Barrier Island System Management (BISM)

A Holistic System-Approach to Adaptively Manage Louisiana's Barrier Islands and Headlands

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Preface

The Barrier Island System Management (BISM) program has been developed by the Louisiana Coastal Protection and Restoration Authority (CPRA) through facilitation by the Water Institute of the Gulf (the Institute). BISM is intended to be a holistic and systemwide approach to manage the entire barrier island and headland chain through restoration and maintenance, replacing a project-based prioritization approach previously adopted as part of the Louisiana Coastal Master Plan. Because BISM will be a new effort within CPRA, processes must be developed to identify:

- How restoration of barrier islands should be prioritized
- Methods for leveraging existing synergistic programs within CPRA, such as the Louisiana Sediment Management Program (LASMP) (including the Louisiana Sand Resources Database (LASARD) and Louisiana Sediment Availability and Allocation Program (LASAAP)) and the Barrier Island Comprehensive Monitoring (BICM) program
- Strategies for optimizing program implementation

A key need for BISM is to structure the program to be a robust and science-driven approach to prioritize barrier island restoration projects. The team identified the **development of a standardized workflow for project identification and prioritization** as the necessary first step in developing the program. The workflow, contained within this report, enables consistency and transparency in restoration project selection and includes guidance on regional considerations for system-level barrier island and headland management.

A second goal of BISM is the use of **quantitative, objective tools for evaluating local and regional benefits to prioritize project implementation**. Numerous data collection, numerical modeling, and cost/benefit analysis efforts have been developed that can be utilized by BISM; these existing resources are described within this report. In addition, a conceptual framework has been developed for a quantitative analysis toolkit that leverages these resources in evaluating the costs and benefits of barrier island restoration alternatives as part of a regional sediment management approach.

During program development, it was recognized by CPRA/the Institute that BISM has multiple opportunities for continued development that were beyond the scope of the current project, and that as an active program BISM should continue to be evaluated for opportunities to be more efficient and cost-effective. In addition to refinements of the workflow and the implementation of a quantitative analysis tool, the program development process identified other areas of advancement for BISM. The report concludes with a section describing these opportunities and their value in executing BISM as an operational program.

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List of Acronyms

Acronym	Term
BIRTA	Barrier Island Restoration Tradeoff Analysis
BISM	Barrier Island System Management
BOEM	Bureau of Ocean Energy Management
CIMS	Coastal Information System
CPRA	Coastal Protection and Restoration Authority
CWPPRA	Coastal Wetland Planning, Protection, and Restoration Act
E&D	Engineering and Design
EFH	Essential Fish Habitat
ESA	Endangered Species Act
FWA	Future with Action
FWOA	Future without Action
GRG	Generalized Reduced Gradient
ICM-BI	Integrated Compartment Model, Barrier Island Module
LASAAP	Louisiana Sediment Availability and Allocation Program
LASMP	Louisiana Sediment Management Plan
LASARD	Louisiana Sand Resources Database
LDEQ	Louisiana Department of Environmental Quality
LDWF	Louisiana Department of Wildlife and Fish
MRDP	Mississippi River Delta Plain
NGSAAP	Northern Gulf Sand Availability and Allocation Program
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRDA	National Resources Damage Assessment
OCM	Office of Coastal Management
OSB	Operational Sediment Budget
RSM	Regional Sediment Management
SDM	Structured Decision-Making
SHPO	State Historic Preservation Office
SSD	Surficial Sediment Distribution
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

Acknowledgements

This report was developed, in part, through a set of working group sessions designed to elicit information and recommendations on the development of the BISM program. In addition, one-on-one engagement between team members from CPRA and the Water Institute of the Gulf were part of input to the content. The primary developers of the report and framework are listed as authors. Diana Di Leonardo developed the Inventory of Stakeholder Concerns Geodatabase in addition to contributing to the report. Blaire Hutchison and Rocky Wager developed the "Database of Databases" Geodatabase. Catherine Fitzpatrick, Stu Brown, Greg Grandy, Justin Merrifield, Jonathan Bridgeman, Alyssa Dausman, Ioannis Georgiou, and Lauren Grimley contributed during the working group sessions and/or provided one-on-one input and review that was invaluable in developing the BISM framework and this report.

Executive Summary

WHAT WILL BISM ACHIEVE?

Louisiana’s barrier island restoration efforts have historically been implemented on a project-by-project basis. The barrier island system management (BISM) program will enable projects to be integrated components of a long-term, system-wide restoration strategy as part of a holistic regional sediment management (RSM) approach that supports increased restoration project longevity and a more sustainable barrier island system. In addition, BISM utilizes adaptive management principles to minimize costs and maximize benefits while achieving the Coastal Master Plan barrier island restoration targets

Goal of BISM:

A holistic, system-wide approach to barrier island management that guides when and where to focus restoration resources (funding and sediment) to **maintain barrier island integrity** as defined in the Coastal Master Plan, while **minimizing overall system maintenance costs** and **reducing project implementation times**.

Programmatic Objectives:

1. Mechanism to prioritize projects that provide the greatest value on a long-term, system-wide scale.
2. Reduce overall costs and delineate expected future costs to inform planning and budgeting.
3. Employ and advance Regional Sediment Management (RSM) practices to reduce overall sediment need and delineate expected future need.
4. Incorporate adaptive management into barrier island management.
5. Reduce implementation time for projects.

WHAT IS REGIONAL SEDIMENT MANAGEMENT?

The BISM approach for management of Louisiana’s barrier islands as an integrated system centers around the concept of Regional Sediment Management (RSM). Sediment is a valuable and limited resource that must be strategically placed to provide the greatest overall and long-term benefits to the landscape. The general definition of RSM is a systems approach to address sediment management for more sustainable solutions across multiple projects and programs, and as such stakeholder engagement and coordination is key for successful RSM.

RSM must be informed by an understanding of the sediment budget and sediment dynamics, anthropogenic influences on natural processes, and stakeholder needs in coastal management. A thorough understanding of the sediment dynamics can inform a management plan that ensures natural transport processes are not disrupted and can identify sediment sinks (deposits) that might be exploited to provide sediment resources to areas that are eroding. There is a net deficit in the regional sediment budget along most of Louisiana’s barrier coastline that requires supplementation with out-of-system sediment resources to offset losses. These resources, such as offshore deposits, Mississippi River sediment, and depositional sinks within the barrier system, must be considered as a component of the overall RSM strategy.

In Louisiana, considerable effort has been undertaken to incorporate RSM principles as part of adaptive management of the coast. Tools and data to support RSM have been developed under the Louisiana Sediment Management Plan (LASMP), including the Louisiana Sand Resources Database (LASARD), Surficial Sediment Distribution (SSD) map, Operational Sediment Budget (OSB), and the Louisiana Sediment Availability and Allocation Program (LASAAP), all of which support identification and best use of available sediment. Data to support understanding of sediment need are collected annually under the Barrier Island Comprehensive Monitoring (BICM) program, while the Breach Management Program (BMP) has developed criteria for decisions on subaerial island management. BISM is designed to leverage and build on these programs as part of a comprehensive approach to regional barrier island management.

HOW WILL BISM ACHIEVE ITS GOAL?

The first step in BISM program implementation was the establishment of a workflow (Figure i, Table i) to guide the development of a list of prioritized barrier island and headland restoration projects based on a transparent and science-driven process. The workflow also includes a mechanism for identifying potential future shortfalls in funding and/or sediment that would prevent the integrity of the barrier island system from being maintained.

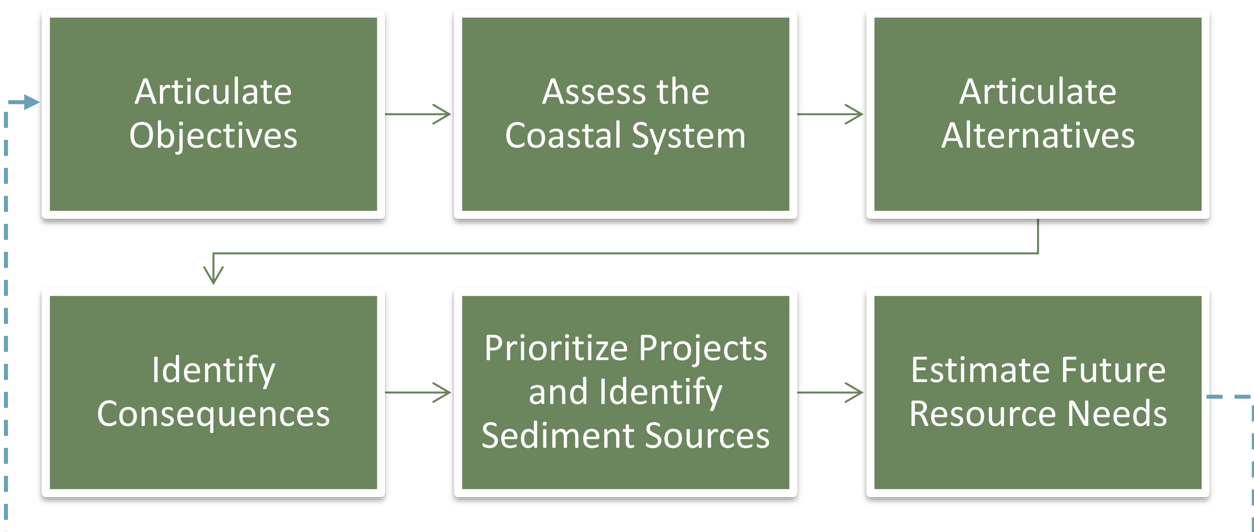

Figure i. Steps in the BISM restoration project prioritization workflow. The primary outputs of this process are: (1) a list of prioritized barrier island restoration projects and (2) an estimate of future resource needs, including sediment and restoration funding. Each time the workflow is implemented it builds on previous iterations as part of an adaptive management approach (represented by the dashed blue arrow).

The decision-making workflow was created using principles of structured decision-making (SDM), an objectives-orientated approach to making robust, transparent decisions that supports the direct use of existing data, models, and other resources in considering the consequences and tradeoffs of potential management actions[1]. The outputs of each step in the workflow are shown in Table i. In addition to the workflow, two companion products to support workflow implementation were created: (1) the *BISM Database of Databases*, an inventory of data relevant to barrier island restoration decisions, and (2) a *BISM Stakeholder Concern Inventory*, outlining decision-makers and other stakeholders with interests relevant to barrier island restoration, including potential funding entities and regulatory authorities.

Table i. Outputs of each step in the BISM project prioritization workflow.

Workflow Step	Output
1. Articulate Objectives	Updated coastal protection and ecosystem restoration objectives for barrier island restoration and their current relative priority.
2. Assess the System	Description of the state (condition) of each coastal reach along the Louisiana coast. Includes regional metrics such as marsh as well as metrics for barrier island and headland units.
3. Articulate Options	List of potential barrier island restoration project alternatives and their value in advancing the specific priorities identified in (2). At this stage, all potential alternatives should be considered but not yet prioritized.
4. Identify Consequences	Description of the likely trajectory of each of the potential restoration site location identified in (3) with and without restoration action.
5. Prioritize Projects	**Prioritized list of barrier island restoration projects that will be pursued for immediate action.** This list is a primary outcome of BISM and is the basis for moving into project implementation.
6. Estimate Future Resource Needs	**Inventory of gaps in sediment and/or funding available to support future restoration action.** This outcome is used to inform need for investment in, for example, identification of new sediment sources and in budgeting to ensure long-term success of the BISM program.

The BISM team will proceed through the workflow when barrier island restoration projects must be identified and/or prioritized, such as on an annual basis or when the best response to catastrophic erosion events such as storms is being considered.

1. Articulate Objectives

The objectives of barrier island restoration within Louisiana are included below. During the first step of the workflow, these objectives are to be reviewed and revised as needed.

Barrier Island and Headland Restoration Project Objectives

- Preserve geomorphic form and ecological function of the coastal system
  - Restore habitat types that are absent or degraded
  - Protect habitats that are well-utilized
  - Protect interior wetlands and inland marsh creation projects
- Promote the long-term sustainability of the system through enhancing coastal connectivity
  - Promote regional sediment transport connectivity along the coast
  - Restore system-level connectivity in hydrology and habitat

[1] Hammond, J., Keeney, R., & Raiffa, H. (1999). Smart Choices: A Practical Guide to Making Better Decisions. Howard Business School Press.

- Promote natural recovery following storm events

- Minimize risk to regions of socioeconomic value
  - Protect local and regional infrastructure, including industrial and commercial investment
  - Protect coastal communities
  - Maintain or enhance estuarine function

2. Assess the Coastal System

The next step in the BISM workflow is the systematic assessment of the current state of the barrier island system. To facilitate that process, the system is divided into coastal cells. Each cell is characterized by a set of value descriptors that reflect the condition of that coastal region and **relate to the fundamental objectives articulated in the first step of the workflow.** Value descriptors include basin marsh and estuary condition, infrastructure protection, and land loss condition and trajectory. Barrier islands and headlands are represented as units within each cell and are also characterized through a set of value descriptors including habitat value, coastal protection value, geomorphic integrity and trajectory, and sediment connectivity. A relative ranking system of 1-5 is used for each value descriptor, with 5 representing highest/"best" value and 1 representing lowest/"worst" value.

Existing CPRA resources that can facilitate this assessment include:

- *BISM Database of Databases:* BICM data (shoreline, seafloor, habitat, and sedimentary change)
- Barrier Island Status Reports
- Coastal Information Management System (CIMS)
- Breach Management Program[2]

3. Articulate Alternatives

During this step, a portfolio of potential restoration projects is developed. Because the goal of BISM is to evaluate a project and sediment source options simultaneously as part of a comprehensive approach to RSM, a rough estimate of the required sediment volume for each project and a potential sediment source is identified for each project with an estimate of the funding required for execution. In addition, each project is cross-referenced to other potential restoration projects (either under consideration in BISM or as part of the Coastal Master Plan) that it may influence or be influenced by it (through sediment transport, wave attenuation, etc.). Land ownership, cultural resources, and any other considerations relevant to project selection or implementation are also noted.

Existing CPRA resources that can facilitate this portfolio development and sediment source identification include:

- BISM Database of Databases: inventory of prior restoration projects
- Coastal Wetland Planning, Protection, and Restoration ACT (CWPPRA) Project Viewer
- CWPPRA Priority Project Lists, current year and prior
- CIMS Spatial Viewer

[2] Coastal Engineering Consultants, Inc. (2015). *Breach Criteria and Classification Technical Memorandum* (CPRA Contract No. 2503-15-15; p. 68).

- Louisiana Sand Resources Database (LASARD)
- Surficial Sediment Distribution (SSD) Map[3]
- Louisiana Sediment Availability and Allocation Program (LASAAP)[4]

4. Identify Consequences: Regional Outcomes with and Without Project Portfolio Alternatives

In this step, the likely trajectory of the coastal system under different potential restoration alternatives and the positive and negative impacts of an individual project on local and regional scales are evaluated. This evaluation is conducted by estimating what the value descriptors from the coastal assessment (step 2) would be if the project were executed. In addition, projects are identified for which the uncertainty in estimating the impact the project would have on the coastal system is so large that the optimal next step may be further analysis rather than project authorization.

Existing CPRA resources that can facilitate consequence analysis include:

- Analyses of prior project performance:
  - Barataria Basin Restoration Program Performance Assessment (PPA)[5]
  - Teche, Lafourche, and Modern Delta Study[6]
  - CWPPRA Adaptive Management: evaluation of restoration projects constructed at Raccoon Island, Whiskey Island, Trinity Island, East Island, and East Timbalier Island[7]

- Project-scale numerical model output:
  - Coastal Information Management System (CIMS), model domain inventory

- Sediment connectivity:
  - Operational Sediment Budget (OSB) and attendant BICM data[8]
  - Shoreline change analyses for Raccoon Point to Sandy Point[9]
  - Sediment dynamics, Belle Pass to Sandy Point[10]
  - BICM1 seafloor change analysis

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[3] Khalil, S. M., Forrest, B. M., Hayword, E.L., & Raynie, R. C. (2018). Surficial sediment distribution maps for sustainability and ecosystem restoration of coastal Louisiana. *Shore and Beach*, *86*(3), 21–29.

[4] Aptim Environmental & Infrastructure, Inc. (APTIM). (2020). *Louisiana Sediment Availability and Allocation Program (LASAAP): Sediment Resource Analysis Tool Development and Barataria Basin Pilot Study Results* (CPRA Contract #4400017001 and GOMA Contract GSC-121813, Task 10.; Final Report Prepared for Louisiana Coastal Protection and Restoration Authority (CPRA) and Gulf of Mexico Alliance (GOMA)., p. 53).

[5] Royal Engineers and Consultants, LLC., & Coastal Engineering Consultants, Inc. (2019). *Performance Assessment of Restoration Projects/Programs in the Barataria Basin, Louisiana* (p. 35).

[6] Coastal Engineering Consultants, Inc. (2012). *Barrier System Perfomance Assessment* (LDNR Contract no. 2503-12-22; p. 42).

[7] Penland, S., Connor, P., Cretini, F., & Westphal, K. (2003). *CWPPRA Adaptive Management: Assessment of Five Barrier Island Restoration Projects in Louisiana*. 102.

[8] Applied Coastal Research & Engineering, Inc. (2020). Louisiana Operational Sediment Budget: Raccoon Point to Sandy Point, 1985-89 to 2013-16 (p. 182) [Louisiana Coastal Protection and Restoration Authority]. Applied Coastal Research & Engineering, Inc.

[9] Coastal Engineering Consultants, Inc. (2013). *Evaluation of the Impact of Hurricanes Katrina and Rita on Coastal Louisiana Barrier Shorelines* (LDNR NO. 2503-12-22).

[10] Georgiou, Ioannis Y., Weathers, H. D., Kulp, Mark A., Miner, M. D., & Reed, D. J. (2010). *Interpretation of Regional Sediment Transport Pathways using Subsurface Geologic Data* (CESU Contract # W912HX-09-2-0027; p. 40).

5. Prioritize Projects and Identify Sediment Sources

During this step of the workflow, the portfolio of projects is prioritized by evaluating the consequences tables developed in the previous step of the workflow. In addition, sediment sources identified for each project are reevaluated and adjusted for the developing portfolio of alternatives. The total estimated volume of sediment needed across all projects should not exceed the likely sediment volume available in each nonrenewable sediment source, with replacement sources identified where needed. The tradeoffs of different options for potential sediment source use are considered in this process, such as impacts of sediment grain size on potential loss rates and long-term resiliency of projects. The potential benefits and tradeoffs of renewable sediment sources (such as riverine deposits) will also be evaluated, including the potential for use in long-term maintenance of restoration sites.

Existing CPRA resources that can facilitate cost/benefit analysis and sand sourcing include:

- Barrier island restoration project cost analysis tool (used in project-level planning)
- Louisiana Coastal Master Plan, Plan Development Database (tracks project costs and sediment availability)
- Louisiana Sediment Management Plan (LASMP)[11] and its associated resources:
    - Louisiana Sand Resources Database (LASARD)[12]
    - Surficial Sediment Distribution (SSD) Map[13]
    - Louisiana Sediment Availability and Allocation Program (LASAAP)[4]
- Northern Gulf Sand Availability and Allocation Program (NGSAAP)

6. Estimate Future Resource Needs

The last step in the workflow consists of evaluating current and projected future needs for sediment, funds, and data. Identifying short- and long-term funding needs allows for more robust budgeting and planning. Comparing expected sediment needs for restoration to known sediment resources is similarly important for planning purposes, informing when investment is needed in either sand exploration or further delineation of sediment volumes within known borrow areas. Lastly, it is important to explicitly consider data or modeling gaps that limit fully understanding trajectories of the barrier island system with and without restoration. Doing so enables gaps that are limiting robust decision-making to be filled in a timely manner and can save costs in the long-term by addressing these needs before significant investment is made in carrying through potential project alternatives that have high uncertainty in their feasibility or effectiveness.

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[11] Khalil, S. M., Finkl, C. W., Roberts, H. H., & Raynie, R. C. (2010). New approaches to sediment management on the inner continental shelf offshore coastal Louisiana. *Journal of Coastal Research*, *26*(4), 591–604. https://doi.org/10.2112/10A-00004.1

[12] Khalil, S. M., Haywood, E., & Forrest, B. (2016). *Standard Operating Procedures for Geo-scientific Data Management*. 30.

[13] Khalil, S. M., Forrest, B. M., Hayward, E.L., & Raynie, R. C. (2018). Surficial sediment distribution maps for sustainability and ecosystem restoration of coastal Louisiana. *Shore and Beach*, *86*(3), 21–29.

Existing CPRA resources that can facilitate future resource needs evaluation include:

- Louisiana Sediment Management Plan (LASMP)[9] and its associated resources:
  - Louisiana Sand Resources Database (LASARD)[10]
  - Surficial Sediment Distribution (SSD) Map[11]
  - Louisiana Sediment Availability and Allocation Program (LASAAP)[4]
- Northern Gulf Sand Availability and Allocation Program (NGSAAP)
- Louisiana Coastal Master Plan, 2023 Barrier Island Model (ICM-BI)

BISM DATABASES

In addition to the workflow, two databases have been created to support the BISM program.

Inventory of Stakeholder Concerns

This resource, which consists of a short memorandum and a simple GIS database, has been compiled to provide information on entities relevant to barrier island and headland management within the state of Louisiana. Stakeholder concerns are sorted into six categories. Categories 1-3 encompass entities and actions with interests relevant in the project selection and prioritization: 1) those who may provide funding; 2) those that may have the authority or jurisdiction to influence prioritization of barrier island restoration projects conducted under BISM; and 3) those whose actions may impact the coastal barrier system independently of BISM. The other categories are: 4) organizations and entities with whom CPRA can engage in developing best practice in barrier island management; 5) regulatory entities and organizations that have interests relevant to project implementation; and 6) stakeholders with whom it is advisable to develop a communication strategy for the purpose of transparency. The GIS database delineates stakeholders associated with specific geographic areas, such as navigable waterways that are maintained and recurrently dredged.

Database of Databases and Inventory of Available Information Sources

A Database of Databases has been developed that compiles resources that are directly relevant to BISM program implementation, capturing them in a programmatic geodatabase for straightforward discovery and access. This database and the relevant fields are described in a short report. This report also describes other information sources that are not fully integrated into the Database of Databases and that provide coast-wide or regional information for informing project prioritization and/or use of sediment in restoration as part of a regional sediment management approach, with links on where to access this information. Additional information sources not included in the Database of Databases include, for example, reports on barrier island restoration or monitoring results.

QUANTATIVE ANALYSIS FOR MORE ROBUST DECISION-MAKING

The BISM workflow can be immediately implemented using best professional judgement based on the databases and resources identified. However, Louisiana has invested substantially in the collection of data and development of tools that can be leveraged more directly in prioritizing barrier island restoration projects. The conceptual framework of a Barrier Island Restoration Tradeoff Analysis (BIRTA) toolkit has been developed as part of this project to utilize these resources more directly (Figure iii) and support quantitative, objective analysis of restoration project consequences and tradeoffs; identification of future sediment and funding needs; and input into the design of monitoring programs.

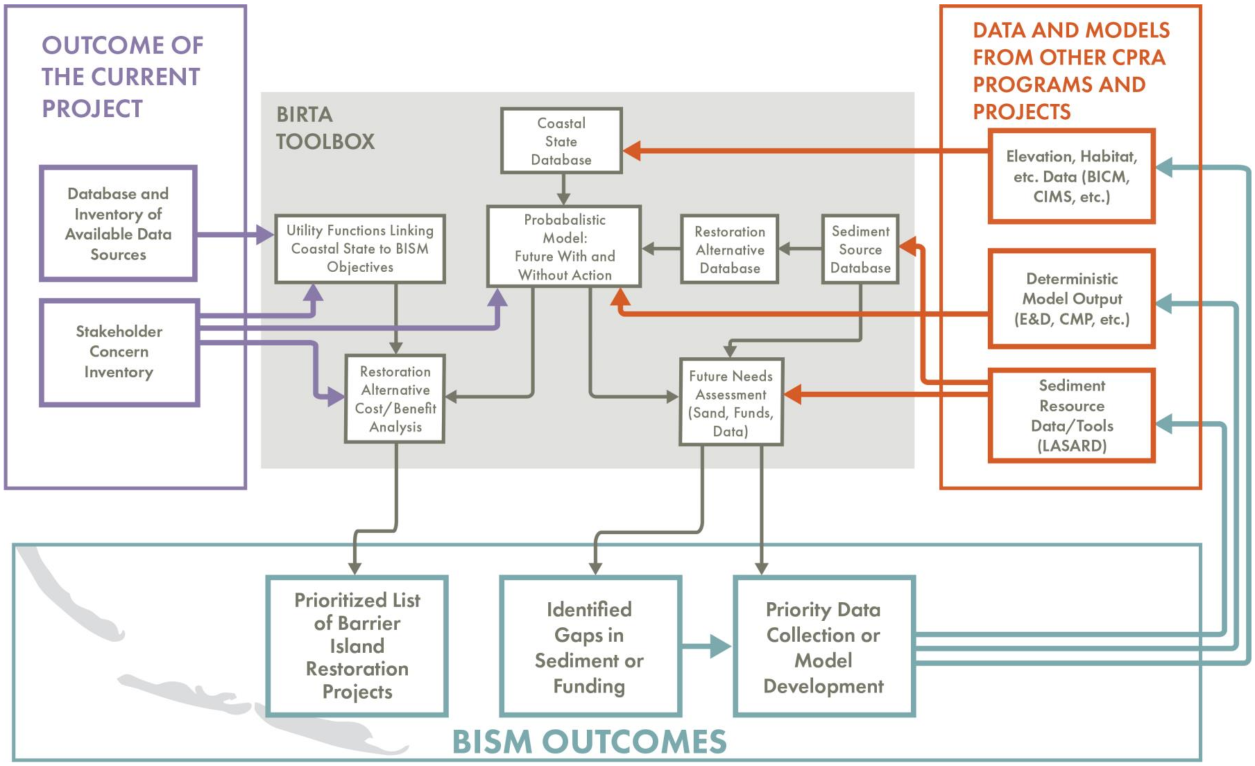

Figure ii. Interaction of the Barrier Island Restoration Alternative (BIRTA) Toolbox with the outputs of the current project and other projects and programs within CPRA.

The conceptual design of the BIRTA toolkit consists of several components:

- **Coastal Condition Database:** uniform set of metrics to assess the condition of coastal cells and associated barrier island and headland units based on analysis of observational data
- **Objective Utility Functions:** algorithms that link the metrics of the coastal cells and barrier islands in the coastal condition database to the objectives of barrier island restoration
- **Restoration Alternative Database**: database of potential restoration project alternatives and estimates of sediment volume needs and financial cost.
- **Sediment Resource Database:** characteristics of available sediment resources for use in optimizing use of available sediment for restoration projects on a holistic, regionwide scale. This component has particularly high synergy with LASAAP and its associated tools and data can be leveraged for this component.
- **Probabilistic Coastal Forecast Tool:** Bayesian model trained with existing model output and data to probabilistically predict the evolution of the coast for each restoration alterative (figure 6).
- **Tradeoff Analysis Tool**: set of analysis tools for conducting benefit analysis to prioritize barrier island and headland restoration projects based on their cost (in sediment and funding) relative to local and regional benefits, quantified through their impacts to restoration objectives.

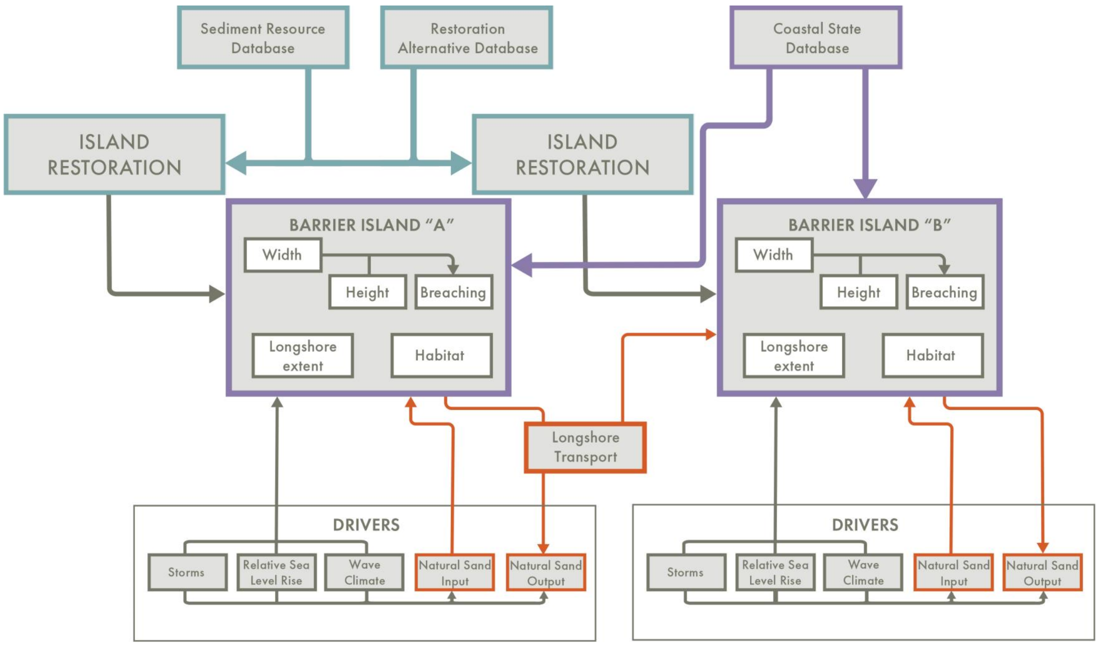

Figure iii. Conceptual diagram of the probabilistic coastal forecast model in BIRTA. Each barrier island is characterized by metrics in a coastal condition database. System evolution with and without restoration is predicted probabilistically and informed by data and deterministic models. Figure does not include all metrics for characterizing a barrier island and only two barrier islands are shown.

The BIRTA toolkit has been designed so that components could be developed modularly. For example, development of the coastal condition database and tradeoff analysis could provide an initial mechanism for moving to a more quantitative system assessment and incorporate adaptive management principles. In addition to evaluating the benefits of restoration alternatives, the BIRTA toolkit can identify future shortcomings in sediment and/or funding to inform the need for sand exploration and/or future budget requests. Because the model is probabilistic and driven directly by available data, it can also be used to identify the largest uncertainties and most critical gaps (data, modeling, etc.) limiting robust decision making in barrier island restoration prioritization.

OTHER RECOMMENDATIONS

In addition to the workflow and BIRTA analysis toolkit described above, there are several additional next steps that can be taken to advance the programmatic objectives of BISM. These include:

- **Expansion of LASAAP for Broader Use in Regional Sediment Management (RSM) and Linkage with BISM BIRTA Toolkit.** The LASAAP is a pilot tool for evaluating the best-use of available sediment for individual projects using sediment resources identified within the LASARD database. This database and tool could provide greater benefit to BISM if it is expanded to include non-surficial sediment deposits and expanded to include the entirety of the Louisiana coast. Some of these advancements are currently ongoing as part of the Northern Gulf Sediment Availability and Allocation Program (NGSAAP). The tool could also consider non-geological aspects of sediment resource selection, such as environmental considerations, permitting, and the probability of conflicting use from other projects. The *BISM Stakeholder Inventory* Geodatabase includes data relevant to these considerations; this database could be expanded and directly linked to a sediment sourcing tool to automate the identification of potential issues.

- **Coordination of BISM and BICM as part of an Adaptive Management Approach to Barrier Island and Headland Restoration and Monitoring.** Close coordination of BISM and BICM will advance the BISM programmatic objective to use an adaptive management (AM) approach to restoring, maintaining, and monitoring the barrier island system. BICM data can inform assessment of the condition of the coastal system and prediction of the likely impacts of restoration alternatives. Relative confidence in the BISM predictions can then be considered in designing monitoring approaches under the BICM program. For example, it may be challenging for the BISM team to evaluate the trajectory of a particular region due to a lack of data, suggesting that this spatial area should be prioritized in future monitoring. Similarly, uncertainties identified in BISM may be valuable in determining the frequency or type of data collection that might be most informative to collect under BICM, such as the relative value of post-storm data collection vs. baseline data under quiescent conditions.
- **Enhance Linkages of BISM with the Louisiana Coastal Master Plan.** Barrier island modeling for the 2023 Coastal Master Plan was developed based on the assumption that the BISM program will execute projects that maintain the integrity of the barrier island system. Under master plan modeling, the coastal system is divided into a set of restoration units corresponding to barrier islands and headlands that would be managed under BISM. Profiles within a unit erode according to historic shoreline and shoreface retreat rates until an island or headland integrity threshold for the unit is exceeded and a restoration template is automatically applied. This approach enables the barrier islands to evolve in a manner consistent with managed transgression, but it does not allow for comprehensive assessment of sediment transport and morphology feedbacks or the impacts of storm events. The BIRTA toolkit could fill these gaps and enable more robust prediction of coastal evolution under specific restoration alternatives, which could then be used to improve barrier island predictions within the master plan model.
- **Working Group to Streamline Project Permitting.** A priority in barrier island restoration that was identified during the BISM development workshop series was a reduction in project implementation time. The primary impediment was identified as permitting, which is complicated by multiple entities having different roles, regulatory responsibilities, and timelines. A potential solution to this problem is the development of a programmatic approach to permitting, wherein a regional permit is issued with programmatic environmental coverage along with specified criteria for individual projects. This approach would require coordination with, and approval of, multiple partners and regulatory agencies (U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) and Office of Coastal Management (OCM), State Historic Preservation Office (SHPO) and National Park Service (NPS), Bureau of Ocean Energy Management (BOEM), U.S. Fish and Wildlife Service (USFWS); Louisiana Department of Wildlife and Fisheries (LDWF) and Department of Environmental Quality (LDEQ), etc.). The recommended next step is the development of a working group that includes representation from federal and state entities with regulatory roles related to restoration project permitting to evaluate the development of a programmatic permitting approach.

1.0 Introduction

1.1. BACKGROUND

Coastal Louisiana's barrier island systems constitute an important component of the Mississippi River Delta Plain (MRDP), providing ecosystem services such as habitat, storm-surge buffering capabilities, and maintenance of marine and estuarine water quality gradients. To preserve the integrity of the MRDP and the health of this interconnected coastal system, holistic and system approaches to sediment management must be utilized in the management of barrier islands and headlands (Khalil et al., 2010; 2013). Prior to implementation of an aggressive project-based restoration program over the past two decades, these barrier shorelines were documented as some of the most rapidly disintegrating in the world (McBride et al., 1992). Louisiana's barrier island restoration efforts have historically been implemented on a project-by-project basis, which has ultimately led to the successful restoration of most of the barrier islands along the south-central coast. However, this approach has focused on the islands as individual geomorphic entities, rather than as a continuous system within which sand is exchanged in littoral cells on a regional scale. Moreover, due to the complexity of planning and permitting construction projects, regulatory constraints, and limited sand resources, individual projects are subject to high levels of uncertainty related to project cost, constructability, and timing (Appendix A). This uncertainty can make it nearly impossible to effectively respond to large-scale erosion and coastal loss such as may occur rapidly during storms.

To address the shortfalls of a discrete approach to managing the system, the Louisiana 2017 Coastal Master Plan (hereafter referred to as the master plan) articulated the need for a strategic implementation process for barrier island system management that identifies available sources of sand and uses a programmatic approach to addresses environmental considerations so that projects can be integrated components of a long-term, system-wide restoration strategy. The programmatic approach would allow for science-based assessments of the barrier island system to enable project selection, regional sand/sediment management, and science and monitoring investments. Through the identification and accurate prediction of the dominant physical processes acting on the barrier systems and the geomorphic response to those drivers, the natural processes can inform successful management strategies. The incorporation of system-wide process-geomorphic knowledge and identification of adequate sources of compatible sediment to supplement deficits in sediment budget is critical to managing Louisiana's barrier shoreline in an efficient and cost-effective manner.

1.2. REGIONAL SEDIMENT MANAGEMENT

The BISM approach for management of Louisiana's barrier islands as an integrated system centers around the concept of Regional Sediment Management (RSM). Sediment availability—along with financial considerations—is the greatest limiting factor for implementation of the Louisiana Coastal Master Plan. Sediment must therefore be treated as a highly valuable and limited resource that is closely monitored, managed, and strategically placed in locations that provide the greatest overall long-term benefits to the landscape. The general definition of RSM is a systems-based approach to address sediment management for more sustainable solutions across multiple projects and programs. Stakeholder engagement and coordination across local, state, and federal agencies is key for successful RSM.

More specifically, RSM is an adaptive management approach informed by an understanding of sediment budget and dynamics, anthropogenic influences on natural processes, and stakeholder needs. A thorough understanding of a system's sediment dynamics can inform a sediment management plan that ensures natural transport processes are not disrupted and identifies sinks within the system that might be utilized to provide sediment resources to nourish zones where erosion dominates. Along the majority of Louisiana's barrier shoreline there is a net deficit in the regional sediment budget, requiring supplementation with out-of-system sediment resources to offset losses. These out-of-system resources are also considered as a component of the overall RSM strategy. Successful implementation of BISM to offset both sediment loss from the system and accommodation space created by relative sea level rise requires that all potential sediment sources be considered, monitored, and managed including: 1) offshore surficial and buried sands, 2) Mississippi River sand (sourced from dedicated dredging of bars and beneficial use of dredged material from navigation channels), and 3) depositional sinks within the barrier system (Figure 1).

In Louisiana, considerable effort has been undertaken to incorporate RSM principles as part of adaptive management of the coast. Tools and data to support RSM have been developed under the Louisiana Sediment Management Plan (LASMP), including the Louisiana Sand Resources Database (LASARD), Surficial Sediment Distribution (SSD) map, Operational Sediment Budget (OSB), and the Louisiana Sediment Availability and Allocation Program (LASAAP), all of which support identification and best use of available sediment. Extensive data to support understanding of regional sediment needs are collected annually under the Barrier Island Comprehensive Monitoring (BICM) program, while the Breach Management Program (BMP) has developed criteria for decisions on subaerial island management. BISM is designed to leverage and build on these programs as part of a comprehensive approach to regional barrier island management.

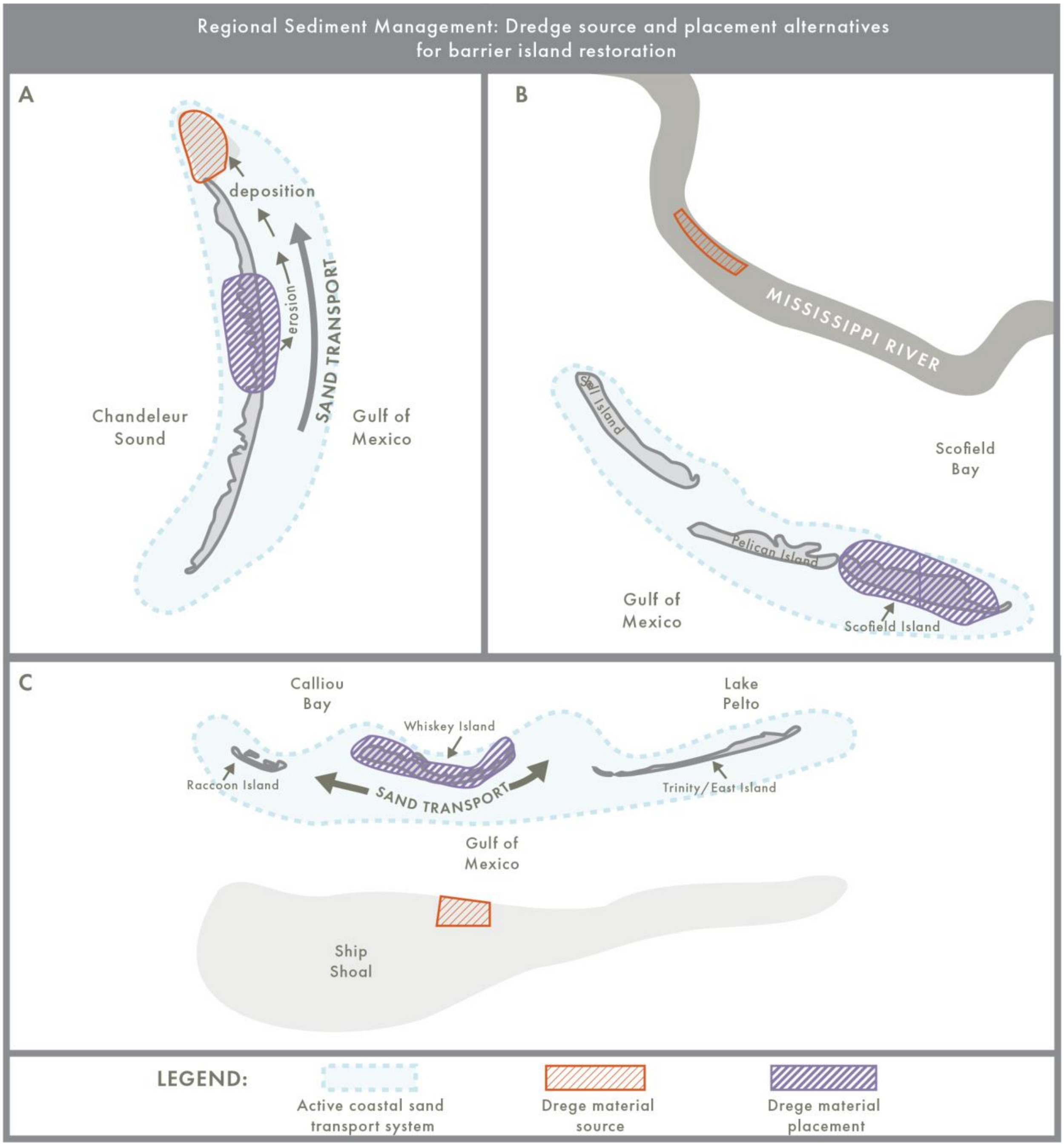

Figure 1. Examples of in-system versus out-of-system approaches to regional sediment management for Louisiana barrier island systems. The Chandeleur Islands (A) provide for a unique opportunity to manage sediment within the active barrier system. Sand is eroded from the central portion of the islands is transported by waves and storms to a sink at the northern terminus of the active sand transport system. Because no downdrift coast is naturally nourished by this material, it can be dredged and placed back in the central, sediment-starved portion of the islands for natural redistribution by waves over the long term. Examples of out-of-system sediment resources that have been used to supplement the deficit in the coastal sand budget include the Mississippi River (B) and distal offshore sand bodies such as Ship Shoal (C).

1.3. BISM FRAMEWORK DEVELOPMENT

To address the challenges and opportunities described above, the Water Institute of the Gulf (hereafter "the Institute") was tasked with facilitating a CPRA team to advance the BISM program as a long-term and holistic systems-based approach to adaptively manage the barrier shoreline systems and maintain barrier island ecosystem functions and services as required in the master plan. The focus of the CPRA/Institute team was on 1) defining the suite of issues that BISM needs to address; 2) determining the objectives of a programmatic approach to barrier island management; 3) providing a mechanism for identifying potential portfolios of barrier island maintenance projects that informs long-term planning, while also allowing rapid updates as needed to evaluate if and how restoration plans should evolve following catastrophic storm events; and 4) creating a process to objectively evaluate those portfolios in terms of benefits, costs, and tradeoffs. In addition, the CPRA/Institute team developed a conceptual framework for a quantitative tool that, in conjunction with the workflow, could be used in both prioritizing barrier island restoration projects based on their local and regional benefits and optimizing management of the coastal system as a whole. The CPRA team ensured products and outcomes would be useful and practical in supporting decision-making. This process occurred through a sequence of facilitated working group meetings complemented with one-on-one and small group calls. In addition, the Institute team undertook desktop research into available resources that could support BISM, including reports and tools developed by CPRA and other entities.

1.4. USE OF THIS REPORT IN BISM IMPLEMENTATION

This report is designed as a reference source to facilitate the making of science-based decisions for the prioritization of barrier island restoration projects on a system scale. *Section 2.0* includes a description of the goals and objectives of BISM that were identified by the CPRA and Institute team. This overview provides the context for future implementation and refinement of BISM, which is envisioned as a dynamic program that will continue to evolve in terms of the supporting tools and process in the same way the master plan has evolved over time. *Section 3.0* outlines a systematic approach to decision-making for prioritizing barrier island restoration projects, including a decision-making flowchart. This component is designed as a workflow for initial BISM implementation and includes documentation, information, and other references that are linked to the flowchart and support its use in prioritizing barrier island restoration projects. *Section 4.0* describes the conceptual design of a data management and quantitative project prioritization tool (Barrier Island Restoration Tradeoff Analysis – BIRTA) that can be developed to advance and enhance use of the BISM framework in practical application. Lastly, *Section 5.0* revisits the goal and objectives of the BISM framework and identifies other potential next steps in program implementation.

2.0 Goals and Objectives of BISM

BISM's programmatic goal and objectives are the foundation of the program and should direct its continued development into the future, being revisited and refined as needed for synergy with CPRA's overall efforts in coastal system management.

2.1. GOAL OF BISM

A holistic, system-wide approach to barrier island management that guides *when* and *where* to focus restoration resources (funding and sediment) to **maintain barrier island integrity** as defined in the master plan, while **minimizing overall system maintenance costs** and **reducing project implementation times**.

There are several key components to the BISM program goal. First, from a programmatic perspective, the primary concern is guiding and prioritizing the investment of funds and the use of available sediment in barrier island restoration to meet the targets of restoration established by the master plan. The design of individual restoration projects (*how* to construct specific barrier island and headland restoration projects) is part of the engineering and design (E&D) that occurs during project implementation. However, BISM incorporates adaptive management in that data, models, and other information developed for individual projects are leveraged as part of the future restoration project process in BISM. In addition, BISM will clarify the goals and objectives of restoration projects such that the E&D process results in project plans that address those goals. Second, the program is charged with maintaining the integrity of the barrier island system as defined by the master plan. The 2023 master plan assumes that this integrity will be maintained when screening other types of coastal restoration efforts (e.g., marsh creation, diversions, etc.). Consistent with that assumption, the barrier islands are restored and maintained the same way in both the master plan future without action (FWOA) and future with action (FWA) scenarios for the 2023 Coastal Master Plan modeling efforts currently in development. Therefore, the BISM program must provide additional clarity on 'barrier island integrity' (i.e., specific thresholds of barrier island configuration that achieve the master plan target) and focus restoration efforts to sustain that integrity. Third, the program is concerned with minimizing costs and maximizing benefits while achieving barrier island restoration targets established in the master plan. To accomplish these objectives, the program must have access to techniques, data, and tools that allow the short- and long-term costs and benefits of a complete portfolio of projects to be considered and analyzed. Although the specific design of restoration projects is part of E&D, the program should enable an adaptive management approach in which lessons learned in prior projects guide future project planning. Lastly, the program should advance mechanisms for facilitating project implementation to reduce costs and timelines.

2.2. BISM PROGRAMMATIC OBJECTIVES

The programmatic objectives of BISM are as follow:

1) Mechanism to prioritize projects that provide the greatest value on a long-term, system-wide scale.
    a) Consider local benefits (e.g., habitat) that are currently evaluated in project selection
    b) Consider regional benefits and costs (e.g., sediment source to downdrift islands; protection of inland marsh creation projects; restoration of system-level connectivity in sediment, hydrology, and habitat)

c) Identify and include consideration of natural system trajectories in project prioritization (e.g., prioritize islands nearing "tipping points" where a delayed response would increase restoration costs; consider delaying restoration of islands that are more likely to naturally recover from storms)
d) Identify and consider the potential impacts of master plan projects executed outside of BISM (e.g., storm protection or navigation channel projects)

2) Maximize cost benefit ratios and estimate expected future costs to inform planning and budgeting.
    a) Articulate upcoming needs to potential funding entities
    b) Expand the scale of what is included in "cost effective" beyond project scale (e.g., consider downdrift effects in cost/benefit analysis of individual projects)
3) Employ and advance RSM practices to reduce overall sediment need and delineate expected future need
    a) Optimize use of available sand, including providing recommendations of which sources of sediment should be used for which projects
    b) Identify gaps between available sediment volumes and expected need to inform investment in sand source identification
    c) Develop novel approaches and explore alternative technologies for RSM including beneficial use, extraction and conveyance value engineering, and techniques to monitor sediment dynamics
    d) Include oil and gas pipelines and other conflicts in evaluation of sand availability, with potential to identify high-value pipeline removal opportunities
4) Incorporate adaptive management into barrier island management
    a) Link "health" of system to observable metrics that can fall out of data and modeling, including identifying methods for evaluating project success and incorporating lessons learned into planning
    b) Inform monitoring of barrier islands programmatically (e.g., BICM and BISM aligned or integrated) and for individual restoration projects.
    c) Identify most pressing gaps (e.g., research, models) limiting system management
5) Reduce implementation time for projects
    a) Streamline the regulatory process through working with federal and state permitting agencies to develop programmatic regulatory (including environmental compliance) coverage with streamlined project-specific approval process

The workflow described *Section 3.0* outlines a systematic approach for **creating a prioritized list of barrier island restoration projects** and **an estimate of future sand/sediment and funding needs** as part of advancing BISM's goal and programmatic objectives 1–4.

3.0 Prioritization of Barrier Island Restoration Projects and Identification of Resource Needs: Decision-making Flowchart

3.1. ARTICULATE OBJECTIVES

A list of barrier island and headland restoration project objectives was developed as part of this project and is included below.

3.1.1. Barrier Island and Headland Restoration Project Objectives

- Preserve geomorphic form and ecological function of the coastal system
    - Restore/replicate habitat types that are destroyed or degraded
    - Protect habitats that are well-utilized
    - Protect interior wetlands and inland or back-barrier marsh creation projects
    - Maintain or enhance estuarine function
- Promote the long-term sustainability of the system through enhancing coastal connectivity
    - Promote regional sediment transport connectivity along the coast
    - Restore system-level connectivity in hydrology and habitat
    - Promote natural recovery following storm events
- Minimize risk to regions of socioeconomic value
    - Protect local and regional infrastructure, including industrial and commercial investment
    - Protect coastal communities

During this first step of the workflow, the local and regional objectives are reviewed by the project prioritization team. Although it is not expected that major changes to the list of restoration objectives will be made by CPRA, review by the team—whose members may vary from year-to-year—ensures consensus and consistency of expectations and provides a mechanism for objectives to be revisited for accuracy and clarity. **Articulation of fundamental objectives in restoring the coastal system does not yet include consideration of specific restoration projects**. This approach is strategic and founded in decision science, which has found that articulating the objectives before considering specific alternatives promotes broader, more “out-of-the-box” thinking (Gregory et al., 2012).

In framing restoration objectives, the BISM implementation team should articulate **long-term, regional restoration objectives as well as the short-term, local benefits that an individual project may provide**. This broad range of objectives must be included to achieve the fundamental BISM program goal of being a holistic, long-term approach to coastal system maintenance.

The decision-making workflow (Figure 2, Table 1) was created using principles of SDM (Appendix B), an objectives-orientated approach to making robust, transparent decisions that supports the direct use of existing data, models, and other resources in considering the consequences and tradeoffs of potential management actions (Gregory & Keeney, 2002; Gregory & Long, 2009). The flowchart (Figure 2) is intended to be a reference when 1) barrier island restoration projects are identified and prioritized, including as part of an annual review of restoration project priorities for CPRA funding; 2) when external funding opportunities for projects have been identified, in order to better align priority projects with potential funding sources; and 3) when storms result in significant changes to barrier islands necessitating reevaluation of restoration priorities. In addition, this workflow incorporates evaluation of future resource needs (in terms of sand and funding) to support long-term management of the barrier island system.

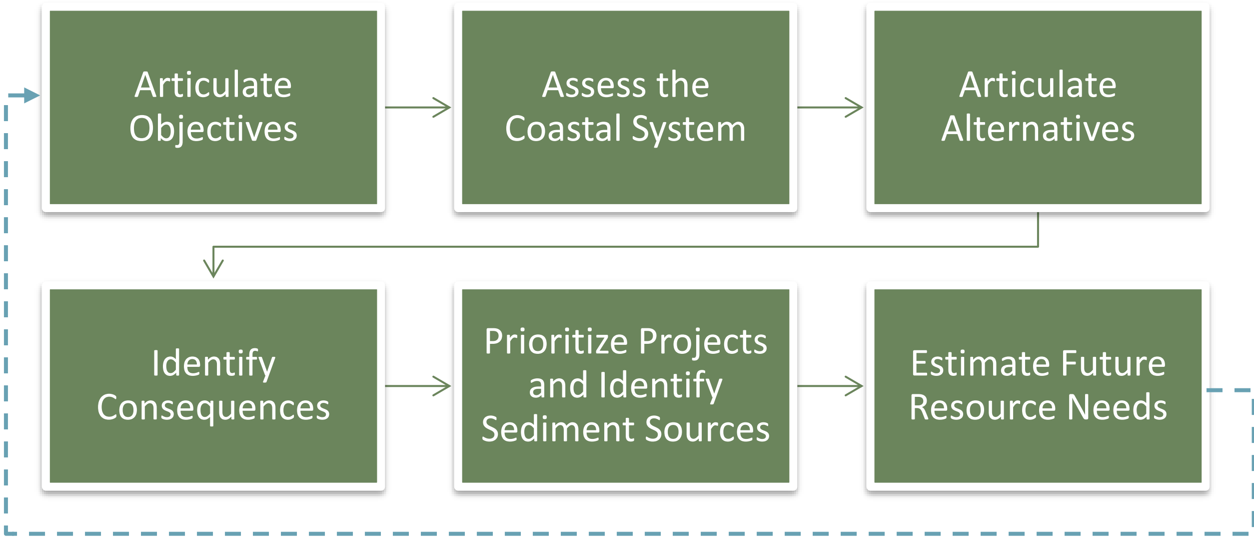

Figure 2. Steps in the BISM restoration project prioritization workflow. The primary outputs of this process are: (1) a list of prioritized barrier island restoration projects and (2) an estimate of future resource needs, including sediment and restoration funding. Each time the workflow is implemented it builds on previous iterations as part of an adaptive management approach (represented by the dashed blue arrow).

The workflow is designed to be modular. When the BISM program is first implemented, the steps can be conducted qualitatively by CPRA decision-makers using professional judgement and external expertise complemented by referencing existing data and models. A workflow manual to support this process is supplied in *Appendix E* and additional supporting materials (e.g., Excel spreadsheets) have been provided separately. As BISM moves forward, the program can directly integrate data and existing tools into a more quantitative cost/benefit analysis approach to prioritize barrier island restoration projects, determine future sand and funding needs, and identify uncertainties (system understanding and/or linkages to restoration objectives) that are the most limiting in robust management of the barrier island system. The conceptual design of this approach, the BIRTA framework, is described in *Section 4.0.*

The process allows for flexibility and iteration during implementation and, in the long-term, supports adaptive management of the barrier island system. Outcomes of each step are reviewed and utilized during subsequent steps and may be refined as needed. In addition, the outputs (coastal assessments, potential restoration alternatives, etc.) developed each time the workflow is executed can be combined with new data and/or model outputs—which can be targeted toward high-priority needs based on BISM workflow implementation—and used the next time the workflow is implemented as part of an adaptive management approach.

Table 1. Outputs of each step in the BISM project prioritization workflow. The details of implementation for each workflow step are described in subsequent sections. After the initial execution of the workflow, the outputs are combined with new data and information for use the next time the workflow is implemented (i.e., Step 6 loops back to Step 1) as part of an adaptive management approach.

Workflow Step	Output
1. Articulate Objectives	Updated (if needed) coastal protection and ecosystem restoration objectives for barrier island restoration and their relative priority.
2. Assess the System	Description of the state (condition) of each coastal cell along the Louisiana coast. Includes regional metrics such as marsh as well as metrics for barrier island and headland units.
3. Articulate Options	List of potential barrier island restoration project alternatives and their value in advancing the specific priorities identified in (2). At this stage, all potential alternatives should be considered but not yet prioritized.
4. Identify Consequences	Description of the likely trajectory of each of the potential restoration site location identified in (3) with and without restoration action.
5. Prioritize Projects	**Prioritized list of barrier island restoration projects that will be pursued for immediate action.** This list is a primary outcome of BISM and is the basis for moving into project implementation.
6. Estimate Future Resource Needs	**Inventory of gaps in sediment and/or funding available to support future restoration action.** This outcome is used to inform need for investment in, for example, identification of new sediment sources and in budgeting to ensure long-term success of the BISM program.

The next step in the BISM workflow is assessment of the current state of the barrier islands and headlands. This assessment includes components of the coastal system that influence—or are influenced by—the barrier islands and headlands, but that may not be part of direct restoration action under the BISM program**.** Doing so enables barrier island restoration projects to be identified and prioritized based on a holistic system assessment rather than exclusively on the local condition or benefits associated with an individual island or headland. This approach also enables explicit consideration of management actions executed outside of BISM, including the potential benefits or negative impacts those actions may have on BISM projects. For example, updrift hardening of the coast that inhibits sediment transport may accelerate erosion of a downdrift barrier island; conversely, a planned mainland marsh restoration project may enhance the potential value a barrier island provides in terms of mitigating mainland erosion.

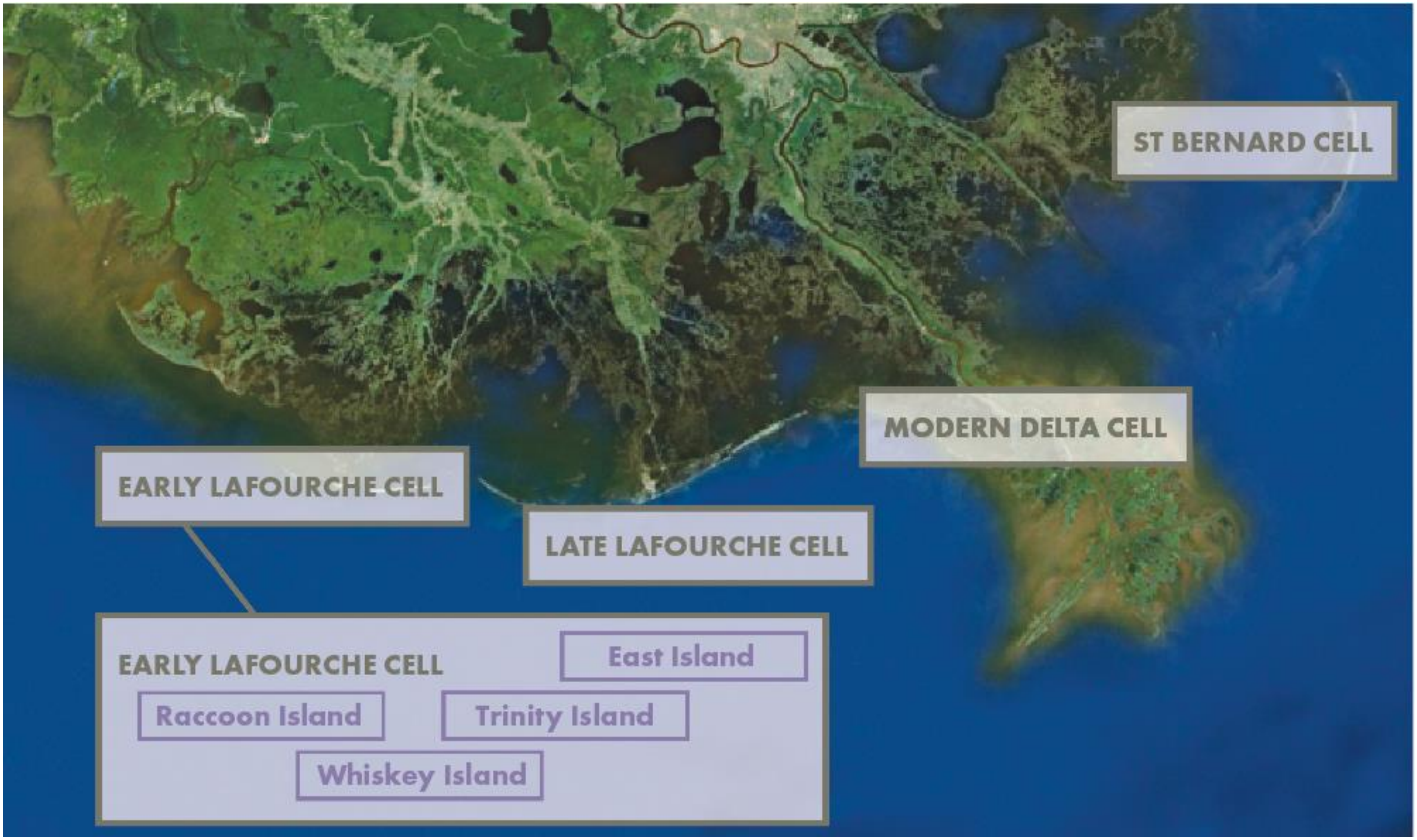

Figure 3. Diagram of units in the coastal system database. Units in gray represent coastal cells, the primary organizational structure of the coastal system database. Coastal cells include barrier island and headland units, with examples for the Early Lafourche cell shown in purple.

The assessment is conducted systematically, subdividing the coast into a set of coastal cells originally defined under the BICM program (Byrnes et al., 2018; Figure 3). Each cell is characterized by a set of value descriptors (described below) that reflect the condition of that coastal region and **relate to the fundamental objectives articulated in the first step of the workflow.** Barrier islands and headlands are represented as units within each cell and are also characterized through a set of value descriptors. A relative ranking system of 1–5 is used for each value descriptor, with 5 representing highest/"best" value and 1 representing lowest/"worst" value. Each of the descriptors is benchmarked according to the ideal for that cell. For example, if the St. Bernard marsh condition is in an "ideal" state from a management perspective, it would receive a ranking of 5.

During initial implementation of BISM, the value descriptors of the coastal cells and the barrier island and headland units that comprise them can be assigned through best professional judgement. This enables the current state of the coast to be systematically evaluated through a process that can be implemented without the development of additional tools or models. For the same reason, the value descriptors are aggregated at a high level to keep the list to a reasonable size for evaluation. For example, the evaluation of the habitat condition for a barrier island is based on a single value descriptor and does not separately consider the different types of habitats a barrier island may be supporting. Ultimately BISM can move toward the objective calculation of the value descriptors based on quantitative analysis of a set of uniform coastal metrics, described in more detail below (*Section 4.2)* which will also enable a larger number of value descriptors to be included.

The basin-wide value descriptors (Table 2) are as follows:

- **Basin marsh condition** evaluates the spatial extent and health of mainland marsh and marsh islands associated with each coastal cell basin.
- **Basin estuary condition** describes the overall water quality and habitat condition of the estuary, considering factors such as salinity regime and hypoxia.
- **Basin infrastructure sheltering** captures how protected infrastructure within the basin are from flooding and coastal erosion. A low value indicates that infrastructure is exposed (at high risk) whereas a high value indicates that infrastructure is well-protected (at low risk).
- **Basin land loss condition** captures the current condition of the basin in terms of ratio of land and marsh coverage to open water. A low value indicates a significant amount of marsh and land has converted to open water (relative to the ideal).
- **Basin land loss trajectory** captures the current rate of land loss from the basin. A low value indicates rapid land loss and associated increase in the tidal prism, which may reflect the basin approaching a tipping point of collapse, whereas a high value reflects relative stability.

Table 2. Sample table for assessing the basin-wide condition of coastal cells. These value descriptors capture the overall condition of the coastal cell, with the barrier islands and headlands also characterized through a set of value descriptors (Table 3). Each descriptor is ranged on a scale of 1-5 relative to the "ideal" for that cell, with 5 indicating the "best" possible state and 1 indicating the "worst" possible state from a management perspective. Cells are not ranked relative to each other at this point in the workflow.

Coastal Cell	Basin Marsh Condition	Basin Estuary Condition	Basin Infrastructure Protection	Basin Land Loss Condition	Basin Land Loss Trajectory
Early Lafourche					
Late Lafourche					
Modern Delta					
St Bernard					

A set of barrier island and headland unit value descriptors has similarly been chosen to allow best professional judgement to be used to characterize these units. These descriptors include the following (Table 3):

- **Habitat value** describes the extent and diversity of habitat associated with the barrier island or headland.
- **Coastal protection contribution** evaluates the value a headland or barrier island is providing to local or mainland infrastructure relative to the optimal protection it could be providing. Low values indicate the island has been degraded and, as a result, infrastructure is more exposed.
- **Geomorphic integrity** characterizes the overall physical state of the barrier island at the current time. For example, an island that has narrowed or lowered and is at high risk of breaching would have a low value.
- **Trajectory** evaluates the unit in terms of its resiliency (i.e., likelihood to maintain its subaerial acreage and/or littoral sediment volume over time). A low value indicates a unit is rapidly losing integrity, whereas a high value indicates the unit is stable.
- **Sediment connectivity** describes the barrier island or headlands contribution to sediment connectivity in the system relative to its ideal. A low value indicates that the unit is not contributing to overall sediment connectivity as much as preferred (e.g., an island with the potential to provide sediment to downdrift locations has degraded to the point that no longer occurs).

Table 3. Sample table for assessing the state of barrier island and headland units for each coastal cell. These value descriptors relate to the condition of individual islands and headlands, with condition of the cell basin also captured in a set of value descriptors (Table 2). Each descriptor is ranged on a scale of 1-5 relative to the "ideal" for that cell, with 5 indicating the "best" possible state and 1 indicating the "worst" possible state from a management perspective. Units are not ranked relative to each other at this point in the workflow.

Coastal Cell	Unit	Habitat Condition	Coastal Protection Contribution	Geomorphic Integrity	Trajectory	Sediment Connectivity
Early Lafourche	Raccoon Island					
	Whiskey Island					
	Trinity/East Island					
Late Lafourche	Timbalier Island					
	East Timbalier Island					
	West Belle Pass					
	Caminada Headland					
	Grand Isle					
	West Grand Terre					
	East Grand Terre					
Modern Delta	Grand Pierre					
	Chaland Headland					
	Shell Island					
	Pelican Island					
	Scofield Island					
St. Bernard	Breton Island					
	South Chandeleurs					
	North Chandeleurs					

The connections between the coastal state descriptors and the initial set of restoration objectives developed by CPRA and the Institute are described below:

Fundamental Objectives of Barrier Island and Headland Restoration Projects

- Preserve geomorphic form and ecological function of the coastal system
    - Restore/replicate habitat types that are destroyed or degraded
    - Protect habitats that are well-utilized
    - Protect interior wetlands and inland or back-barrier marsh creation projects
    - Maintain or enhance estuarine function

The coastal state descriptors associated with this objective include basin estuarine and marsh condition along with barrier island/ headland habitat value.

- Promote the long-term sustainability of the system through enhancing coastal connectivity
    - Promote regional sediment transport connectivity along the coast
    - Restore system-level connectivity in hydrology and habitat
    - Promote natural recovery following storm events

The coastal state descriptors associated with preserving the long-term sustainability of the system include basin land loss condition/trajectory and barrier island/headland condition, trajectory, and connectivity.

- Minimize risk to regions of socioeconomic value
    - Protect local and regional infrastructure, including industrial and commercial investment
    - Protect coastal communities

The value descriptors associated with this objective are basin infrastructure sheltering and unit coastal protection contribution.

3.1.2. Synergistic Programs and Available Resources

Comparison of recent and historical data can be used to inform assessment of the current state and trajectory of the barrier island and headlands. In addition, BMP has identified criteria for breaching potential that can be used in considering the potential for integrity failure of a barrier island. The following data sources that can be used in assessing the coastal system:

- *BISM Database of Databases*, BICM shorelines
- Barrier Island Status Reports: available from https://coastal.la.gov/.
- Coastal Information Management System (CIMS): https://cims.coastal.louisiana.gov/
- BMP (Coastal Engineering Consultants, Inc., 2015).

3.2. ARTICULATE ALTERNATIVES: RESTORATION PROJECTS AND SEDIMENT SOURCES

The potential restoration alternatives include two components: *which* portfolio of projects to implement/prioritize and *where* to source the sediment needed by those projects. The goal of BISM should be to evaluate a portfolio of project and sediment source options simultaneously as part of a comprehensive approach to RSM. As a first step, a rough estimate of the required sediment volume for each project and a potential sediment source along with the estimate of volume available should be identified for each project in addition to an estimate of the funding required for execution (Table 4).

The portfolio of potential projects is revisited each time through the workflow to ensure that new projects or opportunities are not missed by exclusively evaluating “known” (previously identified) options. **For the same reason, projects are not yet prioritized at this stage**. Instead, the focus is on thinking broadly to consider all potential alternatives that might advance the fundamental objectives identified in the first workflow step and/or to improve the condition of the barrier island system as captured by the coastal state value descriptors.

There should be a heavy emphasis on broadly considering all restoration alternatives, including novel approaches that may not have been previously implemented within Louisiana. Review of restoration strategies considered elsewhere, either through literature review or direct engagement of the barrier island restoration community (see *Appendix C: Inventory of Stakeholder Concerns*), can be used in identifying potentially beneficial new approaches. For example, “mega-nourishment” (placement of a large volume of sand at a feeder location on the coast to nourish the downdrift coastline) has been tested as a potentially cost-effective replacement for multiple smaller restoration projects, most notably with the Dutch “Sand Engine” (Stive et al., 2013). Although not all approaches used elsewhere may be appropriate for use in Louisiana, they should be considered in alternative development, particularly if they may provide long-term system benefit as part of RSM.

The approximate cost of, and sediment required for, each potential project can be estimated from existing E&D documents for similar past projects. Any additional considerations for that restoration alternative should also be noted at this time, such as updrift modification to the coastal system that may impact the restoration alternative and/or synergy of the alternative with other restoration activities being considered under the master plan. Other considerations that can be noted are factors related to project implementation, such as restoration projects to be built on lands owned by entities other than the state, locations where factors such as cultural resources or downdrift navigation channels exist, or projects that may have reduced resiliency due to updrift or local disruptions to sediment transport. Although these factors do not automatically preclude a project from being implemented, they can be considered in project prioritization if, for example, there is a limited window for using available funding. The *BISM Inventory of Stakeholder Concerns* (Appendix C) summarizes these considerations and includes a GIS database identifying spatial areas of stakeholder concern.

Identification of sediment sources for project implementation should be based on RSM considerations. For example, sediment supply in nearshore sources is limited, therefore the use of riverine or offshore sediment sources may be preferable for projects where it is feasible. Renewable sources of sediment and options for beneficial use of dredge material should be considered where appropriate as part of a long-term plan for project maintenance. Considerable ongoing advancement in identification and analysis of sand resources under LASMP, including the development of pilot tools for identifying the optimal choice of sediment source for a given project, can be utilized for this process. Additional investments that could potentially be made to support BISM are described in *Section 5.0 BISM: Additional Program Activities and Next Steps*.

Table 4. Restoration alternatives table. For each restoration alternative, the coastal cell(s) and barrier island or headland unit(s) that the alternative will affect is noted along with cross-referencing to other potential restoration projects the alternative may influence (either other alternatives under consideration in BISM or as part of the Coastal Master Plan) or be influenced by (updrift disruptions to sediment transport). An approximate cost and sediment volume need should also be included, as well as identifying the likely sediment source for the project. Land ownerships, relevant cultural resources, and any other considerations relevant to project selection or implementation should also be noted.

ID	Coastal Cell	Unit	Cross-Reference to Other Projects	Cost Estimate	Sediment Volume Need Estimate	Sediment Volume Source	Land Owner	Cultural Resources	Other Considerations

3.2.1. Synergistic Programs and Available Resources

CPRA has considered and implemented numerous coastal restoration projects throughout the Louisiana coastal system. Lists of prior or proposed projects may be used as a starting point in considering restoration alternatives. Available resources include:

- *BISM Database of Databases*, inventory of prior restoration projects.
- Coastal Wetland Planning, Protection, and Restoration ACT (CWPPRA) Project Viewer: https://lacoast.gov/new/Projects/Default.aspx
- CWPPRA Priority Project Lists, current year and prior: https://www.mvn.usace.army.mil/Missions/Environmental/CWPPRA/Priority-Project-Lists/ .
- CIMS Spatial Viewer, which includes identification of projects that may have been conducted outside of CWPPRA: https://cims.coastal.louisiana.gov/MapHome.aspx

Resources for identification of sediment sources for projects include:

- Louisiana Sand Resources Database (LASARD): https://www.arcgis.com/apps/MapSeries/index.html?appid=65cca038794d4ded8daaec8e6fb1a3ae
- Surficial Sediment Distribution (SSD) Map (Khalil et al., 2018)
- Louisiana Sediment Availability and Allocation Program (LASAAP; Aptim Environmental & Infrastructure, Inc. [APTIM, 2020])

3.3. IDENTIFY CONSEQUENCES: REGIONAL OUTCOMES WITH AND WITHOUT PROJECT PORTFOLIO ALTERNATIVES

This step in the workflow encompasses evaluation of the likely trajectory of the coastal system under different potential restoration alternatives and consideration of the positive and negative impacts of an individual project on a local and regional scale. Systematic evaluation of potential project outcome also facilitates the identification of potential projects for which there is insufficient knowledge or existing tools to robustly identify how the coast would evolve if it were executed (i.e., the consequences of implementation cannot be estimated with confidence). In these cases, the optimal next step may be investment in further analysis rather than formal E&D or project authorization.

During the initial implementation of BISM, best professional judgement informed by existing data and tools can be used to evaluate the local and regional benefits of potential restoration projects. The local (i.e., condition and trajectory of the barrier island/headland) and regional (i.e., basin and downdrift islands) impacts of the restoration project are estimated (predicted). A systematic approach to this evaluation is conducted with the use of consequences tables, which are used in SDM to organize information on potential outcomes (Hammond et al., 1999). The consequences tables include evaluation of the predicted condition of the basin, barrier islands, and headlands impacted by each restoration alternative (Table 5 and Table 6), replacing the **current** value descriptor scores with the **predicted value score should that restoration alternative be implemented**.

Table 5. Consequences table for predicting the coastal cell value descriptor after each restoration alternative is applied. These value descriptors relate to the overall condition of the coastal cell, with the barrier islands and headlands also characterized through a set of value descriptors (Table 6). Each descriptor is ranged on a scale of 1-5 relative to the "ideal" for that cell, with 5 indicating the "best" possible state and 1 indicating the "worst" possible state from a management perspective. Cells are not ranked relative to each other at this point in the workflow.

Restoration Alternative	Coastal Cell	Basin Marsh Condition Outcome	Basin Estuary Condition Outcome	Basin Infrastructure Protection Outcome	Basin Land Loss Condition, Trajectory Outcome

Table 6. Consequences table for assessing the predicted state of barrier island and headland units for each restoration alternative. These value descriptors relate to the condition of individual islands and headlands, with condition of the cell basin also captured in a set of value descriptors (Table 5). Each descriptor is ranged on a scale of 1-5 relative to the "ideal" for that cell, with 5 indicating the "best" possible state and 1 indicating the "worst" possible state from a management perspective. Units are not ranked relative to each other at this point in the workflow.

Restoration Alternative	Unit	Habitat Condition Outcome	Coastal Protection Contribution Outcome	Geophysical Integrity Outcome	Trajectory Outcome	Sediment Connectivity Outcome

3.3.1. Synergistic Programs and Available Resources

Numerous resources exist to inform best professional judgement evaluation of the consequences of restoration alternatives. Regional assessments that evaluated the performance of previously constructed projects can be used to inform the likely performance and trajectory of future projects. E&D models may be available for restoration alternatives that have reached that phase of authorization. Lastly, data on sediment connectivity in the system can be used to estimate the likely regional impacts of a given alternative. Available resources include:

- Analyses of prior project performance:
  - Barataria Basin Restoration Program Performance Assessment (PPA; Royal Engineers and Consultants, LLC., 2020; Royal Engineers and Consultants, LLC. & Coastal Engineering Consultants, Inc., 2019)
  - Teche, Lafourche, and Modern Delta Study (Coastal Engineering Consultants, Inc., 2012)
  - CWPPRA Adaptive Management: Evaluation of the performance of barrier island restoration projects constructed at Raccoon Island, Whiskey Island, Trinity Island, East Island, and East Timbalier Island (Penland et al., 2003)
- Project-scale numerical model output:
  - CIMS model domain inventory: https://cims.coastal.louisiana.gov/viewer/metadata/Model_Domains.xml)

- Sediment connectivity:
    - Operational Sediment Budget (OSB; Applied Coastal Research & Engineering, Inc., 2020)
    - Shoreline change analyses for Raccoon Point to Sandy Point (Coastal Engineering Consultants, Inc., 2013)
    - Sediment dynamics, Belle Pass to Sandy Point (Georgiou et al., 2010)

3.4. PRIORITIZE PROJECTS AND IDENTIFY SEDIMENT SOURCES

During this step, a documented, prioritized list of projects is developed from the list of alternatives (identified in *Section 3.2 Articulate Alternatives: Restoration Projects and Sediment Sources*) based on a cost/benefit analysis of their likely impacts to the coastal system (identified in *Section 4.4 Identify Consequences: Regional Outcomes with and without Project Portfolio Alternatives*). Taken together, this portfolio of projects is the mechanism through which BISM manages the barrier island system through an RSM approach.

The consequences tables developed in the previous step of the workflow provide a basis for prioritizing restoration projects, with alternatives within that table reordered (prioritized) during this step based on benefits and tradeoffs. In addition, sediment sources identified for each project are reevaluated and adjusted for the developing portfolio of alternatives. The total estimated volume of sediment needed across all projects should not exceed the likely sediment volume available in each nonrenewable sediment source, and replacement sources should be identified where needed. The costs associated with each project in the alternatives table should be updated accordingly if the source of the sediment for that project changes. The tradeoffs of different options for potential sediment source use should be considered in that process, such as impacts of sediment grain size on potential loss rates, considerations of cut-to-fill ratios, and long-term resiliency of projects. Lastly, the potential benefits and tradeoffs of renewable sediment sources (such as riverine deposits) should be evaluated, including the potential for use in long-term maintenance of restoration sites.

Because the initial phases of BISM implementation will rely on best professional judgement, strategies are needed for the systematic evaluation of alternatives. One approach identified for alternative prioritization by the BISM team was the use of a two-step approach to project prioritization. In this approach, a coastal cell of highest priority would be identified before focusing on individual restoration projects. This approach can be implemented by identifying the coastal cell in the poorest current condition based on the value descriptor assessment and/or the cell that has the highest potential opportunity for improvement in response to the restoration alternatives. This evaluation can be conducted in concert with the master plan effort, which will also be identifying priority projects based on regional impact and benefit. Coordination with the master plan will also enable other restoration projects to be considered in coastal cell prioritization. If there is considerable ongoing investment to, for example, expand a marsh through sediment diversions and marsh creation, that region may be of high priority for restoration if the current state of the barrier island is providing minimal protection value to the basin.

Once a coastal cell is prioritized, the team can then prioritize individual restoration actions within that cell based on the consequence tables. The list of objectives for coastal restoration, developed in the first phase of the workflow, should be used as weighting factors in prioritization. For example, if the primary objective is coastal infrastructure protection, the benefit an alternative provides to coastal infrastructure protection value descriptors should be given more weight than those associated with habitat. The factors that should be considered in project prioritization are:

- **Benefit of each restoration alternative.** This assessment is based on considering the difference between the value descriptors for the current state of the coast (*Section 3.2****Error! Reference source not found.***) and their project value with project implementation (*Section 3.4 Identify Consequences: Regional Outcomes with and without Project Portfolio Alternatives*). This difference captures the improvement (benefit) provided by each alternative.
- **Cost of each restoration alternative.** The benefit each restoration alternative provides should be benchmarked against its cost in terms of both funding and sediment. Projects that require substantial resources and do not provide correspondingly high benefit should be deprioritized.
- **Value of coastal cells and barrier island/headland units impacted by the restoration alternatives**. In addition to the differential benefit provided by each restoration alternative, the overall value of individual barrier islands and headlands as they relate to the fundamental objectives may be considered. For example, alternatives for restoring barrier islands that are part of a wildlife refuge may be of higher value and well-aligned to receive funding targeted toward habitat restoration for specific species (such as damaged resources under the Natural Resources Damage Assessment [NRDA]).
- **Tipping points.** Islands that are in a degraded state and on a rapid trajectory for loss may need to be prioritized for restoration action to prevent additional land loss.
- **Alternative portfolios.** The prioritization team should consider the potential value of combinations of individual projects that might produce greater cumulative benefit if executed concurrently than they would if done sequentially over several years.
- **Alongshore sediment connectivity.** The team should evaluate the downdrift impacts of restoration alternatives given that projects that enhance the sediment connectivity of the coastal system are more likely to have sustained, long-term benefit. The impacts of local and updrift management actions on an alternative should also be considered. Sustained sediment supply to a restoration alternative can potentially positively enhance its value by increasing its long-term sustainability, whereas local or updrift coastal hardening may have the opposite effect.

Because this step will be conducted qualitatively, it may be difficult to prioritize between individual restoration projects or coastal cells that provide different benefits. For example, one project may provide significant long-term benefit in terms of coastal resiliency and connectivity, while providing relatively little immediate benefit to enhancing the ecological function of the coast or protecting coastal infrastructure. A technique that may be used in these cases is the “even swap” approach (Hammond et al., 1999), where the tradeoffs between different objectives are explicitly considered. In this technique, the team would identify the conditions under which the benefit provided to one objective—such as long-term coastal resiliency—is equal to or exceeds the benefit to other objectives. In the previous example, a project might need to provide a decade’s worth of long-term benefit to overall coastal connectivity to be considered “equivalent” to the immediate value provided by another coastal restoration project in protecting infrastructure, and/or the long-term benefits may only be considered of value if no other islands in the system are approaching tipping points of drowning.

3.4.1. Synergistic Programs and Available Resources

The two components of this workflow step are prioritization of projects based on cost/benefit analysis and the identification of sediment resources to use for those projects. The likely benefits of projects can be evaluated with the consequence analysis conducted in the previous step of the workflow and benchmarked against project costs.

Additional resources that can inform cost/benefit analysis include:

- Barrier island restoration project cost analysis tool (used in project-level planning)
- Louisiana Coastal Master Plan, Plan Development Database (tracks project costs and sediment availability)

Additional resources that can inform the sourcing of sediment for prioritized projects include:

- Louisiana Sediment Management Plan (LASMP; Khalil et al., 2010; Underwood, 2012) and its associated resources:
    - Louisiana Sand Resources Database (LASARD; Khalil et al., 2016): https://www.arcgis.com/apps/MapSeries/index.html?appid=65cca038794d4ded8daaec8e6fb1a3ae
    - Surficial Sediment Distribution (SSD) Map (APTIM, 2020; Khalil et al., 2018)
    - Louisiana Sediment Availability and Allocation Program (LASAAP; Aptim Environmental & Infrastructure, Inc. [APTIM, 2020])
- Northern Gulf Sand Availability and Allocation Program (NGSAAP; currently under development)

3.5. ESTIMATE FUTURE RESOURCE NEEDS

The last step in the workflow consists of evaluating current and projected future needs for sediment, funds, and data based on the prioritized project list. The identification of short- and long-term funding needs allows for more robust budgeting and planning. Comparison of expected sediment needs for restoration to known sediment resources is similarly important for planning purposes, informing when investment is needed in either sand exploration or further delineation of sediment volumes within known borrow areas. Lastly, it is important to explicitly consider data or modeling gaps that limit full understanding of the trajectories of the barrier island system with and without restoration. Doing so enables gaps that are limiting robust decision-making to be filled in a timely manner (e.g., through targeted data collection under BICM) and can save costs in the long-term by addressing these needs before significant investment is made in carrying through potential project alternatives that have high uncertainty in their feasibility or effectiveness.

In the near-term, the estimate of future sediment and funding needs can be informed through the use of existing data tools available to CPRA. Projects, and their associated sediment sources, that are identified and prioritized during previous steps in the workflow can be binned according to their likely timescale for implementation: near-term (1-3 years), mid-term (4-10 years), and long-term (10+ years). The estimated sediment volume needs for each project, which is included in the alternative list, can then be added over each timescale, and compared to sediment resources identified within LASARD. Prior data on storm impacts and post-storm restoration projects can be used to estimate an uncertainty associated with the predicted sediment volume needs, allowing for an estimate range to be produced. The estimated funding needs to execute projects can be estimated over different timescales in a similar way.

The restoration alternatives should also be assessed for critical data needs. Questions that should be asked include:

- What is the trajectory of each island based on existing data and any available model output?
- Are there mitigating factors that may alter that trajectory in the short- or long-term, such as local coastal protection infrastructure or updrift changes to the sediment budget?
- How might the trajectory of the barrier island influence the feasibility of the project at the time of implementation?
- How might the trajectory of the barrier island influence the long-term benefits the project provides?
- Is there a viable sand/sediment resource available for project implementation?

The uncertainties associated with answering these questions can be used to guide future data collection and/or modeling. Near-term projects with critical uncertainties should also be reevaluated for readiness to move to implementation, versus the costs and benefits of additional data collection or preliminary modeling prior to moving to that stage.

3.5.1. Synergistic Programs and Available Resources

Once future sediment resource needs have been benchmarked, these can be compared against the estimated volume of sediment in identified borrow areas to evaluate when those resources will be exhausted. In addition, the Louisiana Coastal Master Plan Barrier Island model (ICM-BI) includes a rough estimate of sediment volume needs based on preserving the integrity of the barrier island system. Available resources include:

- Louisiana Sediment Management Plan (LASMP; Khalil et al., 2010; Underwood, 2012) and its associated resources:
  - Louisiana Sand Resources Database (LASARD; Khalil et al., 2016): https://www.arcgis.com/apps/MapSeries/index.html?appid=65cca038794d4ded8daaec8e6fb1a3ae
  - Surficial Sediment Distribution (SSD) Map (APTIM, 2020; Khalil et al., 2018)
  - Louisiana Sediment Availability and Allocation Program (LASAAP; Aptim Environmental & Infrastructure, Inc. (APTIM, 2020)
- Northern Gulf Sand Availability and Allocation Program (NGSAAP; currently under development)
- Louisiana Coastal Master Plan, 2023 Barrier Island Model (ICM-BI)

The BISM prioritization workflow described in this section provides an objective process for prioritizing barrier island and headland restoration projects based on their local and regional benefits, financial cost, and sediment needs as part of an adaptive management approach to regional sediment management. In addition, implementation of the workflow results in estimates of upcoming needs for sediment resources and funds for restoration projects. Each stage of the workflow is based on expert elicitation in which members of a BISM planning team give specific, structured input on the current state and trajectory of the barrier island system, as well as predictions of the costs and benefits of potential restoration alternatives, using available information, data, and model output to inform that input. The workflow can be used immediately in BISM program implementation and serve as an objective mechanism for prioritizing restoration projects.

4.0 Barrier Island Restoration Tradeoff Analysis (BIRTA) Toolkit: Conceptual Framework

The workflow described in *Section 3.0* can be augmented with a cost/benefit toolkit that will allow for quantitative analysis of costs and benefits of potential restoration project portfolios through more direct leveraging of existing data, models, and other resources. In addition, the toolkit allows for faster assessment of a wider suite of alternatives, including evaluation of how portfolios of projects may be constructed to provide the greatest overall benefit to the coastal system. The conceptual design of this toolkit, referred to as the Barrier Island Restoration Tradeoff Analysis (BIRTA), has been developed as part of this project to augment the BISM workflow through development of tools that leverage existing data and models wherever possible. Components of BIRTA support:

1) Prioritization of barrier island and headland restoration projects based on quantitative assessment of regional and long-term benefit;
2) Quantification of future sediment and funding needs to maintain the Louisiana coastal system; and
3) Identification of the most pressing data or information gaps that limit effective barrier island management decisions.

The toolkit design (Figure 4, Table 7) consists of (1) a Coastal State Database, composed of a set of quantitative metrics derived from existing data sources to allow objective and consistent characterization of the condition and potential restoration needs for each region of the coast; (2) Objective Utility Functions that link the metrics contained within the coastal condition database to the value descriptors characterizing the how well the coastal system is meeting BISM program objectives; (3) a Restoration Alternative Database, containing a portfolio of potential restoration projects, approximations of their sand/sediment and funding requirements, and preliminary identification of their sediment source; (4) a Sediment Resource Database, containing information about potential borrow areas for restoration projects and linked to the LASARD database; (5) a Probabilistic Coastal Forecast Tool (node/link model) for evaluating the likely trajectory of the coastal system; (6) a Tradeoff Analysis Tool for evaluating the costs and benefits of different restoration alternatives (projects or portfolios of projects); and (7) analysis scripts that automate the creation, updating, and cross-linkage of the BIRTA databases and model with each other and external CPRA data. These components are described and linked to the workflow below.

Table 7. Databases, scripts, and models that comprise the conceptual design of the BIRTA toolkit. The enhancement that BIRTA provides to the BISM workflow is summarized along with the connection to other CPRA data, tools, and programs.

Workflow Step	BIRTA Tools (DB = Database)	Enhancement of Workflow	Connection to Other CPRA Data, Tools, and Programs
1. Articulate Objectives	n/a	• Fundamental objectives weighted in priority based on relative importance for use in quantitative cost/benefit analysis	n/a
2. Assess the Coastal System	• Coastal State DB • Objective Utility Functions	• Database automatically updated to provide real-time snapshot of state of the system • Objective assignment of value descriptors based on uniform set of metrics calculated from data	• Metrics calculated from BICM data and can be updated automatically as new data are collected • Database of databases enhanced to directly link new data to BIRTA
3. Articulate Alternatives	• Restoration Alternative DB • Sediment Source DB[1]	• Allows consideration of a wider range of alternatives (e.g., project portfolios) that is possible with the workflow • Multiple potential options for sediment sources can be considered	• LASARD provides the input data on potential sediment sources • LASAAP enhanced and linked with BIRTA to inform sediment source selection for each project or portfolio
4. Identify Consequences	• Probabilistic Coastal Forecast Tool	• Future coastal state predicted based on data and numerical models and can incorporate uncertainty • Wider range of projects and portfolio combinations can be considered	• OSB informs sediment transport • Monitoring data, E&D models, etc. used as training data in predicting system response
5. Prioritize Projects and Identify Sediment Sources	• Tradeoff Analysis Tool	• Initial project prioritization list automatically created based on predicted with-alterative evolution of the coast and weighted objectives • Multiple variations of restoration projects can be tested (portfolios, sequencing of projects, timing, use of different sediment sources, etc.)	• Master plan tools form basis for cost/benefit analysis • Prioritized project list can inform modeling of the system within the master plan and be used to evaluate interaction of barrier island restoration projects with other types of projects (marsh restoration, etc.)
6. Estimate Future Resource Needs	n/a	• Scenarios evaluate sediment volume need and compare to known borrow areas • Future funding needs evaluated quantitatively • Value-of-information scenarios to identify uncertainties and critical data/modeling gaps	• Informs future funding need • Identifies need for sand/sediment exploration and/or in-depth evaluation of available sediment within borrow sites • Guides monitoring data collection under BISM as part of an adaptive management approach

[1]Sediment Source DB structured to provide linkage between BIRTA and LASARD

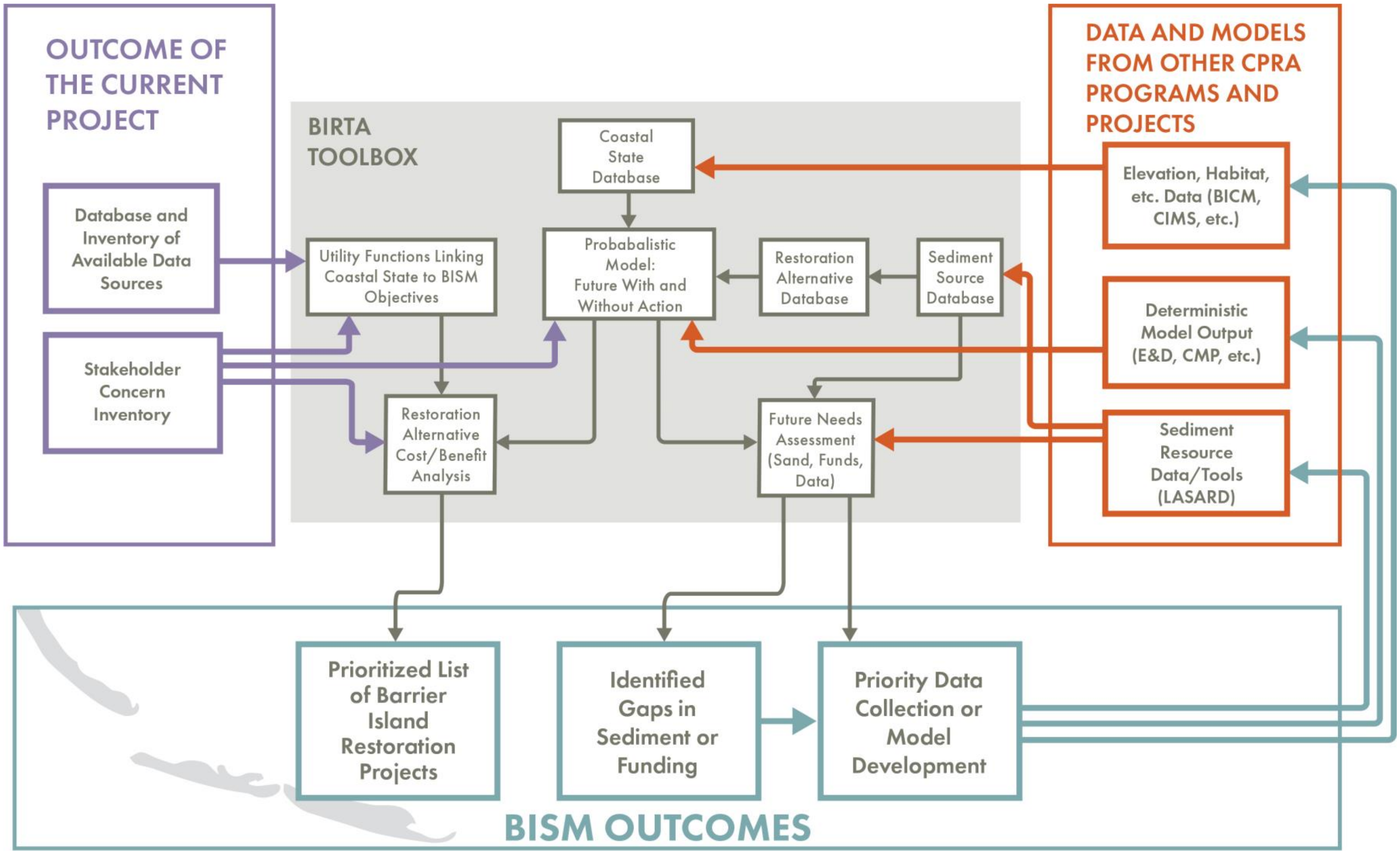

Figure 4. Interaction of the Barrier Island Restoration Alternative (BIRTA) Toolbox with the outputs of the current project and other projects and programs within CPRA. The Coastal State Database includes values for value descriptors and metrics characterizing the current condition (or state) of the coast.

4.1. ARTICULATE OBJECTIVES

A core benefit of the BIRTA quantitative cost/benefit analysis framework is that it allows for greater consideration of the relative importance of different objectives. Once a set of objectives is reviewed and finalized during workflow implementation, scores (weights) can be assigned to each objective that are later be used in quantitative cost/benefit analysis (Dalyander et al., 2016; Gregory et al., 2012; Gregory & Keeney, 2002). The importance of each of the objectives can be assessed on a score of 1-5 to capture their relative importance. This process facilitates inclusion of input from multiple stakeholders (such as coastal residents, industry, etc.), while allowing increased weighting to be placed on CPRA objectives as the decision-maker. When priority projects are being aligned to potential external funding sources, the relative influence of objective scores that align to funding source priorities can be increased so that projects likely to be selected for that funding are ranked highest. For example, the sub-objective of "restore habitat types that are absent or degraded" might be ranked a 5 while "protect local and regional infrastructure" subobjective is ranked a 2 when considering funding sources such as NRDA. This would reflect that—for this specific funding source—benefits to damaged resources are of particularly high significance, while also allowing important CPRA objectives to be included in considering projects to put forward in leveraging those resources. Conversely, the objective scores provided by CPRA can have increased influence during the annual funding cycle to reflect the agency's role in, and need for, holistic coastal management across BISM and other programs.

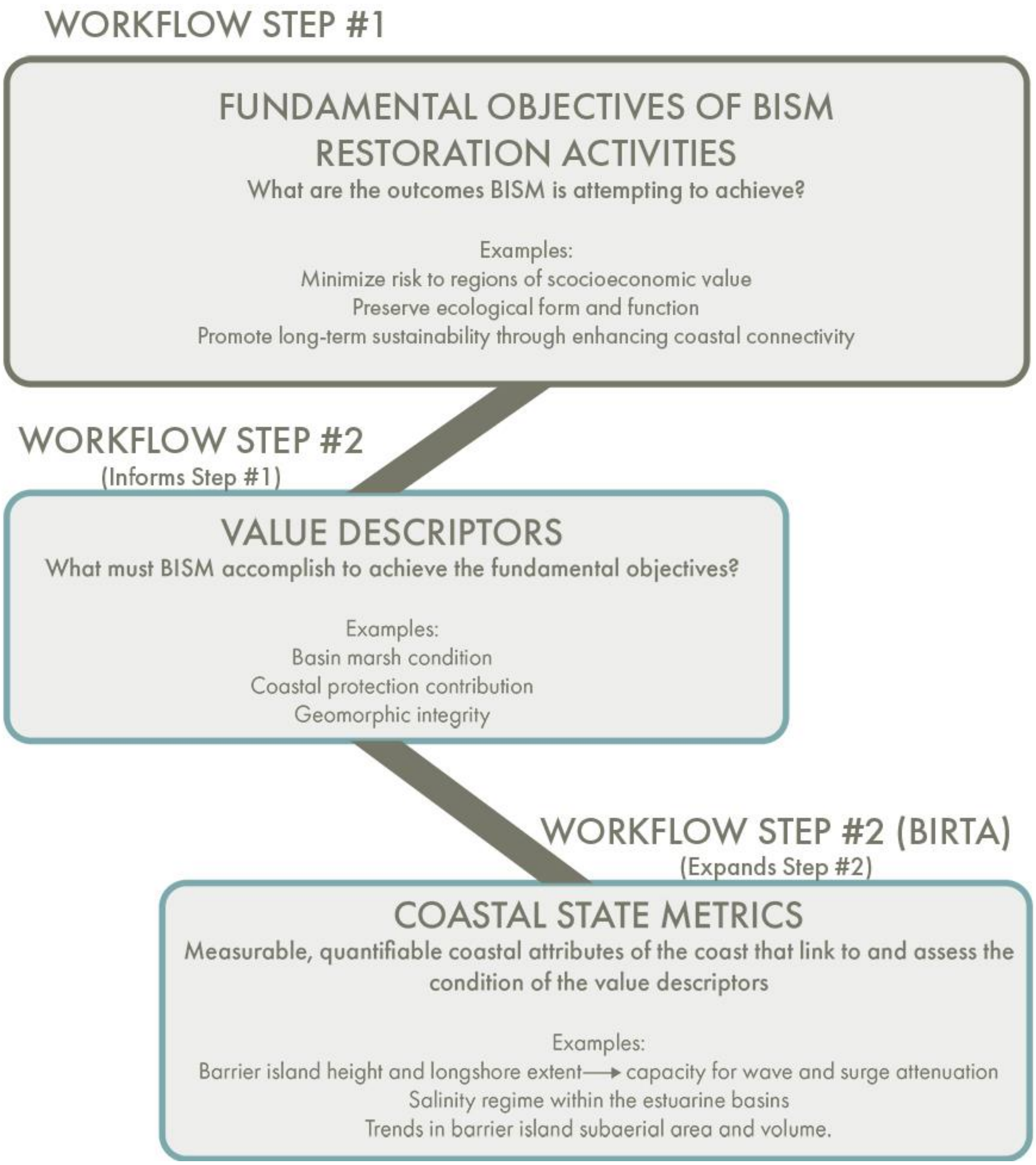

Figure 5. Linkage of BIRTA metrics to coastal cell and barrier island/headland value descriptors. The fundamental objectives capture the desired outcomes of restoration, with the value descriptors providing a quantitative framework for describing how well the coast is meeting those objectives. During initial BISM implementation, value descriptors can be provided by best professional judgement. With the BIRTA toolkit, coastal state metrics are calculated via scripting algorithms from observational data and then used to objectively calculate the value descriptors.

4.2. ASSESS THE COASTAL SYSTEM

Under the BIRTA framework, value descriptors for assessing the state of the coastal system relevant to restoration objectives (Table 2; Table 3) can be calculated objectively through quantitative analysis of a set of uniform metrics (Table 8) derived from available data (Figure 5). Metrics are well-established as providing high value in coastal state characterization for management application (Carapuço et al., 2016) and extensive data are available to support calculation, including *in situ* data (Byrnes et al., 2018;

Kindinger et al., 2013) as well as increasingly automated techniques for deriving data such as shoreline location from satellite data (Vos et al., 2019). Because the calculations of value descriptors are based on data rather than being manually prescribed with best professional judgement, the list of descriptors can be refined and expanded to provide more specificity and direct linkage to restoration objectives. For example, value descriptors characterizing different types of priority habitats may be identified, or coastal protection metrics to be refined to characterize risk of storm-driven flooding or near-term threat of coastal erosion to infrastructure. These metrics also serve as outcome success criteria that can be linked to restoration project objectives and ultimately used as part of an adaptive management framework. Extensive existing data are available to populate this database and are included in *Appendix D: Database of Databases and Inventory of other Available Information Sources*, which was developed under this project. Automated analysis tools (i.e., Python scripts) can be used for extracting these metrics, allowing for rapid updating as new data become available.

Table 8. Metrics used to assess the coastal system using the BIRTA framework. Metric calculation from available data can be automated using computer scripts, allowing objective evaluation of the coastal system. Metrics include both basin-wide and regional metrics, characterizing coastal cells (Early Lafourche, Late Lafourche, Modern Delta, St. Bernard; Figure 3), and barrier island and headland metrics to characterize the condition of those landforms.

Basin-wide and Regional Metrics	Barrier Island and Headland Metrics

• Socioeconomic metrics of local or regional value, including infrastructure associated with the barrier island and along the basin in the lee of the island
• Wetland vs open water area in the estuary (and change trajectory)
• Salinity and water quality indicators
	• Island dimensions/characteristics (width, height, subaerial and littoral system sediment volume, subaerial land area)
	• Shoreline length and long-term retreat rate
	• Beach dimensions (width, slope, sand volume)
	• Dune dimensions (height, width, sand volume)
	• Breaching and breaching potential
	• Inlet size
	• Backbarrier marsh width, acreage, and width relative to overall island width
	• Habitat metrics
	  ○ Overall acreage
	  ○ Utilization
	  ○ Distribution of habitat, e.g., backbarrier marsh, dune, seagrass meadows, etc.

The regional cell and barrier island/headland unit metrics, which characterize the **state of the system**, and the value descriptors, which characterize **how well the system is performing relative to the fundamental objectives**, are connected through objective utility functions that provide a relative (normalized) scale through which to gauge the value each metric is providing relative to its "optimal" value. For example, the value a barrier island provides in wave attenuation and surge mitigation is related, in part, to its subaerial height. The protection provided increases with increasing subaerial height (relative to recurrence interval of storm surge) until reaching a point of diminishing return, beyond which limited additional value is provided (Figure 6; Table 9). These curves can be parameterized with the use of historical data and deterministic model output; by comparing metrics to critical values established for barrier islands in the literature (Coastal Engineering Consultants, Inc., 2012, 2015; Rosati, 2009); or by benchmarking against process-based threshold points, such as the likelihood of dune overwash and inundation as a function of storm recurrence interval (Dalyander et al., 2016; Sallenger Jr., 2000). Each value descriptor can be a function of multiple metrics if appropriate. For example, a value descriptor of coastal infrastructure protection may be calculated as a function of normalized curves for island width, height, and longshore extent. These utility functions can be based on deterministic or probabilistic relationships that leverage existing model output and data, or through best professional judgement if insufficient data are available. Similarly, existing data and model tools can be used to refine the choice of metrics and their mechanism of calculation for each value descriptor, such as the specific statistic (e.g., mean, median, minimum) to use for an island or headland in the case of metrics (such as island height) that have spatial variability.

Table 9. Example coastal protection utilities as a function of height for three idealized barrier islands. Each island is assigned a normalized utility value based on height relative to its own "ideal" value for coastal protection. This "ideal" can be selected based on the recurrence interval of storm surge (or total water level) for that island.

Island Height (m)	Coastal Protection Utility - Island 1	Coastal Protection Utility - Island 2	Coastal Protection Utility - Island 3
0	0.00	0.00	0.00
0.1	0.10	0.18	0.05
0.2	0.18	0.33	0.10
0.3	0.26	0.45	0.14
0.4	0.33	0.55	0.18
0.5	0.39	0.63	0.22
0.6	0.45	0.70	0.26
0.7	0.50	0.75	0.30
0.8	0.55	0.80	0.33
0.9	0.59	0.83	0.36
1	0.63	0.86	0.39
1.1	0.67	0.89	0.42
1.2	0.70	0.91	0.45
1.3	0.73	0.93	0.48
1.4	0.75	0.94	0.50
1.5	0.78	0.95	0.53
1.6	0.80	0.96	0.55
1.7	0.82	0.97	0.57
1.8	0.83	0.97	0.59
1.9	0.85	0.98	0.61
2	0.86	0.98	0.63

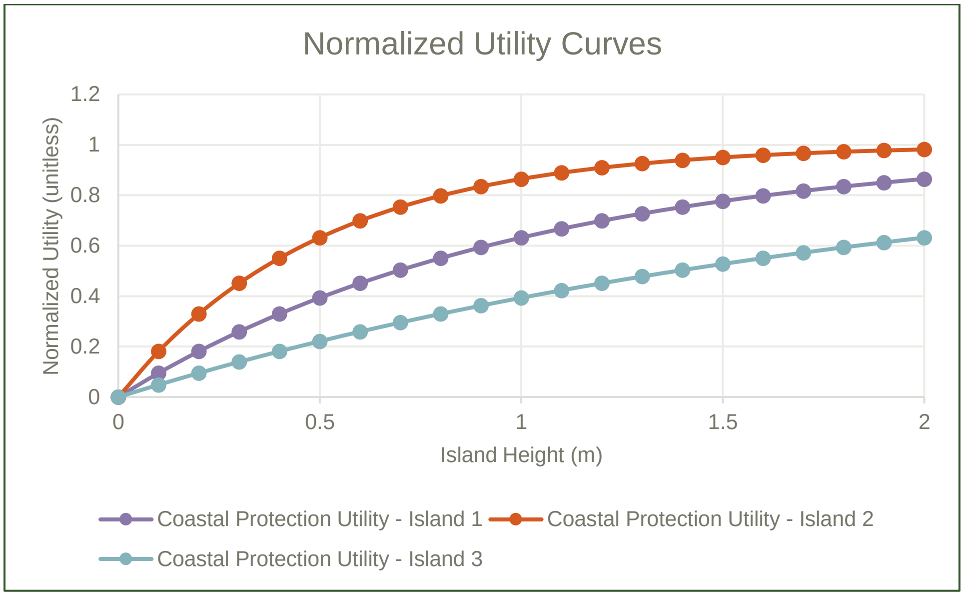

Figure 6. Normalized coastal protection utility curves. The normalized utility value for each island based on benchmarking its actual height to its own "ideal" value for coastal protection. This metric ideal can be selected based on, for example, the recurrence interval of storm surge (or total water level) for each island (Dalyander et al., 2016).

4.3. ARTICULATE ALTERNATIVES: RESTORATION PROJECTS AND SEDIMENT SOURCES

The BIRTA toolkit would provide the capacity to simultaneously consider restoration project and sediment source alternatives together as part of a quantitative, analysis-driven approach to RSM. Although restoration must occur through implementation of individual projects, taken together these projects comprise the RSM portfolio that enables BISM to manage the barrier island system at the system scale. The BIRTA framework enables this approach by allowing multiple projects and their combined impact to be evaluated simultaneously and in terms of short- and long-term effects. Two databases are required to support this approach.

The first database contains an inventory of potential restoration alternatives and includes:

- Identifier for each potential restoration project
- Location of restoration project
- Cross-referencing of project with other potential restoration projects that may be conducted concurrently
- Estimate of cost
- Estimate of sediment volume need
- Potential source of sediment for use in the project

The second database is a sediment resource database that includes:

- Identifier for each borrow area
- Location of borrow area
- Estimate of usable sediment volume within the borrow area considering potential conflicts, such as pipelines
- Additional information on sediment characteristics, if known

Existing lists of potential restoration project alternatives and available sand inventories can be heavily leveraged in the creation of these databases. For example, extensive work has been conducted to identify existing sediment resources as part of LASMP (Khalil et al., 2010). Databases including LASARD[14] (Khalil et al., 2016) and the Surficial Sediment Distribution Map (Khalil et al., 2018) can be linked to and directly utilized by BIRTA. After the initial creation and population of the databases, they can be updated during implementation of the workflow and/or as new data become available, such as with updated information on the estimated volume of usable sediment within a known borrow area.

4.4. IDENTIFY CONSEQUENCES: REGIONAL OUTCOMES WITH AND WITHOUT PROJECT PORTFOLIO ALTERNATIVES

In the BIRTA framework, sediment within the system is explicitly tracked by moving it through the previously defined coastal cells and units (Figure 7). This approach allows the framework to simultaneously evaluate the trajectory of the coast with and without restoration, as well as evaluate the optimal use of sediment resources to execute potential projects as part of an integrated approach to RSM. The methodology uses a node/link approach, which has been shown to provide a mechanism for analyzing sediment connectivity and characterizing (simplifying) complex coastal morphodynamics (Pearson et al., 2020).

In order to account for stochastic uncertainty in the coastal system, particularly the potential influence of storm events, the BIRTA toolkit would extend the node/link approach to include a Bayesian probabilistic model (Dalyander et al., 2016; Goldstein et al., 2018; Gutierrez et al., 2011; Plant et al., 2016), which can be incorporated within a GIS framework to provide spatially and temporally resolved predictions of coastal evolution (Carver, 1991; Jankowski, 1995; Malczewski, 2006; Stelzenmüller et al., 2010). Instead of predicting a specific outcome for a given combination of future drivers (storms, relative sea level rise, etc.), a probabilistic approach directly incorporates and propagates the stochastic uncertainty associated with those drivers into the model to characterize the likely condition of the coast in the future. In addition to tracking sediment volume, each barrier island or headland would also be characterized based on the discrete set of metrics contained within the Coastal State Database. The evolution of these characteristics over time can be predicted as a function of drivers (storms, relative sea level rise, wave climate, differences in input and output sand flux) by training the model with existing historical data and deterministic model output (Figure 2, Figure 7) and/or through the use of reduced complexity models (Robinet et al., 2018). Sediment transport between barrier islands can be accounted for by prescribing a fraction of the sediment lost from a given barrier island as an influx to the downdrift barrier island. These processes can be informed with existing data within the Operational Sediment Budget (Applied Coastal Research & Engineering, Inc., 2020). The model framework could be expanded to predict habitat based on available data and models (Enwright et al., 2018; Fearnley et al., 2009) and output linked to the value descriptors of ecological function.

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[14] https://www.arcgis.com/apps/MapSeries/index.html?appid=65cca038794d4ded8daaec8e6fb1a3ae

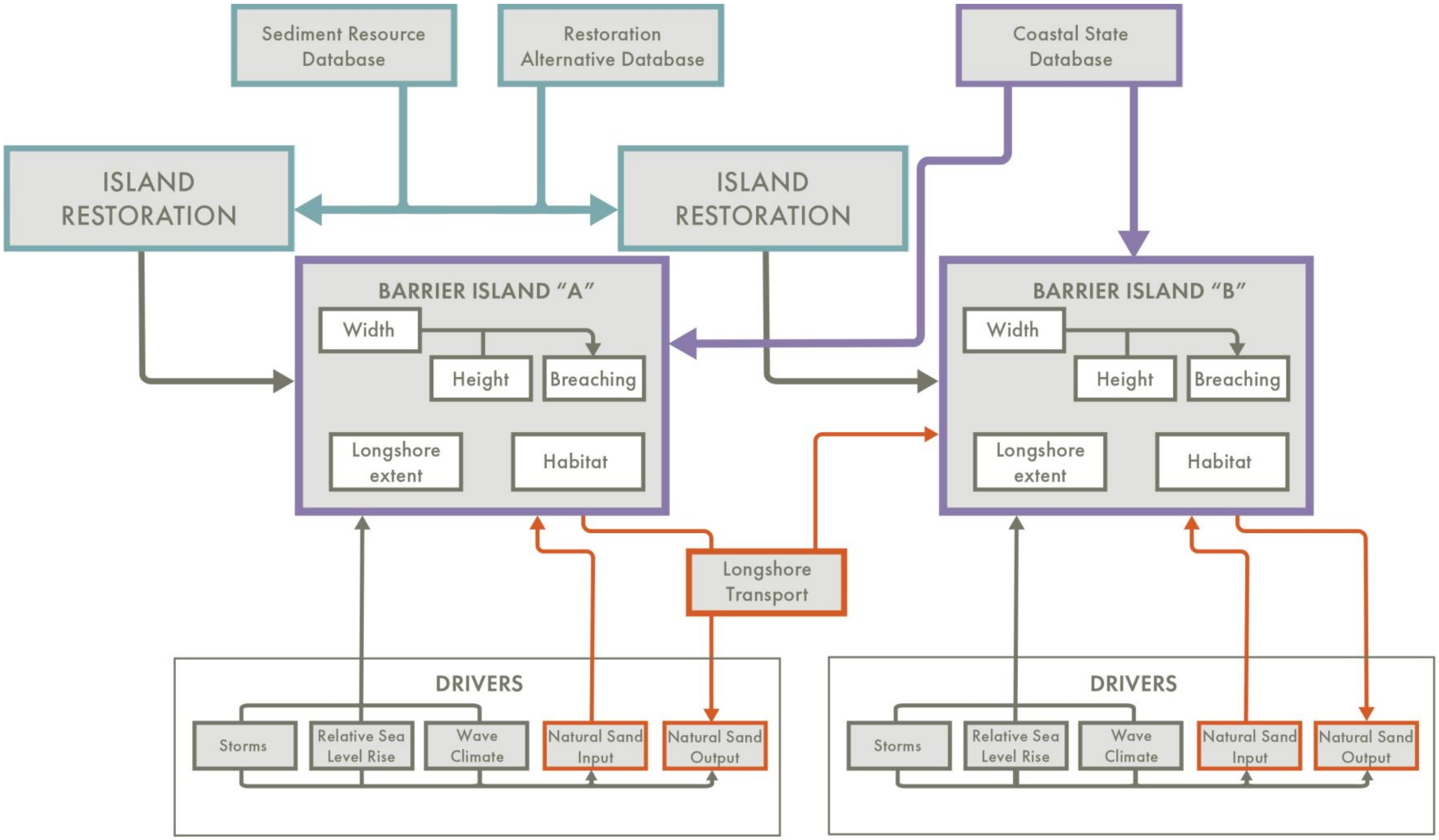

Figure 7. Conceptual diagram of a portion of the probabilistic coastal forecast model in BIRTA. Each barrier island or headland is characterized by metrics contained within the Coastal State Database. The evolution of those characteristics with and without restoration as a function of drivers such as storms and relative sea level rise is predicted probabilistically, informed by existing data and deterministic models. Figure does not include all metrics for characterizing a barrier island and only two barrier islands are shown; model would include the full suite of metrics from the Coastal State Database and all barrier islands and headlands in the system.

A set of deterministic models were developed in Excel to test the potential for BIRTA toolkit concept to be used in forecasting coastal system evolution and prioritizing restoration projects. The first model (referred to as the “No Action Test Model”) illustrates the use of a node/link model to predict the evaluation of the coastal system based on parameterizations of coastal response. Three idealized barrier islands are included in this model, each characterized by their subaerial sand volume, average height, average width, and longshore extent. For testing purposes, each idealized island is approximated as a rectangular prism, with subaerial sand volume calculated as a simple function of island length, width, and height. (Note, a realistic model would also consider estimates of subaqueous sediment volume within the littoral cell). The model is prescribed sediment influx/outflux rates and the fraction of sediment that a downdrift island recaptures out of the sediment volume lost from an updrift source (Table 10). The model was run over a period of 20 years to characterize the change in subaerial sand volume and island characteristics over time (
Table 11, Table 12, Figure 8).

Table 10. Inputs and outputs for a No Action Test Model illustrating a link-node approach to regional sediment transport modeling. Based on the initial condition of a set of barrier islands and parameterizations for island behavior, the model predicts change in subaerial sand volume, height, width, and longshore extent for each barrier island over time.

No Action Test Model Inputs	No Action Test Model Outputs
• Initial subaerial sand volume for each island • Initial island characteristics (average height and width, longshore extent) • Percentage of sand volume lost from each island each year, including longshore and cross-shore sediment transport; can alternately be prescribed as an annual loss in height, width, and longshore extent • Fraction of sediment volume lost from an island that is captured by the downdrift island (i.e., longshore transport input) • Functional relationships distributing sediment volume gained or lost into corresponding changes in island width, height, and longshore extent	• Subaerial sand volume over time for each island • Island characteristics (average height and width, longshore extent) over time for each island

In the test case, the model is operating deterministically with a simplified set of parameters and prescribed formulations (e.g., sediment volume lost and sediment connectivity between the islands). In the BIRTA framework, a probabilistic Bayesian approach enables training the model with existing deterministic model output and data analysis such as the Operational Sediment Budget (Applied Coastal Research & Engineering, Inc., 2019).

Table 11. Change in predicted littoral sand volume over time for three barrier islands in the No Action Test Model illustrating a link-node approach to regional sediment transport modeling. Each island has a prescribed sediment volume loss rate, and downdrift islands (2 and 3) recapture a fraction of the sediment lost from the updrift island.

Island Subaerial Sand Volume (m^3)			
Year	Island 1	Island 2	Island 3
1	800000.00	2200000.00	4000000.00
2	648000.00	1782000.00	3240000.00
3	525480.00	1512540.29	2815495.95
4	425939.03	1281121.25	2435191.92
5	345010.61	1083073.26	2103738.79
6	279458.60	914047.83	1815161.16
7	226361.46	770143.08	1564213.63
8	183352.79	647917.44	1346269.46
9	148515.76	544329.67	1157241.68
10	120297.76	456711.12	993520.50
11	97441.19	382734.03	851917.41
12	78927.36	320378.48	729617.53
13	63931.16	267899.45	624138.31
14	51784.24	223795.34	533293.16
15	41945.24	186778.51	455159.16
16	33975.64	155748.22	388048.20
17	27520.27	129766.09	330480.94
18	22291.42	108034.16	281163.46
19	18056.05	89875.42	238966.17
20	14625.40	74716.68	202904.75

Table 12. Change in predicted island height for three barrier islands in a No Action Test Model illustrating a link-node approach to regional sediment transport modeling. Island characteristics are linked to the sand volume associated with each cell so that the model is mass conserving.

Island Average Height (m)			
Year	Island 1	Island 2	Island 3
1	2.00	2.00	2.00
2	1.80	1.80	1.80
3	1.62	1.65	1.66
4	1.46	1.50	1.53
5	1.31	1.37	1.40
6	1.18	1.25	1.29

Island Average Height (m)			
Year	**Island 1**	**Island 2**	**Island 3**
7	1.06	1.14	1.19
8	0.96	1.04	1.09
9	0.86	0.95	1.01
10	0.78	0.87	0.92
11	0.70	0.79	0.85
12	0.63	0.72	0.78
13	0.57	0.65	0.72
14	0.51	0.60	0.66
15	0.46	0.54	0.60
16	0.41	0.49	0.56
17	0.37	0.45	0.51
18	0.33	0.41	0.47
19	0.30	0.37	0.43
20	0.27	0.34	0.39

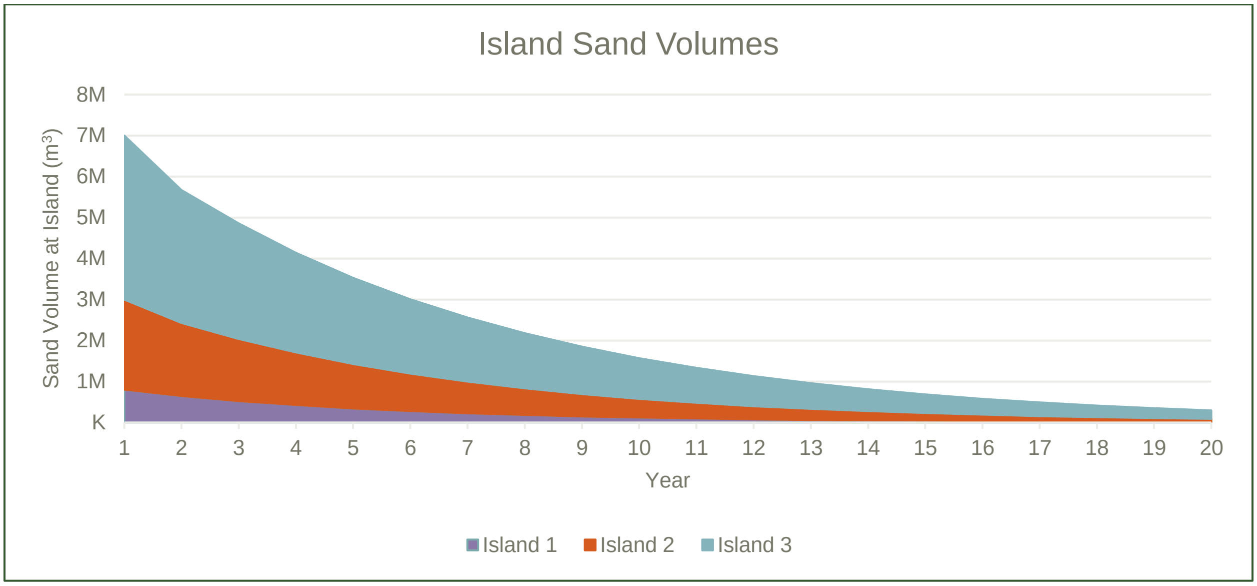

Figure 8. Change in predicted littoral sand volume over time for three barrier islands in the No Action Test Model illustrating a link-node approach to regional sediment transport modeling. Each island has a prescribed sediment volume loss rate, and downdrift islands (2 and 3) recapture a fraction of the sediment lost from the updrift island.

4.5. PRIORITIZE PROJECTS AND IDENTIFY SEDIMENT SOURCES

Within the BIRTA toolkit, alternatives for restoration project portfolios and use of available sand sources can be considered through a cost/benefit analysis that links the predicted future with action under various alternatives to their benefit in achieving BISM objectives for barrier island and headland restoration. The conceptual framework of the model has been designed to allow different types of analyses depending on program needs, which are described in more detail in the following sections:

1. **Project Prioritization with No Sediment Source Constraint.** When operating in this mode, the portfolio of projects can be prioritized without explicit consideration of the volume of sand/sediment available in known borrow areas. This mode allows "what-if" scenarios to be run regarding the benefit that could be gained from identification of additional sediment sources, thus informing if the cost of sand exploration to identify new sediment resources is merited.
2. **Best Use of Available Sediment across Identified Restoration Alternatives.** In this mode, both the sediment volume available within borrow areas and the sediment required for restoration alternatives are provided as constraints; the overall sediment need for projects must be less than the available sediment. This mode allows the use of known sediment sources across multiple projects to be optimized across a preferred set of restoration alternatives.
3. **Combined Analysis for Regional Sediment Management: Project Prioritization and Best Use of Available Sediment Sources.** In this mode, the available sediment volume is provided as a constraint, but the restoration projects using that sediment are not provided as an input. The model optimizes the placement and use of those available resources across the barrier islands and headlands to maximize the longevity and benefits of the system.

4.5.1. Project Prioritization with No Sediment Source Constraint

In this mode of operation, a list of restoration alternatives is provided as an input to the model without constraining the volume of available sediment. The benefit each restoration alterative will provide is evaluated through the value descriptors previously used to assess the current condition of the coastal system (*Section 4.2*; Figure 5). These value descriptors are now calculated from the predicted future condition of the system under each potential restoration alternative, allowing the value provided by that alternative to be objectively evaluated. The overall benefit of each project (the "total utility") can be calculated by summing across all value descriptors, each of which is given a weight based on the relative priority of restoration objectives identified in the first step of the workflow (*Section 4.1;* Figure 9). Scores can be calculated based on their benefit to specific coastal cells to allow, for example, comprehensive regional planning in conjunction with the master plan. Benefits can also be calculated on a system-wide basis. After the projected benefits of individual projects or project portfolios have been calculated, they can be compared to the costs of projects and used to develop a final list of prioritized projects based on cost/benefit analysis.

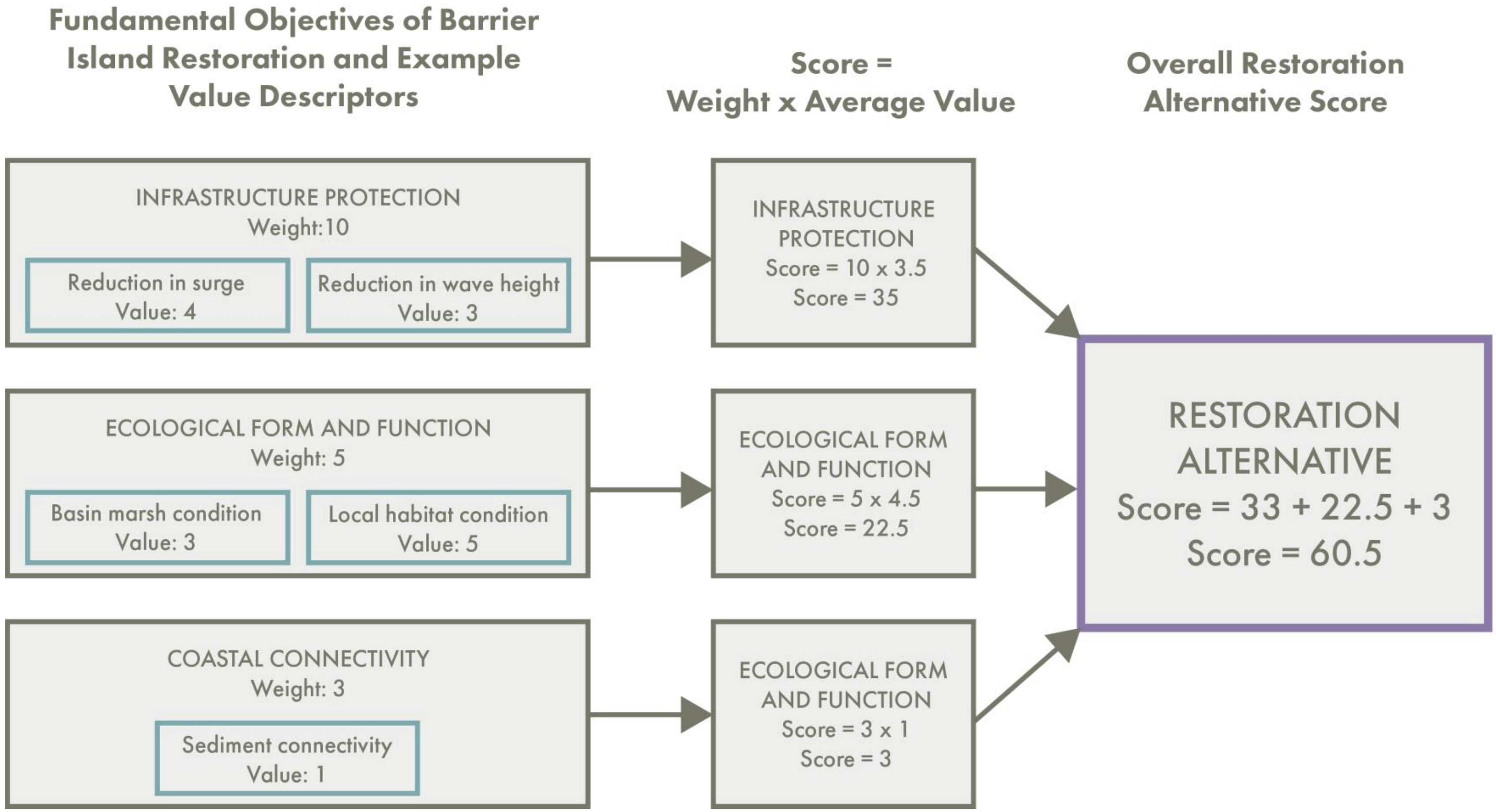

Figure 9. Example of calculating a score (overall value) for a potential restoration project. Each fundamental objective is characterized by a set of value descriptors, and a weighting based on the relative importance of each objective is used to sum those values and calculate an overall utility for each restoration alternative. The values given are for illustrative purposes only and do not include a comprehensive set of value descriptors or finalized set of algorithms for score calculations.

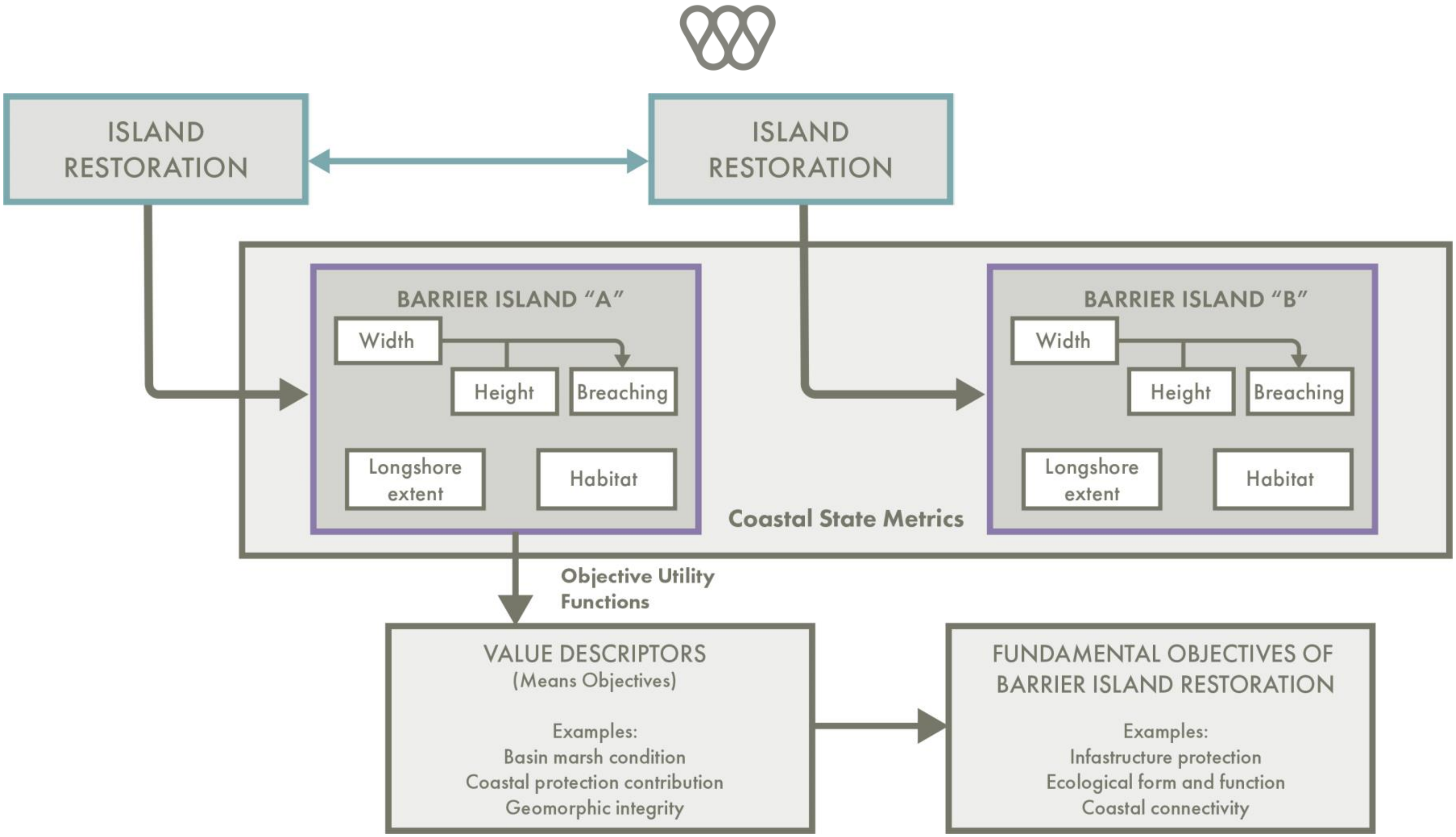

Figure 10. Conceptual diagram of cost/benefit analysis of restoration project portfolios for an example set of metrics and value descriptors. Coastal state metrics are used to calculate value descriptors with utility functions.

The algorithms used to calculate the objective and overall score for restoration alternatives can be modified and refined based on best professional judgement. Weights on value descriptors and the calculation of their overall score can also be spatially dependent, allowing for aspects of barrier islands or headlands that may not be reflected in their geological state to be considered. For example, a multiplier might be added to ecological form and function value descriptors for a barrier island that is part of a refuge, given the protection that designation might provide to species utilizing the habitat. The database of stakeholder concerns described with *Appendix C: Inventory of Stakeholder Concerns* identifies these areas for future linkage to BIRTA.

When operating in this mode, the BIRTA toolkit allows for the benefits of restoration alternative portfolios to be quantified and evaluated to prioritize multiple projects based on their cumulative and synergistic long-term benefit (
Figure 10). For example, the model can evaluate the benefits of focused efforts to restore multiple barrier islands within one coastal cell, including if adding sediment across multiple islands enhances sediment connectivity and increases the longevity and resiliency of each restoration project within the portfolio. Because the model framework predicts the future condition across the entire coast, however, it can evaluate what the tradeoffs are of that approach. For example, islands across multiple cells may be approaching "tipping points" of collapse, therefore finite available funding and sand may be needed to be focused toward immediate action at high-risk, high-value barrier islands across the system rather than targeted regional action within one coastal cell.

A deterministic Prescribed Alternatives Test Model was built in Excel to illustrate this mode of operation (Table 13). The No Action Test Model (Table 10, Figure 8) was modified so that sediment volume can be added to the barrier islands at various times, simulating sediment placed via restoration (Figure 11). In the test case 1,000,000 m^3 of sediment was placed in year 3 at barrier island 1, the most updrift island in the model chain. Because the model includes parameterizations that allow downdrift islands to recapture sediment lost from updrift sources, the propagation of the placed sediment through the system and the benefits to islands 2 and 3 are predicted.

Table 13. Inputs and outputs for a Prescribed Alternatives Test Model. In addition to the inputs and outputs of the No Action Test Model (Table 10), this configuration includes an input of the sediment volume placed via restoration during each year at each barrier island.

Prescribed Alternatives Test Model Inputs	Prescribed Alternatives Test Model Outputs
• Initial subaerial sand volume for each island • Initial island characteristics (average height and width, longshore extent) • Percentage of sand volume lost from each island each year, including longshore and cross-shore sediment transport; can alternately be prescribed as an annual loss in height, width, and longshore extent	• Subaerial sand volume over time for each island • Island characteristics (average height and width, longshore extent) over time for each island

Prescribed Alternatives Test Model Inputs	Prescribed Alternatives Test Model Outputs
• Fraction of sediment volume lost from an island that is captured by the downdrift island (i.e., longshore transport input) • Functional relationships distributing sediment volume gained or lost into corresponding changes in island width, height, and longshore extent • Sediment volume placed each year at each barrier island	

Table 14. Sediment volume placed at each island over time for three barrier islands in a Prescribed Alternatives Test Model (Table 13). Sediment placement volumes are prescribed based on preferred restoration alternatives and the model propagates that sediment through the system (Figure 11).

Sediment Placed at Island (m^3)				
Year	**Island 1**	**Island 2**	**Island 3**	**Total**
2	0.00	0.00	0.00	0.00
3	1000000.00	0.00	0.00	1000000.00
4	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00
			All Years	1000000.00

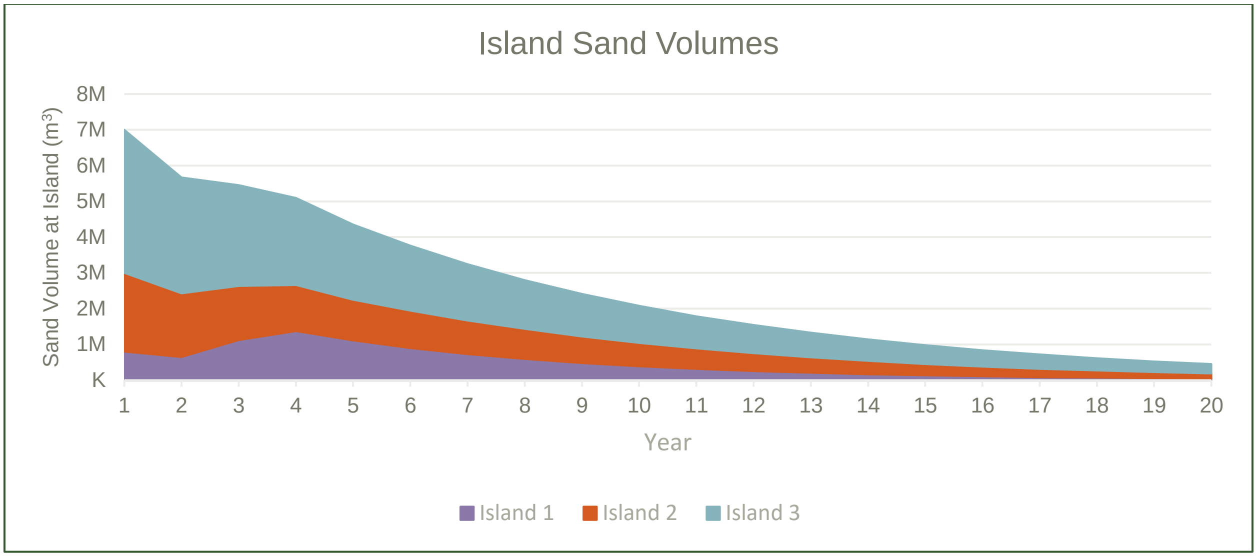

Figure 11. Sediment volume change over time for three barrier islands in a Prescribed Alternatives Test Model. In the alternative shown, 1000000 m^3 of sediment is placed at year 3 at island 1 (Table 13), the most updrift island in this idealized change. The model in the test case is parameterized to allow a fraction of sediment lost each year from island 1 to be recovered by island 2 and for a fraction of sediment lost from island 2 each year to be recovered by island 3. The local and downdrift benefits of the sediment placed at island 1 over years 3-8 can be seen by comparing this case to the No Action Test Model (Figure 8).

4.5.2. Best Use of Available Sediment Sources Across Identified Restoration Alternatives

The optimal use of finite sediment resources for project implementation across a set of preferred restoration projects can also be informed using the BIRTA framework. This analysis can be done in two different ways. In the first, different scenarios of restoration alternatives (sediment placement volumes) can be prescribed as inputs to the predictive coastal system model (for example, the Prescribed Alternatives Test Model, Figure 11, could be run multiple times for differing sediment volumes placed across the islands at different times). A comparison of the long-term regional benefits of those alternative scenarios can then be used to select an optimal portfolio of restoration projects.

Alternately, optimal use of available sediment across a set of identified restoration projects can be calculated by the model as an output. Under this scenario, optimization algorithms are used to distribute the sediment available within borrow sites. This approach has been tested with a simple model constructed in Excel that uses a Generalized Reduced Gradient (GRG) nonlinear optimizer (Lasdon et al., 1978) within the Microsoft Excel Solver (Fylstra et al., 1998). Inputs to the model include the sediment volume needs for restoration alternatives across a set of barrier islands (Table 16); the sediment volume available in a set of borrow areas (Table 17); and the distance between the islands and borrow areas (Table 18), which is used to calculate the cost of transporting material. The model distributes (optimizes use of) the available sediment from each borrow site to the barrier islands based on minimizing total restoration cost across all projects (Table 19).

Table 15. Inputs and outputs for a Source Optimization Test Model. The model is given the sediment volume need for a set of barrier islands, the available sediment volume within a set of borrow sites, the locations of the islands and borrow sites, and a cost to transport sediment per unit distance. The model then uses an optimization algorithm to distribute the sediment available at the borrow sites to the barrier islands based on minimizing the overall cost.

Source Optimization Test Model Inputs	Source Optimization Test Model Outputs
• Restoration sand volume needs for each island • Sediment volume available within a set of borrow sites • Locations of islands and borrow sites • Cost to transport sediment per unit distance	• Optimal distribution of available sediment sources across barrier island restoration sites

The mobilization cost of equipment is incorporated into the cost per unit distance used within the Source Optimization Test Model but could alternatively be prescribed as a fixed cost for each restoration action. In addition, there is considerably more complexity associated with selecting optimal sediment sources for a given restoration project than transport cost. The full range of factors influencing sediment source selection could be incorporated into the model and pilot tools that have been developed within CPRA and beyond (LASAAP, NGSAAP, etc.) can be leveraged or linked to the BISM framework (Aptim Environmental & Infrastructure, Inc. [APTIM], 2020).

Table 16. Sediment volume needs for restoration projects identified for a set of five barrier islands. These volumes are provided as inputs to the Source Optimization Test Model that optimizes the best use of all available sediment across multiple islands.

Barrier Islands	Latitude	Longitude	Volume Needed (m^3)
Island 1	29.068268	-90.492244	10000000
Island 2	29.185156	-90.06365	10000000
Island 3	29.23493	-89.99195	10000000
Island 4	29.283443	-89.928571	10000000
Island 5	29.046877	-90.826644	8000000

Table 17. Sediment volume available in a set of three borrow areas. These volumes are provided as inputs to the Source Optimization Test Model that optimizes the best use of all available sediment across multiple islands.

Borrow Areas	Latitude	Longitude	Volume Available (m^3)
Borrow Site 1	28.903796	-91.020636	400000000
Borrow Site 2	29.119898	-89.486079	40000000
Borrow Site 3	28.835247	-90.175792	8000000

Table 18. Transport distance between borrow sites and barrier island restoration sites. A multiplier is used to calculate per-volume cost of transporting sediment between a borrow site and an island based on the distance between them. These distances are provided as inputs to the Source Optimization Test Model.

Transport Distance	Borrow Site 1	Borrow Site 2	Borrow Site 3
Island 1	54.55166833	97.93175907	40.24188686
Island 2	98.14933385	56.5549728	40.40743949
Island 3	106.5401416	50.75119614	47.902014
Island 4	114.198871	46.64084678	55.32754198
Island 5	24.68264842	130.5211	67.56391692

Table 19. Optimized use of available sediment based on overall minimum cost. These volumes are outputs of the Source Optimization Test Model and are based on optimizing the best use of all available sediment across multiple islands.

	Borrow Site 1	Borrow Site 2	Borrow Site 3	Total Volume
Island 1	10000008	0	0	10000008
Island 2	0	2000000.362	7999999.881	10000000.24
Island 3	0	9999999.99	0	9999999.99
Island 4	0	10000000	0	10000000
Island 5	7999999.913	0	0	7999999.913
Total from Site	18000007.91	22000000.35	7999999.881	48000008.15

4.5.3. Combined Analysis for Regional Sediment Management: Project Prioritization and Best Use of Available Sediment Sources

Under this mode of operation, borrow areas and associated sediment volumes are given as inputs to the model framework but preferred restoration projects are not defined (Figure 12). Instead, the distribution of sediment from borrow areas to barrier islands and headlands is optimized within the model. Outputs are the restoration alternatives including when and where to place sediment, as well as which sediment resources to use for each project.

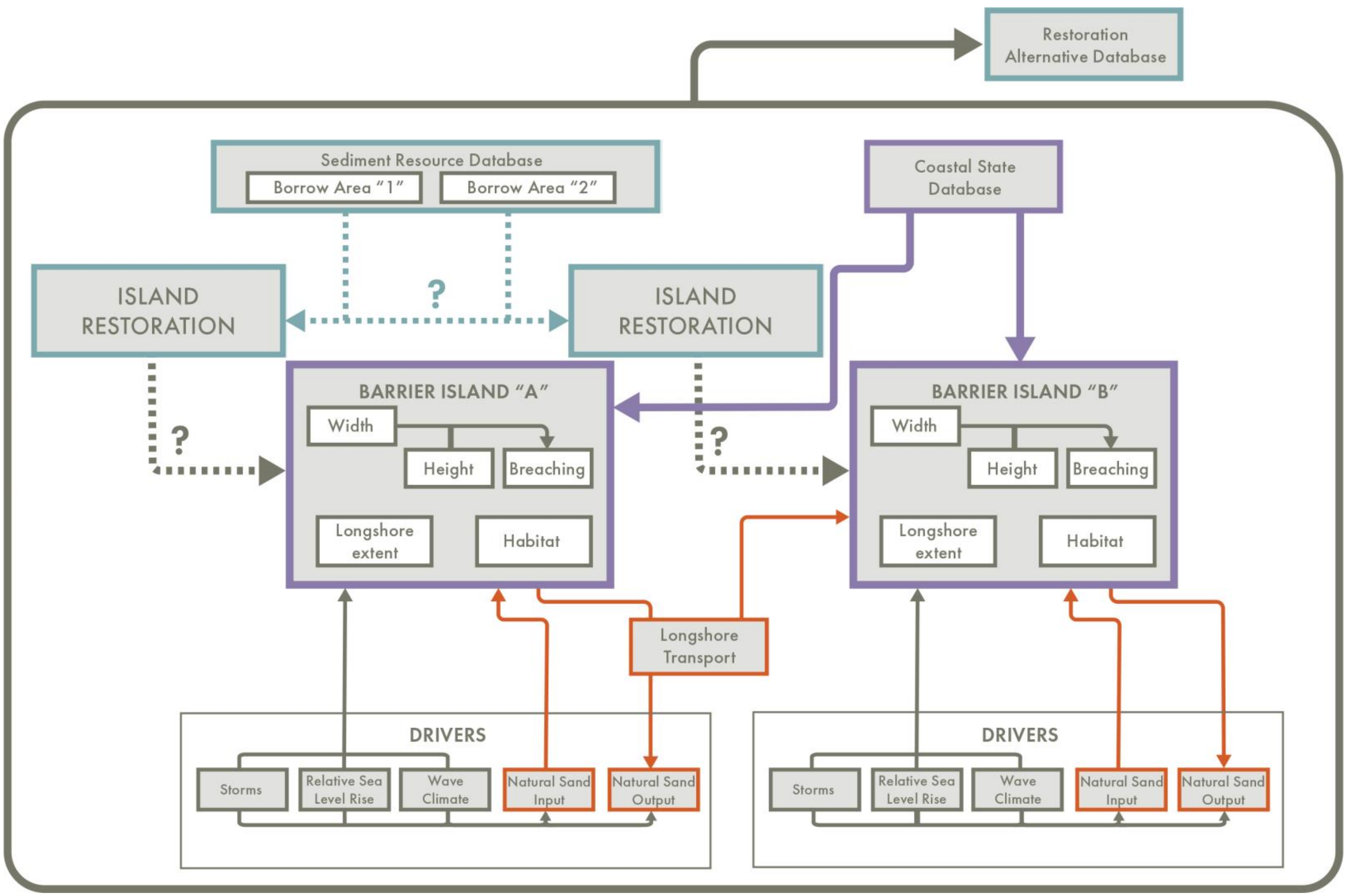

Figure 12. Use of the BIRTA toolkit to optimize use of available sand as part of a comprehensive regional sediment management (RSM) approach. In this approach, use of available sediment is optimized in terms of when and where placement should occur, as well as the sediment source. The set of preferred restoration alternatives based on their calculated long-term and regional benefit is an output of the model framework run in this mode.

A deterministic RSM Test Model was constructed in Excel to illustrate the BIRTA toolkit working in this mode. The model configuration is modified from the Prescribed Alternatives Test Model in several ways. Instead of specifying when and where sediment volume is placed as part of a predefined set of restoration projects, the model is given a time period over which to optimize the benefits of restoration projects and a method of benefit calculation. Alternatives (when and where to place sediment) are outputs of the model based on optimizing those benefits using the GRG nonlinear optimizer (Lasdon et al., 1978) within the Microsoft Excel Solver (Fylstra et al., 1998). For the test model, benefit is calculated as the total sediment volume added across all barrier islands. The use of utility functions to calculate habitat and coastal protection value descriptors was also tested and found to be a feasible approach (Figure 5, Figure 6). However, the simple algorithms that could be constructed in the Excel-based RSM Test Model (i.e., maximizing island height as a proxy for coastal protection benefits and/or island subaerial acreage as a proxy for habitat benefits) produced the same results as using island sediment volume as the value descriptor. A Bayesian model informed with data could be parameterized more accurately and results would be sensitive to the benefit that alternatives provide to different fundamental objectives. Similarly, combining the Source Optimization Test Model (Table 15) and the RSM Test Model into a single model framework that optimizes sediment placement across multiple sources and project locations was too complex for execution with algorithms available within Excel. However, the BIRTA framework could be used to optimize sediment placement and source selection simultaneously.

Table 20. Inputs and outputs of the RSM Test Model. This configuration is similar to the model configuration and parameterization used in the Prescribed Alternatives Test Model (Table 13). However, the sediment volume placed each year at each barrier island is a model output based on maximizing cumulative benefit (in this case, barrier island littoral sand volume over all islands) over a prescribed time period. Bolded inputs represent variables that were explored with sensitivity test cases (Table 21).

RSM Test Model Inputs	RSM Test Model Outputs
• Initial subaerial sand volume for each island • Initial island characteristics (average height and width, longshore extent) • Percentage of sand volume lost from each island each year, including longshore and cross-shore sediment transport; can alternately be prescribed as an annual loss in height, width, and longshore extent • **Fraction of sediment volume lost from an island that is captured by the downdrift island (i.e., longshore transport input)** • Functional relationships distributing sediment volume gained or lost into corresponding changes in island width, height, and longshore extent	• Subaerial sand volume over time for each island • Island characteristics (average height and width, longshore extent) over time for each island • Sediment volume placed each year at each barrier island

RSM Test Model Inputs	RSM Test Model Outputs
• **Time period of benefit optimization** • Value descriptor capturing island benefits; maximizing littoral sediment volume across all islands for the test case	

Four cases were run with the RSM Test Model (Table 21) to evaluate the sensitivity of model predictions to the timescale of benefit calculation and the degree of sediment connectivity in the system. Benefits were calculated to either **maximize the benefit after 20 years** (i.e., the best possible end state after 20 years) or the determine the **cumulative benefit over 20 years** (i.e., total benefit summed over all islands and integrated over time). Sediment connectivity was prescribed as either **high** (50 percent of the fraction of sediment volume lost from an island is recaptured by the downdrift island) or **low** (10 percent of the fraction of sediment volume lost from an island is recaptured by the downdrift island). These test cases produced results that are informative and provide confidence in the RSM Test Model approach. When the benefit is calculated based on maximizing the amount of sediment volume across all islands at the end of the model run, the optimization algorithm identifies a preferred solution of distributing the available sediment at year 20 regardless of sediment connectivity in the system. This solution reflects that any sediment volume placed through restoration action begins to be lost from the system immediately after it is placed, therefore the calculated benefit is maximized by preserving available sediment until the end of the run and placing it just before the snapshot in time when the benefits are calculated.

Because the goal of BISM is to maximize the long-term sustainability of the coastal system, this analysis suggests that alternatives should be evaluated based on the cumulative benefit they provide over time rather than from a single snapshot. The RSM Test Model becomes sensitive to the degree of sediment connectivity in the system when benefit is calculated cumulatively (Table 21). When the sediment connectivity in the system is high, the optimization algorithm places sediment early (years 1-3) at the most updrift island in the system. Doing so provides restoration benefit to the downdrift islands as well as to the barrier island where sediment is originally placed. When the sediment connectivity is low, the optimization algorithm places sediment across all three islands in the system during the first half of the model run (years 1-5). Placing sediment early in the 20-year model run allows the cumulative benefit of restoration over time to be realized for each island. Because there is limited connectivity between islands, however, there is greater benefit to placing sediment at degraded islands to increase their subaerial volume directly rather than placing sediment updrift and allowing it to propagate through the system.

Table 21. Summary of model output across four cases evaluated with the RSM Test Model (Table 20).

Model Test Case	Sediment Connectivity	Timescale of Desired Benefits	RSM Test Model Results
1	High	End State After 20 years	Available sediment is placed at year 20 across all three islands, maximizing the benefit at the end of the model run.
2	Low	End State After 20 years	Available sediment is placed at year 20 across all three islands, maximizing the benefit at the end of the model run.
3	High	Cumulative Benefit over 20 Years	Available sediment is placed early in the run (years 1-3) at the most updrift island, which maximizes the long-term benefit across multiple islands as sediment lost from one island is recaptured by downdrift islands.
4	Low	Cumulative Benefit over 20 Years	Available sediment is placed during the first half of the model run (years 1-5) at multiple islands to maximize the direct, local benefit provided to each island.

4.6. ESTIMATE FUTURE RESOURCE NEEDS

The conceptual design of the BIRTA toolkit, described in *Sections 4.1-4.5*, allows for more robust, quantitative analysis of sediment and funding needs over multiple scenarios of restoration alternatives. Because a Bayesian probabilistic model would be used, stochastic and environmental trends and uncertainty (relative sea level rise, storms, etc.) can be incorporated into those calculations. In addition, the framework provides a mechanism for evaluating critical data needs and research as part of a targeted adaptive management approach.

4.6.1. Sand and Funding

As described in *Section 4.5*, the BIRTA toolkit could be configured to run in several ways to inform future sediment and funding needs without functional changes to the model framework. First, the model can be run to evaluate the benefits of potential restoration alternatives without constraints placed on available funding or sediment resources for projects (Figure 7). This approach allows alternatives to be evaluated purely on their overall benefit to the coastal system and enables the sediment needs and funding costs of a preferred set of restoration alternatives to be calculated and compared to available funding and costs. Gaps in funding and available sediment resources can then be identified and pursued. Alternatively, the model can be run to optimize the use of available sediment resources across project alternatives (Figure 12). Both sediment and funding can be incorporated as constraints within this model configuration. Multiple scenarios of funding and sediment availability can then be run to evaluate the benefit of pursuing new funding streams and/or sand exploration based on the overall increase in benefit those resources provide.

4.6.2. Adaptive Management - Critical Uncertainty Reduction

The BIRTA model framework (Figure 7) is reliant on data and model output to parameterize the algorithms used in predicting the evolution of the coast. Because the model is probabilistic, it can incorporate input from a variety of sources. For example, deterministic model predictions and observational data analysis can be incorporated into an estimate of the likely volume of sediment lost from the littoral system of a barrier island over time. This approach enables identification of critical uncertainties. If the data and model output provided to the model are consistent—i.e., the same correlations between different variables are found across multiple input data sets—the predictive probabilistic model will produce a precise prediction reflecting high confidence in the predicted outcome. Conversely, the model will have a high degree of uncertainty associated with predicted outcomes for which there are inconsistent correlations between input data or there are data gaps. The uncertainty associated with model predictions can then be used to identify critical data gaps (e.g., to focus data collection under BICM), modeling needs, or areas of future research. For example, prior work using a probabilistic approach for evaluating tradeoffs in barrier island restoration alternatives identified a high degree of uncertainty associated with predicting the sediment volume lost during a storm event (Dalyander et al., 2016). If this were identified as a critical uncertainty limiting BISM decision-making confidence, it could be prioritized as an area of future research investment.

5.0 BISM: Additional Program Activities and Next Steps

One of the outcomes of the BISM development workshops was the identification of a programmatic goal and associated objectives. In addition to the workflow and BIRTA analysis toolkit described above, there are several additional next steps that can be taken to advance those programmatic objectives. The objectives of the BISM program are reiterated on page 51, along with a description of how the workflow advances these objectives and what additional gaps remain. Potential solutions and next steps to close these gaps are then described.

The two primary outputs of the BISM workflow are a prioritized project list and an estimate of future sand and funding needs, advancing objectives 1-3. The workflow similarly addresses aspects of objective 4 through identification of descriptors of the coastal system that can inform the focus of monitoring and enable objective assessment of system condition. During the initial implementation of the program, however, the workflow will need to be executed qualitatively through use of best professional judgement. Each of these objectives can be more robustly achieved through a quantitative approach that directly leverages coastal data collected by CPRA. In addition, subjective evaluation limits the capacity for BISM to directly connect to the Louisiana Coastal Master Plan, which includes substantial numerical modeling to understand the future state of the system as well as the costs and benefits of coastal projects. Lastly, use of a numerical modeling approach can identify key uncertainties inhibiting decision-making, allowing for implementation of an adaptive management approach (objective 4) to target new research and/or data collection. The conceptual framework of the BIRTA toolkit has been designed to address these gaps as BISM moves forward. Although the workflow and BIRTA toolkit may streamline the project prioritization process, additional approaches are needed to reduce implementation time (objective 5).

PROGRAMMATIC OBJECTIVES OF BISM

1) Mechanism to prioritize projects that provide the greatest value on a long-term, system-wide scale.

a) Consider local benefits (e.g., habitat) that are currently evaluated in project selection
b) Consider regional benefits and costs (e.g., sediment source to downdrift islands; protection of inland marsh creation projects; restoration of system-level connectivity in sediment, hydrology, and habitat)
c) Identify and include consideration of natural system trajectories in project prioritization (e.g., prioritize islands nearing “tipping points” where a delayed response would increase restoration costs; consider delaying restoration of islands that are more likely to naturally recover from storms)
d) Identify and consider the potential impacts of master plan projects executed outside of BISM (e.g., storm protection or navigation channel projects)

2) Maximize cost benefit ratios and estimate expected future costs to inform planning and budgeting.

a) Articulate upcoming needs to potential funding entities
b) Expand the scale of what is included in “cost effective” beyond project scale (e.g., consider downdrift effects in cost/benefit analysis of individual projects)

3) Employ and advance Regional Sediment Management (RSM) practices to reduce overall sediment need and delineate expected future need

a) Optimize use of available sand, including providing recommendations of which sources of sediment should be used for which projects
b) Identify gaps between available sediment volumes and expected need to inform investment in sand source identification
c) Develop novel approaches and explore alternative technologies for RSM including beneficial use, extraction and conveyance value engineering, and techniques to monitor sediment dynamics
d) Include oil and gas pipelines and other conflicts in evaluation of sand availability, with potential to identify high-value pipeline removal opportunities

4) Incorporate adaptive management into barrier island management

a) Link “health” of system to observable metrics that can fall out of data and modeling, including identifying methods for evaluating project success and incorporating lessons learned into planning
b) Inform monitoring of barrier islands programmatically (e.g. BICM and BISM aligned or integrated) and for individual restoration projects.
c) Identify most pressing gaps (e.g., research, models) limiting system management

5) Reduce implementation time for projects

a) Streamline the regulatory process through working with federal and state permitting agencies to develop programmatic regulatory (including environmental compliance) coverage with streamlined project-specific approval process

5.1. BISM PROGRAM DEVELOPMENT AND IMPLEMENTATION: RECOMMENDATIONS

5.1.1. Development of the Barrier Island Restoration Tradeoff Analysis (BIRTA) Toolkit

The components of the BIRTA toolkit, described in *Section 4.0*, can be developed modularly and sequentially. For example, development of the Coastal State Database could be initially developed as a first step toward more quantitative assessment of the system. The toolkit includes:

- **Coastal State Database:** A uniform set of metrics for evaluating the condition and resources associated with different coastal cells, along with metrics quantifying the state of barrier island and headland units within each cell.
- **Objective Utility Functions:** Development of a set of utility functions that link the characteristics of the coastal cells and barrier islands in the Coastal State Database to the objectives of barrier island restoration.
- **Restoration Alternative Database**: Database identifying potential restoration project alternatives. These alternatives are not necessarily at the Engineering and Design phase. However, projects should include an estimate of sediment volume needs and financial cost.
- **Sediment Resource Database:** Database with characteristics of available sediment resources for use in optimizing use of available sediment for restoration projects on a holistic, regionwide scale. This component has particularly high synergy with LASAAP and existing tools and data that can be leveraged and expanded under that program, as noted below.
- **Probabilistic Coastal Forecast Tool:** Bayesian model trained with existing model output and data that is used to probabilistically predict the evolution of the coast for each restoration alternative.
- **Tradeoff Analysis Tool**: Set of analysis tools for conducting benefit analysis to prioritize barrier island and headland restoration projects based on their local and regional benefits, quantified through their impacts to restoration objectives. This linkage is captured by the Objective Utility Functions. In addition, this tool can be used in conjunction with the sediment resource database to optimize the use of the available sediment on a regionwide basis.
- **Future resource scenario and uncertainty analysis:** This component does not require the development of a new tool, but rather targeted analysis using the probabilistic coastal forecast and the tradeoff analysis tools.
    - Scenarios evaluating the coastal sediment volume and funding need can be run and compared to the volume of usable material available at known sediment resource sites and expected funding levels, respectively, to identify when shortcomings are expected to arise in the future. This information can inform the need for sand exploration and/or future budget requests.
    - Evaluation of the largest uncertainties in the BIRTA analysis framework can be used to identify the most critical gaps (data, modeling, etc.) limiting robust decision making in barrier island restoration prioritization

5.1.2. Expansion of LASAAP for Broader Use in Regional Sediment Management (RSM) and Linkage with BISM BIRTA Toolkit

The LASAAP is a pilot tool for evaluating the best-use of available sediment for individual projects using sediment resources identified within the LASARD database (Aptim Environmental & Infrastructure, Inc.

(APTIM), 2020; Khalil et al., 2016). This database and tool could provide greater benefit to BISM if it is expanded to include non-surficial sediment deposits, as well as for broader use along the entirety of the Louisiana coast. Some of these advancements are currently ongoing as part of the Northern Gulf Sediment Availability and Allocation Program (NGSAAP).

In addition to those focused enhancements, the LASAAP tool could be linked to and/or integrated within the BISM BIRTA framework for more comprehensive use in RSM and holistic barrier island system management. As described above, the tool could be expanded to consider the best use of available sediment sources across multiple projects, drawing on principles used by business in supply chain design (Amin & Zhang, 2013; Ene & Öztürk, 2014; Varsei & Polyakovskiy, 2017). The tool could also be expanded to consider non-geological aspects of sediment resource selection, such as environmental considerations, permitting, and the probability of conflicting use issues such as pipelines. The GIS databases described in *Appendix D: Database of Databases and Inventory of Other Available Information Sources* includes data relevant to these considerations; this database could be expanded and directly linked to a sediment sourcing tool to automate the identification of potential issues.

5.1.3. Coordination of BISM with BICM, LASMP, etc. as part of an Adaptive Management Approach to Barrier Island and Headland Restoration and Monitoring

Extensive data have been collected under the BICM program that can be used by BISM. In addition to characterizing the historical and current condition of the coastal system, BICM data allows the effectiveness of prior restoration alternatives to be evaluated and for the short- and long-term benefits that restoration alternatives provide (such as habitat creation) to be quantified. Close coordination with BICM will further enable advancement of the fundamental BISM programmatic objective to use an adaptive management (AM) approach to restoring, maintaining, and monitoring the barrier island and headland system (Figure 13). In the initial phases of BISM implementation (*Section 3.0*), data provided by BICM can be used to inform use of best professional judgement in assessing the current condition of the coastal system and in predicting the likely impacts of various restoration alternatives. Relative confidence in those predictions can then be considered qualitatively in designing monitoring approaches under the BICM program. For example, it may be challenging for the BISM team to evaluate the trajectory of a particular region of the coast due to a lack of data, suggesting that this spatial area should be prioritized in future monitoring. Similarly, uncertainties identified in BISM may be valuable in determining the frequency or type of data collection that might be most informative to collect under BICM, such as the relative value of post-storm data collection vs. baseline data under quiescent conditions. When using the BIRTA toolkit (*Section 4.0*), value-of-information model scenarios (Runge et al., 2011) can be run to objectively quantify the potential reduction in long-term program cost and/or sediment volume needs that could be achieved through reducing specific data uncertainties. The output of this quantified “information cost/benefit analysis” can then be used to focus BICM data collection.

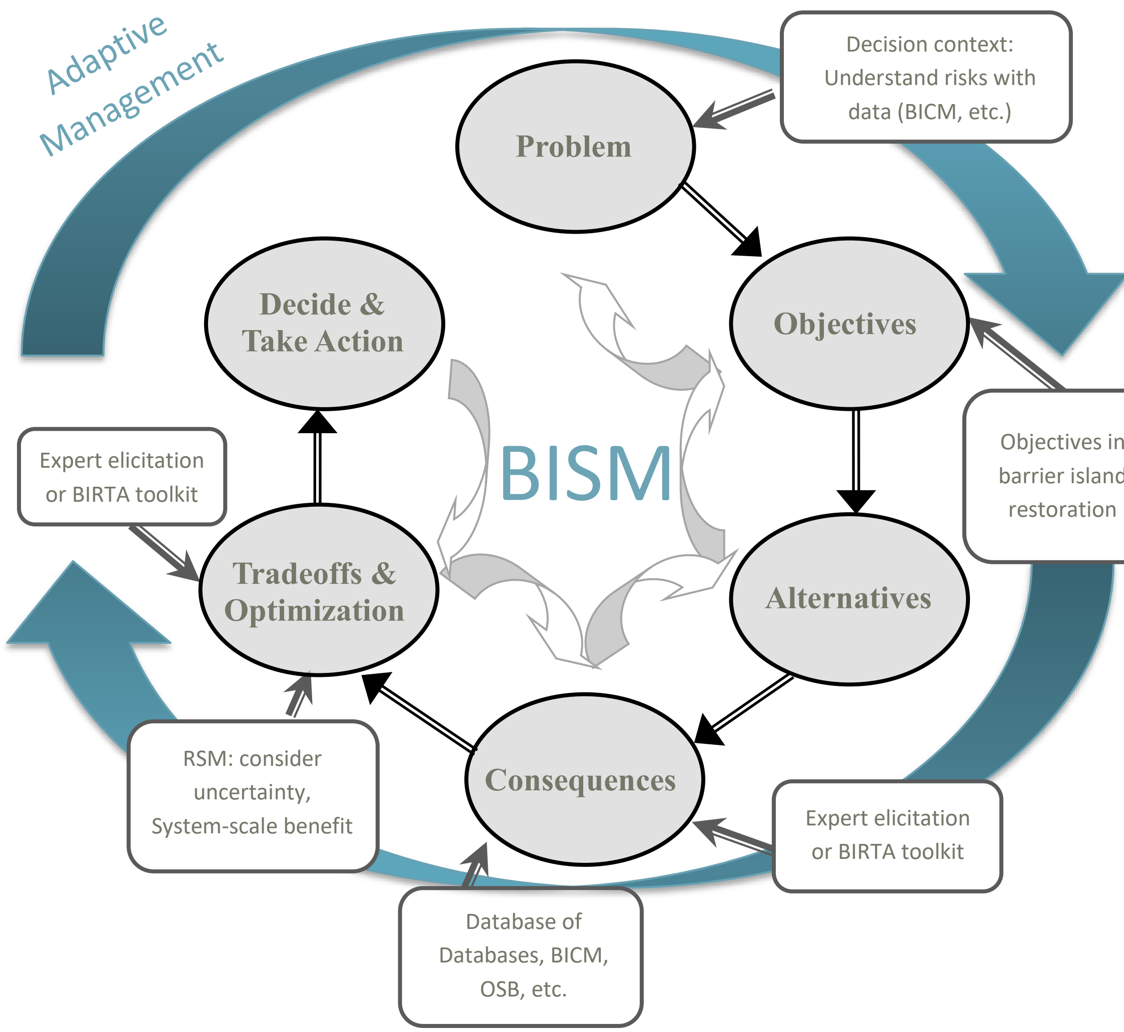

Figure 13. Visualization of BISM as part of an Adaptive Management approach to Regional Sediment Management. Existing data and tools can be combined with the workflow and BIRTA toolkit to maximize the system benefit of portfolios of restoration projects. During each iteration of the workflow, new data and models are incorporated with outcomes from previous workflow iterations. Adaptive Management is an iterative form of SDM, which forms the basis of the BISM workflow; additional information on SDM may be found in Appendix B. Background Figure Source: Jean Fitts Cochrane

5.1.4. Enhance Linkages of BISM with the Louisiana Coastal Master Plan

The development of barrier island modeling for the 2023 Coastal Master Plan was based on the assumption that the BISM program will execute projects that maintain the integrity of the barrier island system, and formulations within the modeling framework were developed to be consistent with this assumption. Under master plan modeling, the coastal system is divided into a set of restoration units corresponding to barrier islands and headlands that would be managed under BISM. Profiles within a unit erode according to historic shoreline and shoreface retreat rates, accounting for modulation of those rates under variable sea level rise scenarios, until an island or headland integrity threshold for the unit is exceeded and a restoration template is automatically applied. This approach enables the barrier islands to evolve in a manner consistent with managed transgression and provides a first rough estimate of the sediment volume needed to maintain the system. However, it does not allow for comprehensive assessment of sediment transport and morphology feedbacks related to restoration or for analysis of the impacts stochastic storm events will have on the barrier system or restoration sediment volume needs. The BIRTA probabilistic forecast system would fill these gaps and enable more robust prediction of coastal evolution under specific restoration alternatives, which could then be used to update and improve barrier island predictions within the master plan model.

5.1.5. Working Group to Streamline Project Permitting

A priority in barrier island restoration that was identified during the BISM development workshop series was the need for a reduction in project permitting and implementation time, with a goal that projects complete that process in six months or less. The primary impediment to this timeline was identified as permitting, which is complicated by multiple entities having different roles, regulatory responsibilities, and timelines. In particular, the National Environmental Policy Act process and associated Federal statutes (Endangered Species Act [ESA]; National Historic Preservation Act [NHPA]; Essential Fish Habitat [EFH], etc.) can be time consuming, introduce planning and financial uncertainty, and create bottlenecks that increase the implementation time of barrier island restoration projects.

A potential solution to this problem was identified as the development of a programmatic approach to permitting, wherein a regional permit would be issued with programmatic environmental coverage along with specified criteria for individual projects. Restoration projects that met those criteria and the overall guidelines of the programmatic permit would have a simplified approval process that could be executed much faster than would occur otherwise. This approach would require coordination with, and approval of, multiple partners and regulatory agencies (USACE, National Oceanic and Atmospheric Administration's [NOAA] National Marine Fisheries Service [NMFS] and Office of Coastal Management [OCM], State Historic Preservation Office [SHPO] and National Park Service[NPS], Bureau of Ocean Energy Management [BOEM], U.S. Fish and Wildlife Service [USFWS]; Louisiana Department of Wildlife and Fisheries [LDWF] and Department of Environmental Quality [LDEQ], etc.). The recommended next step, therefore, is the development of a working group that includes representation from federal and state entities with regulatory roles related to restoration project permitting to evaluate the development of a programmatic permitting approach. Additional information on regulatory entities and their potential role in this process can be found in the *Appendix C: Inventory of Stakeholder Concerns*.

6.0 Conclusion

This report outlines the development of a Louisiana Barrier Island System Management (BISM) program to adaptively manage the barrier shoreline systems and maintain barrier island ecosystem functions in the long-term. The BISM program is designed to leverage principles of SDM, which provides a framework for transparent, objectives-oriented management practice. The goal of the BISM program is to holistically manage the barrier island system for its long-term health and benefit to the state of Louisiana, ensuring resources such as sediment and funds are used as efficiently and effectively as possible. BISM is designed to complement existing programs and projects within CPRA as part of a RSM approach to coastal sediment management, in which understanding of the sediment budget and sediment transport patterns developed through the LASMP and other programs/projects are used to inform the placement of available sediment resources in restoration projects based on the overall, long-term benefit to coastal Louisiana. BISM also incorporates adaptive management, using data collected under the BICM program and elsewhere to assess the state of the coastal system, inform evaluation of the benefits of potential restoration alternatives, and continually improve decision-making through monitoring and evaluation of prior restoration impacts.

This report:

- Defines the suite of issues that BISM needs to address
- Identifies the objectives of a programmatic approach to barrier island management
- Outlines a mechanism (workflow) for identifying and prioritizing portfolios of barrier island maintenance projects based on objective evaluation of benefits, costs, and tradeoffs
- Develops and describes the conceptual framework of a quantitative tool that, in conjunction with the workflow, could be used in prioritizing barrier island restoration projects
- Describes additional next steps for BISM program development.

The contents of this report were developed through a sequence of facilitated working group meetings complemented with one-on-one and small group calls between the Institute and CPRA. In addition, the BISM team undertook desktop research into available resources that could support BISM, including reports and tools developed by CPRA and other entities.

This report is designed as a reference source to facilitate the making of transparent and science-based decisions in prioritizing barrier island restoration projects on a systemwide scale. It describes the BISM workflow, a step-by-step process to transparently identify and prioritize barrier island restoration projects based on their short-and long-term benefit. The workflow, which was developed by the project team as part of this effort, relies on structured input from a BISM planning team to objectively prioritize projects and identify future resource needs (sediment and funding) based on evaluation of existing data and model outputs and use of best professional judgement. The workflow can be used immediately as the BISM program is implemented.

The conceptual design of a cost/benefit analysis toolkit has also been developed as part of this effort. This tool, referred to as the BIRTA (Barrier Island Restoration Alternative Tradeoff Analysis) toolkit, is designed to augment the workflow by utilizing existing data and model output directly as part of quantitative analysis of the funding and sediment costs for potential restoration alternatives and evaluation of their regional and local benefit in the short- and long-term. In addition to providing quantitative cost/benefit output, the use of the toolkit would enable a broader range of restoration alternatives to be considered than is possible with the workflow alone, such as the benefits of portfolios of projects that may be complimentary to each other or to other master plan projects if implemented together. Lastly, the report identifies other high priority next steps that lay out a path forward for implementation and continued improvement of BISM as a program, such as a strategy for developing a programmatic approach to barrier island through coordination with state and federal regulatory entities; targeted investments in existing RSM tools that can be leveraged under BISM; and recommendations for enhanced linkage with the master plan and monitoring programs as part of holistic approaches to adaptive management for coastal Louisiana.

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Appendices

APPENDIX A: CHALLENGES TO IMPLEMENTING SYSTEMATIC BARRIER ISLAND MANAGEMENT

Multiple limitations must be overcome to implement a holistic management approach to barrier islands including, but not limited to: 1) regulatory constraints related to antiquated policy and processes, 2) limited available tools that utilize existing data and monitoring efforts to inform management practices, 3) identification, quantification, and management of available sand resources, 4) technology and industry practices that favor discrete construction projects over a programmatic sand management approach, and 5) a dependable funding stream.

Regulatory Constraints

Many of the existing regulatory processes do not provide flexibility necessary to implement a holistic sand management approach with rapid response capabilities. Poorly defined regulatory processes introduce uncertainty relative to project requirements and construction timelines. However, a programmatic approach can be designed to be compliant with existing regulations and statutes. In addition, BISM development and implementation can identify efficiencies and work with resource agencies to develop processes that accommodate the programmatic approach.

Readily Available Tools to Inform Best Management Practices

There exists a wealth of information from decades of research and monitoring programs that can be used to inform barrier island system management in Louisiana. BISM provides an opportunity to improve utilization and feedback of existing monitoring programs into an adaptive management and project design framework. Development of tools that employ these information sources can be applied to identify problems and solutions, track progress, and inform predictive models.

Regional Sand/Sediment Management

The development and tracking of regional sediment budgets are key to identifying the timing and location of nourishment actions that extend island lifespans. By strategically placing sand (from outside of the active coastal system or managing sand within the system) barrier shoreline geomorphic form and function can be maintained and enhanced over the long term. CPRA has long recognized that a programmatic approach to identifying and inventorying sediment resources reduces project costs and uncertainty about constructability. BISM provides an opportunity to implement this type of approach.

Technological Limitations and Industry Practices

The technology employed to transport and manage sand resources should continue to be evaluated. Limited equipment availability drives up cost and dictates implementation approach. A value engineering exercise could be conducted to explore efficiencies related to implementing a long-term, regional sand/sediment management program versus traditional barrier island construction templates. Examples might include exploring alternative types of sand excavation equipment, sand transportation techniques, and sand bypassing/backpassing systems.

Dedicated Programmatic Funding

A programmatic approach to barrier island management will require dedicated funding to inform program scale and implementation options. BISM is an opportunity to demonstrate the importance of investing in a robust barrier island system because of their role in the overall coastal protection and restoration effort in Louisiana, and the benefits they afford other projects, such as diversions, because of their important functions as a component of the deltaic landscape. Moreover, it is important to demonstrate the long-term cost savings of implementing a programmatic approach.

APPENDIX B: STRUCTURED DECISION-MAKING OVERVIEW

The decision-making workflow that underlies BISM roughly follows an SDM approach. SDM is a conceptual framework (i.e., organized process) for systematically making decisions based on clear identification of objectives and goals, leveraging of tools and information to predict the deliberate and unintended consequences of decisions, and objective cost-benefit analysis of alternatives (Martin et al., 2009) that has previously been applied to support decision-making in barrier island management (Dalyander et al., 2016). The SDM process, referred to as PrOACT (Figure 13), includes:

- Defining the Problem (i.e., the full suite of issues that BISM needs to address)
- Determining the Objectives (i.e., specific preferred outcomes of site-specific and regional barrier island management)
- Identifying Alternatives (i.e., potential portfolios of barrier island maintenance projects)
- Evaluating alternatives and forecasting the Consequences (i.e., predicting the local, mainland, and regional effects of projects based on data, models, and expert knowledge)
- Evaluating the Trade-offs (i.e., analyzing the costs and benefits of different management alternatives)
- Making the decision and taking action (i.e., project implementation)

The methodical approach of SDM makes it particularly well-suited to problems such as regional barrier island management, where the potential ramifications of decisions and interconnected issues to consider are complex (such as predicting the mainland or downdrift effects of barrier island restoration, optimizing use of sand resources across multiple projects, and managing physically dynamic systems within the constraints of regulatory processes). Because SDM is a deliberate, transparent, and replicable decision-making process that can incorporate multiple, potentially conflicting perspectives and objectives, it is more likely that the decisions made under BISM can be effectively communicated and understood by other stakeholders with interest in Louisiana's barrier islands.

PrOACT, as used in the development of BISM, is designed for incorporation into an *adaptive management approach*. In addition to informing the timing and selection of barrier island maintenance and restoration projects, the framework can be continually updated as, for example, the state of the barrier islands changes; new data or model output becomes available to reduce the uncertainty associated with predicting the consequences of alternatives; new sources of sand are identified; and/or stakeholder priorities evolve.

APPENDIX C: INVENTORY OF STAKEHOLDER CONCERNS

Introduction

There are many decision-makers and other stakeholders with authorities and interests that must be considered as part of the Louisiana Barrier Island System Management (BISM) program. For example, entities such as communities and Port Authorities may modify the coastal system to protect their interests through actions such as sediment placement and jetties or other engineered structures, which can alter regional sediment transport patterns with implications for BISM restoration projects. Entities such as Natural Resources Damage Assessment (NRDA) Trustee Implementation Groups (TIGs) have funds that can be leveraged for restoration projects that align to their objectives, while landowners and coastal communities have interest and potential influence over restoration projects in their area.

This Inventory of Stakeholder Concerns has been compiled to provide information on entities relevant to barrier island and headland management within the state of Louisiana. The inventory is intended as a companion to the BISM program workflow and will serve as a source of information referenced from that workflow. The inventory is organized into six categories which describe and summarize stakeholders with interests relevant to different stages of barrier island project prioritization and the overall BISM program. The stakeholder concerns in categories one through three encompass entities and actions with interests that are potentially relevant in the project selection and prioritization stages. Specifically, these categories describe: 1) those who may provide funding; 2) those that may have the authority or jurisdiction to influence prioritization of barrier island restoration projects conducted under BISM; and 3) those whose actions may impact the coastal barrier system independently of BISM. Category four includes organizations and entities with whom CPRA can engage in developing best practice in barrier island management. Category five addresses regulatory entities and organizations that have interests relevant to project implementation, whose potential concerns must be addressed after projects have been selected to move forward or engaged to attain programmatic regulatory/environmental compliance. Category six includes stakeholders with whom it is advisable to develop a communication strategy for the purpose of transparency.

Some of the stakeholder concerns described below are associated with specific geographic areas. For example, stakeholders who are modifying the coastal system outside of BISM (Category 3) includes entities such as the U.S. Army Corps of Engineers (USACE), who have navigable waterways that they maintain and recurrently dredge. In addition to this memo, a GIS database has been created that identifies the spatial location of these areas of stakeholder concern; a description of the fields of this database is included in this memo. (Note, it is suggested to use a polygon without a fill color when viewing the Stakeholder Concern GIS Database due to the extensive overlap between stakeholder concerns in some regions.) Lastly, the memo concludes with recommended next steps for enhancing the GIS database to directly interface with the Barrier Island Restoration Tradeoff Analysis (BIRTA) Toolkit, a quantitative analysis framework that has been conceptually designed to support BISM.

Category 1: Funding Entities

The funding category of the stakeholder inventory is provided as a point of reference of potential sources of financial support for barrier island and headland restoration. In addition, the background and objectives of each funding source are overviewed here to inform what projects may be competitive for receiving support under that funding. Links and references are provided throughout for additional information.

From 1990 the primary mechanism for the funding of coastal restoration projects in Louisiana was the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA; CWPPRA, 2014). Funding for coastal restoration has since expanded due to settlements made by Deepwater Horizon (DWH) Responsible Parties (RPs). Funds from these settlements are dispersed through the Natural Resource Defense Assessment (NRDA), the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf States Act of 2012 (the RESTORE Act), and the 501(c)3 National Fish and Wildlife Foundation's (NFWF) Gulf Environmental Benefit Fund (GEBF) to support restoration activities. Multiple state and federal agencies are represented within each of these funding entities and determine the allocation of DWH funds to individual restoration projects. A breakdown of how these agencies intersect with funding entities is detailed in Figure 14.

For a more detailed compilation of funding source information, see "Louisiana Adaptive Management Status and Improvement Report: Vision and Recommendations" (The Water Institute of the Gulf, 2020).

Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA)

CWPPRA was passed as federal legislation in 1990 to provide targeted funding for the planning and implementation of projects that create, protect, restore, and enhance wetlands in coastal Louisiana. Funding is provided by the State of Louisiana, and matching funds are sourced from State Mineral Revenues on an annual basis.

The CWPPRA Program, which allocates these funds, is overseen by a Task Force composed of representatives from the State of Louisiana (represented by the Governor's Office of Coastal Activities [GOCA]), USFWS, USACE, the Natural Resource Conservation Service (NRCS), the Environmental Protection Agency (EPA), and the National Marine Fisheries Service (NMFS).

USACE is responsible for administering funds and tracking the status of CWPPRA projects (USACE, 2020). CWPPRA's funding stands at between $30 - $80 million per annum.
More information: LACoast.gov

State Surplus Funds

Where state surplus funds are available, coastal protection and restoration is one of six permitted uses of those funds.

Natural Resources Damage Assessment

The Natural Resources Damage Assessment (NRDA) is the implementation of a legal process whereby designated natural resource trustees represent the public to ensure the restoration of natural resources that are injured in an oil spill, by a ship grounding, or by a hazardous waste site. Following the DWH oil spill in 2010, the NRDA Trustees formed Trustee Implementation Groups (TIGs) of representatives of state and federal agencies to oversee the allocation of restoration funds leveed from RPs.

Louisiana Trustee Implementation Group

The Louisiana Trustee Implementation Group (LA-TIG) is responsible for the allocation of $5 billion in restoration funds leveed from DWH RPs within the Louisiana Restoration Area (LRA), which will fund projects over a 15-year period ending on April 4, 2031. The LA-TIG's trustees comprise state-level representatives from CPRA, Louisiana Oil Spill Coordinator's Office (LOSCO), Louisiana Department of Environmental Quality, LDWF, and LDNR. At the federal level trustees include representatives of the U.S. Department of the Interior (DOI), The National Oceanic and Atmospheric Administration (NOAA), The U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (EPA).

A breakdown of LA-TIG's restoration goals and types for the LRA is available on NOAA's website. More information: Louisiana Deepwater Horizon Oil Spill: Natural Resource Damage Assessment & Restoration

Regionwide Trustee Implementation Group (Regionwide TIG)

The Regionwide TIG oversees the Regionwide Restoration Area and is composed of representatives from each northern Gulf state along with federal trustees. The Regionwide TIG funds projects that cross jurisdictional boundaries. Funds are divided into two high-level restoration goals, with $245 million allocated to a goal to "Replenish and Protect Living Coastal and Marine Resources" and $105 million allocated to "Monitoring, Adaptive Management, and Administrative Oversight." A more detailed table of funding allocations for the Regionwide Restoration Area can be found here.

Non-Deepwater Horizon Funds

NRDA continues to be used when there are instances of injury to natural resources by an oil spill, ship grounding or hazardous waste site. As such, restoration of natural resources may be through the NRDA process in circumstances unrelated to DWH.

More information: Department of the Interior: Natural Resources Damage Assessment and Restoration Program and http://www.losco.state.la.us/nrda.html.

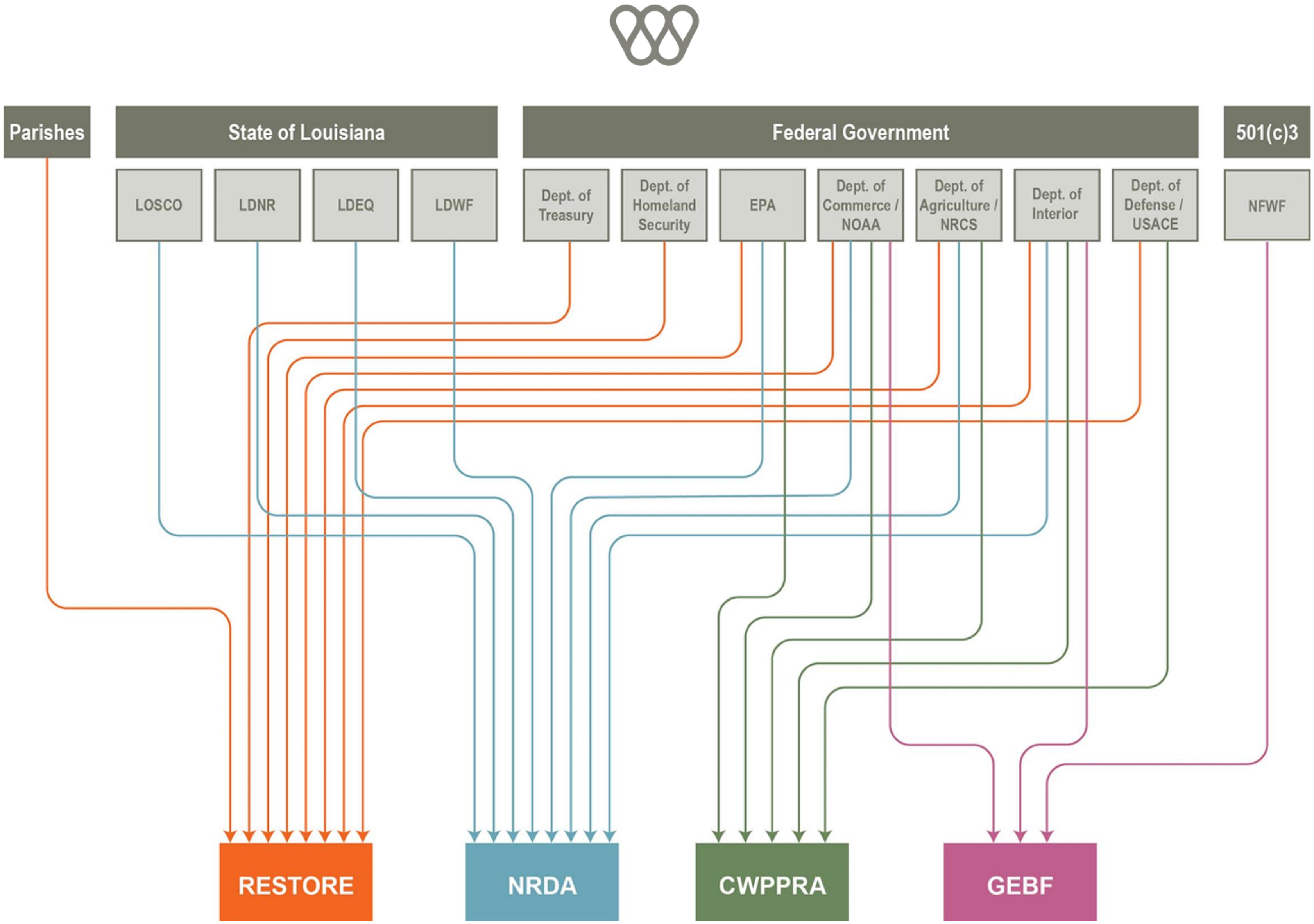

Figure 14. Illustration of institutional responsibilities related to the key funding entities listed within this section. Note that CPRA is engaged with all these mechanisms and the illustrated responsibility pathways are for programmatic governance only and do not reflect the implementation, regulatory, or other programmatic roles. LOSCO – LA Oil Spill Coordinator's Office, NRCS – Natural Resources Conservation Service. (The Water Institute of the Gulf, 2020)

RESTORE Act

The Gulf Coast Ecosystem Restoration Council (RESTORE Council) oversees funds drawn from DWH penalties paid by BP, Transocean. and Anadarko under the Clean Water Act (CWA). Eighty percent of these penalties are directed to the Gulf Coast Restoration Trust Fund and are currently being allocated over a 15-year period, which will end on April 4, 2031. These funds are dispersed across five 'buckets.' Of these buckets, shown in Figure 15, BISM projects may be eligible for funding from buckets one through three: the Direct Component, the Comprehensive Plan Component, and the Spill Impact Component, respectively. However, only buckets one and three (highlighted in red) have funding specifically dedicated to restoration work in Louisiana and therefore represent that most likely source of support for projects.

Work funded by the Gulf Coast Restoration Trust Fund encompasses projects which restore and protect the "natural resources, ecosystems, fisheries, marine and wildlife habitats, beaches, coastal wetlands and economy of the Gulf Coast region" (Gulf Coast Ecosystem Restoration Council, 2020).
More information: RestoreTheGulf.gov

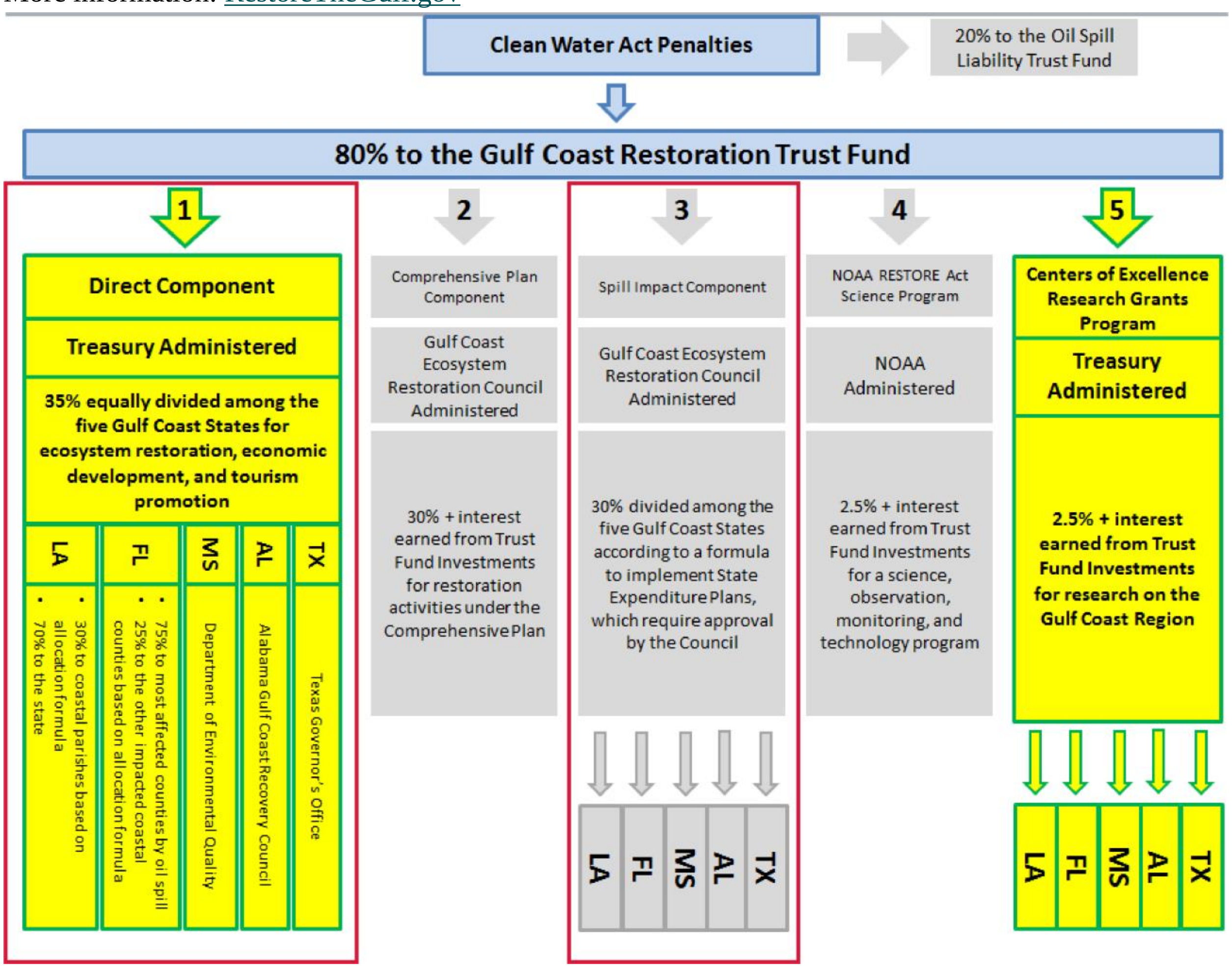

Figure 15. Allocation of RESTORE Act Gulf Coast Restoration Fund. Buckets outlined in red are those that having funding specifically designated for restoration work in Louisiana. Adapted from U.S. Department of the Treasury (U.S. Department of the Treasury, 2020)

Gulf of Mexico Energy Security Act (GOMESA)

The Gulf of Mexico Energy Security Act of 2006 established a revenue-sharing model by which the Land and Water Conservation Fund, along with four northern Gulf states (Texas, Louisiana, Mississippi, and Alabama) and their political subdivisions, receive a portion of the revenue generated by the oil and gas industry in the GOM. GOMESA is administered by the DOI, with funds dispersed each spring. In FY2020 the State of Louisiana received $124,574,776 in revenue. Additional funds were dispersed to individual parishes. In Louisiana, GOMESA funds are constitutionally dedicated to the Coastal Protection Trust Fund and are primarily used to fund hurricane protection projects.

National Fish and Wildlife Foundation

NFWF is a 501(c)3 conservation grant maker with programs throughout the U.S. to "protect and restore our nation's fish, wildlife and plants for current and future generation."

Two of NFWF's current programs intersect with the goals and geographical coverage of BISM:

Gulf Environmental Benefit Fund

GEBF totals $1.272 billion for the State of Louisiana, composed of settlement funds from DWH/Transocean plea agreements.

The plea agreements mandate that these funds be "allocated solely to barrier island restoration projects and river diversion projects along the Mississippi and Atchafalaya Rivers (NFWF, 2020a)." NFWF consults with CPRA, USFWS, and NOAA to identify priority projects for consideration under GEBF and considers both the Louisiana Coastal Master Plan and the Louisiana Coastal Area Mississippi River Hydrodynamic and Delta Management Study.
More information: Gulf Environmental Benefit Fund

National Coastal Resilience Fund

The National Coastal Resilience Fund was established by NFWF in 2018 to invest in "conservation projects that restore or expand natural features such as coastal marshes and wetlands, dune and beach systems, oyster and coral reefs, forests, coastal rivers and floodplains, and barrier islands that minimize the impact of storms and other naturally occurring events on nearby communities.

NFWF uses the Regional Coastal Resilience Assessments to "identify public and private lands ideal for restoration and analyses projects for their potential to provide maximum benefit for both people and wildlife. The resulting outcome-based approach ultimately minimizes the impacts of natural disasters (NFWF, 2020b)." As such, projects are awarded based on consideration of both the restoration and strengthening of natural systems that protect coastal communities and the enhancement of habitats for fish and wildlife.
More information: National Coastal Resilience Fund

Category 2: Authorities with Potential Influence on BISM Restoration Projects

Barrier island restoration projects may intersect with geographic areas in which state or federal authorities have jurisdictional influence. These authorities can exercise significant influence regarding if and how a restoration activity can take place. Land managers may have specific responsibilities to the lands they oversee that will require consideration in restoration planning. It is advisable to engage with these groups to determine their specific concerns early in the project prioritization process given their potential influence on successful project implementation.

Land Management/Land Rights

United States Fish and Wildlife Service (USFWS)

USFWS is a Federal Land Manager for National Wildlife Refuges.
More information: Breton National Wildlife Refuge.

Louisiana Department of Wildlife and Fisheries (LDWF)

LDWF serves as the land manager for Louisiana State Wildlife Management Areas, Refuges and Conservation Areas.
More information: Isles Dernieres Barrier Islands Refuge (Wine, Trinity/East, Whiskey and Raccoon Islands, and associated waters); Elmer's Island Wildlife Refuge

Private Ownership

Where areas of the coastal barrier system are privately owned, landowners may influence if and how a restoration activity may take place.

Coastal Barrier Resources System

USFWS has regulatory authority over the John H. Chafee Coastal Barrier Resources System, which is an area of "relatively undeveloped coastal barriers along the Atlantic, Gulf of Mexico, Great Lakes, U.S. Virgin Islands, and Puerto Rico (USFWS, 2020)." These lands were designated as the CBRS by the Coastal Barrier Resources Act of 1982. The CBRA restricts federal expenditures that would encourage development in areas covered by the CBRS.

Under the CBRA, sand may be removed from CBRS units to "replenish beaches located both within and outside the CBRS, so long as the proposed project is consistent with the purposes of the act (USFWS, 2020)." Consultation with USFWS is required for any such project.
More information: USFWS Coastal Barrier Resources System Federal Project Consistency Consultations

Category 3: Entities that can Impact the Barrier Island System Through Actions Conducted Outside of BISM

In addition to restoration projects selected and implemented by BISM, there are ongoing projects to augment lands within the Louisiana coastal barrier system. These projects may be conducted to mitigate the impacts of coastal erosion and enhance flood protection along the Louisiana coast; to protect habitats; or to protect industrial/commercial interests. Such work can be conducted by state and federal agencies, municipal entities, port authorities, or by CPRA's coastal protection program. These actions may have conflicting or synergistic influence on a restoration program. For example, management of an island upstream of a potential BISM project site may be positively or negatively impacted by sediment placement or the use of hard structures that inhibit sediment transport, respectively. These potential influences should be considered in prioritizing barrier island projects and must be accounted for in managing the coast on a systemwide scale.

Flood Risk Protection and Erosion Mitigation

Parishes, Counties, and the Town of Grand Isle

Individual parishes, counties and the Town of Grand Isle may apply for and receive funding from the RESTORE Council to plan and implement coastal projects that impact the coastal barrier system.

CPRA Coastal Protection

CPRA conducts structural and non-structural Risk Reduction Projects that are independent of restoration activities. These projects, when conducted for Grand Isle, may impact the coastal barrier system.
More information: CPRA Risk Reduction Projects

Port Authorities

The Greater Lafourche Port Commission, in partnership with federal, state, and local authorities and entities, implements and enhances coastal protection and restoration projects in the immediate vicinity of Port Fourchon.
More information: Greater Lafourche Port Commission

Targeted Habitat Conservation

The following entities may coordinate restoration actions in support of habitat conservation or creation, including in barrier island and headland areas. Although such action would likely occur with direct involvement from CPRA, the projects may not be coordinate through BISM. The potential impacts of such projects on the barrier island system and on restoration alternatives pursued under BISM should be considered in project prioritization and implementation, however.

LDWF

LDWF may conduct targeted habitat conservation in the areas in which they serve as land managers.
More information: Isles Dernieres Barrier Islands Refuge (Wine, Trinity/East, Whiskey and Raccoon Islands, and associated waters); Elmer's Island Wildlife Refuge.

USFWS

USFWS is the Federal Land Manager for the Breton National Wildlife Refuge and may pursue restoration or conservation action on those lands.
More information: Breton National Wildlife Refuge.

Navigation Channels

USACE

USACE works with local government subdivisions (as local sponsor) to maintain (and enhance) navigation channels. Maintenance of navigation channels removes sediment from the nearshore system and may impact downstream restoration action taken under BISM. There are four federally authorized

channels in the study area. Additionally, there is a deepening project planned for the federally authorized channel in Gulfport which —while not intersecting with the Louisiana Barrier System—may be a potential source of sediment for beneficial reuse in the Chandeleurs.
More information: U.S. Army Corps of Engineers Navigation

Cultural/Historic Preservation

Louisiana State Historic Preservation Office (SHPO)

Within the barrier system, properties on the National Register of Historic Places (NRHP) include Fort Livingston, located at the western end of Grand Terre, and the Humble Oil Camp Historic District on Grand Isle. NRHP concerns and restoration action to protect cultural resources may involve CPRA but would not necessarily be executed under the BISM program.
More information: Louisiana SHPO

Category 4: Entities Interested in Best Practice in Barrier Island Restoration and/or Understanding Coastal Systems

There is a wealth of research and monitoring data available in coastal Louisiana that has been developed by a range of institutions and entities. In addition, successful approaches for coastal system management have and are being developed throughout the Gulf region and beyond. Engaging broadly with other entities with barrier island restoration interests and experience allows CPRA to benefit from the investment of other others while also sharing the substantial knowledge gained in its own history of coastal system management. With the application of adaptive management approach to engaging with a community of practice, incorporating lessons learned into the project prioritization and implementation process, BISM stands to improve and advance barrier island restoration efforts in the region. It should be noted that buckets four and five under the RESTORE Act (Figure 14) provide support for research that potentially can be used to advance best practice in barrier island restoration, therefore opportunities may exist to leverage outcomes from those funding sources and/or for BISM to partner as a management entity in informing research directions under proposals and projects funding through those sources within Louisiana and across the Gulf.

Research Institutions

Academic Institutions

There are academic institutions regionally, and nationwide, whose research informs or otherwise supports barrier island restoration in Louisiana. For example, substantial investment has occurred through the RESTORE Center of Excellence (Figure 1) that is directly relevant to barrier island project prioritization and implementation. Similarly, academic entities throughout the U.S. and Worldwide have invested millions of dollars in researching barrier island dynamics and approaches to successful short- and long-term management of these systems; this information can be used or adapted to use in the Louisiana coast where relevant.

Federal Research

USGS

USGS conducts and supports extensive research in issues related to coastal Louisiana. One key component of this research is the support the USGS Wetland and Aquatic Research Center currently provides for the Barrier Island Comprehensive Monitoring Program. In addition, the Coastal and Marine Hazards and Resources Program (CMHRP) is a federal program that supports barrier island and coastal system research that can potentially be leveraged by BISM.

USACE-Engineer Research and Development Center (ERDC)

USACE-ERDC's Water Resources programs engage in research related to the Louisiana coast and barrier islands of the northern Gulf and has performed restoration assessments in partnership with USGS. These studies present opportunities to identify new approaches and/or information that is relevant to BISM. More information: USACE ERDC

Environmental Research Non-Governmental Organizations (NGOs)

Environmental research NGOs who work in partnership with other research institutions, as well as state and federal agencies and private entities, can provide scientific expertise for restoration projects. In addition, these organizations also have experience in the linkage of fundamental research with applied use, which is of relevance to the BISM program.

Implementation Community

Environmental and Engineering Consultants

There are a number of private environmental and engineering consulting firms and individuals in the northern Gulf Coast actively engaged in state coastal restoration projects. These entities have developed substantial expertise in monitoring, project design, and construction that can inform a programmatic approach to barrier island management, as well as the longevity and regional benefits of potential projects with relevance to the prioritization process.

Army Corps Districts

USACE is involved in many aspects of barrier island restoration, including developing design alternatives for projects. Local Army Corps Districts throughout the Gulf have extensive knowledge of the landscape and stakeholders within their region; communication with Districts can allow BISM to leverage this expertise in the barrier island management within the state of Louisiana.

Category 5: Program Implementation Considerations (Regulatory Authorities)

There are significant and varied implementation considerations, the combination of which varies for any given project depending upon its area of potential effect. Some of these implementation considerations, such as a potential need for the removal or avoidance of pipelines, may impact the cost/benefit ratio of a given project. Other factors, such as the permitting process, will influence the time it takes for a project to move from the design phase onto the landscape. As such, the entities described here are potentially relevant during program development (e.g. attaining programmatic regulatory/environmental coverage), project prioritization phase of BISM, and after projects have been selected for implementation (post-BISM).

Pipelines

Bureau of Safety and Environmental Enforcement (Federal Waters)

The Bureau of Safety and Environmental Enforcement (BSEE) holds regulatory authority regarding the decommissioning of oil or gas exploration or production facilities in the Outer Continental Shelf (OCS), including pipelines that are removed or prepared for abandonment in place. BSEE is also responsible for issuing of permits for pipeline placement in federal waters.
More information: BSEE; DNR-MMS Louisiana Offshore Pipeline and Platform Map

Bureau of Ocean Energy Management (Federal Waters)

As stewards of federal offshore sand resources, the Bureau of Ocean Energy Management (BOEM) has developed a Significant Sediment Resources policy to manage multiple use conflicts related to oil and gas infrastructure on the federal OCS and has developed coordination procedures with BSEE, CPRA, and LDNR Office of Coastal Management (for Coastal Zone Management Act [CZMA] Federal Consistency Determinations) to ensure access to sediment resources is not impacted by abandoned oil and gas infrastructure.
More information: BOEM Managing Multiple Uses in the Gulf of Mexico; BOEM Data Center

LDNR (State Waters)

The Pipeline Division of the LDNR Office of Conservation regulates natural gas and liquid petroleum pipeline operations in the state waters of Louisiana
More information: LDNR Pipeline Division

Coastal Zone Management Act (CZMA)

LDNR

LDNR is responsible for implementation of the Coastal Zone Management Act. Any activities that may have reasonably foreseeable effects on the land use, water use, or natural resources of the Coastal Zone are required to undergo a Federal Consistency Review, as performed by LDNR Office of Coastal Management. In addition, LDNR's Permits/Mitigation Division is responsible for the implementation of the Louisiana Coastal Resources Program, under authority of the State and Local Coastal Resources Management Act. For activities in the Coastal Zone requiring Coastal Use Permits and Section 10/Section 404 permits (from USACE see below), LDNR and USACE have developed a joint permit application and evaluation process.
More information: Applying for a Coastal Use Permit

Rivers and Harbors Act

Section 10

Section 10 of the Rivers and Harbors Act of 1899 requires authorization from the Secretary of the Army, through the USACE, for the construction of any structure in or over any navigable waterway in the United States. The law applies to the "dredging or disposal of dredged materials, excavation, filling, rechannelization or any other modification of a navigable water of the United States" in addition to any permanent or semi-permanent obstacle or obstruction.
More information: USACE, Section 10 of the Rivers and Harbors Act; USACE New Orleans District Regulatory Permits

Section 14/Section 408

Section 14 of the Rivers and Harbors Act of 1899 provides that the "Secretary of the Army, on the recommendation of the Chief of Engineers, may grant permission for the temporary occupation or use of any sea wall, bulkhead, jetty, dike, levee, wharf, pier or other work built by the United States."
More information: USACE, Section 408

Clean Water Act

EPA

Section 404 of the Clean Water Act (CWA) regulates the discharge of dredged or fill material into waters and of the United States, including wetland. Under Section 404, a permit must be obtained before any dredged or fill material is discharged.

USACE (Section 404 on behalf of EPA)

USACE is responsible for implementation of Section 404 of CWA on behalf of the EPA.
More information: USACE Section 404 Permits; USACE New Orleans District Regulatory Permits

Magnuson-Stevens Fishery Conservation and Management Act

NOAA NMFS

The Magnuson-Stevens Fishery Conservation and Management Act is the primary law governing marine fisheries in U.S. Federal waters. The Act is administered by NOAA-NMFS and includes a provision for the protection of essential fish habitats.

Marine Protection, Research, and Sanctuaries Act

EPA

The Marine Protection, Research, and Sanctuaries Act (MPRSA) prohibits the dumping of materials into the ocean that would "unreasonably degrade of endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities." MPRSA is overseen by EPA.
More information: MPRSA

USACE (Section 103 on behalf of EPA)

Under Section 103 of MPRSA, USACE has the regulatory authority to determines whether a permit may be issued for the ocean disposal of dredged materials. Section 103 permits may be required for projects with offshore borrow areas that have overburden sediments that must be side-cast to access the underlying, target sand resources.

More information: USACE Section 103 Permits; USACE New Orleans District Regulatory Permits

Safety Fairways and Anchorage Establishments

USACE/USCG

Section 7 of the Rivers and Harbors Act authorizes the establishment of anchorage grounds for vessels in the navigable waters of the United States whenever it is apparent that these are required by the maritime or commercial interests of the United States for safe navigation. There are specific regulations applied to anchorage and shipping safety fairways in the Gulf of Mexico to ensure safe approaches to oil fields and coastal ports. The USCG is responsible for enforcing the rules and regulations of appropriate anchorage and safety fairways.

More information: Title 33: §166.200, Shipping safety fairways and anchorage areas, Gulf of Mexico

Geological and Geophysical Prospecting

BOEM

It is required that authorizations be obtained from BOEM for geological or geophysical prospecting for marine minerals (sand) on the Federal Outer Continental Shelf. Separate authorizations are issued for geophysical (sub-bottom profiling) and geological (vibracores, borings, grab samples) exploration.

More information: BOEM Geological and Geophysical Permits

Habitat

Endangered Species Act

USFWS and NOAA are responsible for implementation of the Endangered Species Act (ESA) depending on the species and where the activity is taking place. NOAA and FWS have joint jurisdiction regarding the protection of sea turtles under the ESA (NOAA in water, FWS on land). Section 7 of the ESA requires interagency coordination and/or consultation by Federal agencies on any action they authorize, fund, or carry out that may jeopardize the continued existence of endangered or threatened species or destroy or adversely modify critical habitat. Therefore, any action that requires a federal authorization (e.g., USACE 10/404 permit, BOEM minerals lease or mineral exploration permits, etc.) must comply with Section 7. Consultations and compliance can be pursued by the Federal agency on a project-by-project basis or programmatically.

More information: NOAA NMFS Interagency Consultation in the Southeast United States; Endangered Species Conservation; FWS Endangered Species Act Overview

Migratory Bird Treaty Act

USFWS is responsible for the implementation of the Migratory Bird Treaty Act (MBTA).

More information: Migratory Bird Treaty Act Protected Species

Marine Mammal Protection Act

USFWS and NOAA have joint jurisdiction regarding implementation of the Marine Mammal Protection Act.
More information: Marine Mammal Protection Act Policies, Guidance and Regulations

National Historic Preservation Act (NHPA)

SHPO (State administration of Section 106)

Section 106 of the National Historic Preservation Act requires Federal agencies take into account effects of their actions (including authorizations and permits) on historic properties. For most projects related to BISM, this process involves cultural resources clearance activities to be conducted unless the area to be disturbed has already been cleared by the State Historic Preservation Officer (SHPO). Much like ESA Section 7 is the responsibility of the Federal authorizing or action agency, and coordination often takes place during the USACE permitting process.

Within the barrier system properties listed on the NRHP consist of Fort Livingston, located at the western end of Grand Terre, and the Humble Oil Camp Historic District on Grand Isle.
More information: Louisiana SHPO

Tribal Consultation and Coordination

Each federal agency has a policy regarding Government-to-Government Consultation and Coordination with Indian Tribes. In an instance where a Tribe may have a claim to or interests in an area of proposed restoration, consultation with the Tribe will be required.

Category 6: General Interest

There is notable interest in coastal restoration activities in Louisiana. These interests are far ranging and may include short- and long-term concerns in maintaining coastal communities, economic interests, infrastructure, or ecosystems. At various stages of BISM program development and implementation, it may be beneficial to develop targeted strategies for communicating with regional decision makers as well as residents and the public at large.

Public Entities

State and Federal Agencies

In addition to the partnering and funding entities listed in the other categories, there are many other state and federal agencies throughout the northern Gulf of Mexico with interest in the impacts of Louisiana coastal restoration. In some cases, decisions made for barrier island restoration in Louisiana may have impacts on coastal water quality and/or wave attenuation that can influence other regional interests. Regional decision makers and stakeholders may therefore include a wide array of agencies with interest in coastal protection, fisheries management, ecosystem restoration, and beyond. A single restoration project will not involve active engagement with all regional barrier island decision makers. However, projects planned under BISM may impact or inform proposed, planned, or future restoration activities by these other entities and/or the resources that they steward. As such, communication with regional barrier island decision makers and stakeholders during project selection and implementation may be beneficial.

Private Entitites

Residents/The Public

It is beneficial to keep the public informed of restoration planning activities. These include individuals with local interests, such as residents (Grand Isle), tourists, and recreational/commercial users of the barrier island systems (fishing, boating, etc.). In addition, the broader public has interest in the state of the coast due to the protection barrier islands provide to the mainland coast and marches, as well as in the responsible stewardship of public funds in coastal system management.

Advocacy Organizations

Advocacy organizations often have intense interest in activities that may impact their areas of concern, some of which intersect barrier islands or the influence they have on coastal protection or ecosystem health. Entities that may have interest in barrier island projects under BISM include representatives of maritime organizations, the offshore oil and natural gas industry, and environmental advocates. Maintaining transparency through an effective communication strategy with these entities early in the project prioritization process can help mitigate potential issues arising later in the implementation phase.

Contents of the Stakeholder Inventory GIS Database

Stakeholder_Inventory.gdb

The geodatabase Stakeholder_Inventory contains the Stakeholder_Inventory shapefile as well as supplementary that will be useful to consider alongside the stakeholder data. All of the files in this database are referenced to NAD83 in a UTM15N coordinate system. The attribute tables of each shapefile contain more detailed information about each point, line, and polygon.

1) Stakeholder_Inventory.shp
   This polygon shapefile contains all the areas of interest related to stakeholder categories identified by BISM. The attribute table contains a name for each polygon, a list of stakeholder categories relevant to each polygon, and additional information about the location.

2) Infrastructure and Cultural Resource Information
   a. *BOEM_offshore* dataset: Information on locations of pipelines, platforms, fairways, and lease blocks
      i. al_20200803.shp – active BOEM lease blocks
      ii. blocks.shp – BOEM lease blocks
      iii. Fairways.shp – location of BOEM fairways
      iv. platform.shp – locations of offshore platforms
      v. ppl_arcs.shp – locations of pipelines
   b. *Oil_Gas* dataset: Information on the location of pipelines and platforms
      i. DNR_CMD_lines_v10.shp – locations of pipelines from the Department of Natural Resources (DNR)
      ii. DNR_CMD_platforms_v10.shp – locations of pipelines from DNR
      iii. LGS_piplines.shp – locations of pipelines from the Louisiana Geological Survey (LGS)
      iv. NPMS_pipelines.shp – locations of pipelines from the National Pipeline Mapping System (NPMS)
   c. NOAA_wrecks_obstructions_utm15N.shp: Location of shipwrecks from the National Oceanic and Atmospheric Administration (NOAA)

3) Fisheries
   a. *Oysters* dataset: Information on locations that are important to oyster fisheries
      i. LDWF_oyster_seedground_UTM15N.shp – locations of oyster seed grounds from the Louisiana Department of Wildlife and Fisheries (LDWF)
      ii. LDWF_oysterlease_active_20200803_utm15N – locations of active oyster leases from the LDWF

4) Coastal Management
   a. *CBRS* dataset: Boundaries within which Federal Emergency Management Agency (FEMA) Coastal Barrier Resources System (CBRS) restrictions apply. Additional information may be found here.
      i. CBRS_Buffer_Zone_03122019_utm15N.shp – this layer is intended to be used with the CBRS polygons or CBRS prohibitions layers to illustrate the horizontal accuracy of the areas define in those layers
      ii. CBRS_Polygons_03122019_itm15N.shp - locations of each area designated under CBRS

iii. CBRS_Prohibitions_03122019_utm15N.shp - locations of each area designated under CBRS, including the dates on which prohibitions on federal flood insurance and other expenditures took effect

b. Breton_NWR_utm15.shp: Boundaries of the Breton National Wildlife Refuge management area

Recommended Next Steps

The inventory of stakeholder concerns is designed to support the BISM workflow by providing the project prioritization team with information on issues that may be relevant to project funding, implementation time, and short- and long-term success. As more quantitative tools are developed in support of BISM (i.e., the development of the Barrier Island Restoration Tradeoff Analysis (BIRTA) toolkit), the Stakeholder Inventory GIS database can be updated to interface directly with BIRTA so that potential costs or benefits of projects are incorporated into project prioritization analysis. For example, potential landownership issues may be flagged automatically for the team to consider in project planning timelines; the enhanced benefit projects located within wildlife refuges may provide to species are weighted in cost/benefit analysis; etc.

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APPENDIX D: DATABASE OF DATABASES AND INVENTORY OF OTHER AVAILABLE INFORMATION SOURCES

Introduction

One of the underlying principles of the Barrier Island System Management (BISM) program is to be data- and science-driven in prioritizing barrier island and headland restoration projects. This memorandum describes data sources that can be used in project prioritization and/or in informing future sediment needs for those projects.

There are two categories of information sources provided below. The first is a description of a Database of Databases that was developed for BISM under the leadership of CPRA with support from the U.S. Geological Survey (USGS). This database compiles resources that are directly relevant to BISM program implementation, capturing them in a single database for easy access in program implementation. As BISM evolves, the data contained within may be directly linked to quantitative analysis tools used in restoration alternative cost/benefit analysis.

The second section of the report describes other information sources that are not fully integrated into the Database of Databases (existing CPRA databases, tools, programs, etc.). The focus of this data inventory is on resources that provide coast-wide or regional information for informing project prioritization and/or use of sediment in restoration as part of a regional sediment management approach. In addition to these resources, there are numerous project-scale data collection and modeling efforts that can be used to evaluate the status or trajectory of individual barrier islands and headlands with and without coastal resources. Many of these resources are discoverable and accessible through the Coastal Information Management System (CIMS; https://cims.coastal.louisiana.gov/).

The last section of the report describes recommended next steps for the Database of Databases and how it can be enhanced to interface with the Barrier Island Restoration Tradeoff Analysis (BIRTA) Toolkit, a quantitative analysis framework that has been conceptually designed to support BISM.

Information Sources

Source 1: Database of Databases

The BISM database of databases consists of two geodatabases that were generated by CPRA and USGS. Included below are a description of the data and information contained within those databases (BISM.gdb and BISM_2.gdb). These databases are cross-cutting and include, or link to, resources that can be used in evaluating the current state of the barrier island system, its trajectory over time, and the performance of prior restoration activities.

BISM.gdb

This database contains information on previously conducted barrier island restoration projects and modeling work done in support of project planning. Barrier island projects and numerical models are housed separately and cross-linked where appropriate (BI_FeatureClasses)

- BI_Model_Domain_Points, BI_Model_Domain_Polys. Contains information on numerical modeling efforts that have been conducted for the barrier islands, including links to available reports.
- BI_Project_Pts, BI_Project_Polys. Contains information on barrier island restoration projects, including (where available) the year and amount of sediment placed, project objectives, project benefits, etc.

BISM_2.gdb

This database contains and/or links to a variety of data that may be useful for barrier island project prioritization, estimation of sediment or funding requirements, and/or project implementation.

1) Coastal Management Information
   a) MasterPlan_BI. Delineation of the barrier island regions managed under BISM
   b) CPRA BI Projects. Information on barrier island projects conducted by CPRA. In some cases this contains more detailed information than the barrier island points and polygons in the **BISM** geodatabase, such as borrow areas and types of vegetation planted. Includes:
      i) CPRA_BI_prj (polygon file, general information)
      ii) CPRA_BI_inf_ply (polygon file, more detailed information)
      iii) CPRA_BI_inf_arc (polyline information)
      iv) CPRA_BI_pt (point information)
2) Geophysical Data
   a) BICM_shorelines. Includes shorelines collected from the time periods of:
      i) 1855-1898
      ii) 1904-1952
      iii) 1996-1998
      iv) 2004
      v) 2005
   b) LGS_geology. Info characterizing surficial geology from the Louisiana Geological Survey.
   c) gSSURGO_soils. Data from the Gridded Soil Survey Geographic (gSSURGO) database.
   d) Monuments. Location of geodetic monuments (i.e., survey markers/benchmarks) placed by various organizations.
3) Ecosystem Data
   a) Habitat. Includes habitat information from USFWS including:
      i) USFWS Critical Habitat
      ii) USFWS National Wetland Inventory (NWI), 1988
      iii) Habitat_1956. National Wetland Inventory (NWI) from 1956.
      iv) Habitat_1978. National Wetland Inventory (NWI) from 1978.
   b) LDWF_oyster_seedground. Location of known oyster seedgrounds from the Louisiana Department of Wildlife and Fish (LDWF)
   c) LDWF_oysterlease_active_20200803. Locations of active oyster leases from the Louisiana Department of Wildlife and Fish (LDWF)
4) Demographic, Infrastructure, and Cultural Resource Information
   a) DOTD_parishes. Delineations of the Louisiana parishes from the Department of Transportation and Development (DOTD) office
   b) Oil_gas. Information on the location of pipelines and platforms from:
      i) Department of Natural Resources (DNR)
      ii) Louisiana Geological Survey (LGS)

iii) National Pipeline Mapping System (NPMS)
c) BOEM_offshore. Includes data from BOEM on the location of:
i) Offshore platforms
ii) Offshore pipelines
iii) Fairways
iv) Lease blocks
v) Active lease blocks
d) NOAA_wrecks_obstructions. Location of shipwrecks from the National Oceanic and Atmospheric Administration (NOAA)

5) Other
a) CRMS_sites. Location of the Coastwide Reference Monitoring System (CRMS) monitoring sites.
b) Quad100K_LOSCO_1999. Louisiana Oil Spill Coordinators Office (LOSCO) spatial delineations of Louisiana, 1:100,000 scale
c) Quad25K_LOSCO_1999. Louisiana Oil Spill Coordinators Office (LOSCO) spatial delineations of Louisiana, 1:25,000 scale
d) CPRA_monitoring. Location of other available data, most of which is available through the CIMS database (https://cims.coastal.louisiana.gov/).

Source 2: Other CPRA Databases, Tools, and Programs

General

1. Coastal Information Management System (CIMS). The CIMS database is the access point for most data and model output generated across programs within CPRA. It includes geophysical and ecological data, numerical model output, and links to reports with additional information (Raynie et al., 2020). It may be accessed here: https://cims.coastal.louisiana.gov/

Current Status of Barrier Island and Headland System

2. Barrier Island Status Reports. Each year, the CPRA creates a barrier island status report as part of the Annual Plan. These documents summarize the state of the barrier island and headland system and may be located and downloaded from https://coastal.la.gov/. An example of an annual report (from 2020) can be found at http://coastal.la.gov/wp-content/uploads/2017/04/AppB-FY20-Barrier-Island-Report.pdf.
3. Barrier Island Comprehensive Monitoring Program (BICM). The BICM program collects and analyzes shoreline change data for the state of Louisiana (Byrnes et al., 2018; Kindinger et al., 2013). BICM data are available through the CIMS database, above.

Prior and Proposed Restoration Alternatives

4. Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) priority project lists. The CWPPRA program priority lists include Louisiana coastal restoration projects at various stages of authorization and construction https://www.mvn.usace.army.mil/Missions/Environmental/CWPPRA/Priority-Project-Lists/ . In addition, a project viewer is available at https://lacoast.gov/new/Projects/Default.aspx.

Performance of Prior Restoration Projects

5. Barataria Basin Study: analysis quantifying and evaluating the performance of historical barrier island restoration projects for the Barataria Basin.
    a. Barataria Basin Restoration Program Performance Assessment (PPA). The PPA includes a comprehensive assessment of the performance of barrier island restoration projects within the Barataria Basin, including recommendations for metrics of evaluating coastal change and project performance (Royal Engineers and Consultants, LLC., 2020).
    b. Performance Assessment of Restoration Projects/Programs in the Barataria Basin, Louisiana: evaluation of the performance of prior restoration projects within the Barataria Basin (Royal Engineers and Consultants, LLC. & Coastal Engineering Consultants, Inc., 2019).
6. Teche, Lafourche, and Modern Delta Study: analysis quantifying and evaluating the performance of restoration projects within these delta regions, along with an inventory of available data and identifying of priority data gaps.
    a. Database Summary and Data Gap Analysis: a database was generating compiling and reviewing existing surveys and reports in spreadsheet format; high priority gaps are also summarized (Coastal Engineering Consultants, Inc., 2012a).
    b. Future Monitoring Recommendations: this report includes recommendations to improve future monitoring of the barrier island system (Coastal Engineering Consultants, Inc., 2012).
    c. Wetland Value Assessment Model Recommendations for Barrier Systems: evaluation of the Wetland Value Assessment (WVA) model for quantifying the benefits of barrier island restoration(Coastal Engineering Consultants, Inc., 2012c).
    d. Barrier System Performance Assessment: Evaluation of the performance of barrier island restoration based on analysis of shoreline change, land area, and other metrics (Coastal Engineering Consultants, Inc., 2012b).
7. CWPPRA Adaptive Management: evaluation of the performance of barrier island restoration projects constructed at Raccoon Island, Whiskey Island, Trinity Island, East Island, and East Timbalier Island (Penland et al., 2003).

Management of Barrier Islands and Headlands (Best Practice)

8. Breach Management Program. The breach management program was designed to guide decisions regarding management of breaches that form along the Louisiana barrier islands. It includes three components:
    a. Breach criteria and classification: This analysis includes shoreline change rates and storm erosion modeling and establishes minimum width and thresholds at which barrier islands become vulnerable to storms (Coastal Engineering Consultants, Inc., 2015a).
    b. Breach prevention: This report summarizes alternatives for preventing breaching in vulnerable regions of the Louisiana coast, including beneficial use projects and other sediment management approaches (Coastal Engineering Consultants, Inc., 2014).
    c. Breach response measures: This report builds on the inventory of breach response alternatives and measures and includes identification of potential partnerships and contract mechanisms for implementing the breach management program (Coastal Engineering Consultants, Inc., 2015b).

Regional Sediment Management

9. Louisiana Sediment Management Plan (LASMP). LASMP outlines a holistic approach to managing sediment within the Louisiana Coastal System (S. M. Khalil et al., 2010; Underwood, 2012). Several databases and tools have been developed to support implementation of LASMP, including:
    a. Louisiana Sand Resources Database (LASARD). Database containing sediment characteristics of surficial deposits throughout Louisiana Coastal Waters (Khalil et al., 2016). Database Link: https://www.arcgis.com/apps/MapSeries/index.html?appid=65cca038794d4ded8daaec8e6fb1a3ae
    b. Surficial Sediment Distribution (SSD) Map. Map delineating surficial sediment surface deposits for reconnaissance purposes (Khalil et al., 2018).
    c. Louisiana Sediment Availability and Allocation Program (LASAAP). Pilot tool developed to optimize use of sediment sources in coastal resources, initial developed for the Barataria Basin region (Aptim Environmental & Infrastructure, Inc. (APTIM), 2020).
10. Regional Sediment Transport and Sediment Budget Analyses. Several studies have analyzed sediment transport patterns and/or created sediment budgets for the Louisiana coast on a region scale:
    a. Operational Sediment Budget (OSB). The OSB includes a sediment budget analysis for coastal Louisiana from Racoon Point to Sandy Point, calculated over the periods of 1985-1989 and 2013-2016 (Applied Coastal Research & Engineering, 2020).
    b. Hurricane impacts. Shoreline change analyses for historical periods and as a result of Hurricanes Katrina and Rita have been generated for the Louisiana coast from Raccoon Point to Sandy Point (Coastal Engineering Consultants, Inc., 2013).
    c. Sediment dynamics, Belle Pass to Sandy Point. This analysis evaluates sediment transport over the portion of the Louisiana Coast between Belle Pass and Sandy Point (Georgiou, Ioannis Y. et al., 2010).
11. Northern Gulf Sand Availability and Allocation Program (NGSAAP). This ongoing effort will expand the spatial coverage of the LASAAP tool and expand its usage to include, for example, characteristics of available sediment beyond surficial sediment data.

Recommended Next Steps

The Database of Databases has been developed to support the current BISM workflow, which is based on expert elicitation[15]. As more quantitative tools are developed in support of BISM, such as the development of the Barrier Island Restoration Tradeoff Analysis (BIRTA) Toolkit, the database of databases can be modified to interface with that toolkit and provide direct linkage with existing CPRA tools and models. For example, sediment resources are already identified as part of the LASARD database; the database of databases can serve as a link for accessing that data and incorporating it into BISM analysis of best use of available sediment across multiple restoration projects. Similarly, data collected under BICM can be used linked to BIRTA through the database of databases and used to automatically update metric-based assessment of the current state of the coastal system.

[15] Expert elicitation is a structured process for deriving information and predictions about how a system will respond by surveying individuals with relevant expertise (Gregory et al., 2012).

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APPENDIX E: WORKFLOW IMPLEMENTATION STEP-BY-STEP GUIDE

A step-by-step manual and implementation guide has been developed to facilitate the implementation of the BISM workflow in practice and is included in this appendix. Supporting materials for use in implementation (e.g., Excel worksheets) have been provided separately.

Workflow Step	Product	Process
1. Articulate Objectives	Updated coastal system restoration objectives (documented in Word)	Discuss and confirm during working group meeting #1 (WGM1)
2. Assess the System	Coastal condition assessment (documented in Excel)	Individual input elicited ahead of WGM1, discussed during WGM1
3. Articulate Options	List of potential restoration project alternatives (documented in Excel)	Individual input elicited ahead of WGM2, discussed during WGM2
4. Identify Consequences	Prediction of the trajectory of each potential restoration site (documented in Excel); begin identification of priority data gaps (documented in Excel)	Individual input elicited ahead of WGM3, discussed during WGM3
5. Prioritize Projects	Prioritized list of restoration projects that will be pursued for immediate action (documented in Excel)	Individual input elicited ahead of WGM4, discussed during WGM4
6. Estimate Future Resource Needs	Inventory of gaps in sediment and/or funding available to support future restoration action (documented in Word); identification of priority data gaps (documented in Excel)	Individual input elicited ahead of WGM4, discussed during WGM5

Preparation for WGM1

1. Identify the participants for the BISM project prioritization working group.
    a. It is recommended that the same team members participate in all stages of the workflow.
    b. The steps will include four working group meetings, each approximately 2 hours long, with team members filling in preparatory worksheets (Excel spreadsheets) ahead of each meeting.
    c. A fifth WGM will focus on longer-term planning, RSM, sediment resource needs, and data collection. This WGM should have representation from the BISM project prioritization working group.
2. Schedule WGM1 and send out materials to the team members (CoastalConditionWorksheet.xlxs and Instructions_for_Team, found in the “ForTeam” folder of “WGS1_Objectives_Assessment” in the Workflow package. In addition, the *“BISM Executive Summary”* should be provided for context.)

3. Ask participants to submit their scoring worksheet (numeric values) ahead of WGM1 (see schedule).
4. Compile input from individuals and calculate an initial mean raw score for each metric. This can be done by cut and pasting individual scoresheets as new sheets in “CoastalConditionMasterSheet.xlsx” and updating the formulas as indicated within the spreadsheet.

Working Group Meeting 1: Objectives and Coastal State Assessment

During this meeting, the team will reach consensus on objectives and the coastal state assessment. Because this is the first time through the workflow, the process and workflow specifics (e.g., the regional cell and barrier island delineations, etc.) may be a point of discussion. Suggestion is to keep the first round of prioritization moving forward as-is as much as possible and note potential updates for future rounds.

1. Barrier Island and Headland Restoration Objectives – team members should have reviewed the objectives ahead of the meeting, so this is opportunity for comments/suggestions/group discussion. Objectives were recently refined during BISM product development, therefore suggest that the team lead/facilitator keep this discussion short and very focused (5-10 minutes).
2. Coastal State Assessment – team members should have completed their own numerical assessment of the cells/islands and have it in hand, along with notes. Suggested workflow:
    a. Going cell-by-cell, assigning a consensus descriptor value for each cell and associated units before moving to the next unit.
    b. Team lead start discussion by showing the calculated mean values (“CoastalConditionMeanValues” sheet in “CoastalConditionMasterSheet.xlsx”) and noting if there was considerable variation across team member input.
    c. Allow each team member an opportunity in turn to provide rationale for their answer.
    d. Denote the consensus score for each coastal cell and a unit in the “CoastalConditionConsensusValues” sheet within “CoastalConditionMasterSheet.xlsx”.
    e. Based on a two-hour workshop with some time for objective discussion and workshop close out, there will be approximately 25 minutes to discuss each of the coastal cells.

Meeting outcomes:

- Consensus on fundamental objectives
- Consensus evaluation of coastal system state (in the “CoastalConditionConsensusValues” sheet within “CoastalConditionMasterSheet.xlsx”)

Between WGM1 and WGM2

1. Schedule WGM2 and send out materials to team members:
    a. Consensus coastal system state scores from WGM1 (“CoastalConditionMasterSheet.xlsx”, “Coastal ConditionConsensusValues” sheet)
    b. “RestorationAlternativeWorksheet.xlsx” and “InstructionsForTeam” (in WGM2_Retoration_Alternatives/ForTeam folder)
2. Ask participants to submit their proposed restoration alternatives ahead of WGM2 to allow for collation (see schedule).
3. Compile input from individuals into a master restoration alternative list. This can be done by cut and pasting into the “RestorationAlternatives (Raw)” Sheet in

“RestorationAlternativemaster.xlsx”. After compiling, short IDs should be assigned for reference. The alternatives can be grouped by coastal cell to facilitate discussion.

4. Fill in missing data where possible, such as the approximate sediment need for each alternative. Prior restoration volumes may be used to inform these quantities.

Working Group Meeting 2: List of Restoration Alternatives

The focus of this meeting is on identifying a list of restoration alternatives for consideration and evaluation. The identification of alternatives during the first round of the workflow is expecting to take more time than it will in subsequent iterations of the workflow. Because this process is being done through expert elicitation[16], a short list of preferred alternatives for further consideration will be identified during this meeting.

1. Restoration Alternatives
    a. Using the consolidated list of restoration alternatives (“RestorationAlternatives (Raw)” Sheet in “RestorationAlternativemaster.xlsx”) and working cell-by-cell, develop an updated list of restoration alternatives for consideration through team discussion.
    b. Potential modifications to the alternatives list may include adding, combining, or modifying alternatives.
    c. Be sure the team completes all columns in the worksheet, systematically identifying potential sand sources and other project considerations.
    d. Note that the team lead/facilitator should keep the discussion focused on potential restoration alternatives and keep the team from moving immediately to “picking favorites” or prioritizing.
    e. Based on a two-hour workshop, there will be approximately 30 minutes to discuss each of the coastal cells.
2. Determine a list of restoration alternatives for in-depth consideration and prioritization. Ideally, all alternatives would be considered. **Because the workflow relies on expert elicitation of project effects and this is the first iteration through the workflow, however, the list of potential alternatives may be too long to evaluate all of them.** The team should achieve consensus on a realistic number of potential alternatives to carry forward to the next step, considering:
    a. Potential desire to focus on one region of the coast in support of other restoration projects (e.g., wave attenuation to protect marsh/wetland building projects) or to rebuild sediment connectivity in one reach of coast
    b. Short- and long-term impacts of potential restoration alternatives
    c. Sediment availability in known borrow areas
    d. External factors that may influence (diminish) restoration project success
3. The final short-list of restoration alternatives can be housed in the “RestorationAlt(Consensus) sheet of “RestorationAlternativeMaster.xlsx”

Meeting outcomes:

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[16] Expert elicitation is a structured process for deriving information and predictions about how a system will respond by surveying individuals with relevant expertise (Gregory et al., 2012).

- Consensus list of potential restoration alternatives, in the "RestorationAlt(Consensus) sheet of "RestorationAlternativeMaster.xlsx"

Between WGM2 and WGM3

1. Prepare participant worksheets: cut and paste the restoration alternatives for evaluation into the first three columns of the "ConsequenceAnalysisWorksheet.xlsx". (Note that the formatting of the cells for the team to fill out should become highlighted).
2. Schedule WGM3 and send out materials to team members:
    a. Consensus coastal system state scores from WGM1 (in the "CoastalConditionConsensusValues" sheet within "CoastalConditionMasterSheet.xlsx")
    b. Consensus list of restoration alternatives from WGM2 (in the "RestorationAlt(Consensus) sheet of "RestorationAlternativeMaster.xlsx")
    c. "ConsequenceAnalysisWorksheet.xlsx" (updated per (1) above) and "InstructionsForTeam" (in WGM3_Consequence_Assessment/ForTeam folder)
    d. "PriorityDataGaps.xlsx". This will be used for team members to note priority areas of data collection and/or modeling.
3. Ask participants to submit their consequence analysis and priority data gaps assessment ahead of WGM3 to allow for collation (see schedule).
4. Compile input from individuals and calculate an initial mean raw score for each metric/alternative. This can be done by cut and pasting individual scoresheets as new sheets in "ConsequenceAnalysisMaster.xlsx" and updating the formulas as indicated within the "ConsequenceAnalysisMean" sheet.
5. The team lead should familiarize themselves with the priority data gaps identified by the team members as limiting to robustly predicting the evolution of the coast with and without action, particularly if it impacts the potential success of projects.

Working Group Meeting 3: Evaluation of Consequences of Alternatives

The focus of this meeting will be estimating the likely consequences of alternatives on the coastal system (regional and local). Priority data gaps will be discussed insofar as they limit assessment of future with and without action.

1. Consequence Analysis
    a. Going alternative-by-alternative, assigning a consensus descriptor value for each cell and associated units before moving to the next restoration alternatives. The team lead should raise any location-specific concerns for data gaps or uncertainty in how a restoration alternative will respond that team members included in the submitted "PriorityDataGaps.xlsx" spreadsheets. (Note that these gaps should not automatically exclude a project but should be integral to the prioritization discussion).
    b. Team lead start discussion by showing the calculated mean values ("ConsequenceAnalysisMean" sheet in "ConsequenceAnalysisMaster.xlsx") and noting if there was considerable variation across team member input.
    c. Allow each team member an opportunity in turn to provide rationale for their answer.
    d. Denote the consensus score for each coastal cell and a unit in the "ConsequenceAnalysisConsensus" sheet within "ConsequenceAnalysisMaster.xlsx".

e. After discussion, note concerns on priority data gaps or modeling that would be needed to robustly assess the system with or without restoration in the "PriorityDataGapsMaster.xlsx" spreadsheet for future use (for consideration under BICM data collection or elsewhere).
f. Based on a two-hour workshop with some time for objective discussion and workshop close out and assuming ~6 restoration alternatives under consideration, there will be approximately 20 minutes of discussion per alternative.

Meeting outcomes:

- Consensus list of impacts of restoration alternatives (in the "ConsequenceAnalysisConsensus" sheet within "ConsequenceAnalysisMaster.xlsx")
- Identification of priority data gaps or modeling needs (in the "PriorityDataGapsMaster.xlsx" worksheet)

Between WGM3 and WGM4

1. Prepare participant worksheets:
   a. Cut and past the short list of alternatives into "PrioritizationWorksheet.xlsx" (from "RestorationAlt(Consensus)" sheet of "RestorationAlternativeMaster.xlsx"). Note that the first column in the new worksheet is the ranking column that participants will be filling out, so the alternative info will go into columns B-K.
   b. Fill in the "SedimentResourceInformation" Sheet with approximate sediment volumes available for each borrow area that has been tentatively identified as a sediment source for one or more of the restoration alternatives. This information may be available through the LASARD database. In addition, sum over the approximate sediment volume needs over the restoration alternatives that are flagged as using that source.
2. Schedule WGM4 and send out materials to team members:
   a. Consensus coastal system state scores from WGM1 (in the "CoastalConditionConsensusValues" sheet within "CoastalConditionMasterSheet.xlsx")
   b. Consensus list of restoration alternatives from WGM2 (in the "RestorationAlt(Consensus) sheet of "RestorationAlternativeMaster.xlsx")
   c. Consensus evaluation of impacts of restoration alternatives on the coast (in the "ConsequenceAnalysisConsensus" sheet of "ConsequenceAnalysisWorksheet.xlsx"
   d. Priority data and/or modeling gaps (i.e., critical uncertainties) (in the "PriorityDataGapsMaster.xlsx" spreadsheet)
   e. "PrioritizationWorksheet.xlsx" (updated per (1) above) and "InstructionsForTeam" (in WGM4_ProjectPrioritize/ForTeam folder)
3. Ask participants to submit their prioritized list of alternatives ahead of WGM4 to allow for collation (see schedule).
4. Compile input from individuals and calculate an initial mean ranking for each alternative. This can be done by cut and pasting individual scoresheets as new sheets in "PrioritizationWorksheetMaster.xlsx" and updating the formulas as indicated within the "AltPrioritizationMean" sheet.

Working Group Meeting 4: Prioritization of Restoration Alternatives and Sediment Source Identification

The short list of preferred restoration alternatives will be ranked and prioritized at this stage. In addition, sediment sources for each project will be refined and revised based on the complete list.

1. Prioritization of Projects: using the mean ranking as a starting place, discuss each of the alternatives and their prioritization.
    a. The team lead should review the factors for consideration (see below) ahead of discussion prioritization, so the team has these in mind during the discussion.
    b. The mean ranking scores may be used to identify alternatives with immediate consensus as being the highest-priority or lowest priority restoration project. These can be noted in the "AltPrioritizationConsensus" sheet, with discussion focused on the more contentious alternatives.
    c. The prioritized projects should each have a sediment source identified; projects for which no sediment source can be identified should be deprioritized.
    d. Based on a two-hour workshop with some time for objective discussion and workshop close out and assuming ~6 restoration alternatives under consideration, there will be approximately 20 minutes of discussion per alternative.

Factors for consideration in ranking alternatives:

- **Benefit of each restoration alternative.** This assessment is based on considering the difference between the value descriptors for the current state of the coast (found within the "CoastalConditionConsensusValues" sheet in "CoastalConditionMasterSheet.xlsx") and their project value with project implementation ("ConsequenceAnalysisConsensus" sheet of "ConsequenceAnalysisWorksheet.xlsx"). This difference captures the improvement (benefit) each alternative is providing.
- **Cost of each restoration alternative.** The benefit each restoration alternative is providing should be benchmarked against its cost in terms of both funding and sediment. Projects that require substantial resources and do not provide correspondingly high benefit should be deprioritized (information within "PrioritizationWorksheet.xlsx").
- **Value of coastal cells and barrier island/headland units impacted by the restoration alternatives**. In addition to the differential benefit each restoration alternative is providing, the overall value of individual barrier islands and headlands as they relate to the fundamental objectives may be considered.
- **Tipping points.** Islands that are in a degraded state and on a rapid trajectory for loss may need to be prioritized for restoration action to prevent additional land loss.
- **Alternative portfolios.** The potential value of combinations of individual projects might produce greater cumulative benefit if executed concurrently than they would if done sequentially over several years.
- **Alongshore sediment connectivity.** Consider the downstream impacts of restoration alternatives given that projects that enhance the sediment connectivity of the coastal system are more likely to have sustained, long-term benefit. The impacts of local and upstream management actions on an alternative should also be considered. Sustained sediment supply to a restoration alternative can potentially positively enhance its value by increasing its long-term sustainability, whereas local or upstream coastal hardening may have the opposite effect.

- **Uncertainty.** If there is considerable uncertainty in the success of a restoration project, it may be advisable to focus efforts in that region on data collection and/or preliminary modeling rather than moving to the E&D phase.

Meeting outcomes:

- Prioritized ranking of barrier island restoration projects (in the "AltPrioritizationConsensus" sheet within "PrioiritizationWorksheetMaster.xlsx")

WGM5 is focused on advancement of adaptive management and use of RSM principals within BISM and extends the planning horizon for BISM beyond the prioritization of projects in the near-term. Topics include assessing regional sediment availability and needs, priority data and/or modeling that could inform best-use of sediment, and long-term planning. It is recommended that this WGM be coordinated with the LASMP and BICM programs. If this team includes representatives that were not a part of the original project prioritization team, it is recommended that they be provide the "BISM Executive Summary" for review.

Working Group Meeting 5: Long-term RSM, Sediment resource availability, and Data/Modeling Needs

1. Regional sediment availability, best-use of available sediment, and priority data collection and modeling needs. On a basin-by-basin basis:
    a. Present the assessment of the state of the coastal system using the coastal condition spreadsheet ("CoastalConditionConsensusValues" from "CoastalConditionMasterSheet.xlsx") and discussion from WGM1
    b. Present the complete list of restoration alternatives identified in WGM2 ("RestorationAlt(Consensus)" sheet in "RestorationAlternativeMaster.xlsx") and the consequence analysis from WGM3 ("ConsequenceAnalysisConsensus" sheet in "ConsequenceWorksheetMaster.xlsx")
    c. Present the uncertainties and priority data/modeling needs identified in WGM3 ("PriorityDataGapsMaster.xlsx").
    d. Present sediment volumes available within borrow areas (nearshore, offshore, riverine). Existing expertise should be leveraged (e.g., slides could be prepared ahead of time denoting sediment borrow areas identified in LASMP), which can be used to update the "SedimentResources" tab of the "LongTermRSMMaster.xlsx" worksheet).
    e. Discuss best-use of sediment on a regional basis for long-term maintenance of the barrier island system. Also discuss sediment gaps based on the list of alternatives (e.g., if/when future investment in sand source identification is merited). Document this discussion in notes, include specific identification of best use of available sediment. This can be done in a revised Restoration Alternative spreadsheet ("RSM_LongTerm" in "LongTermRSMMaster.xlsx"
    f. Revise and update the priority data gaps and modeling and provide to BICM for consideration; this can be done in "PriorityDataGaps" in "PriorityDataGapsRSMMaster.xlsx".
    g. Based on a two-hour workshop, there will be approximately 30 minutes of discussion per basin.

Meeting outcomes:

- Identification of sediment sources for restoration alternatives in the longer-term as part of RSM (in the "LongTermRSMMaster.xlsx")
- Identification of priority data gaps or modeling needs (in the "PriorityDataGapsRSMMaster" worksheet)

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