FINAL PROJECT MEMORANDUM

1. ADMINISTRATIVE:

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Project title: Structured decision-making to facilitate multi-stakeholder coastal conservation and restoration under climate change uncertainties: case study on barrier islands of the northern Gulf of Mexico

Agreement number: SECSC022

Date of report: August 31, 2015

Period of performance (including no cost extensions): June 28, 2013 - May 30, 2015

Actual total cost: $113,135.37

2. PUBLIC SUMMARY:

Under the Mississippi Coastal Improvements Program (MsCIP), the USACE will place up to 22 million cubic yards (MCY) of sand to restore the physical integrity of Ship Island. Structured decision making (SDM) was utilized to provide a formal process for analyzing decisions about repairing storm-related damages that may arise during island construction to maximize post-construction sustainability of the restoration effort.

Decision support tools were developed to link restoration objectives and management options while accounting for tradeoffs between objectives and uncertainties such as storm events during and after construction. Expert elicitations, predictive models, and quantitative analysis were incorporated into a decision network to represent the 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 SDM process yielded not only management recommendations that could be quickly and effectively implemented during the Ship Island construction, but it also led to a general decision framework and process that could be expanded and adapted for use by future barrier island and restoration projects.

3. TECHNICAL SUMMARY:

The goal of barrier island restoration in the northern Gulf of Mexico is to restore barrier island morphology using sediment to support the functions and habitats the islands provide. Barrier island restoration typically involves placement of sediment either directly on the island footprint or within the littoral zone for system transport and distribution. The re-engineering of barrier islands presents numerous challenges and uncertainties associated with climate change induced hurricanes/storms and other dynamic components of the system such as sediment availability and erosional trends.

The goal of this study was to use a collaborative SDM approach to develop two Bayesian decision network models (DMs) for restoration at Ship Island, Mississippi, where sand will be used to close an extensive breach. The team identified what damage may occur during construction, and the DMs guided decisions within the confines of limited sand and money to select actions that minimized adverse impacts to project objectives. DM input was derived from expert elicitation and augmented with inundation data. The first DM determined that sand was more limiting than funds, and unrepaired major breaching would negatively impact project objectives. The second DM addressed if, how, and when to repair more minor damage, depending on the extent it is more cost-effective to repair immediately than risk more damage to the weakened project. The goals were met by identifying specific management actions from the decision guidance that will be implemented under the MsCIP long-term monitoring and adaptive management (AM) program. This SDM application highlights uncertainty about barrier island physical processes (e.g., storms, inundation, sediment transport, deposition, and erosion) that limit the ability to make robust decisions and demonstrates the potential for direct incorporation of process-based models in a formal adaptive management decision model. More importantly, this research is a prototype for using collaborative structured-decision making in dynamic environments where mid-construction decisions may arise. With numerous barrier island construction projects planned in the northern Gulf of Mexico, this innovative mid-construction application of SDM has regional relevance and importance.

4. PURPOSE AND OBJECTIVES:

Barrier island resource managers within the northern Gulf of Mexico need to more directly incorporate scientific uncertainties and technological challenges inherent with large-scale barrier island restoration projects, and as such, have committed to developing a robust long-term monitoring program and applying adaptive management. These managers want to determine project success in accordance with stated project objectives, and also address critical uncertainties that would inform future decisions on design templates and island performance. They are looking for a process that can help develop adaptive management actions and tools to guide adaptive decision-making within the context of project construction, maintenance, and future prioritization of conservation actions. SDM is a collaborative process that includes stakeholders and scientists to define management objectives, alternative actions, external drivers, predictive models, and quantitative methods for optimization and tradeoff analysis to identify optimal decisions and key uncertainties to be addressed through further gathering of information (Conroy and Peterson 2012 and Gregory et al., 2012). 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 about repairing storm-related damages that may arise during island construction to help support their existing AM program.

The original objective of the project was to use SDM for developing a shared conservation framework and vision of comprehensive barrier island restoration planning, implementation, and assessment in the face of climate change within the northern Gulf of Mexico, using the MsCIP Barrier Island Restoration at Ship Island as a case study. A decision tool tied to various future barrier island system conditions associated with estimating sand loss volumes and costs of repair was designed for the MsCIP to ensure management decisions optimize the sustainability of the constructed barrier island project while also accounting for stakeholder input and uncertainty about future system change (i.e. potential storm related damages). This process established a framework to make defensible, transparent, efficient and coordinated decisions to optimize barrier island restoration at Ship Island in the Gulf of Mexico. The developed framework provided a template that could be expanded and carried forward providing opportunities to refine to specific adaptive management needs for other projects and programs in the future.

During the development of the proposal the original intent was to use the MsCIP as a case study for development of a prototype decision making tool for barrier island restoration and conservation in the northern Gulf of Mexico. Once developed, other regional program managers would be engaged to refine and adapt the draft decision framework to broaden its applicability beyond Mississippi to barrier island restoration and conservation throughout the northern Gulf of Mexico. It was not known however when scoping the project the level of detail that would be necessary to provide a ready to use decision model. After development of the first prototype it was determined by the stakeholder team that it would be more beneficial to the resource community and the MsCIP to add additional detail to the decision tool to create a very detailed ready to use product that could guide decisions related to barrier island construction rather than engage regional program managers in a general framework.

5. ORGANIZATION AND APPROACH:

SDM was applied to four phases of Barrier Island Restoration at Ship Island to set up a decision process that could be quickly and effectively implemented during project construction to make decisions should the restored berm incur damages or environmental dynamics change. The four phases are (1) preliminary Camille Cut closure and subaerial berm with medium sand (0.30mm) to 5' high and 500' wide; (2) subaerial berm height expansion to 7' high and 1000' wide; (3) fine-grained sand (0.21 mm) sediment cap; and (4) nourishment of East Ship southern shoreline with 5.5 MCY of medium-grained sand. There was also a phase 5 dune planting that was not considered in the process. 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. 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 DMs 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 DM was developed at a workshop in November 2013. Results from this workshop were then used in a subsequent series of webinars and workshops through November 2014, to refine the decision questions and consider additional objectives for Ship Island construction and restoration, which were included in a revised decision model. 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.

6. PROJECT RESULTS:

Problem Definition

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

- How can MSCIP partners optimize decision making relative to Ship Island restoration and the benefits, including the use of monitoring & AM practices during construction given the uncertainties in budgets, storm impacts, & 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?

- 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 & adaptive management practices during construction, given the uncertainties in storm impacts and system response? How would potential minor mid-construction damage be handled?

Objectives

The next step was to identify a set of fundamental objectives to guide decision-making. The fundamental objectives were developed using a stakeholder engagement process to discern what the stakeholders ultimately wanted to achieve with the barrier island restoration actions. The fundamental objectives that were selected 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 & Mississippi Sound

- Ecological integrity of Mississippi Sound
    - Maximize shallow sandy acreage for Gulf sturgeon feeding habitat
    - Maintain normal 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 the 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) , storm inundation, available sand, and remaining funding. The alternative management strategies identified were as follows:

- Phases 1-4 decision: 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 decision: If longshore sediment transport is greater than expected should sediment placement be offset with additional sand placement to account for the increased rate?

- Phase 1 decision: 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 behind construction during Phase 4, 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 measurable attributes of each of the fundamental objectives, while explicitly considering the external effects. For the initial decision model 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 (Figure 1). These fundamental objectives represent biophysical processes and functions of the barrier island restoration on Ship Island. Some of the management actions that could be taken to influence the fundamental actions are associated with how to manage 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, storms and budget were identified as important drivers to include in the decision frameworks that would impact the success of the fundamental objectives.

The initial influence diagrams were developed further to include a temporal component and the phases of 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 increased the risk of additional damage, potentially increasing future costs. For damage in Phase 4, there was also the choice to use finer or coarser sand. The finer grain material is less stable but more readily available at a reduced cost. 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.

The developed influence diagrams subsequently were converted to DMs using the Netica software program (Norsys Software Corp: Vancouver BC, Canada) to represent probabilistic relationships. In general the DM is organized as a collection of linked nodes that take one of 3 forms: 1) decision nodes that distinguish among 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 DM 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 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 DMs during the workshops following a Delphi method (Kuhnert et al. 2010). During the elicitation, the stakeholder team was 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). Expert elicitation values were averaged to assign the probability distributions for different combinations of outcomes for each of the fundamental objectives. The resulting DM tied various potential damages (lowering, narrowing, breaching) 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 DMs. 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.

7. ANALYSIS AND FINDINGS:

Using expert elicitation from the team we identified the expected consequences and tradeoffs of potential actions (repairs, 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 DMs determined that sand could be a limiting factor in making optimal decisions but the available budget was not. From the scenarios examined there was enough funding available; but there may not be enough sand if multiple repairs are required since the maximum amount of sand that can be placed (22 MCY) is limited by the project's authorization. A summary of the results for the identified decision questions are included below.

- Phases 1-4 decision: 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?

  The optimal decision was to always repair a major breach if there was available sand.

- Phase 3 decision: If longshore sediment transport is greater than expected should sediment placement be offset with additional sand placement to account for the increased rate?

  Under scenarios with limited funding and sand a tradeoff was necessary and the optimal decision was to repair the breach but not offset material in future phases to account for increased LST. In a scenario with plenty of 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 robustness of an optimal decision to uncertainty about predicted outcomes of the fundamental objectives and selected drivers. The uncertainties in 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 that was slightly affected was wave attenuation. When the likelihood of wave attenuation decreasing 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 monitoring plan for the project.

The decision framework also helped determine optimal decisions and tradeoffs related to repair of minor damages and identification of scenarios that might result in a shortage of sand in later phases. The tool further helped guide decisions that would allow MsCIP to reserve funding to implement subsequent high priority projects without impacting the fundamental objectives or integrity of the constructed barrier island restoration project at Ship Island.

- Phase 1 decision: 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)?

  The model results showed that the optimal decision for Phase 1 is to repair minor damages at end of each phase rather than waiting until the next phase. A bigger breach was determined to be up to 3 times as likely if the damages were not repaired at the end of Phase 1 but were delayed until Phase 2.

- 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)?

  The model results showed that the optimal decision for Phase 2 is to repair minor damages at end of each phase rather than waiting until the next phase. 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 more likely to occur in later phases if the repairs are not made in Phase 2.

- 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)?

  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 DM did not show negative impacts to the fundamental objectives. In this case a tradeoff was made to implement the high priority projects and not repair the damage since most of the fundamental objectives were predicted to have similar outcomes regardless of whether a repair was made in phase 3. The only fundamental objective that was shown to be potentially impacted was the sea-turtle nesting habitat where the model results showed that there was up to a 0.05 greater probability of losing sea-turtle nesting habitat 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.

- Phase 4 decision: If the Camille Cut berm is lowered behind construction during Phase 4, 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)?

  The phase 4 decision also took the cost of using fine vs. coarse grain sand into consideration; in this scenario fine grain sand is the least costly. Consistent with the results from the previous phases it was determined that a major breach is >20 times more likely to form if damages are left unrepaired than if they are repaired. The optimal decision was to complete repairs with coarse sand, if funding was available. If the cost of repairing with course sands would not leave enough funding left for additional MsCIP projects, fine sand would be considered. When the cost-savings threshold would be crossed by the coarse-sand but not the fine-sand repair, then the recommendation for the optimal decision is to conduct the fine-sand repair. 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 DM) the optimal decision may be to consider not repairing because of the negligible impacts on the fundamental objectives.

8. CONCLUSIONS AND RECOMMENDATIONS:

The Ship Island application demonstrates that a DM developed through collaborative structured-decision making can provide a mechanism to balance potentially competing fundamental objectives while accounting for physical and financial interdependencies. The optimization revealed cost benefit tradeoffs associated with implementing the various repair options and the resulting potential impacts on the fundamental objectives and the budget. Furthermore the decision tool provided a framework to make defensible, transparent, efficient and coordinated decisions in a scenario where decisions may need to be made between the geomorphic island structure vs. ecological and species concerns; decisions which are often controversial. The results that describe optimal decisions regarding when to repair damages in each phase can now be used by MsCIP project and operation managers to build flexibilities into dredging contractor language to act based on uncertainty scenarios evaluated. This concept could be extended to consider multiple projects and inform regional-scale adaptive management.

No problems were encountered on the project; however, the mid-course decision to fully develop the second prototype led to much more time investment by the stakeholder team. This commitment led to participation on ten 1.5 hour webinars rather than 3, which towards the end of the project contributed to SDM fatigue. Much of the additional time spent was associated with clarifying the elicitation questions and the interpretations of the responses, which could have been improved at the onset if the stakeholder team worked through an initial elicitation together.

The approach and findings from this project need to be shared with other partners in the northern Gulf that are currently planning barrier island restoration projects. Meetings will be scheduled in the near-term.

Additionally, we identified a number of opportunities where we can target direct incorporation of process-based physical models in the decision model prototype as a future advancement. This would improve objectivity in response and reduce the potential for different interpretations of elicitation questions.

9. MANAGEMENT APPLICATIONS AND PRODUCTS:

The findings identified by the research have been developed into decision tables that will be incorporated into the MsCIP monitoring and AM plan. The decision framework will be implemented by the Mobile District USACE during the construction of Ship Island. Brady Mattsson (consultant, SDM coach) led a stakeholder team (listed below) that was assembled to provide expert elicitation and test the decision support tool. The stakeholder team included: Justin McDonald – USACE project manager (decision maker); Elizabeth Godsey – USACE project engineer (provided data and modeling output); Nate Lovelace – USACE project operations (navigation channel information); Mark Ford – National Park Service (decision maker); Darin Lee – Louisiana Coastal Protection and Restoration Authority barrier island project manager (outside expert advisor); Mark Byrnes (consultant technical expert, provided sediment budget); Soupy Dalyander (USGS technical expert, geomorphology/waves); Michelle Meyers (USGS technical expert, CEM/AM); and Greg Steyer (USGS technical expert, CEM/AM). Elise Irwin

(USGS, SDM coach) helped facilitate and guide the prototyping workshops and other USACE MsCIP resource managers provided data and information upon request.

We used an SDM framework following PrOACT (Hammond et al. 1999), ten webinars and 2 rapid prototyping workshops with expert elicitation as our decision analysis methods in order to develop two Bayesian decision network model prototypes. The specific mid-construction management decisions that will be made from our results are included in our decision tables and center upon how (with limited sand and budget availability) storm-driven weakening events to the design template during construction will be handled.

10. OUTREACH:

The MsCIP has weekly update calls with decision-makers from USACE and the NPS where the status and findings of this project are discussed. Additionally, updates on this project are also provided at MsCIP monthly stakeholder engagement calls that has over 75 members, representing agencies/organizations such as USACE, USGS, NPS, EPA, MS Department of Marine Resources, MS Department of Environmental Quality, BOEM, US Coast Guard, Academia, Contractors, and Non-governmental Organizations.

The articles and reports associated with this project include:

Manuscript (submitted through IPDS and journal)

> Structured-decision making to inform ecosystem restoration in dynamic environments: case study on barrier islands of the northern Gulf of Mexico. 2015. P. Soupy Dalyander, Michelle Meyers, Brady Mattsson, Gregory D. Steyer, Elizabeth Godsey, Justin McDonald, Mark Byrnes, Mark Ford

MsCIP Monitoring and Adaptive Management Plan (entire plan is still under USACE agency-review)

> U.S. Army Corps of Engineers (USACE). 2015. Mississippi Coastal Improvements Program (MsCIP), Comprehensive Barrier Island Restoration Hancock, Harrison, and Jackson Counties, Mississippi, Supplemental Environmental Impact Statement. Appendix S. Monitoring and Adaptive Management Plan.

Other presentations and forums include:

> Structured decision making to facilitate sustainable barrier island restoration practices in Mississippi, USA. Michelle B. Meyers, Gregory D. Steyer, Brady Mattsson, Soupy Dalyander, Elizabeth Godsey and Justin McDonald. Coastal and Estuarine Research Federation. November 8-12, 2015.

11. REFERENCES:

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Runge, M.C., S.J. Converse, and J.E. Lyons. 2011b. Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. Biological Conservation 144(4):1214-1223.

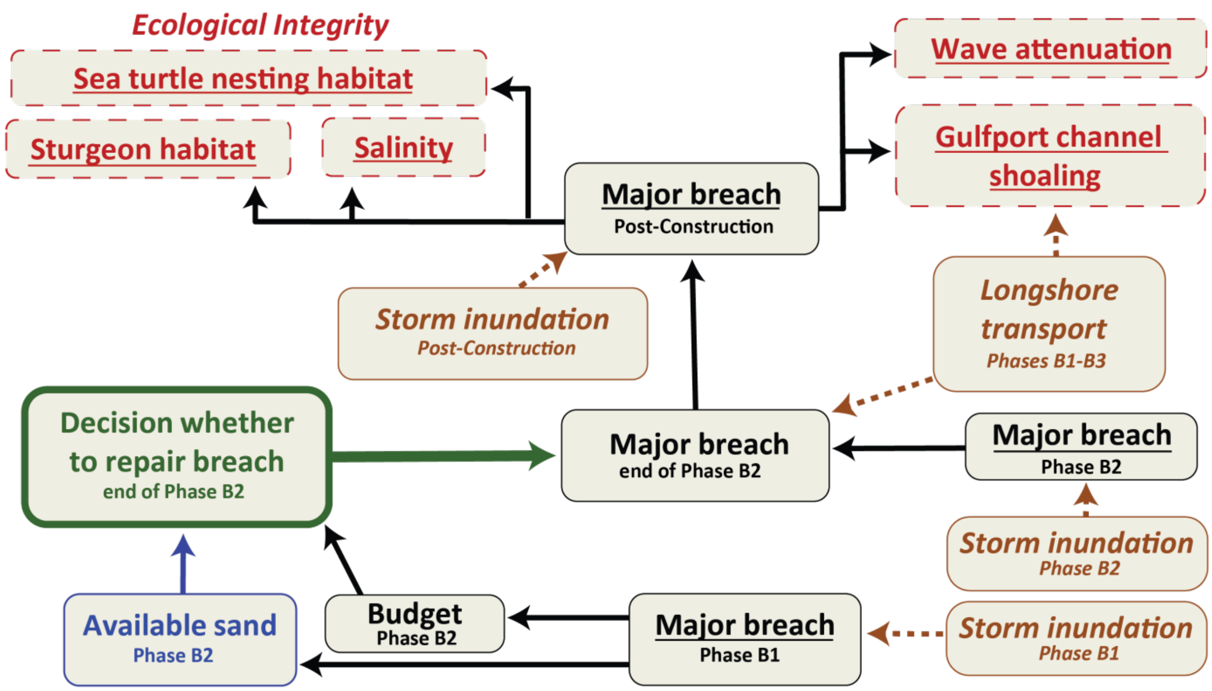

Figure. 1 Influence diagram for decision model 1. External drivers (brown) are in italics with dashed arrows; decision node (green) is a thick box with thick arrow; and fundamental objectives (red) are in dashed boxes, a cluster of which are related to the ecological integrity of the beach and Mississippi Sound. Expert elicitation used for underlined nodes. The decision to repair a major breach in phase B1 is automatic, but influences the budget and available sand (in blue).