RESTORE
SCIENCE PROGRAM

Structured Decision Making to Co-Produce an Actionable Science Plan in Support of

Louisiana, Mississippi, Alabama Coastal System Water Quality Management

Research and Development Plan

P. S. DALYANDER, G. RAMSEUR, J. PAHL, D. AVERION, A. LINHOSS, M. MINER, P. MICKLE

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LIST OF ACRONYMS

Acronym	Term
ADCNR	Alabama Department of Conservation and Natural Resources
D3D-FM	Delft3D-Flexible Mesh
DEM	Digital Elevation Model
FWOA	Future without Action
GOMA	Gulf of Mexico Alliance
HAB	Harmful Algal Bloom
HSI	Habitat Suitability Index
LCPRA	Louisiana Coastal Protection and Restoration Authority
LMACS	Louisiana, Mississippi, Alabama Coastal System
MDMR	Mississippi Department of Marine Resources
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
PrOACT	Problem, Objectives, Alternatives, Consequences, Tradeoffs
QAQC	Quality Assurance and Quality Control
RESTORE	Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies
RM	Resource Manager
SDM	Structured Decision Making
SME	Subject Matter Expert
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

The Mississippi Department of Marine Resources (MDMR), Louisiana Coastal Protection and Restoration Authority, Alabama Department of Conservation and Natural Resources, and other state and federal agencies along the northern Gulf of Mexico have a shared goal to sustain and improve regional water quality and estuarine/marine habitat within the Louisiana, Mississippi, Alabama Coastal System (LMACS). These entities must identify and implement opportunities that advance this goal but avoid negative impacts to other regional objectives such as flood risk management. Despite having shared needs in the LMACS region, there are limited mechanisms for interagency collaboration. Implementation is further complicated because the LMACS environmental system spans multiple political boundaries. In addition, there is considerable uncertainty in how the LMACS will respond to actions that could potentially improve water quality. A co-production effort of resource managers (RMs) and researchers, supported by 2021 NOAA Restore Science Program funding and executed through a series of workshops, was conducted to address these challenges by 1) identifying critical uncertainties that limit effective water quality management in the LMACS; 2) devising a Research and Development Plan (this document; hereafter, "*Research Plan*") for reducing those uncertainties; and 3) formulating an application plan (*Structured Decision Making to Co-Produce an Actionable Science Plan in Support of Louisiana, Mississippi, Alabama Coastal System Water Quality Management: Application Plan*; hereafter, *"Application Plan"*) that establishes a framework for interagency collaboration and supports the integration of research results into management action (Figure 1).

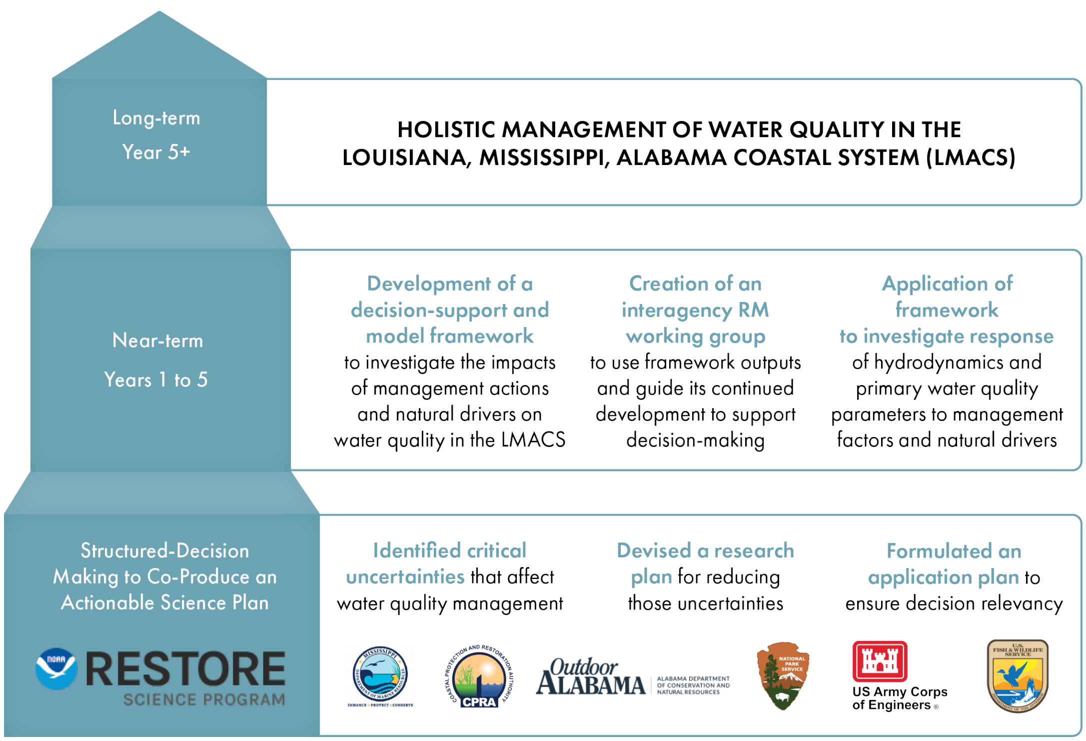

Figure 1. A collaborative, co-production approach that brought together resource managers and researchers (bottom tier) was used to develop research (this document) and application plans. The near-term objectives (middle tier) are designed to serve as the foundation for advancing a long-term goal of more holistic management of the LMACS (top tier).

The **natural resource management decision** that these plans support is selecting which restoration projects or other management actions for improving water quality and estuarine habitat are pursued for permitting in the LMACS. The associated question being asked is: *how can we advance a transboundary, project-oriented planning approach to maximize estuarine water quality and habitat suitability for associated species while also enhancing co-benefits including reducing the risk of Harmful Algal Blooms (HABs), maximizing the extent of coastal habitat, and reducing flood risk for coastal communities*?

Through the workshops, the RMs identified two needs: 1) developing a numerical model-based decision-support framework to investigate the impacts of potential management actions and natural drivers on water quality in the LMACS, and 2) creating an interagency RM working group to use framework outputs to support decision-making. There are numerous management decisions and associated uncertainties this framework could reduce. Therefore, this document and the *Application Plan* were developed with the objectives of establishing a numerical model-based decision support framework that could support near-term management decisions, while also providing the foundation for continued LMACS management in the long-term (5+ years). The near-term focus is to identify the relative impact of factors that could be influenced through management action on water quality in the LMACS given natural variability and trends in environmental factors. This research will guide RMs in identifying projects to pursue in support of improving water quality and habitat suitability for species of ecological and economic importance, such as oysters. More details on the RM working group and integration of the framework into decision-making may be found in the *Application Plan.*

This *Research Plan* outlines the development of a decision-support model to investigate the impact of potential restoration projects on water quality in LMACS. The project will begin with a review of available literature and data relevant to water quality conditions and response to natural and anthropogenic drivers in the LMACS. A numerical model framework, chosen based on criteria identified by the RMs and with implementation led by the USGS, as a federal science agency capable of providing long-term hosting and support, will be used to evaluate the impacts that scenarios that present varied natural and anthropogenically influenced factors have on hydrodynamics and primary water quality variables of salinity and temperature. These scenarios will be finalized after facilitated discussion of the RM working group but are likely to include increasing the integrity and continuity of the northern Gulf of Mexico barrier island and marsh system, changing freshwater inflows and/or navigation channel alignments or locations, and investigating the impacts of environmental factors including relative sea level rise, seasonal variability, and storms. As the near-term phases of the effort finish, the focus will shift to identifying pathways of continued research and interagency decision-making support that can leverage and expand from the initial effort in the long term.

1. NATURAL RESOURCE MANAGEMENT DECISION AND RELATED RESEARCH QUESTIONS

The Mississippi (MS) Department of Marine Resources (MDMR), Louisiana Coastal Protection and Restoration Authority (LCPRA), Alabama Department of Conservation and Natural Resources (ADCNR) and other management entities with authority in the Louisiana, Mississippi, Alabama Coastal System (LMACS; Figure 2) have a goal to sustain and improve water quality and habitat for estuarine/marine resources, which includes oysters as a keystone species. MDMR has had a strong focus on this topic in recent years. Ninety percent of Mississippi's historic oyster production has been from the western Mississippi Sound near the Louisiana border. This fishery has been in protracted decline for over a decade and has been closed for the past three years (Figure 3). Improving water quality in the LMACS to sustain a robust estuarine system, including one that can support a healthy oyster population, will require bold restoration and management action. Finite funds exist for this purpose; therefore, resource managers must decide what restoration actions to select for multilateral consideration, development, and permitting based on scientific evidence of local and/or regional benefits.

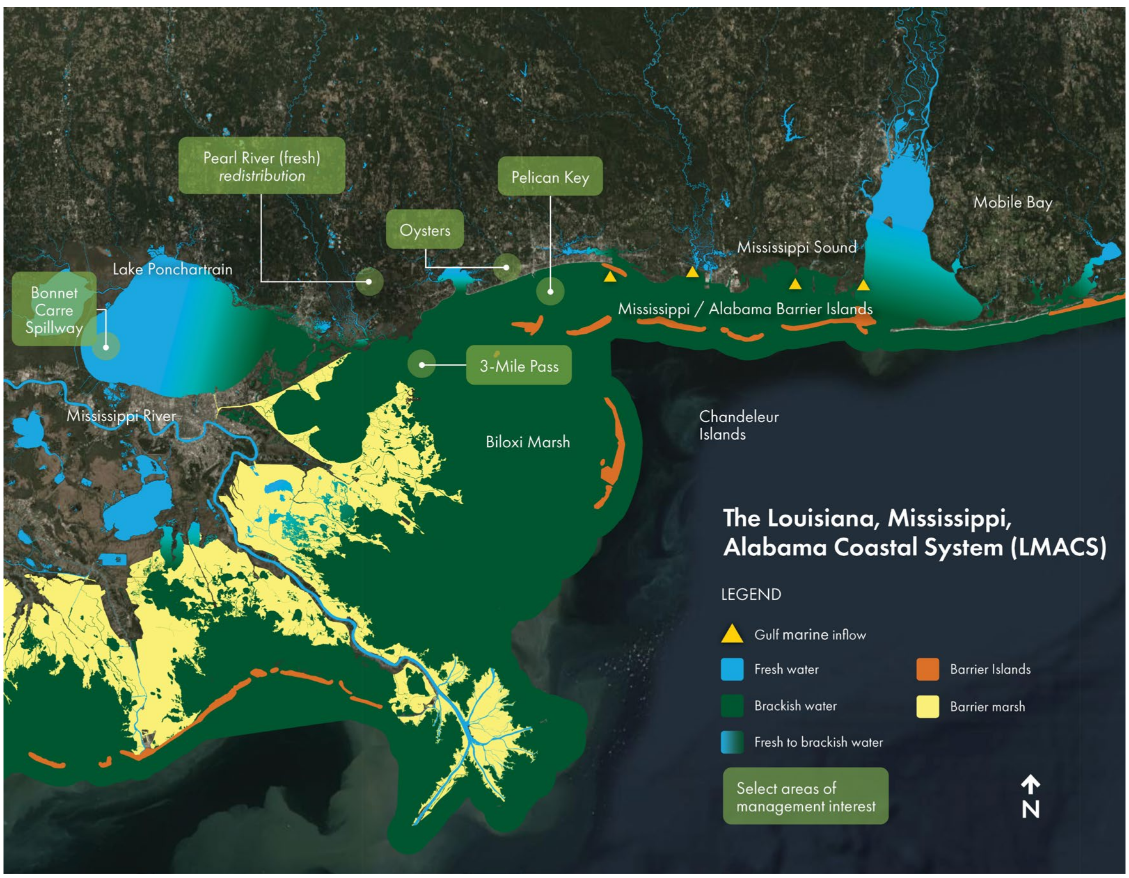

Figure 2. The Louisiana, Mississippi, Alabama Coastal System (LMACS) is a science planning domain defined by geomorphic and hydrodynamic boundaries that can be manipulated by traditional restoration practices such as rebuilding landforms.

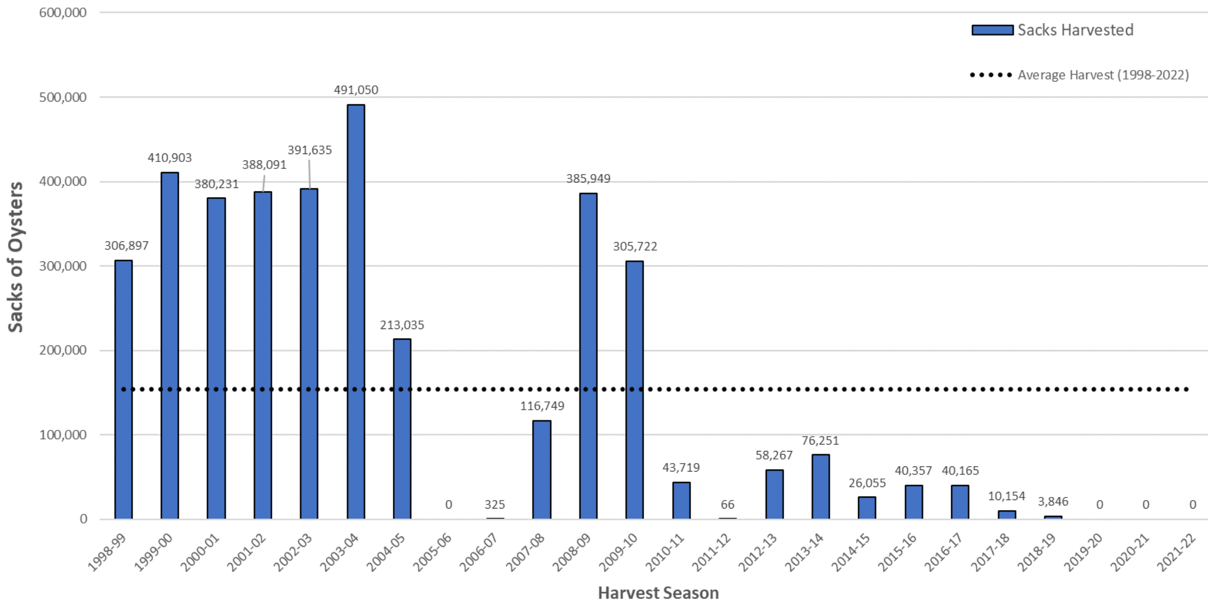

Figure 3. Time series of the Mississippi (MS) oyster harvest from public reefs between the harvest seasons (October through April) of 1998–1999 and 2021–2022. Provided by MDMR.

These decisions are hampered by the complexity of the environmental system as well as uncertainty in how it will respond to management actions such as changing the distribution and volume of freshwater inputs and altering exchange between the estuarine system and the Gulf of Mexico through the barrier island and marsh system. In addition, the management landscape of the LMACS is as complex as the natural environment, further complicating the implementation of projects to improve water quality in the region. For example, the proximity of Mississippi Sound to the Louisiana border dictates that some priority restoration projects of value to the State of Mississippi may be within Louisiana waters. Federal agencies such as the U.S. Army Corps of Engineers (USACE) and U.S. Fish and Wildlife Service (USFWS) also play key roles in LMACS management through their regulatory oversight, while multiple barrier islands that regulate conditions in the estuary are under the purview of the National Park Service (NPS) as part of Gulf Islands National Seashore or, in the case of the Chandeleur Islands, USFWS as part of the Breton National Wildlife Refuge. Research and tools to support decisions made to enhance water quality in the LMACS and improve habitat for keystone species, such as oysters, must be developed and applied within the context of this interagency decision-making context.

An additional complexity is that some management actions that could improve water quality, such as altering operation of the Bonne Carré Spillway to change freshwater input to the LMACS, might produce unacceptable effects for state and regional objectives like flood risk mitigation. Tools are therefore needed that can evaluate the tradeoffs associated with potential management actions and identify strategies that produce the maximum benefit to water quality as well as other regional objectives while minimizing negative ancillary effects. In some cases, potential management strategies that could benefit water quality and species viability within the LMACS may be unimplementable due to constraints (federal or individual state policies, regulations, etc.). In these cases, tools are needed for identifying the best possible outcome for water quality and species viability within the context of practically implementable alternatives.

For these reasons, representatives from three state agencies (MDMR, LCPRA, ADCNR) and three federal agencies (USACE, USFWS, and NPS) were brought together as part of a resource manager (RM) advisory group to inform what uncertainties were most critical to resolve—and what specific form research products should take—to provide the most decision-relevant information for improving water quality in the LMACS system. In addition, subject matter experts (SMEs) with expertise in water quality, geomorphology, hydrodynamics, and oysters helped identify uncertainties and research questions that they considered relevant to supporting management decisions. This information was elicited through a facilitated structured decision-making (SDM) process (Figure 4). SDM consists of a sequence of decision-making steps including articulating the Problem and Objectives, identifying Alternatives, evaluating the Consequences of those alternatives, and considering Tradeoffs (PrOACT; Gregory et al., 2012).

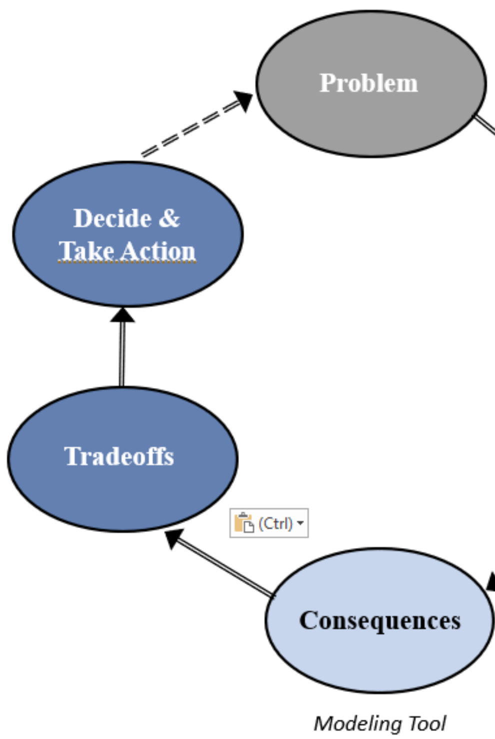

Figure 4. The PRoblem, Objectives, Alternatives, Consequences, and Tradeoffs & Optimization (PrOACT) cycle, with solid black arrows indicating initial application and dashed black arrow indicating adaptive management. Figure modified from https://www.usgs.gov/centers/eesc/science/structured-decision-making, J. Cochrane.

The natural resource management issues addressed with this plan were refined through a series of facilitated workshops with LMACS RMs and SMEs to complete the first three steps in PrOACT (gray ellipses in Figure 4): articulating the Problem (the water quality and estuarine species management issues for the LMACS), Objectives (desired outcomes for the region, including co-benefits for other interests), and Alternatives (potential management actions that could be taken to improve water quality and estuarine habitat). The research questions and methodology were developed based on uncertainties in predicting the potential Consequences of management alternatives (light blue ellipse in Figure 4). The remaining PrOACT steps are considering the tradeoffs associated with the predicted consequences and an MDMR-led, interagency supported decision on what management actions to pursue for planning and feasibility analysis (dark blue ellipses).

The **natural resource management decision** being made is identifying which restoration projects or other management actions to pursue for permitting in order to improve water quality and estuarine habitat in Mississippi Sound, and the associated question being asked is: *How can we advance a transboundary, project-oriented planning approach to maximize estuarine water quality and habitat suitability for associated species while also enhancing co-benefits including reducing the risk of Harmful Algal Blooms (HABs), maximizing the extent of coastal habitat, and reducing flood risk for coastal communities*?

Primary Management Question Articulated by State and Federal Resource Managers
What opportunities exist to manage freshwater, saltwater, sediment, and the coastal landscape so that water quality (salinity, biochemical stability, turbidity, dissolved oxygen, harmful algal blooms, etc.,) and habitat (estuarine, barrier island, and marsh) across the LMACS are improved while enhancing co-benefits and/or minimizing negative impacts to communities and commerce (e.g., flood risk reduction, cost of navigation channel maintenance)?

Over a dozen specific actions have been identified to date by the RM and SME groups as potential ways to improve water quality in the LMACS and increase the population of oysters within Mississippi Sound. The potential management actions were grouped in a set of five high-level alternatives that included:

Modification of freshwater input into the LMACS;

Preservation and restoration of barrier island and barrier marsh integrity;

Preservation and restoration of mainland marshes;

Direct restoration of oysters and historic reef structures;

Nutrient input management, and

Potential navigation channel realignment or modification.

The research questions and approach, as well as the design of a decision-support framework to facilitate incorporating that research into management application, were developed by beginning the "identifying Consequences" step in PrOACT. Using the potential management actions as a lens, the RMs and SMEs were asked to

1. Consider what the outcomes (i.e., consequences) of these alternatives would be;
2. Identify existing data, tools, and studies relevant to those predictions; and
3. Articulate what uncertainties most limited robustly predicting alternative outcomes.

Dozens of uncertainties that were identified in how water quality and oyster resources in the LMACS would respond to the potential alternatives, including unknowns in how climate change will impact precipitation and freshwater inflow from rivers; the influence of barrier island and barrier marsh erosion on water quality in Mississippi Sound; and the relative impact of freshwater inflows (rivers, diversions, spillways) on salinity and temperature in the LMACS.

It was apparent based on this breadth of input from the RMs and SMEs that a science-based decision support framework is needed to support holistic management of habitats and species within the LMACS. In addition, **a numerical model-based decision support framework that can analyze the effects of portfolios of projects on a wide range of environmental factors across the LMACS would be of considerable value in supporting LMACS management**. Lastly, the workshop input reinforced that interagency coordination is necessary to ensure that research is decision-relevant and is feasible and actionable, meaning that it can be successfully transitioned through the permitting process and into application. Addressing these needs will require sustained, long-term coordination of federal and state agencies, as well as resolving the full breadth of uncertainties in how the LMACS and associated species such as oysters will respond to potential management actions.

For that reason, this document and the associated *Structured Decision Making (SDM) to Co-Produce an Actionable Science Plan in Support of Louisiana, Mississippi, Alabama Coastal System (LMACS) Water Quality Management: Application Plan (*hereafter*, Application Plan)* consider several time scales of implementation. The long-term (5+ years) vision is catalyzing a new paradigm in management of the LMACS under which multiple states and federal agencies collaborate to identify and implement management actions that improve water quality; increase habitat for marine, estuarine, and terrestrial species; reduce the risk of HABs; and enhance the resiliency of coastal communities in this region. This vision would be supported by the development and utilization of a numerical model-based decision support framework to address a wide range of uncertainties about the LMACS region. In addition, an interagency RM working group will be created that will use that framework to determine if management actions that provide holistic benefits to the region can be identified. In the long term, this group can use the decision support and model framework to address the full breadth of management questions and related uncertainties identified during the workshops, with the focus evolving based on agency priorities and increased understanding of the LMACS system.

The long-term vision and associated activities are referenced throughout this document and the *Application Plan.* However, the primary focus within these documents is on the near-term (1–5 year) priority of establishing a foundation for that long-term vision. This includes the creation of the interagency RM working group (Figure 5), which builds on the RM advisory group engaged in the planning workshops; developing a decision support and model framework that can address priority, management-relevant uncertainties about the LMACS in the next 5 years, while also having the flexibility to be readily extended to address future research questions and management needs; and the application of that framework to address priority areas of uncertainty identified for the LMACS. The areas of uncertainty that will be addressed in the near-term are how management strategies can influence *hydrodynamics, salinity*, and *temperature* in Mississippi Sound. This initial focus was chosen because hydrodynamic conditions within the LMACS are a primary control on the system that influences all factors relevant to habitat suitability (e.g., turbidity, dissolved oxygen, nutrient load, etc.). Specifically, salinity and temperature are primary water quality variables that must be within tolerable ranges for oyster populations to recover and be sustained.

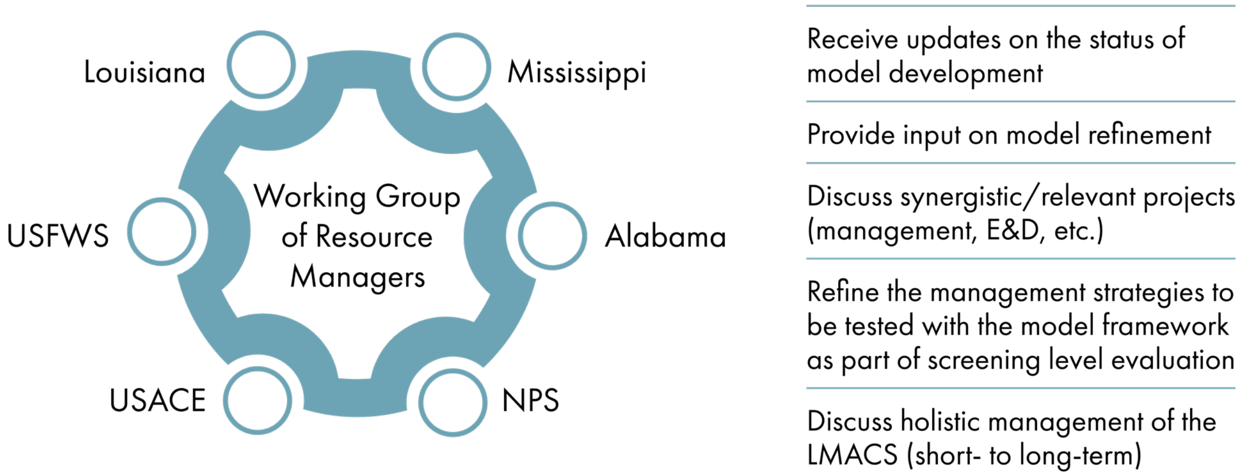

Figure 5. Interagency Resource Managers Working Group

The near-term research question that will be addressed in this plan is therefore: **how do hydrologic flow, salinity, and temperature in Mississippi Sound vary in response to natural environmental variability and factors that can be controlled through management action, such as restoration of barrier island and marsh integrity or changes in freshwater inflow?**

An initial list of "actionable factors" (i.e., aspects of the environmental system that can be altered through management intervention) that have been identified for potential investigation under this research question, and that are thus informing the capacities of the numerical modeling framework, include:

- Range and seasonal variability in freshwater inflows, including from the Mississippi River, Rigolets, Pearl River, Pascagoula River, and Mobile Bay;
- Integrity (i.e., longshore extent) of the northern Gulf islands and Biloxi Marsh barrier system from the Chandeleur Islands east to Dauphin Island; and
- Navigation channel locations and alignments.

These actionable factors will be investigated in the context of present variability and past and future change, including the response of the LMACS to:
Relative sea level rise;
Seasonal and annual variation in environmental conditions (temperature, salinity, water level, currents, freshwater inflows); and
Quiescent and stormy condition.

2. GOALS AND OBJECTIVES

The goal of this work is the development and application of a science-based decision support and model framework) to address uncertainties and unknowns in the response of the LMACS to potential management strategies and incorporates the results of that analysis into practice through an interagency working group for advancing holistic management of the LMACS. This decision-support framework is based on the SDM PrOACT cycle (Figure 4); a more detailed description of the process of incorporating results into management decisions may be found in the *Application Plan*.

The near-term goal of this research is to predict how hydrodynamics, salinity, and temperature would respond to changes in the integrity of the barrier island and barrier marsh system, modifications to freshwater inflows, restoration of historic reef structures or analogs and potential variation in the location of navigation channels. This would also reveal if a currently envisioned MDMR portfolio of major projects is likely to achieve the desired improvements in water quality, or if it needs refocusing. However, one of the key goals of this project is ensuring that the decision-support framework and associated model framework developed through this work can be modified and expanded in the long term (5+ years) to answer a wider range of management-relevant research questions necessary to support holistic management of the LMACS.

The *research objectives* of this project are to:

> Identify the relative influence of "actionable factors" (i.e., aspects of the system which can be feasibly influenced by management action) on hydrodynamics, salinity, and temperature in the LMACS. These actionable factors include the integrity of the northern Gulf barrier islands and marshes; freshwater inflows; historic reef structures and configuration of navigation channels.
>
> Evaluate how the relative influence of actionable factors varies with seasonal and annual trends and variability in environmental factors, including temperature and precipitation, frequency and intensity of tropical and extratropical storms, and groundwater inflows.
>
> Determine how long-term environmental trends driven by climate change—including sea level rise, variations in storm frequency and intensity, and changes in precipitation patterns—will influence the response of the LMACS to actionable factors.
>
> Characterize the response of the LMACS to actionable factors through metrics and outputs that:
>
> > Resonate with state, federal, and public interests,
> >
> > Increase understanding of the resilience of the dynamic coastal environment,
> >
> > Inform management of acute and chronic stressors,
> >
> > Are relevant and applicable to regulatory and permitting processes associated with implementation, and
> >
> > Can be used as part of justifying and competing for available funding opportunities to support restoration or other management action (e.g., National Fish and Wildlife Foundation; Deepwater Horizon Natural Resource Damage Assessment Restoration; Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies Act; Gulf of Mexico Energy Security Act; Coastal Wetlands Planning Protection and Restoration Act).

The research proposed in this report is intended to produce a numerical model-based decision support tool that will provide outputs informing management actions in the LMACS. Due to the complex management and regulatory landscape that ultimately dictates if and what actions can be permitted in the LMACS, interagency RM input was elicited on what specific research methods and outputs would produce decision-relevant output. The consensus was that a predictive model, quality controlled to have confidence in the outputs and applied to estimate the relative impact of actionable factors and natural drivers on LMACS water quality, was the most effective research mechanism for closing decision-relevant uncertainties and producing actionable information to inform decisions. The RMs also indicated that there was value in a model framework that could be extended to future research questions after the near-term priority uncertainties in water quality response to actionable factors was addressed.

The *model framework objectives* developed based on that feedback are to:

> Produce a **numerical model framework appropriate for screening-level evaluation** of the response of the hydrodynamics, salinity, and water quality in the LMACS to actionable factors, including changes in barrier island and barrier marsh integrity, freshwater inflows, historic reef structures and navigational channel alignments.
>
> Develop and utilize a model framework that can be **expanded in the future** to address a wider range of management concerns and associated uncertainties.
>
> Ensure that quality assurance and control (QAQC) and rigor of the model provides the RMs with enough **confidence in the information produced** to make decisions about which management strategies to advance for further analysis.
>
> Show benefits and costs of management strategies that are directly tied to RM interests in the LMACS to enable projects to be **identified for scoping and feasibility analysis** (i.e., more detailed modeling associated with project planning and permitting).

3. METHODS

Research conducted in the near-term (1–5 years) for this effort will be conducted in seven phases (Figure 6).

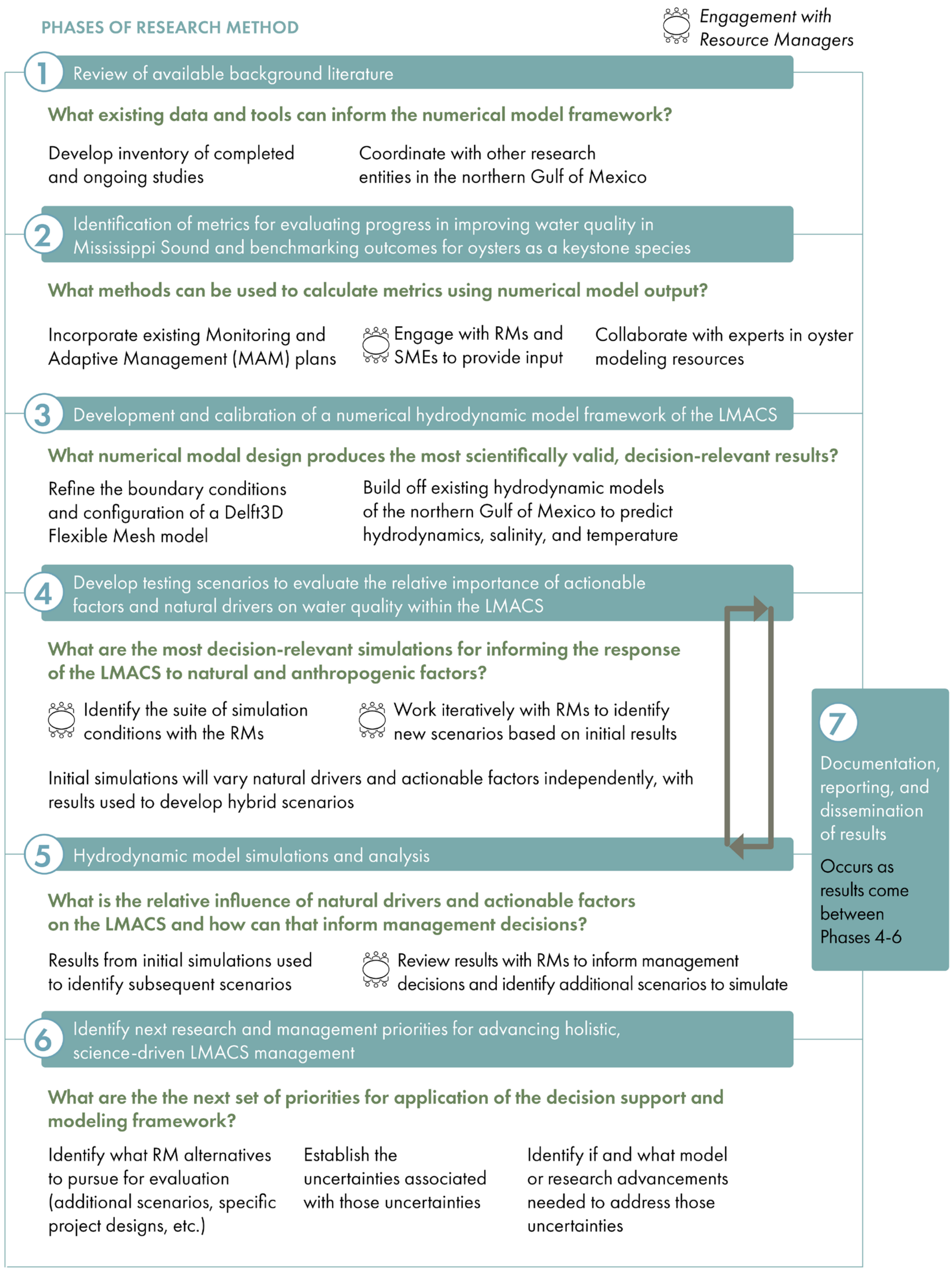

Figure 6. Seven phases of research associated with a near-term (5 year) effort to support science-based management of water quality in the LMACS.

Phase 1. Review of available background literature. An inventory will be developed of data, journal articles, gray literature, and completed and ongoing studies that include historical information on natural drivers, water quality, abundance of oysters, and response of the LMACS and/or oysters to perturbations in natural drivers or anthropogenic influences. Assembly of the relevant data inventory will include coordination with the Louisiana and Mississippi RESTORE Act Centers of Excellence, as well as with other Federal and state research entities operating in the northern Gulf of Mexico. Evaluation of the inventory will inform environmental scenarios to be tested within numerical model framework simulations, such as by testing the response of water quality to historical, current, or restored barrier island footprints.

Phase 2. Identification of metrics for evaluating progress in improving water quality in Mississippi Sound and benchmarking outcomes for oysters as a keystone species. This phase of the project will rely on the background literature review in (Phase 1); guidance from relevant Monitoring and Adaptive Management (MAM) plans that have been developed for the northern Gulf under initiatives such as the Deepwater Horizon Natural Resource Damage Assessment; and direct engagement of the RMs and SMEs identified by managers to provide input. The metrics will include values that can be directly calculated by the numerical model output, such as daily, seasonal, or annual means, maxima, and ranges of salinity and temperature. In addition, the team will collaborate with oyster modelers to determine what methodologies might be used to derive metrics for oyster response using model outputs. Recent efforts at improving oyster modeling beyond traditional habitat suitability indices will provide this research plan with a strong starting point. Those efforts include, among others,

- A 2022 Gulf of Mexico Conference workshop on oyster modeling led by the Pew Charitable Trust,
- A recently announced Deepwater Horizon Louisiana Trustee Implementation Group-led project titled “Modeling to Inform Sustainable Oyster Populations in Louisiana Estuaries” (https://www.gulfspillrestoration.noaa.gov/project?id=302), and
- ADCNR’s planned (oyster) Larval Transport and Flow Modeling development (https://marinelab.fsu.edu/media/5303/al-oyster-restoration-strategy-presentation-for-apalachicola-bay-system-initiative-5-25-2022.pdf).

Phase 3. Development and calibration of a numerical hydrodynamic model framework of the LMACS. A set of criteria (Table 1) were developed through an RM and SME working group to guide the design of the numerical model to ensure it could both support research into the LMACS and produce actionable, decision-relevant results.

Table 1. Criteria for the selection of a numerical model for informing management of the LMACS through research into decision-relevant uncertainties.

Parameter	Requirements
C1. Access to results	Open-source modeling code and open access to model inputs and outputs. Several RMs (e.g., NPS) indicated that, in addition to the value of the simulation results, there is utility for them in being able to use the model itself for other applications.
C2. Underlying model	Most RM agencies do not have specific models that are required or prohibited for use. While USACE has a list of models certified for use in their projects (others can be certified), the only constraint is scientific consensus on the validity of the model.
C3. Spatial domain	To capture the LMACS region of interest and be robust in predicting the environmental system dynamics, the domain should include Mississippi Sound and the associated barrier islands; extend west to include Biloxi Marsh and inflows such as from the Rigolets and Bonnet Carré spillway; and extends east to encompass the Alabama shoreline and Mobile Bay outflows.
C4. Spatial resolution	The resolution must be sufficient to accurately predict hydrodynamics (water levels and flows), salinity, and temperature in Mississippi Sound and to capture the actionable factors being evaluated. In the longer term, RMs indicated value in sufficient spatial resolution to resolve project-scale changes to the landscape, either through nested higher resolution domains or through variable grid resolution.
C5. Quality control and calibration	Water levels, salinity, and temperature must be calibrated and validated for the LMACS domain.
C6. Time scale of simulation	The model must predict mean and range values of seasonal and annual conditions under the actionable factors and natural drivers being considered in the study. The RMs indicated there was added value if the model could be readily expanded for decadal-scale dynamic simulation (i.e., multi-year prediction of the feedbacks of sediment transport, morphology, water quality, etc.)
C7. Forcing parameters	The model must include forcing from winds, freshwater inflows, and the Gulf of Mexico boundary. It is preferable to select a model that can be expanded to consider a wider range of atmospheric forcing, such as air pressure.
C8. Output parameters	The output parameters required to achieve the short-term objectives include depth-average water level, flow velocities (atmospheric and tidally driven), salinity and temperature. It is also preferable to select a model that can be readily expanded to include three-dimensional flow and sediment transport, which further requires inclusion of waves and wave-driven flow; morphology changes of the barrier islands and marshes; explicit modeling of additional water quality and outcomes for species of interest.
C9. Computational expense	Although RMs identified value in desktop models and online "what if" tools that would enable end-users to evaluate their own scenarios, the requirement for robust quality control limits the appropriateness of many of these types of models. RMs indicated that accuracy and QAQC were more important than direct access for non-technical users, therefore models that run on High-Performance Computing resources are acceptable.

In addition to identifying criteria, there was considerable discussion with the RMs and SMEs on utilizing an existing model for the LMACS versus developing a new one. There is a strong desire to avoid replication of effort and to leverage the wide range of existing models and expertise (Dalyander et al., 2020), including through the engagement of researchers with expertise in Louisiana, Mississippi, and Alabama, as well as within federal agencies such as the U.S. Geological Survey (USGS) and USACE. However, there are potential negative management ramifications to using some existing models “as is”. Depending on model ownership, agency leadership may be hesitant to fully support the use of a model framework that was completely developed by other agencies for their own purposes. For this reason, the team determined that a “clean slate” model, developed for the purposes of interagency and interstate decision-support of the LMACS, was the optimal choice. The USGS was identified as the most suitable entity to lead development and maintain stewardship of the hydrodynamic model and its results. USGS is a Federal, non-regulatory science agency with established scientific integrity protocols, providing confidence to all state and Federal RMs on robustness of the outputs. In addition, the USGS has established expertise in hydrodynamic modeling of regions of the LMACS (Passeri et al., 2016, 2020; Plant et al., 2013), and has the institutional capacity to host model inputs, outputs, and associated metadata long-term. At the same time, steps will be taken to incorporate existing capacity and knowledge to streamline development of the LMACS model framework and ensure it is as efficient and robust as possible. The development team will include researchers with expertise across all three states of the LMACS, representing academic and non-profit organizations, allowing expertise and existing information (e.g., model boundary conditions, portions of existing domains, etc.) to be utilized where possible.

The criteria identified by the RMs and SMEs (Table 1) and the additional considerations described above were used to identify the primary platform on which to base the model framework. The selected platform is Delft3D-Flexible Mesh (D3D-FM), an online, freely available, open-source (Criterion 1 from Table 1) hydrodynamic model that can simulate 2-dimensional hydrodynamics, salinity, and temperature (Criterion 8; Deltares, 2019). By utilizing a flexible mesh, D3D-FM can have increased spatial resolution where needed to resolve flow conditions and/or projects of interest, with lower spatial resolution elsewhere (Criterion 4). This flexibility allows the model to be optimized in areas of project consideration and reduces the computational expense, allowing the entire domain of the LMACS to be included and simulations to be run on seasonal, annual, or decadal time scales (Criteria 3, 6, and 9). D3D-FM has been previously used to simulate conditions in the northern Gulf, is widely accepted within the scientific and management communities, and has the capacity to link with other Deltares models for predicting waves, sediment transport, and morphology change, in addition to water quality and ecosystem response models (Criteria 2, 5 and 8; The Water Institute of the Gulf, 2022). The model can be driven by winds, oceanic and freshwater inputs and boundary conditions, as well as through full atmospheric forcing including air pressure and precipitation (Criterion 7). These characteristics will make the model suitable for the short-term priority of simulating hydrodynamics, salinity, and temperature response of the LMACS to actionable factors and natural drivers/variability, while also meeting criteria for future expansion to predicting the response of a wider range of water quality parameters and species habitat suitabilities. In addition, the project will build off hydrodynamic models USGS has previously developed for the northern Gulf of Mexico (Passeri et al., 2016, 2020) that predict hydrodynamics, salinity, temperature, sediment transport, and morphodynamic evolution of portions of the LMACS. These applications are similar to the current need in that they were developed for management application; operate on relevant time scales of interest (yearly, decadal); and have been linked to and used in conjunction with water quality and habitat models to reduce uncertainties in the response of the system to management action.

A high-resolution flexible model grid will be developed to resolve the offshore and nearshore areas of the LMACS, including influential riverine inputs, barrier islands, barrier marshes and embayments within the study area. Initial conditions including elevations (topography/bathymetry) will be parameterized from the USGS Coastal National Elevation Database 2nd Generation Northern Gulf of Mexico Digital Elevation Model (DEM), a newly developed state of the art DEM. The model will be validated with respect to hydrodynamics (astronomic tide validation using measured versus modeled tidal constituents at the tide gauge stations within the study area), as well as other available observational data (e.g., time-series water levels). Tidal hydrodynamic forcing will be provided from a previously validated large-scale Adaptive Circulation model that was developed for this region (Passeri et al., 2016). Wind forcing will be provided from regional-scale models such as the North Atlantic Mesoscale model (https://www.ncei.noaa.gov/products/weather-climate-models/north-american-mesoscale). For simulations of salinity and temperature, existing data within the study area will be identified during the background literature review in Phase 1 for parameterization of initial conditions as well as model validation. This may include observations from meteorologic/water quality stations, collected *in situ* data from field studies and/or other regional-scale models (e.g., the National Oceanic and Atmospheric Administration's [NOAA's] 2nd Generation Northern Gulf of Mexico Operational Forecast System https://tidesandcurrents.noaa.gov/ofs/ngofs2/ngofs.html). The model will initially be run for a set of baseline (current) conditions, which will be used for QAQC for the model framework. The baseline time-period will be selected based on the availability of input data to use for QAQC, identified during the background literature review in Phase 1. Existing model grids, forcing and boundary conditions, and institutional knowledge of the region from USGS and the Institute will be leveraged to streamline model development.

Phase 4. Develop testing scenarios to evaluate the relative importance of actionable factors and natural drivers on water quality within the LMACS. These scenarios will include future without action (FWOA) simulations that capture the mean, range, and variation in annual and seasonal hydrodynamics, salinity, and temperature under a range of realistic quiescent and storm conditions, as well as freshwater and groundwater inflows and potential future changes in sea level, storminess, and precipitation. The range of conditions will be driven by facilitated discussion with the RMs and informed by the background literature review conducted in Phase 1, including through trend and correlation analysis of water quality data and response to historical conditions (i.e., determining which parameters have historically been associated with changes in water quality metrics identified in Phase 2). Scenarios will include variations and trends of parameters identified during the development of this plan through RM workshops:

- Rainfall, including seasonal variability and future climate scenarios,
- Wind,
- Storms (tropical and frontal) – intensity and frequency,
- Groundwater and freshwater inflows, and
- Relative sea level rise.

A working session will be conducted with the RMs to develop the range in variation of actionable factors that will be applied in a set of simulations. In addition to those identified through the literature review and RM engagement, these scenarios will include variations of actionable factors identified during the development of this plan:

- Barrier island configurations;
- Barrier marsh configurations, particularly the Biloxi Marsh complex;
- Freshwater input under anthropogenic influence;
- Historic oyster reef structures or analogs; and
- Navigation channel alignments, specifically the Pascagoula navigation channel.

During the initial round of model simulations, each of the actionable factors will be independently varied across the range of natural variability and trends to evaluate their relative influence on the water quality metrics identified in Phase 2. These results will be reviewed with the RMs, who will then select the hybrid scenarios under which combinations of actionable factors are varied to capture the influence of more holistic management strategies.

Phase 5. Hydrodynamic model simulations and analysis. The hydrodynamic model developed in Phase 3 will be used to simulate the set of scenarios identified in Phase 4 to produce outputs including maps of mean, range, and variability in salinity, temperature, water levels, and currents in the LMACS. In addition, the metrics developed in Phase 2 will be used to benchmark the relative influence of natural drivers and actionable factors on the response of the LMACS, supporting the MDMR-led, interagency-supported identification of management actions to pursue for permitting. Phases 4 and 5 will be conducted iteratively, with results from an initial set of simulations focused on varying actionable factors individually shown to the RM working group and used to determine what actionable factors and natural drivers should be co-varied in the next round of simulations. If time permits and there are additional simulations the RMs would find beneficial, this iteration may occur 3–4 times, with each set of results used to guide the next round of simulations.

Phase 6. Identify next research and management priorities for advancing holistic, science-driven LMACS management. One of the strongest conclusions from the workshops used to develop this research plan was that there is considerable value in a framework that can support interagency RM collaboration on identifying restoration projects and/or management strategies for more holistic management of the LMACS. This Phase advances that vision by working with RM group to define the next set of priorities for application of the decision support and model framework developed and applied in Phases 1–5. This includes identifying what RM alternatives to pursue for evaluation (additional scenarios, specific project designs, etc.); establishing the uncertainties associated with those uncertainties; and identifying if and what model or research advancements needed to address those uncertainties.

Facilitated discussion will be conducted with the RM working group during this phase to identify these priorities through the same Problem, Objectives, Alternatives, and Consequences steps of PrOACT that were used in the development of this research plan (Figure 4). Revisiting these steps allows for identification of the next set of priorities provides a framework for incorporating knowledge gained during the initial application of the model. In addition, the RM working group can consider leveraging newly available opportunities for research advancements that been developed outside of this project, as well as evolving management priorities. Some areas of continued advancement were identified during the workshops used to develop this plan, however, and will form the initial basis of facilitated discussion (Table 2).

Table 2. Areas of research identified for reducing management-relative uncertainties outside the scope of the described in Phases 1–7 of this research plan. These activities will form the initial basis for facilitated discussion of long-term work (5+ years) that builds on Phases 1–7. If additional funding is available (see Budget and Potential Funding), their timeline could also be accelerated.

Habitat Modeling	Developing and/or applying habitat suitability indices (HSI) or other species models to identify the spatial range of oysters or other species under the modeled scenarios.
Secondary Water Quality Parameter Modeling	Adapting the numerical model to project (or linking to an external model that projects) changes in secondary water quality parameters such as dissolved oxygen, nitrogen, and phosphorous in response to environmental and management variables.
Dynamic Yearly and Decadal Simulations	Applying the model to predict the dynamic response of the LMACS on yearly and decadal time scales under a FWOA and alternate management scenarios.
Project-scale Modeling	Spatially refining the model grid to evaluate the impacts of portfolios of restoration projects identified by the RM working group
3D Hydrodynamics	Adapting the numerical model framework to predict 3D hydrodynamics, allowing more detailed understanding of near-bed conditions for species.
Sediment Transport and Morphodynamic Evolution	Adding the capability to predict waves, sediment transport, and morphology.

Phase 7. Documentation, reporting, and dissemination of results. The technical report, academic journal articles, presentations for academic and practitioner conferences, and a public-facing story map with visually rich, plain language summaries of the research outputs will be developed in this Phase (more details in *4. Expected Products)*. Reports, presentations, and journal articles will be drafted by

members of the core team, then provided to the RM working group for review and input before finalizing (see *6. Resource Managers, Researchers, and Other Stakeholders*).

The public-facing story map will be developed with input from social scientists. Development will include input from, and beta testing by, RMs and select stakeholders. This engagement will help ensure that the presentation is effective and intuitive for a range of stakeholders and the public.

4. EXPECTED PRODUCTS

The research outputs of this project in the near-term (1–5 years) include:

- **Inventory of data collected, models developed, and ongoing and completed studies** relevant to historical water quality and oyster viability in the LMACS, and/or to the development of a numerical model for predicting the response of hydrodynamics, salinity, and temperature in the region to changes in natural drivers (relative sea level rise, quiescent and storm conditions, etc.) and management actional factors (barrier island/marsh integrity, freshwater inflows, and alignment of navigation channels).
- **A calibrated and validated 2D D3D-FM hydrodynamic model** with spatial domain encompassing Mississippi Sound and associated barrier islands and extending from Breton and Chandeleur Sounds east to Mobile Bay.
- **Model simulation results** evaluating the response of LMACS hydrodynamics, salinity, and temperature to varying natural drivers and actionable factors.
- **Calculated metrics** comparing the relative influence of natural drivers and actional factors on water quality in the LMACS.
- **Updated research and application plans** describing the next set of priority uncertainties that will be addressed with the numerical model framework, the enhancements needed to address those uncertainties, and incorporation of results into LMACS management.

The outputs described above will be captured in:

- A **technical report** summarizing the research. This report will summarize the project in its entirety as an end-to-end summary of methods and results.
- A public, freely accessible **online repository** (such as a USGS Open File Report or Data Series) containing all inputs necessary to run the numerical model developed in Phase 3, including new simulations as desired by a user, as well as the outputs for specific simulations that are developed in Phases 4–5.
- One or more **academic journal articles** summarizing the knowledge gained on the response of the LMACS to natural drivers and actionable factors, along with **annual presentation at academic conferences on progress and results**. The journal articles and academic conference presentations will be used to disseminate the knowledge gained to the research community. In addition to advancing understanding of the LMACS, the techniques used may be applicable to other regions.
- Annual presentation at **practitioner conferences and meetings** such as the Gulf of Mexico Alliance (GOMA) annual All Hands and/or future iterations of the Gulf of Mexico Conference, and a practitioner **webinar and Question & Answer session** at the completion of the project. These venues will allow the results to be disseminated to a broad range of RMs, and engagement of this community during the project may result in additional representatives being added to the RM working group.

- **Online story map** for public consumption of the results of the RM-driven model runs and evaluation of the output datasets. The RMs engaged during the development of this plan identified that a key potential impediment to execution of some management actions may be the public not understanding the expected results. The project will therefore include the development of a visually rich, plain-language story map, developed in conjunction with input from social scientists and members of the public.

5. SCHEDULE

Phases 1–7 encompass a near-term (5 year) project to establish an interagency RM working group, build the framework, and apply it to investigate how hydrodynamics, salinity, and temperature vary in response to “actionable factors” that can be influenced by management action. That project sets the foundation for continued use of the framework in supporting management of the LMACS and a shift toward increased interagency coordination and collaboration in years beyond year 5.

The near-term timeline (Figure 7) for this effort is as follows:

- Phase 1. Review of available background literature: **Year 1**
- Phase 2. Identification of metrics and calculation methods for evaluating progress in improving water quality in Mississippi Sound and benchmarking outcomes for oysters as a keystone species: **Year 1**
- Phase 3. Development and calibration of a hydrodynamic model of the northern Gulf of Mexico: **Years 1–2**
- Phase 4. Identify testing scenarios to evaluate relative importance of actionable factors and natural drivers on influencing water quality metrics (identified in Phase 2) within the LMACS: **Years 2–4 (iterative with Phase 5)**
- Phase 5. Hydrodynamic model simulations and analysis: **Years 2–5 (iterative with Phase 4)**
- Phase 6. Identify next research and management priorities for advancing holistic, science-driven LMACS management: **Year 5**
- Phase 7. Documentation, reporting, and dissemination of results: **Years 1–5**

As discussed above, the activities described above are intended to provide a foundation for science-based management of the LMACS facilitated by collaboration and coordination of Federal and state entities. The intent, therefore, is for the products and outcomes of this work to lead to continued research, development, and management application. The PrOACT planning cycle (Figure 4), in conjunction with the establishment of an RM working group that will utilize the results, provides the mechanism for continuing to update and extend this document and the associated *Application Plan* to address management needs in the long-term (5+ years).

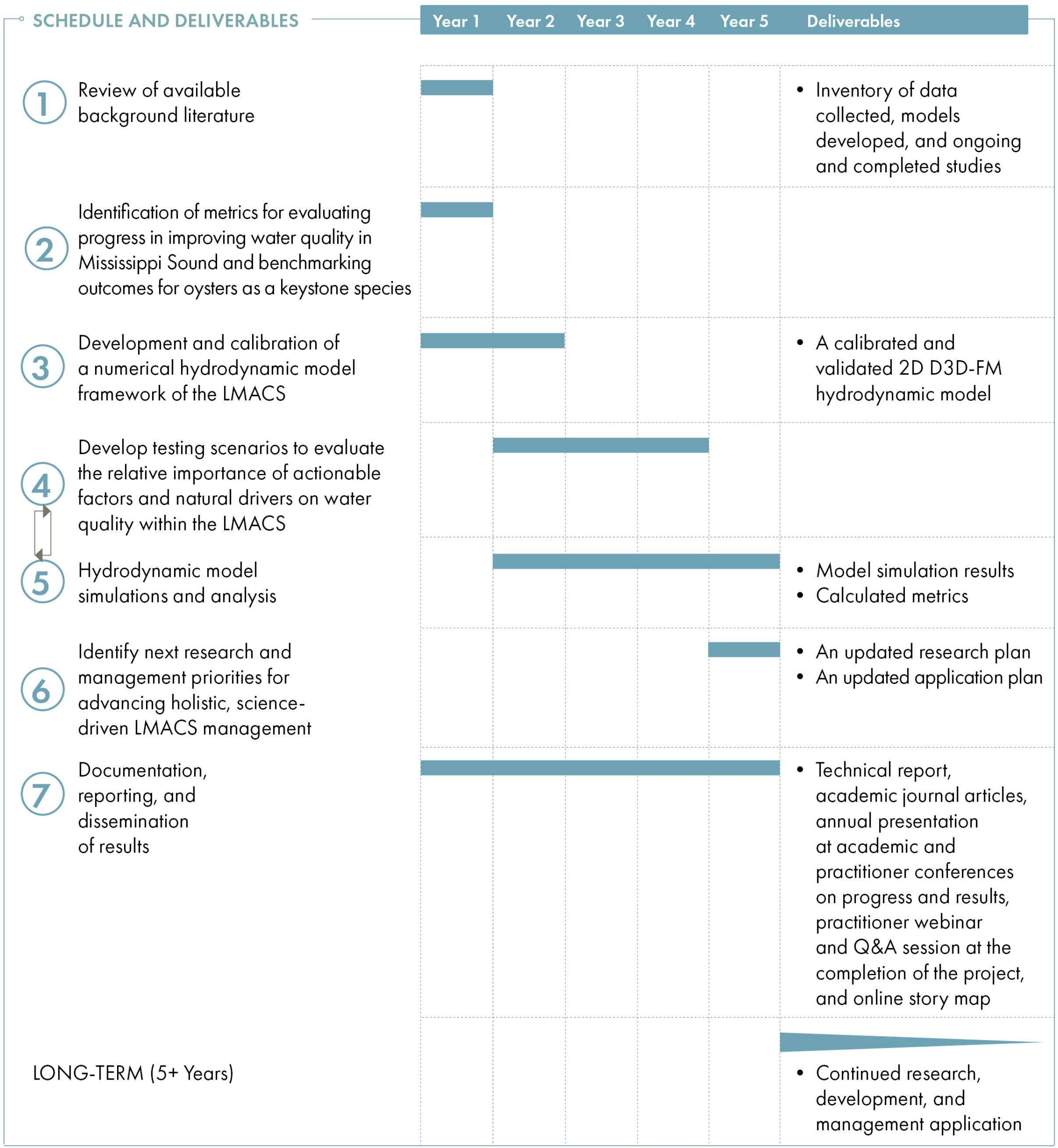

Figure 7. Diagram showing the schedule for developing and implementing a decision support and model framework for reducing uncertainties relevant to improving water quality and habitat in the LMACS (Figure 2).

6. RESOURCE MANAGERS, RESEARCHERS, AND OTHER STAKEHOLDERS

Individuals for an RM working group were identified based on input received during development of this research plan regarding which agencies and entities needed direct representation, with the understanding that all representatives on the list would also reach out within their agencies as needed. The role of the RM working group will be to provide input at select points in each of the project Phases as described in the *Application Plan*. Input will be solicited from the RMs throughout Phases 1–6 on any additional representatives that should be added to the RM group as the project progresses. The working group will build off the RMs engaged during plan development, including:

- Jared Harris and Rhonda Price, MDMR
- Jim Pahl, LCPRA
- Will Underwood, ADCNR
- Justin McDonald, USACE Mobile District
- Jon Hemming, USFWS
- Jonathan Kleinman, USFWS
- Bruce Leutscher, NPS

Other management agencies with interests in the LMACS will be provided the opportunity to add representatives to the RM working group, including (but not limited to):

- Alabama Geological Survey,
- Alabama Marine Resources Division,
- Louisiana Department of Wildlife and Fisheries,
- Mississippi Department of Environmental Quality,
- USACE New Orleans District, and
- USACE Mississippi Valley Division.

The core team of researchers and a subset of the RM working group that will be fully integrated within the continued co-development process described in Phases 1–7:

- Mr. Jared Harris and Ms. Rhonda Price (MDMR) will provide guidance to ensure the research and outcomes are relevant to MDMR management of water quality and species in the LMACS, including decisions on projects or management actions to pursue based on the project outcomes. In addition, Mr. Harris will serve as the overall project lead.

- Dr. James Pahl (LCPRA) will represent the interests of Louisiana in management of the LMACS, including providing input on the tradeoffs of potential management actions to improve water quality with other priorities for the state.
- Dr. Soupy Dalyander (The Water Institute of the Gulf) will lead implementation of the SDM framework (e.g., facilitation of working sessions with the RM working group to identify scenarios) and development of metrics for characterizing LMACS system response.
- Dr. Mike Miner (The Water Institute of the Gulf) will provide expertise on the response of the LMACS to natural drivers and actionable factors and support development of metrics for characterizing LMACS system response.
- Dr. Ioannis Georgiou (The Water Institute of the Gulf) will provide input on the development of the hydrodynamic model in the western portion of the LMACS.
- Dr. Scott Hemmerling (The Water Institute of the Gulf) will provide guidance and input on the development of a story map for disseminating results to stakeholders and the public.
- Dr. Davina Passeri (U.S. Geological Survey) will develop, calibrate, validate, and implement the D3D-FM numerical hydrodynamic model and support the identification and calculation of outcome metrics. In addition, USGS will host and support development of the story map.
- Dr. Anna Linhoss (Auburn University) will lead the background literature review on the LMACS, provide input in the development of the hydrodynamic model, and support characterizing water quality and oyster response.
- Dr. Paul Mickle (Northern Gulf Institute) will serve as a liaison to the Mississippi research community, particularly those researchers engaged in water quality and oyster research through Mississippi Based RESTORE Act Center of Excellence.
- Mr. George Ramseur (Moffatt & Nichol) will provide continuity in concept origination, development and management context between the planning and implementation phases of this project.

Note, all core team members will be involved throughout the project.

Researchers with expertise relevant to water quality and species management will be identified during Phases 1–6 by the RM working group or the core team researchers and engaged as SMEs to provide input and expertise. This SME group will provide input through targeted participation in working sessions with the RM working group. The RMs will be given an opportunity to identify SMEs with whom they have trusted relationships and/or whose input they would like to have; for example, Alabama DNR suggested that a representative from the AGS participate. An initial set of SMEs will be identified after the completion of the background literature review, which will be used to identify expertise relevant to the effort that is not represented on the core team.

Other stakeholders with interest in water quality and oyster viability in the LMACS include local, state, and Federal governance entities (e.g., state governors); recreational and commercial fishermen; boaters and other non-consumptive recreational users; coastal communities; tourists; and the public. These entities will primarily be engaged through the development and dissemination of the plain-language summaries and story map described in *4. Expected Products*. However, the core team will review the potential value of direct engagement throughout the project and incorporate feedback from additional stakeholders if and where valuable.

7. DATA MANAGEMENT PLAN

With guidance from the RM working group, the core team will ensure all data and model output associated with the project are available in a straightforward, usable format to allow for further integration into management decision making. The varied types, volumes and seasonality of data resulting from this effort will require the data collectors and researchers to address ISO data and XML metadata specifications, geo-spatial feature attribution and parameterization documented within a living Data Management Plan. It is anticipated that data for this project will be between 300–400Gb of total storage. Expected data products include:

> D3D-FM model output: modeled salinity, temperature, water level, and currents for current conditions as well as management action and natural driver scenarios; expected volume: 300 Gb; .nc
>
> Maps of annual and seasonal mean, range, and variability in salinity, temperature, and water levels; expected volume: 500 Mb; .tif
>
> Decision-support metrics characterizing the range and variability in water quality and species relevant parameters, such as salinity and temperature; expected volume: 100 Mb; .csv

The USGS St. Petersburg Coastal and Marine Science Center has dedicated information technology support to assist with data redundancy and back-up to prevent the catastrophic loss of data during the project. Model data are anticipated to be shared outside the project team within one year of the project completion after the following have been completed: pertinent file formatting applied, quality assurance verified, agency specific reviews performed, and data packaging finalized. Findings will be shared with the scientific community through publications in peer-reviewed scientific journals. The USGS will develop an interactive web mapping application to be used as a public-facing display vector for most of the project datasets, similar to the story map developed for the previous ESLR-NGOM project www.gommarsh.com). As per USGS policy, data collected and finalized by USGS participants will reside in ScienceBase (https://www.sciencebase.gov/catalog/), an authoritative USGS online repository.

USGS Science Centers and The Water Institute have dedicated data stewards that assist with the preparation and publication of data products. The data stewards help to ensure the general data quality and data documentation standards are met for all data products. This will include model inputs and outputs. USGS participant publications will reside in the USGS Publications Warehouse (https://pubs.usgs.gov). All other data will be submitted to the NOAA National Centers for Environmental Information for long-term preservation.

8. BUDGET AND POTENTIAL FUNDING

Due to the nature of the proposed effort, which continues to strongly integrate RM input into the implementation of research to resolve critical uncertainties and research into the decision-making process being established for the LMACS, the Budget is the same as in the associated section of the Application Plan.

The estimated costs associated with the near-term phases of this project are:

- Phase 1. Review of available background literature: **$100,000**
- Phase 2. Identification of metrics and calculation methods for evaluating progress in improving water quality in Mississippi Sound and benchmarking outcomes for oysters as a keystone species: **$200,000**
- Phase 3. Development and calibration of a numerical hydrodynamic model framework of the LMACS: **$400,000**
- Phase 4. Develop testing scenarios to evaluate relative importance of actionable factors and natural drivers on water quality (identified in Phase 2) within the LMACS: **$200,000**
- Phase 5. Hydrodynamic model simulations and analysis: **$200,000**
- Phase 6. Identify next research and management priorities for advancing holistic, science-driven LMACS management: **$75,000**
- Phase 7. Documentation, reporting, and dissemination of results: **$75,000**

Potential sources of funding for this work generally need to be viable for simultaneous application across multiple states and could include:

- **NOAA Restore Science Program.** A Federal Funding Opportunity (FFO) for collaborative, actionable science research projects representing implementation of at least part of the actions outlined in this Research Plan and its attendant Application Plan is currently open, with an estimated $15 million available to support approximately 10 projects. The core team outlined in Section 6 is preparing proposal information pursuant to that FFO.
- **Gulf of Mexico Alliance (GOMA).** Pursing the development of an LMACS decision-support capacity is currently included in the Tier 2 Work Plan of the GOMA Integrated Planning Cross-team Initiative. GOMA activities are funded through a combination of private sector donations through the Gulf Star Public-Private Partnership, and competitive federal awards. Recently, GOMA was eligible for Infrastructure, Investment and Jobs Act funds in support of the nation's Regional Ocean Partnerships. GOMA is currently preparing its application for those funds and will then develop guidance to the individual priority issue teams for pursuit of those funds. Mr. Harris, Ms. Price, and Dr. Pahl will lead consideration of an LMACS project submission through GOMA once that guidance is released.
- **NOAA – Bonnet Carré 2019 Fisheries Disaster Recovery Program**. The U.S. Department of Commerce is providing disaster-relief funding to mitigate the negative impacts of 2019 openings

of the Bonnet Carré Spillway. Although not yet confirmed, this funding may include support for restoration of oysters in Mississippi.

In addition to the priority activities identified for the near-term project, several other areas of research were identified through the collaborative workshops used in developing this research plan (Table 2). The schedule for these activities is in the 5+ year time frame based on the budget and timeline that has been developed for project. However, additional funding from the sources identified above could be leveraged to advance these activities on a faster timeline.

9. MECHANISM FOR UPDATING THE PLAN

The decision-support framework that will be implemented in conjunction with the research outlined here (described in more detail in the *Application Plan*) provides an effective structure for continued updating of this research plan.

The research plan will be reviewed and—as needed—revised during meetings with the RM working group (described for each Phase in the *Application Plan*). The outputs produced during the project will be used to inform an RM-led decision, made through collaboration with the interagency RM working group, on what management actions to pursue for planning and permitting.

During Phase 6 of the project, the first steps of the PrOACT cycle (Figure 4) will be revisited to prioritize what management alternatives and associated uncertainties should be the focus of an updated research plan for the long-term (5+ years). Iterating through the complete PrOACT cycle is a method of Adaptive Management and enables the RM working group and core team to prioritize and refine the next steps based on results from Phases 1–5 of the research in this plan; updated understanding of the LMACS system and associated species advanced through research conducted elsewhere; and current management priorities that may evolve over time based on chronic (sea level rise, coastal erosion, etc.) and acute (oil spills, hurricanes, etc.) stressors. This process will be done through an in-person meeting with the RM working group as described in the *Application Plan*. In addition to updating the research plan, this structure provides a mechanism for results of research conducted outside of this project to be used to support decision-making in the LMACS. Data collected and tools developed can either be directly incorporated into the model framework (e.g., HSI models can be applied to calculate habitat ranges for specific species based on results such as WQ variability from the hydrodynamic model), or the results of other studies can be presented to the interagency RM working group for additional consideration in identifying projects to pursue for permitting and/or in the identification of priority uncertainties and research areas during future iterations of the PrOACT cycle.

The decision-support framework provides a durable mechanism for the research plan to be continually updated in collaboration with the interagency RM working group. The PrOACT cycle can be executed multiple times to refine future priority research areas. Furthermore, the input and output files of the numerical model, which is the open source D3D-FM model, will be published online by the U.S. Geological Survey. This will enable any RM, researcher, or stakeholder (or technical staff or contractors acting on their behalf) to replicate the results of the research and/or use the model to evaluate their own scenarios of interest, a criterion that was identified by RMs as being of significant inter- and intra-agency value in improving science-based decision-making for the region.

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