted to the tracer release site(s) since there may be limited transport in the first few months after placement. Additionally, in order to accurately conduct a mass balance calculation in the areas of specific interest, more samples shall be concentrated in these areas. In the wider area sampling zone, samples shall be collected over a wider grid area. Refinement determined through coordination with the Mobile District Coastal Engineer POC) of each sampling zone shall be made based on results from earlier sampling events prior to the next.

iii. Tracer Sampling Timing: Conduct sampling over a 12-18 month period generally as follows:

*Sampling Event 1*: 1-2 months after release, ideally after a period of quiescent conditions tidal currents only, or ahead of first storm whichever is the sooner

*Sampling Event 2*: After localized small storm with seas, as determined through coordination with the Mobile District Coastal Engineer POC

*Sampling Event 3*: After a larger storm with swells, as determined through coordination Mobile District Coastal Engineer POC

iv. Tracer sampling Evaluation: Analyze, interpret, and report the tracer data along with any locally available **oceanographic and meteorological** data. Available data sources include but are not limited to USACE-Mobile District, NOAA, and the National Weather Service. Integrate relevant **oceanographic and meteorological** data and information into the evaluation.

Task 3. Meetings and Final Report. The results of all tasks within this SOW will be summarized into a final report and presented the Mobile District Mississippi Coastal Improvements project delivery team. Three hard copies and an electronic copy of the report shall be provided.

Work performed will conform to the additional criteria and data listed below. Addresses are specified below for those documents which are available electronically.

a. Engineer Regulation 1110-2-1150, "Engineering and Design for Civil Works Projects", U.S. Army Corps of Engineers, August 1999 (Internet address http://140.194.76.129/publications/eng-regs/er1110-2-1150/toc.htm).
b. Engineering Regulation 1110-2-1403, "Engineering and Design - Studies by Coastal, Hydraulic, and Hydrologic Facilities and Others," U.S. Army Corps of Engineers, January, 1998 (Internet address http://140.194.76.129/publications/eng-regs/er1110-2-1403/toc.htm).
c. Engineering Regulation 1110-2-1407, "Engineering and Design - Hydraulic Design for Coastal Shore Protection Projects", 30 November 1997. (Internet address http://140.194.76.129/publications/eng-regs/er1110-2-1407/toc.htm).
d. Engineering Manual 1110-2-1100, "Coastal Engineering Manual - Part I - IV", 30 April 2002 (Internet address http://140.194.76.129/publications/eng-manuals/).
e. Engineer Circular 1110-2-6065 "Comprehensive Evaluation Of Project Datums," 1 December 2007. (Internet address http://www.mvn.usace.army.mil/ENG/EC%201110-2-6065.pdf).

In the event of any conflict between this SOW and the above criteria, the SOW will govern.

## References

Heidemann, H.K. 2012. Lidar base specification version 1.0: US Geological Survey Techniques and Methods; Book 11, USGS, Sioux Falls, SD, USA chap.

# APPENDIX D - MONITORING PROCEDURES

The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate ecological success and inform the adaptive management program.

## 2 HYDROLOGICAL DATA

### *i. Wave, Currents, Circulation*

Wave and current data, should be collected by self-contained wave and current systems in trawler resistant mounts deployed at three locations north and south of Camille Cut prior to, and up to two years after project construction. *In-situ* current sensors should be acoustic type with Acoustic Wave and Current profilers (AWAC) preferred for deployment at depths greater than 10 feet. Data will be retrieved and downloaded every 90 days.

Wave data will be analyzed and made available within 30 days of data retrieval, and annual reports will contain processed spectral wave heights, periods, and direction. Collection of these data will provide site-specific wave data for quantifying wave attenuation results before and after Camille Cut closure and provide data for further validation of wave prediction models.

Additionally, Acoustic Doppler Current Profile (ADCP) transects should be conducted to get a horizontal/vertical profile across Ship Island Pass, Little Dog Key Pass, and Dog Keys Pass during maximum spring-neap tide. Two transect data sets should be collected – one prior to the closure of Camille Cut and one six months after closure of Camille Cut. Current measurements at each transect should be measured for at least one full tidal cycle. Pre- and post-closure data should be collected at the same time of year for similar tidal conditions.

Data from the AWACs will be available within 90 days of data retrieval and annual reports will contain processed velocity and current profile measurements. In addition, current profile measurement after each ADCP survey will be available within 60 days of data retrieval. These data will allow for direct comparisons of flow through each pass and at two points within the sound before and after Camille Cut closure, and provide data for further validation of hydrodynamic models.

# APPENDIX D - MONITORING PROCEDURES

## 2 HYDROLOGICAL DATA

### *ii. Water Quality*

To document changes and assess whether closure of Camille Cut results in significant changes in water quality, time-series data will be collected at two sites, and discrete data will be collected at six to eight sites. Data will be collected before, during and two years post-construction.

Time series water-quality data; including salinity, turbidity, dissolved oxygen and temperature, will be collected at a minimum of one-hour intervals at two locations. The first location will be near the proposed work area, and the second at a control location proximate to the first to allow the determination of natural or background water quality variations. Discrete water-quality sampling will be collected at four sites in the vicinity of Ship Island, three control sites in the lee of Cat, Horn and Petit Bois islands, and at two time series data sites. Depending on the location, some sites may serve to meet two of the criteria reducing the total number of sites required.

Sites will be sampled every six to eight weeks, with a minimum of six samples per year pre-construction and up to two years post-construction. Major environmental events such as extreme drought, hurricanes, or opening the Bonnet Carre' Spillway for flood control purposes may alter the fixed schedule by requiring additional sample collection. Field measurements, collected at the water surface and at 5 foot increments, will profile water temperature, specific conductance, pH, dissolved oxygen, and turbidity to document any water column stratification, particularly of salinity and/or dissolved oxygen.

In addition to these *in situ* water column measurements, water samples will be collected at mid depth and will be analyzed for: Total Organic Carbon, Dissolved Organic Carbon, Nitrate, Ammonia, Total Kjeldahl Nitrogen, Dissolved Kjeldahl Nitrogen, Total Phosphorus, Dissolved Inorganic Phosphorus, Total Organic Phosphorus, Dissolved Organic Phosphorus, Total Suspended Solids, and Chlorophyll. These data will allow comparison with previous modeling result. It is expected that closure of Camille Cut will have minimal impact on overall water quality in the Sound. Data is also expected to provide a unique data set for validating water quality models that can be applied to future coastal restoration and navigation dredging activities adjacent to the project site.

Processed water quality data will be available every two months. Annual reports will be prepared, which provide a clear comparison of water quality constituents against control sites, existing background data and CE-QUAL-ICM model runs. Should an identified concern in water quality be observed that cannot be explained with existing data, additional water quality modeling simulations may be necessary to aid in data interpretation.

# APPENDIX D - MONITORING PROCEDURES

The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate ecological success and inform the adaptive management program.

## 3 BIOLOGICAL

### i. *Gulf Sturgeon*

Gulf sturgeon monitoring focuses on three different evaluations: (1) an initial assessment to determine the relative occurrence of Gulf sturgeon within the project area (e.g., specific zones; seasonal timing); (2) a secondary assessment will address occupancy patterns of Gulf sturgeon within identified project areas to evaluate potential changes in occupancy patterns between years and project zones; and a (3) benthic assessment to develop a relationship between Gulf sturgeon and benthos.

The initial assessment will utilize an automated acoustic telemetry array to monitor Gulf sturgeon presence within the project area including 39 telemetry receivers deployed during the pre-fill assessment period, during the construction and post-fill periods. Automated VR2W telemetry receivers (Vemco; Nova Scotia, Canada) will be used for the acoustic array. Receivers will be positioned at the surface in a top down orientation deployed from a large polyform buoy and marked with signage (Sulak et al. 2009). Concrete blocks (68 kg or larger) will be used to anchor receivers in locations where passage at project sites are expected. Data acquired during this phase will provide information on the relative use of Camille Cut by acoustically tagged Gulf sturgeon in comparison to the passes located at the east and west ends of Ship Island, and will provide a comparative perspective of habitat utilization of the passes within (E, W and Camille Cut) and among years (pre-construction, during construction post-fill, and post-construction).

In addition, broad-scale aquatic habitat features for Ship Island will be mapped using aerial imagery and lidar (topobathymtric lidar, if possible) and overlaid with acoustic telemetry data to evaluate additional Gulf sturgeon habitat utilization patterns.

An assessment of occupancy patterns in specific zones within the telemetry array will provide a means to quantify changes in Gulf sturgeon occurrence patterns between designated zones and years following a method outlined by Peterson et al. (2013). These analytical efforts will allow us to evaluate potential shifts among habitat zones during the noted project periods (i.e., pre-construction, during construction post-fill, and post-construction). Netting within riverine habitats and tagging will follow the methodology outlined in Heise et al. (2004, 2005) and Havrylkoff (2010).

In addition to the habitat occupancy patterns, monitoring for Gulf Sturgeon also will be evaluated in conjunction with benthic and infaunal species sampling to develop a relationship between Gulf sturgeon and benthic habitat. Benthic data for the project area was acquired and processed in 2011 for a pre-fill assessment and will also be conducted post-construction. Integration of those data will provide a crucial data layer for assessment of Gulf sturgeon habitat and foraging within the project area. Data will be utilized to infer potential use of the specified habitat (e.g, presumed feeding). The benthic data will be categorized based on the occurrence of constituent taxonomic groups that are known prey resources (family-level identification) for all reported Gulf sturgeon diets (Peterson et al. 2013) to determine relative prey availability among the benthic samples and sites. Additionally, physical factors such as sediment texture, percentage, organic matter content and depth collected during the benthic macroinfaunal sampling may also be correlated with benthic macrofaunal composition, Gulf sturgeon activity patterns, and determining favorable Gulf sturgeon habitat.

The resulting data from these approaches will allow project managers to better evaluate the uniqueness of these specific habitats to Gulf sturgeon. Specifically, whether reducing barrier island pass habitat by filling Camille Cut will, or will not, have an impact on Gulf sturgeon populations. The proposed multi-year monitoring program includes pre-construction baseline assessments followed by during construction, post-fill and post-construction assessments.

**References**

Havrylkoff, J-M. 2010. Gulf sturgeon of the Pascagoula: Post-Katrina assessment of seasonal usage of lower estuary. Unpublished MS Thesis. The University of Southern Mississippi, Ocean Springs, Mississippi.

Heise, R.J., W.T. Slack, S.T. Ross, and M.A. Dugo. 2004. Spawning and associated movement patterns of Gulf sturgeon in the Pascagoula River drainage, Mississippi. Transactions of the American Fisheries Society, 133(1), 221–230.

Heise, R.J., W.T. Slack, S.T. Ross and M.A. Dugo. 2005. Gulf sturgeon summer habitat use and fall migration in the Pascagoula River, Mississippi, USA. Journal of Applied Ichthyology, 21(2005), 461-468.

Peterson, M.S., J-M. Havrylkoff, P.O. Grammer, P.F. Mickle, W.T. Slack, and K.M. Yeager. 2013. Macrobenthic prey and physical habitat characteristics in a western Gulf Sturgeon population: differential estuarine habitat use patterns. Endangered Species Research, 22(2), 159-174.

Sulak, K. J., M.T. Randall, R.E. Edwards, T.M. Summers, K.E. Luke, W.T. Smith, A.D. Norem, W.M. Harden, R.H. Lukens, F. Parauka, S. Bolden, and R. Lehnert. 2009. Defining winter trophic habitat of juvenile Gulf sturgeon in the Suwannee and Apalachicola river mouth estuaries, acoustic telemetry investigations. Journal of Applied Ichthyology, 25(5), 505-515.

# APPENDIX D - MONITORING PROCEDURES

The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate ecological success and inform the adaptive management program.

## 3 Biological

### *ii. Shorebirds, Secretive Marsh Birds, and Associated Benthos*

Threatened and endangered species, critical habitat, and nesting shorebirds must be monitored for this project to determine impacts pursuant to the Endangered Species Act and the Migratory Bird Treaty Act. This project is located within the boundaries of Gulf Islands National Seashore, whose barrier island beaches are listed as critical habitat for the Threatened Piping Plover and contains suitable habitat for the Threatened Red Knot. The U.S. Army Corps of Engineers (USACE) (and its Contractor and/or subcontractor) shall keep construction activities under surveillance, management, and control to prevent impacts to shorebirds and/or their nests. The Piping Plover is a federally protected species that occurs in the construction area. The USACE and its Contractor may be held responsible for harming or harassing the birds, their eggs or their nests as a result of the construction. Eggs and chicks of beach-nesting birds blend in with their surroundings and are nearly invisible on the ground, making it easy for people and equipment to accidentally crush the eggs or kill young chicks; young chicks can get stuck in deep tire ruts, etc.

Monitoring includes bird identification, counts, habitat use, behavior observed, and GPS locations of the main groups of birds using the beach areas on West Ship Island and East Ship Island, and Cat Island. The three main groups of birds are solitary nesters, colonial nesters, and winter migrants (including threatened Piping Plover and the threatened Red Knot). Species identification information will be provided by the U.S. Fish and Wildlife Service, (USFWS), Jackson, Mississippi. An NPS Biologist will be available for assistance if needed during all periods of the monitoring.

Specific time frames for monitoring will vary with the avian season, weather, and actual construction logistics. As the project moves from place to place, the Bird Monitor will also have to be able to move with the project and/or with the birds.

There are two avian seasons:
**Migration/Mid-Winter** from July 15 to May 30. During this time, the Bird Monitor will focus on migratory shorebirds including Piping Plover and Red Knot, but should also report on other birds, such as ospreys and eagles.

**Nesting** from March to end of September. Monitoring for nesting birds is only required during construction.

There are three monitoring periods: **pre-construction, during construction, and post-construction.** Monitoring for nesting shorebirds (during construction) will focus on colonial and solitary shorebird species, but will also report on other birds, such as ospreys and eagles. Species documented to nest on the Mississippi barrier islands include solitary nesting species such as: Wilson's Plover, Snowy Plover, Semi-palmated Plover, Willet and American Oystercatcher. Documented colonial species include: Least Tern, Gullbilled Tern, Royal Tern, Sandwich Tern, Common Tern and Black Skimmer.

**1. Monitoring Periods:**

**a. <u>Pre-Construction:</u>**

The one-year requirement for pre-construction shorebird monitoring activities for West and East Ship islands was completed, with the exception of the following 2 weekly migration period surveys, in 2013: (Aug 19-23); (Aug 26-30) that were missed due to contractual issues. These weekly surveys were subsequently collected in 2014.

Pre-construction monitoring for Cat Island was conducted in 2014.

(1) Migration/Mid-Winter: Monitoring should take place on a weekly basis at Cat Island, except in the event of adverse weather conditions.

(2) Nesting Shorebirds: No requirement for preconstruction.

(3) Benthic Monitoring: Benthic monitoring along beach transects on East, West Ship islands, and Cat Island will be performed in accordance with the shorebird benthic sampling protocol, located at the end of this portion, Appendix D3ii.

**b. <u>During Construction:</u>**

The Contractor shall start this frequency of monitoring activity for a period of two weeks prior to work commencement and continue with this frequency until completion of the construction and the current bird season ends. A site survey should be conducted before the resumption of any break in activity.

(1) Migration/Mid-Winter Shorebirds: Monitoring frequency a minimum of weekly throughout entire project area where sand will be placed on East and West Ship islands, and Cat Island, except in the event of adverse weather conditions.

(2) Nesting Shorebirds: Monitoring frequency daily during active construction, except in the event of adverse weather conditions. However, nesting surveys only need to take place within the project area where activities are ongoing or will be within 90 days prior to active construction in order to prevent impacts to nests/nesting activities. If a nest is found to impede construction work, the USACE must contact the USFWS as soon as possible.

**c. <u>Post-Construction:</u>**

The Contractor shall start post-construction monitoring activities, approximately one to two years after the end of construction and continue for two years. If the second year of post-construction surveys need to be delayed due to weather, etc., further coordination will occur with USFWS. The second year of surveys should overlap with benthic collection, which may require a delay in the timing of the second year of bird monitoring.

(1) Migration/Mid-Winter Shorebirds: Monitoring will occur every other week, throughout the entire project areas of East and West Ship islands and Cat Island, except in the event of adverse weather conditions.

(2) Nesting Shorebirds: No requirement for post-construction.

(3) **Benthic Monitoring**: Benthic monitoring along beach transects on East and West Ship islands will be performed two years after construction, based on optimal conditions, i.e. lack of sand shifting, hurricane events, etc., during the December – January timeframe in accordance with the shorebird benthic sampling protocol, located at the end of this monitoring plan and Appendix D3v.

## 2. Visual Surveys and Survey Protocols:

Shorebird monitoring is dependent upon the avian season, shall include species, observed breeding behavior, nest location, chicks observed, and location of recently fledged chicks. Surveys shall be conducted during the dawn or dusk time frames by a trained or experienced Bird Monitor contractor, approved by the USACE/USFWS. Bird monitoring should not take place immediately following turtle monitoring, where birds have been disturbed by the use of ATVs.

Surveys should be conducted by traversing the length of the project/construction area and visually inspecting, using binoculars or spotting scope, for the presence of shorebirds exhibiting courtship or nesting behavior. The preferred method for monitoring is by foot patrol. During the construction phase, if an ATV or other vehicle is needed to cover large project areas, the vehicle must be operated at a speed <6 mph, shall be run at or below the high-tide line, and the Bird Monitor will stop at no greater than 200 meter intervals to visually inspect for nesting activity. An ATV will be used only on the unvegetated beach face of the new beach, not on the natural beach face of East Ship or West Ship islands. Even with the use of an ATV, the Bird Monitor will use a drive and walk technique coupled with scanning ahead to detect secretive solitary nesting species. During post-construction monitoring, an ATV will not be used, surveys will be conducted by foot or boat.

Surveys shall be conducted using survey protocols outlined here and the form provided.

(1) **<u>During Construction (Nesting):</u>** A daily report of nesting shorebird monitoring and nest activity shall be kept by the contractor's Bird Monitor. Daily logs shall summarize each shorebird species observed (adults and chicks/fledglings) and provide a rough estimate of numbers of each species, the location of species (GPS coordinates preferred), leg bands (if applicable), and their activity (e.g. foraging, resting, nesting, courtship behavior, feeding chicks). In addition, daily logs shall summarize upon locating a dead or injured bird that may have resulted from direct or indirect results of the project, the USACE shall notify the USFWS as soon as possible (Paul Necaise: 228-493-6631, or paul_necaise@fws.gov). Care shall be taken in handling an injured bird, contact a local permitted wildlife rehabilitation center to ensure treatment or disposition of the dead bird. Banded birds should also be noted and recorded (color of bands and location on bird, i.e. one red band on lower right leg and one green band on upper right leg). All activity will be submitted in a report format, and provided within one week of data collection during construction. Contractor will also enter all data into the USACE Mobile District's database for MsCIP on a weekly basis.

Nesting season surveys for detecting new nesting activity will be completed prior to movement of equipment, operation of vehicles, or other activities that could potentially disrupt nesting behavior or cause harm to the birds or their eggs or young (see aforementioned 90-day requirement). Once nesting activity is confirmed by the presence of a scrape, eggs, or young, the USACE will notify the USFWS as soon as possible. This is only required when there is “new” nesting activity (this is defined as a new species seen and/or new area). Bird Monitor will install red wire flags in area identifying location until buffer zone is established (see number 3 below).

(2) **<u>During Construction, and Post-Construction (Migration/Mid-Winter)</u>**: Monitoring will be done on a weekly basis during construction and bi-weekly for post-construction. The areas to be monitored should include the east tip of West Ship Island, specifically from the vegetation line to the water’s edge and East Ship Island, specifically the area from the edge of the forested area to the water’s edge and covering the east tip, the south shore, and west tip. When construction timeframes are identified, the east shoreline of Cat Island from the vegetation line to the water’s edge shall be monitored. Reports shall be submitted once a month during the construction time frames. Contractor will also enter all data into the USACE Mobile District’s database for MsCIP on a monthly basis.

The following data shall be included in the surveys:

a) Negative and positive survey data;
b) Piping Plover and Red Knot locations with a Global Position System (GPS-decimal degrees, preferred);
c) Habitat features used by Piping Plovers and Red Knots when seen (i.e. intertidal, fresh wrack, old wrack, dune, mid-beach, vegetation, other);
d) Landscape features where Piping Plovers or Red Knots are located (i.e. Gulf of Mexico shoreline, bayside shorelines, inlet spit, tidal creek, shoals, lagoon shoreline, lakeside sand flats, ephemeral pools, etc.);
e) Substrate used by Piping Plovers and Red Knots (i.e. sand, mud/sand, mud, algal mat, etc.);
f) Behavior of Piping Plovers or Red Knots (i.e. foraging, roosting, preening, bathing, flying, aggression, walking);
g) Color-bands seen on Piping Plovers or Red Knots;
h) All other shorebirds/waterbirds seen within the survey area.

Any bands/flags seen on Piping Plovers and Red Knots shall also be carefully documented, and should also be reported according to the information found at the following websites. Information regarding Piping Plover band/flag observations can be found at: http://www.fishwild.vt.edu/piping_plover/Protocols_final_draft.pdf, http://www.waterbirds.umn.edu/Piping_Plovers/piping2.htm, and http://www.fws.gov/northeast/pipingplover/pdf/BahamasBandReporting2010.pdf.

Information regarding Red Knot band/flag observations can be found at: http://www.bandedbirds.org/Reporting.html, http://www.flshorebirdalliance.org/resources-pages/bands.html, and http://www.pwrc.usgs.gov/bbl/.

3. **Buffer Zones:** A temporary, 300-foot buffer zone, or as approved by the USFWS, shall be created around any nesting or courtship behavior, or around areas where Piping Plovers, Red Knots, or winter migrants congregate in significant numbers. Designated buffer zones must be posted with clearly marked "Area Closed" signs around the perimeter and left undisturbed until nesting is completed or terminated, and the chicks fledge. No access will be permitted to the nesting sites by humans or equipment under control of the Contractor, except limited access when approved by USFWS and accompanied by the Bird Monitor. Construction activities, movement of vehicles, or stockpiling of equipment are prohibited in the buffer zone. Buffer zones shall be increased if birds appear agitated or disturbed by construction, or other activities in the adjacent area. Disturbed adult birds will attempt to drive a predator away by calling out, dive bombing, or dropping feces on the predators. Adult birds may pretend to have a broken wing to lure a predator away from their young.

4. **Equipment:** Travel corridors and staging areas outside of buffer zones near nesting sites shall be coordinated with the USFWS, Jackson, Mississippi Field Office (Mr. Paul Necaise at 228-493-6631), and these areas shall be designated and marked outside the buffer areas. Heavy equipment, other vehicles or pedestrians may transit past nesting areas in the corridors.

5. **Shorebird Signs:** If nesting occurs within the construction area, the Contractor shall place and maintain a bulletin board in the contracting shed with the location map of the construction site showing the bird nesting areas and a warning, clearly visible, stating that "BIRD NESTING AREAS ARE PROTECTED BY THE MIGRATORY BIRD TREATY ACT."

6. **Report Submission:** The results of the daily shorebird monitoring and nest activities report shall be forwarded weekly or monthly (depending on the time of surveys) to the USFWS and USACE. Following completion of the project, a summary report of the shorebird monitoring and nesting activities shall be forwarded within 30 days to USFWS (Attn: Mr. Paul Necaise (228-493-6631) at paul_necaise@fws.gov, 6578 Dogwood View Pkwy, Jackson, MS 39213), NPS (Ms. Jolene Williams, 228-230-4132, Gulf Islands National Seashore, 1801 Gulf Breeze Parkway, Gulf Breeze, FL 32563 or email: jolene_williams@nps.gov), and USACE.

**7. Shorebird Benthic Sampling Protocol**

**Purpose:** To perform biological surveys required to collect surface sediment samples, sort and identify benthic macroinfauna organisms on beaches located on East and West Ship islands, Cat Island, and Horn Island, as associated with Piping Plover and Red Knot foraging areas to support the Mississippi Coastal Improvements Program (MsCIP) barrier island restoration project.

Objective:

- To establish a pre-construction baseline of macroinfaunal taxonomy and abundance within future project-influenced and reference beaches on East and West Ship islands, Cat Island, and Horn Island.

**Sampling and Analysis Plan:** The protocol is to determine the characterization of benthic communities at the tips of Eastern and Western Ship islands near Camille Cut and the eastern shoreline of Cat Island, and appropriate reference areas, and includes the sorting, identification, and enumeration of benthic macroinvertebrate organisms collected in each area. Sediment texture and organic content will be determined at each location where benthic macroinfaunal samples are collected. Hydrographic measurements will also be taken at each sampling location. Benthic community studies will be conducted during the November/December timeframe prior to construction activities and post-construction. This winter benthic community survey is to determine the pre- and post-construction habitat characteristics and macroinfaunal assemblages on beaches used by the Piping Plover and Red Knot.

**Benthic Sample Locations and Schedule:** Benthic community samples will be collected along beach transects on East and West Ship islands, Cat Island, and Horn Island associated with Piping Plover and Red Knot foraging areas. Sample locations will include sites in which Piping Plover are actively foraging on the tips and pre-sand placement and reference sites. The sample locations are anticipated to include:

- Three beach transects on the west tip of East Ship Island (including one through a tidal pool area, one on the northern shoreline area, and one on the southern area of the tip).
- Three beach transects on the east tip of West Ship Island (including one through a tidal pool area, one on the northern shoreline area, and one on the southern area of the tip).
- One transect on the Gulf front shoreline of East Ship Island (pre-placement location).
- One transect on the Gulf front shoreline of West Ship Island (reference for pre-placement location).
- Four beach transects on the eastern shoreline of Cat Island (including one on the north tip, two on the south tip, and one through a tidal inlet area).
- Three beach transects on the west tip of Horn Island as reference (including one through a tidal pool area, one on northern shoreline area, one on the southern area of the tip).

Two sampling stations will be arrayed along each transect at mean lower low water and mean high tide line to capture tidally exposed flats and wet sand samples. Both wet sand and high tide line intertidal samples will be collected within a 1 $m^2$ sampling zone in homogenous beach or flat environments.

**Benthic Sample Replication:** Adequate replication of benthic sampling is necessary to provide statistical power for comparisons of pre-construction and post-construction data. Based upon earlier USACE benthic community studies, four replicate samples per sample station are estimated to be required to represent over 75% of the taxa present at the sample sites. Both wet sand and high tide line intertidal samples will be collected within a 1 $m^2$ sampling zone in homogenous beach or flat environments.

**Benthic Sample Collection Methods:** Beach/subtidal samples will be collected with a 3" hand core (to a depth of 6") which samples an area approximately 0.0044$m^2$. The samples may be rinsed in the field through a 0.5-mm mesh screen if silty sediments are encountered; sand sediments generally will not be rinsed in the field. All cores will be preserved with 10% buffered formalin.

At each station, standard hydrographic measurements will be taken at mean lower low water surface, depths prior to benthic sampling. A YSI® Model 600XL Datasonde, or equivalent, will be used to measure temperature, conductivity, salinity, pH, and dissolved oxygen (DO) concentration. **Table 1** provides a summary of the benthic macroinfaunal and sediment texture/TOC sampling program.

**Table 1. Summary of benthic community characterization sampling, pre-construction**

| STUDY AREA | STATIONS/SURVEY<br>Winter |
|---|---|
| **Beach/Intertidal Benthos** | |
| Project | 12 |
| Reference | 3 |
| Total Stations *(2 per transect)* | 30 |
| Replicates | 4 |
| Total Samples | 120 |
| **Sediment Texture** | 30 |
| **Sediment TOC** | 30 |

**<u>Laboratory Analyses:</u>** *<u>Infauna</u>:* In the laboratory, benthic samples will be inventoried, rinsed through a 0.5–mm mesh sieve to remove preservatives and sediment, stained with Rose Bengal, and stored in 70% isopropanol solution until processing. Sample material will be sorted and all macroinvertebrates will be removed and placed in labeled glass vials containing 70% isopropanol, with each vial representing a major taxonomic group (*e.g.* Oligochaeta, Mollusca, Arthropoda). Oligochaetes will be individually mounted and cleared on microscope slides prior to identification. All sorted macroinvertebrates will be identified to the lowest practical identification level (LPIL), which, unless the specimen is a juvenile, damaged, or otherwise unidentifiable, will in most cases be to species level. The number of individuals of each taxon, excluding fragments, will be recorded. A voucher collection will be prepared, composed of representative individuals of each species not previously encountered in samples from the region. Additionally, each sample will be analyzed for wet-weight biomass ($g/m^2$) of the major taxonomic groups identified, to facilitate evaluation of Piping Plover and Red Knot feeding habitat.

*<u>Sediment Grain Size Analysis and Sediment Total Organic Carbon (TOC)</u>*: One sample will be collected at each station for sediment grain size analysis. Each sample will be washed with deionized water, dried, and weighed. Each sediment sample will be washed with deionized water, dried, and weighed, and the following physical parameters determined for each sample: coarse (sand) and fine (silt, clay) fractions, median grain size and percentages of gravel, sand, silt, and clay.

A subsample of each sediment sample will be analyzed for total organic carbon (TOC). Sediment TOC analyses will be performed according to the guidelines in EPA-600/4-79-020, 1983, Method 415.1 for determination of total organic carbon in sediment and soils.

**<u>Data Analyses:</u>** The number of replicate samples taken with the 3" hand core will be sufficient to permit statistical comparisons of pre- and post-placement data. The macroinfaunal data will be analyzed using univariate and multivariate approaches to identify any differences in community structure between project and reference station groups.

The following numerical indices will be calculated for each sample:

1) Infaunal abundance (total number of individuals per station);
2) Infaunal density (total number of individuals per square meter);
3) Species richness (total number of taxa represented in a given station and by Margalef's D);
4) Taxa diversity (Pielou's Index H`);

5) Evenness (Pielou's Index J`).

An appropriate test of significance will be performed on the univariate indices to determine significant differences between groups (stations). Multivariate analyses will be used consisting of ordination of station species abundance data by multi-dimensional scaling using the Bray-Curtis similarity coefficient, displayed in two dimensions. Classification analyses will be used including the Bray-Curtis similarity measure and hierarchical clustering of similarity values using the group-average sorting strategy. A test of the significance of dissimilarities determined by the ordination will be conducted using a non-parametric permutation procedure on the ordination similarity matrix. The Analysis of Similarities (ANOSIM) module in the Primer statistics program, or an analogous routine, will be used. A species analysis will be done to determine the contribution of taxa to the average dissimilarity between groups. The SIMPER module of the Primer statistical package or an analogous routine will be used.

**Macroinfaunal Data Interpretation:** Data interpretation will consist of habitat characterization (water depth, salinity, sediment texture) and benthic community characterization (faunal composition, abundance, and community structure, numerical classification analysis and taxa assemblages). A discussion should also include a comparison of relevant samples collected as part of previous surveys.

Macroinfaunal and sediment data will be used to evaluate the suitability of the sediment for feeding habitat for the Piping Plover and Red Knot. Potential prey species will be identified and an interpretive report will be prepared to describe use of the study area by Piping Plover and Red Knot.

# APPENDIX D - MONITORING PROCEDURES

The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate ecological success and inform the adaptive management program.

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### *iii. Habitat Composition/Habitat Mapping*

Habitats will be mapped for all MsCIP islands prior to construction to serve as a baseline, during construction and post-construction. To date, two pre-construction maps have been developed including data from January 2015 and December 2015. For all mapping efforts, MsCIP will acquire project-specific 0.3-m resolution, color-infrared stereo and orthophotography during the late fall to winter. Habitat categories are developed from existing classification schemes including the National Wetlands Inventory (NWI, Cowardin et al. 1979) and Anderson Land Use/Land Cover classification system (Anderson et al. 1976), as well as custom special modifiers to characterize habitat for dune and spoil (Table 1). Habitat classifications are developed via heads up digitizing by an expert photointerpreter. All habitat photointerpretation will adhere to NWI protocols and standards. All habitats will be mapped to subclass-level to distinguish tidal regimes: 1) irregularly-exposed; 2) regularly flooded; and 3) irregularly flooded (Table 2).

As part of the initial baseline mapping efforts, field data collection was conducted in August 2015 to assist with the photointerpretation of barrier island habitats. The best available lidar data, along with ancillary imagery datasets from 1998 through January 2015, will also be utilized to help classify areas that may be difficult to identify. Imagery of the project area will also viewed in stereo (i.e., as a three-dimensional image), which helps determine vegetation height and proper habitat classification. Lidar data will be utilized for elevation information that may help discern habitats from one another, especially where floating aquatics may be present.

After completion of habitat classifications, the photointerpreter will perform a Quality Assurance self-check of their work. In addition, a second photointerpreter will perform a final in-house Quality Control, assuring accuracy and data integrity. The final in-house Quality Control also will review all ancillary data including all available dates of imagery for the project area to ensure consistency of habitat mapping for each time period. After the data has undergone QA/QC protocols, the data will be sent to the MAM Technical Advisory Group for their review and comments. Once all comments have been addressed, the final data product will be ready for map production and submitted to an online distribution source.

**Table 1.** Habitat Classification Scheme for MsCIP.

| Habitat class | Description |
|---|---|
| Open Water Salt | Includes all open water in estuarine and marine wetlands and deepwater habitats with vegetative cover less than 30 percent. |
| Open Water Fresh | Includes all open freshwater areas with vegetative cover less than 30 percent |
| Beach/Mud Flat Salt | Includes all wetland habitats adjacent to the subtidal zone less than 30 percent areal cover of vegetation other than pioneer plants that become established during brief periods when growing conditions are favorable. These areas include wetlands that are regularly and irregularly flooded just above the subtidal zone and below about 1.5 m relative to the North American Vertical Datum of 1988 (NAVD88). |
| Beach/Mud Flat Fresh | Includes all non-tidal wetland habitats less than 30 percent areal cover of vegetation other than pioneer plants that become established during brief periods when growing conditions are favorable. |
| Wetland Forested Fresh | Forested freshwater wetlands with woody vegetation greater than 6 m that covers at least 30 percent areal coverage. |
| Wetland Scrub Shrub Fresh | Scrub-Shrub freshwater wetlands with woody plants less than 6 with at least 30 percent areal coverage. |
| Wetland Scrub Shrub Salt | Estuarine wetland areas dominated by woody vegetation less than 6 m tall that covers at least 30 percent areal coverage. |
| Marsh Salt | Wetland vegetated areas subject to regular inundation by marine or estuarine waters or influenced by tidal action. This class includes wetland vegetation characterized by erect, rooted, herbaceous hydrophytes that is regularly and irregularly flooded land just above the subtidal zone and below about 1.5 m relative to the NAVD88. |
| Marsh Fresh | Wetland vegetated areas within freshwater tidal or non-tidal that are dominated by erect, rooted, herbaceous hydrophytes. This vegetation is present for most of the growing season in most years. |
| Upland Forested Dune[1] | Upland areas dominated by woody vegetation that is 6 m or taller. These areas grow on ridges and are higher in elevation than other forested areas. |
| Upland Scrub Shrub Dune[1] | Upland areas dominated by woody vegetation less than 6 m tall. This vegetation grows on ridges that are higher in elevation than other areas with scrub shrub. |
| Upland Range Dune[1] | Areas of built up sand along shoreline with established herbaceous vegetation. |
| Upland Barren Dune[1] | Areas of built up sand along shoreline that is free of vegetation. |
| Upland Urban | Any man-made object fixed to the land surface as a result of construction including roads, industry, or residential or recreational structures. |
| Upland Spoil | Areas of spoil deposition along excavated canals. |

[1]These areas include subaerial habitat greater than about 1.5 m relative to the NAVD88 and encompasses foredune, dune, and backslope habitats. Although dune habitat occurs at elevations below about 1.5 m NAVD88, lower elevation dunes are more ephemeral and more frequently overwashed, which reduces their habitat value. Lower-elevation dunes often consist of vegetation more commonly associated with swale habitat and lack a high percentage of common dune vegetation species.

**Table 2.** Hydrologic Regime for MsCIP.

| Habitat class | Description |
|---|---|
| Irregularly exposed | Includes all wetland habitats in which tides expose the substrate less often than daily. |
| Regularly flooded | Includes all wetland habitats in which high tides alternately flood and expose the substrate at least once daily. |
| Irregularly flooded | Includes all wetland habitats in which tides flood the substrate less often than daily. |

**References**

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A Land use land cover classification system for use with remote sensor data. Professional Paper 964. United States Department of Interior, Geological Survey, Washington D.C., 28 pp.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. United States Department of Interior, Fish and Wildlife Service, Washington D.C., 134 pp.

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The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate ecological success and inform the adaptive management program.

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### *iv. Sea Turtles*

Threatened and endangered species, critical habitat, nesting shorebirds, and sea turtles must be monitored for this project to determine impacts pursuant to the Endangered Species Act and the Migratory Bird Treaty Act. This project is located within the boundaries of Gulf Islands National Seashore, whose barrier island beaches are used by nesting endangered and threatened sea turtles. The U.S. Army Corps of Engineers (USACE), which includes its Contractor/Subcontractor, shall keep construction activities under surveillance, management, and control to prevent impacts to sea turtles, their nests and hatchling sea turtles. The USACE may be held responsible for harming or harassing sea turtles, their eggs or their nests as a result of the construction. Sea turtle nests are easily missed by those unaware, making it easy for people and equipment to accidentally crush the eggs; young sea turtle hatchlings can get stuck in deep tire ruts; bright construction lights at night can disorientate adults and hatchlings causing them to migrate in the wrong direction (away from the ocean), which almost assures the hatchlings' death.

Sea turtle monitoring includes documenting defined parameters of sea turtle nesting activity including species, abundance, locating crawls, marking nests and relocating vulnerable nests (see U. S. Fish and Wildlife Service/National Park Service [USFWS/NPS] monitoring protocol). Monitoring will be conducted on the project beaches of Cat Island, West Ship Island, and East Ship Island. In order to prevent disturbance to nesting shorebirds, monitoring of sea turtles should be done in the morning, prior to the required shorebird monitoring.

There are five species of sea turtles: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), and Kemp's Ridley (*Lepidochelys kempii*), that may be found in the Gulf of Mexico. Green, loggerhead and Kemp's Ridley sea turtles are regularly documented in the waters surrounding the barrier islands of Gulf Islands National Seashore. Of these, loggerhead and green sea turtles have been documented nesting on the barrier islands in the Mississippi Sound. Though never documented, Kemp's Ridley sea turtles are likely to nest on the Mississippi islands, and nests have been documented on Santa Rosa Island in the Florida District of the Seashore.

Sea turtle nesting and hatching season for Mississippi starts around April 15 and ends around November 30. Incubation for the loggerhead sea turtle ranges from about 45 to 95 days and incubation for the green sea turtle ranges from about 45 to 75 days. Potential hatching dates will be determined for each crawl documented and monitored for nesting success 95 days beyond the crawl date or until construction ends.

**Monitoring Periods:**

There are three monitoring periods: **pre-construction, during construction, and post-construction.** An NPS Biologist will be available for assistance if needed during all periods of the monitoring.

**a. Pre-Construction:**

No pre-project surveys will be required if project activities are initiated between November 30 and April 15. If the project will be initiated between April 15 and November 30, daily pre-project surveys should begin at least 100 days beforehand in the immediate vicinity of work, as well as in the area where work will be occurring within the next 100 days, weather permitting.

**b. During Construction:**

Nesting surveys, marking, and potential relocation activities must be conducted daily, weather permitting, while construction activities are on-going during nesting and hatching season, April 15-November 30 in work areas.

**c. Post-Construction:**

Weekly sea turtle monitoring shall be conducted and include two full nesting and hatching seasons (April 15th thru November 30th), starting approximately one to two years after the end of construction. The goal of the post construction monitoring is to ensure that suitable habitat for sea turtles is established.

**Monitoring Protocols:**

**Survey Methods:**

1. For sea turtle nesting surveys during construction, a meeting between representatives of the contractor, the USACE, the USFWS, the NPS, the USWFWS-permitted sea turtle surveyor, and other species surveyors, as appropriate, must be held prior to the commencement of work. This meeting will be held approximately ten days prior to commencement of surveys, as required by the Biological Opinion. The meeting will provide an opportunity for explanation and/or clarification of the sea turtle protection measures, as well as additional guidelines when construction occurs during the sea turtle nesting season, such as storing equipment, minimizing driving, and reporting within the work area, as well as follow-up meetings during construction. At that meeting the USACE will provide the USFWS and the NPS with specific information on the actual project that is going to proceed (form on the following web link: http://www.fws.gov/northflorida/SeaTurtles/Docs/Corp%20of%20Engineers%20Sea%20Turtle%20Permit%20Information.pdf) and emailed to the Service at seaturtle@fws.gov.

2. On native beaches, surveys will be conducted first thing in the morning by All-Terrain Vehicles (ATV/UTV), foot, or boat. All ATVs will be operated at <6 mph, to provide adequate opportunity to view the beach, to avoid obstacles and hazards, and to visually investigate all possible turtle crawls. **The ATV will be operated low on the beach, on the un-vegetated dune face, at or below the last high tide line.** This will allow even the shortest turtle crawls to be located and minimize impacts to bird nests. Be careful not to drive through a bird nesting area or bird closure areas. Back track on foot if necessary to survey the area not accessible by ATV. If it is high tide during your survey, do not attempt to drive the ATV through water. Also, do not drive the vehicle over dunes and vegetation. If there is a path wide enough for the ATV to drive through without impacting vegetation, use the path to circumvent the area where there is no beach. **Operators need to be careful not to drive through a bird nesting area.** Back track on foot if necessary to survey the area that was missed.

3. During the survey, be alert for tracks, stranded turtles, nests uncovered by predators, hatchlings, etc. or any evidence of a sea turtle incident. Check any marked nests found during previous surveys.

**Investigating Nesting Activities:**

1. If a turtle crawl is discovered, stop and evaluate the incident as thoroughly as possible. A completed "Sea Turtle Monitoring" form is required for all incidents, false crawl or nest. Identify the species of the turtle crawl. Record the GPS location. Take photos of the turtle crawl.

2. Mark the turtle crawl to prevent double-counting and/or a nest associated with the crawl. Look for evidence of a body pit, which will look like a roughly circular area of disturbed sand which may or may not be slightly lower than surrounding areas. If no body pit is discovered, the crawl will be assumed to be a false crawl. False crawls will be recorded on a report form. If a conspicuous area of disturbed sand is found (body pit), assume that a nesting event has occurred. Look for signs of animal depredation or human tampering.

3. Measure the crawl at three different locations and calculate an average width from them. Straight-line measurements should be taken from the tip of the flipper mark on one side to the tip of the flipper mark on the other. With loggerheads, since the flipper marks alternate, the measurements should be from flipper mark on one side to an extended straight line from the flipper mark on the other side.

4. If the incident was a nest, record the distance from the water to the nest site. This does not need to be exact as water level fluctuates with each wave, but it should be fairly accurate. Also, note if the nest is above or below the rack line (highest debris line on the beach).

5. Estimating egg cavity location. Determine the direction of travel along the crawl, locate a body pit, and locate an escarpment in the shape of an arc at the front of the pit. Typically, the female faces away from the water during nesting, although this is not always the case. The escarpment is the result of the turtle using her front flippers to cover the nest with sand when she is done laying. The egg cavity is usually centered behind this escarpment, approximately 3-5 feet back, although it may be further back if the turtle was moving forward while covering the nest site.

6. Occasionally, a nest may be uncovered by predators or beach erosion. If you find a nest where eggs or the remains of eggs are visible, the incident will be reported as a nest. If the nest was predated, the nest must be checked for viable eggs. Do not assume the nest has been totally predated.

   If a nest is partially depredated, the remaining eggs can be reburied with the necessary precautions. Eggs must be rinsed off with freshwater to remove all albumen and other fluids that came from the damaged eggs. Rough handling and turning of the eggs should be avoided. The nest cavity, if still intact, should be emptied out down to clean sand before the eggs are replaced. Do not dig too deep. Occasionally, most eggs can be left in place and only the top few need to be removed, cleaned and returned to the nest. The nest should then be filled with moist sand. Compress the sand with your hands using slight to moderate pressure. Damaged eggs and shells should be removed from the area.

   If the nest was totally depredated, fill in the hole and clean up the area. If you find an area where eggs are strewn about and there is a hole in the sand, but no crawl, this is an old nest that has been depredated. File a nest report, including photo and GPS coordinates.

**Marking Nests for Pre- and During Construction:**

Equipment for nest perimeter buffer zone marking:

1. Four wooden perimeter buffer zone stakes. Dimensions 1" x 2", 4 feet long.

2. One roll of 3/16" fluorescent orange flagging tape

**Marking Nest Sites to Protect Buried Eggs from Hazardous Activities**

The goal of this marking method is to clearly identify the nest area and protect it from such human activities as vehicular traffic and other disturbances.

A series of stakes and highly visible survey ribbon or string shall be installed to establish a 10-foot radius around the nest. No activity shall occur within this area nor will any activity occur that could result in impacts to the nest. Nest sites shall be inspected daily to assure nest markers remain in place and that the nest has not been disturbed by the project activity. The stakes should extend more than 36" above the sand. To further identify the nest site, surveyor's ribbon can be tied from the top of one stake to another to create a perimeter around the nest site. Additionally, a nest sign can be attached to one of the stakes used to create the perimeter. A nest-identifying number and the date the eggs were laid should be placed on at least one of the nest perimeter stakes. At least one additional stake should be placed a measured distance from the clutch location at the base of the dune or seawall to ensure that future location of the nest is possible, should the nest perimeter stakes be lost.

Signs should have the following information:

**SEA TURTLE NEST - DO NOT REMOVE**

**VIOLATORS SUBJECT TO FINES AND IMPRISONMENT**

U.S. Endangered Species Act of 1973: No person may take, harass, harm, pursue, hunt, shoot, wound, kill, trap, or capture any sea turtle, turtle nest, and/or eggs, or attempt to engage in any such conduct. Any person who knowingly violates any provision of this Act may be assessed a civil penalty up to $25,000 or a criminal penalty up to $100,000 and up to one year imprisonment.

**SHOULD YOU WITNESS A VIOLATION OR OBSERVE AN INJURED OR STRANDED TURTLE OR DISORIENTED HATCHLINGS, PLEASE CONTACT:**

US Fish and Wildlife Service at (601) 965-4900

**Nests Relocation Protocol:**

After a nest is identified, three circumstances would warrant nest relocation:

(1) If the eggs have been exposed as a result of erosion,
(2) If you observe that the nest, due to its location on the beach, is in danger of being inundated by daily tides or lost through erosion, or
(3) The nest is within active construction zone, or any zone that will be active within 95 days from the date of discovery.

**Do not move the nest unless you are completely confident the nest will be lost.**

If the nest requires relocation, then call the designated person(s) permitted to relocate nest and contact Paul Necaise (USFWS: 228-493-6631) as soon as possible.

Sea turtle nests on Ship Island shall be relocated pre- and during construction according to the Turtle Nest Relocation Siting and Preparation Guidelines shown in Figure 1. The relocation zone map for Cat Island is included at the end of this section as Figure 2.

Nests requiring relocation must be completely moved to a nearby self-release beach site in a secure setting where artificial lighting will not interfere with hatchling orientation, no later than 9 a.m. the morning following deposition. The specific site for nest relocation will be determined in coordination with USFWS and NPS. Relocated nests must not be placed in organized groupings, but must be randomly staggered along the length and width of the beach in settings that are not expected to experience daily inundation by high tides or known to routinely experience severe erosion and egg loss, or subject to artificial lighting. Relocated nests should have a predator-proof screen/cage as outlined in the nest marking protocols where raccoons are a problem. Nest relocations in association with construction activities must cease when construction activities no longer threaten nests.

A new nest location can be excavated above the high tide line, but not above the dune line, in an area that is not impacted by construction. The top of the new nest, or egg cavity, should be located approximately 10-12 inches below the level of the sand, with the bottom of the new cavity about 22 inches deep. The nest cavity should be in the shape of a vase with a round bottom and long neck. Dig the new nest cavity before you begin to move the eggs, and then move the eggs one by one to the container with care, but in a timely manner. **Handle the eggs with care.** Use the supply container to store the eggs, or a cooler if one is available. Fill the bottom of the container with some sand from the nest area to prevent the eggs from rolling. The sand will also cushion the eggs. Use the lid to shade the eggs as large temperature changes need to be avoided. After all the eggs have been deposited (not dropped) carefully in the new nest cavity one at a time, fill the cavity with moist sand from the original nest site. Then use surrounding sand as needed, compressing the sand with your hands with slight to moderate pressure. Mark these nests in accordance with the general guidelines for a positive nest. A more detailed description of this process can be found in USACE, 2015. Monitoring datasheets are displayed in Figures 1-2, and turtle relocation zones are shown Figures 3-5.

## Mississippi Sea Turtle Crawl Datasheet

For nesting and non-nesting emergences

| | |
|---|---|
| Survey Date (mm/dd/yyyy): | Weather: |
| Surveyor(s): | Time Discovered: |
| Species: CC CM LK UNK Other | Crawl Type: NA NB FA FB |

| Species Key: | | Crawl Type Key: | |
|---|---|---|---|
| CC=Caretta caretta | LK=Lepidochelys kempii | NA=Nest above recent high tide | FA=False crawl above recent high tide |
| CM=Chelonia mydas | UNK=Unknown | NB=Nest below recent high tide | FB=False crawl below recent high tide |

### Original Crawl/Nest Information

| | |
|---|---|
| GPS wpt # | |
| Latitude: | Longitude: |
| # Abandoned Body Pit: | # Abandoned Egg Chamber: |
| **Distance from clutch/apex to:** | |
| Toe of Dune (ft): | High Water Line (ft): |
| Clutch Deposited ? **YES NO Unknown** | Clutch: **MOVED MARKED** |
| Nest above Wrack Line? **YES NO** | **Nest ID:** |
| Crawl Width Measurements: | Nest Screened: **YES NO** |
| 1 __________ cm | Buffer Stakes: **YES NO** |
| 2 __________ cm | Nest Relocated: **YES NO** |
| 3 __________ cm | Reason: |
| Hidden Stake (ft): | Main 4' Stake Location: |
| Toe of Dune Stake (ft): | Main 4' Stake Height (cm): |
| Total Clutch Size: | # of Broken Eggs: |
| Depth to Top of Clutch (cm): | Depth to Bottom of Clutch (cm): |

**Photos Taken?** **YES NO** (***At least 3 photos should be taken***. Photos should include an overhead view of the nest/false crawl location with marking stake visible so that the location of the nest site relative to the dune, wrack line, and water can be seen in the image.)

**Obstructions Encountered?** **YES NO**
If yes, please describe:

**Disturbances?** (humans, predators) **YES NO**
If yes, please describe (including # of eggs predated):

**Notes:**

**Site Description:**

### Crawl Sketch (Must show dune, apex or nest location, obstacles, HWL)

### Relocated Nest Information

| | |
|---|---|
| New GPS wpt #: | Inventory Date: |
| Latitude: | Longitude: |
| Total Clutch Size: | # of Broken Eggs: |
| Depth to Top of Clutch (cm): | Depth to Bottom of Clutch (cm): |
| **Notes:** | |
| **Site Description:** | |

**Figure 1.** Sea Turtle Crawl Datasheet

| Reproductive Success | |
|---|---|
| Key: H = Hatched HNO = Hatch Not DNH = Did Not B = Broken | |
| **Nest ID:** | **Observer:** |
| Fate: **H HNO DNH B Other** r, describe} | |
| First Emergence Date: | Other Emergence Dates: |
| 75 Day Date: | Excavation Date: |
| 4' Stake Height (cm): | |
| Depth to Top of Clutch (cm): | Depth to Bottom of Clutch (cm): |
| **Hatched:** | **Unhatched:** |
| Live Hatchlings: | Dead Hatchlings: |
| Yolkless Eggs: | Total Clutch Size: |
| **Development Arrested At:** | |
| Early Stage Mortality: | Addled: |
| Late Stage Mortality: | Infertile: |
| Pipped Live: | Pipped Dead: |
| **Eggs Affected By:** (describe if nest was affected by predators or | |
| Roots (circle all that apply): **Inside Clutch Invade Eggs Hatchlings Trapped** | |
| Crab Holes (within 60 cm of clutch): **YES NO** | Ants: **YES NO** |
| **HATCHING SUCCESS** % (number of hatched shells/total clutch size x 100): | |
| **EMERGING SUCCESS** % (number of hatched shells - (live + dead hatchlings)/total clutch size) x 100: | |
| Comments: | |
| | |

| RTK Survey Summary (summary measurements recorded on this sheet may be rounded to whole numbers) | |
|---|---|
| Surveyor(s): | Survey Date: |
| Equipment Make and Model #: | Equipment Serial #: |
| ASCII file name (if known): | Weather: |
| Total Length of RTK Profile (ft): | Highest Elevation (ft): |
| Lowest Elevation (ft): | Nest Elevation(ft): |
| | |
| **Profile Sketch** (include location of gulf or soutnd water's edge, nest/false crawl loation, dune, berm, vegetation, wrack line, obstructions, as | |

**Figure 2.** Sea Turtle Reproductive Datasheet


**Figure 3.** Cat Island Turtle Relocation Zone Map


**Figure 4.** West Ship Island Turtle Relocation Zone


**Figure 5.** East Ship Island Turtle Relocation Zone Map

**Recording Data:**

Completely fill in the Mississippi Sea Turtle Crawl Datasheet form (Figure 1) provided for all nests and false crawls, being as accurate as possible, and paying particular attention to describing the location of the nest and how the nest was marked. Use the back of the sheets for additional information or maps and diagrams. Use a separate data sheet for each nest.

**Beach Profile Survey at Turtle Nesting/False Crawl Locations:**

An elevation profile shall be obtained through an identified sea turtle nesting site or false crawl with a bearing perpendicular to the average shoreline orientation. The seaward limit of the profile should begin at the -2.0 foot contour and continue landward a minimum of 150 feet but no less than 75 feet landward of the nesting site or landward extent of the false crawl track; however, the transect shall terminate at any substantial standing water or at the dense vegetation line landward of the nest. Points along the profile should be spaced such than there is no more than 0.5 foot difference in elevation, but no more than 15 feet between points along the profile. Additionally, a point shall be located at the centroid of the nesting site or the false crawl track. Points should be collected by using a high-precision real-time kinematic (RTK) global positioning system (GPS). Positioning data shall be referenced to Mississippi State Plane East, NAD83 HARN, U.S. Survey feet and NAVD88 (Geoid 12A), U.S. Survey feet. Survey control, accuracy, and procedure shall be in accordance with EM 1110-1-1005. Survey information shall be emailed to the following USACE staff: Mr. Nathan Lovelace at

Nathan.D.Lovelace@usace.army.mil, Mr. Stephen Reid at Stephen.H.Reid@usace.army.mil, and Ms. Lekesha Reynolds at Lekesha.W.Reynolds@usace.army.mil.

**Sediment Sample at Turtle Nesting/False Crawl Locations:**

A sediment sample shall be obtained at the centroid of the nesting site or the false crawl track. Care should be taken to not harm the eggs at the nesting site during the collection. Each sample will include approximately one pint of material and will be labeled with the date and site reference. Samples will be turned in to the Mobile District Office, in care of Mr. Nathan Lovelace, Nathan.D.Lovelace@usace.army.mil for analysis. No lab work is required.

**Routine Monitoring of all existing Nest Sites:**

1. All sea turtle nests will be monitored throughout the incubation period. This monitoring is for the purpose of determining the duration of incubation, and identifying the incidence of depredation, damage from beach erosion, or disturbance by human activities.

2. Make sure all the stakes are readable and in good condition. If a stake or sign is missing, replace it and note the replacement in the log book and on the nest sheet.

Sites will be evaluated for evidence of disturbance including tracks, digging, ghost crab holes, tire tracks, beach erosion or wash-overs, or any other indication of nest disturbance. Photographs and observations of any disturbance should be recorded and provided in the report.

**Monitoring at Expected Time of Hatching**

1. Beginning at the 50$^{th}$ day from initial discovery, each nest will be monitored more closely. This intensive regime of monitoring will be conducted to determine the precise duration of incubation, and to gather data on hatchling emergence, depredation, and disorientation.

2. Nest sites will be evaluated to determine if hatching has occurred by looking for tracks of hatched turtles which have left the nest. In general, the majority of hatchlings will leave the nest as a group during the night. Their tracks will appear as a clutter of small (approximately 2" wide), tracks which radiate out from the nest. The area where the eggs are located will usually appear collapsed.

3. Look for evidence of depredation from ghost crabs and/or birds, and any indication of turtle remains. Look for evidence of hatchling disorientation. Note any tracks which deviate from a straight course to the water, and attempt to follow any tracks which have headed in the wrong direction. If disoriented hatchlings have been located, contact Paul Necaise (FWS, 228-493-6631) and Jolene Williams (NPS: 228-323-3176) as soon as possible.

4. Record all observations made at the site on the specific Reproductive Success form developed for that nest. Please be as complete as possible. Any information which can be learned about the fate of the hatchlings after they emerged from the nest is of value.

**Final Nest Assessment and Excavation:**

1. All nests will be assessed at the conclusion of the nesting process to gather data on overall nesting success.

2. In general, the final assessment will be conducted three days after hatchlings have been documented as emerging from the nest or 80 days after initial discovery of a nest, if no evidence of hatching has been recorded. (This is dependent upon the identified species).

3. When excavated, the sites are evaluated to determine the fate of the nest. The data collected includes, at minimum, the total number of eggs found (both hatched and unhatched), the presence of any hatchlings inside the nest, the number of unhatched eggs with embryonic development, the number of eggs without embryonic development, and any evidence regarding factors which may have affected the nest, such as ghost crab burrows, vegetation roots, etc.

4. Results will be recorded on the USFWS form and all protective material including screens and stakes will be removed from the nest location.

**Construction protection measures to be monitored (compliance/noncompliance observations should be included in weekly report):**

1. During turtle nesting and hatching season, staging areas for construction equipment must not be located in the natural dunes and vegetation on the island. In project areas on natural beaches, construction pipes will be as short in length as possible to allow nesting sea turtles use of the natural beach and limit trapping of nesting sea turtles behind the construction/dredge pipes. Additionally, all construction pipes placed on the beach must be located as far landward as possible without compromising the integrity of the dune system. Pipes placed parallel to the dune must be five to ten feet away from the toe of the dune if the width of the beach allows. Temporary storage of pipes must be off the beach to the maximum extent possible. If the pipes are stored on the beach, they must be placed in a manner that will minimize the impact to nesting habitat and must not compromise the integrity of the dune systems.

2. To minimize possible boat impacts to nesting sea turtles feeding and loafing in the surf off the outer bar of the south beach, support vessels should observe a no wake zone 300 yards from the south shoreline.

3. Direct lighting of the beach and nearshore waters must be limited to the immediate construction area during the nest laying season through end of hatching season (April 15 – November 30) and must comply with safety requirements. Lighting on all equipment must be minimized through reduction, shielding, lowering, and appropriate placement to avoid excessive illumination of the water's surface and nesting beach while meeting all Coast Guard, Corps EM 385-1-1, and OSHA requirements. The light intensity of all lighting equipment must be reduced to the minimum

standard required by OSHA for General Construction areas, in order to avoid misdirecting sea turtles.

4. Sea Turtle Signs: If nesting occurs within the construction area, the nest should be relocated, and the construction contractor shall place and maintain a bulletin board in the contracting shed with the location map of the construction site showing the sea turtle nesting areas and a warning, clearly visible, stating that "SEA TURTLE NESTING AREAS ARE PROTECTED BY THE THREATENED AND ENDANGERED SPECIES ACT".

5. Beach Rutting: Ruts created by heavy equipment located along the beach face between the nest and the water will be smoothed to avoid trapping of hatchlings as they move down the beach face to feed.

**Reporting:**

1. Report any activity as soon as possible, including nesting, false crawls. This reporting can be in form of an email. The logs shall summarize sea turtle species observed (adults and hatchlings), the location of turtle crawls and/ or nests (GPS coordinates), and construction compliance/noncompliance observations. In addition, logs shall summarize upon locating a dead or injured sea turtle that may have resulted from direct or indirect results of the project. Nests with estimated hatch dates should be supplied with the submitted logs. If an injured or dead sea turtle is discovered, contact Paul Necaise (FWS), and Jolene Williams (NPS) immediately to ensure treatment or disposition of the dead sea turtle. A NOAA Sea Turtle Stranding and Salvage Network – Stranding Report should be completed and filed with NOAA, and provide a copy to NPS (Jolene Williams 228-323-3176). A copy of the form can be found at the MS Sea turtle stranding and salvage network website at https://www.nrc.gov/docs/ML1434/ML14345A279.pdf. Ms. Wendy Teas, Wendy.Teas@noaa.gov, 228-549-1628, is the POC for stranded or dead sea turtles. Ms. Patricia Rosel is the POC for stranded or dead mammals, her email is Patricia.Rosel@noaa.gov, and the hotline number is 888-806-1674. Please also provide a copy to Mobile District, PD-EC, Coastal Environment Chief, Ms. Lekesha Reynolds and NPS (Jolene Williams).

2. Report Submission: A monitoring report should be submitted weekly to USACE, USFWS, and NPS POCs listed in the contact list below (including logs and all data forms/sheets).

3. Following completion of the project, a summary report of the monitoring and nesting activities shall be forwarded within 30 days to USFWS and NPS.

**Requirements for monitor:**

Monitoring will be conducted by trained individuals with proven sea turtle experience and identification skills. Credentials of the Sea Turtle Monitor will be submitted to the USFWS and NPS Biologists for review and approval. Not every monitor will require relocation experience and permits; however, at least two individuals approved for relocation should be available to allow one person to monitor the construction site every day during the nesting season when there are active construction activities occurring. An NPS Biologist will be available if needed during all periods of the monitoring.

Mississippi Department of Wildlife, Fisheries and Parks (MDWFP), USFWS, NPS, and anyone permitted by MDWFP or USFWS shall be allowed on the work site during construction as needed, to assist with sea turtle monitoring and nest search, or to post nest buffers when needed with the approval of the USACE on-site inspector in order to comply with safety regulations.

**CONTACT LIST:**

USFWS: Mr. Paul Necaise at 228-493-6631, Paul.Necaise@fws.gov, 6578 Dogwood View Pkwy, Jackson, MS 39213
NPS: Ms. Jolene Williams, at 228-323-3176, Jolene_Williams@nps.gov, Gulf Islands National Seashore, 3500 Park Road, Ocean Springs, MS 39564
USACE: Ms. Lekesha Reynolds, 251-690-3260, email Lekesha.w.reynolds@usace.army.mil, 109 St. Joseph St., Mobile, AL 36602
USACE COR: Mr. Stephen Reid, Contracting Officer Representative, 251-957-6019, Cell 251-802-2009, Stephen.H.Reid@usace.army.mil
USACE DMPM: Mr. Nathan Lovelace, Dredge Material Project Manager, 251-694-3713, Cell 251-802-2010, Nathan.D.Lovelace@usace.army.mil

**Penetration Resistance Testing**
**Purpose:**

The purpose of this supplemental information is to outline procedures for the establishment of baseline penetration resistance conditions of the sandy beachface sediments at Ship Island and Cat Island, Mississippi using a dynamic cone penetrometer testing apparatus. It is believed that beach sediment penetration resistance is an important factor in sea turtle nesting and constructed beach management.

**Dynamic Cone Penetrometer Apparatus**

The dynamic cone penetrometer (DCP) is a test apparatus that can be used for field sediment testing to estimate the *in situ* strength characteristics of undisturbed sediments or compacted materials. The shear strength, penetration resistance, and thickness of strata can be estimated by measuring the depth of penetration per hammer drop (blow) as a drive rod penetrates a substrate andcalculating the desired strength parameter through empirical equations using the depth-per-blow data as input. The DCP is typically used for material assessments to a depth of 36 inches.

Complete operating instructions for the dynamic cone penetrometer apparatus utilized for testing, as well as further details regarding its application, may be requested from the Mobile District MsCIP team at this email address: mscip@usace.army.mil.

**Shear Resistance Testing Locations and Configuration**

Shear resistance testing stations should be established along transects that extend from the seaward base of the dune to the swash zone. A transect is defined as a straight line that runs shore-normal from the dune to the water's edge of the island, along which observations and measurements will be taken. There will be two test stations located on each of the transect lines. A station is defined as the place specified for the DCP shear resistance measurements or sampling to occur. Three spatially independent DCP measurements will be taken to a depth of at least 18 inches at each station.

**Test Station Location**

One test station is to be located at the seaward edge of the dune and one station located in the dry berm midway between the dune line and the high water line (normal wrack line). At each station, the dynamic cone penetrometer test will be applied three replicated test spots, configured in a triangular pattern with the vertices being spaced 24 inches apart.

**Transect Intervals**

The alongshore distance between transects shall allow testing stations to be located midway between the wrack line and the dune and along the seaward edge of the dune. Unless there is a physical obstruction that prevents testing within that interval, the testing station intervals shall be no greater than 500 feet apart

**Samples for Validation**

It is suggested that sediment samples be procured from the existing island sediments for the purpose of validating the data obtained from the DCP measurements. The samples will be used to determine characteristics such as classification and unit weight of the sediments.

A series of sediments samples should be collected along transects located at the center and each of the distal tips of the island so that at least three transects will be physically sampled on each island. The series should consist of sediment samples collected at the 8-10- and 12-14- inch depths (below the surface) at one spot at each station located along a transect. The locations of collected samples may vary with the specific site conditions of each barrier island, and it may be necessary to collect additional samples if the island sediments are highly stratified or exhibit a large range of variability among transects.

See Figure 3 for a layout of the DCP testing scheme described in this document.

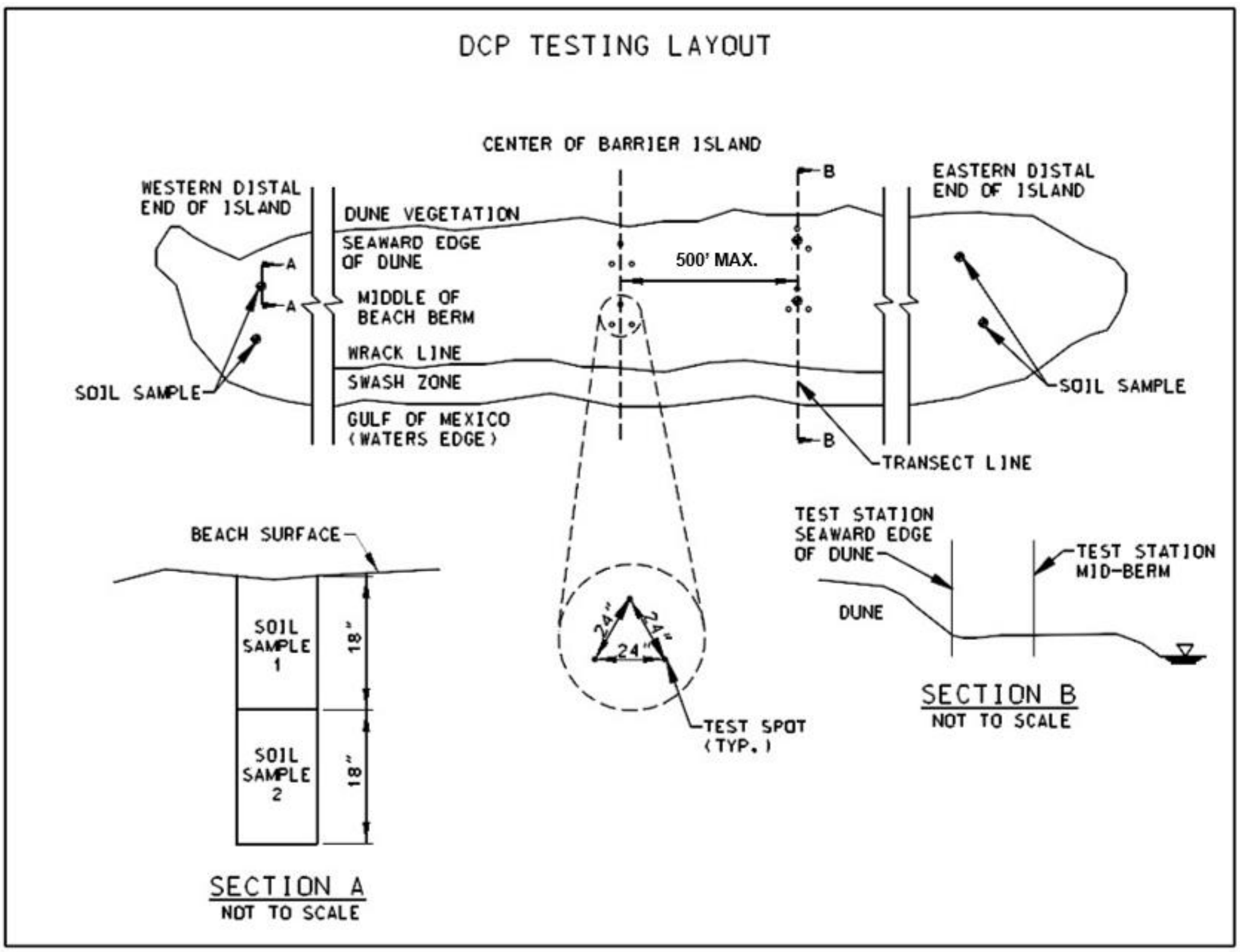


**Figure 3:** Typical DCP testing layout and details.

**Dynamic Cone Penetrometer (DCP) Pre-Construction Values**

Baseline value reports will include all measured values for each transect line, as well as the final averaged shear resistance values. The resistance values shall be reported in pounds per square inch (psi).

The pre-construction penetration resistance values of the sandy beachface at specified locations on the Mississippi barrier islands (East and West Ship islands, and Cat Island) shall be measured and reported based upon these testing methods. These same testing methods are to be applied after the restoration projects at the islands are completed. Data from the pre-construction and the post-project conditions will be analyzed, compared, and reported to the USFWS.

**Constructed Project Comparisons to Pre-Construction Values**
Testing results obtained from stations along the seaward edge of the existing dune will be compared to those that are similarly located along the seaward edge of the constructed dune of the completed project, while results obtained from the stations located midway between the dune and the high water line will be compared to those that are similarly located on the completed project. A report on the baseline and post-construction results of the beach sediments will be submitted to the USFWS. Consultation will occur with the USFWS after each testing event is completed and the results have been analyzed.

**References**

USACE 2015. Biological assessment Mississippi Coastal Improvement Program (MsCIP) Barrier Island Restoration Mississippi Sound Hancock, Harrison and Jackson Counties, Mississippi and Mobile County, Alabama. U.S Army Corps of Engineers, Mobile, Alabama, 01/2015

# APPENDIX D - MONITORING PROCEDURES

The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate ecological success and inform the adaptive management program.

## 3 BIOLOGICAL

### *v. Benthic and Infaunal species*

Benthic macroinfauna community sampling will follow methods described in Appendix I of the 2014 Draft Supplemental Environmental Impact Statement (USACE 2014). Pre-construction baseline benthic community surveys were collected in the 2010 (summer and fall) and 2011 (spring) at borrow and placement sites and reference sites. In late 2011 (fall) additional sites were surveyed to support Gulf sturgeon monitoring and in 2015 (winter), sites were added for shorebird monitoring. Post-construction sampling will be conducted at the sites previously surveyed in 2010, 2011, and 2015, and, potentially, new locations where sturgeon and shorebird feeding would occur after the closure of Camille Cut. Sand placement sites will be surveyed approximately two years after the completion of construction at Cat Island, and two years after the completion of construction on Ship Island. Benthic surveys for shorebird feeding sites will be conducted in the winter, approximately two years after the completion of the construction of Ship Island, but exact dates will be determined by the construction schedule and the temporal correlation of collection requirements across the program. Post construction benthic sampling for Gulf sturgeon feeding sites are scheduled to be sampled in the fall and spring beginning six months after completion of the closure of Camille Cut. Additional details regarding the monitoring procedure can be found in Appendix D3i (Gulf Sturgeon) and Appendix D3ii (Shorebirds).

Sampling sites are planned in the following locations:

1) Reference sites unlikely to be unaffected by construction
2) Sand placement after completion of construction
3) Additional sites to complement the Gulf sturgeon and shorebird monitoring

In the laboratory, benthic samples will be inventoried, rinsed through a 0.5–mm mesh sieve to remove preservatives and sediment, stained with Rose Bengal, and stored in 70% isopropanol solution. Sample material will be sorted and all macroinvertebrates will be removed and placed in labeled glass vials containing 70% isopropanol, with each vial representing a major taxonomic group (e.g. Oligochaeta, Mollusca, Arthropoda). Oligochaetes will be individually mounted and cleared on microscope slides prior to identification. All sorted macroinvertebrates will be identified to the lowest practical identification level (LPIL), which, unless the specimen is a juvenile, damaged, or otherwise unidentifiable, in most cases is the species level. The number of individuals of each taxon, excluding fragments, will be recorded. A voucher collection will be prepared, composed of representative individuals of each species not previously encountered in samples from the region. Additionally, each sample will be analyzed for wet-weight biomass ($g/m^2$) of the major taxonomic groups identified to facilitate evaluation of potential feeding habitat for gulf sturgeon and shorebirds. Numerical indices will be calculated for each sample, including: (1) Infaunal abundance (total number of individuals per station); (2) Infaunal density (total number of individuals per square meter); (3) Species richness (total number of taxa represented in a given station and by Margalef's D); (4) Taxa diversity (Pielou's Index H`); and (5) Evenness (Pielou's Index J`).

In addition to the benthic samples, one sample will be collected at each station for sediment grain size analysis. Each sediment sample will be washed with deionized water, dried, and weighed, and the following physical parameters determined for each sample: coarse (sand) and fine (silt, clay) fractions, median grain size and percentages of gravel, sand, silt, and clay. A subsample of each sediment sample will be analyzed for total organic carbon (TOC). Sediment TOC analyses will be performed according to the guidelines in EPA-600/4-79-020, 1983, Method 415.1 for determination of total organic carbon in sediment and soils.

Once all data are collected and processed, interpretation will consist of habitat characterization (water depth, salinity, sediment texture) and benthic community characterization, including faunal composition, abundance, and community structure, numerical classification analysis and taxa assemblages. A discussion will include a comparison of relevant samples collected as part of previous surveys. Macroinfaunal and sediment data will be used to evaluate the suitability of the sediment placement areas for feeding habitat for the Gulf sturgeon and shorebirds. Potential prey species will be identified and an interpretive report prepared to describe potential use of the study area by Gulf sturgeon and shorebirds. The physical parameters collected during the sampling and habitat characterization may also be correlated with benthic prey composition in order to determine favorable Gulf sturgeon and shorebird habitat.

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## 3 BIOLOGICAL

### *vi. Submerged Aquatic Vegetation*

Submerged aquatic vegetation (SAV) data will be collected through aerial surveys to map coverage and *in-situ* ground condition assessments for examining health and vigor. Orthophotography, and, when possible, coincident topobathymetric lidar will be produced for the mapping component. The orthorectification process will use the digital aerial imagery, ground control/aerotrangulation, and a digital elevation model (DEM). The DMC will utilize a minimum of four panchromatic and one each red, blue, green and near infrared bands, controlled with airborne Global Positioning System (GPS). Three dimensional position and rotation will be determined for each exposure. A 1-meter native pixel resolution is required for the entire study area. Digital orthophotos will produced as individual rectified images and will be projected to the North American Datum of 1983, Universal Transverse Mercator (UTM) Zone Number 16 North. Aerial imagery will cover the barrier island system: Cat Island, East Ship Island, West Ship Island, Horn Island and Petit Bois Island.

SAV boundaries from the orthoimagery will be digitally delineated with a minimum mapping unit of 0.03 hectares. Polygons will be assessed for vegetation density and categorized as continuous (>50% coverage), or patchy (<50% coverage). Field surveys will be conducted within two months of acquisition to verify photographic signatures, with data collected at a minimum of 15 locations on the north side of Ship Island.

SAV condition assessments will be conducted in mid to late summer during peak seagrass standing crop, in conjunction with GUIS surveys for a period of up to nine years. Fixed stations established under the NPS GUIS surveys will be sampled as well as new fixed stations established north of Camille Cut. Four replicate $0.25m^2$ quadrat samples will be taken per station, using an underwater digital camera (or through direct observation in shallow waters), and by visually estimating seagrass cover and canopy height, maximum leaf length of each shoot, and overall canopy height based on 80% of leaf material. If water visibility is poor, one 15.2 cm inner diameter core to a depth of 15 cm will be taken at each sampling station. Information on water depth, transparency, water temperature, salinity dissolved oxygen, and photosynthetically active radiation (PAR) will also be collected at each station.

SAV aerial survey mapping and ground condition assessment data will be made available within 12 months of surveys. A report will be prepared which compares SAV coverage extent, health, and vigor with existing background data to document observed changes following closure of Camille Cut and restoration of the Cat Island component.

# APPENDIX D - MONITORING PROCEDURES

The following monitoring procedures will provide information necessary to evaluate project objectives for the MsCIP Barrier Island Restoration project. This plan proposes and builds upon existing data to establish a detailed baseline condition. This monitoring will continue during and post-construction to evaluate short-term and long-term response to the proposed restoration. These procedures will be updated as required to provide the necessary information to evaluate project success and inform the adaptive management program.

## 4 CULTURAL

The RECENTPAST Geographic Information Systems (GIS) tool is being developed by the Cultural Resources staff of the Planning and Environmental Inland Environment Team as part of management and compliance for the Cultural Resources Program at the USACE Mobile District. This tool was developed to evaluate the cultural resources objectives applicable to management of archaeological sites within the Mobile District and aid in compliance responsibilities under Section 106 of the National Historic Preservation Act.

The purpose of this tool is the creation of a real-time remote accessed map showing culturally sensitive areas and the effects of USACE Mobile water and land management practices. Additionally, email alerts can be configured to notify USACE Mobile District Archaeologists when factors of negative site impacts are present. Erosion data will be tracked by lidar analysis, and archaeological site boundaries monitored for the potential impacts of the restoration on cultural resources. The USACE Geo-portal website is the portal for real-time end user view. Furthermore, this sensitive information can be restricted and permission accessed as needed.

Monitoring will ensure that all previously identified eligible, or potentially cultural resources are avoided. Additionally, a monitor trained in recognizing cultural material that may be inadvertently discovered during construction will identify such material so that the material/site can be evaluated before construction resumes in order to prevent further destruction to the cultural resource. Continued post-construction monitoring by NPS archaeologists will assess erosion to sites. Datum stakes will be placed around cultural resources to monitor vertical and horizontal movement of placed material as lidar and aerial photography is made available. National Park Service (NPS) archaeologists will continue to monitor post-construction erosion around cultural resources.

# Appendix E. Data Management Plan

VERSION 1.8

June 1, 2018

# APPENDIX E-DATA MANAGEMENT PLAN-1

PRESENTED BY:

U. S. Army Corps of Engineers, Mobile District, Operations
Division, Spatial Data Branch

U. S. Geological Survey, Wetland and Aquatic Research Center, Advanced Applications Team

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# 1 PROGRAM OVERVIEW

The US Army Corps of Engineers, Mobile District (USACE), intends to restore the Mississippi Barrier Islands as part of the Mississippi Coastal Improvements Program (MsCIP) Comprehensive Plan, which was authorized by Congress in the Department of Defense Appropriations Act, 2006 (Public Law 109-359) 30 December 2005. The restoration of the Mississippi Barrier islands and ecosystem restoration components of the MsCIP were authorized and funded in Public Law 111-32 in June 2009.

The Comprehensive Barrier Island Restoration Plan contains detailed supporting data and technical information on the various options proposed to meet the goals of the MsCIP Comprehensive Plan. Coordination with the National Park Service (NPS) which has ownership of most of the islands, as well as other involved agencies has resulted in a plan that will provide continuing existence for the islands. The plan includes direct sand placement in the breach of Ship Island with plantings of dune grasses, additional sand placement along the southern shoreline of East Ship Island, changes in the dredged material placement practices for the Pascagoula Federal Navigation Channel, restoration of the northern shoreline of West Ship Island, and restoration of the eastern shoreline of Cat Island. The program also has the potential to make beneficial use of dredged material that has been deposited in both inland and offshore areas if quality objectives are clearly demonstrated.

In light of the fact that restoration of the Mississippi barrier islands is a large-scale project that may influence regional conditions, a monitoring program was proposed to be implemented before, during, and after construction. Such monitoring during and following the implementation of barrier island restoration actions will allow the USACE to assess the progress of restoration and both short- and long-term impacts to the barrier island system, including natural and cultural resources. **Data** collected as a part of this monitoring program will allow the success of this restoration effort to be evaluated, and will be used to provide the necessary information for guiding Adaptive Management (AM) and future decision-making, as well as providing the NPS with information they can use to better manage their coastal resources.

# 2 DATA MANAGEMENT PLAN REVISIONS

This Data Management Plan is a dynamic document that will be updated as needed. Table 1 provides a history regarding modifications and/or additions to the plan.

| Date | Version | Comments |
|---|---|---|
| **05/3/18** | 1.8 | Updated Turtle appendix |
| **09/25/17** | 1.7 | Updated delivered Monitoring Data |
| **09/29/16** | 1.6 | Added appendix: Habitat Mapping |
| **12/28/15** | 1.5 | Added data inventory entries |
| **02/20/15** | 1.4 | Added appendices: Turtles, Birds 2015 |
| **01/21/15** | 1.3 | Added appendix: Shoreline |
| **10/24/14** | 1.2 | Added appendices: ADCP, SAV, Borrow Area |
| **06/19/14** | 1.1 | Added appendix: Benthic |
| **10/22/13** | 1.0 | Initial Draft |

**TABLE 1.** DATA MANAGEMENT PLAN REVISIONS

# 3 DATA MANAGEMENT PLAN OVERVIEW

## 3.1 DATA MANAGEMENT PLAN PURPOSE

The MsCIP barrier island restoration project will contain an extensive monitoring and adaptive management program producing a large amount of varying types of data as well as utilizing legacy data for analysis purposes. This document outlines a plan for the lifecycle of data types included in this project. This plan also promotes standardized approaches to data acquisition, submission, and dissemination. This document will also serve as a record of what data has been collected and archived as part of the barrier island restoration effort. Standards developed during this effort may also be leveraged to manage data acquired for future MsCIP projects.

## 3.2 MONITORING AND ADAPTIVE MANAGEMENT (MAM) PLAN GUIDANCE

The MsCIP Monitoring and Adaptive Management (MAM) plan will outline the types of data to be monitored before, during, and after construction needed to produce a beneficial monitoring program or network. Additionally, the MAM plan will provide details describing desired locations and frequency of data collection for each named data type. This Data Management Plan (DMP) was developed in conjunction with the MAM plan; all data types within the MAM Plan will be covered by this DMP. The level of detail in this DMP is based on currently available data and information developed during MAM planning to date. Once monitoring data types are outlined and finalized within the MAM Plan and the data type does not appear within this DMP, a new version of the DMP containing the new data type as an appendix will be created and released.

## 3.3 DATA MANAGEMENT PLAN STRUCTURE

Over-arching data management details are described within the main sections of this plan. Data-specific details for each type of data being collected as part of the MsCIP barrier island restoration effort are located in the corresponding appendix for that data type. Information including data format attributes, delivery method, storage, and visualization details will be outlined within the corresponding data appendix.

Data-specific appendices have been developed for the following data types to date:

- Appendix A ……………………………………………… Shorebirds 2013
- Appendix B ……………………………………………… Gulf Sturgeon
- Appendix C ……………………………………………… Benthic
- Appendix D ……………………………………………..…. ADCP
- Appendix E ……………………………………………… SAV
- Appendix F ……………………………………………… Borrow Area
- Appendix G …………………………………………...... Shoreline
- Appendix H …………………………………………….. Turtles
- Appendix I ……………………………………….…….…. Shorebirds 2015

## 3.4 AUDIENCE

The intended audiences of this Data Management Plan are:

- MsCIP Program Management
- MsCIP Project Team
- All people involved in data collection for the MsCIP program
- All stakeholders and cooperators utilizing MsCIP collected data
- Public

## 3.5 DATA MANAGEMENT COORDINATION

Coordination and open communication is key to a successful Data Management Plan. A partnership between USACE Mobile District and US Geological Survey (USGS) has been established to create the MsCIP data management team. For each defined data type to be monitored and managed within the MsCIP project, the data management team will require a data type point of contact (POC) to be named by the MsCIP Program Management Team with guidance from the MsCIP Technical Advisory Group. The data management team will reach out to the named POC and present a series of questions to answer regarding their specific data being collected/analyzed. Working with the POC and/or actual data collectors, data format and submission will be decided and documented within the appendices of this data management plan.

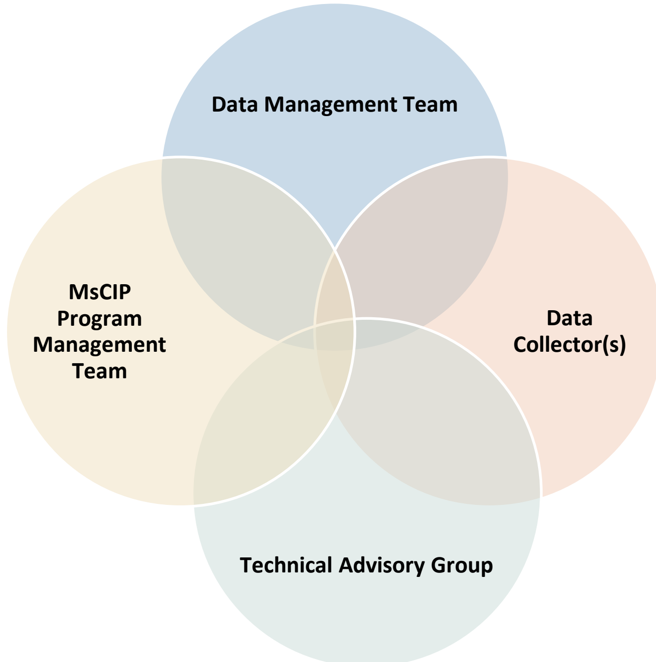


**FIGURE 1.** DATA MANAGEMENT COORDINATION

# 4 DATA TYPES COVERED BY THIS PLAN

## 4.1 DATA TYPE SUMMARY

The MsCIP effort will produce an abundant amount of data of varied data types. Example data products that will be managed include:

- Original monitoring data consisting of temporal observations
  - Field data sheets
- Verified monitoring data converted to tabular format
  - Electronic data sheets
  - Databases
- Analyzed data products
  - Summarized data/reports
  - Statistical result data/reports
- Documentation
  - Metadata
  - Data collection protocols
- GIS Data (Baseline/Supplemental Data)
  - Bathymetry
  - Lidar
  - Side scan sonar
  - Aerial photography
  - Location data (point/polygon)
  - Attribute data

### 4.2 DATA TYPE CATEGORIES (GROUPS)

The following list provides anticipated baseline and monitoring data types to be collected by the MsCIP barrier island restoration project. Once a determination has been made regarding a new data type to be monitored, an appendix for that data type will be added to this plan.

- Physical
  - Aerial Imagery (AI)
  - Survey data (SD)
    - Bathymetry
    - Lidar
    - Topography
- Hydrological
  - Waves (WS)
  - Water quality (WQ)
- Biological
  - Threatened and endangered species (TES)
    - Gulf sturgeon
    - Shorebirds
      - Piping Plover
      - Red Knot
  - Habitat Composition (HC)
  - Sea turtles (ST)
  - Nesting shorebirds (NS)
  - Benthic and Infaunal species (BT)
  - Submerged Aquatic Vegetation (SAV)
- Chemical
  - Oil (present/not present)
- Analysis
  - Landscape Change (LC)

## 5 DATA SUBMISSION STANDARDS

The Data Management Team will work with the various data collectors regarding data submission, which may vary by data type. By following the submission standards, the data being submitted will integrate seamlessly into the appropriate database. The particular data submission method along with data format used will be documented in the corresponding data appendix.

## 6 DATA STORAGE AND PROTECTION

All electronic data submitted following the data-specific guidelines presented in the data appendices will be stored on a USACE data server.

This section lists data storage and protection details:

All Spatial data must be collected in the SDSFIE 3.1 (*http://www.sdsfieonline.org/default.aspx*) data standards; previously collected data will be converted to the SDSFIE 3.1 data standard by the

Spatial Data Branch. The Spatial Data Branch is responsible for providing an SDSFIE 3.1 data schema for future collections and contracting for specific datasets.

MsCIP Program Management will request permission for the USACE, Mobile District Spatial Data Branch to load data to the USACE Enterprise database which also provides a public access point to the data. Collected data will be given to the Spatial Data Branch for uploading.

Users requesting access to password-protected data must complete an iPass request form. An iPass template form will be provided to the MsCIP Program Management Team to give to users requesting access to the password-protected site. Completed iPass forms will be submitted to the Army Corps of Engineers Information Technology (ACE-IT) group by the MsCIP Program Management Team.

A full backup of the USACE database is performed every Sunday, and incremental backups are performed every other day. Backups can also restore to a specific date/time. All backups are saved to disk and taken off site.

Data housed in the local SDE geodatabase will be replicated to the USACE Enterprise database to ensure up-to-date data.

# 7 DATA DOCUMENTATION

## 7.1 METADATA

If data is to maintain a long-term value, certain information about the data must be consistently documented. All data submitted by data collectors must have metadata delivered with it. It is the responsibility of the data collector to create the metadata for their submitted data. It is recommended that data collectors follow the ISO Metadata Standard 19115 (www.iso.org) when creating metadata.

# 8 DATA SHARING

## 8.1 DATA AVAILABILITY

The intent of the Data Management Team is to disseminate all data collected and delivered under the MAM plan. The MsCIP Program Management Team will inform the data management team regarding access levels of collected/delivered data since not all data types will have the same access. Data with access restrictions will be made available through a password protected interface. Data with no access restrictions will be made available through the MsCIP public web interface (TBD).

## 8.2 DATA SHARING PROTOCOLS

When data is loaded into the USACE Enterprise database, an ArcGIS rest service is created to allow users to download data. A MsCIP site will be created to host all MsCIP services. The services available to each user will be based on his/her profile.

## 8.3 DATA VISUALIZATION

The Data Management Team will work with the Program Management Team and Technical Advisory Group to design applicable visualization tools. Some tools may be used to gauge project progress, such as if restoration success has been achieved or if adaptive management needs to be implemented to adjust project performance. Discussions will occur regarding applicable datasets (baseline and/or monitoring) the tools should target, as well as identifying the potential analysis operations that can be incorporated in tool development.

Overall, each data type will have a visualization component integrated within the data management visualization platform offering temporal and spatial information where applicable. The data management team will document the visualization strategy for each data type within the corresponding data appendix. A private and a public interface will be designed and implemented to comply with potential data access restrictions. Through the private password-protected interface, all data (i.e. locations and observational data) will be made available to the project team and those specific users defined by the MsCIP program management team. Based on guidance provided by the project team, summarized and/or partially obfuscated data where applicable will be made available through the MsCIP public interface, along with all public data.

# 9 DATA MANAGEMENT POINTS OF CONTACT

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# 10 APPENDIX A: BIRD MONITORING DATA (2013)

## 10.1 BIRD MONITORING ATTRIBUTES (2013)

MsCIP is to monitor certain bird species pre, post, and during the barrier island restoration construction. The table within this section gives the attributes expected to be recorded by any data collector. These attributes will be uploaded into the databases discussed in Section 6.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| SPECIES | Text | 200 | Species name observed |
| LOCATION | Text | 150 | Descriptive location (i.e. West Ship Island) |
| DATE_ | Date | mm/dd/yyyy | Observation date |
| BIRDS | Double | | Number of birds observed |
| TIDE | Text | 50 | Low, Mid, or High Tide |
| WEATHER | Text | 100 | General weather description (i.e. Sunny) |
| TEMPERATUR | Text | 50 | General temperature description (i.e. Cool) |
| WIND | Text | 50 | General wind description (i.e. Low, Moderate, High) |
| HABITAT | Text | 150 | General habitat description (i.e. Sand Beach, Lagoon) |
| SIDE | Text | 50 | Side of island (i.e. Gulf Side, Bay Side) |
| VEGETATION | Text | 50 | General vegetation density description (i.e. Sparse) |
| SUBSTATE | Text | 50 | (i.e. Mud/Sand) |
| BEHAVIOR | Text | 200 | General bird behavior (i.e. Walking, Foraging, Roosting) |
| NESTS | Double | | Number of observed nests |
| DISTURBANC | Text | 250 | Activities occurring nearby (i.e. BP Survey, planting…) |
| COMMENTS | Text | 250 | Species name when type "Other" is selected |
| OBSERVERS | Text | 200 | First and Last name of observer |
| TRANSPORAT | Text | 50 | Transportation being used when observing (i.e. Foot) |
| DOCUMENTS | Text | 250 | Pictures taken with GPS at time of data capture or additional links to documentation. |
| COLOR_BAND | Text | 250 | Description of any bands on bird if present |

**TABLE 2.** BIRD MONITORING DATA ATTRIBUTES

## 10.2 BIRD MONITORING DATA DELIVERY PROCESS

Mobile District has implemented an upload solution for bird related data built upon ArcGIS Mobile. The data collector will be provided with a handheld Global Positioning System (GPS) containing the aforementioned software and will be required to enter and sync the data to Mobile District where the data will be archived. All attributes shown in Table 2 will be included in submitted data.

## 10.3 BIRD MONITORING DATA STORAGE

The data collector will use a GPS with ArcGIS Mobile installed. When a data collector syncs the observation data, the data is ingested into the Spatial Data Branch SDE geodatabase. From there the data will be replicated up to USACE Enterprise database for visualization. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 10.4 BIRD MONITORING DATA VISUALIZATION/DESSIMINATION

All bird data including locations and attributes will be available through the password-protected private interface. Locations will be viewable within the web map along with the attributes from that particular data observation. Due to the threatened and endangered nature of the particular bird species being monitored, obfuscated bird data may be available within the public interface giving total number of birds seen during a time range, but not bird siting locations.

# 11 APPENDIX B: GULF STURGEON MONITORING DATA

## 11.1 GULF STURGEON MONITORING ATTRIBUTES

MsCIP is to monitor Gulf sturgeon pre, post, and during the barrier island restoration construction. The monitoring started in 2011 and is to continue through construction and for a number of years (TBD) post-construction.

Table 3 contains attribute details for Gulf Sturgeon tags detected within the telemetry array over the course of the study period to date.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| RIVER | Text | 25 | River where fish was tagged |
| TRANSMITTER | Text | 25 | Uniquely coded acoustic tag |
| DATE_TAGGED | Text | mm/dd/yyyy | Date tag placed |
| SIZE_CLASS | Text | 5 | Size class at tagging |
| FORK_LENGTH | Double | | Fork length at tagging (cm) |
| WEIGHT | Double | | Weight at tagging (Kg) |

**TABLE 3.** GULF STURGEON TAG LIST ATTRIBUTES

Table 4 contains attribute details for the location of deployed stations/receivers.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| STATION_NAME | Text | 25 | The name of each VR2W location, corresponds to the station name found in the data tabs |
| LATITUDE | Double | | The GPS coordinate recorded for each station, in WGS 1984 Datum |
| LONGITUDE | Double | | The GPS coordinate recorded for each station, in WGS 1984 Datum |

**TABLE 4.** GULF STURGEON STATION LOCATION ATTRIBUTES

Table 5 contains attribute details for monitoring data collected.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| DATE_TIME_UTC | Date | mm/dd/yy hh:mm:ss | Date and time of each tag relocation, recorded in UTC time |
| DATE_TIME_LOCAL | Date | mm/dd/yy hh:mm:ss | Date and time of each tag relocation, corrected for local CST & CDT time |

| | | | |
|---|---|---|---|
| RECEIVER | Text | 25 | The serial number for each VR2W |
| TRANSMITTER | Text | 25 | Uniquely coded acoustic tag of Gulf sturgeon detected on the array |
| STATION_NAME | Text | 25 | The name of each station in the array. |
| LATITUDE | Double | | The GPS coordinate recorded for each station, in WGS 1984 Datum |
| LONGITUDE | Double | | The GPS coordinate recorded for each station, in WGS 1984 Datum |

**TABLE 5.** GULF STURGEON DATA ATTRIBUTES

## 11.2 GULF STURGEON MONITORING DATA DELIVERY PROCESS

The data collector will deliver data-corrected Gulf sturgeon monitoring data to the MsCIP data management team by electronic data files in Microsoft Excel format. The data is to be organized based on the attribute information given in the tables above.

## 11.3 GULF STURGEON MONITORING DATA STORAGE

The Gulf sturgeon data will be converted into SDSFIE 3.1 data standards by the Spatial Data Branch and replicated up to USACE Enterprise database for visualization. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 11.4 GULF STURGEON MONITORING DATA VISUALIZATION/DESSIMINATION

Gulf sturgeon data will be available through the password-protected MsCIP private web interface. Receiver locations by year will be viewable within the web map along with aggregated details of the actual monitoring data. The data will be password-protected until given further notice by the data collector and the Program Management Team.

# 12 APPENDIX C: BENTHIC MONITORING DATA

## 12.1 BENTHIC MONITORING ATTRIBUTES

Benthic community surveys will be collected in the spring and summer before and one year after project construction. Sampling will be conducted at Gulf sturgeon and shorebird feeding sites previously surveyed in 2010 and 2011, and potential new locations where feeding would occur after closure of Camille Cut. Sediment texture will also be determined at each location where benthic macroinfaunal samples are collected. Hydrographic measurements will also be taken at each sampling location.

The tables below outline the necessary attributes from benthic monitoring.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| STATION | Text | 25 | Name/ID of benthic station |
| LATITUDE | Double | | The GPS coordinate (decimal degrees) recorded for each station, in WGS 1984 Datum |
| LONGITUDE | Double | | The GPS coordinate (decimal degrees) recorded for each station, in WGS 1984 Datum |

**TABLE 6.** BENTHIC STATION LOCATION ATTRIBUTES

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| STATION | Text | 25 | Name/ID of benthic station |
| TAXA | Text | 50 | Macroinfaunal taxonomic group name |
| TOTALNOTAXA | Double | | Total number of corresponding taxa at station |
| TOTALTAXA% | Double | | Taxa percentage |
| TOTALNOINDIV | Double | | Total number of individuals within taxa at station |
| TOTALNOINDIV% | Double | | Total number of individuals percentage |
| DATE_ | Date | mm/dd/yyyy | Observation Date/Datetime |

**TABLE 7.** BENTHIC ABUNDANCE AND DIVERSITY SUMMARY ATTRIBUTES

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| STATION | Text | 25 | Name/ID of benthic station |
| DEPTHDESC | Text | 50 | Bottom, Mid-Depth, Surface |
| DATE_ | Date | mm/dd/yyyy | Observation Date/Datetime |

| | | | |
|---|---|---|---|
| DEPTH | Double | | Depth (ft) |
| TEMP | Double | | Temperature (C) |
| SPCOND | Double | | Specific Conductance (mS/cm) |
| SALINITY | Double | | Salinity (ppt) |
| PH | Double | | pH |
| ODO% | Double | | Dissolved Oxygen (%) |
| ODOCONC | Double | | Dissolved Oxygen Concentration (mg/L) |

**TABLE 8.** WATER QUALITY ATTRIBUTES (SAMPLES AT BENTHIC STATIONS)

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| STATION | Text | 25 | Name/ID of benthic station |
| DATE_ | Date | mm/dd/yyyy | Observation Date/Datetime |
| GRAVEL% | Double | | Gravel percentage |
| SAND% | Double | | Sand percentage |
| SILT% | Double | | Silt percentage |
| CLAY% | Double | | Clay percentage |
| SILTCLAY% | Double | | Silt + Clay percentage |
| TOC% | Double | | Total Organic Carbon percentage |

**TABLE 9.** SEDIMENT ATTRIBUTES (SAMPLES AT BENTHIC STATIONS)

## 12.2 BENTHIC MONITORING DATA DELIVERY PROCESS

The data collector will deliver benthic data to the MsCIP data management team by electronic data files in Microsoft Excel format. A sample data file can be provided. The data is to be organized based on the attribute information given in the tables above. Additional data files, giving more detailed benthic information (additional taxa break-down, mean number of taxa, abundance, density, total taxa, total individuals, diversity, and evenness) is also still to be delivered in Excel, but does not need to adhere to a specified format.

## 12.3 BENTHIC MONITORING DATA STORAGE

The benthic data will be converted into SDSFIE 3.1 data standards by the Spatial Data Branch and replicated up to USACE Enterprise database for visualization. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 12.4 BENTHIC MONITORING DATA VISUALIZATION/DESSIMINATION

The benthic data attributes given in the tables above, as well as the sediment and hydrological measurements taken at the benthic stations, will be available through the MsCIP web mapping interface. Any additional data files giving additional diversity and/or abundance information may be available through download links.

# 13 APPENDIX D: ACOUSTIC DOPPLER CURRENT PROFILER (ADCP) DATA

## 13.1 ADCP DATA FILES AND ATTRIBUTES

To document changes and assess whether closure of Camille Cut impacts overall circulation in the sound adjacent to the islands, Acoustic Doppler Current Profiler (ADCP) transect data will be collected at each pass.

The data collector will deliver multiple files in regards to ADCP data. For each ADCP dataset the data collector will deliver the raw WinRiver™ binary file, WinRiver™ classic Ascii-out file, and the ERDC. GIS file format to the MsCIP data management team. Associated metadata should also be delivered along with each dataset specifying projection, units, and reference information.

Delivered binary files may consist of the following:

| | |
|---|---|
| ***r.000 | WinRiver™ raw binary data file |
| ***n.000 | WinRiver™ navigation file |
| ***h.000 | WinRiver™ header file |

**Table 10.** WinRiver™ Binary Files

Delivered ascii files may consist of the following:

| | |
|---|---|
| ***t.000 | WinRiver™ 1 older text file format |
| ***_ASC.TXT | WinRiver™ 2 ascii-out file |
| ***.GIS | Cleaned up Ascii Text (***t.000 or ***_ASC.TXT) File |

**Table 11.** Ascii Files

An example WinRiver™ II Classic Ascii-out file appears below.

```
This is WinRiver II comment line #1
This is WinRiver II comment line #2
    50      25      40     124       1       9       1
11 6 21 13 15 9 62  1961       1     2.700    -3.700   313.120    28.740
-0.86     1.50     0.00     0.00      0.00     25.69      0.82      9.10     30.71
40.38    38.71    32.05
6.72          3.89          5.82         -3.36          6.72
29.99097562   -90.42193135    -0.86      1.50           6.7
212.6           32.9           64.7           0.0           75.0           0.0
75.0  4.07  25.39
124 ft GGA dB 0.42  0.065
  4.07      0.55    342.82    -0.2     0.5     1.3    -0.6    89.5    90.7    89.9
95.8  100       1.36
  5.71      1.46    149.66     0.7    -1.3     0.0     0.4    90.8    89.5    88.3
92.5  100       0.09
  7.35      0.95     91.13     0.9    -0.0     0.3    -0.2    92.2    88.8    88.0
89.7  100       8.92
  8.99      1.30    127.79     1.0    -0.8     0.0    -0.1    89.6    90.1    88.8
88.0  100       5.41
 10.63      2.61     71.05     2.5     0.8     0.4     0.7    86.7    88.0    87.6
88.0  100      28.27
```

**FIGURE 2.** EXAMPLE WINRIVER CLASSIC ASCII-OUT FILE

The above Ascii-out file values are described in detail below (extracted from the WinRiver™ II User Guide).

## Classic ASCII Output Format

**Each time *WinRiver II* opens a new ASCII-out data file, it first writes the following three lines.**

| Row | Field | Description |
|---|---|---|
| A | 1 | NOTE 1 – You can enter these lines by right-clicking **Transect** and selecting **Add Note** (see Add Note). |
| B | 1 | NOTE 2 – You can enter these lines by right-clicking **Transect** and selecting **Add Note** (see Add Note). |
| C | 1 | DEPTH CELL LENGTH (cm) |
| | 2 | BLANK AFTER TRANSMIT (cm) |
| | 3 | ADCP DEPTH FROM CONFIGURATION NODE (cm) |
| | 4 | NUMBER OF DEPTH CELLS |
| | 5 | NUMBER OF PINGS PER ENSEMBLE |
| | 6 | TIME PER ENSEMBLE (hundredths of seconds) |
| | 7 | PROFILING MODE |

Whenever *WinRiver II* displays a new data segment (a raw or averaged data ensemble), it writes the following data to the ASCII-out file. The first six rows contain leader, scaling, navigation, and discharge information. Starting with row seven, *WinRiver II* writes information in columns based on the bin depth. When *WinRiver II* writes the information for all bins in the current ensemble, it goes to the next ensemble and repeats the cycle starting with row one. Fields are separated by one or more spaces. *WinRiver II* does not split ensembles between files. The file size automatically increases to fit at least one ensemble. Missing data (data not sent from ADCP) are not included (no dashes or fill values). "Bad data" values: velocity (−32768); discharge (2147483647); Latitude/Longitude (30000).

| Row | Field | Description |
|---|---|---|
| 1 | 1 | ENSEMBLE TIME -Year (at start of ensemble) |
| | 2 | - Month |
| | 3 | - Day |
| | 4 | - Hour |
| | 5 | - Minute |
| | 6 | - Second |
| | 7 | - Hundredths of seconds |
| | 8 | ENSEMBLE NUMBER (or SEGMENT NUMBER for processed or averaged raw data) |
| | 9 | NUMBER OF ENSEMBLES IN SEGMENT (if averaging ON or processing data) |
| | 10 | PITCH - Average for this ensemble (degrees) |
| | 11 | ROLL - Average for this ensemble (degrees) |
| | 12 | **CORRECTED HEADING** - Average ADCP heading (corrected for one cycle error) + heading offset + magnetic variation |
| | 13 | ADCP TEMPERATURE - Average for this ensemble (°C) |
| 2 | 1 | **BOTTOM-TRACK VELOCITY** - East(+)/West(-); average for this ensemble (cm/s or ft/s) |
| | 2 | Reference = BTM - North(+)/South(-) |
| | 3 | - Vertical (up[+]/down[-]) |
| | 4 | - Error |
| 2 | 1 | **BOTTOM-TRACK VELOCITY** - GPS (GGA or VTG) Velocity (calculated from GGA String) Reference = GGA East(+)/West (-1) |
| | 2 | Reference = VTG - GPS (GGA or VTG) North(+)/South(-) Velocity |
| | 3 | - BT (up[+]/down[-]) Velocity |
| | 4 | - BT Error |
| | 5 | **GPS/DEPTH SOUNDER** - corrected bottom depth from depth sounder (m or ft) as set by user (negative value if DBT value is invalid) |
| | 6 | - GGA altitude (m or ft) |
| | 7 | - GGA Δaltitude (max - min, in m or ft) |
| | 8 | - GGA HDOP x 10 + # satellites/100 (negative value if invalid for ensemble) |
| | 9 | **DEPTH READING** - Beam 1 average for this ensemble (m or ft, as set by user) |
| | 10 | (Use River Depth - Beam 2 |
| | 11 | = Bottom Track) - Beam 3 |
| | 12 | - Beam 4 |
| | 9 | **DEPTH READING** - Depth Sounder depth |
| | 10 | (River Depth - Depth Sounder depth |
| | 11 | = Depth Sounder) - Depth Sounder depth |
| | 12 | - Depth Sounder depth |
| | 9 | **DEPTH READING** - Vertical Beam depth |
| | 10 | (River Depth - Vertical Beam depth |
| | 11 | = Vertical Beam) - Vertical Beam depth |
| | 12 | - Vertical Beam depth |

**FIGURE 3.** WINRIVER™ CLASSIC ASCII-OUT FILE FORMAT

The .GIS file is created from custom software. It creates a "cleaned up" version of the WinRiver™ classic Ascii-out file. A subset of a .GIS file (one row of data) appears below.

```
11  6  21  13  15  9  62  3569344.194031  543357.940803  4.070000  0.550000  342.820000
-0.200000  0.500000  1.300000  -0.600000  89.500000  90.700000  89.900000  95.800000
```

**FIGURE 4.** EXAMPLE .GIS FILE

The above example .GIS file values are described in detail below.

1. Year
2. Month
3. Day
4. Hour
5. Min
6. Sec
7. Hundredth sec
8. State plane X
9. State plane Y
10. Depth (z) from water surface
11. Velocity Magnitude
12. Velocity Direction
13. East Velocity Component - East (+)/West(-)
14. North Velocity Component - North(+)/South(-)
15. Vertical Velocity Component - Up(+)/Down(-)
16. Error velocity
17. Backscatter beam 1
18. Backscatter beam 2
19. Backscatter beam 3
20. Backscatter beam 4

**FIGURE 5.** .GIS ASCII FILE FORMAT

## 13.2 ADCP DATA DELIVERY PROCESS

The ADCP data collection team will upload their data to their own project web site (TBD) as the SOW states, and a notification will be sent to the MsCIP program management team that the data is now available. The data will be downloaded by the MsCIP data management team to be catalogued, processed, stored, and visualized.

## 13.3 ADCP DATA STORAGE

The ADCP transect and observational point data will be converted into SDSFIE 3.1 data standards by the Spatial Data Branch and replicated up to USACE Enterprise database for visualization. The data and attributes will be hosted through ArcGIS rest services for consumption.

## 13.4 ADCP DATA VISUALIZATION/DESSIMINATION

The ADCP data contains two separate visualization components - the transect data (line) and the individual observational point data (point) that can be displayed at a specified zoom level on the web map. The observational point data contains velocity observations at varying depths of the water column. These values can be plotted dynamically in a line or bar chart displaying on mouse-click of an observational point.

# 14 APPENDIX E: SUBMERGED AQUATIC VEGETATION (SAV) DATA

## 14.1 SAV MONITORING ATTRIBUTES

Submerged aquatic vegetation (SAV) data will be collected through both aerial surveys to map extent and ground-condition assessments to examine health and vigor.

The table below outlines the SAV polygon monitoring attributes.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| SPECIES | Text | 20 | Species type code (hw = Shoal grass (*Halodule wrightii*)) |
| HABITAT | Text | 20 | SAV density (i.e. Patchy/Continuous *) |
| PERIMETER | Double | | Perimeter measurement of SAV polygon feature |
| AREA | Double | | Area measurement of SAV polygon feature |
| ACRES | Double | | Acres within SAV polygon feature |
| ISLAND | Text | 20 | Nearest island where SAV polygon is located (W Ship, Cat, Horn, Petit Bois) |

**TABLE 12.** SAV MONITORING ATTRIBUTES

* Patchy: <50% coverage; Continuous: >50% coverage

## 14.2 SAV MONITORING DATA DELIVERY PROCESS

The data collector will deliver SAV data to the MsCIP data management team by electronic data files in ArcGIS shapefile format. The shapefile should contain a polygon feature class containing the SAV determined areas/boundaries near the islands. The data is to be attributed based on the information given in the table above.

## 14.3 SAV MONITORING DATA STORAGE

The SAV data will be converted into SDSFIE 3.1 data standards by the Spatial Data Branch and replicated up to USACE Enterprise database for visualization. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 14.4 SAV MONITORING DATA VISUALIZATION/DESSIMINATION

The SAV polygon and attribute data given in the table above will be available through the MsCIP web mapping interface.

# 15 APPENDIX F: BORROW AREA DATA

## 15.1 BORROW AREA MONITORING ATTRIBUTES

The borrow area dataset designates where the approved material will be obtained for use in the closing of Camille Cut.

The table below outlines the borrow area polygon attributes.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| DREDGE DEPTH | Double | | Borrow dredge depth |
| ELEV_U_D | Text | 16 | Borrow dredge depth units |
| NAME | Text | 30 | Borrow Site Name |
| NARRATIVE | Text | 240 | General description of the borrow area |
| SUBTYPE_ID | Small Int | | Type of borrow area (1 = Open Water Borrow Area) |
| LOCATION | Text | 20 | Nearest island where borrow is located (Ship Island, Cat Island, Horn Island, Petit Bois Island) |

**TABLE 13.** BORROW AREA ATTRIBUTES

## 15.2 BORROW AREA DATA DELIVERY PROCESS

The data collector will deliver borrow area data to the MsCIP data management team by electronic data files in ArcGIS shapefile format. The shapefile should contain a polygon feature class containing the determined borrow areas/boundaries. The data is to be attributed based on the information given in the table above.

## 15.3 BORROW AREA DATA STORAGE

The borrow area data will be converted into SDSFIE 3.1 data standards by the Spatial Data Branch and replicated up to USACE Enterprise database for visualization. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 15.4 BORROW AREA DATA VISUALIZATION/DESSIMINATION

The borrow area polygon and attribute data given in the table above will be available through the MsCIP web mapping interface.

# 16 APPENDIX G: SHORELINE DATA

## 16.1 SHORELINE DATA ATTRIBUTES

The shoreline is the boundary where land meets the edge of a large body of fresh or salt water. The shoreline is the mean high water line between high and low tide.

Shoreline data will be collected through both aerial surveys to map extent and ground-condition assessments to examine health and vigor.

The table below outlines the shoreline line monitoring attributes.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| bankType | String | Domain (see BankType Domain Values table) | The type of bank the shoreline segment represents (correlates to a manmade shorelineType). |
| collectionDate | Date | | Date the shoreline data was collected |
| heightAboveVerticalDatum | Decimal | | The nominal height of the shoreline above the vertical datum provided by the geometry of the shoreline. |
| heightAboveVerticalDatumUOM | String | Domain (see GSIP_LengthUOM Domain Values table) | The units of measure for the like-named value. |
| sdsFeatureDescription | String(Max) | | A narrative describing the feature |
| sdsFeatureName | String | 80 | The common name of the feature |
| shorelineIDPK | String | 20 | Primary Key. A unique, user- defined identifier for each record or instance of an entity. |
| shorelineTidalDatum | String | Domain (see VerticalDatumType Domain Values table) | In general, a datum is a base elevation used as a reference from which to reckon heights or depths. A tidal datum is a standard elevation defined by a certain |

| | | | |
|---|---|---|---|
| | | | phase of the tide. Tidal datums are used as references to measure local water levels and should not be extended into areas having differing oceanographic characteristics without substantiating measurements. In order that they may be recovered when needed, such datums are referenced to fixed points known as bench marks. Tidal datums are also the basis for establishing privately owned land, state owned land, territorial sea, exclusive economic zone, and high seas boundaries. |
| shorelineType | String | Domain (see ShorelineType Domain Values table) | Indicator of the type of shoreline, natural, manmade, or unknown. |

**TABLE 14.** SHORELINE DATA ATTRIBUTES

| Value | Description |
|---|---|
| ASPHALT | Asphalt |
| CEMENTD_STONE | Cemented stones |
| CONCRETE_LINED | Concrete lined |
| DUMP_BRICK_CONC | Dumped brick and concrete |
| DUMPED_ROCK | Dumped rocks |
| FORMEDLINING | Formed channel lining |
| GABIONS | Gabions |
| PILEDIKE | Pile dike |
| PLACED_STONE | Placed stone |

| | |
|---|---|
| SAND_CEMNBGRR | Sand cement/bag riprap |
| WILLOW_MAT | Willow Mat |
| NA | Not applicable |
| OTHER | Other |
| TBD | To be determined |

**TABLE 15.** SHORELINE BANKTYPE DOMAIN VALUES

| Value | Description |
|---|---|
| astronomicUnit | A conventional unit of measurement of length equal to 1.4959787 x 10^11 meters. |
| centimetre | A conventional unit of measurement of length equal to 0.01 meters. |
| dataMile | A conventional unit of measurement of length equal to 6,000 feet (1,828.8 meters). Used in the Joint Tactical Information Distribution System (JTIDS) and Variable Message Format (VMF). |
| decafoot | A conventional unit of measurement of length equal to 10 feet (3.048 meters). |
| decakilometre | A conventional unit of measurement of length equal to 10,000.0 meters. |
| decametre | A conventional unit of measurement of length equal to 10.0 meters. |
| decifoot | A conventional unit of measurement of length equal to one tenth of a foot (0.03048 meters). |
| decimetre | A conventional unit of measurement of length equal to 0.1 meters. |
| deciNauticalMile | A conventional unit of measurement of length equal to one tenth of a nautical mile or 185.2 meters. |
| fathom | A conventional unit of measurement of length equal to 6 feet (1.8288 meters). |
| foot | A conventional unit of measurement of length equal to 0.3048 meters. |
| halfFoot | A conventional unit of measurement of length equal to one half of a foot (0.1524 meters). |
| halfHectometre | A conventional unit of measurement of length equal to 50.0 meters. |
| halfMetre | A conventional unit of measurement of length equal to 0.5 meters. |
| hectofoot | A conventional unit of measurement of length equal to 100 feet (30.48 meters). |

| | |
|---|---|
| hectokilometre | A conventional unit of measurement of length equal to 100,000.0 meters. |
| hectometre | A conventional unit of measurement of length equal to 100.0 meters |
| Inch | A conventional unit of measurement of length equal to 0.0254 meters. |
| kilofoot | A conventional unit of measurement of length equal to 1000 feet (304.8 meters). |
| kilometre | A conventional unit of measurement of length equal to 1,000.0 meters. |
| kiloyard | A conventional unit of measurement of length equal to 1000 yards (914.4 meters) |
| metre | The base unit in SI for the physical quantity length, defined as the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second. |
| micrometre | A conventional unit of measurement of length equal to 0.000001 meters. |
| millimetre | A conventional unit of measurement of length equal to 0.001 meters. |
| nanometre | A conventional unit of measurement of length equal to 0.000000001 meters. |
| nauticalMile | A conventional unit of measurement of length equal to 1,852.0 meters. |
| picometre | A conventional unit of measurement of length equal to 0.000000000001 meters. |
| statuteMile | A conventional unit of measurement of length equal to 5,280 feet (1,609.344 meters). |
| usSurveyFoot | A conventional unit of measurement of length equal to 0.3048006 meters. Set by the U.S. Coast and Geodetic Survey as exactly 1200/3937 meters. |
| usSurveyMile | A conventional unit of measurement of length equal to 5,280 U.S. Survey Feet (1,609.347 metres). |
| Yard | A conventional unit of measurement of length equal to 0.9144 meters. |
| NA | Not applicable |
| TBD | To be determined |

**TABLE 16.** SHORELINE GSIP_LENGTHUOM DOMAIN VALUES

| **Value** | **Description** |
|---|---|
| ALWP | Average Low Water Plane |

| | |
|---|---|
| DHQ | Mean Diurnal High Water Inequality - The difference in height of the two high waters of each tidal day for a mixed or semidiurnal tide. |
| DLQ | Mean Diurnal Low Water Inequality - The difference in height of the two low waters of each tidal day for a mixed or semidiurnal tide. |
| DTL | Diurnal Tide Level - The arithmetic mean of mean higher high water and mean lower low water. |
| GT | Great Diurnal Range - The difference in height between mean higher high water and mean lower low water. |
| HWI | Greenwich High Water Interval - The average interval (in hours) between the transit of the moon over the Greenwich meridian and the following high water at a location. |
| LWI | Greenwich Low Water Interval - The average interval (in hours) between the transit of the moon over the Greenwich meridian and the following low water at a location. |
| LWRP | Low Water Reference Plane 1974 |
| MHHW | Mean Higher High Water - The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. |
| MHW | Mean High Water - The average of all the high water heights observed over the National Tidal Datum Epoch. |
| MLG | Mean Low Gulf |
| MLLW | Mean Lower Low Water - The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. |
| MLW | Mean Low Water - The average of all the low water heights observed over the National Tidal Datum Epoch. |
| MN | Mean Range of Tide - The difference in height between mean high water and mean low water. |
| MSL | Mean Sea Level - The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch. Shorter series are specified in the name; e.g., monthly mean sea level and yearly mean sea level. |
| MTL | Mean Tide Level - The arithmetic mean of mean high water and mean low water. |
| NAVD_88 | North American Vertical Datum of 1988 |
| NGVD_29 | National Geodetic Vertical Datum of 1929 |
| NTDE | National Tidal Datum Epoch - The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. |

| | |
|---|---|
| SD | Station Datum - A fixed base elevation at a tide station to which all water level measurements are referred. The datum is unique to each station and is established at a lower elevation than the water is ever expected to reach. |
| NA | Not applicable |
| OTHER | Other. Must be described in the sdsFeatureDescription attribute. |
| TBD | To be determined |

**TABLE 17**. SHORELINE VERTICALDATUMTYPE DOMAIN VALUES

| Value | Description |
|---|---|
| manmade | The shoreline is manmade |
| natural | The shoreline is naturally occurring |
| NA | Not applicable |
| Other | Other. Must be described in the sdsFeatureDescription attribute. |
| TBD | To be determined |

**TABLE 18.** SHORELINE SHORELINETYPE DOMAIN VALUES

## 16.2 SHORELINE DATA DELIVERY PROCESS

The data collector will deliver shoreline data to the MsCIP data management team by electronic data files in file geodatabase format. The geodatabase should contain a line feature class containing the determined shoreline boundaries. The data is to be attributed based on the information given in the table above.

## 16.3 SHORELINE DATA STORAGE

The shoreline data will be replicated to USACE Enterprise database by the Spatial Data Branch once received. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 16.4 SHORELINE DATA VISUALIZATION/DESSIMINATION

The shoreline line and attribute data given in the table above will be available through the MsCIP web mapping interface.

# 17 APPENDIX H: TURTLE DATA

## 17.1 TURTLE DATA ATTRIBUTES

The table below outlines the turtle monitoring attributes.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| turtlePermitNo | String | 50 | Turtle Permit Holder (TP#) |
| contractNo | String | 50 | Contract Number |
| prinPermitHolder | String | 50 | Principal permit holder |
| organization | String | 50 | Data Collector Organization |
| address | String | 150 | Data Collector Address |
| telephoneDay | String | 20 | Data Collector daytime telephone # |
| telephoneNight | String | 20 | Data Collector evening telephone # |

**TABLE 19.** DATA COLLECTOR ATTRIBUTES

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| obsStartDate | DateTime | mm/dd/yyyy | Initial observation date and time |
| weather | String | 25 | Weather conditions |
| species | String | | Species type (Loggerhead, Green, Leatherback, Kemp's Ridley, Unknown) |
| incidentType | String | 25 | Incident Type (nest/false crawl) |
| incidentID | String | 25 | Turtle Nest/Crawl ID ([IslandID_mmddyy]<br>Island IDS: Cat Island = 1; Ship Island = 2; Horn Island = 3; Petit Bois Island = 4) |
| topClutch_in | Decimal | | Depth to top of clutch in inches |
| botClutch_in | Decimal | | Depth to bottom of clutch in inches |
| crawlMeasurement_in | Decimal | | Crawl Measurement (width) in inches |
| crawlDescription | Text | 20 | Crawl Description (alternating, symmetrical) |

| | | | |
|---|---|---|---|
| markers | Text | 20 | Markers around nest (signs, stakes) |
| siteDescription | String | 150 | Site Description |
| relocated | String | 20 | Is this a relocated nest? (yes, no) |
| relocatedReason | String | 150 | Reason why the nest was relocated. Value required if “relocated” attribute is yes. |
| previousNestID | String | 20 | Nest ID (incidentID) before relocation to track movement of nest. Relocated nest gets a new Nest ID. |
| clutchMeasurements_in | Decimal | | Measurements from center of body pit/egg cavity to marker signs/stakes in inches |
| clutchDeposited | String | 20 | Clutch deposited (yes, no, unknown) |
| totalClutchSize | String | | (number of eggs) |
| inventoryDate | DateTime | | Inventory date of hatchling data |
| emerged | String | 20 | Hatchlings emerged? (yes, no) |
| broken | Integer | | How many broken? |
| stakes | String | 20 | Stakes? (yes, no) |
| hatched | Integer | | Number of hatchlings |
| bufferStakes | String | 20 | Buffer stakes? (yes, no) |
| liveHatchlings | Integer | | Number of live hatchings |
| deadHatchlings | Integer | | Number of dead hatchlings |
| earlyStageMortality | String | 20 | Early stage mortality? (yes, no) |
| addled | String | 20 | Addled? (yes, no) |
| lateStageMortality | String | 20 | Late stage mortality (yes, no) |
| infertile | String | 20 | Infertile? (yes, no) |
| pippedDead | Integer | | Number of pipped dead |
| pippedLive | Integer | | Number of pipped live |
| hatchlingSuccess% | Decimal | | Hatchling Success % (number of hatched shells/total clutch size X 100) |
| emergingSuccess% | Decimal | | Emerging Success % (no. hatched shells – {live + dead hatchlings}/total clutch size) X 100) |

| | | | |
|---|---|---|---|
| eggsAffectedBy | String | 150 | Describe if nest was affected by predators or inundation |
| Notes | String | 250 | Additional notes |

**TABLE 20.** TURTLE MONITORING DATA ATTRIBUTES

### 17.2 TURTLE DATA DELIVERY PROCESS

The Data is to be collected using an iPad app that will be discussed with the data collector. Data will be collected in the field using an iPad and synced with a master database once connectivity is regained. All attributes shown in Table 20 will be included in submitted data.

### 17.3 TURTLE DATA STORAGE

When a data collector syncs the observation data, the data will be ingested into an interim protected online GIS database. The data will be regularly transferred to the USACE Spatial Data Branch where it will be uploaded into an SDE geodatabase. From there the data will be replicated up to USACE Enterprise database for visualization. The location data and attributes will be hosted through ArcGIS rest services for consumption.

### 17.4 TURTLE DATA VISUALIZATION/DESSIMINATION

The turtle monitoring given in the table above will be available through the MsCIP web mapping interface. Access restrictions to the data will be determined by the MsCIP program management team.

# 18 APPENDIX I: BIRD MONITORING DATA (2015)

## 18.1 BIRD MONITORING ATTRIBUTES (2015)

The MsCIP Data Management Team re-defined the required bird monitoring attributes to more thoroughly document the birds seen on the island and to comply with the required USACE data standard. The table within this section gives the attributes expected to be recorded by any data collector.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| birdSpeciesIDPK | Text | 20 | Primary Key. A unique, user defined identifier for each record or instance of an entity. |
| birdSpeciesXID | Integer | | Unique ID used for indexing and linking purposes. |
| sdsFeatureName | Text | 150 | Name of the observed bird species |
| sdsFeatureDescription | Text | Max | A narrative describing the feature |
| mediaIDFK | Text | 20 | Used to link the record to associated multimedia records the reference data such as imagery, video, audio, scanned documents, drawings, and other digital media. See service implementation guidance for details as to the target of this foreign key. |
| projectID | Text | Max | A foreign key reference to a project identifier used by an external business system. |
| sdsID | GUID | | A unique identifier for all features and objects in the SDSFIE |
| sdsMetadataID | Text | 80 | The foreign key to a metadata record |
| species | Text | 80 | Species of the observed bird |
| location | Text | 150 | Descriptive location (i.e. West Ship Island) |
| observationDate | Date | | Observation date |
| observationCount | Double | | Number of birds observed |
| tide | Text | 50 | Low, mid, or high tide |
| weather | Text | 100 | General weather description |
| temperature | Text | 50 | General temperature description (i.e. cool) |
| wind | Text | 50 | General wind description (i.e. Low, Moderate, High) |

| | | | |
|---|---|---|---|
| habitat | Text | 150 | General habitat description (i.e. Sand Beach, Lagoon) |
| side | Text | 50 | Side of Island (i.e. Gulf Side, Bay Side) |
| vegetation | Text | 50 | General vegetation density description (i.e. Sparse) |
| substrate | Text | 50 | Substrate (i.e. Mud, Sand) |
| behavior | Text | 200 | General Bird behavior (i.e. Walking, Foraging, Roosting) |
| nests | Double | | Number of observed nests |
| disturbances | Text | 250 | Activities occurring nearby (i.e. BP Survey, planting…) |
| speciesRange_Comments | Text | 255 | Species name when type "Other" is observed |
| observers | Text | 200 | First and last name of observer |
| obsTransportation | Text | 50 | Transportation being used when observing (i.e. foot, boat,…) |
| hyperlinks | Text | 250 | Hyperlinks to pictures taken with GPS at time of data capture or additional documentation |
| notableCharacteristics | Text | 250 | Description of any bands on bird if present |

**TABLE 21.** BIRD MONITORING DATA (2015) ATTRIBUTES

## 18.2 BIRD MONITORING DATA DELIVERY PROCESS

The Data is to be collected using an iPad app that will be discussed with the data collector. Data will be collected in the field using an iPad and synced with a master database once connectivity is regained. All attributes seen in Table 21 will be included in submitted data.

## 18.3 BIRD MONITORING DATA STORAGE

When a data collector syncs the observation data, the data will be ingested into an interim protected online GIS database. The data will be regularly transferred to the USACE Spatial Data Branch where it will be uploaded into an SDE geodatabase. From there the data will be replicated up to USACE Enterprise database for visualization. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 18.4 BIRD MONITORING DATA VISUALIZATION/DESSIMINATION

All bird data, including locations and attributes, will be available through the password-protected private interface. Locations will be viewable within the web map along with the attributes from that particular data observation. Due to the threatened and endangered nature of the particular bird species being monitored, obfuscated bird data may be available within the public interface giving total number of birds seen during a time range but not bird siting locations.

# 19 APPENDIX J: HABITAT MAPPING DATA

## 19.1 HABITAT MAPPING DATA ATTRIBUTES

The table below outlines the habitat mapping data attributes.

| Attribute | Data Type | Size/format | Description |
|---|---|---|---|
| Attribute | String | 50 | National Wetlands Inventory (NWI) Classification Code |
| Perimeter | Double | | Perimeter of classified habitat (m) |
| Area | Double | | Area of classified habitat |
| Acres | Double | | Total acreage of classified habitat |
| Hectares | Double | | Total hectares of classified habitat |
| Class | String | 50 | Descriptive name of NWI Classification Code used above |

**TABLE 22.** HABITAT MAPPING DATA ATTRIBUTES

## 19.2 HABITAT MAPPING DATA DELIVERY PROCESS

The Data will be delivered electronically as an Esri shapefile. All attributes seen in Table 22 will be included in submitted data.

## 19.3 HABITAT MAPPING DATA STORAGE

The habitat mapping data will be replicated to a USACE Enterprise database by the Spatial Data Branch once received. The location data and attributes will be hosted through ArcGIS rest services for consumption.

## 19.4 HABITAT MAPPING DATA VISUALIZATION/DESSIMINATION

The habitat mapping data will be classified by habitat and will be available through the MsCIP web mapping interface. Habitat Mapping field photos will also be available through the mapping interface at the locations where taken. Access restrictions to the data will be determined by the MsCIP program management team.

# 20 APPENDIX K: DATA INVENTORY

## 20.1 MONITORING DATA

| Data Group | Date | Data Collector | Data Type | Data Format |
|---|---|---|---|---|
| **TES*** | 2013 | Tropical World | Bird | Database |
| **TES** | 2011-2013 | William T. Slack, ERDC<br>Mark S. Peterson, USM - Gulf Coast Research Laboratory | Gulf Sturgeon | Excel |
| **TES** | 2014 - Mar 2015 | William T. Slack, ERDC<br>Mark S. Peterson, USM - Gulf Coast Research Laboratory | Gulf Sturgeon | Excel |
| **BT** | June 2010<br>Sept 2010<br>Apr-May 2011 | Barry A. Vittor & Associates, Inc. | Benthic (also includes sediment and hydrological measurements) | Excel |
| **SAV** | Aug - Oct. 2010<br>2014 | Barry A. Vittor & Associates, Inc. | Seagrass (Submerged Aquatic Vegetation) | Shapefile |
| **AI** | Jan 2015 | USGS | Aerial Imagery | 12 inch Stereo Orthoimagery |
| **HC** | Jan 2015 | William Jones | Habitat Composition (Habitat Mapping) | Shapefile |
| **HC** | Dec 2015 (based on aerial data from Jan 2015) | William Jones | Habitat Composition (Habitat Mapping) | Shapefile |
| **LC** | Mar 2017 | Brady Couvillion | MS barrier island land area change 1984-2016 | PDF, tif |

| | | | | |
|---|---|---|---|---|
| **TES** | Mar 2015 – Mar 2016 | Barry A. Vittor & Associates, Inc. | Bird | Database |
| **WS** | Oct 2014 – June 2016 | ERDC | Wave and Currents | .mat, .xlsx |
| **ST** | May 2017 – Aug 2017 | | Turtle | .xlsx |

**TABLE 23.** MONITORING DATA INVENTORY

*See Data Groups in Section 4.2 *Data Type Categories*

## 20.2 BASELINE DATA

Additional datasets besides those being collected under the MAM Plan have been compiled and are listed in the table within this section. These supplementary datasets provide baseline information to be used in conjunction with the proposed monitoring data for analysis purposes. The authoritative sources of these datasets will vary and will be noted when applicable. Depending on the dataset, its source, and its comparative potential regarding project progress, data accessibility may vary. Possible accessibility options include providing a download link to the original source, providing the actual data to be downloaded, and/or including the dataset within visualization tools to aid in project decision-making.

| Data Group | Date | Collector | Data Type | Data Format | Data Link | Data Description |
|---|---|---|---|---|---|---|
| **SD** | 2010 | USGS | Side scan sonar; Bathymetry | shapefile; tif; txt; pdf | http://pubs.usgs.gov/ds/577/ | Archive of Side Scan Sonar and Swath Bathymetry Data collected during USGS Cruise 10CCT02 offshore of Petit Bois Island Including Petit Bois Pass, Gulf Islands National Seashore, Mississippi, March 2010 |
| **SD** | 2010 | USGS | Side scan sonar; Bathymetry; tracklines | shapefile; tif | http://pubs.usgs.gov/ds/739/Data_downloads_Cat.html | Bathymetry and Acoustic Backscatter Data collected in 2010 from Cat Island, Mississippi |
| **SD** | 2010 | USGS | Side scan sonar; | shapefile; tif; pdf | http://pubs.usgs.gov/ds/724/html/contents.html | Archive of Digital Chirp Subbottom Profile Data collected during USGS Cruise 10BIM04 Offshore Cat Island, Mississippi, September 2010 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Bathymetry; tracklines | | | |
| **SD** | 2010 | USGS | Side scan sonar; Bathymetry; tracklines | shapefile; tif; png | http://pubs.usgs.gov/of/2010/1178/html/GIS_catalog.html | Geophysical Data from offshore of the Gulf Islands National Seashore, Cat Island to Western Horn Island, Mississippi |
| | 1950 | LSU | Shoreline | shapefile | | 1950-1957 high water line (HWL) shoreline survey of the Mississippi Gulf Coast. Data were digitized from NOS U.S. Coast and Geodectic T-Sheets by Louisiana State University. These shorelines represent reliable positions for use in analyzing rates of change and documenting the location of the shoreline. |
| | 1966 | LSU | Shoreline | shapefile | | 1966 high water line (HWL) shoreline survey of the Mississippi Gulf Coast. Data were digitized from NOS U.S. Coast and Geodectic T-Sheets by Louisiana State University. These shorelines represent reliable positions for use in analyzing rates of change and documenting the location of the shoreline. |
| | 2002 | MDEQ | Shoreline | shapefile | | This data set was created by conflating multiple data sources onto the most up to date high water shoreline. The data can be used as an inventory of recent shoreline conditions. |
| | 2006 | MARIS | Wells | shapefile | | Oil and Gas Wells. Created by the MS Oil and Gas Board. The data are not survey products and not intended for legal use. |
| | 2007 | USACE | Model Stations | shapefile | | These points represent the "save points" or "output stations" for predicted storm surge or water levels from the Advanced CIRCulation (ADCIRC) model. The surge information is being used in the HEC-FDA modeling for the MsCIP. |
| | 2007 | USACE | Boreholes | shapefile | | To locate and display borehole locations in Mississippi. |
| | 2006 | MARIS | Contours | shapefile | | Mississippi 1:24,000 USGS topographic hypsography contours. Contour intervals are 5, 10 or 20 feet |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | depending on the area of the state. Supplemental contours (where applicable) are 5 or 10 feet. |
| 1850 | USGS | Shoreline | shapefile | | Historical shoreline change is considered to be a crucial element in studying the vulnerability of the national shoreline. These data are used in a shoreline change analysis for the USGS National Assessment Project. |
| 1917 | USGS | Shoreline | shapefile | | Historical shoreline change is considered to be a crucial element in studying the vulnerability of the national shoreline. These data are used in a shoreline change analysis for the USGS National Assessment Project. |
| 1986 | USGS | Shoreline | shapefile | | Historical shoreline change is considered to be a crucial element in studying the vulnerability of the national shoreline. These data are used in a shoreline change analysis for the USGS National Assessment Project. |
| 2005 | FEMA | Contours, Surge | shapefile | | The Hurricane Katrina surge inundation contour shapefile represents the extent of land inundation by coastal storm surge as calculated by spatial analysis of collected high water marks. |
| 2005 | USACE | Track | shapefile | | Display of the Hurricane Katrina Track. This track was developed to help track damages from the hurricane. |
| 1992 | USGS | Seagrass | shapefile | | This data set consists of digital data describing the submerged aquatic vegetation (seagrass) beds in the Pensacola Bay of Florida in 1992. The data set includes 12 7.5' quadrangles, which were digitized at the Mid-Continent Ecological Science Center from 1:24,000 scale hard copy maps developed by the U. S. Geological Survey, National Wetlands Research Center. The seagrass beds were classified according to a US Geological Survey, National Wetlands Research Center derived classification scheme based on the C-CAP Coastal Land Cover Classification system of NOAA Coastwatch Change Analysis Project. |

| | | | | |
|---|---|---|---|---|
| 1994 | US Dept of Agriculture | NRCS General Soil Map | shapefile | This data set consists of general soil association units. It was developed by the National Cooperative Soil Survey and supersedes the State Soil Geographic (STATSGO). It consists of a broad based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. |
| | US Dept of Agriculture | SSURGO Detailed Soil Survey | shapefile | SSURGO depicts information about the kinds and distribution of soils on the landscape. The soil map and data used in the SSURGO product were prepared by soil scientists as part of the National Cooperative Soil Survey. |
| | US Fish and Wildlife | National Wetlands Inventory | shapefile | This data set represents the extent, approximate location and type of wetlands and deepwater habitats in the conterminous United States. |
| | | Pisces Species Pop Area | shapefile | Display, location, and analysis of pisces species population areas. |
| 2005 | USACE | PMH Innundation Surge | shapefile | A data set used to display the maximum possible surge height from any storm along the Mississippi coast. |
| | | Reptilian Species Population Area | shapefile | Display, location, and analysis of reptilian species population areas. |
| 2007 | USACE | Risk Zones | shapefile | This shapefile represents the union of five return periods surge limits for a 1 in 25, 1 in 50, 1 in 100, 1 in 500, and 1 in 1000 annual chance surge surface limits. These show annual chance event surge-only inundation surface limits for coastal Mississippi. |
| | | Gulf Sturgeon Critical Habitat | shapefile | This data represents the critical habitat for Gulf sturgeon as designated by Federal Register Vol. 68, No. 53, Wednesday, March 19, 2003, Rules and Regulations. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 1988 | USGS | Habitats | shapefile | | This data set consists of digital data describing wetland and upland habitats in the coastal Mobile Bay and nearby Gulf Coast areas of Alabama. |
| | | NOAA | Aves Species Population Area | shapefile | | Birds are divided into several species subgroups based on behavior and taxonomy. The species table lists all the birds included on the maps, sorted by subgroup. These species were included either because of their likelihood of impact by an oil spill, or special protection status as threatened or endangered. |
| | 1917 | Mississippi Office of Geology | Petit Bois Island USGS T-Map 1917 | imagery | | These maps are the earliest reliable indicators of shoreline position and shoreline type. |
| | 1917 | Mississippi Office of Geology | Horn Island USGS T-Map 1917 | imagery | | These maps are the earliest reliable indicators of shoreline position and shoreline type. |
| | 1917 | Mississippi Office of Geology | Cat Island & Ship Island USGS T-Map 1917 | imagery | | These maps are the earliest reliable indicators of shoreline position and shoreline type. |
| **ST** | 2015 | The State of the World's Sea Turtles (SWOT) | Frequency of Sea Turtle Species per Nesting Site | Map Service URL | http://gcplcc.databasin.org/datasets/c184967650e7419190efd4366971e9f6<br>http://service.ncddc.noaa.gov/arcgis/rest/services/DataAtlas/SWOT_NestingSites_FrequencyBySpecies/MapServer/ | Data Provided by: National Centers for Environmental Information, NESDIS, NOAA, U.S. Department of Commerce<br><br>Data Uploaded by: Gulf Coast Prairie LCC |

**TABLE 24.** BASELINE DATA INVENTORY

# 21 APPENDIX L: DATA TYPE QUESTIONNAIRE

Whenever a new data type has been received that does not appear within this DMP as an appendix, the data collector for that data will be presented with the following data attribute questions regarding the data that has been, or will be, collected. The responses to these questions will be used to better understand the data being submitted and assist in creating appropriate data format, submission, and dissemination standards.

**General Description of the Data to be Managed?**

- Dataset Name
- Data Keywords
- Data Summary Description
- Temporal Extent of Data
- Geographic Extent of Data
- Data Type(s)
- Data Capture/Creation Method
- DMP Storage Location
- Data Volume
- PII or Restricted Info Included?

**Points of Contact (Name, Title, Location, Mailing Address, Email Address, Phone)?**

- Project Representative(s)
- Overall Project POC
- Responsible Party—Verification of Data Quality
- Responsible Party—Answering Data Collection Questions
- Responsible Party—Data Documentation & Metadata
- Responsible Party—Data Storage & Disaster Recovery
- Implementation/Adherence

**Data Stewardship?**

- Quality Control Procedures
- Overall Data Lifecycle (Collection-->Customer Availability)

**Data Documentation/Metadata?**

- Metadata Repository Catalog
- Additional Info (Besides Discovery-Level Metadata)
- Collection/Update Method for Metadata
- Additional Data Catalog
- Data/Metadata Standards

**Data Sharing?**

- Public Availability

- Date of First Public Availability
- One-Time or Ongoing Data Collection
- Hold/Delay between Data Collection & Publication
- If a Hold/Delay, How Long
- If no Public Availability, Why
- User Access Conditions/Restrictions
- Data Access Protocols Used for Data Sharing
- Registered in What Catalogs to be Discoverable

**Initial Data Storage and Protection?**

- Where/How Stored Before Storage in Long-Term Archive Facility
- Method of Data Protection from Accidental/Malicious Deletion (Data Backup, Disaster Recovery/Contingency Plan, Off-Site Storage)
- Data Access Limitations, How Protected from Unauthorized Access
- How Permissions Managed
- What Process Followed in Case of Unauthorized Access

**Long-Term Archiving and Preservation**

- Data Archive Location
- Has this Location been notified?
- If no Data Archive Location Identified, what is Long-Term Strategy for Maintaining/Curating/Archiving Data
- Method of Providing/Maintaining Archiving Costs
- Transformations Required to Prepare Data for Archiving/Sharing
- Related Information Submitted to Archive to Enable Future Data Use/Understanding

**Hardware/Software Requirements**

- Storage Requirements
- Software Requirements
- Products

# Appendix F.  Conceptual Ecological Model

# 1.0 INTRODUCTION

## 1.1 Conceptual Ecological Model Definition

Although the term "conceptual ecological model" (CEM) may be applied to numerous disciplines, CEMs are generally simple, descriptive models, represented by a diagram, that describe general functional relationships among the essential components of an ecosystem. CEMs typically document and summarize current understanding of, and assumptions about, ecosystem function. When applied specifically to ecosystem restoration projects, CEMs also describe how restoration actions propose to alter ecosystem processes or components to improve system health (Fischenich 2008). To describe ecosystem function, a CEM usually diagrams relationships between major anthropogenic and natural stressors, biological indicators, and target ecosystem conditions.

## 1.2 Purpose and Functions of Conceptual Ecological Models

CEMs can be particularly helpful with the Mississippi Coastal Improvements Program (MsCIP) Comprehensive Barrier Island Restoration by providing assistance with four important tasks: ecosystem simplification; communication; plan formulation; and science, monitoring, and adaptive management.

### 1.2.1 Ecosystem Simplification

Because natural systems are inherently complex, resource managers must utilize tools that simplify ecosystem relationships and functions within the target ecosystem. An understanding of the target ecosystem is paramount to planning and constructing effective ecosystem restoration projects. During CEM development, known and unknown connections and causalities in ecosystems are identified and delineated (Fischenich 2008).

CEMs can promote ecosystem simplification by:

- Organizing existing scientific information;
- Clarifying system components and interactions;
- Promoting understanding of the ecosystem;
- Diagnosing underlying ecosystem problems;
- Isolating cause and effect relationships; and
- Identifying elements most likely to demonstrate an ecosystem response.

### 1.2.2 Communication

CEMs are an effective tool for the communication of complex ecosystem processes to a large diverse audience (Fischenich 2008). It is important that project teams understand ecosystem function in order to reliably predict accomplishments to be achieved by restoration projects. CEMs can facilitate effective communication among project team members regarding ecosystem function, processes, and problems, and can assist in reaching consensus within the project team on goals and objectives.

Because CEMs summarize relationships among the important attributes of complex ecosystems, they can serve as the basis for sound scientific debate. Stakeholder groups, agency functions (e.g., planning and operations), and technical disciplines typically relate to system resource use and management independently, but CEMs can be used to link these perspectives.

The process of model development is at least as valuable as the model itself, and affords an opportunity to draw fresh insight as well as address unique concerns or characteristics for a given project. Workshops to construct CEMs facilitate brainstorming sessions that explore alternative ways to compress a complex system into a small set of variables and functions. This interactive process of system model construction facilitates communication among project team members and almost always identifies inadequately understood or controversial model components.

CEMs can promote communication by facilitating the following:

- Integrating input from multiple sources, and informing groups of the ideas, interactions, and involvement of other groups (Fischenich 2008);
- Assembling project/study managers with the project team and stakeholders to discuss ecosystem condition, problems, and potential solutions;
- Synthesizing current understanding of ecosystem function;
- Developing consensus on a working set of hypotheses that explain habitat changes;
- Developing consensus on indicators that can reflect project specific ecological conditions; and
- Establishing a shared vocabulary among project participants.

### 1.2.3 Plan Formulation

Formulating a plan for an effective ecosystem restoration project requires an understanding of the following elements:

1. The underlying cause(s) of habitat degradation;
2. The manner in which causal mechanisms influence ecosystem components and dynamics;
3. The manner in which intervening with a restoration project may reduce the effects of degradation.

These three elements should form the basis of any CEM applied to project formulation (Fischenich 2008).

CEMs can provide valuable assistance to the plan formulation process through the following:

- Supporting decision-making by assembling existing applicable science;
- Assisting with formulation of project goals and objectives, indicators, management strategies, and results;
- Providing a common framework among team members from which to develop alternatives;
- Supplementing numerical models to assess project benefits and impacts;

- Identifying biological attributes or indicators that should be monitored to best interpret ecosystem conditions, changes, and trends.

### 1.2.4 Science, Monitoring, and Adaptive Management

By recognizing important physical, chemical, and biological processes in an ecosystem, CEMs identify aspects of the ecosystem that should be measured. Hypotheses about uncertain relationships or interactions between components may be tested and the model may be revised through research and/or an adaptive management process. Indicators for this process may occur at any level of organization, including the landscape, community, population, or genetic levels; and may be compositional (i.e., referring to the variety of elements in a system), structural (i.e., referring to the organization or pattern of the system), or functional (i.e., referring to ecological processes) in nature.

CEMs can be helpful in restoration science, monitoring, and adaptive management through the following:

- Making qualitative predictions of ecosystem response;
- Identifying possible system thresholds that can warn when ecological responses may diverge from the desired effect;
- Outlining further restoration and research and/or development needs;
- Identifying appropriate monitoring indicators and metrics;
- Providing a basis for implementing adaptive management strategies;
- Interpreting and tracking changes in project targets;
- Summarizing the most important ecosystem descriptors, spatial and temporal scales, and current and potential threats to the system;
- Facilitating open discussion and debate about the nature of the system and important management issues;
- Determining indicators for monitoring;
- Interpreting monitoring results and exploring alternative courses of management;
- Establishing institutional memory of the ideas that inspired the management and monitoring plan;
- Forecasting and evaluating effects on system integrity, stress, risks, and other changes;
- Identifying knowledge gaps and the prioritization of research;
- Interpreting and monitoring changes in target indicators; and
- Assisting in qualitative predictions and providing a key foundation for the development of benefits metrics, monitoring plans, and performance measures.

### 1.2.5 Limitations of Conceptual Ecological Models

CEMs cannot identify the most significant natural resources within a target ecosystem or prioritize project objectives. They do not directly contribute to negotiations and trade-offs common to ecosystem restoration projects. CEMs are not "*The truth*", but are simplified depictions of reality. They are not "*Final*", but rather provide a flexible framework that evolves as understanding of the ecosystem increases. CEMs are not "*Comprehensive*" because they focus only upon those components of an ecosystem deemed relevant, while ignoring other important (but not immediately germane) elements. CEMs do not, in and of themselves, quantify restoration outcomes, but identify indicators that can be monitored to determine responses within the target ecosystem to restoration outputs.

Good conceptual models effectively communicate which aspects of the ecosystem are essential to the problem, and distinguish those outside the control of the implementing agency. The best conceptual models focus on key ecosystem attributes; are relevant, reliable, and practical for the problem considered; and communicate the message to a wide audience.

## 1.3 Types of Conceptual Ecological Models

CEMs can be classified according to their composition and presentation format. They can take the form of any combination of narratives, tables, matrices of factors, or box-and-arrow diagrams. The most common types of CEMs are narrative, tabular, matrix, and various forms of schematic representations. A comprehensive discussion of these types of CEMs is provided in Fischenich (2008). Despite the variety in types of CEMs, no single form will be useful in all circumstances (Fischenich 2008). Therefore, it is important to establish specific plan formulation needs to be addressed by the CEM, and develop the CEM accordingly because "[c]onceptual models . . . are most useful when they are adapted to solve specific problems" (Fischenich 2008).

### 1.3.1 Application of Conceptual Ecological Models to MsCIP Comprehensive Barrier Island Restoration

CEMs have been widely used in other regions of North America when planning large-scale restoration projects, including the Louisiana Coastal Area Program and the Everglades Restoration Program (Barnes et al. 2005). The MsCIP Monitoring and Adaptive Management (MAM) Technical Advisory Group (TAG) has decided to utilize the Ogden model (Ogden and Davis 1999). The TAG recognizes that CEM development is likely to be an iterative process, and the CEM developed prior to construction may change during the phased construction or post-construction, as data and supporting information are gathered.

### 1.3.2 Model Components

The CEM structure utilized for the MsCIP Comprehensive Barrier Island Restoration follows the top-down hierarchy using the components established by Ogden and Davis (1999). The schematic organization of the CEM is depicted in Figure 1 and includes the following components:

*Drivers* - External driving forces that have large-scale influences on natural systems. Drivers may be natural (e.g., eustatic sea level rise) or anthropogenic (e.g., hydrologic alteration).

*Stressors* - Physical or chemical changes that occur within natural systems that are produced or affected by drivers and are directly responsible for significant changes in biological components, patterns, and relationships in natural systems.

*Effects* - Biological, physical, and chemical responses within a natural system that are produced or affected by stressors. CEMs propose linkages between one or more stressors and effects and attributes to explain changes that have occurred in ecosystems.

*Attributes* - Indicators or end points of a frugal subset of all potential elements or components of natural systems representative of overall ecological conditions. Attributes may include populations, species, communities, or chemical processes. Performance measures and restoration objectives are established for each attribute. Post-project status and trends among attributes are measured by a system-wide monitoring and assessment program as a means of determining success of a program in reducing or eliminating adverse effects of stressors.

*Performance measures* - Specific features of each attribute to be monitored to determine the degree to which an attribute is responding to projects designed to correct adverse effects of stressors (i.e., to determine success of the project).

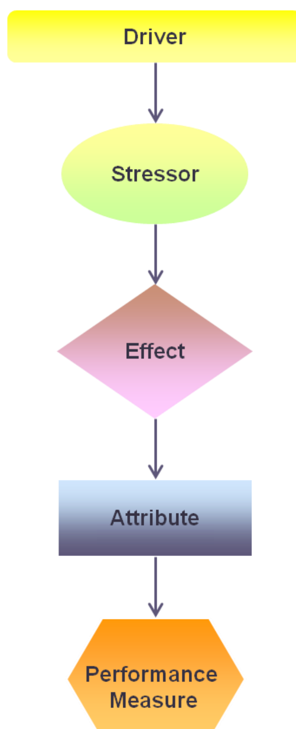


**Figure 1.** Conceptual Ecological Model Schematic Diagram.

This CEM does not attempt to explain all possible relationships or include all possible factors influencing the performance measure targets within natural systems in the study area. Rather, the model attempts to simplify ecosystem function by containing only the information deemed most relevant to ecosystem monitoring goals.

# 2.0 CONCEPTUAL ECOLOGICAL MODEL DEVELOPMENT

## 2.1 Methodology

A CEM was developed for the MsCIP Comprehensive Barrier Island Restoration by members of the TAG through an interactive and iterative review process with technical experts and stakeholders. Prior to CEM development, existing information on the Mississippi barrier island ecosystem was assembled to identify and discuss causal hypotheses that best explain both natural and key anthropogenically-driven alterations in the study area. The CEM was then developed using this information while framed by the four project objectives listed below. A list of appropriate stressors and consequent effects in the study area ecosystem was discussed. Additionally, a series of attributes was identified that exhibited characteristics ideally suited to serve as key indicators of project success through measurement and analysis of assessment performance measures associated with these attributes. The project team used this information to develop an initial draft of the model and to prepare a supporting narrative document to explain the organization of the model and science supporting the hypotheses. Additional information about the components of this CEM is presented below.

## 2.2 Project Background

In 2005, Congress authorized the development of the Mississippi Coastal Improvement Plan (MsCIP) by the Mobile District, U.S. Army Corps of Engineers (USACE), in conjunction with other Federal and State agencies. The MsCIP goals were to support the long-term recovery of coastal Mississippi from the devastation caused by Hurricane Katrina and other Gulf of Mexico hurricanes in 2005, evaluate past navigational dredging activities that have altered sediment transport along the islands, and develop restoration projects and property acquisition strategies to make the coast more resilient against damage from future storms (USACE 2009).

As part of the MsCIP Comprehensive Plan, the Mississippi barrier island system was evaluated with the overall goal of restoring the natural ability of the system to reduce the impact of hurricanes traversing the Mississippi Gulf coast on mainland and Sound ecosystems (Figure 2). The Mobile District proposed restoration of the sediment transport system and augmentation of the sediment budget to preserve and protect the Mississippi barrier islands and, in turn, the Mississippi Sound and the Mississippi mainland.

### 2.2.1 Project Goals and Objectives

The overarching goal of barrier island restoration for MsCIP is environmental sustainability. This includes sustaining estuarine habitat in Mississippi Sound by restoring barrier island habitat and augmenting sediment availability to the natural sediment transport system of central and east Ship Island.

The objectives for barrier island restoration for MsCIP are to:

- Maintain the estuarine ecosystem and resources of the Mississippi Sound.
- Preserve the natural and cultural resources of the Mississippi barrier islands.
- Restore the barrier islands structure to reduce storm damage impacts on the mainland coast of Mississippi.
- Enhance the long-term littoral drift system for the Mississippi barrier islands.

### 2.2.2 Project Description

The restoration plan fulfills the goals identified in the MsCIP Programmatic Environmental Impact Statement (PEIS) for restoration of the Mississippi barrier islands as a first line of defense against storm impacts to estuarine and mainland ecosystems, resulting in a more resilient coast. This plan includes:

- Restoration of Ship Island, including sand placement in Camille Cut and along the Gulf boundary of East Ship Island;
- Sand placement along the Gulf-facing shoreline of Cat Island; and
- Management of maintenance dredging material from the Horn Island Pass segment of the Pascagoula Ship Channel.

The Ship Island restoration component will be constructed in five phases. The first four phases will consist of dredging and placement activities, while the fifth phase will consist of dune planting on the newly restored Ship Island. Phases 3 and 4 will run concurrently and be completed at different locations (i.e., East Ship Island and Camille Cut, respectively). Phase 5 will commence upon completion of all other phases. It is estimated that the five phases will be completed over a period of 2.5 years. Individual phases are detailed below.

1. Phase 1 consists of the placement of approximately 6.0 million cubic yards (mcy) of sand to construct the initial berm across Camille Cut, and approximately 0.9 mcy for a portion of the berm on East Ship Island. The East Ship Island berm, constructed adjacent to the Camille Cut berm along the west end of the southern shoreline of East Ship Island, will serve as a feeder source for Camille Cut until the remaining portion of the East Ship Island berm is constructed during Phase 3. It is estimated that Phase 1 will take 15 months to complete.
2. Phase 2 consists of the placement of approximately 6.3 mcy of sand to raise and widen the fill at Camille Cut. Work under Phase 2 is expected to begin immediately upon completion of Phase 1, and is estimated to take approximately one year.
3. Phase 3 consists of restoring the southern shoreline of East Ship Island. Approximately 5.0 mcy of sand will be placed to extend and expand the initial East Ship Island berm, constructed in Phase 1, and complete the restoration of the southern shoreline of East Ship Island. It is estimated that Phase 3 would be completed over a period of approximately eight months.
4. Phase 4 consists of placing approximately 1.1 mcy of sand in the interior portion of the Camille Cut berm. The work is estimated to take approximately five months. In order to facilitate establishment of dune vegetation, finer grain sized material from the Ship Island borrow area will be used as a cap on the Camille Cut fill section.

5. Phase 5 consists of vegetating the Camille Cut restoration berm to restore stable dune habitat. The newly created island segment will be planted with such native dune vegetation as currently exists in adjacent coastal habitats. Selected species will include sea oats (*Uniola paniculata*), gulf bluestem (*Schizachyrium maritimum*), and/or other grasses and forbs. It is estimated the construction of Phase 5 will be completed in seven months.

Cat Island Restoration

1. The portion of restored Cat Island was acquired by BP following the Deepwater Horizon incident to facilitate the clean-up. Restoration work at Cat Island was accomplished under a separate contract, with the construction preceding the Ship Island Restoration efforts.
2. Restoration work at Cat Island, conducted from July through October 2017, consisted of the placement of slightly >2 mcy of sand along the eastern shoreline. The material was pumped onto the beach and shaped using land-based equipment. The construction profile is expected to adjust rapidly through the erosion of the upper profile, thereby mimicking the natural nearshore profile reaching equilibrium. The total equilibrated fill area encompasses approximately 305 acres. The planting with native dune vegetation finishing on November 15, 2017, and the turbidity barrier was removed on December 7, 2017.

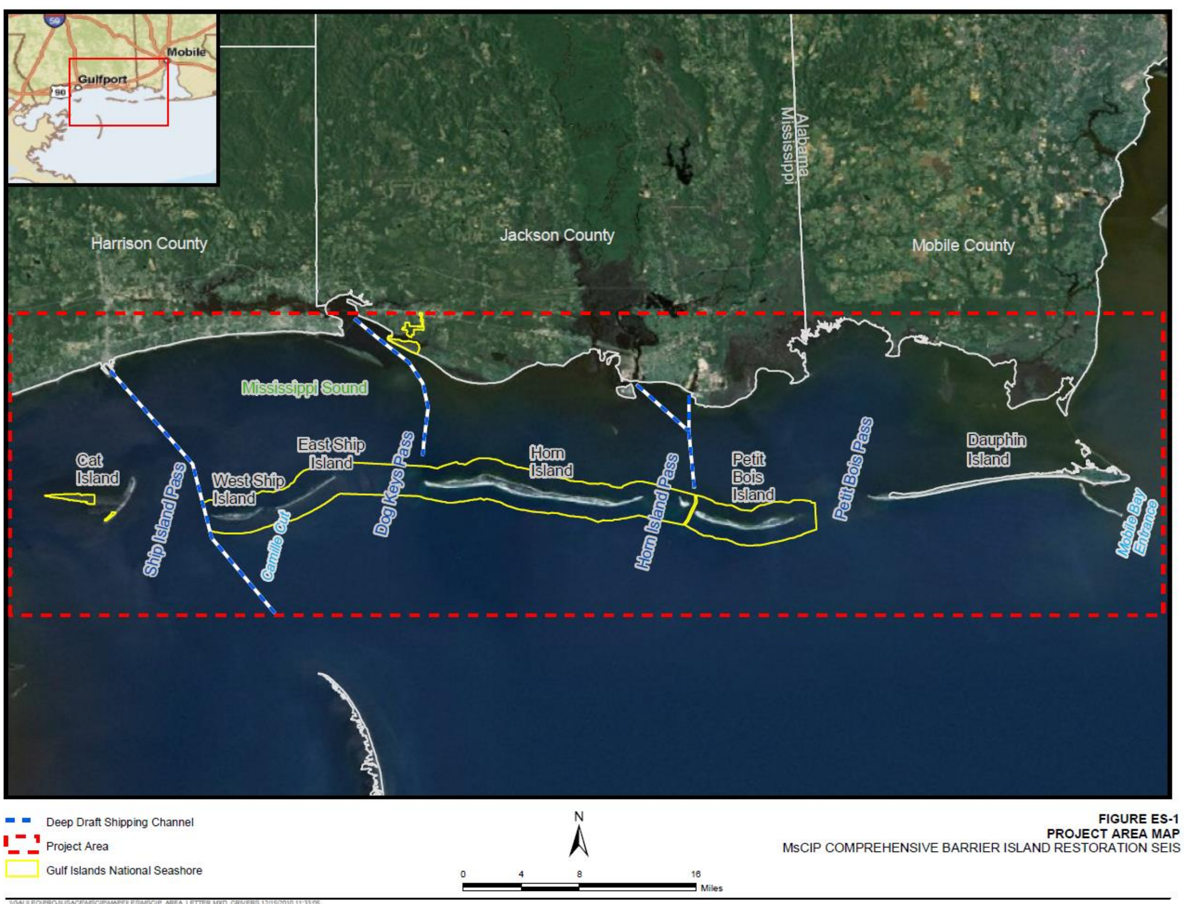


FIGURE ES-1
PROJECT AREA MAP
MsCIP COMPREHENSIVE BARRIER ISLAND RESTORATION SEIS

**Figure 2.** MsCIP Comprehensive Barrier Island Restoration Project Study Area

# 3.0 CONCEPTUAL ECOLOGICAL MODEL DISCUSSION

The CEM developed for the MsCIP Comprehensive Barrier Island Restoration Project is presented in Figure 3. Model components are identified and discussed in the following subsections, and references for additional information are noted. In some cases, information is incorporated from related section of the PEIS.

## 3.1 Drivers

The Mississippi barrier islands form the first line of defense for protecting coastal Mississippi from the direct effects of winds, waves, and storms. The barrier islands serve multiple purposes to: (1) reduce coastal flooding during periods of storm surge; (2) reduce wave intensity on mainland shorelines, which would accelerate rates of erosion and degradation of marshes and other wetlands; and (3) help maintain gradients between saline and freshwater, thereby preserving estuarine conditions in Mississippi Sound.

The major external driving forces that have large-scale influences on the Mississippi barrier islands are coastal processes, acute events and, anthropogenic activities. The continuous sand platform that underlies the Mississippi barrier islands was delivered primarily by erosion of ebb-delta shoals at the entrance of Mobile Bay, continental shelf sediments, and reworking within the sandy platform (Otvos 1979). Maintaining the morphology and integrity of the Mississippi barrier islands is related to sediment availability and transport, and the physical processes operating on the coast of Mississippi. Primary coastal processes influencing the shape of the Mississippi barrier islands include currents and tides, winds and waves, and relative sea-level rise. These natural coastal processes are greatly affected by acute events such as storms, including both tropical (summer) and extratropical (winter) storms, oil spills, and restoration activities. Anthropogenic activities such as navigational channel dredging and placement can also affect the westward migration of barrier islands (Byrnes et al. 1991; Byrnes et al. 2010; Byrnes et al. 2012; Morton 2008). These drivers can affect cultural resources of national importance that exist on the islands, and human uses that can affect biological community composition and integrity.

## 3.2 Stressors

### 3.2.1 Littoral Sediment Transport

Littoral sediments are transported in the nearshore zone by longshore currents. This process is a result of breaking and shoaling waves suspending sand from the bottom and the displacement of the sediment down-drift by the longshore current. The magnitude of the longshore current intensifies with increasing wave height and breaker angle, and the rate of transport is a function of barrier orientation, offshore shelf slope, local depth, normal wave and current conditions, and storm events. Byrnes et al. (2013) used historical shoreline and bathymetric survey data to construct net littoral sand transport pathways for the Mississippi barrier islands and found an east to west sand flux of about 305,000 $m^3$/yr. Study results illustrated that ebb shoals at the entrances and west ends of the islands were net depositional (sediment sinks) and the east ends of the islands were net erosional (sediment sources). Ship Island, located at the end of the littoral transport system, and farthest from original sand sources, is most susceptible to erosion.

### 3.2.2 Relative Sea-level Rise

Relative sea-level rise (RSLR) consists of eustatic sea-level rise combined with subsidence. Eustatic sea-level rise is defined as the global increase in oceanic water levels primarily due to changes in the volume of major ice caps and glaciers, and expansion or contraction of seawater in response to temperature changes. Analysis of historical data suggests a relative sea-level rise of approximately 2 to 3 mm $yr^{-1}$ along the Mississippi coast during the 20th century (Morton 2008).

Recent climate research by the Intergovernmental Panel on Climate Change (IPCC) predicts continued or accelerated global warming for the 21st Century and possibly beyond, which will cause a continued or accelerated rise in global mean sea level. Based on the historical rate of sea-level rise taken from the NOAA tide station located at Dauphin Island, Alabama of approximately

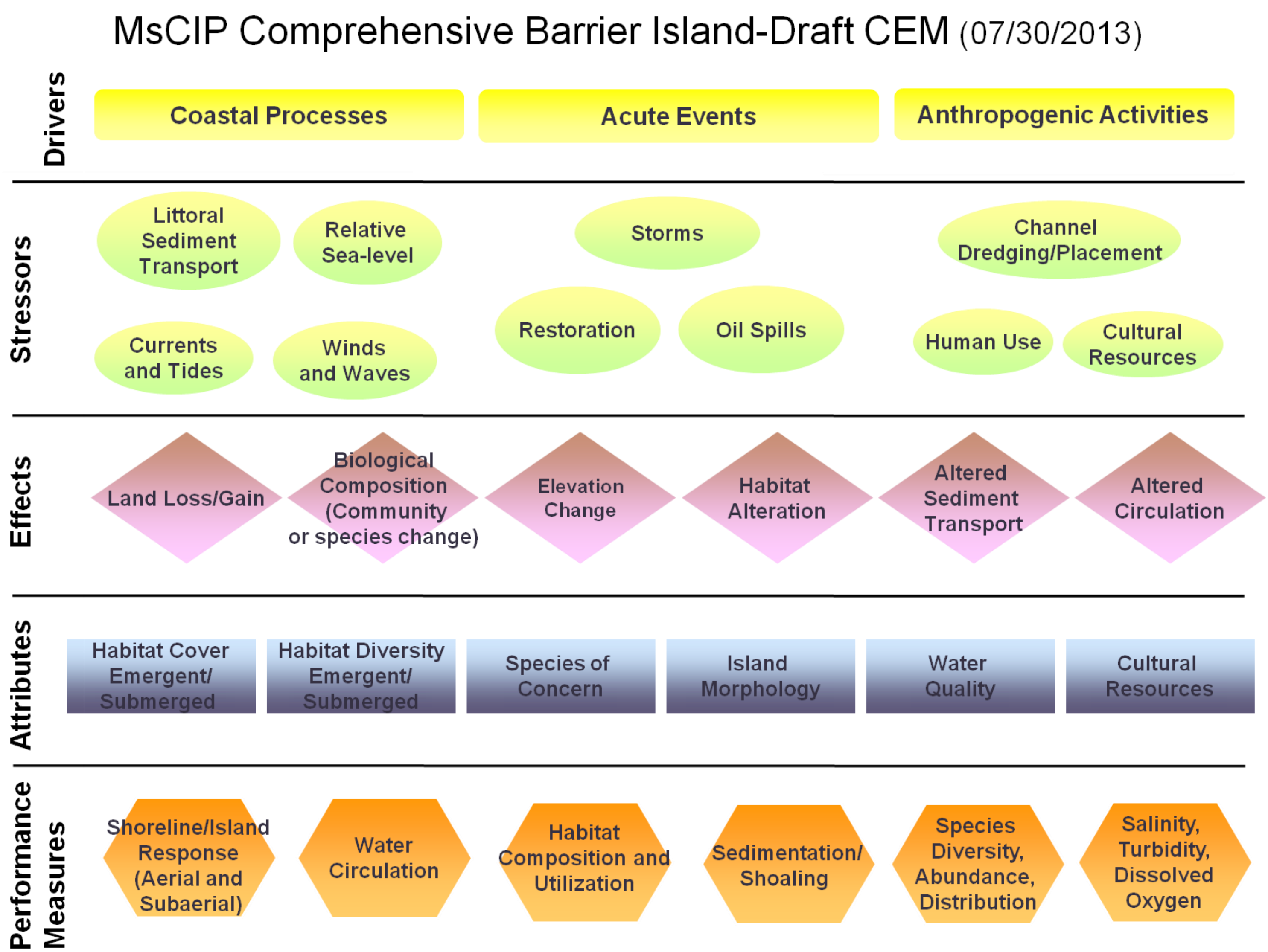


**Figure 3.** Conceptual Ecological Model for the Mississippi Coastal Improvements Program, Comprehensive Barrier Island Restoration Project.

3 mm/yr, sea level is projected to rise approximately 0.12 m above the present level over the next 50 years, with potential rise as high as 0.24 to 0.61 m based on the 1987 National Research Council's (NRC) low and high curves, modified with the current IPCC estimate of mean sea level change rate.

Barrier islands are among the most vulnerable areas to the consequences of climate change. In most cases, rising sea levels result in landward movement of the high-water shoreline, potentially causing the islands to migrate slowly inland, provided sufficient sediment supply is available and the rate of sea-level rise is such that the islands can keep pace. Losses could be accelerated due to a combination of other environmental and oceanographic changes, such as an increase in the frequency of storms and/or changes in prevailing currents, both of which could lead to increased beach loss via erosion. This could translate into continued loss of valuable habitat along the Mississippi barrier islands, including sea turtle nesting habitat, shorebird foraging and roosting areas, dune habitat supporting various flora and fauna, and general island ecosystem functions. The MsCIP barriers island restoration seeks to minimize the impacts of RSLR and island land losses by placement of sand in the most crucial areas of the system.

### 3.2.3 Currents and Tides

The hydrologic characteristics of Mississippi Sound are strongly influenced by wind-driven currents in combination with tidal influences of the Gulf of Mexico. Tides within the Sound are diurnal, with an average range of up to approximately 0.6 m. The tides are strongly influenced by local bathymetry, local river discharges, and winds (Jarrell 1981). The relatively shallow depth and large area of Mississippi Sound can create strong currents in the tidal passes between the islands, during both flood and ebb tides (Foxworth et al. 1962). This can increase the exchange of water and sediment between the Gulf and Mississippi Sound and contribute to widening tidal inlets.

Normal tides are affected by seasonal weather patterns. During the winter months, prevailing winds are from the north and are associated with frontal systems (USEPA 1986). These frontal storm systems occur approximately weekly and have a substantial effect on Mississippi Sound. The resulting response of coastal waters is an initial increase in tidal amplitudes, which causes waves to break higher on the beach, overwashing low barrier islands. Elevated tides increase the flow of Gulf water into the bays and marsh systems behind the barrier islands. As floodwaters reside and exit the passes with passage of a front, abrupt changes in wind direction from southerly to northerly cause increased wave heights in the bays.

### 3.2.4 Winds and Waves

Wind can induce circulation in the form of set-up and set-down, seiche, and wind-waves. Similarly, the presence of front-like weather during the winter, and storms during hurricane season, enhances these processes by producing dynamic wind conditions. The velocity and direction of winds shift abruptly, creating extreme water level fluctuations that are responsible for a significant amount of the erosion taking place along the Mississippi coast (Chaney and Stone 1996; Cipriani and Stone 2001).

The influence of winds on coastal currents and waves within the Sound and on the Gulf side of the barrier islands is well documented (Morton et al. 2004; Byrnes et al. 2013). Wind-driven waves and associated currents are the primary mechanisms for entraining and transporting nearshore sediments (Morton et al. 2004; Morton 2008; Byrnes et al. 2012). Wave energy is a key factor in sediment re-suspension and promotion of lateral transport through longshore water movements. Prior characterizations of wind conditions in the project area indicate that prevailing nearshore surface winds are from the south from March to July. The gradual shift to more easterly winds in August and September drive currents toward the west (Cipriani and Stone 2001). During winter months, prevailing winds are from the north and are associated with frontal systems (USEPA 1986). While much of the literature focuses on these east-to-west currents as being major factors in influencing barrier island migration westward, and to some degree landward, these same factors influence localized current speed and direction conditions on the Sound side of the islands.

### 3.2.5 Storms

The Gulf Coast region is affected by both tropical and extra-tropical storms. These atmospherically driven storm events can directly and indirectly contribute to coastal land loss through a variety of processes: (1) erosion and breaches from increased wave energies; (2) removal and/or scouring of vegetation from storm surges; and (3) storm-induced saltwater intrusion into interior wetlands and Mississippi Sound. These destructive processes can result in the loss and degradation of large areas of coastal habitats in relatively short periods of time (days and weeks versus years). Tropical storms have made landfall along the Mississippi coast (Biloxi to Pascagoula) approximately every 10-12 years (Byrnes et al. 2012). In 2005, Hurricane Katrina devastated coastal Mississippi and impacted the entire barrier island chain, resulting in gulf shoreline erosion, overwash from beach/dune habitats to back-barrier habitats, land loss, and damage to infrastructure.

### 3.2.6 Restoration

Acute events, such as large-scale barrier island restoration projects, may immediately alter existing conditions and system dynamics of the islands and nearshore waters. The restoration of Mississippi barrier islands through placement of sand resources may alter bathymetry and topography, inundation patterns, sediment availability, littoral sediment transport and other hydrologic and coastal processes, wave and circulation patterns, and water quality regimes. Changes in the described conditions will affect biological resources, including changes in habitat composition and utilization on the barrier islands and in Mississippi Sound.

### 3.2.7 Oil Spills

Impacts of oil spills, as well as the various emergency actions taken to address oil spill impacts (e.g., use of oil dispersants, use of Hesco baskets, rip-rap, sheet piling, and other actions), could impact the study area and USACE water resources projects and studies. Potential impacts may include factors such as changes to existing, future-without, and future-with-project conditions, as well as increased project costs and implementation delays. In the event of an oil spill, the USACE will continue to monitor and closely coordinate with other Federal and state resource agencies and local sponsors to determine how to best address any potential problems associated with an oil spill that may adversely impact project implementation.

### 3.2.8 Channel Dredging/Placement

Dredging of the Pascagoula and Gulfport Ship Channels facilitates the exchange of water and sediment between Mississippi Sound and the Gulf of Mexico, and can interrupt the westward transport of littoral sand. Maintenance dredging in Horn Island Pass and Ship Island Pass since initial authorization in the late 1800s has increased channel depths from approximately 7 to 9 m to 12 to 15 m (Byrnes et al. 2012). Placement of dredged material adjacent to Horn Island Pass from September 1917 to June 2009 and Ship Island Pass from September 1917 to November 2005 has been estimated at 352,700 cy/year and 265,200 cy/year, respectively (Byrnes et al. 2012).

### 3.2.9 Human Use

The Mississippi barrier islands are part of the Gulf Islands National Seashore, National Park Service (NPS). They are listed by the NPS as a national watchable wildlife area and include designated wilderness areas that afford a variety of recreational activities and other human uses. Human activities, such as visitor and recreational usage, park management actions, and resource extraction and consumption, can stress biological resources and critical habitats, and alter coastal ecological processes.

### 3.2.10 Cultural Resources

Cultural resources eligible for nomination to the National Register of Historic Places, such as Fort Massachusetts, are threatened by active shoreline processes, including erosion, migration and encroachment. The comprehensive barrier island restoration would add a greater land area between these resources and the Gulf waters. This increase in land area, while not totally diminishing the threat of erosion to the resource, will substantially reduce that threat.

## 3.3 Effects

### 3.3.1 Land Loss/Gain

For barrier island shorelines, complex interactions between storm events, longshore sediment supply, coastal structures, and inlet dynamics contribute to erosion and migration of beaches and islands. Barrier islands are important elements of the geomorphic framework of the estuary. Barrier islands separate the Gulf from back-barrier estuarine environments, helping to maintain salinity gradients important to estuarine species. As islands erode and are breached, marine forces impact interior boundaries of the estuaries, thereby accelerating land loss. Barrier islands also serve as valuable storm buffers protecting communities, industry, and associated infrastructure from storm surge. Marine influences, particularly those associated with tropical storm events, gradually erode and rework the structure of islands until they eventually disappear. Barrier islands serve as natural storm protection buffers and limit erosion of Mississippi coastal wetlands, bays, and estuaries by reducing wave energies at the margins of coastal wetlands.

Large-scale conversion of barrier island habitat to open water can occur during hurricane events when breaches are formed and the island is overwashed, exposing underlying soft muddy substrates.

### 3.3.2 Biological Composition (Community or Species Change)

The Mississippi barrier islands and Mississippi Sound support a diversity of habitats that provide essential services for plants and animals that live within these habitats. The Mississippi barrier islands and the adjacent shallow waters of Mississippi Sound include shallow open waters, tidal mud and sand flats and bars, tidal pools and creeks, inlets, submerged aquatic vegetation, beaches, dunes, marshes, and maritime forests. Diverse assemblages of terrestrial and aquatic species utilize these habitats for resting, foraging, breeding, and nursery habitat. Changes to, or loss of, these habitats may affect species utilization and may result in changes or shifts in biological communities and species specific abundance and diversity.

### 3.3.3 Elevation Change

Changes in sediment delivery, circulation, wave dynamics, and overwash regimes have significant effects on the elevation of the Mississippi barrier islands. Coupled with scouring caused by storms and relative sea level rise, the elevation and structural integrity of the barrier islands are negatively affected. Alternatively, restoration can enhance elevations of the barrier island footprint, providing greater stability and resilience to stressors.

### 3.3.4 Habitat Alteration

Barrier islands are an ever-changing and dynamic landscape that consists of many different habitats including shallow open waters, tidal mud and sand flats and bars, tidal pools and creeks, inlets, submerged aquatic vegetation, beaches, dunes, marshes, and maritime forests. Subaerial and subaqueous vegetated and un-vegetated habitats can be altered gradually in response to sea level rise and changes in littoral sediment transport, or they can be altered substantially in a short period of time due to acute events such as hurricanes and restoration activities that change the geomorphic profile and alter salinity and inundation regimes that then force functions in the distribution and diversity of coastal habitats. Alterations in the distribution and diversity of habitats could lead to increases in some critical habitat, and decreases in others, that would affect changes in biological community composition and utilization by species of concern.

### 3.3.5 Altered Sediment Transport

A majority of littoral sand supplied to downdrift beaches is derived from longshore transport during storm events (Byrnes et al. 2013). Longshore currents redistribute available sand westward from eroding beaches and headlands to the east, but it can be captured by shore-perpendicular navigation channels, potentially reducing sand transport to downdrift barrier islands. Additionally, properly sited dredged-material placement west of Horn Island Pass could facilitate natural sediment transport pathways to islands west of the channel, thereby emulating littoral sand transport in the absence of a dredged navigation channel. When sand is placed outside the littoral transport system, the natural littoral sediment budget is altered and dredged sand is no longer available to support maintenance of the barrier islands.

### 3.3.6 Altered Circulation

Kjerfve and Sneed (1984) described tidally-based circulation in the eastern portion of the Sound as having a strong clockwise rotation. The western portions of the Sound are characterized by a weaker, counter-clockwise rotation. These circulation patterns may contribute to how the potential effects of barrier island restoration might be distributed within the Sound, depending on proximity of restoration activities to tidal inflow and outflow at passes. Closing Camille Cut will alter circulation patterns around Ship Island, potentially affecting the updrift erosion and downdrift deposition associated with westward migration (Byrnes et al. 1991; Otvos 1979). The change in circulation patterns may also have some localized effects on water quality, and may influence Gulf sturgeon utilization of Ship Island and Dog Keys Passes.

## 3.4 Attributes and Performance Measures

### 3.4.1 Emergent/Submerged Habitat Cover and Diversity

Habitat and emergent/submerged land cover have been identified as key indicators of project success with respect to preventing habitat conversion and future land loss. Comparison of pre-project habitat characteristics with post-project habitat characteristics would serve to determine if the current trend in conversion of beach and marsh to open water within the study area has declined.

Shoreline and island response have been identified as assessment performance measures for evaluating habitat changes and habitat extent for the proposed project. Spatial analysis may involve comparative analysis of pre- and post-project aerial or satellite imagery and may utilize thematic mapper analysis to determine relative changes in habitat within the study area.

Habitat composition and utilization also have been identified as potential performance measures for determining the response of habitat cover and diversity to the proposed project. Habitat and vegetation types will respond to changes in conditions (e.g., salinity and elevation) based on individual tolerances, and this change will be reflected in the distribution/abundance of habitat community composition and the species that use them. Changes in all submerged and emergent habitats will be captured.

### 3.4.2 Species of Concern

Habitat utilization has been identified as a key indicator of project success with respect to maintaining or increasing the availability of habitat for particular species of concern. The species of concern that will be addressed include: piping plover, red knot, Gulf sturgeon, and sea turtles. Criteria for habitats will be identified to reflect the opportunity to rest, forage, and/or breed, which is dependent on many factors.

Species diversity, abundance, and distribution, along with habitat composition and utilization, have been identified as potential performance measures for determining the response of species of concern to the restoration action. Additionally, tracking island elevation and land change response may allow refinement of habitat specific criteria and dependencies.

### 3.4.3 Island Morphology

Once sand is placed on Ship Island and in the littoral system, island morphology will change. Subaerial extent has been identified as a key indicator of project success with respect to addressing barrier island longevity. Comparison of pre- and post-project island extent will serve to determine if current trends in barrier island loss have changed. Subaqueous extent also will be tracked to determine changes in sedimentation/shoaling patterns.

Elevation has been identified as a key indicator of project success with respect to reducing or reversing land loss on barrier islands. Topographic and bathymetric surveys will be conducted in conjunction with other barrier island geomorphic profiles to (1) detect changes in overwash impacts to morphology; (2) document changes in island habitat (e.g., subtidal, intertidal, shoreface, beach, dune, forest, upland); and (3) relate changes in features to particular events or chronic changes.

### 3.4.4 Water Quality

Surface water quality in the study area has been identified as a key indicator of project success with respect to reducing hydrologic connectivity through Camille Cut and the interior estuarine ecosystem. Comparison of pre- and post-project water quality will serve to determine if there are any changes in salinity, turbidity, and dissolved oxygen within the study area, and whether water quality is maintained over time.

Evaluating flow and circulation patterns in the study area has been identified as a key indicator of project success with respect to reducing hydrologic connectivity between the Gulf of Mexico and the back-barrier bays and interior marshes. Comparison of pre- and post-project hydrography will be used to determine if closure of Camille Cut and restoration of Ship Island have reduced the duration of flooding and the tidal prism.

### 3.4.5 Cultural Resources

Erosion of Ship Island is leading to increased risk to cultural resources sites. Restoration of barrier island form and structure is expected to provide beneficial impacts to reduce threats to these cultural resources. Shoreline/island response, including aerial extent and surveys, will be used to measure project performance in maintaining a land area (buffer zone) around cultural resources.

### 3.4.5 Summary of Conceptual Model Components

**Table 1.** Summary of Conceptual Model Components

| Driver | Stressor | Effect | Level of Confidence That a Relationship Exists | Level of Predict-ability | References for More Information |
|---|---|---|---|---|---|
| Coastal Processes | Littoral Sediment Transport | Reduced littoral sediment transport has led to continued erosion of barrier islands. | High | High | Byrnes et al. 2012 |

| Driver | Stressor | Effect | Level of Confidence That a Relationship Exists | Level of Predict-ability | References for More Information |
|---|---|---|---|---|---|
| Coastal Processes | Relative Sea-level Rise | Changes in inundation frequency and duration and wave dynamics associated with relative sea level rise affects the geomorphology of the island (erosion and accretion) and the habitats they can support. | High | Medium | Rosati and Stone 2009; Morton 2008; McBride et al. 1995 |
| Coastal Processes | Currents and Tides | Altered sediment transport, circulation patterns, and water quality effects | High | Medium | See PDSIES Appendix D |
| Coastal Processes | Winds and Waves | Altered sediment transport due to changes in wind & wave dynamics affects sediment transport and deposition patterns. | High | Medium | Morton 2008; Otvos and Carter 2008; see PDSIES Appendix D |
| Acute Events | Storms | A change in storm regime affects acute erosion (loss of sediment due to shoreline change), and lowers elevation resulting in loss of total sediment volume, changes in overwash, inlet formation, dune morphology and affects supported habitats. | High | Low | Morton 2008; Otvos and Carter 2008; Shabica et al. 1984 |

| Driver | Stressor | Effect | Level of Confidence That a Relationship Exists | Level of Predict-ability | References for More Information |
|---|---|---|---|---|---|
| Acute Events | Restoration | Restoration of barrier island footprints alter bathymetry and topography which influence island morphology, inundation patterns, and salinity regimes, which results in changes in habitat composition and utilization. | High | Medium | Otvos and Carter 2008 |
| Acute Events | Oil Spills | Pollutant discharge and burial may affect existing and future barrier island and Mississippi Sound resources, including sand used for restoration purposes | High | Low | Michel et al. 2013 |
| Anthropogenic Activities | Channel Dredging /Placement | Maintenance of navigation channels affects sediment supply and transport. Placement location affects sediment transport within littoral zone. | High | High | Byrnes et al. 2012; Byrnes et al. 2010; Otvos and Carter 2008 |
| Anthropogenic Activities | Human Use | Recreation activities could alter habitat composition, and habitat usage by species of concern. | High | Medium | Bonanno et al. 1998 |

| **Driver** | **Stressor** | **Effect** | **Level of Confidence That a Relationship Exists** | **Level of Predict-ability** | **References for More Information** |
| --- | --- | --- | --- | --- | --- |
| Anthropogenic Activities | Cultural Resources | Maintenance of sand buffer around historic sites. | High | High | See PDSEIS Appendix D |

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**Appendix G. Data Assesment and Anaylsis Protocols**

**G. Protocols**

101. Morphology, Shoreline Change

102. Sediments Transport

103. Sedimentation, Shoaling

104. Dredged Material Placement

111. Flow Patterns

112. Wave Attenuation

121. Water Quality

131. Habitat Composition

201. Benthic Infauna

211. SAV Acreage and Distribution

212. SAV Condition and Composition

213. SAV Turbidity, Depth and Substrate

214. SAV Long-term Trends

221. Gulf Sturgeon Habitat Area

222. Gulf Sturgeon Occupancy

223. Gulf Sturgeon Foraging Habitat

231. Sea Turtle Habitat Suitability Model

232. Sea Turtle Sediment Shear Strength

233. Sea Turtle Suitable Nesting Habitat from Habitat Mapping

234. Sea Turtle Historical Habitat

241. Shorebirds Benthic Foraging Habitat

242. Shorebirds Critical Habitat Mapping

243. Shorebird Habitat Utilization Modeling

244. Shorebirds Historical Habitat

245. Shorebird Habitat Change Mapping

301. Cultural Resources

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Island Morphology and Shoreline Change
# Protocol 101

*Protocol version date: 04/03/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Morphology/Shoreline
The ability of the Mississippi barrier island system to limit storm impacts to mainland beaches depends upon the islands ability to maintain sufficient width and elevation. Beach erosion and overtopping along East Ship Island, and changes in inlet shoal and channel morphology within Little Dog Keys and Dog Keys Passes, endanger the longevity of East Ship Island, which could result in complete degradation of the island within the next 10 to 20 years (Byrnes et al. 2012). Restoration along Camille Cut and East Ship Island will include increases in island width and elevation to augment natural sediment transport quantities prior to breaching and inlet formation along Ship Island. Once island restoration design templates are complete, it is anticipated that adjustments in shoreline change and subaerial island morphology will occur.

**Purpose of Monitoring and Data Assessment**
Document island elevations, shoreline change rates, and island areal extent. The monitoring will be used to measure project performance against success criteria and to identify breaches that would be used as adaptive management decision criteria under the AM plan (Section 6 of the MAMP). The monitoring will also provide supplementary information to better understand the responses of other biological and physical performance measures, for example, circulation and habitat availability.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Net loss of original island restoration surface area over the ten year monitoring period is less than or equal to the historic average loss of ~ 3% per year, as documented through analysis found within Byrnes et. al., 2012.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
Net loss of original island restoration surface area is less than 15% over the five year monitoring period post-completion of sand placement on Ship Island.

**AM Trigger**
Net loss of original island restoration surface area is greater than an average of 3% per year over the ten year monitoring period. Land loss along Ship Island exceeds 50% of the original restoration area over the ten year monitoring period.
A storm(s) significantly impacts the project before and/or during construction.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Island Morphology and Shoreline Change
# Protocol 101

*Protocol version date: 04/03/2018*

**Task**

Verify that restored sand volumes were adequate to enhance the natural sediment processes along Ship Island. Track the subaqueous movement of sand transported from the subaerial beach during initial beach adjustments toward dynamic equilibrium and in response to storm events. Measure island elevations, quantify bathymetric change, and monitor shoreline erosion rates.

**Analysis Frequency**

Pre- and post-construction, plus three times during the 10-year monitoring effort. Post-construction corresponds to completion of sand placement on Ship Island.

**Data Collection Required for Analysis**

Aerial photography and lidar surveys

**Analysis Methodology**

Simultaneous digital orthophotography and lidar (topobathymetric lidar, if possible) surveys will be collected before and after construction, and a minimum of two two times during the 10-year monitoring effort to verify that restored sand volumes were adequate to maintain Ship Island.

All surveys and imagery shall be referenced to NAD83 Mississippi State Plane East Zone Coordinate System and reported in U.S. Survey Feet. All elevations shall be referenced to NAVD88 (2012A epoch). A Monument Information Report shall be provided that describes the locations of given, found, used monuments and temporary benchmarks, including identification, establishment date, coordinates, elevations, and profile azimuths.

*Analysis of Digital Orthophotography*

Digital orthophotographs of the barrier island will be analyzed using a supported version of the U. S. Geological Survey's (USGS) Digital Shoreline Analysis System (DSAS) (Thieler et al. 2008) extension for ArcGIS Release 10 (ESRI; Environmental Systems Research Institute 2011). Digital orthophotos will be imported into ArcMap, and the shorelines will be digitized into unique feature classes for each survey event. If the shorelines are collected as shapefiles they must be appended to a single file and imported into a geodatabase within ArcCatalog.

To perform DSAS analysis, the data input must be in meters (m) in a projected coordinate system such and Universal Transverse Mercator or State Plane. Data will be imported as feature classes into a personal geodatabase. All shoreline data must be within a single feature class within a personal database. Shorelines will be referenced to the same physical feature for each collection event, such as the mean high water line (MHW), as determined by lidar surveys collected during the time interval of the digital photography.

The digitized shoreline vectors must be assigned a date in the shoreline feature class attribute table. The overall uncertainty value due to measurement and sampling errors will be calculated and used as user-specified input into ArcGIS. References on how to calculate the uncertainty value to specify may be found in the DSAS user's manual (Thieler et al. 2008).

Once shoreline data has been combined into a single feature class within the geodatabase, the ArcMap selection tools will be used to calculate change statistics on subsets of the entire dataset. A proper baseline feature class will be created from pre-construction imagery against which the post-construction shorelines will be compared. Transects will be cast from the baseline feature class perpendicular to the digitized shoreline physical feature (MHW) baseline such that each cast transect intersects both feature classes. The initial transect spacing will be spaced no more than 100 meters apart. A sensitivity check will be conducted using different transect spacing to verify that the appropriate spacing is selected. A closer transect spacing may be necessary depending on the change observed between pre- and post-construction shorelines.

An extended log file will be generated for the calculation of change statistics and transects. The simple transect option will be used as appropriate to minimize over- and under-estimations of shoreline change. When calculating shoreline statistics, the net shoreline movement (NSM) and linear regression rate (LRR) options will be executed when there are more than three shorelines to compute from. When only two shorelines are available, the shoreline change envelope will be calculated instead of the net shoreline movement. A confidence interval of 95% is specified for all statistical calculations performed under this task.

Details regarding the use of the DSAS extension may be found in the DSAS Installation Instructions and User Guide (Thieler et al. 2008), which has been paraphrased in this protocol.

*Data Analysis of lidar surveys*

Lidar data will be processed to bare earth classification to remove vegetation. Pre-construction lidar data will be compared to ground surveys and corrected as necessary. The standard deviation of error in the lidar data will be reported. Post-construction lidar surveys will also be corrected to ground survey data collected at the time of lidar data collection.

A digital elevation model (DEM) of the pre- and post-construction lidar surveys will be generated. The Root Mean Square Error (RMSE) of the georeferenced lidar digital elevation models will be reported. The cell and vertical resolution of the DEMs will also be reported. If there are multiple elevation (z) values in a cell, all values will be averaged to create one value for the cell. If there are no elevation data within a cell, an inverse distance weighting (IDW) method will be used to interpolate a z value from the nearest neighbor cells. All DEMs will be referenced to Mississippi State Plane East, NAD 83.

The lidar elevation models generated from pre- and post-construction data will be compared and analyzed for changes. The pre-construction model will serve as the baseline against which comparisons will be made. A t-test of the DEM data will be performed assuming unequal variances, and the resultant statistics will be reported to determine if the beach morphology is statistically significantly different from the baseline. If the baseline and post-construction DEM are statically different, the rate of change will be reported as well as the percent difference. The rate of change and the percent difference statistics will be used to evaluate the littoral transport patterns of the post-construction fill and to determine if either the desired outcome or the risk endpoint of the project is being realized.

Each island will be segmented into its own unique analysis area so that the outcomes and endpoints can be determined for each island independent of the other. If possible, erosive hotspots or accretion locations will be identified to facilitate a greater understanding of the sediment transport systems around the islands. To the best extent possible, the movement of post-construction fill and subsequent deposition to another portion of the island(s) will be distinguished from the natural accretion or erosion processes observed prior to fill placement.

The segmented island areas will remain the same for each year of monitoring analysis.
The procedure for DEM analysis will consist of segmenting the islands, quantifying the difference between each cell value of the paired baseline and post-construction data, and computing the volumetric change at each location. The net sediment loss along each island will be reported according to a control volume balance procedure. A statistical summary table will be reported for each analyzed DEM area, indicating the minimum and maximum net volumetric change per unit area, the median and mean of the volumetric change per unit area, and the standard deviation (White and Wang 2003).

The eCoastal Survey Tools application for ArcMap, Depth Difference Calculator, compiled within the eCoastal Toolbox can be used to measure and quantify the difference between the baseline and post-construction surface profiles. A graph of the baseline and post-construction profiles will be plotted using the eCoastal Profile Generator and Profile Plotter for multiple profiles at locations along the island(s) and where erosive hotspots or areas of accretion are identified. The geographical limits of the erosion or accretion will also be described. The number of profiles to be sampled and compared with the Profile Generator will be large enough that an accurate assessment of the island elevation(s) can be made. Any changes between the baseline elevation along the island and the post-construction data will be emphasized in the reported results and the limits of the elevation changes will be described.

The eCoastal Toolbox may also be used to create a raster surface from lidar point data as necessary, provided that the user has the appropriate ArcMap tools. More information about the eCoastal toolbox application for ArcMap may be found in the CE-Tools (eCoastal Toolbox) User's Guide (USACE Mobile District Spatial Data Branch 2011).

**Products**

For each year mapped, products from this task will include:

**Digital Orthophotographs**

- Geodatabase for DSAS analysis
- Baseline shoreline feature class
- Shoreline feature class layers
- Overall uncertainty value used
- Transect spacing selected
- ISO-compliant metadata for DSAS shoreline analysis
- Extended log file statistics and transects
- Shoreline statistical methods used
- Resultant files created during the analysis process
- Memo report of methods and results including the shoreline change distance and the rate of change along with a summary of the data used in the analyses

**Lidar Surveys**

- Standard deviation of error between lidar data and ground surveys
- Root Mean Square Error (RMSE) of the georeferenced lidar elevation models
- T-test assuming unequal variances statistics
- Rate of change and percent difference from baseline results for post-construction DEM data comparison
- Unique segmenting strategy for each island
- Net sediment loss or gain volume quantities for each island
- Identified erosion or accretion areas and the limits thereof
- Profiles and identified limits of island areas demonstrating elevation changes
- Memo report of methods and results including the minimum and maximum net volumetric change per unit area, the median and mean of the volumetric change per unit area, and the standard deviation

**Metadata**

Metadata will be created for all analyses, following ISO standards.

**Literature Cited**

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# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol: Long-Term Littoral System Sediment Transport
# Restore Sediment to the Barrier Island System
# Protocol 102

*Protocol version date: 04/02/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Restore Sediment
Based on littoral sand transport estimates along East and West Ship islands and long-term sediment budget estimates for the Mississippi Sound barrier islands (Byrnes et al. 2011), Dog Keys Pass and Little Dog Keys Pass have been a sand sink throughout the historical record, resulting in limited sand movement from Horn Island to East Ship Island. The result has been rapid shoreline recession and chronic beach erosion along East Ship Island, resulting in significant island area losses and habitat degradation.

Presently, the island is in a highly degraded state and is expected to become a shoal within the next decade if island restoration is not considered. If the island is left to naturally grade, valuable wetland habitat will be lost and wave and current energy from the Gulf of Mexico are expected to negatively impact estuarine habitats in the lee of the island, water quality, and mainland beach sustainability. As such, island restoration has been designed to augment natural littoral transport system and create subaerial and subaqueous habitat within the barrier island system.

**Purpose of Monitoring and Data Assessment**
Verify sand restoration volumes are adequate for enhancing sand supply to the littoral transport system to help maintain Ship Island. The monitoring will provide the information required to measure progress against success criteria.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Increase sediment availability for littoral transport along the barrier islands measured over a five and ten year period relative to baseline (pre-construction).

**Areas of Interest**
West Ship Island, East Ship Island, Ship Island Pass, Horn Island Pass.

**Interim Target**
Increase sediment availability for littoral transport along the barrier islands measured over a five year period after completion of sand placement at Ship Island.

**AM Trigger**
During the initial construction phases, the sand material placed at the Ship Island placement location is removed at rates higher than expected, due to unexpectedly strong longshore transport.

**Task**
Verify that placed sediment maintains the barrier islands and enhances natural littoral transport. The subaerial and subaqueous changes in sediment volume as well as the direction of transport

will be monitored and quantified. Natural and anthropogenic sediment sources and sinks will be identified as they are observed.

**Analysis Frequency**
Pre- and post-construction. Post-construction monitoring will occur two times during the ten year period following completion of sand placement at Ship Island.

**Data Collection Required for Analysis**
Orthophotography, lidar and bathymetric surveys

**Analysis Methodology**
Lidar (topobathymetric lidar, if possible) and bathymetric surveys of the barrier islands and adjacent bottoms will be collected before and after construction, and two times during the 10-year monitoring period beginning with completion of sand placement at Ship Island. Lidar and bathymetric surveys will occur at approximately the same time. Survey areas will include the vicinities of Ship Island, Ship Island Pass, and Horn Island Pass. Navigation surveys performed for operation and maintenance will supplement the MAM surveys as appropriate to update the barrier island sediment budget and to refine sediment transport projections.

The MsCIP Mississippi mainland and barrier island regional sediment budget (Rosati et al. 2007), as well as other similar studies (Byrnes et al. 2011), are the foundation for the sediment budget work that will be performed under the MsCIP MAM Program. The hypothetical present-day sediment budget alternative hypothesis described in the MsCIP study should be the baseline alternative for post-construction sediment budget analysis comparisons. Data collected for the MAMP as well as operation and maintenance dredging will be utilized to update the macro and individual sediment budget(s) for the barrier islands. These updates will serve to inform the Technical Advisory Group (TAG) in their assessment of whether the project is meeting the sediment restoration criteria established as a “desired outcome” or a “risk endpoint”. The Sediment Budget Analysis System (SBAS) tool (or functional equivalent) (USACE Mobile District Spatial Data Branch 2012) for ArcGIS will be utilized for littoral transport analysis and sediment budget updates after each combined survey and lidar collection event.

Assessments will be made in SBAS during the 10-year monitoring period as littoral transport and seasonal variability assumptions change, engineering activities occur, or lidar and survey analyses are reported. The assessments will be created and individual cells added within a littoral cell layer if the survey data indicates that these modifications are warranted. Flux lines will also be added or updated for littoral cells as the littoral transport patterns change. These additions will be documented to the TAG and the GPS boundaries of the affected location(s) will be specifically identified. To the best extent possible, the physical event that preceded the transport or flux change will be identified, e.g. natural: storm or seasonal variability, anthropogenic:

construction or dredging. New macro budget cells will be created after the necessary changes are made to the individual cells. The results of the individual cell and macro sediment budget analyses will be reported. Any differences between the updated assessments and the baseline and previous assessments will be documented. These differences will be quantified as appropriate and the rate of change and percent difference statistics will be reported.

The methods used to obtain the littoral cell transport and flux values will be described with the sediment budget results. The source of the data used should also be documented, such as Mobile District lidar data collected for the MAMP and analyzed with the eCoastal toolbox for ArcMap. A statistical summary of the source data will accompany this information. The summary statistics from the source data will be used to identify the littoral cell layer confidence and flux value uncertainty. All source data used for analysis will be referenced to NAD83 Mississippi State Plane East Zone Coordinate System and reported in U.S. Survey Feet. All elevations will be referenced to NAVD88 (2012A epoch).

**Products**

- Individual cell additions within a littoral cell layer and GPS boundary of affected locations as applicable
- All .shp files and associated ISO compliant metadata files created during the sediment budget process
- Rates of change and percent difference from previous sediment budget assessments
- Source data used for analysis
- Report documenting methods of determining transport and flux values, source and statistics of input data, confidence levels assumed, all summary statistics produced, and sediment budget results.

**Metadata**

Metadata will be created for all analyses, following ISO standards.

**Literature Cited**

Byrnes, M.R., J.D. Rosati, S.F. Griffee, and J.L. Berlinghoff. 2012. Littoral Sediment Budget for the Mississippi Sound Barrier Islands. ERDC/CHL Technical Report TR-12-9;. Technical Report, Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Rosati, J. D., .M. R. Byrnes, M. B. Gravens, and S. F. Griffee. 2007. Mississippi Coastal Improvement Project Study; Regional Sediment Budget for Mississippi Mainland and Barrier Island Coasts. ERDC/CHL Report, Vicksburg: U.S. Army Corps of Engineers Engineer Research and Development Center.

USACE Mobile District Spatial Data Branch. 2012. Sediment Budget Analysis System (SBAS) for ArcGIS 10-User's Guide. User's Guide, Mobile: USACE Mobile District Spatial Data Branch.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol: Long-Term Littoral System Sediment Transport Sedimentation/Shoaling
# Protocol 103

*Protocol version date: 04/03/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Sedimentation/Shoaling
Ship Island Pass exists along the western end of Ship Island and encompasses the federally maintained Gulfport Federal Navigation Channel, which generally has depths of 40 feet or less. Long-term dredging records show large annual variability in maintenance dredging quantities; however, long-term annualized dredging requirements for Ship Island Pass are on the order of 156,000 $yd^3$/yr. Although analysis indicates that the restoration of the littoral sediment transport system and changes to local currents resulting from the closing of Camille Cut could potentially result in increased sedimentation in the Ship Island Pass, especially during hurricane events, increased sedimentation over what would naturally occur with the westward growth of Ship Island is expected to be minimal.

**Purpose of Monitoring and Data Assessment**
Monitor and document sedimentation and shoaling that could impact dredging operations and maintenance costs of the Federal navigation channel at Ship Island Pass. The monitoring will provide the information required to assess the risk endpoint.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
No increase over natural variability in average annual maintenance dredging within Ship Island Pass during the five and ten year periods after completion of sand placement on Ship Island.

**Areas of Interest**
Ship Island, Ship Island Pass

**Interim Target**
Shoaling rates in the Ship Island Pass navigation channel remain within the range of natural variability and average annual maintenance dredging per year over a five year period is unchanged compared to baseline values.

**AM Trigger**
Average shoaling rates in the navigation channel increase to be outside the range of natural variability and average annual maintenance dredging costs increase over the ten year monitoring period compared to baseline values.

**Task**

- Monitor sedimentation and shoaling in the Ship Island Pass and compare the post-construction dredging requirements to the annualized baseline dredging requirements of approximately 156,000 $yd^3$/yr.
- Changes in shoaling as well as the location of sedimentation will be measured and quantified.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol: Long-Term Littoral System Sediment Transport
# Sedimentation/Shoaling
# Protocol 103

*Protocol version date: 04/03/2018*

**Analysis Frequency**

Pre- and post-construction, plus a minimum of two times during the 10-year monitoring effort. Post-construction is defined as the completion of sand placement on Ship Island.

**Data Collection Required for Analysis**

Bathymetric surveys, including those completed for navigational purposes

**Analysis Methodology**

Bathymetric surveys of the Ship Island bottoms and Ship Island Pass will be collected before and after construction and at least twice during the 10-year monitoring period. Navigation surveys performed for operation and maintenance will supplement the MAMP surveys as appropriate, with assessments being made on channel shoaling rates at approximately five and 10 years after construction.

The Technical Advisory Group (TAG) will utilize surveys conducted for operations and maintenance as well as bathymetric surveys collected for other MAMP performance measures to determine if the restoration of Camille Cut and East Ship Island impacts the shoaling rates within the Ship Island Pass.

The annualized baseline dredging requirements of approximately156,000 $yd^3$/yr will be considered the baseline against which the post-construction values will be measured. Long-term dredging records indicate large annual variability on the order of +/- 100,000 $yd^3$/yr in dredging requirements. Storm activity and seasonal variability should be considered and documented when shoaling rates are analyzed.

The data collected for operations and maintenance for the MAMP will be used as input to update the barrier island sediment budget, which will be used to quantify changes in sediment volume and pathways including shoaling within the navigation channel. The task(s) required to execute this *Sedimentation/Shoaling* performance measure will be performed concurrently, and with the same methodology, as those prescribed in Protocol 102 (Restore Sediment to the Barrier Island System). The Sediment Budget Analysis System (SBAS) tool (or functional equivalent) for ArcGIS (USACE Mobile District Spatial Data Branch 2012) will be utilized for littoral transport analysis and sediment budget updates after each survey or dredging event.

The methods used to obtain the littoral cell transport and flux values will be described with the sediment budget results. The source of the data used will also be documented. This documentation will include the date of the survey, type of equipment used, and the vertical and horizontal accuracy of the data. A statistical summary of the source data will accompany the documentation as appropriate. The summary statistics from the source data will be used to identify the littoral cell layer confidence and flux value uncertainty. All source data used for analysis will be referenced to NAD83 Mississippi State Plane East Zone Coordinate System and reported in U.S. Survey Feet. All elevations shall be referenced to NAVD88 (2012A epoch).

**Products**

- Documentation of storm events or seasonal changes that might contribute to changes in shoaling rates during the time period of data analysis.
- Rates of sedimentation change and percent difference from the annualized dredging requirements.
- Survey data documentation to include the date of survey, equipment used, and vertical and horizontal data accuracy.
- Report documenting the methods used to analyze shoaling rates, the analysis results and statistics, and any contributing events not attributed to barrier island fill placement.

**Metadata**

Metadata will be created for all analyses, following ISO standards

**Literature Cited**

MsCIP Technical Advisory Group. 2014. MsCIP Comprehensive Barrier Island Restoration Draft Monitoring and Adaptive Management Plan. Monitoring and Adaptive Management Plan, Mobile: USACE Mobile District.

USACE Mobile District Spatial Data Branch. 2012. Sediment Budget Analysis System (SBAS) for ArcGIS 10-User's Guide. User's Guide, Mobile: USACE Mobile District Spatial Data Branch.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol: Long-Term Littoral System Sediment Transport
# Dredged Material Placement
# Protocol 104

*Protocol version date: 04/03/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Dredged material placement
Horn Island Pass is approximately 3.5 miles wide, encompasses the Pascagoula Ship Channel, and is located between Horn Island to the west and Petit Bois Island to the east. Dredging activities within Horn Island Pass have intercepted west-directed littoral sand transport, some of which has not been placed in the littoral zone west of the channel (Byrnes et al. 2013). Although a substantial portion of maintenance dredging sand has been placed in the littoral zone in an area known as Disposal Area #10 (DA-10), this disposal area is located far north on the shoal complex in an area of limited wave energy, insufficiently strong to drive sediment to the west. This has resulted in limiting sediment transport to eastern Horn island.

Based on sediment transport information developed as part of the MsCIP, proposed modifications to maintenance dredging practices have been implemented to redirect placement of maintenance dredging sand to a more active portion of the littoral drift system west of the channel. Modification of USACE dredged-material placement practice is expected to improve current regional sediment management practices and enhance the natural sand transport system.

**Purpose of Monitoring and Data Assessment**
Verify that sand placement west of Horn Island Pass has been relocated to a more active portion of the littoral transport system to increase sediment downdrift to Horn Island. The monitoring will provide the information required to measure progress against success criteria.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Increase sediment availability for littoral transport along the barrier islands measured over a five and ten year period at Horn Island Pass.

**Areas of Interest**
Ship Island, Horn Island Pass, Pascagoula Harbor Navigation Chanel

**Interim Target**
Increase sediment availability for littoral transport along the barrier islands measured over a five year period at Horn Island Pass.

**AM Trigger**
No increase in sediment availability from Horn Island Pass towards Horn Island.

**Task**
To help ensure present day sediment placement practices at Pascagoula are consistent with maintaining the sediment transport of the barrier island system at the least cost, a sand transport study utilizing tracers that mimic the physical properties of sand from the Pascagoula Harbor

Navigation Chanel are being used to supplement longer term monitoring and adaptive management decisions being made from bathymetric change studies.

The specific task of the sand tracer study is to spatially delineate rate and direction of sediment transport with respect to natural forces.

**Analysis Frequency**
Analysis of sediment tracer results will occur after the general sampling events described below, with final reporting of the sediment tracer results approximately two years following tracer release.

Analysis of bathymetric change will occur following before and after dredge placement surveys made during the course of the tracer study and a minimum of two times after the completion of sand placement on Ship Island. Bathymetric change assessments made during the course of the sand tracer study will be reported ~two years following tracer release. Additional, bathymetric change assessments conducted will be conducted twice in the ten years following completion of construction, and will be reported under Protocol 102 (Restore Sediment).

**Data Collection Required for Analysis**
Bathymetric surveys and sediment tracer data.

**Collection Methodology**
Tracer Sampling Timing: Sampling will be conducted in at least three events over a 12 to18-month period, generally as follows:

- *Sampling Event 1*: 1-2 months after release, ideally after a period of quiescent conditions tidal currents only, or ahead of first storm, whichever is sooner.

- *Sampling Event 2*: After localized small storm with high seas, as determined through coordination with the Mobile District Coastal Engineer POC.

- *Sampling Event 3*: After a larger storm with swells, as determined through coordination Mobile District Coastal Engineer POC.

Tracer samples shall be collected from an agreed upon sampling area (approximately 75-80 samples over a sampling area of roughly 3.5 square miles). The sampling area will be adjusted as necessary, based on prior sampling data and review of wave and current conditions occurring between the sampling events. To provide more accurate data in areas of specific interest, initial sampling will be weighted to the tracer release site(s) since there may be limited transport in the first few months after placement, i.e. more samples collected around the initial tracer deployment site. Areas of specific interest include those that are close to the release site, the navigation channel, and the eastern tip of Horn Island.

Additionally, in order to accurately conduct a mass balance calculation in the areas of specific interest, more samples will be collected in these areas. In the wider area sampling zone, samples shall be collected over a wider grid area. Refinement determined through coordination of each sampling zone will be made based on results from the previous sampling event(s). A sampling plan will be prepared prior to each sampling event to ensure that the appropriate locations are being sampled to obtain the most information about littoral transport following dredged material placement at DA-10.

Sand tracer study sediment samples will be collected within the sediment transport area of influence relative to the time of the year that the samples will be collected, as well as the event that the sampling follows. For example, a larger area may need to be sampled after a localized storm than during a routine sampling event, with an even larger sampling area required for a larger storm with swells.

The locations where the sediment tracer samples are collected will be documented in an ArcGIS .shp file format. All coordinate information will be referenced to NAD83 Mississippi State Plane East Zone Coordinate System and reported in U.S. Survey Feet. All elevations will be referenced to NAVD88 (2012A epoch). The .shp file(s) will contain attributes that identify (at a minimum) the sampling event represented by the .shp file, the date of the event, the personnel present for the sampling event, the vessel used for sampling, and the coordinates where the sample was obtained. Any additional information relevant to the sample, such as weather conditions during sampling or past storm activity, will also be documented.

**Analysis Methodology**

To ensure modified maintenance dredging placement practice is achieving its desired outcome, bathymetric surveys will be conducted before and after sand is relocated to the new dredged material placement site adjacent to Horn Island. In addition, at least two extended surveys within Horn Island Pass will be conducted during the 10-year monitoring period.

Over a 12 to 18-month period sand tracer sampling data will collected to be used in conjunction with bathymetric surveys to analyze and interpret the littoral transport patterns along the barrier islands. The tracer study results, along with any locally available oceanographic and meteorological data, will be reported. An interpretation and analysis of the littoral transport patterns surrounding the tracer deployment locations and the areas of specific interest will be submitted in the form of progress reports after each sampling event. At a minimum, the analysis in these reports will include the direction of transport inferred from the sampling results, the volume of sediment being transported (in cubic yards), the region of influence of the sediment transport, and any sensitivity that is observed due to meteorological conditions.

The areas that are analyzed after the sampling events will be refined enough to accurately represent the sediment transport around the deployment site and areas of specific interest.

**Products**

- Plan of proposed sampling locations for approval prior to the sampling event.
- ArcGIS .shp files of sampling locations with attributes containing pertinent sampling information.
- Progress reports after each sampling event.
- Final report summarizing the results of all tasks within the sand tracer study scope of work, including an interpretation and analysis of sediment transport patterns within the littoral system surrounding the areas of specific interest described in this document.

**Metadata**

Metadata will be created for all analyses, following ISO standards.

**Literature Cited**

Byrnes, M. R., J. D. Rosati, S.F. Griffee, and J.L. Berlinghoff. 2013. Historical sediment transport pathways and quantities for determining an operational sediment budget: Mississippi Sound Barrier Islands. Journal of Coastal Research, SI 63,166-183.

MsCIP Technical Advisory Group. MsCIP Comprehensive Barrier Island Restoration Draft Monitoring and Adaptive Management Plan. Monitoring and Adaptive Management Plan, Mobile: USACE Mobile District, 2014.

USACE Mobile District Spatial Data Branch. Sediment Budget Analysis System (SBAS) for ArcGIS 10-User's Guide. User's Guide, Mobile: USACE Mobile District Spatial Data Branch, 2012.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Flow Patterns Analyses
# Protocol 111

*Protocol version date: 04/03/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Flow Patterns at Ship Island Pass, Little Dog Keys Pass, and Dog Keys Pass.
East and West Ship Islands, separated by Camille Cut, are flanked by Ship Island Pass to the west and Little Dog Keys Pass and Dog Keys Pass to the east. Current flows through these passes and Camille Cut affect the estuarine ecosystem and resources of Mississippi Sound. This estuarine ecosystem is expected to adjust to changing flow patterns once Camille Cut is closed. It is anticipated that minimal flow pattern changes will occur after closure of Camille Cut within Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass.

**Purpose of Monitoring and Data Assessment**
Record flow patterns at Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass to evaluate overall circulation changes after closure of Camille Cut. The monitoring is being conducted for the Ship Island Restoration component and will provide the supporting information required to measure progress against the success criteria.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
An assessment of changes in currents through Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass will be made within the first year after completion of closure of Camille Cut. Changes in flows measured from the pre- and one year post-closure surveys through the three passes are within the range of simulated change found through the analysis documented in Wamsley, et al., 2013.

**Areas of Interest**
Ship Island Pass, Little Dog Keys Pass, and Dog Keys Pass

**Interim Target**
N/A

**AM Trigger**
Flows resulting from similar tidal, river and wind conditions exceed predicted values found through the analysis documented in Wamsley, et al. 2013.

**Tasks**
1. Evaluate flows through Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass, before and after closure of Camille cut flows.
2. Compare measured change with simulations having similar tidal, river and wind conditions.

**Analysis Frequency**
2017 - Documented (1) pre-construction observations and (2) simulated model results in pre-construction baseline report.

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Document differences between observations and model simulations one year post-construction. Post construction data collection and analysis will occur one year after the closure of Camille Cut.

**Data Collection Required for Analysis**

*Observational Data*

Acoustic Doppler Current Profiler (ADCP) transects will be taken at each pass – one prior to the closure of Camille Cut and one after the closure of Camille Cut. These measurements at each transect will be measured for at least one tidal cycle. Pre- and post-closure data will be collected at the same time of year, under similar tidal and meteorological conditions.

**Analysis Methodology**

*Numerical Simulations*

Numerical modeling of the circulation around Ship Island was conducted using the ADCIRC and CH3D-WES hydrodynamics models (Wamsley et al. 2013). ADCIRC was run over the period of March 12 to September 18, 1998 using wind data from NOAA National Data Buoy Center buoy 42007, supplemented with data from the USACE Wave Information Study (WIS) hindcast. Tidal forcing was applied at the ocean boundary from the East Coast 2001 Data Base of Tidal Constituents. Water levels from ADCIRC were used at the CH3D open boundary conditions. The model configuration was calibrated and assessed using observational water level data from Waveland, Mississippi, and Dauphin Island, Alabama, for the baseline case (actual island configuration in 1998). Once calibrated, the same time period was modeled for three alternate bathymetry and topographic scenarios. The two of these that will be considered in this analysis are (1) Ship Island in its current configuration, post-Katrina; and (2) a restored Ship Island. Additional details on the simulations may be found in Wamsley et al. (2013).

*Analysis of Flow Conditions*

The volume and velocity of flow through the passes may fluctuate due to a number of variable conditions, for example, neap vs. spring tide, local weather conditions such as storms that may elevate water levels on the Gulf or bay side of the islands, naturally-driven changes to the bathymetry of the pass, and so forth. The flow through these passes is also expected to change somewhat as a result of the closing of Camille Cut; however, these changes are not expected to be significant in terms of the environmental conditions (water quality) in Mississippi Sound. The primary concern, therefore, is whether the changes resulting from the restoration project are greater than were predicted by the numerical simulations.

The benchmark that will be used in assessing flow in both observational data analysis and comparison to model output will be the mean volumetric flow (in $m^3/s$) through the cross-section of the passes, with the mean calculated by averaging over the tidal cycle. This metric will be used to evaluate changes in flow that would potentially alter the flushing, and thus the water quality, of Mississippi Sound.

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**Data Analysis Protocol:**
**Flow Patterns Analyses**
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*Task #1: Evaluate flows through Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass, before and after closure of Camille cut flows*
For this analysis, the mean volumetric flow will be calculated for each of the three passes for the ADCP transect data acquired before and after the closure of Camille Cut. Volumetric flow is calculated from measured flow velocities and the cross-sectional area and configuration of the channel, which may vary between observational surveys and the model. These differences will be analyzed and presented, along with other factors in the observational data (transect location, instrument settings, data processing, etc.) that may lead to variation. Tidal and meteorological condition differences between modeled and observed time periods that would impact volumetric flow will also be analyzed and presented. The difference between the pre- and post-data will be calculated for each pass as both a percentage and an absolute change.

*Task #2: Compare measured change with simulations having similar tidal, river and wind conditions*
Model simulation results will also be analyzed for the mean volumetric flow through each of the passes for the current (post-Katrina) and restored island scenarios, as well as the change due to the restoration of the island. Because the model was not specifically calibrated for the periods of observation and includes a broader range of tidal and wind conditions than the observational data (4 months vs. 1 tidal cycle), volumetric flow averaged over the entire time period may be different between the model and the observations due to temporal variability in the flow (i.e., mean flow averaged over a 4-month period including spring and neap tides may be different than the mean flow over a single neap, spring, or other tidal cycle). A subset of the model data will be selected as the best match (most similar) to the observational time periods based on tide range and wind speed and direction. Water level observations for this selection will be taken from the Waveland and Dauphin Island gauges used in calibrating the model simulations. Wind speed and direction will be used from NOAA Buoy 42040, located 63 nautical miles south of Dauphin Island, Alabama. This gauge is the closest offshore anemometer with wind speed data available at present (Buoy 42007 used for the simulations is no longer in service), and during the time period of simulation.

Comparisons will then be made (percentage and absolute difference) between the pre- and post-restoration model output and observational data for: (1) the pre-restoration mean volumetric flows; (2) the post-restoration mean volumetric flows; and (3) the change between pre- and post-restoration modeled flows. Each of these three comparisons will be made for both the entire time period of the simulations, and the periods selected as the best match (in terms of independent observation of tidal water levels) to the observational time periods. Comparisons (1) and (2) provide an indication of the skill of the model in capturing the time period over which observational data were collected, while comparison (3) serves as the benchmark for evaluating if the changes in flow in the passes due to the restoration are greater than expected. If the mean volumetric flow over the entire period of simulation is different than for the subset of the data best-matched to the times of observation, it may indicate that differences in the observational data are influenced by short time-scale variability and are not as indicative of the influence of the restoration project on long-term flow as the full model simulation. Analysis of potential contributions to differences between the model and the observation data other than real-world changes resulting from the restoration (e.g., differences in the cross-sectional area, observational data processing, etc.) will be used to determine if variation between the model output and observational data are likely due to the restoration, and the results of that analysis may support the need to rerun model simulations to test the sensitivity of the results to parameters that may have changed and/or to use updated bathymetry and forcing conditions that are consistent with the time period of observations.

## Products

Task #1:

- Table showing the measured pre- and post-restoration mean volumetric flow (averaged over a tidal cycle) for Little Dog Keys Pass, Dog Keys Pass, and Ship Island Pass, and the difference between these values as both a percent and absolute change for each pass.
- Table summarizing the physical, meteorological, and tidal conditions for each observational survey, as well as for the model simulations.

Task #2:

- Table showing the simulated pre- and post-restoration mean volumetric flow (averaged over a tidal cycle) for Little Dog Keys Pass, Dog Keys Pass, and Ship Island Pass, and the difference between these values as both a percent and absolute change for each pass for (a) the entire time period of simulation, and (b) the subsets of the time period simulation with the best-match to the observational data.
- Table showing the differences between (1) pre-restoration mean volumetric flow, (2) post-restoration mean volumetric flow, and (3) change in mean volumetric flow as both a percentage and absolute difference between the observational data and the model simulations (a) and (b) above.
- Table summarizing the difference between physical, meteorological, and tidal conditions during the observational time periods compared to the model simulations.

## Metadata

Metadata will be created for all analyses, following ISO standards.

## Literature Cited

Wamsley, T.V., E.S. Godsey, B.W. Bunch, R.S. Chapman, M.B. Gravens, A. S. Grzegorzewski, B.D. Johnson, D.B. King, R.L. Permenter, D.H. Tillman, and M.W. Tubman. 2013. Mississippi Coastal Improvements Program; Evaluation of Barrier Island Restoration Efforts. USACE Engineer Research and Development Center, ERDC TR-13-12, 515 pp.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Wave Reduction
# Protocol 112

*Protocol version date: 04/03/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Wave Reduction Leeward of Ship Island
One of the expected benefits of filling Camille Cut is to reduce Gulf of Mexico wave energy impacting mainland beaches in Harrison County, Mississippi. Wave measurements at locations seaward and soundward of Camille Cut are required to directly measure the extent of wave energy attenuation from the Gulf of Mexico after Camille Cut has been closed. Additionally, wave measurements will provide a valuable dataset for verifying wave prediction models used for the nearshore and estuarine system surrounding Ship Island.

**Purpose of Monitoring and Data Assessment**
Assess wave attenuation (reduction) in the lee of Ship Island. The monitoring will provide the information required to measure progress against success criteria.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
The success criterion is reduced wave height leeward of Ship Island relative to pre-construction baseline conditions during the five years post-construction monitoring period.

**Areas of Interest**
West Ship Island, East Ship Island, Mississippi Sound

**Interim Target**
N/A

**AM Triggers**
No reduced wave attenuation north of Ship Island after the closure of Camille Cut.

**Tasks**

1. Estimate wave height attenuation in the lee of Ship Island, calculated as the 90th percentile of the offshore wave heights minus the paired wave heights in the Mississippi Sound.
2. If a tropical storm affects this area, compare measured wave conditions to those from representative storms contained within existing modeled databases.

**Analysis Frequency**
Document pre-construction wave height attenuation as the 90$^{th}$ percentile of the offshore wave heights minus the paired wave heights in Mississippi Sound in the baseline observations

Document post-construction wave height attenuation as the 90$^{th}$ percentile of the offshore wave heights minus the paired wave heights in Mississippi Sound in the observations taken after the closure of Camille Cut.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
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**Data Collection Required for Analysis**
Wave gauge data

**Collection Methodology**
*Observational Data*
Wave gauges will be deployed prior to, and for a period up to 2 years after closure of Camille Cut, to measure wave height, period, direction, and water level at three locations: (1) in the Gulf, south of Camille Cut; (2) in the sound, just north of Camille Cut; and (3) in the sound, just offshore of Harrison County (Figure 1). Wave and current data will be collected by self-contained wave and current systems in trawler resistant mounts. *In-situ* current sensors will be acoustic type (e.g., Acoustic Wave and Current profilers (AWAC) preferred for deployment at depths greater than 10 feet). Data will be retrieved and downloaded every 90 days.


**Figure 1:** MsCIP wave gage locations.

**Analysis Methodology**
*Tropical Storm Simulations*

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Baseline wave data seaward and soundward of Ship Island are not available during tropical storm events, when wave height reduction is highly desirable to mainland residents. Numerical model simulations were thus conducted to estimate the wave height reduction by Ship Island during tropical storms in both its current condition and under the restoration scenario.

Wave modeling was conducted with STWAVE, a spectral wave model that simulates depth-induced wave refraction and shoaling, current-induced refraction and shoaling, depth- and steepness-induced wave breaking, parametric wave growth because of wind input, wave-wave interaction, and white capping. The domain of the model was 140 km by 150 km, extending over a region including Mississippi Sound, Chandeleur Sound, and other portions of the Gulf of Mexico as far south as the Mississippi bird's foot delta and as far as east as offshore of Dauphin Island, Alabama (Wamsley et al. 2013). Fifteen synthetic storms were modeled to capture a range of conditions including high, moderate, and low storm surge. This suite of scenarios includes storms with five different tracks passing over or near Ship Island under combinations of different values for storm minimum central pressure, radius of maximum winds, and forward speeds. The absolute reduction in wave height at the mainland Mississippi coast for the restored island compared to the baseline case (current configuration) varied between 0.2-1.25 m, depending on the storm. Additional information may be found in Wamsley et al. (2013).

*Task #1: Data Analysis, non-Tropical Storm Conditions*
Wave reduction will be calculated as the 90$^{th}$ percentile of the offshore wave heights minus the paired wave heights in Mississippi Sound. Wave height reduction will be calculated for the baseline observations under the current island configuration and the post-construction wave data for each of the two wave gauges deployed in Mississippi Sound.

*Task #2: Data Analysis, Tropical Storm Conditions*
If a tropical storm hits the area during the time period when wave gauges are operational, they will be used to assess the numerical model simulations and their skill in capturing wave height reduction. It is unlikely that a real storm would be a perfect match to any of the 15 simulated synthetic storms. However, since the primary concern in this case is wave attenuation, wave height reduction from the model can be compared during all times when the local wind and offshore wave conditions are similar between the modeled time periods and the observations. Local wind must be considered because during a near-field storm local wave generation may occur within Mississippi Sound. Wave period should be considered given that wave energy dissipation is a function of wave period. Wave direction also influences wave height reduction: in a theoretical extreme case, for example, no wave reduction would be observed for waves propagating offshore (realistically, wave refraction will result in some component of on-shore directed wave energy during storm conditions).

For each of the Mississippi Sound wave gauges, a time-series of wave height reduction will be calculated as the difference between the measured wave heights at that location and the wave height measured at the offshore gauge. These values will be calculated as both the absolute difference and as the percentage of the offshore wave height. The average wave height reduction will then be calculated in bins of different offshore wave height, period, and direction, water depth at the offshore wave gauge, and wind speed and direction. Data will be taken from NOAA Buoy 42012, 44 nautical miles to the southeast of Mobile, Alabama, and NOAA Buoy 42040, 63 nautical miles south of Dauphin Island, Alabama. Other sources of offshore wind and wave conditions, such as numerical model output, will be considered if available. The number and discretization of bins will be based on the variability in the wind and wave conditions.

Time-series of wave height, period, and direction will be extracted from the numerical simulations of all 15 simulated storms at the location of the wave gauges, along with the wind speed and direction at the location of NOAA Buoy 42012. The wave height reduction will then be calculated for each of the sound wave gauge sites as the absolute and percent difference from the wave height measured at the offshore gauge. These values will be averaged for the same wave and wind bins used for the observational data, to compare the simulated wave height reduction with the measured wave height reduction under similar conditions.

**Products**

Task #1:

- Table showing the pre-construction and post-construction wave reduction, calculated as the 90$^{th}$ percentile of the offshore wave heights minus the paired wave heights in Mississippi, for both of the wave gauges deployed in Mississippi Sound.

Task #2:

- Tables (one for each gauge in Mississippi Sound) showing the absolute and percent reduction in wave height from the offshore gauge, binned by wave height, period, and direction, and wind speed and direction (observational data).
- Tables (one for each gauge in Mississippi Sound) showing the absolute and percent reduction in wave height from the offshore gauge, binned by wave height, period, and direction and wind speed and direction (model simulation output).
- Tables (one for each gauge in Mississippi Sound) comparing the absolute and percent difference between model and observation wave reduction for each of the wind and wave bins (e.g., showing the difference between products (1) and (2) to assess the skill of the model in capturing wave height reduction for the restored island case).

**Metadata**

Metadata will be created for all analyses, following ISO standards.

**Literature Cited**

Wamsley, T.V., E.S. Godsey, B.W. Bunch, R.S. Chapman, M.B. Gravens, A. S. Grzegorzewski, B.D. Johnson, D.B. King, R.L. Permenter, D.H. Tillman, and M.W. Tubman. 2013. Mississippi Coastal Improvements Program; evaluation of barrier island restoration efforts. USACE Engineer Research and Development Center, ERDC TR-13-12, 515 pp.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Water Quality Analyses
# Protocol 121

*Protocol version date: 04/04/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***

Water Quality Analysis

East and West Ship islands, separated by Camille Cut, are flanked by Ship Island Pass to the west and Little Dog Keys Pass and Dog Keys Pass to the east. Current flows through these passes and through Camille Cut affect circulation patterns and water quality in the Mississippi Sound. Restoration of the Mississippi barrier island system is estimated to provide significant system wide benefits to the habitats of the Gulf Islands National Seashore (GUIS) and other ecosystems, as well as economic benefits associated with damage and fishery losses avoided and other regional benefits (USACE, 2010). The analyses provided in the MsCIP Comprehensive Plan and Supplemental Environmental Impact Statement indicates that the comprehensive barrier island restoration would result in minimal changes to the water quality of the Mississippi Sound by helping to maintain salinity conditions.

**Purpose of Monitoring and Data Assessment**

To monitor water quality parameters as long-term indicators of change due to the Ship Island Restoration component and the closure of Camille Cut. The long-term responses will be used to perform a strength of evidence approach to evaluate project success. The MsCIP monitoring data, as well as other readily available quality assured and checked long-term data sets, will be used for the establishment of baseline conditions, as well as providing supporting information required to measure progress against success criteria.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**

Changes in primary water quality parameters (salinity, turbidity, dissolved oxygen and temperature) measured in the lee of Ship Island for a period of up to two years following closure of Camille Cute are within the range of historic variability and compare to changes observed at control stations (shown if Figure 1).

**Areas of Interest**

West Ship Island, East Ship Island, Ship Island Pass, Little Dog Keys Pass and Dog Keys Pass, Mississippi Sound

**Interim Target**

The levels of primary water quality parameters (salinity, turbidity, dissolved oxygen and temperature), measured over a year following the closure of Camille Cut, are within the range of the historic variability, and compare to changes observed at control stations.

**AM Trigger**

The levels of the primary water quality parameters (salinity, turbidity, dissolved oxygen and temperature) exceed predicted values and are outside of the range of historic variability.

**Task**

# MsCIP Monitoring and Adaptive Management Program
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1) Conduct baseline water quality data inventory and analysis documenting range of variability, and pre-restoration correlation of observation stations to control stations. Data sets will include 2014-2016 MsCIP monitoring data as well as other readily available quality-assured and checked long-term data sets in the Mississippi Sound. Parameters to be considered are listed in Figure 1 below.
2) Evaluate post-construction water quality results to determine if they fall within the range of pre-restoration variability and compare to changes observed at control stations. Parameters to be considered are listed in Figure 1 below.
3) Compare measured water quality parameters to model simulated results post-restoration. Parameters to be considered are listed in Figure 1 below.

**Analysis Frequency**

Pre-construction - Document (1) pre-construction observations and (2) simulated model results in pre-restoration baseline report. The two of these that will be considered in this analysis are (1) Ship Island in its current configuration, post-Katrina; and (2) a restored Ship Island.

Post-construction -Yr 1- Document differences between year one observations with baseline and control sites.

Post-construction -Yr 2- Document differences between year two observations with baseline and control sites. Final comparisons of WQ parameters with restored Ship Island Model results

**Data Collection Required for Analysis**

*Observational Data*

To document changes and assess whether the closure of Camille Cut results in significant changes in water quality, time series data will be collected at two sites, and discrete data will be collected at nine sites (three control stations, two time series stations and four discrete stations). Data will be collected before, during, and two years following the closure of Camille Cut. Time series of water-quality data within the Mississippi Sound, including temperature, specific conductance, dissolved oxygen and turbidity, will be collected at a minimum of one-hour intervals at USGS East Ship Island Light (ID #301527088521500) near the proposed work area, and at USGS Gulfport Light monitoring station (ID #301912088583300) (red dots, Figure 1), which will serve as a control location to allow the determination of natural or background water quality variations. Discrete water quality sampling will be collected at four discrete sites in the vicinity of Ship Island (blue dots), three control sites in the lee of Cat, Horn and Petit Bois islands (green dots), and at the two time series data sites (Figure 1).

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| | | Supporting Data Collection Efforts | |
|---|---|---|---|
| All | Active | Measured Samples | Observations In-Situ |
| Temperature | X | | X |
| Salinity | X | | X |
| Fixed Solids | X | TSS | |
| Other Phytoplankton | X | CHl | |
| Labile DOC | X | DOC | |
| Labile POC | X | POC=TOC-DOC | |
| Ammonium | X | NH4 | |
| NO2+NO3 | X | NO3 | |
| Labile DON | X | DON=DKN-NH4 | |
| Labile PON | X | PON=TON-DON | |
| Total Phosphate | X | TIP=TP-TOP, or DIP | |
| Labile DOP | X | DOP | |
| Labile POP | X | POP=TOP-DOP | |
| DO | X | | X |
| Dissolved Silica | X | | |

**Figure 1**. Water quality sampling locations.

Weather permitting, water quality sites will be sampled every six to eight weeks, for a minimum of six samples per year pre-construction, and will continue for a minimum of two years following the closure of Camille Cut. Major environmental events, such as extreme drought, hurricanes, or the opening of the Bonnet Carre' Spillway for flood control purposes, may alter the fixed schedule by requiring additional sample collection. Field measurements, collected at the water surface and at 5 foot increments to the bottom, will profile water temperature, specific conductance, pH, dissolved oxygen, and turbidity to document any water column stratification, particularly of salinity and/or dissolved oxygen.

In addition to these *in situ* water column measurements, water samples will be collected at mid depth and will be analyzed for: Total Organic Carbon, Dissolved Organic Carbon, Nitrate, Ammonia, Total Kjeldahl Nitrogen, Dissolved Kjeldahl Nitrogen, Total Phosphorus, Dissolved Inorganic Phosphorus, Total Organic Phosphorus, Dissolved Organic Phosphorus, Total Suspended Solids, and Chlorophyll. These data will allow comparison with previous modeling results.

**Analysis Methodology**

*Numerical Simulation:* Numerical modeling of the circulation and water quality around Ship Island was conducted using the ADCIRC, CH3D-WES, STWAVE and CEQUAL-ICM hydrodynamic and water quality models (Wamsley et al. 2013). ADCIRC was run over the period of 12 March to 18 September, 1998 using winds from NOAA National Data Buoy Center buoys 42007 supplemented, when unavailable, with data from the USACE Wave Information Study (WIS) hindcast. Tidal forcing was applied at the ocean boundary from the East Coast 2001 Data Base of Tidal Constituents. Water levels from ADCIRC were used at the CH3D open boundary conditions. STWAVE was also applied for the period 12 March to 18 September, 1998 so that the resulting radiation stress gradients could be applied within the 3D circulation model CH3D. CEQUAL-ICM was then applied in concert with the combined wave and current numerical model CH3D. CEQUAL-ICM model configuration was calibrated and assessed using observational water quality data from 10 stations located within the Mississippi Sound, primarily along the coast from Waveland to Biloxi Mississippi, for the baseline case (actual island configuration in 1998). Once calibrated, the same time period was modeled for three alternate bathymetry and topographic scenarios. The two scenarios that will be considered in this analysis are (1) Ship Island in its current configuration, post-Katrina; and (2) a restored Ship Island. Additional details on the simulations may be found in Wamsley et al. (2013).

*Analysis of Water Quality Parameters:*
*Task #1: Water quality data inventory, compilation and analysis to characterize baseline water quality*
Water quality inventory and compilation should include all time series water-quality data in the vicinity of the Mississippi Barrier Islands and western Mississippi Sound collected prior to construction at Cat Island and Ship Island. This should include temperature, specific conductance, dissolved oxygen and turbidity at USGS East Ship Island Light (ID #301527088521500) and USGS Gulfport Light monitoring station (ID #301912088583300), as well as the discrete water-quality sampling collected at the four sites in the vicinity of Ship Island, three control sites in the lee of Cat, Horn and Petit Bois islands, and the two time series data sites (Figure 1). In addition, relevant water quality and related data from the Environmental Protection Agency's (EPA) STORET and other long-term state or local water quality data will be obtained. A complete inventory of all retrieved data will be developed. Descriptive statistics, appropriate box and whiskers and time series plots of the water quality data to characterize annual, seasonal, and period of record central tendencies and trends will be made. In addition, exploratory methods such as principle components and cluster analysis and non-metric multidimensional scaling and other procedures will be performed to examine the spatial and temporal relations among water quality variables. If any gradients are detected in the exploratory phase in task #1, these gradients can be used to assess temporal and spatial variation among stations in tasks #2. The five observation stations (four discrete and one time series) should be correlated to the four control stations (three discrete and one time series). In addition, water quality data should be compared with relevant Mississippi Department of Environmental Quality and EPA national water quality criteria on a station by station basis.

*Task #2: Evaluate post-construction water quality values to determine if they are within the range of pre-restoration variability and compare to changes observed at control stations*

Calculate annual, seasonal and post-restoration water quality values at each site to determine if the values are within the range of pre-restoration variability and compare to changes observed at control stations. The analysis of variance (ANOVA) tests or equivalent procedures will be used to test for temporal differences in water quality results from pre- and post-construction and control stations. A Before-After Control-Impact (BACI) design will be used to test differences before and after (temporal variance), as well as to assess the construction impact using the control stations.

*Task #3: Compare measured water quality parameters to model simulated results post-construction*

Model simulation results will also be analyzed for averaged data output (post-Katrina) and restored island scenarios, as well as the change due to the restoration of the island. Because the model was not specifically calibrated for the periods of observation, water quality parameters averaged over the collection time period may be different between the model and the observations due to temporal variability in the system forcing. A subset of the model data will be selected as the best match (most similar) to the observational time periods based on tide range, river flow and wind speed and direction. Water level observations for this selection will be taken from the Waveland and Dauphin Island gauges used in calibrating the model simulations. Wind speed and direction will be used from NOAA Buoy 42040, located 63 nautical miles south of Dauphin Island, Alabama. This gauge is the closest offshore anemometer with wind speed data available at present (Buoy 42007 used for the simulations is no longer in service) and during the time period of simulation. River flow will be collected from 1) Pearl River, 2) Jourdan River, 3) Wolf River, 4) Biloxi River, 5) East Pascagoula, 6) West Pascagoula, 7) Escatawpa River, 8) Alabama River and 9) Tombigbee River.

Comparisons will then be made (percentage and absolute difference) between the pre- and post-restoration model output and observational data for: (1) the pre-restoration; (2) the post-restoration; and (3) the change between pre- and post-restoration modeled water quality parameters. Each of these three comparisons will be made for both the entire time period of the simulations and the periods selected as the best match to the observational time periods. Comparisons (1) and (2) provide an indication of the skill of the model in capturing the time period over which observational data were collected, while comparison (3) serves as the benchmark for evaluating if the changes in water quality due to the restoration are greater than expected. If the mean over the entire period of simulation is different than for the subset of the data best-matched to the times of observation, it may indicate that differences in the observational data are influenced by short time-scale variability and are not as indicative of the influence of the restoration project on a long-term as the full model simulation. Analysis of potential contributions to differences between the model and the observation data other than real-world changes resulting from the restoration (e.g., differences in forcing, differences in observational data processing, etc.) will be used to determine if variation between the model output and observational data are likely due to the restoration, and the results of that analysis may support the need to rerun model simulations to test the sensitivity of the results to parameters that may have changed and/or to use updated bathymetry and forcing conditions that are consistent with the time period of observations.

**Products**

1. Baseline Report documenting the data inventory, compilation and analysis to characterize baseline water quality.
2. The geospatial data containing the parameters used for the analysis described in this protocol will be provided along with International Organization for Standardization (ISO) metadata for each data set.
3. A summary report and statistics derived from comparisons between the baseline conditions and post-construction results and statistics derived from comparisons will be provided.

**Literature Cited**

U.S. Army Corps of Engineers (USACE). 2010. Record of Decision, Mississippi Coastal Improvements Program (MsCIP), Hancock, Harrison, and Jackson Counties, Mississippi. Signed by the Assistant Secretary of the Army for Civil Works. January 14.

Wamsley, T.V., E.S. Godsey, B.W. Bunch, R.S. Chapman, M.B. Gravens, A. S. Grzegorzewski, B.D. Johnson, D.B. King, R.L. Permenter, D.H. Tillman, and M.W. Tubman. 2013. Mississippi Coastal Improvements Program; evaluation of barrier island restoration efforts. USACE Engineer Research and Development Center, ERDC TR-13-12, 515 pp.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Habitat Composition Analyses
# Protocol 131

*Protocol version date: 07/02/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Habitat Composition

**Purpose of Monitoring and Data Assessment**
Document changes in habitat diversity and acreage of emergent/submerged habitats over time and use these data with supporting datasets (bathymetry and topography, shorebird and sea turtle nesting, Gulf sturgeon distribution, benthic/infaunal density, and SAV cover) to develop relationships between emergent and submerged MsCIP Monitoring and Adaptive Management (MAM) Plan habitat types and habitat utilization on Ship Island and Cat Island. This monitoring will be used to measure project performance as a success criterion.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Ten years following the completion of construction on Ship Island the success criteria is that loss of emergent habitat relative to project completion acreage is less than the historical land loss rate. The assessment will include analyses of loss rates of habitat above mean sea level and mean high water using analyses of the change in areal coverage for habitat maps, satellite imagery, and lidar datasets. The land loss rate will come from either literature, such as Morton (2007), or recent satellite-based land change analyses such as Couvillion (2017). Acreage will be determined from the habitat mapping effort conducted immediately after project completion.
AND
Habitat diversity of emergent and submerged habitats is maintained over time, including beach and dune, intertidal flats, wetlands, and upland/scrub shrub.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
Habitat mapping is scheduled to be conducted at regular intervals post-construction and success criteria will be assessed at each interval.

**AM Trigger**
Loss of emergent habitat within ten years greater than a historical land loss rate. Ten years post-construction a reduction in acreage of wetlands on Ship Island due to overwash and sand burial, compared to historical data.

**Tasks**
1. Detailed habitat mapping of Mississippi barrier islands (required for success criteria)
2. Identify relationships between sand burial from storm overwash and emergent/submerged habitat types (supporting analyses for success criteria)
3. Detect changes in habitat diversity and acreage of emergent/submerged habitats pre- and post-construction and compare to historic trends (required for success criteria)

**Analysis Frequency**

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Habitat Composition Analyses
# Protocol 131

*Protocol version date: 07/02/2018*

Task 1: Data collected pre-construction, during construction, and annually for the first and second years following the completion of the construction and planting on Ship Island will be analyzed and assessed. A minimum of two additional assessments will be conducted within the following eight years; exact dates will be determined by the construction schedule and the temporal correlation of survey requirements across the program.
Task 2: Pre-construction. Note, this assessment is repeatable and can be extended into post-construction periods, if desired.
Task 3: Pre-construction and after the completion of planting of Ship Island, potentially targeting years not mapped with aerial imagery (Task 1). Potential years would be three, four, six, seven, eight, and nine years after planting is completed on Ship Island. The exact years and total years mapped will be decided based on available funds, construction schedule and the temporal correlation of collection requirements across the program.

**Data Collection Required for Analysis**

Project-specific 0.3-m resolution, color-infrared stereo and orthophotography, collected during the late fall to winter, satellite imagery, tide gauge data, and lidar (topobathymetric lidar when possible) data. Data will be collected during pre-construction, construction, and annually for the first and second years following the completion of the construction and planting on Ship Island. A minimum of two additional collections will be conducted within the following eight years; exact dates will be determined by the construction schedule and the temporal correlation of survey requirements across the program.

**Analysis Methodology**

*Task #1: Detailed habitat mapping of Mississippi barrier islands*

Habitats will be mapped for all MsCIP islands prior to construction to serve as a baseline, during construction and post-construction. To date, two pre-construction maps have been developed including January 2015 and December 2015. For all mapping efforts, MsCIP will acquire project-specific 0.3-m resolution, color-infrared stereo and orthophotography during the late fall to winter. Habitat categories are developed from existing classification schemes including the National Wetlands Inventory (NWI, Cowardin et al. 1979) and Anderson Land Use/Land Cover classification system (Anderson et al. 1976), as well as custom modifiers to characterize habitat for dune and spoil (Table 1). Habitat classifications are developed via heads up digitizing by an expert photointerpreter. All habitat photointerpretation will adhere to NWI protocols and standards. All habitats will be mapped to subclass-level to distinguish tidal regimes: 1) irregularly-exposed; 2) regularly flooded; and 3) irregularly flooded (Table 2).
As part of the initial baseline mapping efforts, field data collection was conducted in August 2015 to assist with the photointerpretation of barrier island habitats. The best available lidar data along with ancillary imagery datasets from 1998 through January 2015 will also be utilized to help classify areas that may be difficult to identify. Imagery of the project area will also viewed in stereo (i.e., as a three-dimensional image), which helps determine vegetation height and proper habitat classification. Lidar data will be utilized for elevation information that may help distinguish habitats, especially where floating aquatics may be present.

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After completion of habitat classifications, the photointerpreter will perform a Quality Assurance (QA) self-check of their work. In addition, a second photointerpreter will perform a final in-house Quality Control (QC), assuring accuracy and data integrity. The final in-house QC also will review all ancillary data including all available dates of imagery for the project area to ensure consistency of habitat mapping for each time period. After the data has undergone QA/QC protocols, the data will be sent to the MAM Technical Advisory Group for review and comments. Once all comments have been addressed, the final data product will be readied for map production and submitted to an online distribution source.

**Table 1.** Habitat Classification Scheme for MsCIP.

| Habitat class | Description |
|---|---|
| Open Water Salt | Includes all open water in estuarine and marine wetlands and deepwater habitats with vegetative cover less than 30 percent. |
| Open Water Fresh | Includes all open freshwater areas with vegetative cover less than 30 percent |
| Beach/Mud Flat Salt | Includes all wetland habitats adjacent to the subtidal zone with less than 30 percent areal cover of vegetation other than pioneer plants that become established during brief periods when growing conditions are favorable. These areas include wetlands that are regularly and irregularly flooded just above the subtidal zone and below about 1.5 m relative to the North American Vertical Datum of 1988 (NAVD88). |
| Beach/Mud Flat Fresh | Includes all non-tidal wetland habitats with less than 30 percent areal cover of vegetation other than pioneer plants that become established during brief periods when growing conditions are favorable. |
| Wetland Forested Fresh | Forested freshwater wetlands with woody vegetation with heights greater than 6 m that covers at least 30 percent areal coverage. |
| Wetland Scrub Shrub Fresh | Scrub-Shrub freshwater wetlands with woody plants with heights less than 6 with at least 30 percent areal coverage. |
| Wetland Scrub Shrub Salt | Estuarine wetland areas dominated by woody vegetation with heights less than 6 m tall that covers at least 30 percent areal coverage. |
| Marsh Salt | Wetland vegetated areas subject to regular inundation by marine or estuarine waters or influenced by tidal action. This class includes wetland vegetation characterized by erect, rooted, herbaceous hydrophytes that are regularly and irregularly flooded land just above the subtidal zone and below ~1.5 m relative to the NAVD88. |
| Marsh Fresh | Wetland vegetated areas within freshwater tidal or non-tidal that are dominated by erect, rooted, herbaceous hydrophytes. This vegetation is present for most of the growing season in most years. |
| Upland Forested Dune[1] | Upland areas dominated by woody vegetation with heights ≥ 6 m. These areas occur on ridges and are higher in elevation than other forested areas. |
| Upland Scrub Shrub Dune[1] | Upland areas dominated by woody vegetation with heights <6 m. This vegetation type occurs on ridges that are higher in elevation than other areas with scrub shrub. |
| Upland Range Dune[1] | Areas of built up sand along shoreline with established herbaceous vegetation. |
| Upland Barren Dune[1] | Areas of built up sand along shoreline free of vegetation. |

| | |
|---|---|
| Upland Urban | Any man-made object fixed to the land surface as a result of construction, including roads, industrial, residential or recreational structures. |
| Upland Spoil | Areas of spoil deposition along excavated canals. |

[1]These areas include subaerial habitat greater than about 1.5 m relative to the NAVD88 and encompasses foredune, dune, and backslope habitats. Although dune habitat occurs at elevations below about 1.5 m NAVD88, lower elevation dunes are more ephemeral and more frequently overwashed, which reduces their habitat value. Lower-elevation dunes often consist of vegetation more commonly associated with swale habitat and lack a high percentage of common dune vegetation species.

**Table 2.** Hydrologic Regime for MsCIP.

| Habitat class | Description |
|---|---|
| Irregularly exposed | Includes all wetland habitats in which tides expose the substrate less often than daily. |
| Regularly flooded | Includes all wetland habitats in which tides alternately flood and expose the substrate at least once daily. |
| Irregularly flooded | Includes all wetland habitats in which tides flood the substrate less often than daily. |

*Task #2: Assessing the relationship between storm surge and overwash*

The relationship between habitat changes and overwash events will be assessed by comparing habitat impacts observed in satellite imagery to the occurrence of overwash events estimated through analysis of waves and still water levels. The pilot effort will be focused on the tidal flats found on the tips of East and West Ship islands.

*Run-up Analysis and Overwash Frequency*

Candidate overwash events will be identified as occurring during periods when the total water level (tides, storm surge, and wave run-up) exceeds dune or beach ridge height. For this analysis, still water levels (tides and storm surge) will be taken from the nearby NOAA Dauphin Island, Alabama tide gauge (station ID: 8735180). When data from this gauge is unavailable, still water levels will be taken from the NOAA Pensacola, Florida tide gauge (station ID: 8729840), which has been shown to be well-correlated to the Dauphin Island gauge (Wahl and Plant 2015). Wave run-up will be estimated using an empirical formula that includes wave height and period and beach slope (Stockdon et al. 2006). Wave data will be taken from the NOAA station ID 42012 in 28 m water depth, in operation from 1996-present. Gaps in the observational wave data will be filled as needed using an operational wave model such as the NOAA WavewatchIII model (available 1999-present; Tolman 2002) or the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim analysis (available 1979-present; Dee et al. 2011).

This analysis requires accurate measurements of island characteristics, including beach slope (for run-up calculation) and maximum island elevation (height of the dune height, or in the absence of a dune, the beach ridge). This portion of the overwash frequency assessment will be limited to the period 2001 to 2016, covering multiple existent lidar data collections from East and West Ship islands (e.g., 2001, 2004, 2005, 2007, 2008, 2010, 2012, 2015, and 2016). This analysis could be extended to post-construction periods with future lidar collections. Elevation profiles from select transects corresponding to regions backed by wetlands will be examined from the data sets. These data will first be evaluated to identify surveys with sufficient quality and coverage to provide accurate analysis. For this reason, the exact time period considered and the spatial location of analysis will be refined as needed. Because beach slope varies frequently over time, and lidar data can only provide a snapshot, this value will be calculated as the mean beach slope at a given profile from all available data sets. The variability in beach slope over time will be incorporated into an uncertainty estimate. Overwash events will be identified as times when the total water level exceeds dune or beach ridge height from temporally correlated lidar datasets. The dune height will be assumed to be static between lidar collections (e.g., average elevation between 2001 and 2004). The absence of major storms in between the given surveys lessens the probability of significant dune height change during those periods. Uncertainty estimates will include the potential for vertical elevation bias in the lidar-based dune height elevation (10-25 centimeters; Nayegandhi et al. 2009; Wright et al. 2014). The count and frequency of overwash events (i.e., times when the total water level exceeds the dune or beach ridge height) will be calculated per year over the period of analysis.

*Satellite Imagery Analysis and Overwash Impact*
The U.S. Geological Survey Wetland and Aquatic Research Center (WARC) has previously assessed cloud-free Landsat TM 4 & 5 imagery for breach identification and analysis for the barrier islands in the Mississippi Sound (Couvillion 2017). Building on this assessment, cloud-free, multi-temporal Landsat TM 4-5, Landsat 8, and possibly Sentinel-2 satellite imagery will be used to identify possible overwash events and, when possible, map extent and severity of overwash impacts. Please note, while the use of satellite imagery to detect overwash events and gauge the severity of impacts from overwash is theoretically possible, the availability of cloud-free pre- and post-overwash event imagery will be the limiting factor.

It has long been established that reflectance is driven by the properties of the combinations of materials being remotely sensed (Nash and Conel 1974). Distinct spectra, corresponding to specific material types (e.g., sand, vegetation, and water), function as endmembers and can be correlated with specific land cover classifications. The concept of spectral unmixing operates under the assumption that a relationship exists between the fractional abundance of the endmembers for a remotely sensed observation (i.e., pixel) and the spectra in the reflected radiation (Keshava and Mustard 2002). Two spectral unmixing methods will be explored:
1. least squares linear approach
2. machine learning approach (i.e., artificial neural networks, support vector machine, etc

Linear unmixing requires endmember determination of pixels that are nearly “pure” (i.e., 100% coverage of a single endmember) that bound the data in n-dimensional space (i.e., n-dimensional plot of pixels by spectral bands or indices) (Mathieu-Marni et al. 1996). Largely due to complexities associated with the use of nonlinear unmixing algorithms, the least squares linear approach is the most commonly used algorithm for spectral unmixing (Keshava and Mustard, 2002). Numerous studies have deployed this approach in coastal wetlands and dune systems (Kearney et al. 2002, 2011; Lucas et al. 2002; Shanmugam et al. 2003; Kearney and Ritter 2011). Several constraints, such as requiring that the sum of the fractional abundances equal one, and that fractional abundances are positive values between zero and one, are applied to the least squares algorithm (Keshava and Mustard 2002; Rodgers and Kearney 2003). A normalized difference transformation approach could be explored to develop spectral mixture models for general fractional coverage of vegetation, soils (i.e., bare/sand), and water (Kearney et al. 2002, 2011; Rodgers and Kearney 2003) using Landsat imagery (i.e., Landsat TM 4, 5 and Landsat 8). This approach will involve transformation of cloud-free Landsat imagery into the normalized difference vegetation index (NDVI; Rouse et al. 1973; eq. 2), the modified normalized difference water index (MNDWI; Xu 2006; eq. 3), and the normalized difference built-up index (NDBI, Zha et al. 2003; eq. 4).

$$NDVI = \frac{P_{NIR} - P_{red}}{P_{NIR} + P_{red}} \tag{1}$$

$$MNDWI = \frac{P_{green} - P_{MIR}}{P_{green} + P_{MIR}} \tag{2}$$

$$NBDI = \frac{P_{MIR} - P_{NIR}}{P_{MIR} + P_{NIR}} \tag{3}$$

In the equations above, $P_{NIR}$ represents the reflectance for the near-infrared band, $P_{red}$ represents the reflectance in the red band, $P_{green}$ represents the reflectance in the green band, and $P_{MIR}$ represents the reflectance in the middle-infrared band.

The second approach would use distribution-free (i.e., nonparametric) machine learning algorithms (e.g., artificial neural networks, support vector machine, etc.) that can utilize nonlinear algorithms to develop models for estimating fractional coverage of bare land, vegetation, and water. This approach would follow the approach of Foody et al. (1997) by utilizing satellite imagery indices (i.e., NDVI, MNDWI, NBDI) to create a map of bare land, vegetation, and water from high-resolution orthophotography acquired near the acquisition date of the satellite imagery (i.e., within two-to-four weeks). The map of bare land, vegetation, and water would be used as ground reference data and the satellite imagery indices would serve as predictor variables. Pixels would be randomly sampled and used as training, testing, and validation data to develop models to predict the fractional coverage of bare land, vegetated, and water. Separate models would be created for Landsat 8 and Landsat TM 4-5 images. The feasibility of an automated unmixing method using ERDAS Imagine (Hexagon Geospatial, Norcross, GA) will also be evaluated in order to select the most efficient methods. However, if none of these unmixing methods prove to be feasible within the scope of this effort, we will use the develop simple discrete maps depicting bare land, vegetation, and water developed from the previously mentioned indices through the use of level slicing and manual editing.

For both unmixing approaches, vegetation pixels would be those pixels with 40% or greater fractional vegetation (Kearney and Ritter 2011). Using the multi-temporal satellite imagery, long-term mean annual NDVI curves can be developed for vegetated pixels (e.g., pixels that are vegetated at least four months of the year). Overwash occurrences could then be investigated by identifying instances within the year where the NDVI curve abruptly deviates (i.e., as evidenced by a sharp reduction in greenness) from the long-term mean NDVI curve. Select time periods when satellite imagery data are available will be used to assess the total water level analysis of overwash frequency (e.g., the threshold of overwash may need to include a duration component, wherein overwash events are only estimated to have occurred when the total water level exceeds the dune crest for some, as yet undetermined, minimum amount of time).

For instances where pre- and post-overwash imagery is available, the fractional endmember maps could be used to assess the extent and severity of overwash impacts. Analysis could be used to determine if a vegetation pixel changed (i.e., the change in greenness exceeds the mean change for the pre-post comparison). For overwash events that occur during the fall and winter, it may be difficult to differentiate impacts from overwash impact events from typical fall vegetation senescence. Analysis of long-term senescence rates may be helpful for indicating more rapid reductions in greenness associated with overwash events. If numerous overwash events can be identified and assessed, vegetation impact severity could be measured relative to the mean change in fractional abundance for vegetated pixels for all overwash events, collectively. The vegetation impact severity could be mapped by classifying change pre- and post-overwash into several classes (e.g., low, medium, and high). Testing would be required to determine the feasibility and determine the exact number of instances in which overwash impact severity could be assessed. If feasible, the relationship between storm water level and overwash severity, as well as impacts to habitat, could then be assessed.

*Task #3: Assessing habitat diversity pre- and post-construction relative to historic trends*
Development of the historical habitat change trend and comparison with the contemporary habitat change trend (i.e., pre- and post-construction) will include analyses of historical and project-specific barrier island habitat mapping efforts and land/water analyses using satellite imagery.

*Trend Development with Existing Habitat Maps and Project-specific Habitat Maps*
The habitat map analysis approach could include habitat maps developed as part of the NWI from 2002 and the MsCIP pre-construction baseline data from 2015 and 2016 (i.e., includes NWI classes). While the pre- and post-construction habitat change (i.e., contemporary habitat change) could be compared directly using the classification scheme used by the MsCIP habitat mapping team, comparing the trend from pre- and post-construction with historic data will require some standardization (i.e., the crosswalking of classes). Although older data is available (e.g., 1959

and 1979 habitat maps developed by the U.S. Geological Survey WARC), these data were used a more generalized classification scheme than the does the NWI (Cowardin et al. 1979), making direct comparisons difficult.

The data could be summarized for several categories, including broadly as land and water classes, three classes representing upland, wetland, and water, respectively, and with the most common thematic detail possible across all datasets (e.g., regularly flooded and irregularly flooded wetlands). The habitat mapping trend development could analyze trends for broad habitat classes (i.e., wetland, dune/upland, beach, shrub/scrub, etc.) and/or habitat classes with tidal regimes (e.g., regularly flooded and irregularly flooded wetlands). Contemporary and historical change will be depicted using tables and graphs. Linear trends will be determined for contemporary and historical change periods.

It should be noted that some identified changes may be artifacts of technological advances in imagery resolution and methodology; the NWI maps developed for 2002 were created using 1-m orthophotography, whereas the more recent project-specific, habitat maps were created using 1-ft orthophotography.

*Trend Development with Satellite Image Analyses*
The U.S. Geological Survey WARC has previously assessed cloud-free Landsat TM 4, 5, and 7 imagery for breach identification and land change analysis for the barrier islands in the Mississippi Sound (Couvillion 2017). This analysis will be furthered by the addition of newly-available satellite imagery sources and the calculation of pre- and post-construction trends for assessment of project effects. Pre- and post-construction trends will be developed using 1) previously analyzed Landsat TM 4, 5, and 7 imagery; 2) Landsat 8 imagery which has become available since the last analysis; and 3) Sentinel-2 imagery. Sentinel-2 imagery is only available from 2015, so historical trends will primarily rely on Landsat imagery. Differences in land areas and the resulting trends assessed from the two sensors will be analyzed and a method for facilitating comparability between the two estimates will be developed. All cloud-free images from the previously-mentioned sensors will be utilized in this analysis.

The satellite image analyses trend development will be focused on assessing change in submerged and emergent lands. A subpixel fraction approach similar to the approach outlined in Task 2 will be used. Imagery classification will rely heavily upon the MNDWI. Flexibility in the dates of the pre- and post-construction time periods will be maintained, as construction completion dates are dependent upon a number of highly-variable external factors. While the exact time periods are flexible, there are minimum requirements to which we will adhere. A minimum of two years pre- and post-construction is necessary for adequate distinction of normal environmental variability from real trends, and the determination of statistically significant differences. Contemporary and historical change will be depicted using tables and graphs. Linear trends will be determined for contemporary and historical change periods.

**MsCIP Monitoring and Adaptive Management Program**
**Data Analysis Protocol:**
**Habitat Composition Analyses**
**Protocol 131**
*Protocol version date: 07/02/2018*

### Products

Task #1:

1. Detailed habitat map as a ESRI shapefile with ISO-compliant metadata

Task #2:

1. Count and frequency of overwash events from the total water level and satellite imagery analyses
2. Graphs showing the relationship between storm water levels, dune heights, and likelihood of overwash.
3. *If possible, maps showing the extent of overwash onto emergent wetlands per overwash event for instances in which overwash impacts are identifiable via satellite imagery*
4. *If possible, relationship between storm water level and overwash extent*
5. *If possible, identify recovery times (i.e., return to average vegetation coverage and vigor) from storm-induced overwash impacts*

Task #3:

1. Graphic depiction of contemporary and historical change. Linear trends will be determined for contemporary and historical change periods.

### Metadata

Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Protocol
# Benthic and Infaunal Species
# Protocol 201

*Protocol version date: 03/08/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Benthic and infaunal species

**Purpose of Monitoring and Data Assessment**
Document benthic and infaunal communities (density and diversity) on and around Ship Island and Cat Island prior to and after construction to evaluate the reestablishment of benthic populations post-construction at placement sites. The monitoring will provide supplementary information needed for Gulf sturgeon and shorebirds compliance monitoring as required in the Biological Objectives (BOs) issued for the project and for the suitability of placement areas as feeding habitat for the Gulf sturgeon and shorebirds. See related Protocols 223 (Gulf Sturgeon Foraging Habitat) and Protocol 241(Benthic and Threatened and Endangered Shorebird Foraging).

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Three years post-construction the success criteria is that the average biomass level within the project area is at least 70% of the pre-project average biomass level.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island, Horn Island, Petit Bois

**Interim Target**
There are no interim targets related to benthic and infaunal communities for placement and areas outside of those related to Gulf sturgeon captured. See Protocol 223 (Gulf Sturgeon Foraging Habitat).

**AM Trigger**
Success criteria not met by five years post-sand placement.

**Task**
Identify benthic and infaunal species biodiversity (abundance, biomass, density, richness, diversity, and evenness) and determine whether populations/densities re-establish to pre-project levels.

**Analysis Frequency**
Pre- and post-completion of all Ship Island sand placement activities

**Data Collection Required for Analysis**
Benthic community surveys collected at placement, and reference sites. Sand placement sites will be re-surveyed approximately two years after the completion of construction at Cat Island, and two years after the completion of construction on Ship Island. If success criteria are not met during the three-year sampling event an additional sampling period will be included.

**Background**

# MsCIP Monitoring and Adaptive Management Protocol
# Benthic and Infaunal Species
# Protocol 201

*Protocol version date: 03/08/2018*

Barrier island environments are extremely dynamic due to the exposure to frequent disturbances from storms, sediment disposal, waves, currents, and sea-level change (Peterson and Bishop 2005). As a result, the taxa richness and density of barrier island benthic and infaunal communities can vary significantly, dominated by species able to tolerate disturbances and/or rapidly colonize disturbed areas (Rakocinski et al. 1990, 1993, 1998; Wilber et al. 2007; USACE 2009). Benthic invertebrates are useful as biological indicators because of their relatively sessile nature (i.e., they respond to local effects), potential to be sampled cost-effectively, and ability to reveal ecologically meaningful patterns at coarse scales (Warwick 1988; Martin et al. 2005). Additionally, benthic invertebrates are important food sources for species of concern, such as shorebirds and Gulf sturgeon.

The soft sediment and sand bottoms present in the tidal passes and beaches of the barrier islands and adjacent shallow waters provide habitat for many benthic invertebrate species. It is anticipated that benthic and infaunal communities will be displaced in the short-term in response to dredging and placement of dredged material. Sampling efforts were designed to characterize macrobenthic biological resources at sand placement areas (Cat Island, East and West Ship islands, Horn Island, Petit Bois Island), appropriate reference areas (which are unlikely to be affected by construction), and in foraging habitat utilized by Gulf sturgeon and shorebirds. Benthic studies included the sorting, identification, and enumeration of benthic macroinvertebrates collected in each area.

The objective of this task is to characterize the benthic and infaunal community before and after construction projects associated with the Mississippi Coastal Improvements Program (MsCIP). Information acquired during this task will help assess whether population densities and diversity will return to baseline levels at placement, and shorebird and sturgeon feeding sites.

**Collection Methodology**

*Timing of Sampling*

Pre-construction baseline benthic community surveys were collected in 2010 (June 2 – 10 and September 2 – 6) and 2011 (April 29 – May 6) at borrow, placement, and reference sites. In late fall 2011 additional sites were surveyed to support Gulf sturgeon monitoring and in winter 2015 (January 14 – 19) sites were added for shorebird monitoring. Post-construction sampling will be conducted at the sand placement sites previously surveyed in 2010, 2011, and 2015 and at potential new locations where sturgeon and shorebird feeding would occur after closure of Camille Cut. Sand placement sites will be re-surveyed approximately three years after the completion of all Ship Island sand placement activities.

Where possible, these surveys will be coordinated with those required for Gulf sturgeon and shorebirds. Benthic surveys for shorebird foraging habitat are also planned to occur during the winter three years after the completion of all Ship Island sand placement activities (See Protocol 241-Benthic and Threatened and Endangered Shorebird Foraging). Post-construction Gulf sturgeon foraging habitat surveys are scheduled for the fall and spring approximately six months after the completion of all Ship Island sand placement activities (See Protocol 223-Gulf Sturgeon Foraging Habitat).

The Deepwater Horizon Oil Spill in the Gulf of Mexico occurred on April 20, 2010. The June sampling event, which provided a broad-scale view of habitat characteristics and macroinfaunal assemblages prior to determining where the best sand borrow areas would be located, occurred before significant amounts of oil infiltrated the Mississippi barrier island beaches and Mississippi Sound. The September sampling event occurred after oil was detected on the barrier island beaches and in the Mississippi Sound. The April-May 2011 surveys occurred after months of oil cleanup in the Gulf of Mexico. When significant changes were found in the macrofaunal assemblages between the June and September sampling periods (pre- and post-oil spill), a third survey was established from April to May.

An additional sand borrow site was added to the sampling program in 2011. The Disposal Area 10 (DA10) borrow area was sampled in November 2011.

*Sample Replication*
To provide adequate statistical power, four replicate samples were collected at most stations. However, eight replicate samples were taken per station during each survey at beach/subtidal sites.

*Benthic and Infaunal Sampling Locations*
<u>Offshore Borrow and Reference Sites in the Gulf of Mexico:</u> The borrow area sampling consisted of 12 stations in the western part and four stations in the eastern part. The larger western area is approximately 23 miles long and 3-8 miles wide and contains a wide range of benthic habitats. It included a Littoral Shoal/Disposal Area and a Fluvial/Ebb-tide Delta area. The smaller eastern area is approximately five miles wide and six miles long. Four stations were sampled at the reference sites.

<u>Sand Placement and Reference Sites in the Mississippi Sound</u>: We sampled at five sand placement areas: (1) four stations off East Petit Bios Island; (2) five stations off East Horn Island; (3) five stations off East Ship Island; (4) three stations associated within Camille Cut; (4) one station on the Mississippi Sound side of West Ship Island; and (5) two stations associated with Cat Island. At the request of the U.S. Army Corps of Engineers (USACE), we moved three placement site stations located off the eastern end of Ship Island closer to the island for the September 2010 and April-May 2011 surveys to better represent planned sand placement locations. We also sampled five stations, located closer to Ship, Horn, and Petit Bois islands in the Mississippi Sound, that were previously characterized by the USACE.

<u>Beach/Subtidal Sand Placement Sites</u>: Four transects, oriented perpendicular to the shoreline, were established at Petit Bois, Horn, Ship, and Cat islands in association with the sediment placement areas. Two transects were located in the beach/subtidal zone on the Mississippi Sound side and two transects were located on the Gulf of Mexico side of each island. Three transects

were established in the Cat Island placement area (two east of Cat Island and one to the west of Cat Island). Four transects were established at a reference site on the western end of Horn Island, with two transects being located on the Mississippi Sound side and two transects located on the Gulf of Mexico side of the island. Along each transect, there were three sampling stations positioned at regular distance intervals representing shallow, mid, and deep (depths of 10 ft, 20 ft, and 50 ft, respectively).

**Analysis Methodology**

*Laboratory Processing*

Infauna: Benthic samples were again rinsed through a 0.5 mm mesh screen to remove preservatives and sediment, stained with Rose Bengal, and stored in 70% isopropanol solution until processing. We placed sample material (sediment, detritus, and organisms) in white enamel trays for sorting under Wild M-5A dissecting microscopes. Sorted macroinvertebrates were placed in labeled glass vials contacting 70% isopropanol, with each vial representing a major taxonomic group (e.g., Polychaeta, Mollusca, Arthropoda). All macroinvertebrates were removed and identified to the lowest practical identification level (LPIL), which, unless the specimen was a juvenile, damaged, or unidentifiable, was generally to species level. We recorded the number of individuals of each taxon, excluding fragments. A voucher collection was prepared, composed of representative individuals of each species not previously encountered in samples from the region.

Each sample was analyzed for wet-weight biomass (g) of the major taxonomic groups identified. After identification, each taxonomic group was placed in separate vials and preserved in 70% isopropyl alcohol. A biomass technician removed the organisms from each vial, placed them on a filter paper pad, gently blotted them with a paper towel to remove moisture, placed them in a tared weighing pan, and weighed the pan to the nearest 0.1 mg using a Mettler Model AG-104 balance.

*Community Assemblage Analyses*

All laboratory data were entered for each species by station and replicate. The summary report for each station included a taxonomic species list and quantified benthic community parameters. Several numeric indices were calculated for each sample, including: (1) infaunal abundance, the total number of individuals per square station; (2) infaunal density, the total number of individuals per square meter; (3) taxa richness, the number of taxa present at a station; (4) taxa diversity (Shannon's Index H'); and (5) evenness (Pielou's Index J'). A SIMPER analysis will also be conducted to compare species among years.

Taxa diversity is often related to the ecological stability and environmental quality of the benthos. We used Shannon's Index (Pielou 1966) to estimate taxa diversity, which is dependent upon the number of taxa present (taxa richness) and the distribution of all individuals among those taxa (evenness or equitability). To quantify and compare the evenness in the fauna to the taxa diversity for a given area, Pielou's Index J' (Pielou 1966) was calculated as:

$$J' = \frac{H'}{lnS}$$

Where *ln*S = H'max, the maximum possible diversity when all taxa are represented by the same number of individuals, therefore:

$$J' = \frac{H'}{H'max}$$

Univariate statistics were used to compare taxa richness and density at stations between transects on a given island and between stations on different islands (SAS Institute, 2009).

*Cluster and MDS Analyses*
Cluster analysis was performed on the benthic macroinvertebrate data by calculating the Bray-Curtis similarity coefficient for all pairs of sampling stations after square root transforming the original taxa abundances (Clarke and Gorley 2007). Clusters were formed using the group-average linkage method between similarities.

Non-parametric multi-dimensional scaling (MDS) was then performed on the similarity matrix generated by the cluster analysis. MDS represents sample stations in 2-dimensional space such that the relative distances apart of all points were in the same rank order as the relative dissimilarities of the samples as calculated by the Bray-Curtis coefficients. Points close together in an MDS plot represent sample stations that are similar in taxa composition and points far apart represent different assemblages (Clarke and Gorley 2007).

**Metadata**
Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Acreage Calculations and Distribution
# Protocol 211

*Protocol version date: 02/22/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Submerged Aquatic Vegetation (SAV) Coverage

**Purpose of Monitoring and Data Assessment**
Document SAV distribution and acreage over time at Cat Island and East and West Ship islands and to evaluate the effects of changing circulation and sedimentation patterns on and around Ship Island. This assessment is the Tier I of the MsCIP multi-scale SAV assessment and is focused on distribution and acreage.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Within ten years post-construction the success criteria is total SAV acreage, distribution (compared to 2011 & 2014) and condition (e.g., percent cover and canopy height) and species composition (compared to 2011–2016) on Ship Island are similar to the pre-construction period.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
Within three years post-construction, maintain 2014 pre-construction SAV distribution.

**AM Trigger**
Reduction in SAV cover and condition within six years following the closure of Camille Cut

**Task**
Determine acreage of SAV from the distribution/coverage area maps and imagery provided by a USACE contractor to evaluate the success criteria related to total acreage of SAV (required for success criteria)

**Analysis Frequency**
Analysis of SAV acreage will be based on data collected during pre-construction (2010 & 2014) and a minimum of three post-construction surveys conducted after the closure of Camille Cut, at approximately three, six and nine years following the closure of Camille Cut

**Data Collection Required for Analysis**
Orthophotography, and, when possible, coincident topobathymetric lidar will be collected twice pre-construction (2010 & 2014) and a minimum of three times post-construction. The post-construction surveys will be timed to correspond with U.S. National Park Service SAV monitoring surveys, scheduled to occur every three years beginning in 2019.

**Background**

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Acreage Calculations and Distribution
# Protocol 211

*Protocol version date: 02/22/2018*

Regional SAV monitoring efforts often include a multi-scale monitoring approach that includes station-level field surveys and landscape-scale assessments from remotely sensed data (Dunton et al. 2010; Kopp and Neckles 2009; Moore et al. 2000; Neckles et al. 2012; Wilson and Dunton 2012). Often these programs are interested in monitoring SAV acreage, distribution, condition, and species composition. This protocol will outline how remotely sensed data will be used to assess the acreage and distribution of SAV beds in the nearshore waters of Cat and East and West Ship islands.

Specifically, this protocol will answer the following questions for SAV in nearshore waters of Cat and East and West Ship islands: 1) What is the coverage and spatial distribution of seagrass for the islands pre- and post-construction (i.e., closure of Camille Cut)? and 2) How do the post-construction SAV coverage and spatial distribution compare to the pre-construction coverage and spatial distribution?

**Analysis Methodology**

*Change identified in SAV Aerial Survey Distribution Maps*

The overall acreage of patchy and continuous pre-construction and post-construction SAV will be summarized per island from generalized SAV maps. As the name suggests, laying within the generalized areas of patchy SAV are discrete SAV patches interspersed with gaps (i.e., sandy areas without SAV coverage). To date, USACE Contractor Barry Vittor and Associates, Inc. has mapped SAV as generalized polygons of patchy and continuous SAV in the summer of 2010 and the early fall of 2014 (Vittor, B.A. and Associates, Inc. 2011, 2015). Similar generalized maps will also be produced in the future to characterize SAV post-construction (i.e., one, two and 10 years post completion of Camille Cut closure). One limitation of the 2010 and 2014 pre-construction surveys is the temporal variability. As previously mentioned, the 2010 survey was conducted in the summer, while the 2014 survey was conducted in the early fall during peak biomass. Thus, we will use the 2011 and 2014 data as the pre-construction conditions when comparing pre- and post-construction maps, and we will collect future surveys in the early fall (i.e., late September through early October) during peak SAV biomass to ensure temporal consistency with 2014 data. We will compare the overall coverage and produce maps of spatial change for general SAV coverage maps by comparing the overall 2014 SAV maps to post-construction maps.

*Image processing*

We will build upon the SAV mapping efforts by explicitly delineating and estimating acreage of discrete SAV patches. This is necessary in order to more accurately assess the SAV restoration success criteria. Discrete SAV areas will be calculated from high-resolution color-infrared orthophotography collected by a USACE Contractor. As previously mentioned, the 2010 pre-construction survey was conducted in the summer while the 2014 survey was conducted in the early fall during peak biomass. This will be rectified by mapping discrete beds using orthophotography collected in the fall of 2011.

Specifically, the 2011 SAV maps will be developed from imagery collected via the Deep Water Horizon National Resource Damage Assessment (NRDA) efforts. The 2011 NRDA imagery has a spatial resolution of 0.3 m and the 2014 imagery has a spatial resolution of 0.5 m. In order to standardize the spatial resolution, the 2011 imagery and all future imagery will be resampled to 0.5 m using bilinear interpolation if the native spatial resolution is not 0.5 m. All maps produced will be referenced to the North American Datum 1983 and Universal Transverse Mercator Zone 16 North coordinate system. Imagery will be georeferenced to ensure the spatial registration is consistent (i.e., between years and within year from frame to frame). The root mean square error (RMSE) will be reported for all georeferencing conducted. Digital orthophotography in the form of GeoTIFF frames, not compressed mosaics, will be used for map production.

*Restricting depth of mapped areas*
In the turbid waters of the Mississippi Sound, SAV is commonly restricted to water depths of about 2 to 3 m (Eleuterius 1987, Heck et al. 1996). Restricting the area mapped for the SAV efforts will help to increase the efficiency of the SAV mapping efforts. To delineate the offshore extent for SAV mapping efforts, a generalized contour will be developed for a water depth of 3 m or less using either an existing topobathymetric digital elevation model (TBDEM) or the creation of a new TBDEM using Empirical Bayesian Kriging (Krivoruchko, 2012) in Esri ArcMap (Environmental Systems Research Institute, Redlands, CA), Ordinary Kriging, or inverse distance weighted interpolation. While the source of the bathymetric data may vary by island and by time, the best available data will be used for producing a TBDEM. The TBDEM will need to be transformed from the orthometric datum of North American Vertical Datum 1988 (NAVD88) to a locally relevant tidal datum (e.g., local mean sea level). We will use observations collected at the nearby NOAA Dauphin Island, Alabama tide gauge (station ID: 8735180) to transform elevations relative to NAVD88 to local mean sea level.

*Mapping approach*
The SAV maps will be produced using an object-based approach with Trimble eCognition (Westminster, CO, USA), following the procedures developed by Lathrop et al. (2006) and Urbański et al. (2009) and followed by NRDA's SAV mapping efforts. Object-based classification typically outperforms pixel-based classifications when used to classify high-resolution aerial photography (Myint et al. 2006, Yu et al. 2006). Our methods will be similar to previous mapping efforts in the Mississippi Sound (Carter et al. 2011). Due to the ability to penetrate water, the green band from the color-infrared imagery will be utilized for map production (Peneva et al. 2008). Additionally, for each frame, the imagery will be used to produce an ancillary dataset using a principal components analysis (PCA). Maps will be created using supervised threshold analyses using the information from the green band and the PCA components. Image objects will be classified by either a presence or absence of SAV. Maps will be produced by frame, and will be mosaicked into a seamless classification by island for each year. Classifications will be inspected and manually edited to ensure high accuracy. A minimum mapping unit (MMU) will be selected based on analysis of curves of polygon size per map to standardize the map products (i.e., 3.75 $m^2$ was used as the MMU for the East Ship Island pilot

effort). This MMU will be used as the standard for subsequent classifications. Figure 1 includes a map produced for a pilot project that used this methodology to map SAV for East Ship Island.

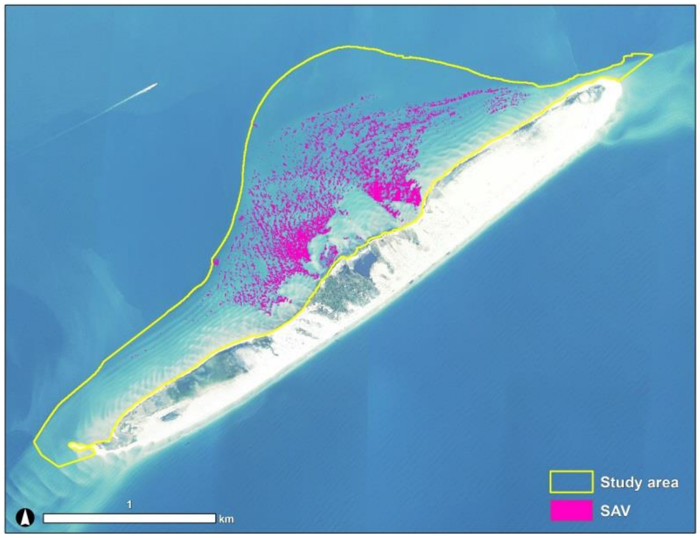


**Figure 1.** Map of discrete SAV beds offshore of east Ship Island for 2014.

*Accuracy assessment*

For each island, an accuracy assessment will be conducted using 50 randomly distributed reference points within areas with SAV presence and 50 randomly distributed points in areas for which SAV was absent. Each point will be buffered by the MMU. For a limited number of areas (~10 per island), we will use temporally-correlated field data collected by either the USACE Contractor or the National Park Service. To augment the number of samples, we may need to use photointerpretation of source imagery to gauge the presence or absence of SAV. The 2011 seagrass map may have limited points for accuracy assessment and will be developed largely from photointerpretation of aerial imagery. For the years with seagrass mapping, we recommend that future field efforts collect sufficient field verification points (i.e., at least 50 points with seagrass and 50 points without seagrass from each island) along longitudinal transects. These data could also be used for analyses associated with the multi-scale assessment (MsCIP MAM protocol 212). Accuracy assessment points will be used to assess the accuracy of SAV maps per island. Accuracy assessments will include a contingency matrix and calculation of Cohen's Kappa statistic (Cohen 1960).

*Distribution and Coverage Change*

The spatial structure of these beds is also an important feature of interest to ecologists and natural resources managers. SAV meadow spatial structure of can be highly variable, ranging from highly fragmented to more continuous meadows (Duarte et al. 2006). Patch configuration has important ecologic implications (Hensgen et al. 2014; Johnson and Heck 2006). Thus, spatial indices (i.e., patch statistics), borrowed from the field of landscape ecology, have increasingly been used to assess SAV meadow patch configuration. Sleeman et al. (2005) assessed the ability of various spatial indices for discerning varying levels of fragmentation of SAV off the coast of western Australia using a quadrat analysis at a single scale. Santos et al. (2011) evaluated the relationship between freshwater inflows and SAV spatial configuration using spatial indices calculated for multiple scales in south Florida. Using field observations, Ramage and Schiel (1999) analyzed SAV patch growth over a 14-month period in southern New Zealand. Barrell and Grant (2013) conducted a hot spot analysis of SAV coverage using Getis Gi* (Getis and Ord 1992) analyses in southeastern Canada. Sheppard et al. (2007) used both Moran's I (Cliff and Ord 1973) and nearest neighbor analysis (Clark and Evans 1954) along with other spatial indices to understand the composition and configuration of SAV habitat in eastern Australia.

Sensitivity to scale changes are an important, but sometimes overlooked, factor related to the application of spatial indices (Wu 2004). Lacunarity, a measure of spatial heterogeneity (Mendelbrot 1983, Plotnick et al. 1996), is a parsimonious metric that could provide information on SAV meadow spatial structure over space and time across a range of spatial scales. Lacunarity has been used to study the habitat fragmentation in tiger bush habitats in West Africa (Wu et al. 2000), patterns related to tree crown size (Butson and King 2006), habitat structure and beetle utilization (McIntyre and Wiens 2000), texture in remotely sensed imagery (Myint and Lam 2005), and gap structure and dispersal success (With and King 1999).

Lacunarity will be used to assess the spatial configuration (i.e., gap structure) of the SAV beds. Esri ArcMap 10.X (Environmental Systems Research Institute, Inc., Redlands, CA, USA) will be used to calculate lacunarity values. Allain and Cloitre ( 1991) calculated lacunarity using the gliding box algorithm () using the following equation:

$$\Lambda(\mathrm{r}) = \frac{\sum_M M^2 Q(M,r)}{[\sum_M M Q(M,r)]^2} \quad (1)$$

In the above equation, $\Lambda$(r) represents the lacunarity for box radius *r*, *M* represents the box mass, and *Q(M,r)* represents the probability of box mass M with a box radius *r* (Plotnick et al. 1996). Analysis will be conducted to determine the extent at which lacunarity can be calculated, while also avoiding issues associated with edges associated with the irregular study area (i.e., the maximum box size may vary by island or region of an island). Lacunarity will be analyzed using standardized log-log plots.

Additional statistics of similarity will be calculated at local and global scales, including the general statistics (i.e., total seagrass mapped, total number of patches, median patch size, variability in patch sizes) and a global and local similarity index calculated for quadrats (e.g., 200 m x 200m). The index will include two parameters measuring coverage agreement and the spatial co-occurrence agreement. Specifically, the absolute value of the difference between spatial SAV percent coverage will be combined with the Jaccard coefficient of similarity (Jaccard 1912) using the following equations:

$$Csim = |PC_{T1} - PC_{T2}| \quad (2)$$
$$J = \frac{A}{B+C+A} \quad (3)$$
$$CSI = 0.6Csim + 0.4J \quad (4)$$

In the above equations, Csim represents the coverage similarity, $PC_{T1}$ represents the percent coverage of SAV for pre-construction, $PC_{T2}$ represents the percent coverage for post-construction, J represents the Jaccard coefficient of similarity, A represents total agreement for SAV pixels for two time periods, and B and C indicate disagreement between seagrass map between time periods for both potential cases (i.e., loss of SAV post-construction and addition of new seagrass post-construction, respectively), and CSI represents the composite similarity index. Note, as currently constructed, the CSI more heavily weights coverage similarity then spatial co-occurrence. Alternative weights can be explored, if necessary.

**Products**

1. Generalized SAV maps and products:
   - Overall acreage of patchy and continuous pre-construction and post-construction SAV area from SAV aerial map products per period
   - Change map between SAV aerial mapping products developed in 2014 and post-construction
2. Discrete SAV patch maps and products:
   - A geodatabase containing maps of discrete SAV patches by island and period
   - Federal Geographic Data Committee (ISO) compliant metadata for all spatial products
   - An accuracy assessment by island and period
   - Plot of lacunarity per SAV patch map
   - Global and local CSI statistics
3. Brief report on methods and acreages

**Metadata**

Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Condition and Composition Analyses
# Protocol 212

*Protocol version date: 03/07/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Submerged Aquatic Vegetation (SAV) Coverage

**Purpose of Monitoring and Data Assessment**
Document SAV distribution, acreage and condition (e.g., percent cover and canopy height) and species composition over time at Cat Island and East and West Ship islands and to evaluate effects of changing circulation and sedimentation patterns on and around Ship Island. This assessment is Tier II of the MsCIP multi-scale SAV assessment and is focused on distribution and acreage.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Within ten years post-construction the success criteria is total SAV acreage, (compared to 2011 & 2014) and condition (e.g., percent cover and canopy height) and species composition (compared to 2011–2016) on Ship Island are similar to the pre-construction period. The analysis presented here will be used in conjunction with the analysis conducted under Protocol 211 (Submerged Aquatic Acreage Calculations and Distribution) to determine if this success criteria are met.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
One year post-construction, maintain 2014 pre-construction SAV distribution.

**AM Trigger**
Reduction in SAV cover and condition within six years following the closure of Camille Cut.

**Task**
Compare/integrate seagrass maps with National Park Service Gulf Island National Seashore monitoring efforts to assess condition and species distribution of SAV (required for success criteria).

**Analysis Frequency**
Analysis will be conducted on data collected during the pre-construction period and a minimum of three post-construction surveys conducted after the closure of Camille Cut.

**Data Collection Required for Analysis**
A core suite of environmental parameters known to impact seagrass health will be collected from 2011 to 2016 during pre-construction, and a minimum of three times post-construction. The post-construction surveys will be timed to correspond with U.S. National Park Service SAV monitoring surveys, scheduled to occur every three years beginning in 2019.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Condition and Composition Analyses
# Protocol 212

*Protocol version date: 03/07/2018*

## Background

Landscape-scale seagrass mapping efforts provide the Tier I aspects of a multi-scale SAV monitoring effort (Neckles et al. 2012). The MsCIP MAM program will include generalized cover maps and detailed maps of discrete SAV beds. For more information on how seagrass maps will be created for the MsCIP MAM program, see MsCIP MAM protocol 211.

Regional seagrass monitoring efforts often include a multi-scale monitoring approach that includes station-level field surveys and landscape-scale assessments from remotely-sensed data (Moore et al. 2000; Dunton et al. 2010; Neckles et al. 2012). Often these programs are interested in monitoring SAV acreage, distribution, condition, and species composition.

The National Park Service (NPS) began a long-term SAV monitoring program for the NPS Gulf Seashore in 2011 (Kopp and Neckles 2009; Dunton et al. 2010; Neckles et al. 2012). Specifically, the assessment outlined in this protocol serves as Tier II of the MsCIP multi-scale SAV analyses. *In situ* SAV monitoring in the nearshore waters surrounding East and West Ship islands will be integrated with the MsCIP SAV mapping efforts to provide the necessary ground reference information for SAV maps, and to document temporal changes in seagrass conditions. The information will also be used to assess changes in condition over time and aid in identifying the possible drivers (i.e., temperature, salinity, light availability, etc.).

## Collection Methodology

*National Park Service SAV monitoring*

NPS began a long-term SAV monitoring program for their Gulf Island National Seashore in 2011 (Kopp and Neckles 2009; Neckles et al. 2012), providing Tier II information in a multi-scale SAV monitoring effort (Neckles et al. 2012). The overall goals of this program are to: 1) to determine current condition of seagrass, 2) document change in condition through time, and 3) collect and analyze a core suite of environmental parameters known to impact seagrass health.

The NPS SAV sample framework was developed from a tessellated hexagon network (750 m edges). The network was draped over the mapped seagrass beds within park waters, and random points were generated for each hexagon. These points serve as a permanent station for long-term monitoring efforts (Figure 1). The NPS plans to add sample stations if SAV colonizes areas created by the restoration of the Camille Cut.

Tier 2 field data has been collected by the Dauphin Island Sea Lab through a cooperative agreement with the National Park Service Gulf Coast Inventory and Monitoring Network. Field crews from Dauphin Island Sea Lab initiated a protocol developed by the U.S. Geological Survey (USGS) and implemented throughout the Northeast Coastal and Barrier Network (Kopp and Neckles 2009). Annually, permanent stations (i.e., randomly created points in the hexagon network) are occupied during peak biomass. A global position system (GPS) is used to navigate to the station (~4 m accuracy). The sampling station is generally defined as a 10-m diameter area around the station coordinate to account for GPS accuracy and the surface area of the boat. The protocol includes the collection of both SAV and water quality metrics, including species composition, canopy height, percent coverage, temperature, dissolved oxygen, salinity, light attenuation, and Secchi depth (Table 1). The seagrass coverage at each site is estimated from four subsample observations within a 0.25 $m^2$ quadrat acquired from the four cardinal directions. Data are collected during the lowest possible tides during daylight hours, with the depth to activity recorded for all measurements. For rationale on sample parameters and more detailed information regarding sampling procedure, see Kopp and Neckles (2009) and Neckles et al. (2012).

**Table 1.** Seagrass metrics collected at monitoring stations.

| Parameter | Unit | Measure |
|---|---|---|
| Percent cover: All SAV | % cover | Estimated |
| Percent cover: *Thalassia testudinum* | % cover | Estimated |
| Canopy height: *Thalassia testudinum* | cm | Calculated |
| Percent cover : *Halodule wrightii* | % cover | Estimated |
| Canopy height: *Halodule wrightii* | cm | Calculated |
| Percent cover: *Syringodium filiforme* | % cover | Estimated |
| Canopy height: *Syringodium filiforme* | cm | Calculated |
| Percent cover: *Ruppia maritima* | % cover | Estimated |
| Canopy height: *Ruppia maritima* | cm | Calculated |
| PCov: *Halophila engelmannii* | % cover | Estimated |
| Canopy height: *Halophila engelmannii* | cm | Calculated |
| Water temperature | °C | Actual |
| Salinity | ppt | Actual |
| Light attenuation | % light | Actual |
| SecchiDepth | m | Actual |
| DO | mg/l | Actual |

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Condition and Composition Analyses
# Protocol 212

*Protocol version date: 03/07/2018*

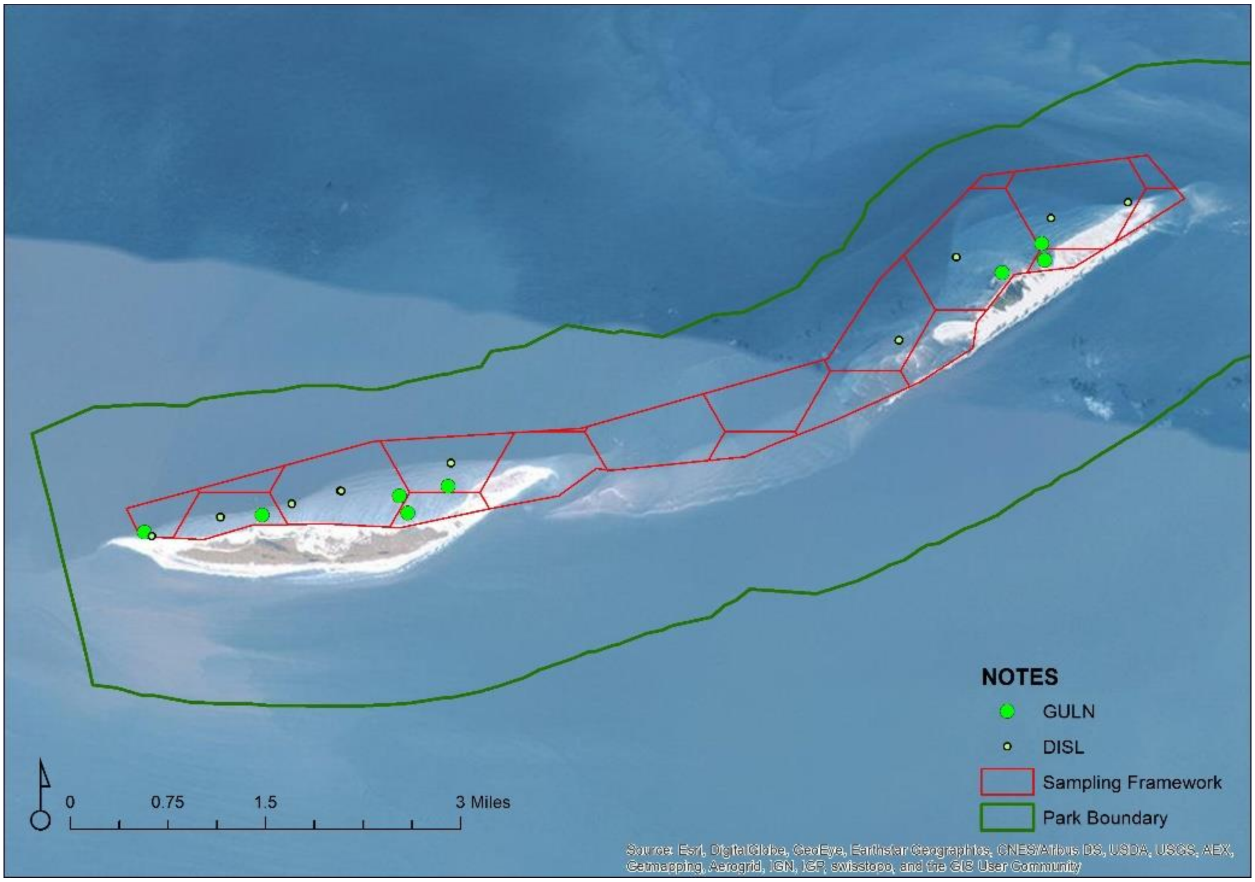


**Figure 1.** National Park Service SAV sample locations, sample framework, and potential SAV. The green dots (GULN) are NPS Gulf Coast Network sites, yje white dots (DISL) are Dauphin Island Sea Lab sites.

## Analysis Methodology

*Integrating seagrass maps and National Park Service SAV monitoring*

Statistical analysis will be used to assess temporal changes in SAV conditions. Permanent stations will be categorized by depth (e.g., shallow, mid-depth, and deep) for East Ship Island and West Ship Island, respectively and collectively (i.e., the East Ship Island and West Ship Island data can be pooled at a later date after construction reestablishes East Ship Island and West Ship Island as a single island). The mean percent cover (e.g., all SAV or specific species) will be calculated for each depth category per island, respectively. Following the methodology of Neckles et al. (2012) and Kopp and Neckles (2009), the change in condition over time for depth categories by island will be assessed by univariate repeated measures analysis of variance (ANOVA). This test assumes that between-period correlations are similar, which can be tested using the Mauchley's criterion (Potvin et al. 1990). Like most parametric techniques, the validity of ANOVA relies upon the assumption of independent observations, normal distribution and homogeneity of error variances (Green 1993). The results of these analyses will be used to determine whether temporal changes in seagrass condition differ significantly among depths. A similar approach may be used to assess changes to condition metrics such as species composition, canopy height and biomass.

**Metadata**

Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Water Clarity, Depth, and Substrate
# Protocol 213

*Protocol version date: 03/07/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Submerged Aquatic Vegetation (SAV) Coverage

**Purpose of Monitoring and Data Assessment**
Document SAV distribution, acreage and condition (e.g., percent cover and canopy height) and species composition over time at Cat Island and East and West Ship islands and to evaluate effects of changing circulation and sedimentation patterns on and around Ship Island

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
N/A This protocol provides supporting information.

**Areas of Interest**
West Ship Island, East Ship Island

**Interim Target**
Maintain or increase areal extent of potential seagrass habitat area relative to pre-construction values, based on pre-construction turbidity, depth, and substrate. Within the potential seagrass habitat maintain suitable levels of turbidity, deposition/erosion rates, and substrate.

**AM Trigger**
N/A

**Task**
Evaluate turbidity, depth, and substrate with regards to SAV distribution (supporting analyses for success criteria)

**Analysis Frequency**
Data collection has been completed for the pre-construction assessment (2010 and 2014). Three additional fall surveys following the closure of Camille Cut will be conducted (currently scheduled for 2019, 2022, and 2025, this is flexible).
Additional post-storm surveys could be conducted as needed to provide valuable additional information.

**Data Collection Required for Analysis**
Sedimentology and substrate characteristics will be sampled in nearshore waters surrounding East and West Ship islands and Cat Island. Field data, including substrate sampling and *in-situ* SAV monitoring, should be scheduled to achieve the closet possible temporal correlation with all collections and associated with Protocol 211 (Submerged Aquatic Vegetation Calculation and Distribution) and Protocol 212 (Submerged Aquatic Vegetation Condition and Composition), including aerial and lidar surveys.

**Background**

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Water Clarity, Depth, and Substrate
# Protocol 213

*Protocol version date: 03/07/2018*

SAV, including seagrass, requires a specific set of physical conditions to grow and thrive. The MsCIP restoration project aims to maintain, and possibly increase the current SAV area around Ship Island. Water clarity, depth, and substrate characteristics will be measured in the area surrounding around the islands, including both inside and outside of vegetated areas, in order to monitor the physical conditions conducive to desired SAV growth. This assessment will cover the area of potential seagrass habitat around Ship Island, approximately bounded by the 2 m depth contour (Moncreiff 2007).

Most species of seagrass need shallow, low-turbidity water in order to meet light requirements and low-energy environmental settings that help inhibit strong currents and dramatic erosional/depositional events (Eleuterius 1987; Yates et al. 2011), as rhizomes require stable substratum to successfully establish themselves and propagate. Areas of unstable substrate such as the surf zone or locations with strong currents, are unsuitable for seagrass growth (Iverson and Bittaker 1986). Severe storms can also negatively impact seagrass distributions, either by burial or removal (Eleuterius 1987), although seagrass patches in protected locations have been observed to withstand storm impacts (Byron and Heck 2006; Carter et al. 2011).

SAV can be killed when completely covered by the rapid placement of sediment layers, thick enough to block photosynthesis, although this threshold has not been quantified (Yates et al. 2011). However, by slowing bottom currents and fastening the sediments in their roots seagrass can facilitate sediment deposition and stabilization in some cases (de Boer 2007), suggesting that seagrass can tolerate deposition if occurring at low rates. The shallow shelves north of the Ship Islands, the area of SAV occurrence, is relatively protected from wave energy, but does experience frequent overwash deposition (Eisemann et al. in review).
The objective of this protocol is to use field sampling in areas both with and without SAV to evaluate water clarity, depth, and substrate in the nearshore waters surrounding East and West Ship islands.

**Methods**

*Water Clarity:*

Available pre-construction data includes Secchi depth and light attenuation for both Cat (limited) and Ship Islands. Additionally, suspended solids volume concentrations were collected during August 2015 and February 2016with a Laser In-Situ Scattering and Transmissometry (LISST)-100X turbidity meter manufactured by Sequoia Scientific Inc, in the shallows around East Ship Island, West Ship Island, and in Camille Cut. This includes many sites re-sampled for comparison (Figure 1). Similar water-clarity metrics will be collected during the execution of Protocol 212.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Water Clarity, Depth, and Substrate
# Protocol 213

*Protocol version date: 03/07/2018*

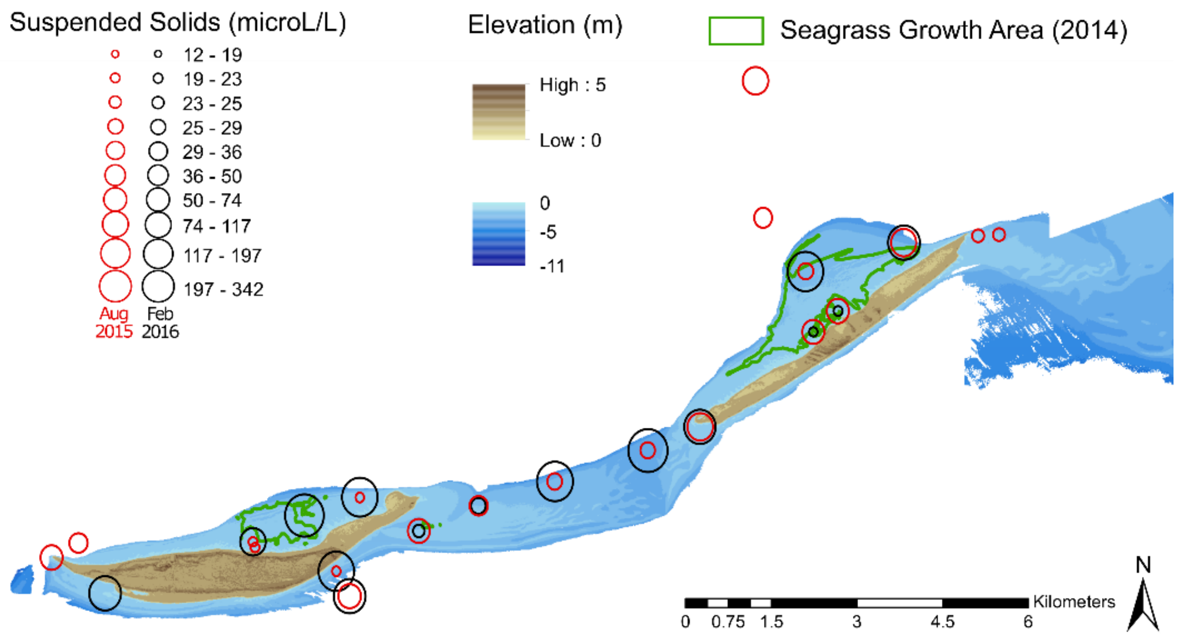


**Figure 1**. Average downcast suspended solids concentrations collected in August 2015 (red circles) and February 2016 (black circles). Magnitude is indicated by the size of the circle (note the exponential scale). SAV, primarily seagrass, growth area as mapped by Barry A. Vittor in 2014 is shown outlined in green. Lidar-derived bathymetry and topography provides the background map.

*Depth:*

Lidar-derived Digital Elevation Models (DEMs) provide high-resolution topography and bathymetry. Depth changes, indicating erosion or deposition, in both vegetated and non-vegetated areas will be monitored from year to year. This analysis will complement the general bathymetric SAV analysis conducted for Protocol 211.

Pre-construction topographic/bathymetric lidar datasets available include 2012 and 2016, collected by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), and executed by the USACE National Coastal Mapping Program (NCMP). These capture the areas of SAV growth and provide a valuable baseline for SAV growth conditions, including depth and bathymetric change ranges (Figure 2).

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Water Clarity, Depth, and Substrate
# Protocol 213

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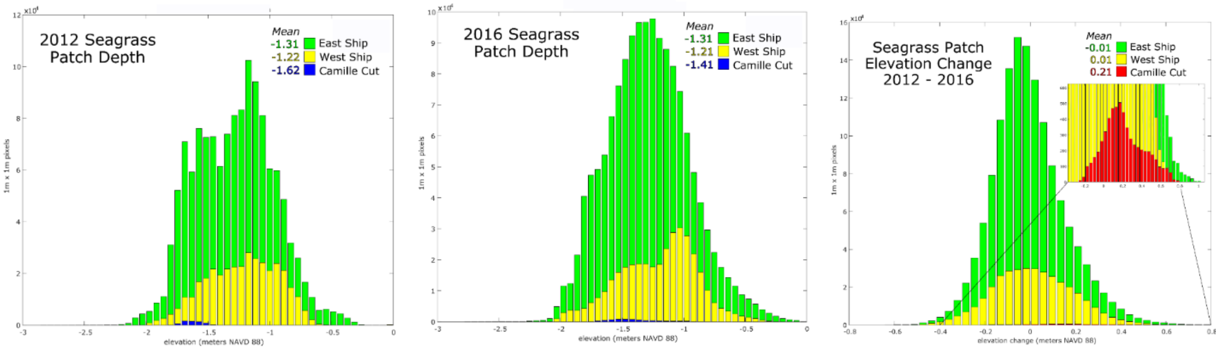


**Figure 2.** Elevations in SAV growth areas measured in 2012 (left) and 2016 (center). Total lidar-derived elevation change between 2012 and 2016 (right).

*Substrate:*

Grab samples, corresponding with Protocol 212 water clarity sampling locations, will be analyzed for grain size, and organic matter content.

The pre-construction substrate characteristics were assessed using grab samples collected in August 2015, simultaneously with the first turbidity dataset. Sediment grabs were obtained from water depths of <1 m to 9 m around the islands and in Camille Cut (Figure 3). Particle size distributions of these samples, measured using a Malvern 3000 Laser Particle Analyzer, were used to determine the D50 (mean - 50% pass particle size) for each.

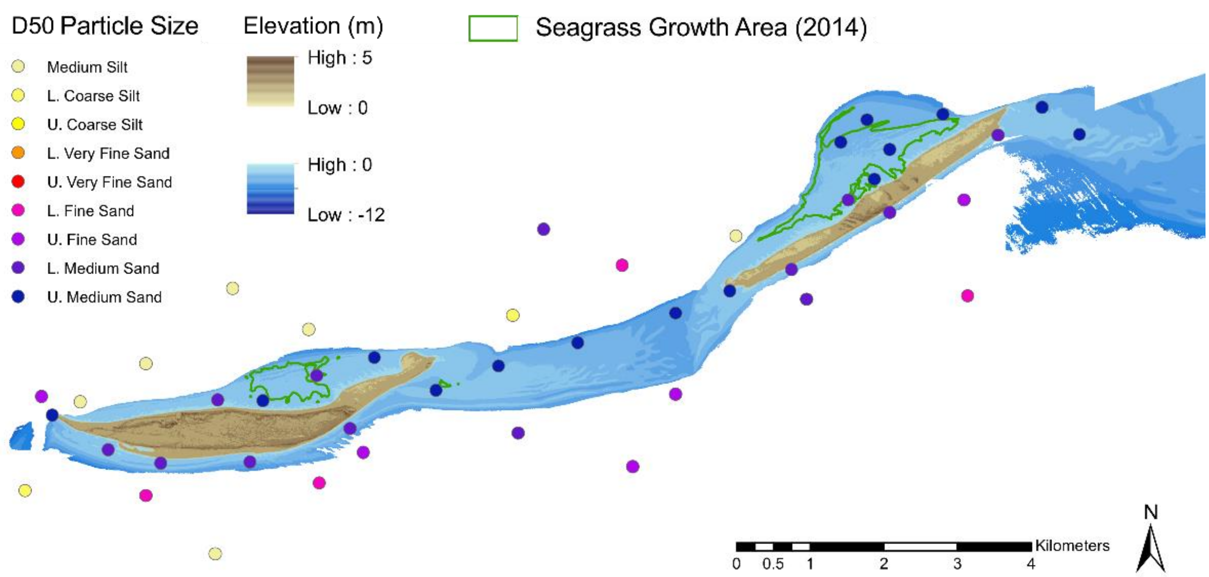


**Figure 3**. Sediment grab sample locations and D50 particle sizes, collected Aug. 2015.

*Comparison to SAV Distribution:*

**MsCIP Monitoring and Adaptive Management Program**
**Data Analysis Protocol:**
**Submerged Aquatic Vegetation Water Clarity, Depth, and Substrate**
**Protocol 213**

*Protocol version date: 03/07/2018*

Spatial correlations will be established between the SAV growth areas and the water clarity, depth, and substrate datasets. Aerial imagery mapping of SAV, capturing the general growth areas as well as a more detailed patch geometry, will be collected as described in Protocols 211 and 214. SAV metrics characterizing species composition and percent cover will be assessed as described in Protocol 212. These datasets will provide the basis for evaluating water clarity, depth, and substrate over the assessment period as a means to help identify the relationships between physical conditions and SAV growth.

It is expected that the inclusion of the discrete SAV patch maps for both the pre-construction and post-Camille Cut closure analyses will result in improvements to the analyses previously derived from the generalized SAV polygons (i.e., the 2010 and 2014 Barry Vittor and Associates data) (see MsCIP MAM protocol 211 on SAV acreage and distribution).

## Metadata

Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Coverage Long-Term Areal Coverage
# Protocol 214

*Protocol version date: 03/13/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Submerged Aquatic Vegetation (SAV) Coverage

**Purpose of Monitoring and Data Assessment**
Document SAV distribution, acreage and condition (e.g., percent cover and canopy height) and species composition over time at Cat Island and East and West Ship islands and to evaluate effects of changing circulation and sedimentation patterns on and around Ship Island. This assessment supports the Tier I of the MsCIP multi-scale SAV assessment and is focused on adding contemporary distribution and acreage observations and historical distribution for long-term change analyses.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Within ten years post-construction the success criteria is total SAV acreage, distribution (compared to 2011 & 2014) and condition (e.g., percent cover and canopy height) and species composition (compered to) 2011–2016 on Ship Island are similar to the pre-construction period.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target:**
N/A

**AM Trigger:**
N/A

**Task**
Evaluate SAV areal coverage over time (supporting analyses for success criteria)

**Analysis Frequency**
This effort will be ongoing from pre-construction through post-construction monitoring. SAV acreage data will be compiled from 2011 (Protocol 211 [Submerged Aquatic Vegetation Acreage Calculations and Distribution]), 2014, and three surveys taken three, six and nine years after the completion of the closure of Camille Cut) and historical SAV coverage data developed by Carter et al. (2011)

**Data Collection Required for Analysis**
We will inventory imagery data sources for any potential additional fall images, including analog and digital aerial imagery and seagrass maps. The creation of additional historical habitat maps will be based on available funds for this task.

**Background**

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Coverage Long-Term Areal Coverage
# Protocol 214

*Protocol version date: 03/13/2018*

Regional seagrass monitoring efforts often include a multi-scale monitoring approach including station-level field surveys and landscape-scale assessments from remotely sensed data (Moore et al. 2000; Kopp and Neckles 2009; Dunton et al. 2010; Neckles et al. 2012; Wilson and Dunton 2012). Often these programs are interested in monitoring SAV acreage, distribution, condition, and species composition.

The objective of this assessment is to explore areal coverage of SAV over time in the nearshore waters of Cat and East and West Ship islands. The historical SAV areal coverage for each island will be assessed using existing historical maps and pre- and post-construction maps developed via Protocol 211 (Submerged Aquatic Vegetation Acreage Calculations and Distribution).

**Analysis Methodology**

*Historical maps*

Carter et al. (2011) utilized analog and digital aerial imagery to analyze historical coverage of discrete SAV beds for the Mississippi barrier islands periodically from 1963 to 2007 (Figure 1). Prior to 2006, film photography was utilized, whereas, digital photography was utilized for 2006 and 2007. Imagery resolution was 2 m or less. All imagery mapped was acquired in fall, predominately in the month of October. Ship Island (i.e., East and West Ship islands after Ship Island was breached by Hurricane Camille in 1969) was mapped five times (1963, 1975, 2003, 2006, and 2007) during this study, and Cat Island was mapped three times, in 2003, 2006, and 2007. We will inventory imagery data sources for any potential additional fall images.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Coverage Long-Term Areal Coverage
# Protocol 214

*Protocol version date: 03/13/2018*

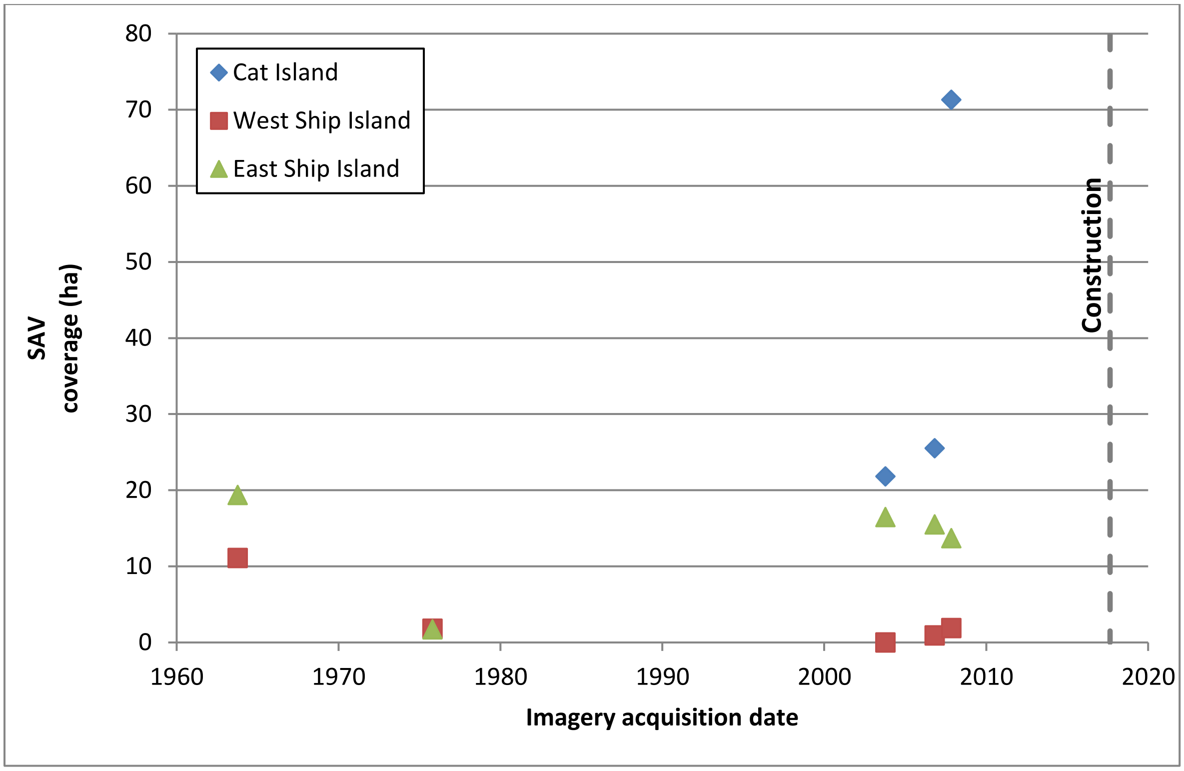


**Figure 1.** Pre-Construction SAV coverage estimates for Cat Island and East and West Ship islands from Carter et al. (2011).

Carter et al. (2011) used image segmentation in ENVI (Broomfield, CO) to map discrete SAV beds. The green-band was used for the mapping effort (Peneva et al. 2008), with the exception of panchromatic imagery used for the 1963 Ship Island map. Errors of omission and commission for seagrass classification were corrected manually through intensive editing. We will also inventory imagery data sources for any potential additional historical fall images, including analog and digital aerial imagery for use for creating additional SAV maps. The creation of additional historical SAV maps will be based on available funds for this task.

*Contemporary maps*

Contemporary maps will be created following a protocol similar to the one used by Carter et al. (2011). For more information on the discrete SAV bed mapping see Protocol 211 (Submerged Aquatic Vegetation Acreage Calculations and Distribution).

*Long-term seagrass coverage*

We will combine SAV coverage estimates developed by Carter et al. (2011) with maps developed for the MsCIP MAM effort to explore long-term temporal SAV coverage (Figure 1).

**Products**

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Submerged Aquatic Vegetation Coverage Long-Term Areal Coverage
# Protocol 214

*Protocol version date: 03/13/2018*

1. Brief report on methods and acreages
2. Spatial analyses of distribution of long-term SAV data

**Metadata**

Metadata will be created for all analyses, following ISO standards.

**Literature Cited**


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# MsCIP Monitoring and Adaptive Management Protocol: Assessing High Potential Habitat Suitability Areas for Gulf Sturgeon Task using Digital Elevation Models
# Protocol 221

*Protocol version date: 03/13/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Gulf sturgeon (*Acipenser oxyrinchus desotoi*)

**Purpose of Monitoring and Data Assessment**
Support documentation of potential suitable Gulf sturgeon habitat areas over time and determine whether Ship Island restoration and the filling of Camille Cut has an impact on these suitable habitat areas.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Not directly related to an established success criterion, analysis will be used to support Protocol 222 (Gulf Sturgeon Pre- and Post-Construction Occupancy) and Protocol 223 (Gulf Sturgeon Foraging Habitat)

**Areas of Interest**
West Ship Island, East Ship Island, Horn Island

**Interim Target:**
N/A

**AM Trigger:**
N/A

**Task**
Identify changes in acreage of high-potential suitability areas within Gulf sturgeon critical habitat for areas with updated nearshore bathymetry in the vicinity of East and West Ship islands, and Horn Island (supporting analyses for success criteria)

**Analysis Frequency**
Pre-construction, plus two times after the completion of the closure of Camille Cut. The analysis timing and extent will be dependent upon collection of nearshore bathymetry data.

**Data Collection Required for Analysis**
Either an existing topobathymetric digital elevation model (TBDEM) or sufficient data necessary to produce a custom TBDEM. The collection dates will be dependent upon the construction schedule and the temporal correlation of collection requirements across the program.

**Background**
Ross et al. (2009) completed the first extensive study of Gulf sturgeon habitat utilization in the Mississippi Sound. Specifically, they used sonic transmitters to study estuarine and coastal habitat characteristics of Gulf sturgeon in the Mississippi Sound and the northern Gulf of Mexico

(NGOM) longitudinally from the Pearl River to Pascagoula River. While the study included four different latitudinal zones (i.e., near the mainland, middle sound, barrier islands, and offshore), the majority of the observations came from shallow waters near barrier islands. Results from the study suggested that Gulf sturgeon were found predominately in shallow waters with a mean depth of 3.9 m (95% CI = 0.3 m, N = 69) with a minimum depth of 1.2 m and a maximum depth of 6.6 m.

**Analysis Methodology**

Results from Ross et al. (2009) will be used to delineate high-potential suitability areas for Gulf sturgeon from a TBDEM using a water depth threshold of 4.2 m (the upper bounds of the 95% CI of mean depth; relative to local mean sea level) in the vicinity of East and West Ship islands, Horn Island, and Cat Island (e.g., standardized distance for analyses likely 1-2 miles from the shoreline). If an existing TBDEM does not cover the relevant water depths and/or extent necessary for the effort, then multiple sources of data will be combined to create a custom TBDEM. While several sources of data (i.e., pre-construction baseline data and post-construction data) may be available by island, the best available data will be used for producing a TBDEM. Empirical Bayesian Kriging (Krivoruchko 2012), Ordinary Kriging, or inverse distance weighted interpolation will be used to develop a custom TBDEM from existing data sources. In order to directly link data from the TBDEM to findings from Ross et al. (2009), the TBDEM will need to be transformed from the orthometric datum of North American Vertical Datum 1988 (NAVD88) to a locally relevant tidal datum (e.g., local mean sea level). We will use observations collected at the nearby NOAA Dauphin Island, Alabama tide gauge (station ID: 8735180) to transform NAVD88 to local mean sea level. Please note, the analysis timing and extent will be dependent upon collection of nearshore bathymetry data.

Digital elevation models, like any model, contain errors. Errors associated with a DEM are often ignored by data users (Wechsler 2003). Errors related to DEMs are categorized under three categories: blunders, systematic, and random errors (Cooper 1998; Fisher and Tate 2006). Although blunders related to user error or equipment failure (Fisher and Tate 2006) are not a concern, both systematic and random errors are especially relevant in this case. Systematic errors are those errors introduced through biased sampling or data processing, while random errors include spatially autocorrelated variations around the true elevation value (Fisher and Tate, 2006). For instance, alongshore topographic error can vary by land cover type. Often, marsh and forested areas or other densely vegetated areas have a higher error than bare unvegetated areas (Hodgson and Bresnahan 2004; Schmid et al. 2011; Cooper and Chen 2013; Medeiros et al. 2015). For offshore areas, bathymetry error can be related to water depth or slope (Brynes et al. 2002; Guenther 2006). Error nonstationarity can be difficult to account for without sufficient ground reference data (Wechsler and Kroll 2006). Due to the lack of ground reference data, the vertical accuracy of topobathymetric data will rely on information reported in the metadata of the various data sources. Applying a vertical datum transformation can introduce additional uncertainty that needs to be accounted for (Gesch 2013; Cooper et al. 2013). The cumulative vertical accuracy (i.e., combined elevation source data error and datum transformation error) will be calculated for the TBDEM as a root mean square error (RMSE) for topobathymetric data.

Numerous techniques have been developed for DEM error propagation (Hunter and Goodchild 1995; Wechsler and Kroll 2006; Cooper et al. 2013; Leon et al. 2014). For the Gulf sturgeon high-potential suitability area assessment, error propagation will follow an approach similar to the neighborhood autocorrelation filter method outlined in Wechsler and Kroll (2006). As mentioned previously, we will assume that topobathymetric errors do not differ based on land cover types due to lack of ground reference data. We will assume that cumulative vertical error has a normal distribution with one standard deviation being equal to the RMSE. The first step in the error propagation is the development of a random field. A raster with the same cell size and registration of the TBDEM will be created to hold the random field. This raster will be generated with a Gaussian distribution using the Create Normal Raster tool in Esri ArcMap (Environmental Systems Research Institute, Redlands, CA). Next, a local filter (i.e., 3-pixel by 3-pixel neighborhood) will be used to incorporate spatial autocorrelation into the simulated random fields (Eastman 1992). The filtered raster will then be multiplied by the RMSE and added to the original TBDEM. A Monte Carlo simulation will be used to repeat these steps for n iterations (i.e., testing will be conducted to determine when variability is stabilized for simulations). For each iteration, pixels will be coded as a binary variable for the presence or absence of a high-potential suitable area for Gulf sturgeon based on water depth. Pixels with positive water depths less than 4.2 m would be coded to 1 (i.e., indicating the area is a high-potential suitability area for Gulf sturgeon). Pixels not meeting the previously stated water depth criteria will be coded as 0 (i.e., representing absence of high-potential suitability area for Gulf sturgeon). The output from the iterations will be combined into a single raster containing the probability of each pixel being a high-potential suitability area for Gulf sturgeon using the formula below (Cooper and Chen 2013).

$$P_{x,y} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}$$

In the equation above, $P_{x,y}$ represents the probability of a pixel being an area of high suitability for Gulf sturgeon, $x_i$ represents the binary classification of presence or absence (i.e., 1 or 0) of highly suitable area for Gulf sturgeon for iteration *i*, and n equals the total number of iterations. A threshold to estimate discrete acreage from the probability maps (e.g., ≥50% probability) will be decided by the MsCIP Technical Advisory Group. A script will be developed for the probability model discussed above so the analysis can easily be rerun using alternative water depth thresholds.

**MsCIP Monitoring and Adaptive Management Protocol:**
**Assessing High Potential Habitat Suitability Areas for Gulf Sturgeon Task using Digital Elevation Models**
**Protocol 221**
*Protocol version date: 03/13/2018*

It is important to note that while we are using a discrete threshold for delineating the high potential suitability zone of Gulf sturgeon, in reality, high potential-suitability areas likely occur around a much more poorly constrained threshold. Thus, we will also calculate the magnitude of change from pre- and post-construction analyses with error propagation using an approach similar to Brashington et al. (2000). We will determine the cumulative error using the following using equation:

$$E = \sqrt{(e_1)^2 + (e_2)^2} \tag{2}$$

Where $E$ is the cumulative error and $e_1$ is the pre-construction error and $e_2$ is the post construction error. If the magnitude of change is less than the propagated error then the area will be classified as “no change”, while pixels with change greater than $E$ can be considered areas of deposition and erosion. These areas will be assessed and binned based on magnitude. The exact bin size will be determined based on the distribution of the data. This calculation will provide insight beyond the binary high-potential suitability threshold change analyses by allowing for the assessment of areas that were considered high-potential suitability areas for only one of the periods assessed (i.e., pre-construction or post-construction), yet only experienced a minor magnitude change in water depth (e.g., ≤0.3 m).

**Products**

For pre-construction, post-construction and change:

1. A geodatabase containing probability raster surfaces for high-potential suitability areas for Gulf sturgeon
    - Pre-construction high-potential suitability areas with average magnitude difference from threshold (i.e., 4.2 m)
    - Post-construction high-potential suitability areas with average magnitude difference relative to the high-potential suitability threshold (i.e., 4.2 m)
    - Change from pre-construction to post-construction for high-potential suitability areas (i.e., using binary presence/absence of high-potential utilization areas) with error propagation with the following additional information:
        - Areas with “no change” and binned magnitude of difference

2. Federal Geographic Data Committee (FGDC) compliant metadata

3. Brief report on methods and acreages

## Metadata

Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Protocol
# Gulf Sturgeon Pre- and Post-Construction Occupancy Task
# Protocol 222

*Protocol version date: 03/13/2017*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Gulf sturgeon (*Acipenser oxyrinchus desotoi*)

**Purpose of Monitoring and Data Assessment**
Compliance monitoring to document Gulf sturgeon critical habitat utilization over time at Ship Island and Dog Keys Pass and determine whether Ship Island restoration and the filling of Camille Cut has an impact on Gulf sturgeon utilization of these habitat features

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Two years post-construction the success criteria is if occupancy values fall within two standard deviations of pre-construction values. The post-construction period for this protocol and Protocol 223 (Gulf Sturgeon Foraging Habitat) is defined by the completion of sand placement on Ship Island.

**Areas of Interest**
West Ship Island, East Ship Island, Horn Island

**Interim Target**
Immediately post-construction of Ship Island track potential movement of Gulf sturgeon shift to other surrounding habitat zones.

**AM Trigger**
Reduction in Gulf sturgeon habitat usage and occupancy patterns within the Ship and Horn Island System.

**Tasks**

1) Determine if Gulf sturgeon utilization of Ship Island, Little Dog Keys, and Dog Keys passes has increased/declined beyond variability detected in pre-construction (required for success criteria)
2) Investigate whether Gulf sturgeon will continue to utilize these areas by comparing coarse-scale relative occupancy within the project area pre- and post-construction (required for success criteria)

**Analysis Frequency**
Pre-construction and post-construction.

**Data Collection Required for Analysis**
Automated acoustic telemetry array data quantifying Gulf sturgeon occupancy.

**Background**

**MsCIP Monitoring and Adaptive Management Protocol**
**Gulf Sturgeon Pre- and Post-Construction Occupancy Task**
**Protocol 222**
*Protocol version date: 03/13/2017*

The federally threatened Gulf sturgeon is an anadromous species that migrates to upriver spawning grounds in spring, while post-spawning and non-spawning individuals spend much of the spring and summer in staging areas in mid to lower river reaches (Heise et al. 2005). In late fall and winter, adults and large subadults migrate to nearshore and offshore marine critical feeding habitat, including the barrier island passes, before returning upriver in the spring (Rogillio et al. 2007; Ross et al. 2009). The western population suffers from relatively lower abundance and a higher natural mortality rate, which may be due to habitat loss (Ahrens and Pine 2014), exacerbated by natural events such as hurricanes (Rudd et al. 2014).

Gulf sturgeon movements and habitat use can be affected by environmental changes. To determine how restoration projects associated with the Mississippi Coastal Improvements Program (MsCIP) Barrier Island Restoration Project will affect sturgeon utilization of the habitat surrounding Ship Island, the monitoring program associated with this task will have two components: (1) an initial assessment to determine the relative occupancy of Gulf sturgeon within the project area (e.g., specific zones and seasonal timing); and (2) a secondary assessment to address occupancy patterns of Gulf sturgeon within identified project areas in order to evaluate potential changes in occupancy patterns between years and project zones.

## Collection Methodology

*Gulf Sturgeon Tagging Procedures*

The methodology for netting Gulf sturgeon within riverine habitats and tagging is described in detail in Heise et al. (2004, 2005) and Havrylkoff (2012). Gulf sturgeon have been tagged upriver starting in 2010 (from other concurrent projects) and continues through the present time (Fall 2017). The first detections of fish on the Ship Island array occurred in Fall 2011.

*Automated Telemetry Arrays*

The initial assessment of relative occurrence will utilize an automated acoustic telemetry array to monitor Gulf sturgeon presence within the project area. During the pre-fill period, we deployed 21 (14, April – 9 May 2011 and 20, September 2011 – 30 June 2012) and 29 (13 September 2012 – 11 June 2013) automated VR2W telemetry receivers (Vemco; Nova Scotia, Canada). The array was expanded to 39 receivers during the 2013 – 2014 deployment period (30 September 2013 – 12 June 2014) to cover Dog Keys Pass. The same number of receivers was deployed during 2014 – 2015 (1 October 2014 – 4 June 2015), with the receivers generally stationed at Camille Cut being redistributed to Dog Keys Pass and the west end of Horn Island. Due to impending construction activities, no receivers were deployed following the 2014 – 2015 deployment period.

During post-construction monitoring efforts, receivers will be positioned at the surface in a top down orientation, deployed from a large polyform buoy and marked with signage (Sulak et al. 2009). Concrete blocks (68 kg or larger) will be used to anchor receivers in locations where passage at project sites is expected. Detection data will be downloaded from the receivers at 3-4 week intervals. Data acquired during this phase will provide information on the relative use of Camille Cut by acoustically-tagged Gulf sturgeon in comparison to the passes located at the east and west ends of Ship Island. These data will also contribute to a comparative perspective of habitat utilization of the passes within and among years (before and after construction). Following this initial assessment period, we will continue telemetry-based monitoring into the post-fill periods.

**Analysis Methodology**

*Telemetry Data Organization*

Telemetry data will be reviewed for quality assurance and control after retrieval. Individual Gulf sturgeon will be considered present on the array if the fish is detected at least two times on a single receiver on the same date (Peterson et al. 2016). Detections from each overwintering sampling period (year) will be first sorted into chronological order and later separated by transmitter number. Following data organization, the time between successive detections will be calculated for individuals during each overwintering sampling period (year) (Peterson et al. 2013, 2016). If there are exact duplicate detections (two or more records of an individual at the same time at the same station) in the database, we will remove all detections except for one. Simultaneous detections are defined as detections occurring on multiple receivers from a single tagged Gulf sturgeon, where the time between detections is shorter than the minimum tag delay minus 10 seconds (to account for receiver clock drift). After identifying a group of simultaneous detections, we will remove all but one of the records that do not meet the minimum tag delay requirement (minimum tag delay minus 10 seconds).

In most cases the retained detection record will be from the same station as the last valid record immediately prior to the occurrence of the simultaneous detections. In cases where there is not a valid record immediately before the occurrence of simultaneous detections, which would set the precedent for the station from which the record was to be kept, the first detection in a group identified as simultaneous will be retained and the rest removed.

*Occupancy Index Calculations*

To quantify changes in Gulf sturgeon occurrence between areas and sampling periods (years), we will assess occupancy patterns in specific zones within the telemetry array. Information gleaned from these occurrence patterns will allow us to evaluate potential shifts among habitat zones before, during, and after construction.

We will use the effort-adjusted, normalized, and scaled occupancy index (Peterson et al. 2013) to estimate use of array zones while accounting for differences in the number of receivers, and thus detections. The index will be applied to the detection database after exact duplicates and simultaneous detections are removed. First, we will account for the different number of receivers in each zone by calculating an effort-adjusted value ($w$) (Eq. 1) as a proportion, and multiplying that weighting factor by the number of detections for each fish within each zone (Eq. 2). The weighted detections will be normalized (Z-scores) for each fish by zone and sampling period (year) (Eq. 3). Global mean ($\bar{x}_g$) and global standard deviation ($SD_g$) will be calculated from the total number of Gulf sturgeon detections on the entire Ship Island acoustic array for a given sampling period (year) (Peterson et al. 2013). Occupancy values will then be finally scaled by adding the absolute value of the lowest occupancy value (Z-score) to each occupancy value making the lowest scaled occupancy value now 0 as it corresponds to effort-adjusted 0 detections (Peterson et al. 2013). An occupancy index will be created with the effort-adjusted, normalized, scaled values, and the index will be used to compare occupancy among zones and sampling periods (year). Having a high occupancy value indicates that a particular zone has the greatest average number of detections out of all zones for that sampling period (year) (Peterson et al. 2013).

(Eq. 1) $w = 1 -$ (no. of receivers in zone/total no. of receivers)
(Eq. 2) weighted detections = $w * x_i$
(Eq. 3) Z-score = $[(w * x_i) - \bar{x}_g] / SD_g$)

*Data Analysis*
Occupancy patterns of Gulf sturgeon surrounding Ship Island will be calculated using two different approaches. The two calculations will test the robustness of the Occupancy Index by accounting for potential increases or decreases in total detections within the deployment sampling periods (years) relative to increasing the area (zones) of the acoustic array field. For the first scenario, occupancy (Peterson et al. 2013) will be calculated for zones 1 through 4 as they were consistently deployed for years 1 through 3. With the second scenario, occupancy will be calculated for zones 1 through 5 only for years 2 and 3 (2012 - 2014, after receivers of zone 5 were deployed) to analyze the larger geographic area of the array field and greater number of detections as necessary. Finally, annual occupancy values of the first approach will be directly compared to the annual occupancy values of the second approach for zones 1 through 4 to test the robustness of the Occupancy Index as geographic area within the array and thus the number of receivers collecting data increases. If there is no difference in the occupancy pattern by zones as the array expands, then the occupancy calculation will be considered robust to changes to the data generating array fields over time and space. The pre-construction data has recently been published and will be available online in 2017 and hard-copy in 2018 (see Vick et al. 2018).

The expectation is that if there are no impacts to Gulf sturgeon, then we would not see any appreciable change in activity patterns within defined telemetry zones regardless of the deployment year (i.e., pre- vs post-construction occupancy) and would accept variance levels in post-construction occupancy index values within 2 standard deviations of pre-construction values as our metric to assess no impact.

## Metadata

Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Protocol
# Gulf Sturgeon Foraging Habitat Task
# Protocol 223

*Protocol version date: 03/13/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***

Gulf sturgeon (*Acipenser oxyrinchus desotoi*)

**Purpose of Monitoring and Data Assessment**

Compliance monitoring to document Gulf sturgeon critical habitat utilization over time at Ship and Dog Keys Pass and determine whether Ship Island restoration and filling Camille Cut has an impact on Gulf sturgeon utilization of these habitat features

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**

The success criteria is that there is no significant change in post-construction benthos community assessments as compared to the pre-construction assessment. The post-construction period is defined by the completion of sand placement on Ship Island.

**Areas of Interest**

West Ship Island, East Ship Island, Gulfport Ship Channel, Dog Keys Pass

**Interim Target**

A short-term evaluation of benthic and infaunal species re-establishment will be collected six months after the closure of Camille Cut as part of the Gulf sturgeon benthic prey assessment.

**AM Trigger**

Success criteria not met by five years

**Tasks**

1) Determine the relationship between physical factors and favorable Gulf sturgeon foraging habitat.
2) Determine the relationship between physical factors and benthic macroinfaunal community composition.
3) Evaluate relationship between high prey abundance areas (i.e., predict high or low quality foraging habitat for Gulf sturgeon) and Gulf sturgeon occupancy patterns during both pre- and post-construction periods (see Decision Support Document Protocols 222_223).

**Analysis Frequency**

Pre- and post-construction of Ship Island

**Data Collection Required for Analysis**

The collection of benthic macroinfauna, sediment samples and standard hydrographic measurements

**Background**

# MsCIP Monitoring and Adaptive Management Protocol
# Gulf Sturgeon Foraging Habitat Task
# Protocol 223

*Protocol version date: 03/13/2018*

Gulf sturgeon spawn in upriver reaches during the early spring before traveling downriver to the ocean to feed (Fox et al. 2000). In Mississippi, large subadults and adults overwinter in the Mississippi Sound, where they congregate near the passes between barrier islands (Rogillio et al. 2007, Ross et al. 2009). Upon their return to freshwater areas, they fast and gradually decrease in weight as they use up energy stores that were accumulated in marine waters (Mason and Clugston 1993, Gu et al. 2001). In fact, subadult and adult Gulf sturgeon growth is almost completely dependent upon the resources they acquire in the marine environment (Gu et al. 2001). As the barrier island passes represent critical feeding habitat for this federally threatened species, it is essential to understand how construction projects may change the physical and chemical factors and benthic infauna assemblages associated with sturgeon foraging habitat. While foraging, Gulf sturgeon move across the substrate and suction up prey items with their specialized tubular mouth. They are often found at shallow depths (<10 m) in areas with high sand content (Fox et al. 2002, Edwards et al. 2003, Ross et al. 2009). In the Mississippi Sound, sturgeon regularly use the shallow waters of the barrier island passes, which are characterized by strong tidal currents and clean sand substrata (Ross et al. 2009). Areas of greater sand composition can have higher potential prey abundance (Harris et al. 2005), including higher densities of sturgeon prey items such as Florida lancelets (Rakocinski et al. 1993) and ghost shrimp (*Lepidophthalmus louisianensis*; Peterson et al. 2013). Peterson et al. (2013) determined that sediment characteristics, rather than water depth, was more influential in correlations with macrobenthic density patterns. Mechanical alterations that change sediment characteristics, such as the filling of Camille Cut, could potentially alter the density and/or distribution of infaunal prey items and alter sturgeon foraging habitat.

To monitor how Gulf sturgeon will respond to construction projects associated with the Mississippi Coastal Improvements Program (MsCIP), we will conduct a benthic assessment to develop a relationship between Gulf sturgeon and benthos. Specifically, we will explore how physical factors such as sediment texture, sediment percentage, organic matter content, and depth, collected during the benthic macroinfaunal sampling, may also be correlated with benthic macrofaunal composition and Gulf sturgeon activity patterns; thus, jointly determining favorable Gulf sturgeon habitat.

## Collection Methodology

*Benthic and Infaunal Sampling*

The U.S. Army Corps of Engineers, Mobile District will contract supplementary benthic sampling in the vicinity of Ship Island to examine the relationship between Gulf sturgeon and benthic habitat. Benthic macroinfauna and sediment samples were collected at 80 points in October 2011. The sampling locations include: (1) three transects with 10 sample points each established across the waters between Cat Island and West Ship Island; (2) two sample points in the Gulfport Ship Channel (one station north and one station south of West Ship Island); (3) three transects with 8 sample points each across Camille Cut; and (4) three transects with 8 sample points each across Dog Keys Pass. Post-construction sampling of these stations will occur in the fall and spring beginning six months after completion of construction on Ship Island. Samples will be collected at each station with a Shipek grab or a modified Van Veen grab with a sampling area of 0.04 $m^2$. Both grabs are spring-loaded and are designed for collecting consistent samples in sand and consolidated sediments. The samples will be rinsed in the field through a 0.5 mm mesh screen and preserved with 10% buffered formalin. A subsample (approximately 250 gm) will be collected from each grab for sediment texture analysis.

Prior to benthic sampling, standard hydrographic measurements will be taken at each station at up to three depths depending on ambient water depths, which will include near surface, middle, and near-bottom depths. A YSI Model 600XL Datasonde or equivalent will be used to measure temperature, conductivity, salinity, pH, and dissolved oxygen (DO) concentration.

**Analysis Methodology**

*Laboratory Processing*

Infauna: Benthic samples will again be rinsed through a 0.5 mm mesh screen to remove preservatives and sediment, stained with Rose Bengal, and stored in 70% isopropanol solution until processing. All macroinvertebrates will be removed and placed in labeled glass vials containing 70% isopropanol, with each vial representing a major taxonomic group (e.g., Oligochaeta, Mollusca, Arthropoda). Oligochaetes will be individually mounted and cleared on microscope slides prior to identification. Sorted macroinvertebrates will be identified to the lowest practical identification level (LPIL), which in most cases will be to species level, unless the specimen is a juvenile, damaged, or unidentifiable. The number of individuals of each taxon, excluding fragments, will be recorded.

Sediment Grain Size and Total Organic Carbon:
Each sediment sample will be washed with deionized water, dried, and weighed, and the following physical parameters determined for each sample: coarse (sand) and fine (silt, clay) fractions, median grain size and percentages of gravel, sand, silt, and clay.

*Benthic Data Analyses*

To examine associations between Gulfs and benthic fauna, benthic stations within 500 m of an acoustic receiver will be included in fine-scale analyses of habitat use. We will aggregate benthic data at the genus level and only those taxa that account for 99% of total abundance will be included in the analysis. The two Gulf sturgeon habitat use categories will be defined as "Low" and "High." Following square root transformations, a Bray-Curtis similarity matrix will be created and used to generate a multidimensional scaling (MDS) plot in which benthic stations are depicted based on their proximity to either low or high Gulf sturgeon habitat use. Values (density) that are spatially closer in the MDS plot are more similar in assemblage structure and those farther apart indicate that they are not as similar. We will use an analysis of similarities (ANOSIM) or permutated ANOVA (PERMANOVA) to determine if benthic assemblages differ significantly between low and high use stations. Similarity percentage (SIMPER) analysis will be used to reveal the benthic taxa that contribute to the observed difference (Clarke and Gorley 2006, Peterson et al. 2013).

During the pre-construction assessment “Low” was defined as less than 500 detection and fewer than five individual fish at neighboring acoustic receivers while “High” was characterized by more than 500 detections and greater than 5 individual fish. However over the course of the pre-construction phase of the study, the telemetry array expanded from 21 receivers during the initial deployment period (2011-2012) to 39 receivers during the last deployment period (2014-2015). Consequently, total detections and number of detected fish per receiver increased substantially beyond the development of the initial Low/High categories. To provide an adequate basis of comparions between pre and post-construction periods, we will develop occupancy index values (*sensu* Peterson et al. 2013; Vick et al. 2018) for the zones sampled for benthos during the pre-construction period and compare those with post-construction values. The range in occupancy values will be assessed for natural breaks to further characterize the zones as “Low” or “High” in terms of their degree of habitat use.

For comparisons between pre- and post-construction samples, we propose a measure of percentage similarity (e.g., ≥ 70% faunal similarity) between sampled zones for pre- and post-construction periods as an approach to assessing changes in the benthic assemblage structure. If both levels (baseline and post-construction) indicate no appreciable change in faunal similarity of the sampled benthic macrofauna, then it is assumed the benthos has not been impacted to the level that would adversely affect Gulf sturgeon feeding habitat.

**Metadata**

Metadata will be created for all analyses, following ISO standards.

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Vick, P.E., M.S. Peterson, W.T. Slack, and P.O. Grammer. 2018. Occupancy patterns of Gulf Sturgeon, *Acipenser oxyrinchus desotoi*, associated with Ship Island, Mississippi. Journal of Coastal Research (doi:10.2112/JCOAST-D-17-00027.1).

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Habitat Suitability Model to Determine the Probability of Sea Turtle Nesting
# Protocol 231

*Protocol version date: 03/13/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Sea Turtle Nesting Habitat

**Purpose of Monitoring and Data Assessment**
Document changes to the amount of habitat conducive to sea turtle nesting relative to the baseline conditions. A spatially explicit, multi-criteria decision support model for loggerhead sea turtle nesting habitat suitability has been developed for Florida and will be adapted to Mississippi for this assessment. This analysis will be used to measure project performance as a success criterion.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
This task is not directly used to gauge the success criteria for sea turtle nesting habitat. Instead, data from this analysis will be used to inform success criteria related to suitable acres of sea turtle habitat as described in MsCIP MAM Protocol 233 (Suitable Sea Turtle from Habitat Mapping)."

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
Five years following the completion of the planting on Ship Island maintain areal extent of suitable turtle habitat as evaluated by habitat mapping.

**AM Triggers**
Loss of habitat acreage for sea turtles as evaluated by habitat mapping, Protocol 233 (Suitable Sea Turtle from Habitat Mapping). The total number of acres of suitable nesting habitat will be determined by habitat mapping based on pre-construction conditions.

**Task**
Determine if the island habitat geomorphic conditions have increased the probability of sea turtle nesting along the northern Gulf of Mexico coast after the restoration of Ship and Cat Islands. This primary task includes evaluating the relevant parameters extracted from the post-construction lidar and orthophotography as inputs to the spatially explicit, multi-criteria decision support model for loggerhead sea turtle nesting habitat suitability (Dunkin et al. 2016). The post-construction model results will be compared to baseline conditions to determine how suitable nesting habitat availability has changed.

**Analysis Frequency**
The sea turtle habitat suitability analysis will be conducted four times during the program; once during pre-construction and three times in the 10 years following the completion of planting on Ship Island. The dates of analysis will be determined by the timing of the data collection.

# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Habitat Suitability Model to Determine the Probability of Sea Turtle Nesting
# Protocol 231

*Protocol version date: 03/13/2018*

**Data Collection Required for Analysis**

Simultaneous orthophotography and lidar (topobathymetric lidar, if possible) surveys will be collected before and during construction, and a minimum of three times during the 10-year period following the completion of planting on Ship Island. The collection dates will be dependent upon the construction schedule and the temporal correlation of collection requirements across the program.

Sea turtle monitors (observers) will be used to conduct sea turtle identification, counts, locational assessments and the identification of turtle crawls and nest sites, marking of nests, and Global Positioning System (GPS) locations on beaches of Ship Island and Cat Island following U.S. Fish and Wildlife Service, Ecological Services Office survey guidelines. Monitoring will be conducted from April 15 to November 30 both during and post-construction. No pre-project surveys will be required if project construction activities are initiated between November 30 and April 15. If the project construction is initiated between April 15 and November 30, daily pre-project surveys will begin at least 100 days prior to the project starting or by April 15, whichever is later. Post-construction weekly sea turtle monitoring shall continue for two full nesting and hatching seasons (April 15th thru November 30th), beginning approximately one to two years after the end of construction.

Real Time Kinematic (RTK) survey data and sediment samples will also be collected from each sea turtle nest and false crawl profile. These surveys shall be conducted before or during construction depending on the contract award date(s) and for three years immediately after the completion of the installation of vegetative plantings on Ship and Cat Islands.

*RTK Data and Sample Description*

An elevation profile shall be obtained through an identified sea turtle nesting site or false crawl with a bearing perpendicular to the average shoreline orientation. The seaward limit of the profile should begin at the -2.0 foot contour and continue landward. The transect shall terminate 150 feet landward of the nest/false crawl site or at any substantial standing water landward of the nest. The points along the profile should be spaced such that there is no more than 0.5 feet difference in elevation but no more than 15 feet between points along the profile. Additionally, a point shall be located at the centroid of the nesting site or the false crawl track. Points should be collected by using a high-precision real-time kinematic (RTK) global positioning system (GPS). Positioning data shall be referenced to Mississippi State Plane East, NAD83 HARN, U.S. Survey feet and NAVD88 (Geoid 12A), U.S. Survey feet. Survey control, accuracy, and procedure shall be in accordance with EM 1110-1-1005. GPS tagged photographs shall be taken (1) along the nesting profile from the water's edge facing the nest/false crawl, (2) from the nest centroid facing the water, (3) from the nest centroid facing landward, (4) from the landward extent of the transect facing the nest centroid, and (5, 6) from a shore parallel location located a distance far enough away that the photograph will capture such primary features of the profile as the nest centroid, water edge, dune, vegetation, etc. GPS tagged shore parallel profile photographs shall be taken from both sides of the nest such that a minimum of six photographs will be taken. An illustration shall be provided that indicates the location of the water's edge, wrack line, berm, foredune crest, dune trough, vegetation, and nest or body pit along each collected RTK elevation profile. These illustrations shall be generated using MicroStation and shall be submitted in .pdf and .dwg format.

A sediment sample shall be obtained from the soil column directly adjacent to the centroid of the nesting site or the false crawl track. Care should be taken to not harm the eggs at the nesting site or penetrate the egg flask cavity during the collection. Each sample will include approximately one pint of material and will be labeled with the date, site reference, and corresponding turtle nest/false crawl identification. Samples will be turned in to the Mobile District USACE Office in care of Brian Zettle for analysis.

## Analysis Methodology

The relationship between sea turtle nesting occurrence and beach morphology will be learned from the sea turtle nest and false crawl observation data obtained from the Share the Beach organization (https://www.alabamaseaturtles.com/nesting-season-statistics/), the U.S. Geological Survey, and the National Park Service for the Dauphin Island and Fort Morgan Peninsula in Alabama and applied to Cat and Ship islands. The Alabama beaches will be classified and ranked according to sea turtle nesting densities (low, medium, high). The ranked beaches will be used as subjects for the derivation of spatial parameters that are known to be important to loggerhead nesting in the northern Gulf of Mexico, specifically those shown in Table 1.

*Extraction of geospatial parameters*

The parameters shown in Table 1 will be extracted from lidar and orthophotography and used in the northern Gulf of Mexico multi-criteria decision support model for sea turtle nesting habitat suitability.

**Table 1.** Remote sensing extracted parameters for decision support model for loggerhead sea turtle nesting habitat suitability.

| Variable | Measurements | Scale |
|---|---|---|
| Beach width | distance grid from shoreline to dune toe | Transect |
| Beach elevation | elevation grid from shoreline to dune toe | Pixel-level |
| Dune elevation | dune crest elevation along a transect | Transect |
| Beach slope | neighborhood slope | Pixel-level |

Beach extent will be defined as the area between the mean high tide line and the primary dune toe. For the island tips where there are no primary dunes, the extent will be defined as the mean high tide line on the Gulf side to the MHW shoreline on the bay side of the island. Morphologic parameters, such as shoreline, dune toe, and dune crest, will be extracted as a 1- or 2-m grid (depending on the source data resolution). The dune morphology (primary dune toe and crest) and beach width will be developed using a transect-based approach similar to Dunkin et al. (2016) and Stockdon et al. (2012). Transects will be roughly perpendicular to the shore and spaced about 10 m apart, following the approach used by Stockdon et al. (2012). In some instances, there will be a small amount of overlap in the transects where there is a shift in the general orientation of the shoreline. In these cases, we will manually remove transects that overlap. The dune toe line will be created from a combination of dune toe points derived from the Stockdon method and a generalized line created from the lidar and orthophotography where points were not available. Additionally, we will determine upper slopes and ridges as defined by the topographic position index for a 30-m circular neighborhood to assist with dune toe delineation (Weiss 2001). Developed areas cannot be used for nesting and will therefore be identified by photointerpretation and removed from the final grids. The MHW shoreline will be determined using the Contour List tool in Esri ArcMap (ESRI 2017) using observations collected at the nearby NOAA Dauphin Island, Alabama tide gauge (station ID: 8735180) relative to North American Vertical Tidal Datum of 1988. Neighborhood slope will be assessed using the Slope function in Esri ArcMap (ESRI 2017).

*Model Development*
The extracted geomorphic parameters will be used as inputs for the spatially explicit, multi-criteria decision support model for loggerhead sea turtle nesting habitat suitability (Dunkin et al. 2016). Each of the ranked beaches will be analyzed using a multinomial logistic regression model to identify how the spatial parameters affect the density of loggerhead nesting on the beach. The regression analysis results will be used to develop suitability indices for each parameter which are plotted versus the spatial parameter values. These plots indicate the predicted probability of that spatial parameter's significance with respect to nest site density. The post-construction lidar data will be used to calculate the parameters and compare to the suitability curves. The probability of the suitability for loggerhead sea turtle nesting along the northern Gulf Coast will be approximated, based on this comparison.

The probability of nesting after each survey event will be compared to that of the baseline pre-construction conditions. A Welch's t-test will be performed to determine the statistical significance of the change between the baseline and post-construction conditions. A p-value = 0.05 will be used as the threshold for statistical significance. The midpoint formula for percent difference between each year of analysis and the baseline conditions will be calculated. The midpoint formula percent difference between each year of analysis shall also be calculated along with a Welch's t-test. The Tukey's range test procedure will be utilized to determine the data sets that are statistically significantly different from each other.

The project's progress towards meeting the success criteria established in this protocol will be based on whether the probability of the project area's suitability for nesting has increased from the baseline conditions. The results of the pre-construction sea turtle monitoring, which is currently ongoing, shall be used to determine whether each island shall be segmented and ranked according to the nesting density on sections of the beach which may then be analyzed independent of each other. The model results shall be compared against the nesting and false crawl data collected on Ship and Cat islands and the model may be adapted accordingly with input from subject matter experts.

## Products

1. RTK survey data should include surveyor's field notes, including set up information, naming convention, and benchmarks used. The accuracy achieved for each point shall also be clearly defined. Survey points should be submitted in ASCII format with an XYZ description. XYZ data submission should be in electronic format such as Excel or equivalent. Survey information shall be emailed to the following USACE staff, Brian Zettle at Brian.A.Zettle@usace.army.mil or mailed on a CD to the attention of Brian Zettle, 109 Saint Joseph Street, Mobile, Alabama, 36602.
2. Elevation profile illustrations shall be generated using MicroStation and shall be submitted via email or CD in .pdf and .dwg electronic format.
3. Sediment samples may be hand delivered to the Mobile District USACE office or mailed attention Brian Zettle, 109 Saint Joseph Street, Mobile, Alabama, 36602.
4. The geospatial data used to generate the parameters used for the analysis described in this protocol will be provided along with International Organization for Standardization (ISO) metadata for each data set.
5. A summary report and statistics derived from comparisons between the baseline conditions and post-construction survey results and statistics derived from comparisons of surveys obtained from different years of post-construction data will be provided. Summary statistics will include the midpoint formula percent difference between comparative years, the Welch's t-test significance level, Tukey's test q values, test statistic q values, degrees of freedom and assumptions they were based on, p-value, and determination for statistical significance.

## Metadata

Metadata will be created for all analyses, following ISO standards.

## Literature Cited

Dunkin, L., M. Reif, S. Altman, and T. Swannack. 2016. spatially explicit, multi-criteria decision support model for loggerhead sea turtle nesting habitat suitability: a remote sensing-based approach. Remote Sensing. 8 (7), 573, doi:10.3390/rs8070573.

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# MsCIP Monitoring and Adaptive Management Program
# Data Analysis Protocol:
# Habitat Suitability Model to Determine the Probability of Sea Turtle Nesting
# Protocol 232

*Protocol version date: 07/24/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***

Sea Turtle Nesting Habitat

**Purpose of Monitoring and Data Assessment**

Compliance monitoring to determine any impacts pursuant to the Biological Opinion Terms and Conditions as related to sea turtle nesting, and, in conjunction with the Fish and Wildlife Service, the development of a holistic evaluation of beach sediment characteristics, including penetration resistance values, on the Cat and East and West Ship islands (Mississippi) beaches. DCP (dynamic cone penetrometer) testing and soil sampling shall be performed to obtain data and make observations that will contribute to the limited body of scientific knowledge that currently exists concerning the relationship between sediment parameters and nest site selection of sea turtles on Cat Island, Mississippi.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**

The development of an evaluation formula, driven by improved understanding of the changes in penetration resistance over the monitoring period, such that no further consultations with Fish and Wildlife Service are needed

AND

Compliance with the terms and conditions with respect to sea turtle nesting as they are set forth in the Biological Opinion.

**Areas of Interest**

Cat Island, West Ship Island, East Ship Island

**Interim Target**

N/A

**AM Triggers**

N/A

**Task**

1. Determine the physical properties of sediments in select locations along the Cat Island beach face, their temporal variability, both seasonally and as affected by construction, and their relationship to the physical properties of sediments at documented turtle nesting sites.
2. Compare pre-construction and post-construction sediment characteristics and penetration resistance values calculated from DCP data collected on Cat Island and Ship Island, Mississippi.

3. Post-construction values shall be compared to pre-construction values for the equivalent depth interval for the location and season in which they were collected, e.g. the 12-18” pre-construction penetration resistance values for specific locations on Cat Island in fall/winter shall be compared to the fall/winter 12-18” post-construction penetration resistance values for locations in close proximity to the pre-construction testing sites on Cat Island.

**Analysis Frequency**

Immediately post-construction and for two additional years beyond that, thereby documenting a total of three years of post-construction penetration resistance.

**Data Collection Required for Analysis**

Data used to calculate the penetration resistance of test sites shall be collected using a DCP. Sediment sampling will also be performed at sea turtle nest and false crawl locations, as well as along transects that were established in 2015.

**Background**

Pre-construction baseline testing events were conducted to determine the penetration resistance values of the sandy beachfaces of Cat Island and East and West Ship islands, Mississippi. These baseline events and their subsequent results were extensively coordinated between the Mobile District USACE, ERDC, the Gulf Island National Seashore field office of the National Park Service (NPS), and representatives of the Mississippi, Alabama, and Florida offices of the Fish and Wildlife Service (USFWS). A DCP was approved for use as an alternative to the standard SCP (static cone penetrometer) and field data using this device were collected at Cat and East and West Ship islands in November 2015. Additional testing was performed in March 2016, utilizing both a DCP and a SCP. Extensive analyses were performed on the DCP and SCP field data and the precision of the devices were compared. The analysis of the field data indicated that the DCP was generally more precise than the SCP; therefore, the DCP data were used to establish the baseline penetration resistance value against which the post-construction beach measurements could be compared

**Analysis Methodology**

The following analysis methods will be used:

- The post-construction expected value of penetration resistance plus one standard deviation shall be reported for the 6-12” depth and the 12-18” depth intervals.
- If statistical methods are employed, each data point shall be used in the calculation of the expected value, rather than the average of the three test spots along each transect.
- Results obtained through the use of a DCP device shall be the standard for data reporting and SCP values will be included in the initial post-construction report for information and reference only.
- The data shall be analyzed using computer code written specifically for the purpose of comparing pre- and post-construction penetration resistance values calculated from DCP

data.

**Collection Methodology**
A two-person DCP testing team shall test adjacent to new nest or false crawl site on a bi-weekly basis during the sea turtle environmental monitoring period. Testing may be performed less frequently if only a small number of nests are being reported by the environmental monitor. Each nest or false crawl reported during the environmental monitoring period shall be tested once soon after the activity is observed, and then again during the larger testing effort along the eastern beach face project area such that each turtle nest/false crawl site shall be tested twice.

Previously established transect locations shall be tested and stations shall be located as close as reasonably possible to those established during previous testing events. Two stations shall be tested on each transect in the cross-shore direction. One station shall be located at the dune toe and one station will be located on the berm midway between the dune toe and the wrack line. Three replicate DCP tests (spots) will be performed at each station.

***Testing Procedures***

- The post-construction testing will be performed at the completion of the beach restoration efforts for the Ship Island and Cat Island, MS projects according to the MsCIP SEIS BO terms and conditions.
- Data will be collected using the SCP for the first year of post-construction testing. SCP data and analysis results will be reported for reference and information only.
- The 10 lb hammer shall be used to perform DCP testing.
- Data shall be logged using a magnetic ruler and electronic data collector.
- Testing locations shall be identified prior to testing using the most recently available pre-construction imagery and validated in the field by the team leader. The team leader may adjust testing locations based on field conditions.
- In addition to the post-construction testing locations that are established prior to the testing event, tests shall be performed using the methods described herein at the locations of the nesting sites identified during the pre-construction sea turtle monitoring. For the two years of testing required after the initial construction testing, nesting locations identified during the previous nesting season’s monitoring shall be tested. If possible, based on field conditions at the time of testing, the previous year’s nesting locations shall be re-tested during each testing event. The team leader may modify this option at their discretion under the advisement of the MsCIP TAG.
- Post-construction field notes shall be maintained concurrent with DCP and SCP testing for future reference. Information recorded in field notebooks shall contain the same, or more detailed, information as the pre-construction baseline testing field notebooks.
- Field testing shall be supervised by an engineer (or equivalent geologist or biologist) who is familiar with the pre-construction baseline testing protocols, the pre-construction conditions of the island(s), the locations and conditions that sea turtles typically choose for nesting as published in peer-reviewed literature that has been accepted by subject-

matter experts, and has reviewed the locations of nesting sites recorded during the pre-construction sea turtle monitoring.

A full description of the methods of data collection may be found in the 2015 MsCIP Biological Opinion Terms and Conditions with respect to sea turtles (U.S. Fish and Wildlife Service 2015).

## Products

- A 2-D profile plot of DCP penetration resistance values versus depth with depth on the y-axis and penetration resistance in DCP psi on the x-axis shall be produced and reported. A surface plot of each test spot relative to the penetration resistance in DCP psi and depth below the surface shall also be produced.
- A table of the calculated post-construction expected value of the mean penetration resistance and the sample standard deviation shall be reported for each island at each depth interval.
- An electronic copy of all of the raw data collected and the computer code used in any analysis shall be provided to the MsCIP TAG upon request.
- SCP data and analysis results will be reported for reference and information only.
- Reports should include dates of testing, the names and occupations of the DCP (and SCP if applicable) testing team, a list of the qualifications of the team leader, the make, model name, and serial number of all testing related equipment, the weather during testing, a list of any storm events that occurred within a month of testing, a description of any observations considered relevant to testing by the engineer team leader that supervised the testing, an electronic copy of all field notes, and all results mentioned previously in this document.

## Metadata

Metadata will be created for all analyses, following ISO standards.

## Literature Cited

U.S. Fish and Wildlife Service. 2015. Mississippi Coastal Improvement Program Comprehensive Barrier Island Restoration Project Biological Opinion. U.S. Fish and Wildlife Service: Jackson, MS.

# MsCIP Monitoring and Adaptive Management Protocol
# Suitable Sea Turtle from Habitat Mapping
# Protocol 233

*Protocol version date: 03/13/2018*

### MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)*

Sea Turtle Nesting Habitat

### Purpose of Monitoring and Data Assessment

Support documentation of potential suitable sea turtle habitat areas over time and determine whether island restoration has an impact on these suitable habitat areas. Data analysis to support sea turtle compliance.

### MAM Plan Success Criteria (See Section 3.1 of MAM Plan)

Ten years post-construction the success criteria is to maintain or increase suitable acres of sea turtle habitat as compared to the pre-construction acreage. Sea turtle habitat is defined as upper beach habitat above the mean high water (MHW) line. The total number of acres of suitable nesting habitat will be determined by habitat mapping based on pre-construction conditions

### Areas of Interest

Cat Island, West Ship Island, East Ship Island

### Interim Target

Five years post-construction maintain suitable acres of turtle habitat as evaluated by habitat mapping efforts.

### AM Trigger

Loss of habitat (acreage) for sea turtle as evaluated by habitat mapping efforts. The total number of acres of suitable nesting habitat will be determined by habitat mapping based on pre-construction conditions

### Task

Determine acres of suitable habitat from habitat mapping.

### Analysis Frequency

Pre-construction, during construction, and a minimum of three additional times after completion of the planting of Ship Island.

### Data Collection Required for Analysis

Aerial photography, lidar (bathymetric lidar, when possible) data, habitat mapping. Data will be collected a minimum three times following the completion of construction on Ship Island; exact dates will be determined by the construction schedule and the temporal correlation of collection requirements across the program. Satellite data will be collected once during construction.

### Background

*Sea Turtle Species in the Northern Gulf of Mexico*

The MsCIP Monitoring and Adaptive Management (MAM) plan notes that five sea turtle species are found in the northern Gulf of Mexico, including loggerhead, green, Kemp's ridley, leatherback, and hawksbill. Green, loggerhead, and Kemp's ridley sea turtles are regularly documented in the waters surrounding the barrier islands of Gulf Islands National Seashore. Of these, only loggerhead sea turtles have been confirmed as nesting on the islands in the Mississippi Sound and they are the only species with designated critical habitat within the island chain (Horn and Petit Bois Islands). Green sea turtle nests have been found on the Mississippi islands (USFWS 2015); however, these nests are likely uncommon (USACE 2015). Though never documented, Kemp's Ridley sea turtles potentially nest on the islands. Leatherback and hawksbill sea turtles may be seen in the barrier island waters, but there are no confirmed nest records within the barrier island project area.

*Nesting Habitat and Geomorphic Features*

Sea turtle nest site selection is influenced by topographic, bathymetric, biophysical, and behavioral factors, but the relative importance of these factors is unknown (Wood and Bjorndal 2000). Prior to establishing a nest, female sea turtles may choose beaches based on a combination of natal homing (Brothers and Lohmann 2015), accessibility from underwater (Crain et al., 1995), suitable microclimate and geomorphic features (Provancha and Ehrhart 1987), ease of nest excavation (Crain et al. 1995), low disturbance (Schofield et al. 2015), and low artificial light pollution (Salmon 2003; Dunkin et al. 2016). An ideal nest site will likely favor successful embryo development (e.g., proper temperature, moisture, and salinity levels), as well as hatchling survival during their stressful journey towards the water. Once the hatchlings emerge from the nest they must crawl towards the brightest horizon to reach the ocean while also avoiding predators and dehydration (Lorne and Salmon 2007). Nests placed too close to the ocean have a higher risk of inundation and egg loss to erosion, whereas those too far away risk increased desiccation, hatchling misorientation, and exposure to predators (Wood and Bjorndal 2000).

Loggerheads generally nest on ocean-facing beaches, but they occasionally nest on estuarine shorelines if the sand is suitable (USFWS 2015). Nests are found more frequently on steeper-sloped, narrower beaches (Provancha and Ehrhart 1987; Wood and Bjorndal 2000; Dickerson et al. 2007; Dunkin et al. 2016). Most loggerhead nests are located above the MHW line (Wood and Bjorndal 2000; Yamamoto et al. 2012) in close proximity to the supralittoral vegetation zone (Garmestani et al. 2000) and up to the dune toe (USFWS 2015). Nesting is positively correlated with greater tidal heights, presumably because energy expenditure to the nest site and exposure to predators is reduced (Lamont and Carthy 2007). Although studies have proposed that offshore bathymetric details affect nest site selection, Yamamoto et al. (2012) found that onshore characteristics were more influential for predicting nest density.

## Analysis Methodology

In contrast to the more detailed effort that models sea turtle nesting suitability based on geomorphic conditions (i.e., Protocol 231Habitat Suitability Model to Determine the Probability of Sea Turtle Nesting), the objective of this effort is to delineate general areas that meet the basic conditions for sea turtle nesting (i.e., areas above the mean high water line up to the dune toe or supralittoral vegetation) on Cat and Ship islands. We will use MsCIP MAM habitat mapping efforts as a starting point to delineate suitable habitats for sea turtle nesting. The habitat mapping effort for the MsCIP MAM uses the National Wetlands Inventory (NWI) classification scheme (Cowardin et al. 1979). Based on sea turtle observation data collected by the Share the Beach organization and the U.S. Geological Survey along the Alabama Gulf Coast, sea turtles predominately use the gulf-facing shoreline for nesting. Therefore, suitable sea turtle nesting habitat will largely be captured within in the marine unconsolidated shore irregularly flooded NWI class (M2USP; Figure 1). The irregularly flooded NWI water regime is used for wetlands that are flooded by tides less often than daily (i.e., areas above MHW).


**Figure 1.** Suitable sea turtle nesting habitat from MsCIP MAM habitat mapping data for East Ship Island.

We will analyze sea turtle observation data obtained from the Share the Beach organization and the U.S. Geological Survey along the Alabama Gulf Coast, anecdotal accounts of Mississippi barrier island sea turtle nesting from the National Park Service, and the data collection associated with MsCIP on the Mississippi barrier islands to assess how well the NWI class M2USP captures nesting area. Similar to Protocol 231(231Habitat Suitability Model to Determine the Probability of Sea Turtle Nesting)), entire island tips might need to be included in the nesting area. This can be accomplished by either using the Contour List function in ArcMap (ESRI 2017; Protocol 231 Habitat Suitability Model to Determine the Probability of Sea Turtle Nesting) or by using a combination of photointerpretation and habitat data to determine the mean high water line based on water regime. Additional conceptual model results and monitoring data collected on the MS barrier islands shall also be considered. Protocol 234 (Sea Turtle Historical Suitable Habitat) includes applications of lidar data and satellite data to delineate historical suitable sea turtle nesting habitat. If any of these approaches are deemed helpful for this effort, then we will explore including them in this effort as well.

## Products

1) A geodatabase containing maps of generalized sea turtle habitat based from habitat maps for each year habitat mapping is conducted
2) International Organization for Standardization (ISO) compliant metadata for all spatial products
3) Brief report on methods and acreages

## Literature Cited

Brothers, J.R., and Lohmann, K.J. 2015. Evidence for geomagnetic imprinting and magnetic navigation in the natal homing of sea turtles. Current Biology, 25(3), 392-396.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. United States Department of the Interior, Fish and Wildlife Service, Washington, D.C., 134 pp.

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# MsCIP Monitoring and Adaptive Management Protocol
# Sea Turtle Historical Suitable Habitat
# Protocol 234

*Protocol version date: 03/13/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Sea Turtle Nesting Habitat

**Purpose of Monitoring and Data Assessment**
Support documentation of suitable sea turtle habitat areas over time and determine whether island restoration has an impact on these suitable habitat areas. Data analysis to support sea turtle compliance.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
There are no success criteria directly related to historical sea turtle habitat. Data from the analysis of historic sea turtle habitat will be used to inform sea turtle success criteria related to suitable acres of sea turtle habitat as described Protocol 233 (Suitable Sea Turtle from Habitat Mapping).

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
N/A

**AM Trigger**
N/A

**Task**
Determine historic habitat from available habitat mapping products, aerial photography and lidar data.

**Analysis Frequency**
Pre- and during construction, plus three times during the 10 years after the completion of sand placement on Ship Island.

**Data Collection Required for Analysis**
Existing habitat maps, aerial photography and lidar datasets collected over the past 15 years

**Background**
*Sea Turtle Species in the Northern Gulf of Mexico*
The MsCIP Monitoring and Adaptive Management (MAM) plan notes that five sea turtle species are found in the northern Gulf of Mexico, including loggerhead, green, Kemp's ridley, leatherback, and hawksbill. Green, loggerhead, and Kemp's ridley sea turtles are regularly documented in the waters surrounding the barrier islands of Gulf Islands National Seashore. Of these, only loggerhead sea turtles have been confirmed as nesting on the islands in the Mississippi Sound and they are the only species with designated critical habitat within the island chain (Horn and Petit Bois Islands). Green sea turtle nests have been found on the Mississippi

islands (USFWS 2015); however, these nests are likely uncommon (USACE 2015). Though never documented, Kemp's Ridley sea turtles potentially could nest on the islands. Leatherback and hawksbill sea turtles may be seen in the barrier island waters, but there are no confirmed nest records within the barrier island project area.

*Nesting Habitat and Geomorphic Features*

Sea turtle nest site selection is influenced by topographic, bathymetric, biophysical, and behavioral factors, but the relative importance of these factors is unknown (Wood and Bjorndal 2000). Prior to establishing a nest, female sea turtles may choose beaches based on a combination of natal homing (Brothers and Lohmann 2015), accessibility from underwater (Crain et al. 1995), suitable microclimate and geomorphic features (Provancha and Ehrhart 1987), ease of nest excavation (Crain et al. 1995), low disturbance (Schofield et al. 2015), and low artificial light pollution (Salmon 2003; Dunkin et al. 2016). An ideal nest site will likely favor successful embryo development (e.g., proper temperature, moisture, and salinity levels), as well as hatchling survival during their stressful journey towards the water. Once the hatchlings emerge from the nest they must crawl towards the brightest horizon to reach the ocean while also avoiding predators and dehydration (Lorne and Salmon 2007). Nests placed too close to the ocean have a higher risk of inundation and egg loss to erosion, whereas those too far away risk increased desiccation, hatchling misorientation, and exposure to predators (Wood and Bjorndal 2000).

Loggerheads generally nest on ocean beaches, but they occasionally nest on estuarine shorelines if the sand is suitable (USFWS, 2015). Nests are found more frequently on steeper-sloped, narrower beaches (Provancha and Ehrhart 1987; Wood and Bjorndal 2000; Dickerson et al. 2007; Dunkin et al. 2016). Most loggerhead nests are located above the mean high water (MHW) line (Wood and Bjorndal 2000; Yamamoto et al. 2012) in close proximity to the supra-littoral vegetation zone (Garmestani et al. 2000). Nesting is positively correlated with greater tidal heights, presumably because energy expenditure to the nest site and exposure to predators is reduced (Lamont and Carthy 2007). Although studies have proposed that offshore bathymetric details affect nest site selection, Yamamoto et al. (2012) found that onshore characteristics were more influential for predicting nest density.

## Analysis Methodology

*Historic Habitat Change Trend Analysis*

The objective of the effort will be to assess the spatial extent and coverage of historical suitable sea turtle nesting habitat (i.e., above the MHW line up to the dune toe) on Cat and Ship islands. This analysis will be conducted by using existing habitat maps targeted at extracting the location and areal coverage of supratidal unvegetated beach. The habitat map analysis will include habitat maps from the National Wetland Inventory (NWI) for 1996 and 2002, and the MsCIP preconstruction baseline data from January 2015 and December 2015, along with future MsCIP MAM habitat mapping efforts. This effort will build off the work done for the Protocol 233 (Suitable Sea Turtle from Habitat Mapping). Unvegetated beach environments (i.e., NWI class = marine unconsolidated shore, irregularly flooded, M2USP) will be extracted from habitat maps.

Island tips will be added to the nesting area by using a combination of photointerpretation and habitat data to determine the mean high water line based on water regime.

Areal change (i.e., change in area over time) will be assessed for all maps. A spatial change analysis may be conducted if the registration of source data for maps can be verified as compatible across all maps. A limitation to this approach is that some change identified may be related to technological advances in imagery resolution, ancillary data availability, subjective interpretation, and methodology.

**Products**

1. A geodatabase containing maps of generalized sea turtle habitat based from historical habitat maps for each year habitat mapping is conducted
2. International Organization for Standardization (ISO) compliant metadata for all spatial products
3. Spatial change map (*if feasible*, *if registration of habitat maps is suitable for this analysis*)
4. Brief report on methods and acreages, and change over time

**Literature Cited**

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# MsCIP Monitoring and Adaptive Management Protocol
# Benthic and Threatened and Endangered Shorebird Foraging
# Protocol 241

*Protocol version date: 03/14/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Threatened and Endangered (T&E) shorebirds

**Purpose of Monitoring and Data Assessment**
Compliance monitoring for T&E shorebirds using East and West Ship islands and Cat Island to determine any impacts pursuant to the ESA.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Provide suitable benthic habitat five years after the completion of planting of Ship Island.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island, Horn Island, Petit Bois Island (Petit Bois seems to be only borrow area)

**Interim Target**
Maintain suitable shorebird foraging habitat acreage five years after the completion of construction of Ship Island. Foraging habitat will be mapped via Protocol 245 (Mapping and Assessing Nesting Shorebird Habitat).

**AM Trigger**
Reduction of suitable shorebird foraging habitat after closure of Camille Cut.

**Task**
Correlate benthic samples collected with shorebird foraging sites for Cat Island and East and West Ship islands (required for success criteria)

**Analysis Frequency**
Pre-construction and two years after the completion of construction on Cat Island and two years after the completion of planting on Ship Island.

**Data Collection Required for Analysis**
Samples of benthic communities collected from shorebird foraging areas (offshore, intertidal, supratidal) and avian surveys. Ideally, benthic and avian surveys will be within the same timeframe. Collection is scheduled for the second year after the completion of the construction of Cat Island and Ship Island, respectively, but exact dates will be determined by the construction schedule and the temporal correlation of collection requirements across the program

**Background**
Barrier island environments are extremely dynamic due to exposure to frequent disturbances from storms, sediment disposal, waves, currents, and sea-level change (Peterson and Bishop 2005). As a result, the taxa richness and density of barrier island benthic and infaunal communities can vary significantly by location and that the common species tended to be either disruption-tolerant, or capable of rapidly recolonizing disturbed areas

(Rakocinski et al. 1990, 1993, 1998; Wilber et al. 2007). Benthic invertebrates are useful as biological indicators because of their relatively sessile nature (i.e., they respond to local effects), potential to be sampled cost-effectively, and their ability to reveal ecologically meaningful patterns at coarse scales (Warwick 1988, Martin et al. 2005). Additionally, benthic invertebrates are important food sources for shorebirds.

The soft sediment and sand bottoms present in the tidal passes and beaches of the barrier islands and adjacent shallow waters provide habitat for many benthic invertebrate species. It is anticipated that benthic and infaunal communities will be displaced in the short-term in response to dredging and placement of dredged material. The MsCIP project includes a broad sampling effort designed to characterize macrobenthic biological resources at potential sand borrow areas, sand placement areas (Cat Island, East and West Ship Islands, Horn Island, Petit Bois Island), appropriate reference areas (which are unlikely to be affected by construction), and in shorebird foraging habitat. Benthic surveys and sample analyses, conducted by Barry A. Vittor and Associates, Inc., include sorting, identification, and enumeration of benthic macroinvertebrates collected in each area. For more detailed information on benthic sampling please see the benthic infaunal protocol, Protocol 201 (Benthic and Infaunal Species).

The objective of this task is to correlate benthic samples (i.e., biomass and abundance) acquired on the barrier islands to T&E shorebird count at Cat Island and East and West Ship islands. This protocol will be conducted before and after MsCIP construction projects.

**Collection Methodology**

*Benthic and Infaunal Survey Periods and Sampling Locations*

The surveys in 2010 (June 2-10 and September 2-6) and 2011 (April 29-May 6) did not specifically target shorebird foraging sites, thus only two sample locations will be considered for analysis (Figure 1). One of these sites is located on an intertidal flat on East Ship Island and the other is located on an intertidal flat of the east side of West Ship Island. Each sample included eight replicates.

The U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, National Park Service, and Barry A. Vittor & Associates, Inc. personnel collected additional benthic community samples in 2015 (January 14-19). Samples were collected along two-station transects. The first sample was taken in tidally-exposed flats (i.e., just below the water line) and the second sample was taken at or just above the water line (i.e., wet sand areas). Sampling sites were in tidal flats where Piping Plovers and/or Red Knots were foraging (Figure 1). Specifically, the sample sites included: (1) two beach transects on the eastern shoreline of Cat Island at the northern tip (one through a shallow tidal pool/flat and one on a shoreline area south of the tidal pool); (2) two beach transects through an extensive tidal area on the eastern shoreline of Cat Island near the southern tip; (3) three beach transects on the west tip of East Ship Island (two in an extensive tidal pool/flat area and one on the northern shoreline); (4) one pre-placement transect on the Gulf-front shoreline of East Ship Island; (5) three beach transects on the east tip of West Ship Island (one through a tidal pool, one on the northern shoreline, and one on the southern area of the island tip); (6) one pre-placement transect on the Gulf-front shoreline of West Ship Island; and (7) three beach transects on the west tip of Horn Island as reference areas (one through a tidal pool, one on the northern shoreline, and one on the southern shoreline). One of the transects on each of East Ship Island and West Ship Island is located higher on the beach at about 0.5 m (relative to the North American Vertical Datum 1988). As recommended by previous USACE studies, each station included four replicates within a 1 $m^2$ area in a homogeneous beach or flat environment.

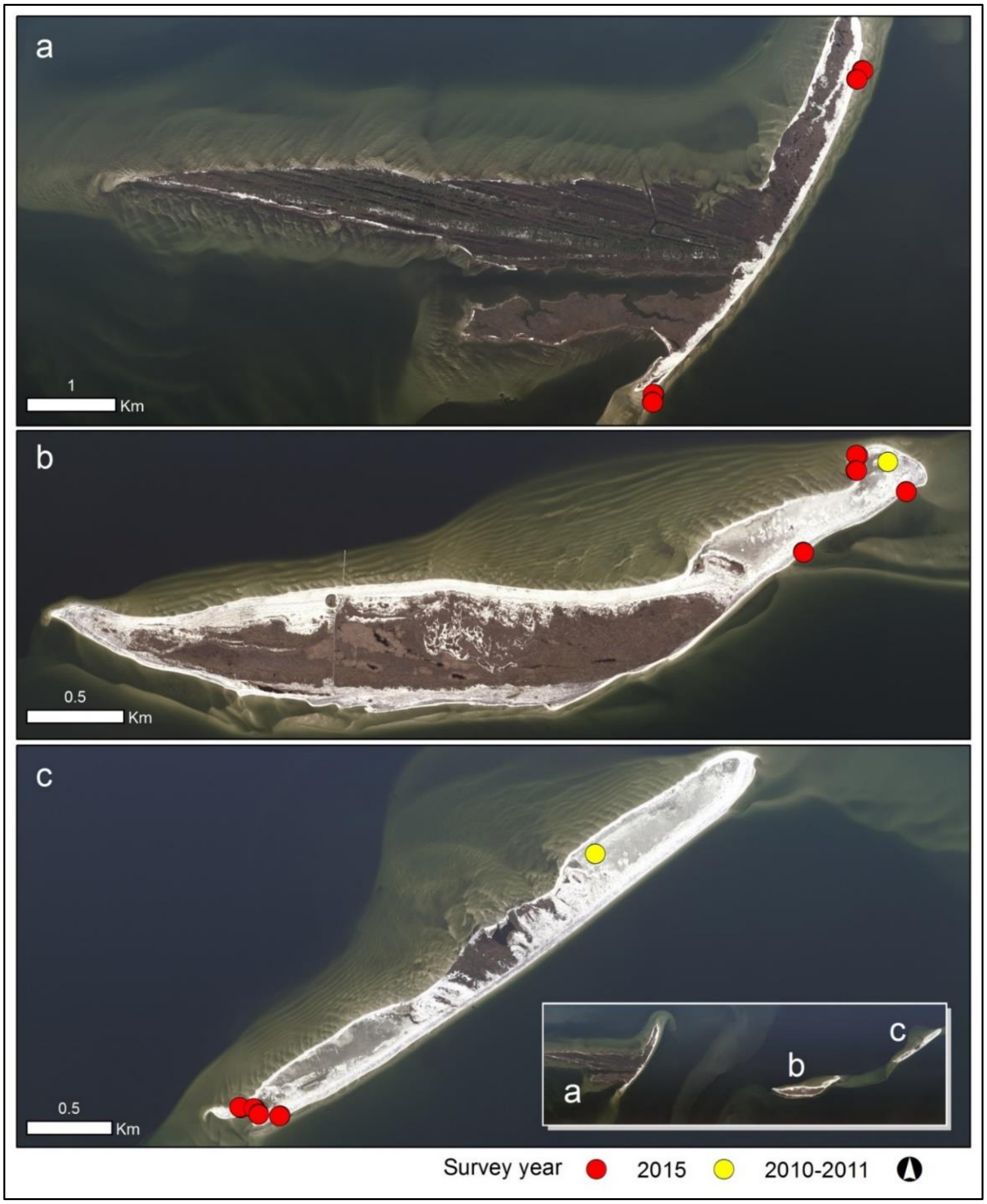


**Figure 1.** Benthic sample transects by year. Samples for 2010-2011 and 2015 for Cat Island (a), West Ship Island (b), and East Ship Island (c). The basemap is 1-ft aerial photography collected in January of 2015.

**Sample Collection**
Offshore samples were collected at each station with a Shipek grab (June 2010) or a modified Van Veen grab (September 2010 and April – May 2011) with a sampling area of 0.04 $m^2$. Both grab samples are spring-loaded and are designed for collecting consistent samples in sand and consolidated sediments. Beach/tidal flat samples were collected with a 3" (7.6 cm) hand corer with a sampling area of 0.0044 $m^2$ to a depth of 6" (about 15.2 cm). The samples were rinsed in the field through a 0.5 mm mesh screen and preserved with 10% buffered formalin. Samples were only rinsed if they contained silty sediments. Prior to sampling, standard hydrographic measurements were taken at each station.

**Analysis Methodology**
*Benthic Laboratory Processing*
Benthic samples were again rinsed through a 0.5 mm mesh screen to remove preservatives and sediment, stained with Rose Bengal, and stored in 70% isopropanol solution until processing. We placed sample material (sediment, detritus, and organisms) in white enamel trays for sorting under Wild M-5A dissecting microscopes. Sorted macroinvertebrates were placed in labeled glass vials contacting 70% isopropanol, with each vial representing a major taxonomic group (e.g., Polychaeta, Mollusca, Arthropoda). All macroinvertebrates were removed and identified to the lowest practical identification level (LPIL), which, unless the specimen was a juvenile, damaged, or unidentifiable, was to species level in most cases. We recorded the number of individuals of each taxon, excluding fragments. A voucher collection was prepared, composed of representative individuals of each species not previously encountered in samples from the region.

Each sample was analyzed for wet-weight biomass (g) of the major taxonomic groups identified. After identification, each taxonomic group was placed in a separate vial and preserved in 70% isopropyl alcohol. A biomass technician removed the organisms from each vial, placed them on a filter paper pad, gently blotted them with a paper towel to remove moisture, placed them in a tared weighing pan, and weighed the pan to the nearest 0.1 mg using a Mettler Model AG-104 balance.

*Community Assemblage Analyses*
All laboratory data were entered for each species by station and replicate. The summary report for each station included a taxonomic species list and quantified benthic community parameters. Several numeric indices were calculated for each sample, including: (1) infaunal abundance, the total number of individuals by station; (2) infaunal density, the total number of individuals per square meter; (3) taxa richness, the number of taxa present at a station; (4) taxa diversity (Shannon's Index H'); and (5) evenness (Pielou's Index J').

Taxa diversity is often related to the ecological stability and environmental quality of the benthos. We used Shannon's Index (Pielou 1966) to estimate taxa diversity, which is dependent upon the number of taxa present (taxa richness) and the distribution of all individuals among those taxa (evenness or equitability). To quantify and compare the evenness in the fauna to the taxa diversity for a given area, Pielou's Index J' (Pielou 1966) was calculated as:

$$J' = \frac{H'}{lnS}$$

Where *ln*S = H'max, the maximum possible diversity when all taxa are represented by the same number of individuals, therefore:

$$J' = \frac{H'}{H'max}$$

Univariate statistics were used to compare taxa richness and density at stations between transects on a given island and between stations on different islands (SAS Institute 2009).

*Shorebird Surveys*

The U.S. Army Corps of Engineers, Mobile District contracted shorebird surveys prior to restoration activities for Cat Island and East and West Ship islands (Figure 1). Surveys were focused on the threatened and endangered species including Piping Plover and Red Knot, colonial nesting shorebirds (e.g., Least Tern, Royal Tern, Black Skimmer, etc.), and solitary nesting shorebird species (e.g., Wilson's Plover, Snowy Plover, American Oystercatcher, etc.). Surveys on East and West Ship islands were conducted from December 28, 2012 through December 18, 2013. Surveys on Cat Island were conducted from March 11, 2015 through March 01, 2016. The islands were visited once a week as weather permitted. Surveyors traveled the perimeter of the islands by foot, all-terrain vehicle (ATV), or boat to identify and count birds on the beach and tidal flats between low tide and vegetated areas upslope of the beach. Bird observations were made using a sighting scope or binoculars and Global Positioning System (GPS). For each observation, surveyors documenteded species present, count by species, the behavior (i.e., foraging, resting, courtship behavior, nesting, etc.), observation date, habitat, weather condition (e.g., wind speed, temperature, etc.), vegetation cover, substrate, tide level, side of the island (e.g., gulf, bay, etc.), number of nests (opportunistically found), disturbance events, presence of color bands, general location, and GPS location.

For surveys conducted on East and West Ship islands, the GPS coordinates are most often located at the position of the observer (i.e., location of sighting scope, not the bird). For points taken on foot, observers reported being no closer than 15.2 m (50 ft) and as far as 61 m (200 ft) from the observed birds. Cat Island bird surveys included the use of an Apple iPad® and a custom application developed by the USGS Wetland and Aquatic Research Center's Advanced Applications Team to support data collection. This application allowed for observers to offset viewing locations (i.e., location birds were seen from sighting scope) to the actual locations occupied by the birds.

Several steps were taken to preprocess the bird survey data. The first step was removing nonshorebird species (e.g., osprey, little blue heron, etc.). Second, points located outside the surveyed zone (i.e., points outside the intertidal beach area) were either omitted or edited. This process included omitting points that were either found inland in vegetated habitats (i.e., outside the surveyed area) or were taken by foot that were located more than 15 m from the shoreline, and projecting observations that were taken via boat onshore. The shorebird observers were consulted to determine the best approach for editing the shorebird data. For more details on how these data were edited please see the MsCIP MAM shorebird modeling tasks modeling protocol, Protocol 243 (Shorebird Habitat Utilization Modeling).

*Relationship between Benthic Surveys and Shorebird Surveys*

We will assess the relationship between benthic abundance and biomass, respectively, to bird count. Benthic survey points will be buffered by 61 m (200 ft). The rationale for this buffer distance is the approximate offset around bird survey locations. The bird count for all shorebirds within each benthic survey point buffer will be summed and associated with the benthic sample location.

Correlation analyses could be conducted at several levels. The first could be pooling all data irrespective of behavior and timing of observation. Other analyses could restrict the bird observations to those with behaviors listed as “foraging” for observations made in the season for which the benthic sample was acquired (i.e., summer for 2010, spring for 2011, and winter for 2015) to account for possible benthic seasonality, both collectively and respectively.

*Limitations*

Associating benthic samples with shorebird surveys is not a trivial task and can be complicated by numerous issues related to sample design and bird mobility which account for some of the major limitations associated with this assessment. First, there is a temporal lag between bird observations and benthic surveys for West and East Ship islands (bird surveys occurred from 2012 – 2013, but benthic invertebrate surveys occurred in 2010, 2011, and 2015). Second, birds are nonstationary. For instance, an observer would almost certainly observe a different number of birds at the same location at a different time irrespective of benthic richness. Third, even with replicates, the benthic survey sample location may not be truly representative of benthic community due to the patchy distribution of some invertebrate prey species. Lastly, the benthic survey points on West and East Ship islands are not well-distributed throughout the island and tend to be clustered (Figure 1).

## Products

1) Brief report with methods and results

## Metadata

Metadata will be created for all analyses, following ISO standards.

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# MsCIP Monitoring and Adaptive Management Protocol
# Mapping and Assessing Change in Critical Habitats for Threatened and Endangered Shorebirds
# Protocol 242

*Protocol version date: 03/14/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Threatened and Endangered (T&E) shorebirds

**Purpose of Monitoring and Data Assessment**
Compliance monitoring for T&E shorebirds (i.e., Piping Plovers [*Charadrius melodus*] and Red Knots [*Calidris canutus*]) using East and West Ship islands and Cat Island to determine any impacts pursuant to the ESA

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Ten years post-construction the success criteria is to maintain or increase the pre-construction acreage of suitable shorebird foraging habitat

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
Maintain suitable shorebird foraging habitat acreage five years post-construction. Foraging habitat will be mapped via Protocol 245 (Mapping and Assessing Nesting Shorebird Habitat).

**AM Trigger**
Reduction of suitable shorebird foraging habitat after closure of Camille Cut.

**Task**
Map and assess change for suitable shorebird foraging habitat pre- and post-construction for East and West Ship islands and Cat Island (required for success criteria)

**Analysis Frequency**
Pre-construction and up to ten years after the completion of planting on Ship Island

**Data Collection Required for Analysis**
Topobathymetric data will be collected a minimum of three times, with exact dates determined by the construction schedule and the temporal correlation of collection requirements across the program.

**Background**
*Threatened and Endangered Shorebirds*
The Piping Plover and Red Knot are threatened and endangered (T&E) migratory shorebirds that winter and stopover along the northern Gulf of Mexico coast. Wintering ground habitat plays a critical role in providing the food resources that fuel migration and affect reproductive success on the breeding ground (Norris et al., 2004). On the wintering ground, Piping Plovers spend the majority of their time foraging on moist sandflats, mudflats, algal flats, ephemeral pools, and overwash areas (Johnson and Baldassare 1988). Schulz (2015) studied wintering Piping Plovers

on Whiskey and Trinity Islands, Louisiana and found that 92% of all observed Piping Plovers foraged in intertidal habitat with preference toward foreshore beach, tidal flats, sand flats, and backshore beach, respectively. Piping Plovers on backshore beach or interior sand flat habitats generally use wet areas around ephemeral pools. Convertino et al. (2011) studied Piping Plover and Red Knots in Florida, finding that the habitat preferences of both birds tended to overlap. Like the Piping Plover, Red Knots wintering in the United States generally use sandy beaches; however, their foraging techniques sometimes differ, as the Red Knot follows the contour of the shoreline while foraging on falling or rising tides over tidal sand flats, mudflats, and beaches (Baker et al. 2013). For our analyses, we will group survey data for T&E birds (i.e., Piping Plover and Red Knot) collectively.

Critical habitat for T&E shorebirds is defined as the island area above mean lower low water (MLLW; 50 C.F.R. § 17 2001). The objective of this assessment is to map critical habitat pre- and post-construction and assess change for East and West Ship Islands and Cat Island.

**Analysis Methodology**

*Topobathymetric Data and Tidal Datums*

Topobathymetric data will be used to quantify the critical habitat for T&E shorebirds for East and West Ship islands and Cat Island (Fig. 1). Pre-construction lidar was collected during the winter of 2015. Post-construction acquisitions are planned. Nearshore bathymetry was collected during the summer and fall of 2016. Post-construction collections are planned. For each critical habitat mapping effort, the best available topobathymetric data closest to the time of the bird surveys will be used to create topobathymetric digital elevation models (DEMs). Empirical Bayesian Kriging (Krivoruchko 2012), Ordinary Kriging, or inverse distance weighted interpolation will be used to develop a custom topobathymetric DEM from existing data sources. We will use observations collected at the nearby NOAA Dauphin Island, Alabama tide gauge (station ID: 8735180) for MLW relative to the North American Vertical Datum of 1988.

# MsCIP Monitoring and Adaptive Management Protocol
# Mapping and Assessing Change in Critical Habitats for Threatened and Endangered Shorebirds
# Protocol 242

*Protocol version date: 03/14/2018*

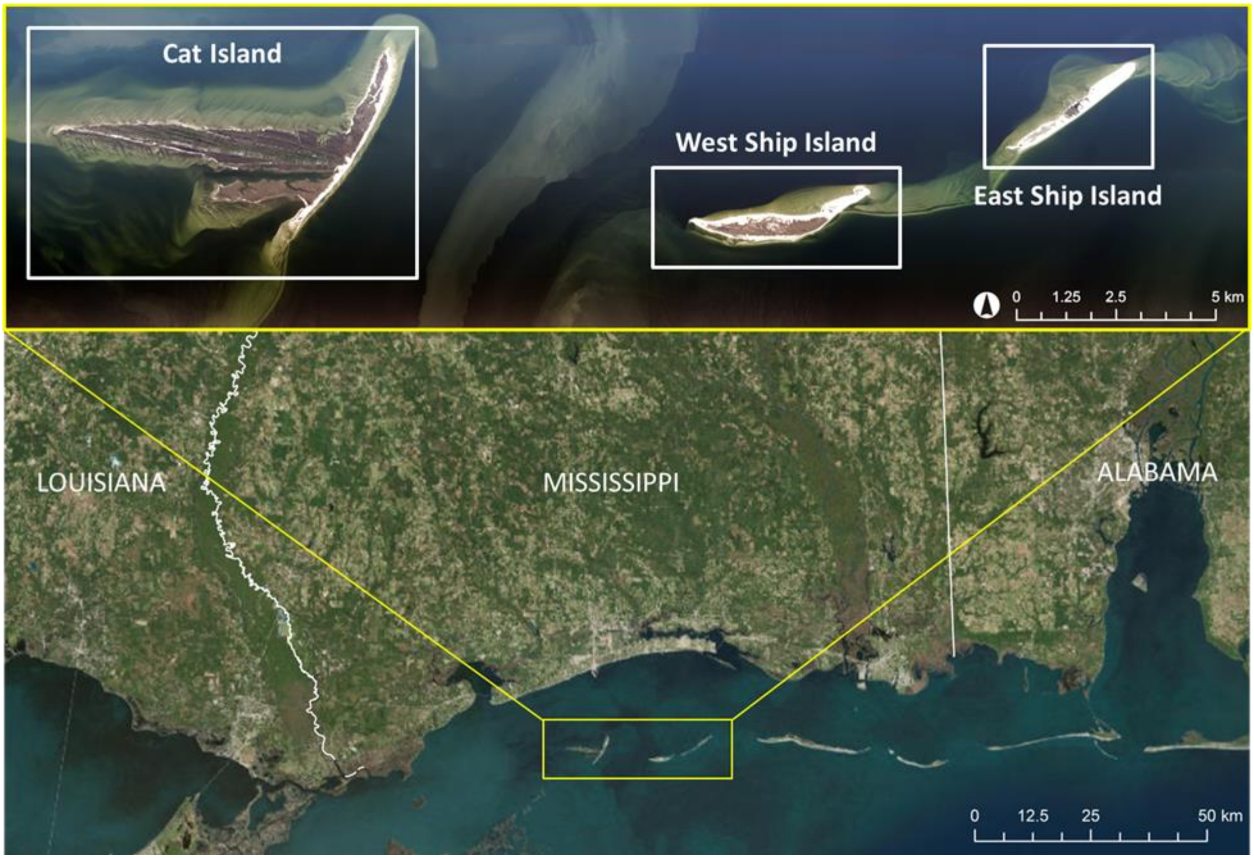


**Figure 1.** Overview of the Mississippi barrier island project area for critical habitat mapping and change assessment.

*Topobathymetric DEM Error Propagation*

Digital elevation models, like any model, contain errors. Errors associated with a DEM are often ignored by data users (Wechsler 2003). Numerous techniques have been developed for DEM error propagation (Hunter and Goodchild 1995; Wechsler and Kroll 2006; Cooper et al. 2013; Leon et al. 2014). For these mapping and change assessment efforts, error propagation will follow an approach similar to the neighborhood autocorrelation filter method outlined in Wechsler and Kroll (2006). For more information regarding DEM error propagation, please see Protocol 243(Shorebird Habitat Utilization Modeling).

*Mapping Critical Habitat*

A raster surface will be created from the error propagation that represents the probability of each pixel being above MLLW. A critical habitat presence/absence map will be developed from the MLLW probability raster surface. Pre- and post-construction lidar will be used to conduct change analysis, both in terms of area and spatial change per island. Spatial change will be determined by overlaying the pre- and post-construction maps in a geographic information system.

**Products**
1. A geodatabase containing pre- and post-construction maps of critical habitat for T&E shorebirds
2. International Organization for Standardization (ISO) compliant metadata for all spatial products
3. Spatial change map from pre- and post-construction
4. Brief report on methods and acreages

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# MsCIP Monitoring and Adaptive Management Protocol
# Shorebird Habitat Utilization Modeling
# Protocol 243

*Protocol version date: 03/14/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Threatened and Endangered (T&E) shorebirds and nesting shorebirds

**Purpose of Monitoring and Data Assessment**
<u>Threatened and Endangered Shorebirds:</u>
Compliance monitoring to document habitat utilization of T&E shorebirds (i.e., Piping Plovers [*Charadrius melodus*] and Red Knots [*Calidris canutus*]) using East and West Ship islands and Cat Island to determine any impacts pursuant to the ESA

<u>Nesting Shorebirds:</u>
Assess utilization of newly created beach and shoreline habitats by colonial nesting shorebirds (i.e., Black Skimmer [*Rynchops niger*], Common Tern [*Sterna hirundo*], Gull-billed Tern [*Gelochelidon nilotica*], Least Tern [*Sternula antillarum*], Royal Tern [*Thalasseus maximus*], and Sandwich Tern [*Thalasseus sandvicensis*]), and solitary nesters (i.e., American Oystercatcher [*Haematopus palliatus*], Semipalmated Plover [*Charadrius semipalmatus*], Snowy Plover [*Charadrius nivosus*], Willet [*Tringa semipalmata*], and Wilson's Plover [*Charadrius wilsonia*])

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
This task is not directly used to gauge a success criterion, instead information will be used to support the success criteria related to acreage of suitable T&E foraging habitat and nesting shorebirds nesting habitat. Data will support analysis conducted under Protocol 242 (Mapping and Assessing Change in Critical Habitats for Threatened and Endangered Shorebirds) and Protocol 245 (Mapping and Assessing Nesting Shorebird Habitat).

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
N/A

**AM Trigger**
N/A

**Tasks**
<u>Threatened and Endangered Shorebirds:</u>
1) Use bird survey data to model habitat utilization (supporting analyses for success criteria)
2) Identify changes in acreage of potential habitat utilization pre- and post-construction (supporting analyses for success criteria)
3) Assess if utilization of island passes (i.e., island tips) has changed after construction (supporting analyses for success criteria)

<u>Nesting Shorebirds:</u>

1) Identify the habitat and geomorphic conditions necessary for actual and potential nesting utilization and track changes over time (supporting analyses for success criteria)
2) Use bird survey data to model habitat utilization (supporting analyses for success criteria)
3) Identify changes in acreage of potential habitat utilization pre- and post-construction (supporting analyses for success criteria)
4) Assess if utilization of island passes (i.e., island tips) has changed after construction (supporting analyses for success criteria)

**Analysis Frequency**
Pre-construction and three years after the completion of planting on Ship Island

**Data Collection Required for Analysis**
Avian surveys, topobathymetric data, orthophotography, and satellite imagery. Collection dates will be determined by the construction schedule and the temporal correlation of collection requirements across the program

**Background**
*Threatened and Endangered Shorebirds*
The Piping Plover and Red Knot are threatened and endangered (T&E) migratory shorebirds that winter and stopover along the northern Gulf of Mexico coast. Wintering ground habitat plays a critical role in providing the food resources that fuel migration and affect reproductive success on the breeding ground (Norris et al. 2004). On the wintering ground, Piping Plovers spend the majority of their time foraging on moist sandflats, mudflats, algal flats, ephemeral pools, and overwash areas (Johnson and Baldassare 1988). Schulz (2015) studied wintering Piping Plovers on Whiskey and Trinity Islands, Louisiana and found that 92% of observed Piping Plovers foraged in intertidal habitat with preference toward foreshore beach, tidal flats, sand flats, and backshore beach, respectively. Piping Plovers on backshore beach or interior sand flat habitats generally use wet areas around ephemeral pools. Like the Piping Plover, Red Knots wintering in the United States generally use sandy beaches; however, their foraging techniques sometimes differ, as the Red Knot follows the contour of the shoreline while foraging on falling or rising tides over tidal sand flats, mudflats, and beaches (Baker et al. 2013). For our analyses, we will group survey data for T&E birds (i.e., Piping Plover and Red Knot) collectively.

*Nesting Birds*
Birds nesting on barrier island habitats select nesting habitat in response to multiple, occasionally divergent, variables. For example, birds nesting on an open beach can more easily spot approaching predators, yet doing so may risk exposing their nests to the flooding tide or disruptive elements such as wind and sunlight. Conversely, while nesting within the dunes and vegetation can provide more shelter from winds and waves, it increases the chance of contact with predators, which can be more abundant in interior habitats (Burger 1987). For our analyses, we will group survey data for all nesting shorebirds (i.e., colonial and solitary nesters).

*Modeling Bird Utilization*

# MsCIP Monitoring and Adaptive Management Protocol
# Shorebird Habitat Utilization Modeling
# Protocol 243

*Protocol version date: 03/14/2018*

Shorebird wintering and nest-site selection are influenced by a combination of factors, including habitat substrate, anthropogenic activities, prey abundance, and predator activity (Burger 1987; Convertino et al. 2011). Within habitats, shorebirds cue in on physical microhabitat features to find benthic macroinvertebrates in surface sediment or to select a suitable nesting site. To adequately detect changes in predicted shorebird habitat utilization following construction activities, it is essential to identify relevant habitat and topobathymetric parameters associated with areas with higher utilization, especially parameters that can be obtained from geospatial datasets. To inform development of our models, we conducted a review of the habitat and physical features that structure wintering and nesting shorebird habitat. Numerous approaches have been used to model wintering ground potential utilization or nesting potential including maximum entropy models (Aiello-Lammens et al. 2011; Convertino et al. 2011), Bayesian inference modeling (Convertino et al. 2011; Gieder et al. 2014), generalized linear models (Seavey et al. 2011), and classification and regression trees (Maslo et al. 2011). Previous studies have modeled bird utilization using such parameters as land cover or habitat type (Aiello-Lammens et al. 2011; Convertino et al. 2011; Maslo et al. 2011; Gieder et al. 2014), vegetation percent cover (Maslo et al., 2011; Owen and Pierce 2013), elevation and related parameters such as distance to tidal datums (Aiello-Lammens et al. 2011; Maslo et al. 2011; Seavey et al. 2011; Owen and Pierce 2013; Gieder et al. 2014), beach physical properties (Gieder et al. 2014), proximity to dunes or dune physical properties (Maslo et al. 2011; Gieder et al. 2014), substrate characteristics (Aiello-Lammens et al. 2011; Convertino et al. 2011), and beach nourishment events (Grippo et al. 2007; Convertino et al. 2011).

Based on these studies, we will use landscape position and habitat parameters coupled with bird survey data to predict utilization (e.g., very low, low, moderate, high, etc.) of shorebird habitat. Utilization will be predicted from these data using a machine learning approach (e.g., classification and regression trees, random forests, K-nearest neighbor, support vector machine, and artificial neural networks). Specifically, the objectives of this monitoring and adaptive management (MAM) task are to: 1) Model T&E and shorebird utilization, respectively, on Cat and East and West Ship islands using landscape position (i.e., intertidal position and topographic position) and habitat variables (i.e., proximity to dune and proximity to vegetation); 2) Use model predictors to explore how utilization has changed pre- and post-construction; and 3) Explore habitat and/or lidar data to explore general trends in shorebird habitat over time. Please note, due to limited data on foraging behavior, we will be modeling general T&E shorebird utilization. The National Park Service (NPS) has tracked nest success for West and East Ship islands. The NPS has annual datasets that includes coordinates for spatial locations of nests, nest success, species, and polygons for nest enclosures, and nesting behavior (solitary shorebirds). We will review these data to determine if they can be used to extend the modeling effort to assessing the relationship between nest success and geomorphic conditions. If not, then we will plan to use the data for model efforts to general nesting bird utilization and not actual/potential nesting.

**Collection Methodology**

Avian surveys were conducted pre-construction data, and will continue during construction and the post-construction period.

*Survey Data*

The U.S. Army Corps of Engineers, Mobile District contracted shorebird surveys prior to restoration activities for Cat Island and East and West Ship islands (Figure 1). Surveys were focused on the threatened and endangered species including Piping Plover and Red Knot, colonial nesting shorebirds (e.g., Least Tern, Royal Tern, Black Skimmer, etc.), and solitary nesting shorebird species (e.g., Wilson's Plover, Snowy Plover, American Oystercatcher, etc.). Surveys on East and West Ship islands were conducted from December 28, 2012 through December 18, 2013. Surveys on Cat Island were conducted from March 11, 2015 through March 01, 2016. The islands were visited once a week as weather permitted. Surveyors traveled the perimeter of the islands by foot, all-terrain vehicle (ATV), or boat to identify and count birds on the beach and tidal flats between low tide and vegetated areas upslope of the beach. Bird observations were made using a sighting scope and a Global Positioning System (GPS) device. For each observation, surveyors documented species present, count by species, bird behavior (i.e., foraging, resting, courtship behavior, nesting, etc.), observation date, habitat, weather conditions (e.g., wind speed, temperature, etc.), vegetation cover, substrate, tide level, side of the island (e.g., gulf, bay, etc.), number of nests (opportunistically found), disturbance events, presence of color bands, general location, and GPS location. While some absences were noted, the survey protocol did not include systematic sampling for bird absences (i.e., transect sampling). Please note, that the survey for East and West Ship islands only contained a single nest observation. Esri ArcMap (Environmental Systems Research Institute, Redlands, CA) was used for bird survey data processing and will be used for subsequent spatial analyses for bird modeling. Table 1 provides a broad overview of bird data per group for each island and a breakdown of species abundance.

**Table 1.** Abundance and number of records by bird group for each island.

| Island | Total | | T&E shorebird | | Nesting shorebird | |
|---|---|---|---|---|---|---|
| | Abundance | Records | Abundance | Records | Abundance | Records |
| Ship | **12,457** | **566** | 1,005 | 144 | 11,452 | 422 |
| Cat | **11,781** | **863** | 202 | 121 | 11,579 | 742 |
| **Sum** | **24,238** | **1,429** | **1,207** | **265** | **23,031** | **1,164** |

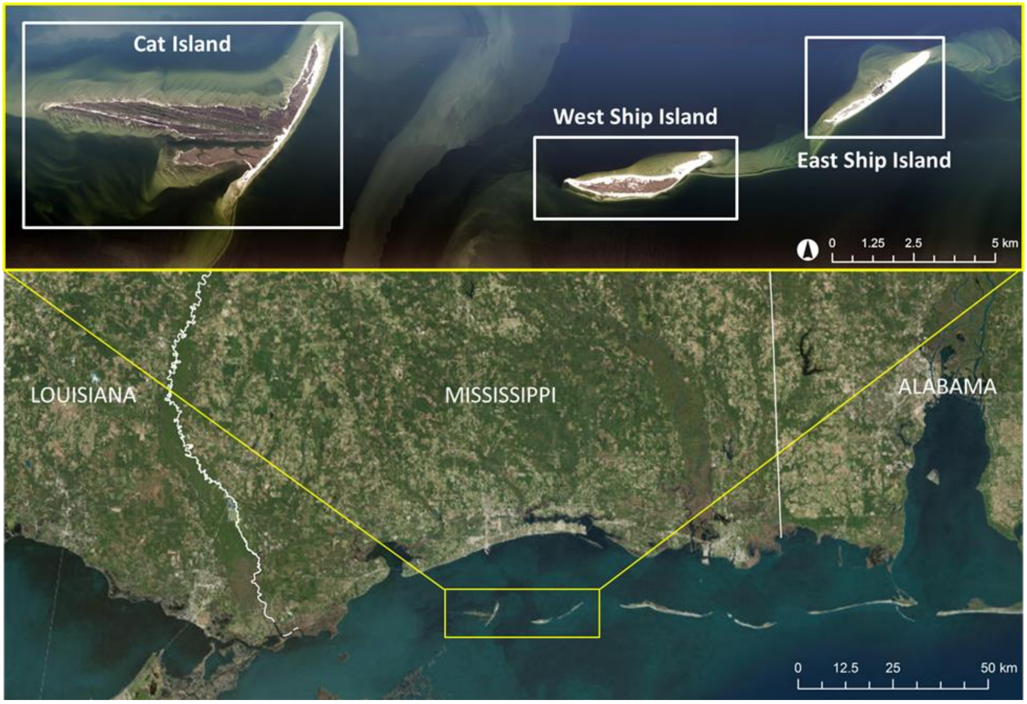


**Figure 1.** Overview of the Mississippi Barrier Island project area. Shorebird surveys occurred on the islands inset in white rectangles.

For surveys conducted on East and West Ship islands, the GPS coordinates are most often located at the position of the observer (i.e., location of sighting scope, not the observed bird). For points taken on foot, observers reported being no closer than 15.2 m (50 ft) and as far as 61 m (200 ft) away from birds. Cat Island bird surveys included the use of an Apple iPad® and a custom application developed by the USGS Wetland and Aquatic Research Center's Advanced Applications Team to support data collection. This application allowed for observers to offset viewing locations (i.e., location birds were seen from sighting scope) to the actual locations where birds were present.

**Analysis Methodology**
The habitat utilization modeling will use pre-construction data. Models will be used to predict post-construction habitat utilization. Post-construction avian survey data will be used to validate new habitat created via restoration.

*Satellite Imagery Processing*
To aid in the data processing, we obtained Satellite Pour l'Observation de la Terre (SPOT) 5 and Landsat 8 imagery to reflect the location of the shoreline during observations at various points during the surveys (Table 2). The temporal coverage of the imagery roughly included the start date of the survey, the midpoint of the surveys, and the near end date of the East and West Ship island surveys. The satellite imagery spatial resolution ranged from 5 m to 15 m. All imagery was referenced to a common datum and coordinate system, specifically WGS 1984 and

Universal Transverse Mercator (UTM) Zone 16 North. To ensure that image registration was consistent, we used 0.5-ft ground resolution digital orthophotography of Harrison and Jackson Counties, MS, collected in early 2012. The high resolution orthophotography was projected from the North American Datum 1983 State Plane system to WGS 1984 and Universal Transverse Mercator (UTM) Zone 16 North to match the satellite imagery. Using affine transformation, we georeferenced the SPOT and Landsat imagery to match the registration of the high resolution aerial photography. The root mean square error of the rectified imagery was less than 2.1 m for 5-m resolution imagery, 7.2 m for 10-m resolution imagery, and 5.6 m for 15-m resolution imagery based on a minimum of 32 control points (Table 2).

**Table 2.** Satellite imagery sources, acquisition dates, resolution, root mean square error of the georeferenced imagery, number of control points used in georeferencing, and extent.

| Island | Source | Date Acquired | Spatial resolution (m) | RMSE | Control Points |
|---|---|---|---|---|---|
| Ship | SPOT 5 multispectral | 6 December 2012 | 10 | 7.2 m | 42 |
| Ship | SPOT 5 panchromatic | 12 June 2013 | 5 | 2.1 m | 32 |
| Ship | Landsat 8 | 11 December 2013 | 15 | 5.6 m | 47 |
| Cat | Landsat 8 | 21 April 2015 | 15 | 4.1 m | 47* |
| Cat | Landsat 8 | 27 August 2015 | 15 | 4.1 m | 47 |
| Cat | Landsat 8 | 22 March 2016 | 15 | 4.1 m | 47* |

*georeferenced using the same control points as 27 August 2015

*Editing Bird Survey Data*

Several steps were taken to preprocess the data. First, we omitted all bird species that were not either T&E shorebirds or nesting shorebirds (e.g., Osprey, Brown Pelican, etc.). Next, we omitted any bird observation for which flying was the recorded behavior since the location of habitat utilization was not known. Because the surveys focused on the unvegetated intertidal beach and flats, any points that were located in vegetated habitats (e.g., marsh, meadow, scrub/shrub, forested, etc.) found on the island were omitted. Additionally, there were multiple records in which the spatial location and the location listed in the attributes differed. In these instances, we omitted records if there was a discrepancy in the island, side of the island (e.g., Gulf or Bay), and/or the cardinal direction (i.e., East or West). For the reasons listed above, we omitted a total of 344 and 241 points (records) for Ship Island and Cat Island surveys, respectively.

Additional processing was required to offset the bird observations from the on East and West Ship islands surveys where location was associated with the location of the observer rather than the birds. As mentioned previously, some observation points were taken via foot, ATV, or boat. For the surveys from East and West Ship islands, as the contractors did not offset boat points these points tended to be in the nearshore waters. During a review of the data, we noticed several contradictions regarding transportation mode and point location. Specifically, some points labeled as collected via foot were located offshore, and some locations labeled as collected via boat were located on land. After consultation with the surveyors, we used the satellite image acquired closest to the date of the observation (Table 2) to omit/reject points on a case-by-case basis; foot-collected points were omitted if located >15 m offshore and retained if located <15 m offshore. All of the points collected by boat that were located on land were omitted. Based on a discussion with the surveyors, we offset the boat points in the water to the shoreline using several assumptions. First, we assumed that when collecting points from a boat the boat trajectory trended roughly parallel to the shoreline. Second, we assumed that shorebirds observed were most often observed utilizing habitat near the water line. Thus, each point collected via boat was projected to be located approximately at the shoreline roughly perpendicular to the general angle of the assumed boat trajectory (i.e., based on the shoreline morphology) using the most relevant imagery at the time of the observation (Table 2). For the majority of these records, this represented the shortest distance to land. We flagged edited boat points to indicate higher uncertainty. Edits were necessary for a total of 383 (~68%) of the points for surveys for East and West Ship islands, collectively.

We followed the same methodology used for editing points from East and West Ship islands in the editing of points on Cat Island. In four instances, we moved points to the shoreline as they were collected via boat and were > 30 m offshore. For points collected by foot, we omitted all points that were > 15 m offshore. Points lacking the transportation mode (foot or boat) or the date were excluded. Edits were necessary for a total of 179 (~21%) points Cat Island points.

We developed two versions of the bird data for modeling. The first dataset was a point abundance dataset (i.e., using the bird field that included count of birds) (Table 1). Because a large percentage of observations are skewed towards low abundance (i.e., about 54% of the observations contained 3 birds or less), we created a second dataset that represented generalized bird presence frequency. In some instances a single location (x, y) contained multiple observations. Most often, these observations were different for different birds observed on the same date, but in a few cases the observations were from different dates (i.e., six of the 213 unique locations). The bird presence frequency dataset was developed using the Dissolve Tool in ArcMap for location (i.e., x, y) and date field to create a count of unique dates that birds were observed at the location.

*General Island Pass Utilization Changes Pre- and Post-Construction*

Of particular interest is the question whether pre- and post-construction utilization of the island passes (i.e., island tips) will differ. To test for differences, we will first develop a standard general definition (i.e., in terms of habitat mapping and topography) that can be applied to the island tips for the pre-construction and post-construction maps. Next, we will determine the count of birds and observations (i.e., survey data point that could represent a group of birds observed at one time), respectively located on a tip, and the count of bird or observations not located on a tip, by island, for pre- and post-construction surveys. The analysis will be conducted for tips on an island collectively and respectively (i.e., specific to a pass). We will use the Chi-square test of independence to assess if the survey data suggests tip utilization differed before and after construction. A potential limitation to this approach is the changes in bird survey methodology. Also, the small sample sizes increase the probability of a Type II error (i.e. failing to find a significant difference in island tip use when one actually exists).

*Response Variable*
To model bird habitat utilization, we will summarize bird count data using multi-scale “fishnet” grids, with the exact scales used determined by model performance.

*Topobathymetric Data and Tidal Datums*
Topobathymetric data will be used to quantify the intertidal area associated with the bird survey grids. The best available topobathymetric data collected closest to the time of the bird surveys will be used to create topobathymetric digital elevation models (DEMs) for East and West Ship islands and Cat Island. Empirical Bayesian Kriging (Krivoruchko 2012) will be used to develop a custom topobathymetric DEM from existing data sources. Tidal gauge records (relative to NAVD88) will be used to determine elevations for tidal datums for the present National Tidal Datum Epoch (NTDE; 1983-2001), particularly for mean low water (MLW), mean high water (MHW), highest astrological tide (HAT), and lowest astrological tide (LAT). The Dauphin Island tide gauge, the closest tide gauge on a barrier island in the Mississippi Sound, will be used, due both to its proximity and length of record. We will use the area between HAT and LAT as a proxy for intertidal wetlands, following Cowardin et al. (1979).

As extreme water levels directly influence the elevation for primary dunes, we will extract these levels to help delineate dune habitats by using exceedance probability data from Dauphin Island (i.e., exceedance probability level surpassed 10 years out of 100), derived from the NOAA exceedance probability dataset (e.g., https://tidesandcurrents.noaa.gov/est/curves.shtml?stnid=8764311). The use of this data is discussed in detail below.

*Topobathymetric DEM Error Propagation*
Elevation and tidal position are important parameters for shorebird habitat utilization as birds tend to heavily utilize intertidal beaches and flats for foraging. Digital elevation models, like any model, contain errors. Errors associated with a DEM are often ignored by data users (Wechsler 2003). Errors related to DEMs are categorized under three categories: blunders, systematic, and random errors (Cooper 1998; Fisher and Tate 2006). Although blunders related to user error or equipment failure (Fisher and Tate 2006) are not a concern, both systematic and random errors are especially relevant in this case. Systematic errors are those errors introduced through biased sampling or data processing, while random errors include spatially autocorrelated variations around the true elevation value (Fisher and Tate 2006). For instance, alongshore topographic error can vary by land cover type. Often, marsh and forested areas or other densely vegetated areas have a higher error than bare unvegetated areas (Hodgson and Bresnahan 2004; Schmid et al. 2011; Cooper and Chen 2013; Medeiros et al. 2015). For offshore areas, bathymetry error can be related to water depth or slope (Brynes et al. 2002; Guenther 2006). Error nonstationarity can be difficult to account for without sufficient ground reference data (Wechsler and Kroll 2006). Due to the lack of ground reference data, the vertical accuracy of topobathymetric data will rely

on information reported in the metadata of the various data sources. Applying a vertical datum transformation can introduce additional uncertainty that needs to be accounted for (Cooper et al. 2013; Gesch 2013). The uncertainty associated with transformation to MHHW and MLLW will be averaged to produce a single uncertainty value for tidal datum transformation. The cumulative vertical accuracy (i.e., combined elevation source data error and datum transformation error) will be calculated for the topobathymetric DEM as a root mean square error (RMSE) for topobathymetric data.

Numerous techniques have been developed for DEM error propagation (Hunter and Goodchild 1995; Wechsler and Kroll 2006; Cooper et al. 2013; Leon et al. 2014). For these shorebird utilization modeling efforts, error propagation will follow an approach similar to the neighborhood autocorrelation filter method outlined in Wechsler and Kroll (2006). Note, the elevation analyses for the avian habitat utilization tasks follow a similar approach as used for the gulf sturgeon utilization assessment, Protocol 221 (Assessing High Potential Habitat Suitability Areas for Gulf Sturgeon). As mentioned previously, we will assume that topobathymetric errors do not differ based on land cover types due to lack of ground reference data. We will assume that cumulative vertical error has a normal distribution with one standard deviation being equal to the RMSE. The first step in the error propagation is the development of a random field. A raster with the same cell size and registration of the topobathymetric DEM will be created to hold the random field. This raster will be generated with a Gaussian distribution using the Create Normal Raster tool in Esri ArcMap. Next, a local filter (i.e., 3-pixel by 3-pixel neighborhood) will be used to incorporate spatial autocorrelation into the simulated random fields (Eastman 1992). The filtered raster will then be multiplied by the RMSE and added to the original topobathymetric DEM. A Monte Carlo simulation will be used to repeat these steps for n iterations (i.e., testing will be conducted to determine when variability is stabilized for simulations). For each iteration, the elevation will be used to determine if the pixel is intertidal. Pixels in each new DEM error realization will be coded as a binary variable for the presence or absence of being within a specified tidal range using the appropriate ranges for elevations relative to NAVD88 as specified for average tides (i.e., MLW-MHW) or tide gauge analyses for the full intertidal range (i.e., HAT-LAT), or above extreme water levels. The output from the iterations will be combined into a single raster containing the probability of each pixel being within or above specified elevation range area using the formula below (Cooper and Chen 2013, eq. 1).

$$P_{x,y} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}$$

In the equation above, $P_{x,y}$ represents the probability of a pixel being an intertidal area, $x_i$ represents the binary classification of presence or absence (i.e., 1 or 0) of intertidal range for iteration i, and n equals the total number of iterations (i.e., 1,000). This process will be conducted three times. The processes will be used to estimate probability of a pixel being intertidal for average tides, intertidal for all tides, or above extreme water levels, respectively. We will use a threshold (e.g., ≥50% probability) to develop discrete presence/absence maps. The exact threshold that we use will be decided by the MsCIP Technical Advisory Group. General coverage of area will be summarized for the fishnet grids as a percent of area intertidal for average tides (i.e., MLW-MHW), intertidal for all tides (i.e., LAT-HAT), and area above extreme water levels.

*Slope and Topographic Position Index*
Slope and topography may also play an important role in the general utilization of the island by shorebirds. The average slope will be determined for grid cells for which bird survey data will be aggregated to. The topographic position index (TPI; Weiss 2001) uses the relationship between a location's elevation with a mean neighborhood elevation and slope to characterize the topographic position of the pixel as a valley, flat, middle slope, upper slope, or ridge. Determination of the appropriate neighborhood size will be optimized via comparison with habitat data over various scales. The exact scales used will be determined using visual inspection of the derivatives and original DEM. The TPI and slope will be calculated for each iteration in the Monte Carlo simulation above. For each iteration, the TPI values and slope will be used to classify the pixels as either valley, lower slope, flat, middle slope, upper slope, or ridge. These data will be used to classify a binary variable for the presence or absence of valleys, lower slopes, or flats, collectively (i.e., absence would infer areas are middle, upper slopes, or ridges).

The output from the iterations will be combined into a single raster containing the probability of each pixel being an intertidal area using the formula above (Cooper and Chen 2013). The same threshold used above will be used to estimate discrete topographic position classes from the probability maps (e.g., ≥80% probability). The percentage of area above MLW covered by valleys, low slopes and flats, collectively will be calculated for each fishnet grid.

*Habitat Variables*
Proximity to non-beach habitats have been important predictors of shorebird habitat models in other shorebird habitat modeling efforts. We will use the satellite imagery shown in Table 2 to produce maps of vegetation coverage. While we used the SPOT 5 panchromatic band for shoreline verification, we will use the multispectral data for vegetation cover estimation. For each imager, we will calculate the Normalized Difference Vegetation Index (NDVI; Rouse et al. 1973). A NDVI threshold will be used to indicate presence or absence of vegetation. The three classified images will be combined to produce a maximum extent of vegetation cover during the survey period. Vegetation characteristics such as coverage and distance to nearest vegetation will be associated with the fishnet grids.

Dunes will be generally delineated from the topobathymetric data. Dunes will be defined as areas identified as upper slopes and ridges from topographic position index analyses (Weiss, 2001) using a 30-m radius. In addition to being defined as upper slopes and ridges, dunes will commonly be above the average storm water level as estimated from NOAA exceedance probability data from Dauphin Island. A Euclidean distance raster surface (i.e., distance to nearest dune) will be generated using the ArcMap Euclidean Distance tool and the average distance within fishnet grid cells may be evaluated as an explanatory variable for shorebird utilization.

*Model Approach*
A generalized additive model (GAM) with a Poisson distribution will be used to predict shorebird abundance using the topographic position and habitat variables listed above (i.e., predictor variables). We may explore several groupings of the data including all shorebirds (i.e., T&E and nesting shorebirds, pooled), and T&E and nesting shorebirds, respectively, and all islands, collectively, and each island respectively.

For each model, we will select a subset of random samples (i.e., likely 75%) from the response variable surfaces stratified based on coverage of class (i.e., very low, low, moderate, and high) for training the classifiers. The remaining data (i.e., 25% of data) will be used for model testing. Model performance comparisons will be used to determine the most appropriate model extent (i.e., Cat Island and East and West Ship islands, collectively or respectively) and parameter (i.e., abundance or occurrence classes). Final model selection will be based on cross-validation error (Hastie et al. 2009).

In addition to a global GAM, we may explore ways to account for spatial autocorrelation by using a geographic weighted regression approach (Ma et al. 2011).

*Identifying Changes in Utilization from Survey Data and Model Outputs for Pre- and Post-Construction*
We will present general differences between pre-construction and post-construction data from the bird surveys, analysis of how pre- and post-construction utilization model outputs differs, and how differences between the pre-construction model predictions for post-construction island configurations compare to outputs of a model trained with post-construction parameters (i.e., post-construction survey data and topographic position parameters). If the assessments above suggest that the utilization is similar then the pre- and post-construction survey data could be pooled to produce a more robust shorebird utilization model for T&E and nesting shorebirds, either respectively or collectively.

## Metadata
Metadata will be created for all analyses, following ISO standards

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# MsCIP Monitoring and Adaptive Management Protocol
# Shorebird Historical Habitat Change Mapping
# Protocol 244

*Protocol version date: 03/14/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Threatened and Endangered (T&E) shorebirds and nesting shorebirds

**Purpose of Monitoring and Data Assessment**
Support documentation of historical shorebird habitat areas over time and determine whether island restoration has an impact on these suitable habitat areas. Data analysis to support T&E compliance pursuant to the ESA.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
There are no success criteria directly related to T&E historical shorebird habitat. Data from the analysis of historical habitat will be used to inform shorebird success criteria related as described in Protocol 242 (Mapping and Assessing Change in Critical Habitat for Threatened and Endangered Shorebirds) and Protocol 245 (Mapping and Assessing Nesting Shorebird Habitat).

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
N/A

**AM Trigger**
N/A

**Tasks**
Determine historical habitat change for Threatened and Endangered Shorebirds and Nesting Shorebirds, respectively (supporting analyses for success criteria)

**Analysis Frequency**
Pre-construction and 10 years after the completion of the planting on Ship Island

**Data Collection Required for Analysis**
Existing habitat maps including MsCIP habitat maps and any habitat maps developed by the U.S. National Park Service, lidar datasets collected over the past 15 years, satellite imagery, and orthophotography.

**Background**
*Threatened and Endangered Shorebirds*
The Piping Plover and Red Knot are threatened and endangered (T&E) migratory shorebirds that winter and stopover along the northern Gulf of Mexico coast. Wintering ground habitat plays a critical role in providing the food resources that fuel migration and affect reproductive success on the breeding ground (Norris et al. 2004). On the wintering ground, Piping Plovers spend the majority of their time foraging on moist sandflats, mudflats, algal flats, ephemeral pools, and overwash areas (Johnson and Baldassare 1988). Schulz (2015) studied wintering Piping Plovers

on Whiskey and Trinity Islands, Louisiana and found that 92% of all observed Piping Plovers foraged in intertidal habitat with a preference toward foreshore beach, tidal flats, sand flats, and backshore beach, respectively. Piping Plovers on backshore beach or interior sand flat habitats generally use wet areas around ephemeral pools. Convertino et al. (2011) studied Piping Plover and Red Knots in Florida, finding that the habitat preferences of both birds generally overlapped. Like the Piping Plover, Red Knots wintering in the United States generally use sandy beaches; however, their foraging techniques sometimes differ, as the Red Knot follows the contour of the shoreline while foraging on falling or rising tides over tidal sand flats, mudflats, and beaches (Baker et al. 2013). For our analyses, we will group survey data for T&E birds (i.e., Piping Plover and Red Knot, collectively).

*Nesting Birds*

Birds nesting on barrier island habitats select nesting habitat in response to multiple, occasionally conflicting, trade-offs. For example, birds nesting on an open beach can more easily spot approaching predators, yet doing so may risk exposing their nests to the flooding tide or such disruptive elements as wind and sunlight. Conversely, while nesting within the dunes and vegetation can provide more shelter from winds and waves, it increases the chance of contact with predators, which can be more abundant in interior habitats (Burger 1987). Thus, we will treat non-developed, unvegetated, supratidal habitats as nesting shorebird habitat. For our analyses, we will group survey data for all nesting shorebirds (i.e., colonial and solitary nesters).

**Analysis Methodology**

*Historical Habitat Change Trend Analysis*

The historical trend analysis will be conducted either by using existing habitat maps or by using lidar datasets collected over the past 15 years. Both analyses will be focused on mapping change in intertidal beach, mudflats and supratidal unvegetated barrier island habitats (i.e., unvegetated beach, dune and barrier flats) over time. Note, both of these assessments are similar to the assessments proposed for the MsCIP MAM habitat composition trend assessment, Protocol 131 (Habitat Composition). The exact method will be determined at a later date, after consultation with the MsCIP MAM Technical Advisory Group.

The habitat map analysis will include habitat maps developed by the U.S. Geological Survey Wetland and Aquatic Research Center for 1959 and 1979, National Wetland Inventory (NWI) maps for 1996 and 2002, and the MsCIP pre-construction baseline data from 2015 and 2016 (i.e., includes NWI classes). This analysis will be focused broadly on changes to foraging habitat mapped as beach and mudflats. Unvegetated beach, unvegetated dune and barrier flats, will also be extracted from habitat maps, if feasible. Areal change will be assessed for all maps (i.e., change in area over time). A spatial change analysis may be conducted if the registration of source data for maps can be verified to be compatible across all maps. We will consider intertidal habitats as shorebird foraging habitat and supratidal unvegetated habitat as important shorebird nesting habitat. Intertidal habitats and supratidal habitats on the barrier islands will be classified as critical habitat (i.e., area above mean lower low water; 50 C.F.R. § 17 2001).

However, there are several limitations to this approach. First, the 1959 and 1979 data were classified under a more generalized classification scheme than the scheme used by NWI (Cowardin et al. 1979). Second, it is possible that some identified change may be an artifact of technological advances in imagery resolution and methodology.

A second approach would utilize lidar datasets. Over the past fifteen years numerous lidar data collections have acquired elevation data for Cat Island and East and West Ship islands. Seven lidar collections have occurred on Cat Island since 2001 (i.e., 2001, 2005, 2007, 2010, 2011, and 2016), and eight lidar collections have occurred on East and West Ship islands (i.e., 2001, 2004, 2005, 2007, 2010, 2012, 2015, 2016) since 2001.

Intertidal habitats provide important foraging habitat for shorebirds. Thus, the habitat change analysis using lidar will be used to determine the amount of land occurring between local mean sea level and the extreme high water springs (EHWS). We will use observations collected at the nearby NOAA Dauphin Island, Alabama tide gauge (station ID: 8735180) to determine local mean sea level and EHWS relative to the North American Vertical Datum of 1988. The rationale for using local mean seal level instead of a low tide datum, such as extreme low water springs (ELWS), is due to the limited amount of nearshore bathymetric data that can be accurately coupled with the various lidar classifications. This compatibility between the various lidar and bathymetric datasets will be analyzed, and, if these data are found to be compatible, the analysis will be extended to include the entire intertidal zone (ELWS to the EHWS). This analysis will utilize the Monte Carlo approach described in the Protocol 243 (Shorebird Habitat Utilization Modeling).

A second component of this analysis will focus on analyzing satellite imagery and lidar data to extract supratidal unvegetated areas. Landsat satellite imagery will be acquired near the lidar acquisition dates with an emphasis on maximizing satellite imagery. For each image, we will calculate the Normalized Difference Vegetation Index (NDVI; Rouse et al. 1973). A NDVI threshold will be used to indicate presence or absence of vegetation. The probability raster for intertidal areas discussed above and satellite imagery will be used to identify unvegetated supratidal lands. A limitation to this effort is that the spatial resolution of the Landsat satellite imagery is 30 m (i.e., a pixel covers a 900 $m^2$ area), so it is possible that some sparsely vegetated areas may falsely appear as unvegetated, due to pixel resolution.

Lastly, we will determine the historical critical habitat for T&E species, the area above mean lower low water (MLLW), using available lidar data. Note, in some cases we will have to assess this from mean sea level and up due to the lack of sufficient bathymetric data to determine MLLW. This analysis will utilize the Monte Carlo approach described in the MsCIP MAM Protocol 243 (Shorebird Habitat Utilization Modeling).

## Products

1. A geodatabase containing maps of generalized historical T&E critical habitat, foraging habitat, and nesting habitat, respectively, based from historical habitat maps and/or lidar datasets
2. International Organization for Standardization (ISO) compliant metadata for all spatial products
3. Spatial change map (*if feasible, if registration of habitat maps is suitable for this analysis*)
4. Brief report on methods and acreages, and change over time

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# MsCIP Monitoring and Adaptive Management Protocol
# Mapping and Assessing Nesting Shorebird Habitat
# Protocol 245

*Protocol version date: 03/14/2018*

**MAM Plan Performance Measure Addressed *(See Section 3.1 of MAM Plan)***
Threatened and Endangered (T&E) shorebirds and nesting shorebirds

**Purpose of Monitoring and Data Assessment**
Support documentation of historical shorebird habitat areas over time and determine whether island restoration has an impact on these suitable habitat areas. Data analysis to support T&E compliance pursuant to the ESA.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Ten years post-construction the success criteria is to maintain or increase suitable acres of nesting habitat as compared to the pre-construction acreage.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
Five years post-construction maintain suitable acres of nesting habitat for nesting birds as evaluated by habitat mapping efforts.

**AM Trigger**
Loss of nesting habitat (acres) for solitary and colonial nesting shorebirds as evaluated by habitat mapping efforts.

**Tasks**
Determine nesting shorebird habitat from habitat mapping and other ancillary data (required for success criteria)

**Analysis Frequency**
Pre-construction and five years and 10 years after the completion of the planting on Ship Island

**Data Collection Required for Analysis**
Habitat maps developed through Protocol 131 (Habitat Composition), any habitat maps developed by the U.S. National Park Service, lidar (topobathymetric lidar when possible) datasets, and orthophotography

**Background**
*Nesting Birds*
Birds nesting on barrier island habitats select nesting habitat in response to multiple, occasionally conflicting trade-offs. For example, birds nesting on an open beach can more easily spot approaching predators, yet doing so may risk exposing their nests to the flooding tide or such disruptive elements as wind and sunlight. Conversely, while nesting within the dunes and vegetation can provide more shelter from winds and waves, it increases the chance of contact with predators, which can be more abundant in interior habitats (Burger 1987). Thus, we will

treat non-developed, unvegetated, supratidal habitats as nesting shorebird habitat. For our analyses, we will group survey data for all nesting shorebirds (i.e., colonial and solitary nesters).

**Analysis Methodology**

We will extract the area and location of unvegetated supratidal areas from MsCIP habitat maps. For these maps, habitat categories were developed from existing classification schemes including the National Wetlands Inventory (NWI; Cowardin et al. 1979) and Anderson Land Use/Land Cover classification system (Anderson et al. 1976), as well as custom modifiers to characterize habitat for dune and spoil. For more information, see Protocol 131(Habitat Composition). We will use will irregularly flooded beach, mudflat, upland barren dune, and upland spoil to represent nesting shorebird habitat. Collectively, these areas represent non-developed, unvegetated, supratidal habitats. We will use a similar process to extract nesting shorebird habitat from any habitat maps available from the U.S. National Park Service.

**Table 1.** MsCIP Habitat classes used for nesting shorebird habitat extraction.

| Habitat class | Description |
|---|---|
| Beach/Mud Flat Salt | Includes all wetland habitats adjacent to the subtidal zone with less than 30 percent areal cover of vegetation other than pioneer plants that become established during brief periods when growing conditions are favorable. These areas include wetlands that are regularly and irregularly flooded just above the subtidal zone and below ~1.5 m relative to the North American Vertical Datum of 1988 (NAVD88). |
| Beach/Mud Flat Fresh | Includes all non-tidal wetland habitats with less than 30 percent areal cover of vegetation other than pioneer plants that become established during brief periods when growing conditions are favorable. |
| Upland Barren Dune | Areas of built up sand along shoreline that is free of vegetation. |
| Upland Spoil | Areas of spoil deposition along excavated canals. |

**Products**

1. A geodatabase containing maps of generalized nesting shorebird habitat based from MsCIP habitat maps products and lidar datasets
2. International Organization for Standardization (ISO) compliant metadata for all spatial products
3. Spatial change map (*if feasible, if registration of habitat maps is suitable for this analysis*)
4. Brief report on methods and acreages, and change over time

**Literature Cited**

Burger, J. 1987. Physical and social determinants of nest-site selection in Piping Plover in New Jersey. The Condor, 89(4), 811-818.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. United States Department of the Interior, Fish and Wildlife Service, Washington D.C., 134 pp.

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# MsCIP Monitoring and Adaptive Management Protocol
# Cultural Resources Task
# Protocol 301

*Protocol version date: 03/15/2018*

**MAM Plan Performance Measure Addressed** ***(See Section 3.1 of MAM Plan)***
Cultural resources

**Purpose of Monitoring and Data Assessment**
Identify resources prior to construction. Document areal island extent surrounding cultural resources eligible, or potentially eligible, for nomination to the National Register of Historic Places (NRHP), and coordinate any needed actions based on monitoring results. The monitoring will provide supporting information to assess potential exposure of cultural resources to erosive forces as Ship Island and Cat Island evolve over time. Monitor dredge locations to ensure that submerged avoidance areas are not disturbed.

**MAM Plan Success Criteria (See Section 3.1 of MAM Plan)**
Ten years following the completion of all construction activities the success criteria is no appreciable loss of listed, eligible, or potentially eligible cultural resources due to erosion or construction, as determined by aerial mapping and baseline conditions. No potential submerged cultural resources are impacted by dredging or placement activities.

**Areas of Interest**
Cat Island, West Ship Island, East Ship Island

**Interim Target**
Five years following the completion of all construction activities no appreciable loss of listed, eligible, or potentially eligible cultural resources due to erosion or construction, based on aerial mapping and baseline conditions.

**AM Trigger**
An inadvertent discovery made during construction
Or
Increase exposure or disturbance to resources eligible for nomination to the NRHP

**Task**
Investigate changes in emergent land surrounding cultural resources. Investigate inadvertent discoveries promptly to make NRHP eligibility and effects determinations and develop a path forward should unanticipated cultural resources be discovered during the course of construction. Effectively utilize Dredging Quality Management System (DQMS) to ensure potential cultural resources located in the borrow areas are avoided by buffers agreed upon by all stakeholders.

**Analysis Frequency**
Pre-construction: complete; during construction: site inspections will be conducted, pipeline placement locations will be reviewed when changed, and RECENTPAST will used to monitor dredging activities in real time; and following the completion of the closure of Camille Cut: datum stakes will be placed around cultural resources to monitor vertical and horizontal movement of placed material as lidar and aerial photography is made available and National Park

Service (NPS) archaeologists will continue to monitor post-construction erosion around cultural resources.

**Data Collection Required for Analysis**
Lidar, Aerial Photography, RECENT PAST GIS Platform

**Background**
Cultural resources are archaeological and architectural resources known to occur within the project area and are listed in, eligible for, or potentially eligible for listing in the NRHP. They are important historical and cultural aspects of the country's shared national heritage. All aspects of construction will be conducted to avoid impacts to cultural resources; subsequent monitoring will document the land surrounding the resources.

Active shoreline processes, including erosion, migration, and encroachment, are leading to increased risk to cultural resources sites. Restoration of the barrier islands' form and structure is expected to reduce threats to these cultural resources, such as Fort Massachusetts on West Ship Island, as comprehensive barrier island restoration would increase the amount of land area between these resources and the Gulf waters. This increase in land area, while not totally diminishing the threat of erosion to the resource, will substantially reduce that threat. Shoreline/island response, including areal extent and surveys, will be used to measure project performance in maintaining land area as buffer zones around cultural resources.

The northern Gulf Coast is rich in maritime history and cultural resources. The placement material will be sourced from borrow areas that have been surveyed for cultural resources prior to the transport of material associated with this project. Anomalies that have the potential to be NRHP eligible cultural resources are being avoided with a buffer sufficient to ensure that neither direct nor indirect effects will occur to them.

**Analysis Methodology**
*Pre-construction Survey*
Per Section 106 of the National Historic Preservation Act, the lead federal agency must take into account the potential their activities have to affect cultural and historic resources. Several federal agencies are involved in the project, with the USACE being the lead federal agency for Section 106 compliance. In an effort to ensure that all cultural resources would be identified and impacts mitigated or avoided as needed, a series of Phase I cultural resource surveys were conducted in the staging, construction, and terrestrial placement areas on both Cat Island (Wharton et al. 2013) and Ship Island (Bezemek 2015). Maritime surveys were conducted of the dredge material borrow areas and the submerged placement area that currently separates East and West Ship islands (Camille Cut,) and the submerged fill template of Cat Island (Enright 2014a, b, c, 2015, 2016, Ho 2015). The terrestrial surveys failed to locate any new sites, as well as failing to locate some known sites, such as the French Warehouse site, within the Area of Potential Effect (APE) that have already suffered from erosion. The Phase I maritime surveys located several potential sites as well as the remains of the Quarantine Station site (another site that has eroded into the

water). While USACE is the lead for Section 106 compliance, the NPS is responsible for making NRHP eligibility and effects determinations for resources located on NPS terrestrial or submerged bottomlands. Thus, sites located on, or within one mile offshore of, Ship Island are under the purview of the Gulf Islands National Seashore of the NPS.

*Cultural Resources Monitoring During Construction*

During construction, a trained monitor will identify any cultural material that may be inadvertently discovered in order to prevent further destruction to that resource. If material is identified, the material and site will be evaluated by a professional archaeologist before construction resumes. Island-specific unanticipated discoveries plans have been established for Cat Island and for Ship Island that identify the proper points of contacts (USACE for Cat Island and NPS and USACE for Ship Island) should cultural material be discovered during construction. USACE archaeologists will perform periodic physical inspections of construction areas during construction and placement to look for inadvertent discoveries and unauthorized encroachment on areas previously identified to the contractor(s) as avoidance areas as an archaeological site. Any such sites or materials located will be assessed by the USACE archaeologist on Cat Island and coordinated with the NPS on Ship Island so that they may make an eligibility and effects determination.

USACE personnel will take GPS locations of areas where the contractor spuds any vessels. This information will be compared to the shapefiles of known and potential cultural resources identified during the surveys to ensure compliance. Actual pipeline placement shapefiles provided by the contractor and verified by USACE personnel can be used to ensure compliance as well.

*Post-construction Monitoring*

*Terrestrial sites located or delineated during the pre-construction survey:*

Cultural resources monitoring will ensure that all previously identified NRHP eligible, or potentially eligible, cultural resources are avoided. Aerial and lidar information that is being collected by the MsCIP team will be used to assess erosion of placed and pre-construction material to monitor for threats to resources. To ensure erosion or littoral movement is being accurately monitored, approximately 5 to ten USGS datums (utilizing existing NPS datum stakes when possible) will be placed around known sites by a USACE archaeologist in conjunction with a GIS/cartographer using sub-centimeter accuracy GPS to accurately place and record the location of the datums. Specifically, the Quarantine Station site, the Native American Graves Protection and Repatriation Act (NAGPRA) site, the French Warehouse site, and Fort Massachusetts will have USGS datums placed in their vicinity. These datums will be entered into a GIS program using the most current survey data from the MsCIP team as the template. After every subsequent aerial data collection (aerial photography or lidar) by the MsCIP team, the data, both horizontal and vertical, will be reviewed using the USGS datums in relation to the new imagery to look for areas of loss of material (or accrual of material via sediment transport) for management purposes. NPS archaeologists will continue physical post-construction monitoring on Ship Island to assess erosion to sites.

*RECENTPAST Tool*
The Cultural Resources staff of the Planning and Environmental Inland Environment Team developed the RECENTPAST Geographic Information Systems (GIS) tool as part of management and compliance for the Cultural Resources Program at the USACE Mobile District. The tool evaluates cultural resources objectives applicable to management of archaeological sites within the Mobile District and aids in compliance responsibilities under Section 106 of the National Historic Preservation Act.

RECENTPAST creates a real-time remotely-accessed map showing culturally sensitive areas and how they are affected by USACE Mobile District water and land management practices. For this project, the program can be integrated with the DQMS data on the dredges used to collect the dredge material in real time. Hopper dredges will be solely employed at the borrow areas. Should the dredges encroach on the buffers established to ensure that cultural resources or potential cultural resources remain undisturbed, e-mail alerts can be configured to notify USACE Mobile District archaeologists (or others) in real time when the location of the dredges has the ability to negatively impact sites that are or may be present. When necessary, sensitive information (such as archaeological sites) can be restricted to permitted users. In this case, the USACE archaeologist and environmental lead would receive the alerts and contact the dredging company, the USACE dredging engineer, etc. as appropriate.

**Metadata**
Metadata will be created for all analyses, following ISO standards

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