Coastal Protection and Restoration Authority
450 Laurel Street, Baton Rouge, LA 70804 • coastal@la.gov • www.coastal.la.gov

2017 Coastal Master Plan

Model Improvement Plan

Report: Version I

Date: August 2013

Prepared By: The Water Institute of the Gulf

THE WATER INSTITUTE OF THE GULF

committed to **our coast**

Coastal Protection and Restoration Authority

The Coastal Protection and Restoration Authority (CPRA) was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties and responsibilities of the CPRA and charged the new Authority to develop and implement a comprehensive coastal protection plan, consisting of a Master Plan (revised every 5 years) and annual plans. This document was prepared in support of the 2017 Coastal Master Plan.

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- The Water Institute of the Gulf - Ehab Meselhe, Alaina Owens, and Denise Reed
- Coastal Protection and Restoration Authority (CPRA) of Louisiana - Mandy Green, Ed Haywood, Mark Leadon, Natalie Peyronnin, and Abby Shao.

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INTRODUCTION

A suite of individual modeling tools was developed for use in the 2012 Coastal Master Plan. These included Eco-hydrology (Meselhe et al., 2013), Wetland Morphology (Couvillion et al., 2013), Barrier Shoreline Morphology (Hughes et al., 2012), Vegetation (Visser et al., 2013), Ecosystem Services (Nyman et al., 2013; Rivera-Monroy et al., 2013), Storm Surge and Wave (Cobell et al., 2013), and Risk Assessment (Johnson et al., 2013). The models were used to estimate the individual and cumulative effects of hundreds of projects on the landscape and ecosystem and the level of impact/risk to communities. The Coastal Protection and Restoration Authority (CPRA) of Louisiana wishes to utilize modeling tools to support the 2017 Coastal Master Plan, building upon existing technical efforts where possible. Specifically, the 2017 modeling analysis will focus on:

- Estimating the effects of individual master plan projects (each restoration and protection project individually) - 50 year analysis;
- Estimating the basin wide effects of select sequences/combinations of restoration and protection project projects - 20-25 year analysis; and
- Estimating the coast wide effects of the master plan (all restoration and protection projects combined) - 50 year analysis;

For the 2017 Coastal Master Plan, the suite of models for assessing landscape outcomes needs to be designed to efficiently run 50 year time sequences, with the ability to predict project effects at the basin-scale. Risk models can also be improved to incorporate newly available data and better estimations of uncertainty. All modeling tools used for the 2017 Coastal Master Plan must be refined/developed, tested, documented, reviewed, and ready for production-level use in early-2015.

CPRA tasked The Water Institute of the Gulf (The Institute) with coordinating the technical tasks and experts needed to refine existing modeling tools and develop new tools for use in the 2017 Coastal Master Plan. The overall vision for predicting landscape change is to develop Integrated Compartment Models (ICMs) by building upon the technical tools used in the 2012 Coastal Master Plan, making revisions and improvements where possible, and developing entirely new tools in some instances. Changes from the 2012 Coastal Master Plan models to the ICMs can be characterized into three broad categories: development of new process-based algorithms (e.g., marsh edge erosion and sediment distribution), integration of model code into a single common framework (e.g., all code integrated into Fortran), and increased resolution of the models (e.g., reducing the size of the 2012 Coastal Master Plan Eco-hydrology compartments). Future scenarios (environmental and risk/damage) will be updated, and it is envisioned that a full set of sensitivity analyses, as well as calibration/validation, performance assessments and uncertainty analyses will be conducted through this effort.

Modeling of fish and shellfish outcomes for the 2012 Coastal Master Plan utilized habitat suitability indices (HSIs) (Nyman et al., 2013), which are beneficial for predicting broad spatial patterns of habitat change. For the 2017 Coastal Master Plan, the use of more dynamic modeling is being explored to quantitatively predict potential changes in important fishery resources in the future. Habitat suitability indices may still be utilized where necessary.

Considering the existing advancement of the modeling tools used for Storm Surge / Wave and Risk Assessment for the 2012 Coastal Master Plan, a very similar strategy will be utilized for the 2017 Coastal Master Plan effort, with new data being incorporated and a better understanding of parametric uncertainties.

In closing, the 2012 Coastal Master Plan modeling effort was widely praised as being a commendable and impressive effort – the 2017 Coastal Master Plan modeling effort will draw upon the existing tools and lessons learned to employ an even more refined and robust effort.

BACKGROUND AND RATIONALE

Background

The Model Improvement Plan (MIP) presented here was developed through a collaborative effort between The Institute and the Coastal Protection and Restoration Authority (CPRA) of Louisiana. It is designed to meet CPRA's needs for the 2017 Coastal Master Plan by building upon lessons learned from previous modeling efforts, including needs that were identified (1) in technical model reports from the 2012 Coastal Master Plan modeling teams[1] , (2) during a series of model-improvement "brainstorming workshops" hosted jointly by CPRA and the Institute in fall 2012, and (3) during the summer/fall 2012 peer review of the 2012 Coastal Master Plan model-specific technical reports including recommendations from both reviewers and review editors[2] (Table 1).

Due to limited time and resources, not all recommended improvements suggested over the last 12 months are included in this document; some will be considered through other efforts (e.g., data management of model inputs/outputs will be a critical component throughout this effort, but it will be funded/directed under an independent data management task. It is, therefore, not explicitly identified as a MIP subtask). Other recommended improvements are considered more appropriate for implementation under research-based initiatives (e.g., nutrient effects on vegetation).

This document is intended to serve as a broad overview of the current vision for ongoing model improvements. As such, it may be periodically revised, as the needs of CPRA change, approaches are developed and tested, and new technologies are developed / become incorporated.

Rationale for Improvements

The improvements proposed herein have been developed through discussions with coastal modeling experts and seek to fulfill CPRA's modeling needs, as they relate to the 2017 Coastal Master Plan. As such, this Model Improvement Plan calls for a number of desired improvements in the modeling approach:

- Refining the size of the compartments to increase the spatial resolution;
- Integrating simulation of physical and ecological processes; and
- Integrating model components where possible to reduce manual data transfer and facilitate an increase in output frequency.

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[1] Appendices D1 – D27; http://www.coastalmasterplan.louisiana.gov/2012-master-plan/master-plan-appendices/

[2] Peer Review of the Predictive Model Technical Reports: Louisiana's Comprehensive Master Plan for a Sustainable Coast. December 14, 2012; http://thewaterinstitute.org/files/pdfs/Peer%20Review%20of%20the%20Predictive%20Model%20Technical%20Reports%20Summary.pdf

As previously mentioned, the MIP was also developed around recommendations made by modeling teams during and following the 2012 Coastal Master Plan effort and comments made by peer reviewers and editors during the peer review of the 2012 Coastal Master Plan model-specific technical reports. Detailed recommendations from the peer review process are provided in Table 1, along with a notation of which MIP Subtask (described later in this document) addresses the issue.

Table 1. Specific Recommendations for Modeling Improvements from the Peer Review of 2012 Coastal Master Plan Model Reports.

Review Comment	MIP Subtask
ECO-HYDROLOGY	
More regionally-integrated thinking is needed on the way that the models are conceptualized and used	4.8
Better representation of the fresh water, sediment and nutrient budgets is needed	4.1
Rethink how the sediment flux calculations are implemented in the models	4.1
Deliberate forethought is needed to design an approach to synthesizing missing data required to drive long-term simulations	4.6
Compare the errors (calibration/validation) with errors achieved for similar parameters in other large-scale coastal simulation modeling exercises, such as for Chesapeake Bay and San Francisco Bay	4.10
WETLAND MORPHOLOGY	
Incorporate research advances and high resolution models	4.1, 4.2, 4.8
Include mechanistic improvements to the soil processes as part of the model (feedbacks between plants, sediments, tides and sediment transport)	4.1, 4.2
Incorporate stochastic effects of storms	4.1, 4.2
BARRIER SHORELINE	
Consider the development and application of a new shoreline change model (e.g., GENESIS)	4.3
Examine and consider developing hybrid models (build/adapt the best model for the application)	4.3
Apply wave and storm surge data on a more frequent basis (at least every three hours)	4.3
Couple shoreline and inlet models more frequently than 25 years	4.3
Illustrate the model capability with a number of idealized cases (e.g., 1. effects of averaged waves and water levels vs. more frequent sampling; 2. effects of storm surge induced currents on tidal inlets)	4.10
Carry out both calibration and verification (validation) phases	4.10
VEGETATION	
Explore other variables derived from salinity (such as maximum salinity, or salinity variation)	4.4

Review Comment	MIP Subtask
Incorporate additional processes into the model (simple dispersal/recruitment mechanisms; SAV response to turbidity; response to eutrophication; and CO_2, hurricanes, and severe freezes [though these may be data limited])	4.4
Test/validate the model	4.10
Address model integration and error propagation	4.8, 4.10
NITROGEN UPTAKE[3]	
Need additional data collection for validation - seasonal and spatial (i.e. different plant community) measurements of denitrification using modern techniques	TBD
Include the following processes and environmental controls: • Response to overlying water nitrate concentration • Effect of temperature on biogeochemical nitrogen processing • Coupled nitrification-denitrification • Water depth and residence time • Direct effects of plant communities on N-cycling • Effects of benthic biota on denitrification (through bioirrigation, mixing)	
Conduct an uncertainty analysis	
STORM SURGE	
Improve bottom friction and surface wind stress (canopy coverage) parameterizations	TBD - 4.9
Include a larger set of synthetic storms	TBD - 4.9
Change wind forcings in future scenarios to reflect the effects of climate change on the surface winds and characteristics	TBD - 4.9
Include more measurements of wave parameters during extreme events, especially along the coastline and within the coastal floodplains to improve model validation	TBD - 4.9
Increase commitment of computational resource	N/A
RISK ASSESSMENT / DAMAGE	
Use hydrographs to estimate flooding volumes	TBD - 4.9
Include breach, erosion and other failure modes	TBD - 4.9
Include uncertainty in the status of gates and other openings	TBD - 4.9
Include time-variant deterioration and aging of defenses	TBD - 4.9
Include wind-effects associated with storms	TBD - 4.9
Include fragility for unenclosed barriers	TBD - 4.9

Technical Strategy: Overview

The MIP strategy serves to enhance the capabilities of the 2012 Coastal Master Plan models where possible, develop new components to capture critical processes, improve the overall models' performance, and their ability to capture the complexity of the Louisiana coastal system. One challenge is to numerically simulate complex ecological and morphological

[3] Nitrogen Uptake falls under the broader category of Ecosystem Outcomes; however, only the Nitrogen Uptake technical report underwent external peer review. Habitat Suitability Indices were not peer reviewed.

processes and demonstrate how the implementation of master plan projects modifies these processes via system hydrodynamics and direct morphological change. Another challenge is to design these tools to be as efficient as possible, to ensure completion of the technical analysis within the 2017 Coastal Master Plan schedule.

One of the key improvements over the 2012 Coastal Master Plan modeling effort proposed herein is direct coupling of the landscape modules to enable more frequent feedbacks among system components while allowing for efficient run times. Thus, rather than continue to develop a set of independent landscape-related models which pass data sets from one to another, the MIP proposes the advancement of a modeling approach that incorporates the algorithms central to the 2012 Coastal Master Plan models and/or improvements, where at all possible. This modeling approach is referred to as Integrated Compartment Models (ICMs), and it will integrate the hydrology, morphology (both wetland and barrier shoreline), and vegetation components. The ability to integrate the fish, shellfish and other ecosystem-related models will be determined as model development and integration gets underway.

Similar to the 2012 Coastal Master Plan modeling effort, the widely used ADCIRC model (Cobell et al., 2013) will be used for storm surge and wave modeling, and the CLARA model (Johnson et al., 2013) will be used for risk assessment modeling. A number of improvements will be made to enhance each of these models compared to previous versions.

The specifics of the fish, shellfish and other ecosystem-related modeling are currently being explored collaboratively by CPRA and the Institute, and the best path forward will be decided upon in late summer 2013 and incorporated into the MIP.

The subtasks listed in Table 2 are designated for inclusion in the 2017 MIP. Subtasks 1 – 3 refer to general planning and coordination of the overall effort and the Predictive Models Technical Advisory Committee (PM-TAC) during the model development and application process, whereas Subtasks 4.1 – 4.13 specifically refer to the implementation of the activities identified in the MIP. An overview of the subtasks is provided in the section titled “Implementing the MIP.”

Table 2. Brief overview and outcome for the subtasks to be included in the 2017 Coastal Master Plan modeling effort (see 'Implementing the Model Improvement Plan' section for more detail on each subtask).

No.	Title	Brief Overview	Primary Outcome	**Origin:** CPRA, Peer Review (PR), Modeling Teams (MT)
		COORDINATION AND EXTERNAL ADVICE / REVIEW		
1	Develop the Model Improvement Plan (MIP)	Utilize lessons learned from the 2012 Coastal Master Plan modeling effort and guidance from the 2012 modeling peer review process to develop an actionable plan for model improvements and development.	MIP to guide model improvements and development for use in the 2017 Coastal Master Plan.	CPRA
2	Coordination, Contracting, and Technical Support	Dedicated coordination and technical support proved very helpful in progressing tasks during the 2012 Coastal Master Plan modeling effort. A similar role / task is included in the 2017 MIP.	Coordination and tracking of the modeling teams, modeling efforts through the duration of this effort. Contracting for all team members.	CPRA
3	Predictive Models Technical Advisory Committee (PM-TAC)	Expert advice proved very important and helpful during the 2012 Coastal Master Plan modeling effort. A six-member PM-TAC will be convened and engaged throughout the model development process.	Ongoing advice and guidance from a committee of regional and national experts; participation in six to eight meetings and up to six calls.	CPRA, PR, MT
		IMPLEMENTATION OF THE MIP (TECHNICAL SUBTASKS)		
4.1	Sediment Distribution	Develop and write code for process-based formulas for the distribution of sediment across compartment water, channel and wetland components, including storm effects.	Formula(s) for modeling sediment distribution.	PR, MT
4.2	Marsh Edge Erosion	Develop and write code for process-based formulas to capture edge erosion to provide for more realistic landscape change modeling.	Formula(s) for modeling edge erosion.	PR, MT

No.	Title	Brief Overview	Primary Outcome	**Origin:** CPRA, Peer Review (PR), Modeling Teams (MT)
4.3	Barrier Shoreline Modeling	Explore options, develop, and write code for a modeling approach to capture barrier shoreline dynamics.	Improved modeling approach for capturing barrier shoreline dynamics.	PR, MT
4.4	Vegetation Communities	Capture the dynamics of recruitment and dispersal, as well as additional vegetation types (bottomland hardwoods, dunes, ridges, and transitions to and from flotant).	More comprehensive vegetation model.	CPRA, PR, MT
4.5	Ecosystem Outcomes	Explore options and develop an approach for modeling ecosystem outcomes for the 2017 Coastal Master Plan. *4.5.1 - Fish and Shellfish Modeling Approach: currently underway*	Modeling approach capable of meeting the 2017 Coastal Master Plan needs for ecosystem-related modeling.	CPRA, PR, MT
4.6	Input Data Sets / Boundary Conditions	Improve previous input datasets and boundary conditions, by updating 2012 Coastal Master Plan input datasets, generating new approaches where possible (e.g., spatial rainfall), and using new approaches for handing missing datasets.	Refined and more up to date landscape and hydrodynamic datasets and improved approaches to handling datasets.	PR, MT
4.7	Future Scenarios	Revisit the future environmental scenarios used in the 2012 Coastal Master Plan and develop new scenarios based on new data/knowledge regarding potential future changes as well as model sensitivity (of the 2012 MP models).	Estimate of 2012 Coastal Master Plan model sensitivity to future conditions; revised ranges and values for use in 2017 Coastal Master Plan modeling scenarios.	CPRA, MT
4.8	Integrated Compartment Model (ICM) Development	This is the actual development of the ICMs, including integrating hydrology, morphology, and vegetation codes, incorporating all improvements made during Subtasks 4.1 – 4.4, increasing overall spatial resolution, and coding into Fortran.	Coast wide coverage of ICMs capable of meeting the modeling needs of the 2017 Coastal Master Plan.	CPRA, PR, MT
4.9	Surge and Damage Improvements	TBD - *Likely improvements include: refined storm database, parametric uncertainty, etc.).*	TBD	CPRA, PR, MT

No.	Title	Brief Overview	Primary Outcome	**Origin:** CPRA, Peer Review (PR), Modeling Teams (MT)
4.10	Validation, Performance Assessment & Uncertainty Analysis	Conduct calibration and validation against observed data, a performance assessment and an uncertainty analysis of the newly developed ICMs to evaluate model performance and gain an understanding of the uncertainty of the newly developed models' predictive abilities.	Calibrated and validated models; reporting on model sensitivity, performance, and uncertainty.	CPRA, PR, MT
4.11	Subtask Leader participation in coordination meetings and calls, including PM-TAC	This includes Subtask Leader participation in coordination meetings and calls, and participation in meetings with the PM-TAC.	Documentation of the effort, communication and coordination across subtask teams.	CPRA

COORDINATION AND COMMUNICATION

Initiating and managing a modeling effort of this magnitude is challenging. As such, it is critical that clear roles and responsibilities are identified and communicated to team members at the onset of the effort. This will not only bring structure to the overall effort, it will also foster team performance and the overall implementation and success of this work.

Model Improvement Plan (MIP) Working Groups

Modeling Decision Team

The Institute will assign a Principle Investigator and a Technical Advisor to help guide, oversee and direct the entire effort. The Principle Investigator and Technical Advisor will work closely with the CPRA Technical Liaison and Project Manager. CPRA may appoint additional experts to this team, but the expectation is that membership will be small and members will reach out to others for information as necessary. Together, this group would form the Modeling Decision Team (MDT), responsible for the implementation and quality of the overall effort. The Institute will provide staff and coordination support to the MDT and other teams identified below, except as noted. Although The Institute will coordinate and manage the overall modeling tasks, decisions will be made jointly through the Modeling Decision Team. In instances of disagreement, CPRA has final decision-making authority on this project.

Modeling Decision Team	
Members	**Responsibility**
Ehab Meselhe (Water Institute Technical Lead)	• Direct and coordinate the implementation of the overall effort • Facilitate communication across task teams and with other efforts • Ensure timely progression and completion of the overall effort • Provide technical advice and guidance • Participate in model tasks, as needed • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee
Denise Reed	• Provide insight based on previous and ongoing modeling efforts • Contribute technical ideas and troubleshoot issues • Review and approve work products • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee
Alaina Owens	• Coordinate across modeling teams • Track progress and deliverables • Provide technical assistance • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee

Modeling Decision Team	
Members	**Responsibility**
Natalie Peyronnin (CPRA Technical Lead)	• Provide agency and technical guidance • Facilitate communication across task teams and with other efforts • Provide oversight and review • Assist in the production of work products and summary reports • Approve final work products • Final decision-making authority • Manage budgetary and contractual component • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee
Mandy Green (CPRA Project Manager)	• Provide agency guidance • Provide oversight and review of work products • Approve final work products • Manage budgetary and contractual component • Final decision-making authority • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee
Ed Haywood	• Provide agency guidance • Provide oversight and review of work products • Approve final work products • Provide coordination with CPRA Research Section • Provide input on data availability and data collection activities • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee
Mark Leadon	• Provide oversight and review of work products • Provide coordination with CPRA Research Section • Provide input on data availability and data collection activities • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee
Abby Shao	• Provide review of work products • Provide input on data availability • Assist in the production of work products, where applicable • Participate in biweekly Modeling Decision Team calls • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee

Model Subtask Leaders

Each specific subtask would be assigned a Subtask Leader. This person could be Institute staff or someone from that particular subtask team. Subtask Leaders would be responsible for day to day progression of the work within their subtask. They will be responsible for communicating and coordinating with their team members, reporting progress and issues to the Modeling Decision Team, ensuring timely completion of subtask, and delivery of work products. Subtask Leaders will be appointed by the Modeling Decision Team.

Model Subtask Leaders		
Members	**Role**	**Responsibility**
Subtask-specific contractors	Subtask Leader (1 per task)	• Direct and coordinate implementation of the subtask • Facilitate communication among subtask team members • Ensure task progression and completion • Report to the Modeling Decision Team • Participate in biweekly Model Subtask Lead calls • Participate in quarterly Model Subtask Lead meetings • Participate in meetings with the Technical Advisory Committee

Model Subtask Members

Each specific subtask would consist of an undetermined number of subtask members. Subtask members are the technical working groups responsible for completing the subtask assigned to them by their Subtask Leader. The Institute and CPRA will each provide at least one representative for each subtask team.

Model Subtask Members		
Members	**Role**	**Responsibility**
Subtask-specific contractors	Subtask Members	• Ensure subtask progression and completion • Communicate with other Subtask Members • Report to the Subtask Leader • Participate in internal Model Subtask calls and meetings as requested by Model Subtask Leader

Communication and Progress Reporting

A well thought out and streamlined communication strategy is critical for maintaining timely progress. Rigorous and continuous communications among the various model teams is needed to ensure the model improvement effort will meet its goals and objectives on time and within budget. This was a key lesson learned during the 2012 Coastal Master Plan process, and the approach proposed here builds on that experience. It is recommended that this proposed communication plan remain somewhat flexible, with adjustments to be made as needed to improve the flow of information among the various model task teams. Table 3 provides a tentative timeline (in months) of modeling phases and primary points of engagement. Narrative descriptions of the modeling groups, roles, and expected meeting frequency are provided in the subsequent subsections. Month 1 is assumed to be August 2013.

Modeling Team Communication

Biweekly Modeling Decision Team Calls - Members of the Modeling Decision Team will participate in bi-weekly conference calls to discuss overall progress of the model improvement effort, the status of and potential connectivity to other ongoing efforts, any administrative issues, troubleshoot technical issues, and identify action items needed to ensure overall task progression. Decisions and action items made during these calls will be documented and circulated to the decision team. Depending on the progress of the modeling effort, during some periods the frequency of calls may be modified to reflect the need. Calls may be periodically replaced with in-person meetings as the need arises.

Biweekly Model Subtask Leader Calls - Model Subtask Leaders and members of the Modeling Decision Team will participate in bi-weekly conference calls, approximately 1 hour in length, during the model development phase and as needed during the production runs phase. Each subtask team will give a brief progress update to highlight the status of their work, communicate any needs and questions they may have, and identify proposed next steps (including a timeline). These calls will help ensure the Modeling Decision Team and Model Subtask Leaders remain fully aware of the activities and details within all tasks teams. Maintaining this level of regular communication across model subtask teams will allow problems to be identified early and for the experiences of the entire team to be exercised on developing solutions, thus ensuring timely progression of the entire modeling effort. Key outcomes from these calls will be documented and circulated to the entire modeling team.

Quarterly Model Subtask Leader Meetings - Model Subtask Leaders, one to two key team members of their choice, and members of the Modeling Decision Team will meet in-person (full-day) on a quarterly basis through the model development phase and as needed during the production run phases. During development, each subtask team will present a progress update to highlight the status of their work, and communicate any needs and questions they may have of other teams. During production, the developers will be engaged for QA/QC and troubleshooting rather than to report on status. Few in-person meetings were held among the model team during the 2012 Coastal Master Plan process; however, the in-person meetings that did occur enabled direct discussions among model teams and enabled the quick resolution of issues. In-person meetings were recognized as value-added to that process and have been planned as part of the 2017 MIP process to enable Model Subtask Leaders and key team members to reserve time to participate. These meetings will help ensure the Modeling Decision Team and Model Subtask Leaders remain fully aware of the activities and details within all tasks teams. Key outcomes from these meetings will be documented and circulated to the entire modeling team.

Model Subtask Team Calls - Model Subtask Teams will meet and participate in conference calls at the discretion of their Model Subtask Leaders. Subtask Team Members will communicate progress to their Subtask Leaders, gain awareness of the status of the other model team subtasks, and discuss any technical questions or problems. Key outcomes and decisions from these interactions will be documented by the Model Subtask Leaders and shared with the entire modeling team and discussed during biweekly calls as appropriate.

Technical Advisory Committee Meetings

Model Subtask Leaders and members of the Modeling Decision Team will meet in person with members of the Predictive Models Technical Advisory Committee (PM-TAC) between six and eight times during the 2017 Coastal Master Plan modeling effort. These meetings will be coordinated with the quarterly Model Subtask Leader meetings. For example, quarterly two-day meetings will be scheduled with the Model Subtask Leaders, with the PM-TAC participating in the second day of a select number of these meetings. These will be structured as working meetings, with each Model Subtask Leader highlighting the status of their work, and raising any discussion points, needs, and questions they may have for direct PM-TAC assistance. The PM-TAC will function as an ‘over the shoulder’ advisory body that will engage directly with the modelers throughout the 2017 Coastal Master Plan modeling process. For more information regarding the role and function of the PM-TAC, please refer to the section titled “Predictive Models – Technical Advisory Committee (PM-TAC).”

Table 3. Primary Communication and Engagement Schedule (in Months and Years) for the Technical Teams.

	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15
Month Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
							Development & Improvement											Validation/Calibration/Uncertainty Analysis					
Biweekly Modeling Decision Team Calls	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Biweekly Model Subtask Leader Calls [4]	[5]X	X	X	X	X	X	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Quarterly Subtask Leader Meetings [6]				X			X			X			X			X			X			X	
Subtask Leader Meetings with the PM-TAC	X[7]			X						X						X						X	

[4] Monthly for first 6 months; biweekly thereafter
[5] Webinar in coordination with the PM-TAC
[6] Once during first 6 months; quarterly thereafter
[7] Webinar in coordination with modeling team

	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16
Month Number	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	Production Runs						Additional Runs, if needed						Reporting and Archiving				
Biweekly Modeling Decision Team Calls	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X
Biweekly Model Subtask Leader Calls	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X	X	X	X	X
Quarterly Model Subtask Leader Meetings		X			X			X			X						
Meetings with the PM-TAC					X						X						

Data Management Coordination

Similar to the 2012 Coastal Master Plan modeling effort, a tremendous amount of data will be generated through the modeling efforts proposed herein. Early and effective coordination of the model improvement effort with a structured data management plan is crucial to foster the utility and organization of input data files, output data files, and model code. Data files must be compatible/standardized, easily accessible and able to be quickly transferred across task teams as needed. Short and long term storage, archival, and accessibility of these data sets is also of particular importance.

Although data management will be conducted and funded through a separate effort within CPRA (not as a subtask in the MIP), it is recommended that CPRA appoint a Data Management Advisor to work alongside the modeling teams. This person would participate in biweekly Model Subtask Leader calls, coordinate with other ongoing or newly initiated data management efforts through CPRA and The Water Institute, and serve in an advisory role to the Modeling Decision Team. The Data Management Advisor would provide guidance to the modeling teams regarding data protocols, develop an overall data management structure for the modeling related data (including a structure for data accessibility and archiving), file naming conventions to ensure smooth data transitions and compatibility across the task teams, and data transfer automations and protocols. As part of the overall model improvement effort, Model Subtask Teams will be contractually required to adhere to the data management structure and framework as designed by the Data Management Advisor, and as agreed upon by the Modeling Decision Team.

Coordination with the Planning Tool

As part of 2012 Coastal Master Plan, CPRA supported the development of a computer-based decision-support tool called the Planning Tool. The Planning Tool was used to (1) make analytical and objective comparisons of hundreds of different risk-reduction and restoration projects, (2) identify and assess groups of projects (called alternatives) that could make up comprehensive solutions, and (3) display the tradeoffs interactively to support iterative deliberation over alternatives (Groves and Sharon, 2013). Similar to the proposed improvements for the models that will support the 2017 Coastal Master Plan, the Planning Tool that was used to inform the 2012 Coastal Master Plan may also undergo a number of revisions for future use. Because the Planning Tool summarizes and synthesizes modeling output, early and continued coordination between the modeling effort and the Planning Tool effort will be critical to ensure a smooth transition of data. Early communication regarding the proposed format of model outputs and those needed by the Planning Tool is of particular importance to foster streamlined data transfer and analysis. Of particular importance is file type and spatial and temporal scales of the model outputs. The details of these interactions will be explored and determined upon additional coordination with CPRA, the Planning Tool team, and The Institute.

EXTERNAL ADVICE AND REVIEW

Predictive Models – Technical Advisory Committee (PM-TAC)

The Modeling Decision Team has identified the six experts listed below with their professional affiliations to serve as "over the shoulder" technical advisors throughout the model improvement process. This team of experts will make up the 2017 Coastal Master Plan Predictive Models Technical Advisory Committee (PM-TAC). They were selected based on their technical area of expertise and their ability to share insight and experience from other relevant efforts.

- **John Callaway (Chair)**, University of San Francisco
- Scott Hagen, University of Central Florida
- Brian Harper, US Army Corps of Engineers
- Courtney Harris, Virginia Institute of Marine Science
- Wim Kimmerer, San Francisco State University
- Mike Waldon, Retired USFWS

In contrast to traditional peer review, which engages toward the end of efforts such as once draft reporting is available, this group will have ongoing "over the shoulder" engagement directly with the modelers, providing working-level assistance throughout the 2017 Coastal Master Plan modeling process. During the 2012 Coastal Master Plan process PM-TAC only met once with the modeling team in person. This limited their ability to interact and discuss problems and solutions directly with those working on model development. The PM-TAC unanimously recommended that more frequent in-person meetings during future such efforts would enhance the overall efficacy of the review process.

Anticipated Meeting Schedule

It is expected that there will be quarterly in-person meetings of the modeling Subtask Leaders, and the PM-TAC meetings will be associated with a subset of these meetings. Table 4 outlines a likely schedule for these phases over time (based on current projections) and identifies appropriate timing of PM-TAC in-person meetings.

Table 4. Outline of PM-TAC meeting schedule. In-person PM-TAC meetings are highlighted.

Phase (approx.)	Date	Meeting Type	Notes
Kick off	July 2013	PM-TAC webinar	Introduce Modeling Decision Team members and provide background on 2012 modeling
Development/ Improvement	September 2013	PM-TAC and Modelers webinar	Introduce PM-TAC to modeling teams and get them up to speed on the 2017 Model Improvement Plan
	December 2013	Modelers & PM-TAC in person	Engage on progress thus far regarding improvements – PM-TAC helps troubleshoot, provides ideas and feedback on approaches

Phase (approx.)	Date	Meeting Type	Notes
	March 2014	Modelers in-person PM-TAC webinar	Webinar with PM-TAC to update on progress/issues (TBD)
	June 2014	Modelers & PM-TAC in person	Consider model components as ICM development begins; comment on key assumptions and other issues (TBD)
Validation/ Calibration/ Uncertainty Analysis	October 2014	Modelers in-person PM-TAC webinar	Webinar with PM-TAC to update on progress/issues (TBD)
	December 2014	Modelers & PM-TAC in person	Review initial work on calibration/validation
	April 2015	Modelers in-person PM-TAC webinar	Webinar with PM-TAC to update on progress/issues (TBD)
	June 2015	Modelers & PM-TAC in person	Comment on how uncertainty is being addressed
Production Runs	October - December 2015	Modelers & PM-TAC in person	Assist with troubleshooting model application issues, review FWOA
	April - June 2016	Modelers & PM-TAC in person	Assist with troubleshooting any model run issues, comment on utility/limitations of model results
	July 2016	Modelers in-person PM-TAC webinar	Webinar with PM-TAC to update on use of model results in plan development

Note - members of the PM-TAC have been contracted to participate in up to eight (full-day) in-person meetings and up to six (2-hour) webinars. The schedule outlined above leaves two in-person meetings available for scheduling on an as needed basis.

Procedure for Meetings and Webinars

The specifics of each engagement will vary according to the subject matter at hand, but the following steps will be followed to the extent practicable. Likely constraints include the availability of information from the model teams and the need to modify agendas, etc. to deal with last minute issues that the PM-TAC can help resolve.

1. **Scheduling Meetings** - Quarterly meetings of the modelers will be scheduled approximately 9 months in advance, where possible, and coordinated with the PM-TAC members for those occasions when a joint meeting will be held. For webinars involving the PM-TAC, scheduling will also begin approximately 3 months prior to the expected date.

2. **Planning Meetings** - Approximately 1 month prior to a PM-TAC engagement (meeting or webinar) the Modeling Decision Team (MDT) will begin brainstorming potential topics for discussion. The Model Subtask Leads will also be consulted during their biweekly calls. Subtask Leads will also be asked if they have any read-ahead or preparatory material they would like the PM-TAC to provide feedback on. The PM-TAC will also be consulted via email regarding any issues arising from previous engagements that they would like an update on. Approximately two weeks before the engagement, The Institute will coordinate with the PM-

TAC Chair regarding the agenda for the meeting based on the ideas generated from the MDT, Model Subtask Leads, and the PM-TAC members. The agenda will be finalized by the MDT and distributed to PM-TAC and Model Subtask Leads. The agenda may include several broad issues that the PM-TAC is being asked to consider during the meeting, or specific issues that are discussed during break-out sessions with specific subject-matter experts on the PM-TAC. Committee members will work directly with the modeling team to help resolve technical issues at hand and provide input, feedback, and recommendations. Note that the agendas may need to be flexible to enable consideration of late breaking issues identified during the quarterly model team meeting immediately prior to the PM-TAC meeting.

3. **Conduct of Meetings** – Read-ahead materials that are available one week before the meeting will be provided to the PM-TAC via email or ftp. The PM-TAC Chair will conduct the meeting which may include any or all of the following elements:

   - General updates from MDT regarding progress and issues;
   - Presentations from modelers regarding specific status or issues;
   - Small group discussions with subsets of the PM-TAC and groups of modelers; and
   - Discussion among the PM-TAC members regarding issues that have arisen.

   At the close of each meeting, PM-TAC members will be asked to provide an oral summary statement including key observations or recommendations related to the identified issues for that meeting and any other comments that may assist the modeling team. Key points and recommendations will be documented by on-site staff.

4. **Meeting Follow Up -** The PM-TAC Chair will work with Water Institute staff to develop a short report for each meeting for review and finalization by PM-TAC members. The Chair will submit the final summary to The Water Institute for distribution to the full modeling team within two weeks following each meeting. These summaries will provide a record of PM-TAC engagement and guide the modeling team. Meeting summaries will be incorporated into the appendices of the 2017 Coastal Master Plan.

Principles of the PM-TAC

- Members of the PM-TAC will not participate directly in any of the modeling, except through their role as advisors to the modeling teams;
- The PM-TAC will not be responsible for making decisions on the current or future direction of the modeling program;
- Members of the PM-TAC are not delegates or representatives of groups or organizations; however, this does not preclude individuals from being selected for their knowledge of particular technical areas;
- Members will do their best to assist the modeling team. This includes reading all briefing materials and fully participating in meetings and calls;
- Members will declare any actual or potential conflicts of interest, and abide at all times to confidentially requirements, including when no longer serving on the PM-TAC; and
- Dissenting or alternative views and recommendations held by PM-TAC members will be noted in meeting summaries.

OVERVIEW OF MODELING STRATEGY AND RECOMMENDATIONS

Application of Models for 2017 Coastal Master Plan

The modeling strategy recommended herein identifies strategic improvements over the 2012 Coastal Master Plan modeling effort, including (but not limited to) the inclusion of greater spatial resolution and critical processes while maintaining computational efficiency in support of the 2017 Coastal Master Plan analysis. The 2017 Coastal Master Plan Model Improvement Plan (MIP) focuses on three primary modeling areas: (1) Integrated Compartment Models (ICMs) for the landscape component, (2) Ecosystem-related models (TBD), and (3) Risk Assessment modeling (including storm surge and waves).

Beyond the 2017 Coastal **Master Plan -** This modeling strategy provides a *framework* that will allow for growth and advancements as technology changes into the future; it is not constrained by the tools that were used during the 2012 Coastal Master Plan, nor is it constrained by an end point of the 2017 Coastal Master Plan. Considerations have been given to developing a modeling strategy that will accomplish the short and long-term goals of modeling needs in coastal Louisiana, while also considering long-term capabilities and possibilities.

Table 5 provides more detail regarding the modeling approaches that will be used to meet the modeling needs currently identified for the 2017 Coastal Master Plan.

Table 5. Overall modeling strategy for the 2017 Coastal Master Plan technical analysis.

Modeling need	Desired outcome	Spatial scale	Simulations per scenario	Simulation length	Technical area / analysis
Individual projects *(each restoration & protection project); 2012 MP & new projects)*	Individual project effects	Local / basin	~100	50 years	- Landscape - ICMs - Ecosystem outcomes - TBD
Select project sequences / combinations *(restoration & protection projects)*	Project interactions	Basin	~20	20-25 years	- Landscape - ICMs - Ecosystem outcomes - TBD - Risk reduction (ADCIRC & CLARA)
Master Plan *(all restoration & protection projects combined)*	Coast wide effects of the Master Plan	Coast wide	1	50 years	- Landscape - ICMs - Ecosystem outcomes - TBD - Risk reduction (ADCIRC & CLARA)

Integrated Compartment Models (ICMs) for Landscape Change

The primary motivations for the Integrated Compartment Models (ICMs) are to develop a set of landscape modeling tools which can be used to conduct a large number of simulations (see Table 5) and to build upon and improve the compartment models used in the 2012 Coastal Master Plan. This is to be accomplished while, to the extent practicable, incorporating new physical processes and exploring coupling/integration approaches and examining techniques to enhance the computational efficiency. The three primary improvements and further developments over the 2012 Coastal Master Plan models are:

- Refining the size of the compartments to increase the spatial resolution;
- Integrating simulation of physical and ecological processes; and
- Integrating model components where possible to reduce manual data transfer and facilitate an increase in output frequency.

The ICMs will serve as the central modeling platform to analyze the landscape performance of individual projects under a variety of environmental scenarios and combinations of model parameters. The computationally efficient approach of the ICMs allows for large numbers of simulations to be performed in a reasonable time frame. It is envisioned that the ICMs would be used to assess over 100 individual project outcomes through simulations of 50-year durations, as well as project sequences/combinations as needed (see Table 5). Key outputs of this effort would be hydrodynamic variables (e.g., salinity and water level), changes in the landscape (e.g., land-water interface and elevation change, including the barrier shoreline), and changes in vegetation (e.g., location and type).

Purpose

The ICMs are computationally efficient models that provide a broad-scale view and estimation of coastal landscape trends and potential future changes. These potential landscape changes may be the result of restoration projects, changes in system dynamics associated with structural protection projects or the result of not implementing any additional projects (i.e., Future Without Action). The ICMs will be used to model the effects of individual projects (~100 model runs per scenario), project sequences/combinations in various basins (~20 model runs per scenario), as well as all the projects included in the 2017 Coastal Master Plan (1 model run per scenario).

Approach

The approach proposed for this modeling path builds on the 2012 Coastal Master Plan models. It includes substantial revisions and improvements to these models, and the potential for entirely new modeling approaches in some cases (e.g., barrier shoreline). It is proposed herein to use spatial boundaries similar to those used by the 2012 Coastal Master Plan Eco-hydrology model, thereby separating the coast into three basins (Figure 1). Within each basin the algorithms are expected to be identical. This will provide ample opportunity to refine the spatial resolution to a level suitable for the vegetation and morphological processes. A fundamental improvement over the 2012 models is the addition of critical processes such as marsh edge erosion, and physically-based sediment distribution.

For the 2017 Coastal Master Plan modeling effort, it is also proposed to integrate several numerical codes into a single platform. This would replace four previous (independent) modules, namely Eco-hydrology, Wetland Morphology, Barrier Shoreline Morphology, and Vegetation, with a single set of coding for each region of the coast. Such integration removes the inefficiency of manual data hand-offs and the potential human error that may occur during the transfer of information from one module to another. The direct coupling and integration also facilitates the inclusion of a full parametric uncertainty investigation and analysis, and makes all variables available in the same output file rather than scattered over several files. As a result, this integration will facilitate storage and query of model output and results.

It should also be noted that moving to an integrated model does not hinder the ability to edit, add, or remove component model codes; this strategy is still very much a “linked, modular” system, with the ability to readily change internal components as desired. As such, the MIP builds upon the investments of CPRA to develop the 2012 Coastal Master Plan models, and considerably enhances their value and utility for future efforts.

Regional Scale Approach

Louisiana’s geographically dynamic coast requires flexible and dynamic modeling tools. Just as the coast differs from one region to another, the modeling tools that are applied to this area will need to vary to ensure they most efficiently reflect the system complexity and produce the desired outputs. Similar to the approach used for the Eco-hydrology models for the 2012 Coastal Master Plan, it is recommended that a three-basin modeling approach be considered, ensuring model coverage of the following regions:

- PB - Pontchartrain / Breton Sound and Barataria Basin;
- AA - Terrebonne Basin / Penchant and Atchafalaya / Vermillion; and
- CP - Chenier Plain.

As the approach to modeling ecosystem outcomes is more integrated (e.g., there are not a number of separate models passing data back and forth), the integration will occur within each basin. However, the algorithms and approaches will be common across the basins. For example, upon complete integration, one ICM will be run in the PB area that predicts hydrodynamics, water quality, landscape change, and vegetation, another will be run in AA, and a third in the CP region.

Note that the domains of individual models may extend beyond the areas shown in Figure 1 in order to effectively simulate the within-basin and across-basin conditions.

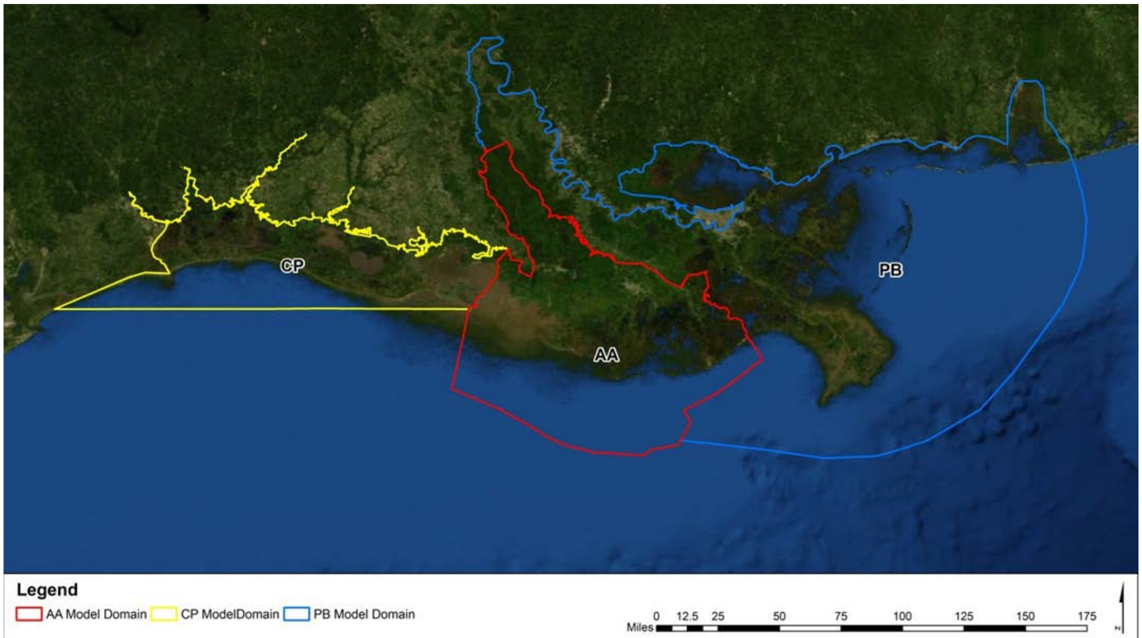


Figure 1. Proposed boundaries for the three basin-scale ICMs.

New Processes to be Included

One of the consistent themes in comments from the 2012 Coastal Master Plan predictive modeling teams, technical reviewers and other experts was the need to reflect a wider array of process-based interactions within models used for the 2017 Coastal Master Plan. Many master plan projects alter coastal processes, in terms of pattern or magnitude, either actively (e.g., diversions) or passively (e.g., by changing tidal prism), and unless these processes are captured, the potential outcomes of projects may not be well reflected by the models.

To consider potential improvements, local, national, and international experts were engaged during two 'brainstorming workshops' in fall 2012 to discuss and establish the technical aspects for developing a refined modeling approach. Recommendations for improvement by the 2012 Coastal Master Plan modeling teams were also considered. Largely, all recommendations pointed to the development of a more integrated and process-based modeling framework for hydrodynamic, morphological, and ecological components and an increase in the resolution and detail.

In addition to the processes and components already included in the 2012 Coastal Master Plan modeling suite, key recommendations are described below for improvements to be incorporated into the ICMs.

- **Process-based Sediment Redistribution (Subtask 4.1)** - The 2012 Coastal Master Plan models had a limited ability to track sediment movement resulting from entrainment due to storms and frontal systems, and an approach to distributing sediment loading from diversions which simplified many process interactions. Sediment released into the system through marsh edge erosion (see above) also needs to be considered.

- **Marsh Edge Erosion (Subtask 4.2)** - Erosion at the edge of marshes caused by wave action was not explicitly included in the 2012 Coastal Master Plan analysis. Rather, land loss rates due to this process were assumed to continue at historic rates unless a shoreline protection project was implemented. No change in marsh edge erosion due to shallowing of water bodies or change in fetch (both potential outcomes of non-shoreline restoration projects) was considered. Edge erosion may also be a critical component of the overall sediment budget in the coastal system. It releases sediment into the system that can be transported and possibly deposited by coastal processes, including both cold fronts and tropical storm events.

- **More Comprehensive Barrier Island Modeling (Subtask 4.3)** - Barrier islands and inlets are dynamic features that experience rapid morphological change during storms. Previous modeling efforts did not adequately capture landward translation, lateral migration, or speed of cross-shore movement of the islands. It is also important to continue to capture changes in the inlets, as these affect the tidal prism (e.g., some inlets open and close, while others are fairly static).

- **Additional Vegetation Types and Establishment Processes (Subtask 4.4)** - To capture the effects of changing coastal conditions (including a variety of coastal restoration and risk reduction features) on vegetation changes, it is recommended that the 2017 Coastal Master Plan models account for a wider array of vegetation types, including the addition of bottomland hardwood forests, swamp, and ridge species, and barrier island species (dune and swale species). It is also important to consider more realistic vegetation establishment patterns/rules, and common transitions between vegetation communities (e.g., fresh marsh to fresh floating marsh).

Additional Processes for Future Consideration

The following processes were also recommended but will be deferred from the current effort due to the length of time and/or monetary resources needed to fully establish these for incorporation into the 2017 Coastal Master Plan models.

- **Soil Development** - Detailed approaches to modeling wetland soil development and changes over time have been developed for local areas. One such approach is the 'cohort model' which tracks changes in soil bulk density and organic matter to reflect compaction and production / decomposition of organics. Such models have rarely been applied at the landscape scale although they show promise locally. Given funds and time for a comprehensive data collection effort, an empirical formulation could be developed to reflect the processes of compaction, belowground biomass, and decomposition processes to capture the organic-based vertical changes across the coast.

- **Vegetation Feedback to Sediment, Substrate, and Friction** - The role of vegetation characteristics in enhancing sedimentation and/or providing friction for storm surge and waves is poorly represented in the existing 2012 Coastal Master Plan models. However, field and lab studies and theoretical work have demonstrated a strong influence of vegetation character on sedimentation and soil development. It is recommended that field and remotely sensed datasets be used to develop an empirical formulation to link vegetation change to sedimentation/morphological change and storm/wave dynamics.

- **Nutrient Effects on Vegetation** - The effect of nutrients introduced into estuaries on wetland vegetation was not captured in the 2012 Coastal Master Plan models. Field studies in many systems have shown a complex response of marsh vegetation to nutrient inputs which may influence the effectiveness of master plan projects. It is recommended that empirical relationships be developed based on nutrient effects on plant biomass or remote sensing data to link nutrient availability and Normalized Difference Vegetation Index (or other measures of vegetative vigor) on a seasonal basis.

Ecosystem-Related Modeling

Purpose

The 2012 Coastal Master Plan evaluated a number of ecosystem outcomes using suitability indices (SIs); although these indices were useful in predicting changes in broad spatial patterns over time, the output of these indices provided estimates of suitability, not population dynamics, biomass, or specific utility to people, all of which are important characteristic of 'ecosystem services.'

Approach

As previously mentioned (Table 5), CPRA identified the following three overarching modeling needs for the 2017 Master Plan:

- Estimate effects of each master plan project (all restoration and protection projects individually) vs. Future Without Action (FWOA) (50 years); local / basin-scale;

- Estimate effects of select sequences/combinations of projects (restoration and protection projects) within coastal basins vs. FWOA (20-25 years); basin-scale; and

- Estimate effects of all master plan projects (all restoration and protection projects combined) vs. FWOA (50 years); coast-wide.

In addition, CPRA has identified a set of ecosystem-related outcomes and fish/shellfish species/groups for consideration, and prioritized them based on relative importance for consideration among each of the three modeling needs. The next step is to identify a modeling strategy for fish, shellfish and other ecosystem-related outcomes including outputs that are applicable to the 2017 Coastal Master Plan modeling needs. Modeling approaches will be considered in relation to the time and resources available for the 2017 Coastal Master Plan modeling effort and the modeling needs identified by CPRA.

Ecosystem-related Modeling Needs

The priority ecosystem-related outcomes and overarching modeling needs for inclusion in the 2017 Coastal Master Plan are provided in Table 6. Outcomes are categorized based on their relative importance for inclusion in the analysis (Tiers 1 - 3) and the associated level of modeling detail desired. For example, many more model runs would be needed for outcomes included in the individual project runs, when compared to those included in the project sequences/combinations.

Table 6. Modeling Needs and Prioritized Ecosystem-related Outcomes / Characteristics.

Modeling Need	Tier 1 *(high priority; high level of effort)*	Tier 2 *(moderate level of effort)*	Tier 3 *(low priority; narrative OK)*
Individual Restoration Protection Projects (each restoration & protection project individually) • 50 years, 5 year intervals • # runs = TBD (2-3 scenarios) • Spring/Summer 2015	• Freshwater supply • Sediment retention • Oysters (spat); need maps • Shrimp (brown and white; juvenile and adult) • Gulf menhaden • General fisheries categories[8]	• Floodwater retention • Rice/agriculture/ cattle	• N/A
Select Project Sequences /Combinations (groups of restoration & protection projects) • 20-25 years, intervals of 5 years or less • # runs = 20-30 combinations (2-3 scenarios) • Summer/Fall 2015	• Surge/wave attenuation • Freshwater supply • Sediment retention • Oysters (spat); need maps • Shrimp (brown and white; juvenile and adult) • Gulf menhaden • General fisheries categories[3]	• Floodwater retention • Rice/agriculture/ cattle	• N/A
2017 Coastal Master Plan Evaluation (all restoration & protection projects together) • 50 years, 5 year intervals • # runs = draft/final Master Plan (2-3 scenarios)	• Surge/wave attenuation • Freshwater supply • Sediment retention • Food web support • Oysters (spat); need maps • Shrimp (brown and white; juvenile and adult) • Gulf menhaden • General fisheries	• Floodwater retention • Rice/agriculture/ cattle • Carbon sequestration • Nitrogen uptake • Roseate spoonbill • Muskrat • Otter	• Nature based tourism • Waste regulation • Climate regulation • Lumber • Fiber timber (cotton /hemp) • Recreational beaches model

[8] As many of the following species as deemed possible by the fisheries modeling approach - juvenile and adult life stages for the following: Gulf sturgeon, red drum, speckled trout, black drum, Atlantic croaker, sheepshead, striped mullet, bay anchovy, southern flounder, largemouth bass, sunfishes, and blue catfish

Modeling Need	Tier 1 *(high priority; high level of effort)*	Tier 2 *(moderate level of effort)*	Tier 3 *(low priority; narrative OK)*
• Spring/Summer 2016	categories[3] • Alligators • Blue crabs	• Invasives – hyacinth / nutria • Crawfish • Waterfowl (3 species)	• Aesthetics

Fish and Shellfish Modeling Strategy

After identifying the priority modeling needs, the next component of the ecosystem-related modeling plan is to consider and evaluate a number of possible modeling approaches for the fish and shellfish. For these species, a number of possible approaches are available (See Appendix 1 for preliminary summary). The Institute with the support of its subcontractor, Dynamic Solutions, is working to prepare a detailed synthesis and strategy document built upon this appendix to identify and describe fish and shellfish modeling approaches that are applicable to the 2017 Coastal Master Plan modeling needs.

The model synthesis and strategy document will focus only on the groups and/or species of interest identified by CPRA (i.e., oysters (spat); juvenile and adult life stages for the following: brown shrimp, white shrimp, blue crab, Gulf menhaden, Gulf sturgeon, red drum, speckled trout, black drum, Atlantic croaker, sheepshead, striped mullet, bay anchovy, southern flounder, largemouth bass, sunfishes, and blue catfish). Where modeling approaches are potentially useful for only a subset of these species/groups and/or a different list of species or species groupings this will be specifically identified.

The applicability of the models to these needs and species will consider issues such as model efficiency, ease of application, spatial and temporal resolution, and availability of input data (either field or model outputs). The document will highlight one or several modeling options for each of the three 2017 Coastal Master Plan modeling needs, and the Modeling Decision Team will identify the preferred approach and recommended path forward.

A group of local and national experts will be identified to participate in a 2-hour webinar during late August 2013. They will review the synthesis and strategy document and consider the recommended path forward, including key assumptions and limitations. Following the webinar and expert review/input, a brief summary will be prepared that covers the main discussion points raised and any recommendations for revising the model synthesis document or the recommended modeling strategy.

CPRA and The Institute, with support from Dynamic Solutions, will finalize the path forward for fish and shellfish modeling for the 2017 Coastal Master Plan by the end of September 2013.

Upon finalizing a path forward, model development, coding and testing will begin to determine how best to model, and in some cases, the feasibility of modeling the targeted outputs. This testing is also needed to identify the input variables needed (including spatial and temporal resolution and which water quality parameters are required) for each of these outputs. Model code will be integrated with the ICMs where possible.

Other Ecosystem Related Modeling Strategy

Similar to the fish and shellfish-specific modeling strategy, a modeling strategy is needed for the other ecosystem related outputs listed in Table 6. These include some items in Table 6, such as roseate spoonbills, otters, sediment retention, freshwater supply, etc.

The Institute and CPRA must first coordinate to determine the most appropriate spatial and temporal resolution needed as well as how the outputs / estimates for these components will be used to support the 2017 Coastal Master Plan decision-making process.

The next step will be to review existing methodology, including suitability indices and other model outputs that were used in the 2012 Coastal Master Plan modeling analysis and draw upon those technical tools where possible. Exploration of available outputs from the newly developed 2017 Coastal Master Plan ICMs will also be necessary to determine which modeling approaches are possible for incorporation in this effort. In the case of Tier 3 components, a basic narrative discussing potential changes into the future may be sufficient.

Lastly, The Institute and CPRA will develop a preferred path forward, for the fish and shellfish modeling component. This is anticipated by the end of 2013, as ICM development proceeds. It will be incorporated into the MIP.

Risk Reduction Modeling

Purpose

Risk reduction modeling was performed for the 2012 Coastal Master Plan. It is again proposed for the 2017 Coastal Master Plan, as a means of estimating potential changes in risk reduction into the future, both with and without the implementation of coastal projects. The approach recommended here is very similar to that used in 2012, with a number of refinements and a better understanding of parametric uncertainty.

Approach

ADCIRC / UnSWAN (Cobell et al., 2013) and CLARA (Johnson et al., 2013) models were used to assess risk reduction for the 2012 Coastal Master Plan. ADCIRC and UnSWAN provide predictions of flood stage and wave time series, whereas CLARA provides flood depths and (economic) risk/damage estimates at various recurrence intervals. It is recommended that these three models should be used again for the 2017 Coastal Master Plan with the refinements described here.

Because the technical details of these models are documented in the 2012 Coastal Master Plan Appendices, this section focuses on a number of improvements that have been recommended prior to using these models for the 2017 Coastal Master Plan technical analysis. These refinements have been identified by peer reviewers (see Table 1) or as improvements to data handling/transfer (e.g., use of NetCDF files), or to improve upon the assessment of model uncertainty conducted during the 2012 Coastal Master Plan analysis.

Several improvement strategies have been recommended for inclusion in the 2017 Coastal Master Plan modeling effort. The following improvements are currently under discussion.

Develop, Incorporate, and Test Parametric Uncertainty in CLARA - To incorporate parametric uncertainty into estimates of flood depth and damage estimates, team members will conduct simulations of a large suite of storms and sensitivity study simulations to demonstrate the effects of various changes to model inputs and model parameters to better understand uncertainty.

- Develop an approach to quantify and evaluate parametric uncertainty;
- Conduct simulations of a large suite of storms;
- Conduct sensitivity testing to determine primary drivers of uncertainty in CLARA;
- Run CLARA to support assessment of uncertainty from ADCIRC modeling assumptions; and
- Evaluate flood depths and damage in selected scenarios with new uncertainty approach.

Expand the Geographic Scope of CLARA to Account for a Growing Floodplain - The study region for the 2012 Coastal Master Plan effort was adopted from the 0.1 percent Annual Exceedance Probability (AEP; or 1-in-1000 annual chance) floodplain estimated by LACPR. Results from the ADCIRC surge analysis, however, indicate that the risk of flooding at more frequent intervals (0.2 percent or 1 percent AEP) is likely to extend further inland when considering future conditions in 2061 in some scenarios.

Update Damage Module Data for 2017 Master Plan Analysis

- Implement a series of updates and new features to the CLARA damage module.
- Update the economic database with any additional relevant 2010 U.S. Census data, like median household income. This may entail changing the plausible ranges for uncertain economic parameters, or revising CLARA's treatment of dispersion between urban and rural areas to stratify by asset class.
- Include modeling potential velocity damage in coastal V Zones; this will be done by modifying Hazus methods to be deterministic rather than stochastic, but otherwise following its methodology and assumptions.
- Review CLARA's depth-damage curves, investigating the uncertainty associated with them and the model's sensitivity to different depth-damage relationships.

Improve the Fragility Calculations in CLARA - For the 2012 Coastal Master Plan analysis, CLARA used a simplified model of system fragility that was only applied in fully-enclosed areas and was based on work done by USACE for the 2008 IPET Risk and Reliability study. Boring samples were only available for the Greater New Orleans HSDRRS, with reasonable assumptions made about the characteristics of other existing systems and future projects. Since that time, additional studies have been completed on Larose to Golden Meadow, Morganza to the Gulf, and the New Orleans HSDRRS (armoring), all of which applied different assumptions and approaches to account for the additional risk introduced by potential structure failures. This activity will include communicating with USACE and CPRA's Flood Protection Division to ensure that the assumptions in CLARA about the modeled characteristics of future structural risk reduction projects are consistent with their latest construction methods and materials.

General Aspects of Model Improvement

This document identifies a number of improvements to modeling which are not necessarily related to any individual model or coastal process. Changes to address such issues, especially as they relate to the ICMs, are described below. [9]

Framework and Standards - A common data platform (central online database), automated read/write, and standard file formats are needed to effectively couple the ICMs. Following the enhancements to existing model codes, the landscape models will be recoded into Fortran. Fortran is the recommended modeling platform for models that are to be directly coupled. The framework and standards will be developed upfront so all models, inputs and outputs can be designed in advance to adhere to certain standards (e.g., NetCDF as a file format). Cables (scripts) will be implemented at the onset of the effort to help integrate the various components. These cables will be part of the framework, and their purpose & limitations will be documented. Version management and tracking will be especially crucial as models change. Although several modeling teams will be developing these cables across the coast, The Institute modeling team will ensure that the integration strategy and cables are fully consistent and fully compatible across all regions.

Frequency of Model Communication - Improved integration of the 2012 Coastal Master Plan landscape modeling components (Eco-Hydrology, Wetland Morphology, Barrier Shoreline Morphology, and Vegetation) means there will not be distinct data hand-offs between these components. Other changes may also be made. For example, to enhance the computational efficiency of the ICM, the morphological change could only be activated when sufficient hydrologic and sediment changes occur to influence hydrodynamics (per a pre-set unit of change). In essence, the full integration of these modules provides many opportunities to adjust the frequency of communications among the various modules.

Temporal Resolution - The output time scales provided by the ICMs will be flexible and can accommodate a wide range of needs. The time scales of outputs for the morphology and vegetation components will be much larger than that of the hydrology component (e.g., hydrology on the order of daily, and landscape / vegetation on the order of a year). As such, the variation in the temporal scale of the physical processes should be considered to decide on the minimum output frequency.

Spatial Resolution - Target size for the ICMs is 1 - 25km^2 per compartment in areas with wetland coverage or potential wetland coverage in the future. Pilot testing will be used to explore reducing resolution until it becomes computationally limiting. This will be done as part of Subtask 4.8 (Integrated Compartment Model Development). The modeling teams may consider using

[9] Some items/details in this section are dependent on specific input needed by the Planning Tool. For more information on the Planning Tool, refer to the section titled "Coordination with the Planning Tool."

common spatial resolution across all models or employing a structure that supports nesting of various scales. Interpolating variables across the compartments (where linkages cross cell boundaries) will also be considered such that values are provided to accommodate the needed resolution of various modules.

Output Years - It is proposed to provide output every five years in the near term and every ten years further along in the model runs (i.e., 5, 10, 15, 20, 30, 40, and 50 years). However, options will exist to extract intermediate results (even when models are still running) for evaluation purposes, and special consideration will be given to ensure the availability of Year 0 output for reporting purposes and for use in the Planning Tool. Output years for storm surge and damage models have not yet been determined.

Computational Capacity - Full understanding of the computational needs of the ICM approach would become clearer through development and testing in Subtask 4.8 (Integrated Compartment Model Development). Such testing would provide estimates of the computational demand of the fully integrated modules. Eventually, the overall computational needs would depend on the balance between: (1) spatial resolution and compartment size, (2) feedback frequency among the various physical processes, (3) and boundary condition schematization. Decisions will need to be made to establish such balance in order to accommodate the overall study time frame.

Model Output QA/QC - Following lessons learned in the 2012 Coastal Master Plan modeling effort, developing and enforcing clear and concise protocols for standard output QA/QC is a high priority. All model developers will be engaged in QA/QC of results even when their codes have been integrated into the ICMs. In this light, it will also be important to have local subject matter experts, familiar with the coast but not involved in the modeling effort, also provide a level of QA/QC at each step. A plan for this, including the appropriate individuals to serve in this capacity, will become clearer as the models are developed. It is possible that a technical subset of the Framework Development Team (per 2012 Coastal Master Plan) could be engaged for such input. Further, technical presentations at in-state university campuses as well at local conferences, such as the State of the Coast, are reasonable avenues to seek such input.

Also, as will be developed through Subtask 4.10 (Validation, Performance Assessment & Uncertainty Analysis), quantitative metrics will be used to establish a consistent and clear evaluation of the modeling tools used. Such metrics will identify areas of strengths and uncertainties that should be considered while using model predictions in evaluating restoration and protection strategies. Lastly, a plan will be developed to ensure software quality assurance and version control.

Facilitation of Model Communications, Data Integration, Exchange of Data Files between Modeling Teams, File Naming Conventions - The explicit need for several of these items will be eliminated through the direct coupling and integration of several landscape models into ICMs. It is anticipated that such integration will speed up the modeling process and will also eliminate potential errors that may occur during the manual transfer process among various modules.

Required Inputs - Input datasets and boundary conditions for ICMs will be prepared in Subtask 4.6 (Improve Input Datasets and Boundary Conditions). This includes open water information (tide and salinity), riverine inflow (water, sediment, and constituents), rainfall, evapotranspiration (ET), and initial conditions for the topography, bathymetry, sediment distribution, and vegetation composition.

Data Hosting and Storage - The Institute will work with CPRA and others as appropriate to design an integrated approach for housing and storing data. Data management for this effort will be handled through a separate effort / contract from CPRA; therefore, coordination across groups will be needed to determine the specific details as both efforts are initiated.

Inputs and Outputs Required for the Decision-making Process - The Modeling Decision Team will develop detailed specifications for a subset of the overall model output files that can be efficiently used for decision-making. It will emphasize to the modeling teams that preparing easy-to-understand graphics and animations is essential and critical for planners and decision makers. As such, inputs and outputs will be tailored to these needs as the new models are developed, tested, and maintained for CPRA as needed. Clear parameter labeling will be necessary to ensure future use of these files.

Post-processing - As the new ICMs, ecosystem related models, and improved risk reduction models are fully developed and tested, ongoing coordination with the Planning Tool team will enable clarification of the specific requirements for outputs and appropriate visualization techniques. Coordination early in the process to better understand the needs of decision makers will enable tailoring of model outputs to meet these needs and minimize post-processing of data. Available techniques and visualization tools will be utilized as necessary. To the extent possible, costly and time-consuming new development of post-processing and visualization techniques will be avoided or at least kept to a minimum.

IMPLEMENTING THE MIP

The implementation of the proposed modeling effort for the 2017 Coastal Master Plan is described in this section. As indicated in Table 2, implementation is separated into 11 subtasks scheduled to occur from mid-2013 through mid-2016. A detailed schedule is provided in Figure 2. Each subtask is described in more detail below.

Subtask 4.1 – Sediment Distribution: development & testing (Months 1- 6)

Rationale: Process-based approaches for the distribution of sediment across Eco-hydrology compartments, including open water, channels and wetland components, were not incorporated in the 2012 Coastal Master Plan modeling. Including these processes in future modeling efforts will foster more realistic predictions of sediment distribution within and across compartments, which is a critical component of modeling restoration and protection project effects. This task will develop and test algorithms for incorporating sediment distribution in the Integrated Compartment Models (ICMs) for use in the 2017 Coastal Master Plan modeling effort.

Proposed Approach:
This task will improve on the modeling strategy to simulate sediment loads calculated for each hydrology compartment and the delivery of that sediment across the vegetated and non-vegetated compartment landscape. It will also estimate the amount and spatial distribution of sediment delivery associated with storm events (e.g., hurricane, frontal, etc.). Several improvements to the wetland morphology 'sediment cost surface' utilized in the 2012 Coastal Master Plan will also be initiated. The new and/or improved formulas will be developed and tested in the ICMs.

Activities will include the following:

- Activity 1 – A review of applicable literature, sediment modeling approaches, and hurricane–sediment dynamics will be conducted.
    - This includes the review of sediment transport and distribution equations and models for incorporation into compartments, including different governing equations / approaches for transport, deposition, and re-suspension for marsh and open water regions.
    - In order to better quantify hurricane and frontal system sediment deposition and spatial distribution, updates will be made to the existing syntheses of all the hurricane sedimentation literature for coastal Louisiana, including a map of the locations and amounts of deposition in relation to storm characteristics and existing landscape characteristics.
- Activity 2 – The team will investigate inundation regimes and resulting access of sediments to the marsh surface, and will identify approaches for developing linkages between mineral sedimentation rates and associated processes. The team will investigate existing sediment transport models and remotely sensed data pertaining to sediment distribution to inform the

development of an improved sediment distribution algorithm. Lastly, associations will be explored to inform how adjustments can be made to the spatial distribution of sediment associated with specific storm influences on water levels. Existing statistical water surface elevations and hurricane tracks and frequencies will be utilized. The processes will be conceptualized and functionalities to be coded into the ICMs will be prioritized. Progress to date, including a selected path forward will be documented and shared for review.

- Activity 3 – Initial coding and testing of the formulas (at the compartment basis) will be conducted.

Subtask 4.1 - Sediment Distribution: Timeline (months)

Activity Description	1	2	3	4	5	6
1. Literature review	X					
2. Conceptualization, prioritization of functionalities, and synthesis report		X	X	X		
3. Initial coding and testing				X	X	X

Subtask 4.2 – Marsh Edge Erosion: development and testing (Months 1 - 6)

Rationale: This process was not explicitly considered in the 2012 Coastal Master Plan modeling, and therefore shoreline protection projects were the only project type that showed 'restoration benefits' for reducing edge erosion. Furthermore, eroded material was 'lost' from the system during previous modeling efforts. The focus of this task is to ensure the models used for the 2017 Coastal Master Plan consider as many important processes contributing to landscape change as possible and to incorporate the eroded material as part of the sediment supply to the open water component of the model compartments. The formula(s) developed through this effort can be utilized in the Integrated Compartment Models (ICMs) to adjust the amounts of land and water within a compartment. This subtask will develop and test formulas to reflect key processes associated with marsh edge erosion and identify a recommended approach for incorporation in the 2017 Coastal Master Plan modeling.

Proposed Approach: This study will establish and test a modeling strategy to simulate the rate of retreat/advance of a marsh edge. A formula will be developed and tested for use within the ICMs. The formula(s) will be also available for incorporation in higher resolution 2-d or 3-d models.

Activities will include the following:

- Activity 1 - Marsh erosion equations and models in the literature will be reviewed.
- Activity 2 - An approach will be developed and conceptualized to calculate and quantify marsh edge erosion for interior and coastal marsh edges. Once the approach is developed and conceptualized, it will be coded into the ICMs. Progress to date, including a selected path forward will be documented and shared for review.
- Activity 3 - Initial coding and testing of the formulas for use in the ICMs will be conducted.

Subtask 4.2 - Marsh Edge Erosion: Timeline (months)

Activity Description	1	2	3	4	5	6
1. Literature review	X					
2. Conceptualization, prioritization of functionalities, and synthesis report		X	X	X		
3. Initial coding and testing				X	X	X

Subtask 4.3 – Barrier Shoreline Model Development (Months 1 - 6)

Rationale: Barrier island restoration projects are very important to Louisiana's coastal restoration and protection program. Being able to forecast their morphological dynamics, including long-term sustainability, is a critical component of the master plan and other modeling efforts. Although the 2012 Coastal Master Plan barrier shoreline model was able to predict inlet area change and island movement based on processes such as wave climate, the external review pointed out that the approach is lacking in dynamic (physical) processes and stochastic events. A variety of approaches for modeling barrier shoreline dynamics currently exist and should be considered for incorporation in the 2017 modeling application. Improvements would include additional physical processes, greater capabilities in terms of predicting change in island morphology, and more realistic event-driven morphodynamic responses. The recommended approach and improvements made herein will be coded into the landscape component of the Integrated Compartment Models (ICMs) for use in the 2017 Coastal Master Plan.

Proposed Approach: This task will involve a summarization of current literature and available modeling approaches (including the model that was used during the 2012 Coastal Master Plan). Subtask participants will be convened for at least one working meeting to discuss and evaluate existing approaches and draft a written recommendation for a proposed path forward for modeling barrier shorelines in the 2017 Coastal Master Plan. The agreed upon approach will be coded, tested, with written documentation to be provided at the end of the six month effort.

Activities will include the following:

- Activity 1 – Summarize current literature and available modeling approaches.
- Activity 2 – Working meeting to discuss and evaluate modeling approaches.
- Activity 3 – A modeling approach will be developed and a written summary of the proposed formulation/approach will be distributed.
- Activity 4 – Code the model, test the newly developed model and report results.

Subtask 4.3 – Barrier Shoreline Model Development: Timeline (months)

Activity Description	1	2	3	4	5	6
1. Literature, model approach review	X					
2. Working meetings	X			X		
3. Develop modeling approach / formulation	X	X				
5. Initial coding, testing, and reporting			X	X	X	X

Subtask 4.4 – Additional Vegetative Communities: development and testing (Months 1- 6)

Rationale: CPRA requested that 2017 models be able to capture dynamics of additional vegetation types. This task will develop strategies (rules/tables) to include swamp, bottomland hardwoods, ridges, and dunes and swales. Transitions to and from floating marsh will also be improved. Preliminary modifications to the existing LAVegMod code, including incorporation of new species, ecological processes and additional information described in the activities below, will be conducted during this effort. The improved code will be available for incorporation into the vegetation components of the Integrated Compartment Models (ICMs) for use in the 2017 Coastal Master Plan; they will also be available for use in other higher resolution modeling efforts.

Proposed Approach: This task is focused on expanding the number of vegetation types that are currently included in the vegetation module (LAVegMod) of the 2012 Coastal Master Plan modeling effort. We anticipate that we will maintain the basic structure of the vegetation model, which requires tables for the mortality of established vegetation as well as possible establishment of new vegetation on vacated "bare land," newly formed, or created land. This improved vegetation component would be available for integration into the modeling effort for the 2017 coastal Master Plan.

Activities will include the following:

- Activity 1 - Task Coordination / Management.
- Activity 2 - Addition of forested vegetation types (swamp, bottomland hardwoods, and ridge species) to LAVegMod.
- Activity 3 - Addition of barrier island vegetation types (dune and swale species) to LAVegMod, including the development of mortality and establishment rules/tables for the barrier island species.
- Activity 4 - Replacement rules for floating vegetation types. This will include an approach to generating a base map that includes the floating nature of certain areas within coastal Louisiana.
- Activity 5 - Dispersal and multiple species establishment upgrade to LAVegMod.
- Activity 6 - Upgrade coding and preliminary testing of code in LAVegMod 2.0.

Subtask 4.4 – Additional Vegetation Types: Timeline (months)

Activity Description	1	2	3	4	5	6
1. Management	X	X	X	X	X	X
2.–5. Development of new / improved coding	X	X	X	X		
6. Initial coding and testing				X	X	X

Subtask 4.5 – Ecosystem-Related Modeling

- Fish and Shellfish Modeling Strategy - underway
- Ecosystem Outcomes Strategy – *TBD*

Subtask 4.6 – Improve Input Datasets & Boundary Conditions (Months 7-12)

Rationale: Considering the effort to update the technical tools for the 2017 Coastal Master Plan, it is critical to ensure the most up-to-date data are being used to drive the models. As such, it is important to devote an appropriate effort to identify new or improved input data for all models, including approaches for handling missing data in time series datasets. The updated information will be used as input data for the 2017 Coastal Master Plan models. This task is focused on generating these input datasets.

Proposed Approach: The objective of this task is to build upon the datasets used for the 2012 Coastal Master Plan by acquiring and assembling any updated data inputs and boundary conditions in a format suitable for archiving and for use by numerical models. Data sets will be carefully examined for completeness and consistency. The team will also perform statistical analyses as part of the quality assurance and quality control process. Gap analyses, correlations, and other filling techniques will be performed to fill all data gaps.

Activities will include the following:

- Activity 1 – gather and process updated tide, salinity, riverine inflow, wind, wave, and water quality input data sets needed to set the boundary conditions; prepare files for use by other team members and submit for archiving.
- Activity 2 – gather and process updated bathymetry, LiDAR, or other landscape datasets that may have become available following the 2012 Coastal Master Plan; prepare files for use by other team members and submit for archiving.

Subtask 4.6 – Input Datasets and Boundary Conditions: Timeline (months)

Activity Description	7	8	9	10	11	12
1. Tide, salinity, riverine inflow, wind, wave, and water quality data sets	X	X	X	X	X	
2. Bathymetry, LiDAR, other landscape datasets	X	X	X	X	X	
Prepare and submit all data files for use in model testing and archiving						X

Subtask 4.7 – Identify and Develop Future Scenarios (Months 3 - 8)

Rationale: Future uncertainty is inevitable, especially when planning projects in a dynamic landscape for decades into the future. Moderate, Less Optimistic, and Moderate with High Sea Level Rise scenarios were included in the 2012 Coastal Master Plan modeling analysis. This provided outputs that captured a range of plausible future conditions. Considering new data have been collected and scientific and technical developments have been made since data were compiled (early 2010) to drive the 2012 Coastal Master Plan modeling effort, it is prudent to revisit the future uncertainties that were included in the previous master plan. It is also prudent to conduct a sensitivity analysis to determine relative effects of the various uncertainty parameters on model output, so an informed decision can be made regarding future scenarios to be considered in the 2017 Coastal Master Plan.

Proposed Approach: It is proposed here that the future uncertainties that were considered in the 2012 Coastal Master Plan are revisited to 1) update the values to be analyzed by incorporating the latest available information from the technical/scientific community, 2) determine the sensitivity of the models to each parameter, and identify key parameters affecting model output and 3) develop future scenarios for consideration in the 2017 Coastal Master Plan effort.

A literature review will be conducted to ensure the most recent and relevant information is being used to inform the analysis. A sensitivity analysis (~40 model runs in the Pontchartrain – Barataria region and ~20 model runs in the Chenier Plain region, using a subset of possible uncertainty variable combinations) will be conducted using the 2012 Coastal Master Plan models and updated values for (eight of the nine) environmental uncertainties considered in the 2012 Coastal Master Plan; marsh collapse threshold will be considered during parametric uncertainty analyses. It is proposed to use the Eco-hydrology, Wetland Morphology, and Vegetation models for this analysis. These models would be run for 50 years with all 2012 Coastal Master Plan projects on the landscape (i.e., G62 from the 2012 Coastal Master Plan analysis) to provide an assessment of the vulnerability of the master plan to plausible future conditions. Consideration will be given to reserve a few simulations for the FWOA conditions to observe if the models will show the same level of sensitivity to the “with MP” simulations. Considering the results of the analysis, an adequate and representative number of scenarios (e.g., 2 – 3) will be identified in coordination with CPRA for application during the 2017 Coastal Master Plan modeling effort.

Activities will include the following:

- Activity 1 - Literature review to determine the uncertainty ranges and values to be analyzed. Use publically available global climate change models for downscaling to the Louisiana Coast area.
- Activity 2 - Approximately 40 sensitivity model runs in PB (and ~20 runs in CP) using the 2012 Coastal Master Plan models (as they currently are) for the values identified during Activity 1, and statistical analysis/summarization of model output/sensitivity to inform Activity 3. Lastly, identification of key parameters affecting model response.

- Activity 3 - Design future scenarios (select variables, ranges, and values) to use in the 2017 Coastal Master Plan modeling effort, based on Activity 1 and Activity 2.

Subtask 4.7 – Future Scenarios: Timeline (months)

Activity Description	3	4	5	6	7	8
Activity 1 – Literature review and updated values	X	X				
Activity 2 – Sensitivity model runs; statistical analysis / summarize model output; identify key parameters			X	X		
Activity 3 – Design future scenarios					X	X

Subtask 4.8 – Integrated Compartment Model Development (Months 7 - 18)

Rationale: In the 2012 Coastal Master Plan modeling effort, manual data transfers between individual models was found to be a substantial time constraint. Another constraint was the resolution of the eco-hydrology compartments in some areas of the coast, allowing distinctions of salinity and water level only across very large spatial areas in some cases. It was recommended by a number of experts, during review processes, subject matter expert workshops, and through lessons learned by the 2012 Coastal Master Plan modeling team that the State move away from utilizing individual models and consider the integration of multiple modeling components (hydrodynamics, landscape (including barrier islands), and vegetation) into a single platform. It was also recommended that the spatial resolution of the 2012 Coastal Master Plan eco-hydrology compartments be enhanced for future efforts. This subtask will integrate, refine, and include newly developed process-based algorithms into a new modeling framework, referred to as Integrated Compartment Models (ICMs).

Proposed Approach: This phase of the Model Improvement Plan marks the actual development of the Integrated Compartment Models (ICMs) for use in the 2017 Coastal Master Plan modeling effort.

Activities will include the following:

- Activity 1 - Integrate individual modeling components into a single framework (e.g., Fortran).
- Activity 2 - Incorporate newly developed algorithms.
- Activity 3 - Reduce compartment size (i.e., increase spatial resolution of integrated components).
- Activity 4 - Test the newly developed ICMs and report results.

Note – although data management activities are not explicitly included/budgeted for herein, there is a comprehensive and ongoing effort between CPRA and USGS (Craig Conzelmann) to develop and implement plans for this important component. Data management activities are far reaching, but specifically as it relates to this modeling effort, the following types of needs are envisioned and will be planned for: file naming, data management of the overall modeling effort, possible automation of QAQC processes, and general guidance and oversight as it relates to preparing, handling, and archiving datasets.

Subtask 4.8 – Integrated Compartment Model Development: Timeline (months)

Activity Description	7	8	9	10	11	12	13	14	15	16	17	18
1. Integrate modeling code	X	X	X									
2. Incorporate newly developed algorithms			X	X	X	X						
3. Reduce compartment size							X	X	X			
4. Testing & Reporting									X	X	X	X

Subtask 4.9 – Storm Surge and Risk Assessment Model Improvements (Months 2 - 10)

Rationale: Risk reduction modeling was performed for the 2012 Coastal Master Plan. It is again proposed for the 2017 Coastal Master Plan, as a means of estimating potential changes in risk reduction into the future, both with and without the implementation of coastal projects. The approach recommended here is very similar to that used in 2012, with a number of refinements and a better understanding of parametric uncertainty.

Proposed Approach: ADCIRC / UnSWAN (Cobell et al., 2013) and CLARA (Johnson et al., 2013) models were used to assess risk reduction for the 2012 Coastal Master Plan. ADCIRC and UnSWAN provide predictions of flood stage and wave time series, whereas CLARA provides flood depths and (economic) risk/damage estimates at various recurrence intervals. It is recommended that these three models should be used again for the 2017 Coastal Master Plan with the refinements described here.

Activities will include the following:

- Activity 1 - Develop, Incorporate, and test parametric uncertainty in CLARA
- Activity 2 - Expand the geographic scope of CLARA to account for a growing floodplain
- Activity 3 - Update damage module data for 2017 Coastal Master Plan analysis
- Activity 4 - Review fragility calculations in CLARA

Subtask 4.9 – Storm Surge and Risk Assessment Model Improvements: Timeline (months)

Activity Description	2	3	4	5	6	7	8	9	10
1. Parametric Uncertainty	X	X	X	X	X	X	X	X	X
2. Expand geography	X	X	X	X					
3. Update datasets	X	X	X	X	X	X	X		
4. Review fragility calculations	X	X	X	X					

Subtask 4.10 – Validation, Performance Assessment & Uncertainty Analysis (Months 13 - 24)

Rationale: This task focuses on calibrating the integrated models against field observations where available. It also includes a comprehensive performance assessment and uncertainty analysis. The team will design numerical experiments for sensitivity analyses, calibration, validation, and uncertainty analyses. These experiments are intended to evaluate model performance as well as provide detailed insights into the uncertainty of the models' predictive abilities. Fully integrating the uncertainty analysis throughout the process of model validation will provide valuable insights into model performance and their predictive abilities. It will also significantly facilitate providing meaningful interpretations of model uncertainties as they relate to the overall performance measures and whether the individual or group of restoration and protection projects are meeting their objectives.

Proposed Approach: The teams will design the runs, which is more coordinated and consistent than what was done in 2012 Coastal Master Plan. CPRA will review the sensitivity analysis design and the uncertainty analysis design prior to the commencement of model production runs. In this effort, it is proposed that the experts review and interpret the outputs. Instead of a single uncertainty analysis report, every modeling team will draft their own section of the uncertainty report (or the uncertainty section of each of the three basin-level modeling reports). This task also includes validation of the models. The uncertainty experiments will be coordinated across all regions for consistency.

Activities will include the following:

- Activity 1 - Sensitivity analysis for each region to determine the dominant calibration and validation model parameters.
- Activity 2 - Calibration and validation of the models against field measurements.
- Activity 3 - Calculations of model performance metrics.
- Activity 4 - Uncertainty analysis of each regional model.

Subtask 4.10 – Validation, Performance Assessment & Uncertainty Analysis: Timeline (months)

Activity Description	13	14	15	16	17	18	19	20	21	22	23	24
1. Sensitivity analysis	X	X	X	X	X	X	X	X				
2. Calibration & validation						X	X	X	X	X		
3. Performance metrics							X	X	X	X		
4. Uncertainty analysis								X	X	X	X	X

Subtask 4.11 – Subtask Leader – Coordination Meetings and Conference Calls (Months 1 - 42)

Rationale: Coordination across multiple components of the model improvement effort is important for idea-sharing, understanding the needs of other components, and linking efforts in an efficient manner when facing a rigid schedule. This task includes six monthly 1-hour Subtask Leader "coordination" conference calls during the first 6 months of the modeling effort to help coordinate technical needs/ideas across the early development subtasks. During the first six months, the Subtask Leaders will also be asked to meet one time (8-hours) in Baton Rouge. After the first six months of this effort, all team/coordination meetings will be accounted for from the individual subtasks. However, through this subtask, Subtask Leaders are still asked to participate in eight (8-hour) meetings with the PM-TAC in Baton Rouge.

Proposed Approach: Several activities are recommended to ensure consistent and meaningful collaboration and communication across early, development-oriented components of the modeling effort.

Activities will include the following:

- Activity 1 - Participation in six monthly 1-hour Subtask Leader "coordination" conference calls (months 1 - 6).
- Activity 2 - Participation in one 8-hour, in-person Subtask Leader "coordination" meeting in Baton Rouge. Likely to occur 3 or 4 months from start date.
- Activity 3 - Participation in six to eight in-person meetings with the Predictive Models - Technical Advisory Committee (PM-TAC) and other Subtask Leaders (1-day meetings in Baton Rouge; to be appended to a subset of the subtask meetings); duration: length of contract.

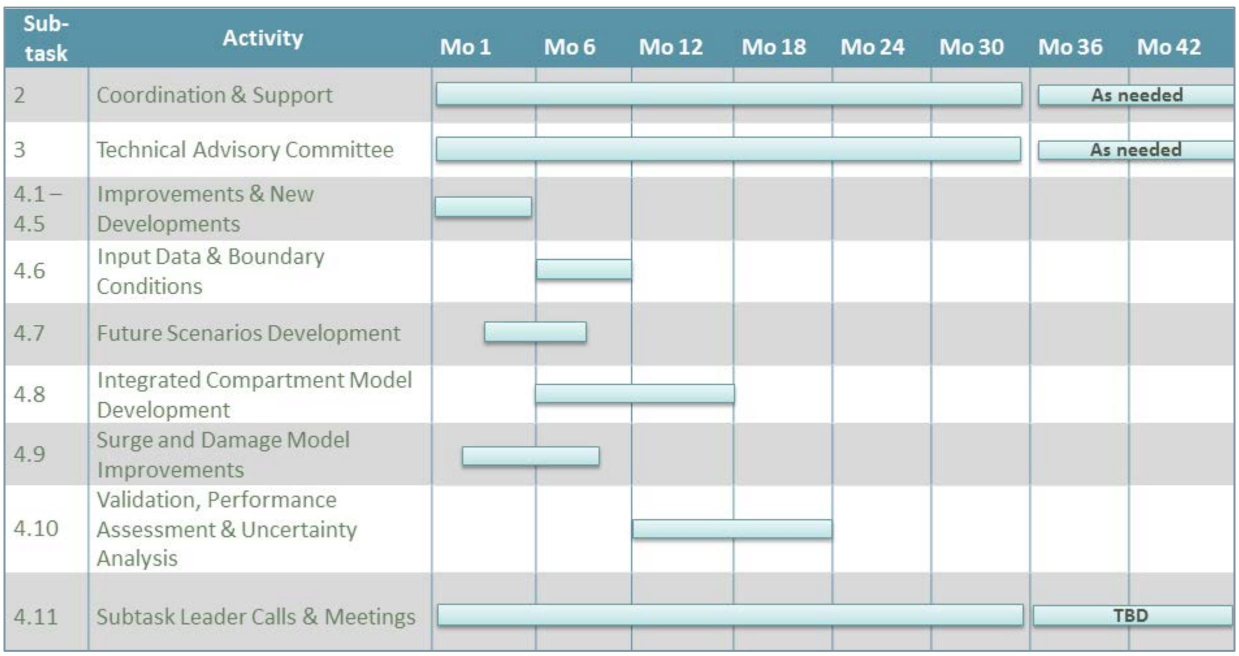
Subtask 4.11 – Timeline (months)

Activity Description	1	3	6	9	12	15	18	21	24	27	30	33	36	39	42
1. Monthly calls (6)	XX	XX	XX												
2. Coordination Meeting (1)		X													
3. Tec Advisory Committee (8)		X	X		X		X		X		X		X		X

Implementation Schedule

Activities detailed in the Model Improvement Plan are shown below in an approximate three year timeline, beginning in mid-2013 and ending in mid to late 2016. Production runs for the 2017 Coastal Master Plan are proposed to end in late 2015, with a six-month window for additional runs to be specified by CPRA as needed. Although reporting will occur throughout this effort, final (reviewed) reports will be submitted to CPRA in December 2016.

Figure 2. Schedule of MIP activities.



CLOSING STATEMENTS

Though the 2012 Coastal Master Plan modeling effort was widely praised as being a commendable and impressive effort, a number of key improvements are needed to raise the technical bar to the next level. While drawing upon the existing tools and lessons learned, the strategic improvements recommended herein will yield a more robust and technical sound modeling effort, including more detailed understanding of model sensitivity and uncertainty of the 2017 Coastal Master Plan technical tools.

It is important to note that this Model Improvement Plan will continue to evolve throughout and beyond the 2017 Coastal Master Plan model improvement process. It will be revised and updated on a regular and ongoing basis to accommodate the needs of CPRA and to incorporate new information / modeling components.

REFERENCES

Cobell, Z.; Zhoa, H.; Roberts, H.J.; Clark, R., and Zou, S., 2013. Storm surge and wave modeling for the Louisiana 2012 Coastal Master Plan. In: Peyronnin, N.S. and Reed, D. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67,

Couvillion, B.R.; Steyer, G.D.; Wang, H.; Beck, H.J., and Rybczyk, J.M., 2013. Forecasting the effects of coastal protection and restoration projects on wetland morphology in coastal Louisiana under multiple environmental uncertainty scenarios. In: Peyronnin, N.S. and Reed D.J. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67.

Groves, D.G. and Sharon, C., 2013. Planning tool to support planning the future of coastal Louisiana. In: Peyronnin, N.S. and Reed, D. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67.

Hughes, Z.; Weathers, D.; Georgiou, I.; FitzGerald D., and Kulp, M., 2012. Appendix D-3: barrier shoreline morphology model technical report. In: Louisiana's Comprehensive Master Plan for a Sustainable Coast. Baton Rouge, Louisiana: Coastal Protection and Restoration Authority, pp. 1–40.

Johnson, D.R.; Fischbach, J.R., and Ortiz D.S., 2013. Estimating surge-based flood risk with the coastal Louisiana risk assessment model. In: Peyronnin, N.S. and Reed, D. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67.

Meselhe, E.; McCorquodale, J.A.; Sheldon, J.; Dortch, M.; Brown, T.S.; Elkan, P.; Rodrique, M.D.; Schindler, J.K., and Wang, Z., 2013. Ecohydrology component of Louisiana's 2012 Coastal Master Plan: mass-balance compartment model. In: Peyronnin, N.S. and Reed, D. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67.

Nyman, J.A.; Baltz, D.M.; Green, M.; Kaller, M.D.; Leberg, P.L.; Richards, C.P.; Romaire, R.P., and Soniat, T.M., 2013. Likely Changes in habitat quality for fish and wildlife in coastal Louisiana during the next 50 years. In: Peyronnin, N.S. and Reed D.J. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67.

Rivera-Monroy, V.H.; Branoff, B.; Meselhe, E.; McCorquodale, A.; Dortch, M.; Steyer, G.D.; Visser, J., and Wang, H., 2013. Landscape-level estimation of nitrogen loss in coastal Louisiana wetlands: potential sinks under different restoration scenarios. In: Peyronnin, N.S. and Reed, D. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67,

Visser, J.M.; Duke-Sylvester, S.M.; Carter, J., and Broussard, W.P., III, 2013. A computer model to forecast wetland vegetation changes resulting from restoration and protection in coastal Louisiana. In: Peyronnin, N.S. and Reed D.J. (eds.), Louisiana's 2012 Coastal Master Plan Technical Analysis. Journal of Coastal Research, Special Issue No. 67.

APPENDIX 1 – PRELIMINARY DRAFT SUMMARY OF MODELING APPROACHES FOR LOUISIANA COASTAL FISHERIES

Prepared by:

Dynamic Solutions, LLC

450 Laurel Street,

Suite 1060, River Side Tower North

Baton Rouge, LA70801

225.490.0090 www.dsllc.com

The purpose of this preliminary draft summary is to provide The Water Institute of the Gulf with a brief overview of modeling approaches, with their respective advantages and limitations, for simulating Louisiana coastal fisheries species and their responses to the planned coastal restoration projects outlined in the 2012 Louisiana Master Plan. Some examples of existing fisheries and ecosystem models are briefly described for each modeling approach. This initial draft draws partly from a technical report prepared by Shaye Sable, Kenneth Rose, and Wim Kimmerer for the selection of an ecological model to represent the lower trophic levels in the San Francisco Estuary (Dynamic Solutions 2011), and is to be revised via comments and reviews from The Water Institute scientists and as additional information and efforts are made available for the planning and development of fisheries models.

Overview of Modeling Approaches for Louisiana Coastal Fisheries

There are a variety of models and modeling approaches available that could be adapted for simulating ecological conditions and/or fisheries population and community dynamics in Louisiana's coastal systems. Many of the approaches can be linked to GIS maps for the coastline, or used with the hydrodynamic, water quality and sediment transport models in development for the Louisiana Master Plan. Upper trophic level models, usually focused on fish, typically are not directly coupled to hydrodynamic models (i.e., fish models are much simpler spatially), focus on population dynamics, and can be biomass-based, structured (age or stage), or individual-based. Whole-ecosystem models attempt to include the major components of the ecosystem, from water quality through fish. Recently, there has been renewed interest in whole-ecosystem models because of the recognition of the need for food web approaches, demands of ecosystem-based management, and a need for tools that can handle both bottom-up effects related to climate change and top-down effects related to harvesting (Rose et al. 2010).

The available modeling approaches, with some examples, are summarized below:

Dynamic habitat suitability models

A technical report from a workshop on Habitat Suitability Models for Chesapeake Bay classified this set of models as those that can combine hydrology, bathymetry, water quality, hard substrate distributions, and behavior by using process oriented studies from the laboratory and field to predict species abundances and distributions in relation to changing habitat landscapes (Secor 2009). The report lists two dynamic habitat approaches that have potential relevance for Louisiana coastal systems. The first model is an oyster larval transport model that is used with 3D hydrodynamic models (ROMS and QUODDY) to determine particle movement through space and time (North et al. 2008). The larval transport model provides the spatial trajectories of the offspring produced by each oyster reef, and provides predictions of settlement success/recruitment based on the transport (advection and turbulence) and behavior (swimming speed, direction, settlement) of the larvae in relation to the hydrology, bathymetry, water quality and reefs. The second model stems from the conceptual model of the habitat mosaic (Peterson 2003), and considers the linkages between dynamic (water mass variables such as temperature and salinity) and stationary (structural) components of the environment and how fish respond to fine-scale habitat differences (using digital maps generated from remotely sensed data with in-situ field measurements -Peterson et al. 2007) that are based on species-specific growth and mortality effects (measured in the laboratory). Peterson and Fulford at USM are currently working on a landscape-based individual-based model to describe how fish respond to habitat mosaics using movement rules and species-specific habitat response functions to predict essential fish habitat (EFH - habitats that support key life history functions such as growth, reproduction and early survival of fishes (Fluherty 2000, Beck et al. 2001) for the Pascagoula River.

Advantages: Models can elucidate the processes to predict the production and spatial distribution of fishery species based on the dynamic and stationary habitat changes over time and behavior/movement of the species; models can be used to identify EFH for important Louisiana coastal species; models have been linked with large hydrodynamic models and high-resolution habitat maps to provide system-wide projections for fishery populations.

Limitations: The data requirements for landscape-based modeling of Louisiana estuary environment are relatively high; data for many of the fishery species within the Louisiana coastal systems might not be available, and laboratory work and field sampling to determine the functional relationships between species vital rates and habitat characteristics is labor intensive; water quality monitoring data are not readily available at the finer-spatial scale needed to evaluate transport and movement of many species; models are single-species and do not currently consider interacting species, prey and predator fields.

Age or stage-structured fish models

The simplest fish models represent the population as a single state variable of biomass (e.g., surplus production models). In contrast, structured fish models project the time-varying numbers within the component ages or stage classes used to describe the population. This approach is justified because of recognized differences in the vital rates of the age (stage) classes that determine the overall dynamics of the population. Most age or stage-structured models are of individual populations; however, examples of multi-species structured models exist (e.g., Rose and Sable 2009). Functional responses are used to describe changes in the stage or age-specific growth and survival rates based on physical-chemical drivers in a system. There are many examples of age and stage-structured fish models (Tuljapurkar and Caswell 1997), in part because these approaches provide the basis of stock assessment and fisheries management (Quinn and Deriso 1999; Rose and Cowan 2003).

Advantages: Models allow for the incorporation and evaluation of age- or stage-specific processes, stressors or effects; models can be constructed relatively quickly and easily as they are widely used for fisheries management and stock assessments; environmental effects and species interactions can be incorporated into the stage-specific vital rates (mortality and growth) as functional responses; stage or age-specific growth and mortality estimates are often available for many key fishery species in the northern Gulf of Mexico, or else likely can be estimated from independent field studies, and fisheries-independent and dependent data collected by LDWF and NOAA-NMFS.

Limitations: Models are typically for single species or else include only a few interacting populations; stage or age-specific growth and mortality estimates for some of the fishery species within the Louisiana coastal systems might not be readily available; the functional responses between growth and mortality of species life stages and habitat characteristics might not be available, and laboratory work and field sampling to determine the functional relationships is labor intensive.

Individual-based fish models (IBMs)

IBMs follow the fate of individuals throughout their life cycle with the assumption that differences in individual traits and behavior are important in determining the overall dynamics of the population (e.g., DeAngelis and Gross 1992; Grimm and Railsback 2005) IBMs are useful for evaluating how differences in the individuals might affect the dynamics of a system. They are usually developed for investigating single populations. A number of IBMs have been developed to consider multi-species dynamics, but these models do not go beyond 3-4 species (i.e., do not represent complex food webs). Functional responses are used to describe changes in the individual rates that influence growth and/or survival based on the user-defined physical-chemical conditions in the system. IBMs have been increasingly applied because of the perceived poor performance of structured approaches in fisheries management (e.g., claims of an overfishing crisis), and because of increased computing power and advances in data collection (e.g., spatially-resolved data, tagging studies). In addition, the logic of IBMs is more straightforward and better mapped to the lives of individual organisms. There are many IBM examples of zooplankton and fish (DeAngelis and Mooij 2005).

The Rose lab at LSU has developed multiple IBMs to evaluate changes in population production and species distribution via changes to individual growth, mortality and movement that are based on differences in structural habitat (Haas et al. 2004, Roth et al. 2008), varying environmental conditions and predator-prey fields (Sable 2007), and contaminant exposure (Murphy 2005) which can occur at different temporal and spatial scales (Shepard 2012). Example models include a brown shrimp IBM that tracks individuals as they grow and move about coastal marsh habitat grids to evaluate how vegetation complex and the degree of marsh edge affect shrimp production, and a 6-species community IBM that tracks individuals as they feed (on zooplankton, benthos and each other), grow, and move about 4-m^2 habitat cells in a tidal marsh grid to evaluate how food web interactions, fine-scale differences in habitat and varying DO levels affect species production. Rose et al. (in review) recently developed a coupled hydrodynamics-fish model and applied it to the Caernarvon diversion to evaluate the potential population-level effects of displacement and exposure to sub-optimal salinities on individual fish. The hydrodynamic model (FVCOM) of Breton Sound simulates outputs for water velocities, depths, and salinities that are used as the inputs to drive the individual movement of the fish model.

Advantages: Models have the same advantages as the Dynamic Habitat Suitability Models.

Limitations: Models have the same limitations as the Dynamic Habitat Suitability Models, with the exception that some of the existing IBMs (e.g., tidal marsh IBM) have been developed to include multiple species and simplified food webs, and incorporate movement and growth based on predator and prey fields; the data requirements for IBMs can be very high, and analysis and validation of the large multivariate output files takes considerable effort.

Whole-ecosystem models

Whole-ecosystem models attempt to represent all of the major components of the system (nutrients through fish). Species or groups of species (functional groups) are often represented as interconnected biomass or nutrient pools and often use bioenergetic-based equations to determine the flows of energy or biomass among model components. In the models which use bioenergetics, biomass production of the species or group is a function of photosynthesis for producers and consumption (ingestion and assimilation of prey) for consumers. Inputs are adjusted for physiological losses due to, for example, respiration, egestion and excretion, and mortality (natural and/or predation). Consumption of the prey species by the predator species is dependent upon the prey preferences of the predator, and the prey and predator biomass. Examples of whole-ecosystem models include Atlantis, the Comprehensive Aquatic Systems Model (CASM), and Ecopath with Ecosim (EwE). Plagányi (2007) provides a comprehensive description and evaluation of 20 models (including EwE and Atlantis) used in ecosystem based approaches for marine fisheries management. Below Atlantis, CASM, and EwE are described in more detail and include their respective advantages and limitations for simulating Louisiana coastal ecosystems.

Atlantis is a biogeochemical ecosystem model that simulates food web dynamics for a user-specified number of species groups that are driven by seasonal variation in light and temperature, and nutrient inputs and exchange within the ocean and from the atmosphere (Fulton et al. 2011, Fulton et al. 2004). The Atlantis model geometry can be matched to geographical features and sub-grids can be used to input different physical properties. Atlantis has an advantage in that NOAA Fisheries is using the model and applying it to multiple coastal areas in the United States for subsequent ecosystem-based fisheries management. NOAA Fisheries has ongoing efforts in the Chesapeake Bay and the California Current system. However, the model code is complicated and application and further development of the model would require participation by its developer, Dr. Elizabeth Fulton. Ken Rose at LSU is working with others on developing an Atlantis model for the Chesapeake Bay, and it is a long-term and labor-intensive effort. Also, Atlantis is just now being directly coupled to hydrodynamics.

Both the CASM and EwE models have been used in combination with hydrodynamic models to evaluate the potential ecological effects of freshwater flow on the food web in estuarine systems of Louisiana. A CASM food web model was used to simulate the daily biomass responses of several key species to proposed operational alternatives of the Violet River Diversion over 55 years at 23 inshore and offshore locations between Lake Pontchartrain and the Chandeleur Islands using the salinity, nitrogen, phosphorus, and total suspended solids outputs from the University of New Orleans (UNO) hydrology and hydraulics model (Bartell et al. 2010). In another application supported by the USACOE-ERDC System-wide Water Resources Program (SWRRP), both the CASM and EwE model were used to simulate changes in the biomass of key species in the Breton Sound ecosystem over one year in response to operational alternatives for the Caernarvon Freshwater Diversion. The CASM food web model for Breton Sound was embedded within each of the grid cells of the Caernarvon ADH model, and used the water depth, salinity, water velocities, nutrients (N, P, SI, POC, DOC), and dissolved oxygen calculated within the grid cells to drive the daily species processes. The Ecosim component of EwE was applied as three single-box models to simulate the food web in the upper, mid-, and lower regions of the estuary. The Ecosim model for Breton Sound used the monthly and spatially-averaged salinity results for the three regions of the estuary from the Caernarvon ADH model to drive the feeding rates of the component consumer species (de Mutsert et al. 2012). A similar EwE model is also under development through the Cowan laboratory at LSU for Barataria Basin.

Versions of the CASM are currently being developed that address processes at different trophic levels and target different numbers of species in California and nGOM estuaries. A lower trophic level (LTL) food web model was developed and calibrated to seasonal biomass data for phytoplankton, various zooplankton groups, mysids, and clams in the San Francisco Estuary (Dynamic Solutions 2012). The model is being used to evaluate bottom-up changes in primary production due to nutrient and sediment loading, and the top-down effects of invasive clam grazing within the estuary. Parts from the CASM MRGO application (Bartell et al. 2010) are being used to develop a CASM that will evaluate the potential aquatic impacts for the LCA project on the proposed Medium Diversion at Myrtle Grove. Researchers at USM are working on the application of the TroSim model (Fulford et al. 2010), which was initially developed from the CASM-COASTES designed for toxicological assessment (Bartell 2003) and expanded upon to include more explicit linkages between detrital pools, a prey refuge term, and non-trophic linkages, in order to examine eastern oyster-ecosystem interactions in the nGOM.

There are some differences between the CASM and EwE that could be seen as advantages and/or limitations to either approach. The CASM has process representations similar to NPZ (nutrient-phytoplankton-zooplankton) models, whereas EwE was developed with a focus on fisheries management (Walters et al. 1997) and thus has extensive options for simulating fish populations but offers fewer options in the water quality and LTL formulations. The CASM has fewer restrictions on the temporal and spatial resolution that can be simulated, and therefore has a greater capacity to link to hydrodynamics and water quality. The temporal and spatial resolution is user-defined for Ecosim, but the foraging algorithm in Ecosim (foraging arena theory) puts constraints on the minimum scales that can be simulated. Spatial versions of Ecosim (using Ecospace) have generally used relatively large spatial cells on the order of tens of kilometers or more (Walters et al. 1999; Pauly et al. 2000); use of Ecospace for evaluating finer-scale spatial differences in highly dynamic systems has been limited to date. Finally, EwE has an automatic calibration option to fit the model to multiple time series of data whereas the CASM does not. The CASM can be calibrated to fit multiple times series of data by linking the model to automated calibration software such as PEST (Dynamic Solutions 2012).

While all categorization schemes are over-generalizations, they are helpful for discussion. There are many examples of models that bridge over two or more of the above categories (e.g., individual-based habitat models), and most models use the techniques from one category to simulate the state variables of another category (e.g., individual-based zooplankton population model, age-structured fish species in whole-ecosystem models). In addition, some of these models are computer codes with enormous flexibility in the state variables and processes that can be included, so they can be configured at one extreme as single-species population models to the other extreme as whole-ecosystem models with dozens of state variables.

It has been extremely difficult to detect quantitative relationships between environmental quality and fish populations (Rose 2000), and perhaps nearly impossible for the complex estuarine habitats of coastal Louisiana. Modeling can help to evaluate and elucidate these relationships and interactions between fish and their environment, and be used to project changes in the species over time and in response to Louisiana coastal restoration efforts. There is no one modeling approach that can address every issue in relation to coastal restoration efforts and their combined effects on the coastal species. Rather a suite of models is likely needed, and which models depend on the scale of the question or impact of the particular restoration measure/s, and the key coastal species that are likely to be affected. Data mining and additional field measurements on both habitat and aquatic species will likely be needed to better define the habitat relationships for species, and to determine if there are sufficient data to adequately calibrate and validate the models.

Finally, the diet matrices of the ecosystem models will need to be validated with diet compositions and interactions determined from field studies (e.g., GMFMC Report on Ecosystem Modeling Workshop in 2007).

References

Bartell, S. M. 2003. A framework for estimating ecological risks posed by nutrients and trace elements in the Patuxent River. Estuaries 26: 385-397.

Bartell, S. M., S. K. Nair, and Y. Wu. 2010. Mississippi River - Gulf Outlet (MRGO) ecosystem restoration study Louisiana and Mississippi: revisions to the Comprehensive Aquatic Ecosystem Model (CASM). Preliminary Evaluation of Proposed Freshwater Diversion In the Vicinity of Violet, Louisiana. Project Report for the U.S. Army Corps of Engineers, New Orleans, LA.

Beck, M. W. and 12 other authors. 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. BioScience 51: 633-641.

DeAngelis, D. L. and L. J. Gross. 1992. Individual-Based Models and Approaches in Ecology. Routledge, Chapman and Hall, New York, New York, USA.

DeAngelis, D.L., and W. M. Mooij. 2005. Individual-based modeling of ecological and evolutionary processes. Annual Review of Ecology, Evolution, and Systematics 36: 147-168.

de Mutsert, K., J. H. Cowan, C. J. Walters. 2012. Using Ecopath with Ecosim to explore nekton community response to freshwater diversion into a Louisiana Estuary. Marine and Coastal Fisheries 4: 104-116.

Dynamic Solutions, LLC. Revised Technical Memorandum for Delta Ecological Model Selection. Submitted to the United States Army Corps of Engineers, Sacramento District, California. July 18, 2011.

Dynamic Solutions. 2012. Delta Ecological Model for Use in the Delta EFDC Hydrodynamic Model. Final Report submitted to the USACOE-Sacramento District, CA. The CalFed/Delta Islands & Levees Feasibility Study Hydrodynamic Models of the Sacramento - San Joaquin Delta.

Fluherty, D. 2000. Habitat protection, ecological issues, and implementation of the Sustainable Fisheries Act. Ecological Applications 10:325-337.

Fulford, R. S., D. L. Breitburg, M. Luckenback, and R. I. E. Newell. 2010. Evaluating ecosystem response to oyster restoration and nutrient load reduction with a multispecies bioenergetics model. Ecological Applications 20: 915-934.

Fulton, E.A., A. D. M. Smith, and C. R. Johnson. 2004. Biogeochemical marine ecosystem models. I. A model of marine bay ecosystems. EcologicalModelling174: 267-307.

Fulton, E. A., J. S. Link, I. C. Kaplan, M. Savina-Rolland, P. Johnson, C. Ainsworth, P. Horne, R. Gorton, R. J. Gamble, A. D. M. Smith, and D. C. Smith. 2011. Lessons in modelling and management of marine ecosystems: the Atlantis experience. Fish and Fisheries 12.

Grimm, V., and S. F. Railsback. 2005. Individual-Based Modeling and Ecology. Princeton Series in Theoretical and Computational Biology. Princeton University Press, Princeton, New Jersey.

Gulf of Mexico Fisheries Management Council. Report of the Ecosystem Modeling Workshop. St. Petersburg, Florida, May 8-10, 2007. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Regional Office.

Haas, H.L., K.A. Rose, B. Fry, T.J. Minello, and L.P. Rozas. 2004. Brown shrimp on the edge: linking habitat to survival using an individual-based simulation model. *Ecological Applications* 14: 1232-1247.

North, E. W., Z. Schlag, R. R. Hood, M. Li, L. Zhong, T. Gross, and V. S. Kennedy. 2008. Vertical swimming behavior influences the dispersal of simulated oyster larvae in a coupled particle-tracking and hydrodynamic model of Chesapeake Bay. Marine Ecology Progress Series 359: 99-115.

Plagányi, É. E. Models for an ecosystem approach to fisheries. FAO Fisheries Technical Paper. No. 477. Rome, FAO. 2007. 108p.

Pauly, D., V. Christensen, and C. Walters. 2000. Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries. ICES Journal of Marine Science 57: 697-706

Peterson, M. S. 2003. A conceptual view of environment-habitat-production linkages in tidal river estuaries. Reviews in Fisheries Science 11: 291-313.

Peterson, M. S., M. R. Weber, M. L. Partyka, and S. T. Ross. 2007. Integrating in situ quantitative geographic information tools and size-specific laboratory-based growth zones in a dynamic river mouth estuary. Aquatic Conservation-Marine and Freshwater Ecosystems 17:602-618.

Quinn, T. J., and R. B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, Oxford.

Rose, K. A. 2000. Why are quantitative relationships between environmental quality and fish populations so elusive? Ecological Applications 10: 367-385.

Rose, K. A., and J. H. Cowan. 2003. Data, models, and decisions in US marine fisheries management: lessons for ecologists. Annual Review of Ecology, Evolution, and Systematics 34: 127-151.

Rose, K. A., and S. E. Sable. 2009. Multispecies modeling of fish populations. *In* Megrey, B. A., and E. Moksness (Eds.). Computers in Fisheries Research, 2nd Ed. Springer Science.

Rose, K. A., J. I. Allen, Y.Artioli, M. Barange, J. Blackford, F. Carlotti, R. Cropp, U. Daewel, K. Edwards, K. Flynn, S. L. Hill, R. HilleRisLambers, G. Huse, S. Mackinson, B. Megrey, A. Moll, R. Rivkin, B. Salihoglu, C. Schrum, L. Shannon, Y-J. Shin, S. L. Smith, C. Smith, C. Solidoro, M. St. John, M. Zhou. 2010. End-to-end models for the analysis of marine ecosystems: challenges, issues, and next steps. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science Volume 2:115–130.

Rose, K. A., H. Huang, D. Justic. In review. Simulating fish movement responses and potential salinity stress to large-scale river diversions. In review at Environmental Management.

Roth, B.M., K.A. Rose, L.P. Rozas and T.J. Minello. 2008. Relative influence of habitat fragmentation and inundation on brown shrimp /Farfantepenaeus aztecus/ production in northern Gulf of Mexico salt marshes. Marine Ecology Progress Series 359:185-202.

Secor, D. H. 2009. Habitat Suitability Models: State of the Art, Chesapeake Applications. Workshop Report. The Chesapeake Bay Program Scientific and Technical Advisory Committee. December 2009. Publication number: 09-006.

Tuljapurkar, S., and H. Caswell. 1997. Structured-Population Models in Marine, Terrestrial, and Freshwater Systems. Chapman and Hall, New York.

Walters, C., V. Christensen, and D. Pauly. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Reviews in Fish Biology and Fisheries 7: 139-172.

Walters, C., D. Pauly, and V. Christensen. 1999. Ecospace: prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas. Ecosystems 2: 539-554.