ADAPTIVE MANAGEMENT FRAMEWORK FOR COASTAL LOUISIANA

October 25, 2013

Produced for and Funded by:
Coastal Protection and Restoration Authority

THE WATER INSTITUTE
OF THE GULF

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This report was developed by Denise Reed and Ann Hijuelos of The Water Institute in close collaboration with Natalie Peyronnin, Carol Parsons, Andrea Galinski, and Rick Raynie of the Coastal Protection and Restoration Authority (CPRA). Ideas were also generated through interaction with the Adaptive Management Guidance Panel: Robert Twilley, Nick Aumen, Mike Donahue, Holly Doremus, Dave Marmorek, and Ron Thom.

The report was reviewed by Clint Willson and edited by Kathleen Hastings, both of The Water Institute.

SUGGESTED CITATION

The Water Institute of the Gulf. (2013). Adaptive Management Framework for Coastal Louisiana. *The Water Institute of the Gulf*. Produced for and funded by the Coastal Protection and Restoration Authority under Task Order 9, Contract No. 2503-12-58. Baton Rouge, LA.

BACKGROUND

Future conditions of coastal Louisiana are highly uncertain, due to the dynamics of riverine and marine processes, climate change, population growth, economic activity, and ongoing human reliance on the natural resources the coast provides. Managing such a complex system in which the natural and socio-economic systems are highly integrated is inherently difficult. As new techniques and projects for restoration and risk reduction are being developed, there exists an opportunity for learning how the system will respond to the coastal protection and restoration program implementation and for using that learning to improve future program management decisions. Adaptive management provides a structured process for making decisions over time through active learning and enables adjustments in program implementation as new information is gleaned. Adaptive management embraces a scientific approach that involves identifying explicit goals and objectives, developing and implementing management actions, assessing the system's response to the action(s), and then using that knowledge to make management decisions. It is designed to be iterative, allowing for the incorporation of new knowledge through every step of the process.

The Water Institute of the Gulf, with guidance and input from the Coastal Protection and Restoration Authority (CPRA) and from an Adaptive Management Guidance Panel, was tasked to develop a programmatic Adaptive Management Framework (AMF) for Louisiana's coastal protection and restoration program. The purpose of the framework is to identify the principles of adaptive management and provide recommendations for integrating adaptive management concepts and ideas into the current coastal program. The framework also serves as the foundation for developing an Adaptive Management Plan (AMP) that will create a formalized structure for implementing adaptive management.

This framework draws upon peer-reviewed literature, government documents, conference proceedings, and independent reports to identify the key processes of adaptive management and offer advice on the importance of information flows to build a knowledge base that supports decision making. In addition to the theoretical aspects of adaptive management, this framework is tailored to meet the specific needs of the coastal protection and restoration program in Louisiana. The framework identifies areas where opportunities exist for implementing adaptive management, where challenges may arise in the future, and the next steps in developing an AMP for the region. The formulation of the framework was guided by an advisory panel that consisted of individuals with national and international experience in implementing adaptive management in systems with complex human and environmental interactions. The panel provided crucial expertise in the development of the framework, corroborating on the essential principles and providing a set of recommendations for adaptive management in coastal Louisiana.

INTRODUCTION TO ADAPTIVE MANAGEMENT

Adaptive management has been the subject of much study and discussion. This section summarizes some of the common points from the literature with a focus on the process steps that are frequently considered. It does not seek to critique the use of adaptive management in others systems, but focuses on the frameworks that have been suggested or used elsewhere. Rather than a comprehensive literature review, key lessons and points that can support the development of an AMF for coastal Louisiana are drawn from a variety of sources.

Numerous uncertainties can affect the management of a large coastal system, e.g., environmental variability, imperfect knowledge of the system or resource state, and a lack of understanding of the biological and ecological relationships (Williams, 2011). In addition, complex social-ecological dynamics challenge how managers approach ecosystem restoration and flood protection. This creates inherent difficulties for managers tasked to restore ecosystems and protect communities with incomplete knowledge of how the system works, or how management actions may impact the system and those that rely on it. As a result, adaptive management has been advocated in order to increase the success of restoration actions, and these learning principles could also apply to protecting communities. Adaptive management is a systematic process for incorporating new and existing knowledge to develop management decisions (Williams et al., 2009). The premise for adaptive management suggests using the best available knowledge to design and implement management plans, while establishing an institutional structure that enables learning from outcomes to adjust and improve future decision making (McLain & Lee, 1996). Key to this process is understanding that not all outcomes may be anticipated, but opportunities exist for learning even from undesirable results. Adaptive management is a rigorous process that generally involves several steps (adapted from Westgate et al., 2013; Williams et al., 2009):

1) **Setup Phase**
    a. Identification of management goals and objectives;
    b. Specification of management options, one of which can be "do nothing";
    c. Development of an assessment process, through the use of conceptual and numerical models and experimental design, to evaluate how the system responds to management actions.

2) **Iterative Phase**
    a. Implementation of management actions;
    b. Monitoring and assessing the system's response to management actions;
    c. Adjustment of management actions in response to results;
    d. Revisiting goals and objects.

A key aspect of adaptive management is the circular nature of the process in which assessment of outcomes leads to decision-making and adjustment of management actions (Murray & Marmorek, 2003). "Closing the loop" is essential to successful adaptive management but is rarely achieved in restoration (Westgate et al., 2013). Also, the order in which these components occur may not always follow in a stepwise fashion but conceptually, the list above lays the groundwork for implementing adaptive management (Murray & Marmorek, 2003).

SETUP PHASE

Implementing adaptive management often begins with engaging the stakeholder to identify the problem in which management actions will be implemented to address (Williams et al., 2009). Once the problem statement has been clearly defined, programmatic goals and key objectives should be identified that support the problem statement and set the stage for what will be the desired system state. It is critical to identify and define these activities in the early stages of adaptive management, as it then links to the next stage of designing a management plan. The goals are designed to broadly identify the desired result, while the objectives delineate specific outcomes to be achieved and should be designed to guide decision making. The development of simple, conceptual models can aid in the identification of goals and objectives that support the overarching problem statement. They can also be used to identify areas of uncertainty with regard to system dynamics and response to management actions (Nuttle et al., 2008). Performance measures should also be identified to quantitatively track the progress towards meeting management goals and objectives (National Research Council, 2000). Management options must then be identified to achieve the goals and objectives.

Modeling is an integral part of adaptive management and can be used to predict the system's response to multiple management alternatives or management inactions (Walters, 1997). Conceptual and numerical models are used to explicitly describe the relationship between management actions and the system response, articulate assumptions in the system's response, and identify uncertainties in both management and the system's response (Schreiber et al., 2004). Numerical models also provide an opportunity to test uncertainty scenarios and evaluate the sensitivity of the system to a range of uncertainties/model scenarios. Walters (1997) states that using dynamic models to predict how alternative management scenarios may impact a system serves three functions: (1) it allows for a clear problem statement to be identified and communicated among scientists, engineers, managers, and stakeholders; (2) it makes it possible to screen alternative management solutions to eliminate those that are not suitable; and (3) it helps to identify knowledge gaps that greatly influence model results. It is important to have a robust experimental monitoring design in order to assess changing conditions and compare to model outputs.

INTERACTIVE PHASE

The iterative phase is where decisions on implementing management actions and adjusting actions are taken as information is gleaned and uncertainties are reduced. Decisions are informed from learning in the setup phase (i.e., stakeholder engagement, planning, and modeling), through implementation of a monitoring program, and ongoing research. Follow-up monitoring is needed to track program performance in meeting goals and objectives, determine if additional management actions are needed by assessing natural or built system conditions, increase understanding of system dynamics, and improve model predictions (Williams, 2011). Well-structured experimental designs can also help define the boundary conditions and assist in identifying meaningful changes in ecosystems characterized by complexity, variability, and uncertainty (National Park Service, 2012). Monitoring social and economic factors is also critical in understanding social acceptance and impacts on the economic system. The value in data collection comes from its ability to contribute to decision making and reduce uncertainty in management actions (Williams, 2011). As a result, the monitoring design must be developed in the context of the decision framework such that relevant information is collected to understand the performance of management actions and determine if goals and objectives are being achieved (Lyons et al., 2008). During program assessment, information is synthesized and evaluated from both system monitoring and ongoing research, both within coastal Louisiana and in coastal areas with similar process regimes or characteristics. Learning in the iterative phase will be achieved through improvements in conceptual and predictive models, refinements to system monitoring, adjustments in plan implementation and/or project operation.

Although the theoretical principles of adaptive management are well established in the literature, not all adaptive management efforts are successful. Porzecanski et al. (2012) developed a diagnostic tool to evaluate a propensity towards successful adaptive management and concluded that without "adequate financial resources, active experimentation with open and effective pathways for learning, effective implementation of comprehensive policies, and engaged stakeholders," adaptive management cannot be successful. Allen et al. (2011), Schreiber et al. (2004), and references therein also provided several reasons why adaptive management is often unsuccessful:

- Inadequate planning and design, including poor communication between managers and policy makers as to what is achievable;
- Insufficient data or learning capabilities;
- Poor understanding of system dynamics and response of the system to management;
- Incomplete adaptive management cycle or feedback loops are not implemented such that results from monitoring and assessment are not used to make changes;
- Unclear approach and definition of adaptive management;
- Lack of successful adaptive management programs to use as a guide;
- Programs that use reactive instead of proactive environmental management approaches;
- Failure to reevaluate objectives.

While some of these provide important lessons for the development of an AMF for coastal Louisiana, some of them, (i.e., the lack of successful programs to use as a guide), will only be addressed as the practice of adaptive management matures and critical reporting of results and lessons expands.

NEED FOR ADAPTIVE MANAGEMENT IN COASTAL LOUISIANA

The adaptive management approach is generally employed when management decisions are hindered by uncertainties in the system dynamics or system response to management actions (Williams, 2011). Louisiana's dynamic coastal environment lends itself to adaptive management, given the difficulty in forecasting the response to management actions and the uncertainty with changing conditions. The shifting baselines associated with ongoing land loss, sea-level rise and subsidence as well as the periodic impact of tropical storms and hurricanes means there is rarely, if ever, a high degree of certainty about how the effects of a project or an entire program will unfold over time.

There have been earlier efforts to move towards adaptive management in coastal Louisiana, including those described by Raynie and Visser (2002), Steyer and Llewellyn (2002), and Steyer et al. (2004). Most recently Louisiana's 2012 Coastal Master Plan identified the need for programmatic adaptive management to guide the implementation of the master plan and the broader coastal protection and restoration program. A key challenge in developing an AMF for coastal Louisiana was the paucity of program-scaled plans with which to learn and apply to the risk reduction and ecological restoration programs. Although many of the components of a project AMP overlap with a programmatic AMP, the key differences occur in the scale at which management actions are implemented and the types of decisions that need to be made. For example, programmatic adaptive management operates on groups of projects, considers the sequencing of project implementation, and evaluates how projects may interact across temporal and spatial scales, while project adaptive management focuses on the performance of individual projects. Given the multiple project types that were recommended in the master plan, there is great uncertainty in the order in which they will be implemented and how they interact with one another and changing coastal conditions. Development of a programmatic AMP will enable a structured approach to guide the implementation of the master plan in the context of the dynamic and unpredictable nature of the coast.

ADAPTIVE MANAGEMENT FRAMEWORK

Using the key adaptive management principles established in the literature and guidance from the advisory panel, a framework was developed specifically for coastal Louisiana. Many of the panel's recommendations addressed how to operationalize adaptive management, and these are considered in more detail in the section below on AM implementation. There is a broad consensus in the AM community, as reiterated by the panel, with regard to the main steps in an adaptive management process. Most documents describing these steps start at the beginning of a planning process, assuming no plan of action has yet been developed. For several reasons, coastal Louisiana is different including:

- The 2012 Coastal Master Plan has completed many of the tasks often associated with the "setup" phase, and been approved. Implementation is underway;
- Restoration and protection efforts have been ongoing for decades, some with features of adaptive management (e.g., monitoring associated with projects implemented under the Coastal Wetlands Planning Protection and Restoration Act [Raynie & Visser, 2002]), and others with no adaptive management (e.g., pre-Katrina levee projects);
- While CPRA is a central institution in master plan implementation, the activities of many other entities such as landowners and other agencies can affect the coast and how restoration and protection proceed;
- The shifting baseline of our coastal system means there is not a fixed point or pre-existing condition against which the success of the program can be benchmarked.

There are two cornerstones of the proposed AMF: decision making and the knowledge base. These elements are linked in specific ways to the establishment of goals and objectives, planning, implementation, and assessment (Figure 1). Brief descriptions of these elements and their linkages are provided here in the context of program-level adaptive management. Adaptive management is by necessity integrated and iterative. The expectation is that the process described in the framework will be followed on a 5-year cycle due to the statutory mandate for an update of the master plan every five years. However, while the elements are described in the sequence shown on Figure 1, interactions among the central elements (e.g., assessment and planning) occurring via decision making and the knowledge base do not only occur in the sequence diagrammed or solely at 5-year intervals. At the end of this section, differences in processes and information flow related to project-level adaptive management are described. Operationalizing the framework is discussed under the adaptive management implementation section of this report.

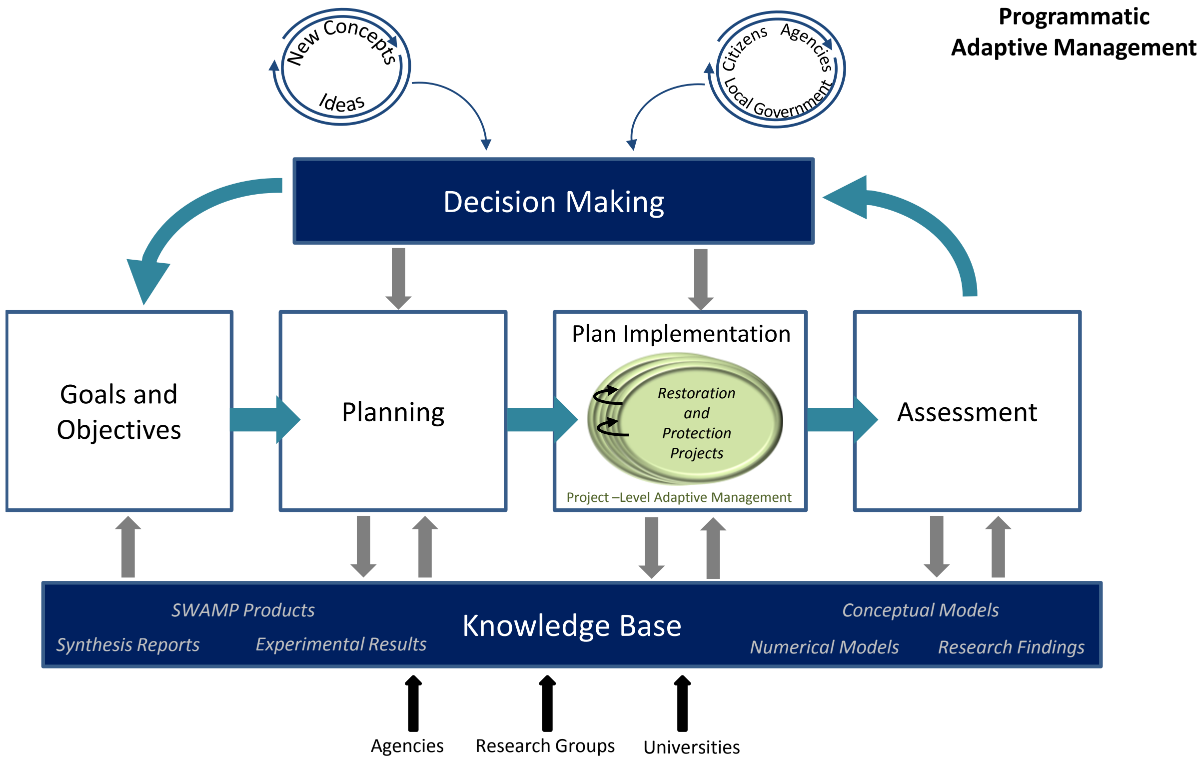

Figure 1: Adaptive management cycle for coastal Louisiana.

Learning should be implicit throughout adaptive management and should be the result of synthesizing and evaluating information from both system monitoring and ongoing research, both within coastal Louisiana and in coastal areas with similar process regimes or characteristics. Learning will be achieved through improvements in conceptual and predictive models, refinements to system monitoring, adjustments in plan implementation and/or project operation. Such learning needs to be realized in the knowledge base to contribute to future adaptive management as well as ongoing project implementation.

Decision Making

The main purpose of adaptive management is to utilize information to make decisions over time that lead to the success of the program in the face of uncertainty regarding system dynamics and response to interventions. Most decisions involve the actual or planned allocation of limited resources (e.g., funds, expertise) across the program and across the coast. Program-level decisions include:

- Which projects to include in the master plan and which to exclude;
- Whether to discontinue investments in existing projects, which may be at various stages in their life cycle, in order to provide funds for other projects;
- How to allocate funds among projects to accelerate or decelerate implementation;
- How to operate and maintain groups of projects to achieve/avoid specific outcomes and/or adjust to changing conditions such as river flow;
- How to adjust program activities in response to unpredictable events (e.g., droughts, hurricanes)

The procedures for some aspects of decision making are governed by statute. For instance, Act 8 of the 1st Extraordinary session of the Louisiana legislature in 2005 requires that the coastal master plan be submitted to specific legislative committees for approval prior to its submission to the legislature. Act 8 also outlines a public engagement strategy that must be undertaken before the plan is submitted. Broad level funding decisions for Louisiana coastal protection and restoration are described in the annual plan which shows projections of how funds will be allocated for the next three years. Similarly, the Act 8 statute identifies the content and approval process for the annual plan.

For the Louisiana coast, it is important that those involved in making program decisions regarding protection and restoration are cognizant of plans, policies, and activities that influence the coastal system but that are made by others. Currently in Louisiana, the CPRA Board is structured to ensure a number of government agencies and boards are engaged in decision making regarding the protection and restoration program (Box 1). The board also includes representatives of other groups, such as the Governor's Advisory Commission, that have been formed to engage a broader array of stakeholders and interest groups as well as members appointed by the governor. Input from such groups and from the public at large is a key element of adaptive management decision making. Decision makers are responsible for seeing the program in a larger context and proactively seeking input from others. In addition to the public engagement process outlined in Act 8, CPRA has successfully employed targeted outreach to interest groups and other stakeholders (CPRA, 2012) using focus groups for specific industries and a broad-based framework development team. CPRA also has an ongoing Outreach and Engagement Program. During the development of the 2012 Coastal Master Plan, the planning team: (1) created a platform for on-going discussion between stakeholders in conflict, (2) was willing to listen to divergent views, and (3) built relationships with adversaries in the planning process. Documenting the input and comments received from such groups and ensuring it is available to those formally engaged in the decision process is an important part of adaptive management.

Box 1: The CPRA Board

The CPRA Board comprises:
The Executive Assistant to the Governor (Chair)
The secretaries of the Department of Natural Resources; the Department of Transportation and Development; the Department of Environmental Quality; the Department of Wildlife and Fisheries; the Department of Economic Development; the commissioners of the Department of Agriculture and Forestry; the Department of Insurance; and the Division of Administration; the director of the State Office of Homeland Security and Preparedness; and the chair of the Governor's Advisory Commission on Coastal Protection, Restoration, and Conservation. Seven members appointed by the governor to representing the Police Juries and Levee Boards of Louisiana.

Figure 1 also shows that new ideas and concepts can be introduced into the process via decision making. As the CPRA Board approves the plan, it approves the inclusion of new projects and ideas. Further, CPRA staff, through efforts such as the Coastal Innovation Partnership Program (CIPP), can identify and bring ideas and projects to the attention of decision makers and those who influence them, such as senior staff, advisory commissions and boards. Innovative approaches that have been tested or explored elsewhere that may be useful to achieving master plan goals, may be identified using this approach. New project concepts may be available for consideration at any time during an adaptive management cycle. Currently, the project development and implementation program provides a mechanism for CPRA to vet new project ideas and test them against projects already included within the master plan.

Decision makers such as the CPRA Board and the Louisiana legislature are supported and informed by the work of CPRA, their own staff, and other experts and groups. How information is developed and presented to decision makers as part of the AMF is described in later sections which focus on specific aspects of the process. Day-to-day decisions regarding project operations, the execution of contracts and project-level development are described below. An AMP based on the framework presented here would provide additional detail on how different types of decisions are made and how information flows appropriately to inform those decisions.

KNOWLEDGE BASE

The other bookend of adaptive management is the knowledge available to make informed decisions. While many descriptions of adaptive management processes point to the need for monitoring, the knowledge base is more than just a series of data streams describing ongoing change in system status. The knowledge base is the foundation for the expectations of system response as a result of program implementation. Key elements of the knowledge base include:

- **Research studies that explain system dynamics.** These can be useful both individually in terms of providing details on specific process-response linkages, but also in synthesis documents that summarize a number of studies and compare/contrast research findings and their relevance to aspects of the coastal program. An example is a report on the State of the Science of the Bay Delta System[1] that highlights the knowledge and uncertainty regarding key system components. Given the rapid pace of knowledge accrual, updating such syntheses on a regular basis is crucial. No such syntheses have been developed recently in Louisiana, although in the past, symposium volumes have attempted to contribute to this need by highlighting recent development (e.g., Rozas et al., 1999). Summaries of recent research studies, however, need to be put in the context of previous studies here and research findings elsewhere to provide a useful foundation for adaptive management.

- **Conceptual models that illustrate chains of cause-effect relationships and how they influence program objectives**. Conceptual models provide an important organizing framework for planning in complex systems and have been considered by others to be an important way of communicating complex information (DiGennaro et al., 2012). Structured approaches to conceptual model development (e.g., Nuttle et al., 2008) can enable ready updates as new information becomes available.

- **Data derived from ongoing monitoring, periodic surveys, and research campaigns**. Monitoring data are the most frequently considered type of data in relation to adaptive management. However, a number of data sources and data streams exist that can be used as a foundation for adaptive management[2] including records of how previous decisions were formulated (e.g., documentation of the 2012 Master Plan process beyond the model results). The 2012 Coastal Master Plan also generated a substantial amount of data and information including modeling input and output files. More information can be found in the 2012 Coastal Master Plan Appendices[3]. A data inventory is currently under development for CPRA and a framework for considering the need for monitoring data is being developed under the System-Wide Monitoring and Assessment Program (SWAMP).

[1] http://www.science.calwater.ca.gov/pdf/publications/sbds/sbds_final_update_122408.pdf
[2] Systemwide Assessment and Monitoring Program GIS Data Inventory, in preparation. Contact info@thewaterinstitute.org for more information
[3] http://www.coastalmasterplan.louisiana.gov/2012-master-plan/master-plan-appendices/

- **Predictive models.** Coastal responses to changes in system configuration or dynamics can be predicted using a combination of statistical and process models. Statistical models can be used to document relationships between specific responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions. Statistical models may allow the empirical characterization of how a system works. However, statistical models do not allow the prediction of all system responses because they apply only within the range of conditions over which data have been collected. Process models rooted in underlying mechanisms provide a much stronger basis for predicting system responses to environmental change (i.e., extrapolating beyond available data), although model calibration and the validation of process models are more challenging than for statistical models.

While these are the main components of the knowledge base, an essential action is also facilitating access to the knowledge. An information management system or central clearing house for knowledge and information is required. This is not necessarily a depository of information, but a portal for access to an existing linkage to knowledge systems. The development of an informatics framework for knowledge management can: (1) empower users by providing fast access to relevant information; (2) lead to faster/better use of existing knowledge in decision making; (3) facilitate collaboration, workflow, mentoring, and training through knowledge-based communities of practice; and (4) maintain and/or increase organizational efficiency by leveraging internal and external information more effectively. Thus far in Louisiana, many components within the knowledge base are well developed (e.g., Coastwide Reference Monitoring System outputs and others shown on Figure 1), but an overarching framework for access and ongoing development is lacking. The coordination of the knowledge base and its access should be supported by CPRA but does not necessarily need to be undertaken within the state government structure. This function may be more appropriately taken on by an independent research- and knowledge-focused entity. However, the structure and function of the knowledge base should be guided by a group of advisors that include CPRA staff and other stakeholders with interests in technical information. Designation of roles and responsibilities and identification of resources should be identified in detail in the AMP.

Goals and Objectives

Identifying goals and objectives is a common first step in adaptive management and is a necessary early outcome of system-wide planning. The 2012 Coastal Master Plan reevaluated the goals and objectives of the 2007 Coastal Master Plan and determined that a key objective was not being addressed, thereby expanding the number of objectives from 4 to 5 (Box 2).

Box 2: 2012 Coastal Master Plan's Goals and Objectives

Goals:

1. Protection – Use a combination of restoration, nonstructural, and targeted structural measures to provide increased flood protection for all communities
2. Restoration – Use an integrated and synergistic approach to ensure a sustainable and resilient coastal landscape.

Objectives:

1. Flood Protection - Reduce economic losses from storm surge based flooding to residential, public, industrial, and commercial infrastructure.
2. Natural Processes - Promote a sustainable coastal ecosystem by harnessing the natural processes of the system.
3. Coastal Habitats - Provide habitats suitable to support an array of commercial and recreational activities coastwide.
4. Cultural Heritage - Sustain the unique cultural heritage of coastal Louisiana by protecting historic properties and traditional living cultures and their ties and relationships to the natural environment.
5. Working Coast - Promote a viable working coast to support regionally and nationally important businesses and industries.

In Figure 1, goals and objectives are developed using information from the knowledge base and periodically revisited by decision makers following assessment. The role of the CPRA Board as a decision maker is described above. In each adaptive management cycle (likely five years in coastal Louisiana) the goals and objectives need to be revisited. Progress towards them can be assessed using performance measures (Hijuelos & Reed, [2013] and The Water Institute, [2013]), and while there is likely to be variable progress during any cycle across the objectives, the assessment phase will identify whether this is due to a lack of the right types of projects or an inability of the existing set of projects to move towards desired outcomes. Modifying the goals and objectives of the program should not be taken lightly, as it may require a redirection of resources—making existing investments less meaningful—and lead to confusion in the public and among stakeholders. However, adjustments to goals and objectives may be merited under any of the following circumstances:

- When projects originally considered to contribute to achieving the objective are not producing meaningful change, and no viable alternatives can be identified. Given the general nature of the program objectives, this is unlikely to lead to an elimination of objectives, but it may lead to some reframing in order that public expectations of the program are clear. For example, if no substantial progress is made on providing structural protection over several cycles, the objective might be reframed to show a more obvious focus on nonstructural approaches.

- When an unanticipated change as a result of an external factor results in a new need. Examples might include a dramatic increase in exotic or invasive species that requires the program to focus on control or management in a manner not consistent with existing objectives (e.g., that is not focused on habitats or natural processes).

- When a change in program scope is introduced by statute. An example might be if riverine flooding from local streams came under the purview of the master plan. Under such circumstances, objectives would need to be modified, as would the plan, to encompass the new responsibilities.

These examples illustrate that modification of goals and objectives should only be undertaken due to major shifts in policy or coastal circumstances, and that those modifications are determined by information from the knowledge base or by higher-level decision making.

The current goals and objectives of the master plan are sufficiently broad to provide suitable guidance to planning and appropriate expectations of the public in terms of what the program is trying to achieve. Modifications to the goals and objectives, or their approval without modification, is the responsibility of the CPRA Board that is informed by their staff and advised by other groups (see Decision Making below).

PLANNING

Moving from goals and objectives toward a program plan requires the selection of specific projects based on a number of factors including: (1) project contribution to achieving the objectives, (2) constraints of funding, (3) the need for short-term as well as long-term benefits, (4) avoidance of unacceptable negative consequences, and (5) the desire to balance achievement across objectives. For the 2012 Coastal Master Plan, the selection of projects for inclusion was initially based on maximizing performance of two key outcomes: progress towards building or maintaining land and progress towards reducing risk, within funding constraints for two major groups of projects—restoration and protection. The draft plan was based on an analytical solution, given the results of specific technical analysis[4]. The project list was subsequently modified as a result of public input and the consideration of factors that were beyond the capability of the technical analysis tools.

One of the areas the assessment phase seeks to identify are those circumstances where plan implementation is not resulting in the expected changes in system state and the identification of why such deviations have occurred. While some of these deviations may be due to individual project performance, some may be programmatic in nature, for example project interactions do not occur as anticipated. The programmatic planning process needs to incorporate this information in one of the following ways:

- Using updated conceptual or predictive models within the knowledge base that incorporate learning from the adaptive management assessment;
- Modifying the list of candidate projects based on prior performance of projects of a similar type;
- Adjusting the sequencing of projects to improved expected plan performance.

The planning process receives information from decision making in terms of concepts and ideas that need to be considered as candidates for inclusion within the plan. For example, this could be in terms of: (1) new project concepts developed under the CPRA project development and implementation initiative; (2) approaches to project implementation identified under the CIPP or other means that result in changes in project costs, benefits or timing of outcomes such that they would rank higher than projects included in the existing master plan; or (3) adjustments in policy which enable changes in implementation. Planning also relies on updated models—both conceptual and predictive—included within the knowledge base, and provides information to the knowledge base in terms of model outputs, especially predictions of expected outcomes that are later accessed during assessment.

[4] The technical analysis underlying the 2012 Coastal Master Plan is described in a series of reports available at http://www.coastalmasterplan.louisiana.gov/2012-master-plan/master-plan-appendices/ and in Special Issue 67 of the *Journal of Coastal Research* available at http://www.jcronline.org/toc/coas//67?seq=67

Planning is conducted by a multidisciplinary team of planners, scientists, and engineers from inside and outside of CPRA and is overseen and advised by both technical and stakeholder groups.

Plan Implementation

Implementation is clearly critical to the overarching goal of the adaptive management process—the success of the plan. This is the step that gets projects off the ground and takes action towards achieving the goals and objectives. Each project included within the plan will be at a different stage of development; some may be permitted and ready for construction, others may require further development and design before actual implementation. A master plan developed under adaptive management should lay out the projects that are expected to be constructed during each 5-year adaptive management cycle and the progress which is expected on others that are not yet ready to build. It is likely that modifications to the specifics laid out in the master plan will be necessary for a number of reasons including:

- The availability of funds to support one project but not another, requiring adjustments to the project sequence;
- Environmental conditions (e.g., droughts, floods) that result in changes in project operations or which limit construction or alter timelines;
- Delays in permitting or unforeseen local project conditions that result in project modifications or adjustments in schedule.

Tracking of such adjustments is crucial in order that assessment of program performance (see below) can be based on actual rather than anticipated implementation conditions. During implementation, adaptive management is also practiced at the project level.

Program implementation is the responsibility of CPRA. Implementation is informed by decision making, particularly in relation to discretionary allocation of funding. Information is exchanged with the knowledge base regarding environmental and contextual issues for implementation, and to inform individual project decision making.

Assessment

One of the key elements of adaptive management is the consideration of observed outcomes in the context of a priori expectations and new knowledge gained. Monitoring data regarding system status and existing project performance, as well as expertise and data generated outside the program, contributes to the knowledge base. Modeling and synthesis are used on the assessment phase to evaluate program performance and support in decision making as the adaptive management process proceeds. Assessment will ultimately be used to determine if the system is reaching its desired goals and objectives, and if alternate management actions are needed and/or how new ideas and concepts can be incorporated.

The assessment component of the programmatic AMF brings together several important elements of the process:

- **Expectations of system response to plan implementation**. These are developed during planning. For coastal Louisiana, modeling is used to predict the response of the coast to actions; one of the challenges of such predictions is that environmental drivers influencing the system in the future cannot be known and are assumed (Table 1). Scenario analysis (e.g., Groves & Lempert, 2007) enables CPRA to explore the implications of some of these assumptions on the expected outcomes of plan implementation. Toward the end of an adaptive management cycle, predictions can be made regarding system response using the actual conditions that occurred during the assessment period (Table 1).

- **The actions that were taken during the adaptive management cycle**. Given uncertainties in important constraints such as availability of funds, permits, construction timelines, etc., at the start of any adaptive management cycle, there will be an expected sequence of actions and the expectations of system response will be based on those assumptions. At the end of an adaptive management cycle, the actual actions taken and the specifics of their character are known. Similarly, the ways in which existing projects, such as river diversions or flood control structures, are operated has to be assumed at the beginning of the cycle, whereas at the end of the cycle it is known and can be incorporated into models.

- **Measurements of system state**. Monitoring will provide data regarding the actual change in the system conditions.

Table 1. Comparison of available information at different phases of an adaptive management cycle

Information	**Start of adaptive management cycle, e.g., planning**	**End of adaptive management cycle, e.g., assessment**
System drivers including uncertainties (e.g., storm impacts) and boundary conditions (e.g., river discharge regime)	Assumed	Known
Knowledge utilization	Captured in models used for prediction	Improved models based on research/monitoring/project implementation
Action Implementation (timing/detail)	Assumed	Known
Operation of existing projects	Assumed	Known
System state	Predicted using assumed conditions	Measured using system monitoring Predictions using known externalities

Modeling is essential to this adaptive management approach as it provides the expectations which justify plan implementation. This is especially important in Louisiana due to the constantly changing baseline. As described above, during assessment modeling conducted during planning must be repeated using the actual changes in system drivers that occurred during the cycle period. The differences between the two predictions can provide insight into the role of specific system drivers, including their variability that should be considered in updates to system models as appropriate. If improvements in the system models were made during the adaptive management cycle due to other improvements in the knowledge base, then the new models should be used to predict system state. New models should be based on input parameters used in the analysis conducted at the start of the cycle, as well as with the end-of-cycle information. The difference between the two sets of analysis will show how model improvement alone can result in changes in expectations of the systems' response to the plan.

The main focus of assessment is the comparison of the two ways in which system state can be characterized at the end of the adaptive management cycle—measured and predicted (Table 1). Differences between these two characterizations may be due to one of several factors:

- **The (improved) models may not adequately capture aspects of the system dynamics which are important to system state.** This can be further explored by hind-casting of historic conditions and/or direct comparison of measured versus predicted states for parts of the system (e.g., a sub-basin where few aspects of the plan have yet been implemented) where there is high confidence in the monitoring. If the models are predicting historic changes or changes in system state in areas with few project-related effects, this factor can be considered of less importance.

- **The monitoring is not adequately capturing the system response or the characteristics of the system drivers**. This can be further explored for some aspects of system dynamics by considering additional data sets, for example, data of higher frequency or density that may be available for local areas to show temporal or spatial changes that coastwide monitoring may not capture. All monitoring data used in assessment should have undergone a QA/QC process so errors in the data should not be a problem, but additional expert review of the data can be used as an additional validation of the monitoring findings.

- **Plan implementation is not resulting in the expected changes in system state.** If the first two factors have been eliminated or minimized in explaining differences between measured and predicted states, then assumptions regarding the effects of plan implementation on the system must be reexamined. This requires parsing of the multiple cause-effect relationships implicit in the predictive models to identify which projects or project interactions are not performing as expected. This part of the assessment can be guided as a series of questions in a decision-tree format that result in a focus on one or more aspects of the plan that require more detailed examination. The conceptual models showing the cause-effect relationships included in the knowledge base and applied in planning can then be used with the available data to identify which of the relationships is not performing as expected.

This step in the adaptive management process is largely undertaken by technical experts with knowledge of the system and its dynamics. While it relies heavily on models and analysis, it is important that members of the expert team conducting the assessment were not involved in the development of the conceptual and/or predictive models used in planning. This may be achieved either through an expanded team of experts or through a core team and an external advisory or guidance panel.

PROJECT-LEVEL ADAPTIVE MANAGEMENT

The main elements of project-level adaptive management are similar to the programmatic framework described above, with some key exceptions. Decision making and the knowledge base still play key roles throughout, but the nature of the interactions is slightly different. For each individual project, a specific adaptive management plan can be developed[5] and templates can be developed to ensure consistency of approach across master plan projects.

This section focuses on how the elements of project level adaptive management different from those of the programmatic framework:

---

[5] For an example of a project level adaptive management plan see http://cw-environment.usace.army.mil/restore/pdfs/LCA-WhiteDitch-2010.pdf

- **Decision making**. Decisions regarding the allocation of funding for the project will still be made through the CPRA Board as part of part of the annual plan process. Decision on permits for construction and operation are made by agencies tasked with that authority. Where a project is deemed—via post-construction assessment—to not be meeting its expected outcomes, adjustments in operation or through enhancements or maintenance may be recommended. A key decision is whether to allocate funding for such adjustments. If the funding was not anticipated, then this becomes a program-level decision as the additional funds allocated to a single project impact other program components.

- **Knowledge base.** The overall content of, and access to, the knowledge base should be the same for project-level as for program-level adaptive management. In particular, project information developed during engineering and design phases should be included in the knowledge base, as well as the details of model runs and assumptions used in project level planning. Where project-specific monitoring of data is conducted, it should be housed with other similar data in the knowledge base context. It is important to note that project-level adaptive management does not rely solely on information developed for the particular project; rather it needs to draw on all available and relevant information.

- **Project goals and objectives**. The purpose of most master plan projects will be to maintain, sustain, or build natural landscape features (e.g., wetlands, ridges) or to provide for risk reduction for coastal communities. During project planning and environmental compliance, constraints may also be identified (e.g., conditions that need to be avoided). While the goals and objectives of projects will be consistent with one or more of the master plan goals and objectives (Box 2) the specific outcomes to be accomplished will be the result of project specific planning. These objectives must be SMART—Specific, Measureable, Attainable, Relevant, and Time bound[6]—in order to guide project implementation and adaptive management.

- **Project development, design and permitting.** This is a key step in project-level adaptive management as it determines the specifics of how a project is initially built. It differs from the Planning step in programmatic adaptive management in that the focus is on fine tuning the project to local, site-specific conditions rather than coast-wide considerations. It is also more likely guided by specific technical or engineering models. Some uncertainties at the program-planning level will be reduced as site-specific information can be collected or developed, while others may emerge, e.g., as local boring provide insight on the spatial variability of substrate conditions. The specific designs and plans developed guide construction and initial project operations and are foundational to project-level adaptive management.

- **Project construction/operation**. Construction and operation of projects must proceed according to accepted professional engineering standards and in accordance with appropriate laws and regulations. On the ground, decisions will be made according to these standards or project-specific standard operating procedures. Any adjustments from plans and specifications made during construction should be tracked and housed in the knowledge base in order that later phases of adaptive management (e.g., assessment), can be informed by "as-built" conditions rather than those anticipated earlier in the process.

[6] SMART planning is a concept commonly used in business. It has been applied to conservation issues; for example Brooks, J. J., & Massengale, R. (2011).

- **Post-construction assessment**. Assessment of project performance is very similar to program-level assessment. The focus is on the project and its interaction with the surrounding environment, including other projects. The difference in actual outcomes versus anticipated outcomes needs to be guided by both modeling and monitoring data. A key recommendation emerging from this step is whether additional funds are required if a project is not meeting its expected outcome to support adjustments in operation or some other corrective action.

KEY IMPLEMENTATION STEPS

This framework has been designed as the foundation of a more detailed AMP. The goal has been to set some expectations for that plan and provide information that can guide its development. This effort has been undertaken by the work of the Adaptive Management Guidance Panel. Their key findings are described in Appendix I and include advice to:

- Integrate adaptive management into the institutional model of the coastal protection and restoration program;
- Support the role of science in decision making;
- Encourage learning throughout the adaptive management process and at all levels of the institutional model;
- Develop and apply a transparent decision-making process;
- Initiate the principles of adaptive management in existing programs and projects;
- Develop a governance structure that facilitates adaptive management implementation.

The panel's guidance to focus on science/learning and how decisions are made was one of the key reasons why the framework is built around decision making and the knowledge base, as critically important and parts of the process that are often revisited and used. Moving from the framework towards an AMP requires a number of steps:

- **Determining decision-making roles, responsibilities, and governance.** Adaptive management cannot function well without a transparent decision process and unless it is made part of routine operations. This will require specific information regarding which groups or individuals are responsible for different parts of the process, how they interact, how their work is overseen, how they report, and how they are accountable for various parts of the process. It will also be necessary to identify resources to support key elements; for example aspects of the knowledge base, and the mechanisms which ensure transparency (a key concern of the panel).

- **Identification of key decision points**. While this report assumes a 5-year cycle for program level adaptive management, within each 5-year cycle there may be intermediate points at which decision makers need assurance of progress or require updated information. This might, for example, coincide with the preparation of the annual plan in non-master plan years when a 3-year plan of funding is being laid out. While much of this will rely on feedback through the project-level adaptive management process, unforeseen issues, such as project delays, hurricane impacts, new funding sources, etc., may impact the program as a whole and require interim assessment to be conducted. During AMP development, such changed circumstances should be considered and flexibility built into the regular 5-year assessment cycle.

- **Guiding principles have been a very useful part of coastal planning in Louisiana for over a decade.** They have guided planning but not implementation. The development of a set of adaptive management principles that can be used to guide day-to-day work as well as periodic planning will be an important part of the AMP. Effective principles will not show people what needs to be done, but they will provide a guide as to how it gets done and ensure that adaptive management is more effectively integrated into all aspects of restoration and protection work.

Development of an AMP based on this framework involves many additional layers of detail to be added. That development needs to be done in collaboration with an array of interested parties who may have ideas to contribute as well as needing to be informed and must be appropriately resourced. Adaptive management is an oft used "buzzword." To make it a reality it will require development of a detailed AMP and the long-term commitment of resources (e.g., financial, personnel, expertise, and infrastructure) to the action of adaptive management and the full implementation of the AMP.

REFERENCES

Allen, C.R., Fontaine, J.J., Pope, K.L., & Garmestani, A.S. (2011). Adaptive management for a turbulent future. *Journal of Environmental Management, 92*, 1339-1345.

Brooks, J. J., & Massengale, R. (2011). Planning for people? An evaluation of objectives for managing visitors at wildlife refuges in the United States. In Watson, Alan; Murrieta-Saldivar, Joaquin; McBride, Brooke, comps. *Science and stewardship to protect and sustain wilderness values: Ninth World Wilderness Congress symposium; November 6-13, 2009*; Merida, Yucatan, Mexico. Proceedings RMRS.

Coastal Protection and Restoration Authority (CPRA). (2012). *Louisiana's Comprehensive Master Plan for a Sustainable Coast, Appendix G, Outreach and Engagement,* Baton Rouge, LA.

DiGennaro, B., Reed, D., Swanson, C., Hastings, L., Hymanson, Z. Healey, M., Siegel, S., Cantrell, S., & Herbold, B. (2012). Using conceptual models in ecosystem restoration decision making: an example from the Sacramento-San Joaquin River Delta, California. *San Francisco Watershed and Estuary Science, 10(3).* Available from: http://escholarship.org/uc/item/3j95x7vt.

Groves, D.G. & Lempert, R.J. (2007). A new analytic method for finding policy-relevant scenarios. *Global Environmental Change, 17*, 73–85.

Hijuelos, A.C. & Reed, D.J. (2013). An approach to identifying environmental and socio-economic performance measures for coastal Louisiana. *The Water Institute of the Gulf*. Produced for and funded by the Coastal Protection and Restoration Authority under Task Order 9, Contract No. 2503-12-58. Baton Rouge, LA.

Lyons, J.E., Runge, M.C., Laskowski, H.P., Kendall, W.L. (2008). Monitoring in the context of structured decision-making and adaptive management. *The Journal of Wildlife Management, 72*, 1683-1692.

McLain, R.J., & Lee, R.G. (1996). Adaptive management: promises and pitfalls. *Environmental Management, 20*, 437-448.

Murray, C., & Marmorek, D. (2003). Adaptive management and ecological restoration. In P. Freiderici (Ed.), *Ecological Restoration of Southwestern Ponderosa Pine Forests* (pp. 417-428). WA: Island Press.

National Park Service. (2012). Guidance on designing an integrated monitoring program. *Natural Resource Report NPS/NRSS/NRR-545*. National Park Service, Fort Collins, CO.

NRC. (2000). *Ecological Indicators for the nation* (p. 199). Washington, DC: The National Academies Press.

Nuttle, W.K, Sklar, F.H., Owens, A.B., Inoue, M., Justic, D., Kim, W., Melancon, E., Pahl, J., Reed, D., Rose, K., Schexnayder, M., Steyer, G., Visser , J., & Twilley, R. (2008). Conceptual ecological model for river diversions into Barataria Basin, Louisiana. In R.R. Twilley (Ed.), *Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration*. *Ch. 7. Vol. IV*. Final Report to Department of Natural Resources, Coastal Restoration Division, Contract No. 2512-06-02. Baton Rouge, LA.

Porzecanskik, I., Saunders, L.V., & Brown, M.T. (2012). Adaptive management fitness of watersheds. *Ecology and Society, 17*, 29.

Raynie, R.C., & Visser, J.M.(2002). *CWPPRA Adaptive Management Review, Final Report.* Prepared for the CWPPRA Planning and Evaluation Subcommittee, Technical Committee, and Task Force. Available online at: http://www.lacoast.gov/reports/program/amrfr/FINAL%20REPORT%2012-20-02.pdf.

Rozas, L.P., Nyman, J.A., Proffitt, C.E., Rabalais, N., Reed, D.J. & Turner, R.E. (Eds). (1999). *Proceedings: Recent Research in Coastal Louisiana: Natural System Function and Response to Human Influence*. Published by Louisiana Sea Grant College Program.

Schreiber, E.S.G., Bearlin, A.R., Nicol, S.J., & Todd, C.R. (2004). Adaptive management: a synthesis of current understanding and effective application. *Ecological Management & Restoration, 5*, 177-182.

Steyer, G., Visser, J. M., Good, B., Nestler, J. M., Nuttle, W., Reed, D. J., Rivera-Monroy, V. H., Rose, K. A. & Twilley, R. R. (2004). Adaptive Environmental Assessment and Management: A Draft Framework, Ch. 22. In R. R. Twilley (Ed.), *Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Model of Louisiana Coastal Area (LCA) Comprehensive Ecosystem Restoration Plan. Vol. II: Tasks 9-15* (Vol. Contract No. 2511-02-24). Baton Rouge, LA: Final Report to Department of Natural Resources, Coastal Restoration Division.

Steyer, G. D., & Llewellyn, D. W. (2000). Coastal Wetlands Planning, Protection, and Restoration Act: A programmatic application of adaptive management. *Ecological Engineering, 15(3–4),* 385-395. doi: http://dx.doi.org/10.1016/S0925-8574(00)00088-4

The Water Institute of the Gulf. (2013). Methodology for Producing a Coastal Louisiana Report Card. Report produced for and funded by the Coastal Protection and Restoration Authority under Task Order 9, Contract No. 2503-12-58. Baton Rouge, LA.

Walters, C. (1997). Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology, 1.*

Westgate, M.J., Likens, G.E., & Lindenmayer, D.B. (2013). Adaptive management of biological systems: A review. *Biological Conservation, 158,* 128-139.

Williams, B.K. (2011.) Adaptive management of natural resources—framework and issues. *Journal of Environmental Management, 92*, 1346-1353.

Williams, B.K., Szaro, R.C., & Shapiro, C.D. (2009). *Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group*. Washington, DC: U.S. Department of the Interior.

Appendix I:
Adaptive Management Guidance Panel's Key Findings

Summary

The Water Institute of the Gulf has been tasked by CPRA to develop an AMF with advisement from an Adaptive Management Guidance Panel. A 6-member group of adaptive management experts has been convened to provide guidance and recommendations of the critical components of a programmatic AMF for coastal Louisiana. The panel participated in a 2-day workshop in Baton Rouge, Louisiana to discuss challenges with implementing adaptive management and to highlight successful programs to use as a guide. Their key findings and recommendations that have been used in the development of this framework are summarized below. The panel's biographies are also provided.

1) **Integrate adaptive management into the institutional model of the coastal protection and restoration program.** The principles of adaptive management must be part of the program's ethos and be fully integrated in the program from planning to design to post-construction. The responsibilities of implementing adaptive management should be assigned to specific individuals, but training is required throughout the organization to ensure a full understanding of adaptive management and its applications. The principles of adaptive management must also be a component of the program's standard operating procedures and incorporated into the annual performance evaluation of staff.

2) **Support the role of science in decision making.** The coastal protection and restoration program should support research, monitoring, and modeling activities for adaptive management. Developing and periodically revisiting conceptual models can assist in defining uncertainties and identify areas for monitoring. An assessment group is needed to synthesize information through the science and monitoring program to support those responsible for project and program decision making. Learning from the assessment group will facilitate adaptation of the program on the basis of what is learned during the program life cycle. The establishment of an independent science review panel could serve to evaluate the contribution of science to the decision-making process. These advisors must be willing to maintain ongoing involvement in a program of projects to ensure that science-based recommendations are effectively conveyed to managers, and that those managers are held accountable for incorporating that science into their management decisions.

3) **Encourage learning throughout the adaptive management process and at all levels of the institutional model.** Learning should be a critical contributor to management decisions and can justify the accountability of science to program effectiveness (see 2 above). Having the underlying monitoring data to assess program performance is essential, as well as the capacity to communicate the information throughout the program as necessary. A clear pathway must be established that identifies how knowledge gained will be used by decision makers. Scientists, engineers, and managers will need to interact on an ongoing basis to share new information and assemble the collective knowledge base.

   The following questions can guide the learning process in adaptive management:

   - What does the program need to learn?
   - How can the program address the learning "gap"?
   - What are the benefits from learning in making future decisions?

4) **Develop and apply a transparent decision-making process.** A decision analysis framework should be developed to define the key decisions and the critical uncertainties affecting those decisions. This will require sharing goals between scientists and managers in order to reduce uncertainties for both the socio-economic and natural systems. Engineering uncertainties must also be included to ensure the risks are clearly defined and understood. Performance measures for each objective may guide the decision analysis framework. A process for rolling up information from projects to program must be in place. Transparency is needed throughout the program planning and implementation process to facilitate adjustments as needed.

5) **Initiate the principles of adaptive management in existing programs.** As mentioned, adaptive management must be part of the culture of the coastal protection and restoration program and as a result, should be infused into existing projects. This should include a review of how projects were originally conceived, how designs and costs were determined, how modeling analyses were used to prioritize projects, and how modifications of design would alter performance. In addition, adaptive management must be applied throughout the entire program lifecycle such that assumptions generated during the planning phase must carry over to the design and implementation phases. Adaptive management must be able to operate in instances where new restoration projects are being implemented within a landscape where other projects already exist.

6) **Develop a governance structure that facilitates adaptive management implementation.** Governance arrangements to implement adaptive management should provide for the uninterrupted flow of information and ideas across various functions (e.g., planning, research, science, project management, engineering, operations). A structure is needed that provides scientists with “credible independence”; the ability to inform/engage in the decision-making process, while at the same time pursuing science in an uncompromised manner. Ensure that the program is sufficiently funded to provide for information exchange across disciplines and authorities as a means to support the decision-making process. A distinct budget item is needed for the program’s science component to ensure an adequate level of coordination.

Guidance Panel Biographies

Nick Aumen

Nick Aumen is an aquatic ecologist and Water Quality Branch Chief for Everglades National Park (U.S. Department of the Interior, National Park Service), and oversees an interagency team of scientists and engineers tracking the progress of the south Florida ecosystem restoration program. His team, located at the Loxahatchee National Wildlife Refuge near West Palm Beach, Florida, assesses the potential impacts of restoration programs on Everglades National Park and other sensitive federal lands. Formerly Nick was the research director at the South Florida Water Management District in West Palm Beach, directing a team of over 120 scientists and engineers conducting research in support of ecosystem restoration. Nick received his B.S. and M.S. in biology at the University of West Florida, and his Ph.D. in microbial ecology at Oregon State University. After completing his Ph.D., he accepted a faculty position in biology at the University of Mississippi, and was a tenured associate professor of biology until 1991, when he returned to Florida. Nick presently is an adjunct professor of biology at Florida Atlantic University in Boca Raton, Florida. Nick serves on the executive committee of the Interamerican Water Resources Network, and helped organize four biennial Dialogues on Water Management (Miami, Florida, Panama City, Panama, Foz do Iguaçu, Brazil, and Medellín, Colombia). He also served on the national board of directors of the Sierra Club, a 120-yr-old environmental organization with more than 750,000 members, and served two terms as its vice president and one as treasurer.

Mike Donahue

Michael J. Donahue, Ph.D. is a corporate vice-president with URS Corporation, a global consulting firm specializing in planning, engineering, architecture, and design. Affiliated with the Water/Wastewater Business Line, he provides companywide leadership, strategic direction, and technical and business development services. He directs the company's National Ecosystem Restoration Technology Practice and oversees special initiatives in the Great Lakes, Chesapeake Bay, and Gulf Coast regions. Areas of special expertise include water resources planning, ecosystem restoration, adaptive management, and governance systems for complex, multijurisdictional resource management. He presently manages numerous multimillion dollar contracts for federal, state, municipal, and private sector clients nationwide.

Dr. Donahue is a 3-time graduate of the University of Michigan, where he holds a B.S. in natural resources management, an M.A. in public policy, and a Ph.D. in urban, technological and environmental planning. His doctoral dissertation entailed the design and evaluation of watershed-based governance systems for resource management and ecosystem restoration in complex, multijurisdictional settings.

Holly Doremus

Holly Doremus is the James H. House and Hiram H. Hurd professor of environmental regulation at the University of California, Berkeley; co-faculty director of the Center for Law, Energy, and the Environment at Berkeley Law; and a member scholar of the Center for Progressive Reform. She has written extensively about environmental and natural resources law and policy. She received her B.S. in biology from Trinity College (Hartford, Connecticut), Ph.D. in plant physiology from Cornell University, and J.D. from the University of California, Berkeley. After law school, she clerked for Judge Diarmuid O'Scannlain of the United States Court of Appeals for the Ninth Circuit and practiced law in Corvallis, Oregon. She began her teaching career at the University of California Davis School of Law, where she taught for 13 years before moving to the University of California, Berkeley.

David Marmorek

David Marmorek is an aquatic ecologist, president of ESSA Technologies Ltd, and an adjunct professor at the School of Resource and Environmental Management at Simon Fraser University. Mr. Marmorek has spent the last three decades combining his technical knowledge (e.g., simulation modeling, ecological risk assessment, aquatic ecology, experimental design, adaptive management, decision analysis) with his skills and experience in the human dimension (e.g., facilitation, team leadership) to tackle complex environmental problems. Much of his work has focused on leading teams of scientists in the development and application of tools to predict, manage, and monitor the impacts of human actions on aquatic ecosystems and fisheries, including such stressors as dams, acid rain, forestry, agriculture, fishing, power plants, climate change, and industrial pollution. In the last decade, his primary focus has been the application of decision analysis and adaptive management to the design of strategies for flow management, habitat rehabilitation, and recovery of fish and wildlife populations in many parts of North America. This includes ecosystems in California (e.g., Clear Creek, Trinity River, Sacramento River, San Joaquin River, Russian River), the Midwest (e.g., Platte River Basin), the Florida Everglades, the Middle Rio Grande, the Columbia Basin (United States and Canadian portions), and British Columbia (e.g., Cheakamus, Okanagan, and Skeena watersheds). While he has predominantly worked in North America, he also has led projects in Peru, Ecuador, Vietnam, and Thailand.

Ron Thom

Ron, who leads the 22 members of the CER technical group at the Marine Sciences Laboratory, Pacific Northwest National Laboratory, has conducted research in coastal and estuarine ecosystems since 1971. His research includes coastal ecosystem restoration; adaptive management of restored systems; benthic primary production; climate change; and ecology of fisheries resources. Over his 41-year professional career, Ron has directed approximately 200 multidisciplinary ecological studies. He has worked on systems in California, Washington, Oregon, Alaska, Massachusetts, New York, Nebraska, and Alabama. He has published five book chapters, over 100 journal articles, hundreds of reports, made hundreds of professional presentations, and served on numerous professional committees. From 1985-1989 he chaired the Technical Advisory Committee of the EPA's Puget Sound Estuary Program. Ron was appointed in 2010 to the science team of the Northwest Straits Commission. Since 2009, Ron has served on the Expert Regional Technical Group (ETRG) that evaluates restoration project proposals aimed at restoring ecosystem health and salmon in the Columbia River estuary. In 2011, Ron served as a member of the U.S. EPA Science Advisory Board panel reviewing the Great Lakes Restoration Program. In 2010, he was elected to the Washington State Academy of Sciences based on career accomplishments. In 2012, he was appointed to the board of directors for the academy. The academy advises the governor on science and medical issues affecting the state. Ron has been an affiliate associate professor, School of Aquatic and Fisheries Sciences, University of Washington since 1991.

Robert Twilley (Panel's Chair)

Dr. Twilley is executive director of Louisiana Sea Grant College and professor in the Department of Oceanography and Coastal Science at LSU. He was a distinguished professor in Louisiana Environmental Studies at LSU in 2005, and served in several administrative capacities including associate vice-chancellor of research and economic development from 2007 to 2010, and director of the Wetland Biogeochemistry Institute from 2004 to 2007. In 2010, Dr. Twilley served for two years as vice-president of research at University of Louisiana at Lafayette (ULL), which manages the UL Research Park and a $70 million research enterprise. He earned the ULL Foundation's Distinguished Professor Award in 2000, where he was a professor in biology from 1986 to 2004. He is the founder of the LSU Coastal Sustainability Studio in 2009, and also founded the Center for Ecology and Environmental Technology (CEET) at ULL in 1999. Most of Dr. Twilley's research has focused on coastal wetlands both in the Gulf of Mexico, throughout Latin America, and in the Pacific Islands. Dr. Twilley has published extensively on wetland ecology, global climate change, and has been involved in developing ecosystem models coupled with engineering designs to forecast the rehabilitation of coastal and wetland ecosystems.