Conceptual Ecological Models Executive Summary

Robert R. Twilley
Professor, Department of Oceanography and Coastal Sciences
Associate Vice Chancellor, Research and Economic Development
3257 Energy, Coast & Environment Bldg.
Louisiana State University
Baton Rouge, LA 708083
rtwilley@lsu.edu
Phone messages: (225) 578-8810
Fax messages: (225) 578-6423

Alaina B. Owens
Coastal Louisiana Ecosystem Assessment & Restoration Program
3201 Energy, Coast & Environment Bldg.
Louisiana State University
Baton Rouge, LA 708083
aowens@lsu.edu
Phone messages: (225) 578-6422
Fax messages: (225) 578-6423

CLEAR Coastal Louisiana Ecosystem Assessment & Restoration
providing scientific evaluation for restoration management

A report to the Louisiana Coastal Area Science & Technology Office

US Army Corps of Engineers

CPRA Coastal Protection and Restoration Authority of Louisiana

EXECUTIVE SUMMARY

N/A – this document is the executive summary of the CLEAR Volume IV (2008) Conceptual Ecological Model tasks.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

We would like to thank the LCA Science & Technology (S&T) Program and Louisiana Department of Natural Resources (LDNR) for financially supporting this effort under contract 2512-06-02, as well as the time and expertise contributed by the following LDRN / S&T staff: Jean Cowan, Jon Porthouse, Rick Raynie, James Pahl, Carol Parson-Richards, Andrew Beall, Barb Kleiss, and Sally Yost. Jenneke Visser, Greg Steyer, and Denise Reed were also integral to the completion of many of the CEM tasks.

Science Communication
We would like to thank the staff of the Integration and Application Network (IAN) for facilitating three workshops and assisting the CLEAR team and local experts in creating three science communication newsletters. Specifically, we would like to thank Bill Dennison, Tim Carruthers, Jane Hawkey, and Jane Thomas. We would also like to thank the many local science and engineering experts who attended the workshops and helped develop the following three newsletters:

Reducing Flood Damage in Coastal Louisiana: Communities, Culture & Commerce:
D. Batker, A. Beall, M. Bourgeois, J. Boydston, M. Brasher, C. Brown, R. Caffey, T. Carruthers, P. Chapman, S. Coffee, C. Courville, J. Cowan, D. Daigle, D. Davis, J. Day, D. Demcheck, C. Duet, D. Fakouri, S. Faulkner, P. Forbes, K. Gautreaux, I. Georgiou, D. Justic, S. Kaderka, P. Keddy, S. Lohrenz, J. Lopez, H. Mashriqui, D. Meffert, E. Melancon, E. Meselhe, A. Owens, C. Parsons, J. Porthouse, D. Reed, L. Rozas, D. Sabins, C. Sasser, L. Smith, K. St. Pe, G. Steyer, C. Swarzenski, B. Thomas, J. Tripp, R. Twilley, J. Visser, H. Warner-Finley, & C. Wilson

Enhancing Landscape Integrity in Coastal Louisiana: Water, Sediment & Ecosystems:
T. Carruthers, J. Cowan, B. Dennison, I. Mendelssohn, A. Owens, C. Parsons, R. Raynie, D. Reed, C. Sasser, G. Steyer, R. Twilley, & J. Visser

Restore vs. Retreat: Securing ecosystem services provided by coastal Louisiana:
D. Batker, J. Boydstun, C. Brown, T. Carruthers, P. Chapman, E. 'Buddy' Clairain, C. Courville, B. Dennison, J. Hawkey, D. Meffert, A. Owens, R. Raynie, D. Reed, C. Sasser, G. Steyer, S. Theriot, R. Twilley, & J. Visser

Technical CEMs – We would like to thank Bill Nuttle and Fred Sklar for facilitating three workshops, and Denise Reed and Fred Sklar for sharing their CEM experiences from CALFED and the Everglades, respectively. Finally, we thank all workshop participants, especially the following report and submodel authors:

Delta building – D. Reed & W. Kim.

Wetland productivity – G. Steyer, J. Visser, J. Pahl, & F. Sklar.

Residence time – W. Nuttle, D. Justic, & M. Inoue

Aquatic primary productivity – D. Justic, E. Melancon, K. Rose, M. Schexnayder, R. Twilley, & J. Visser

Upper trophic group – K. Rose, E. Melancon, & M. Schexnayder

Interactive Web development
We thank Adrian Jones of the Integration and Application Network for completely revising and restructuring the CLEAR website, and Carola Kaiser of the CLEAR Office for creating several interactive web applications, including the CLEAR MapServer and the Google Maps application. We would also like to thank our colleagues at USGS, specifically, Craig Conzelmann, Kevin Suir, and Greg Steyer, for converting the static wetland productivity and delta building submodels into interactive web applications.

Adaptive management
We thank Steve Light and Barbara Stinson for the time they spent meeting with the local restoration and management community, and especially Steve Light for generating the final report for the Adaptive Management task.

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AEAM - Adaptive Environmental Assessment & Management

CALFED – California-Club Fed delta/bay restoration

CEM – Conceptual Ecological Model

CIAP – Coastal Impact Assistance Program

CLEAR – Coastal Louisiana Ecosystem Assessment & Restoration (Office/Program)

CPRA – Coastal Protection & Restoration Authority

CRMS – Coastal Reference Monitoring System

CWPPRA – Coastal Wetlands Planning, Protection, & Restoration Act

IAN – Integration & Application Network

LaCPR – Louisiana Coastal Protection & Restoration

LCA S&T – Louisiana Coastal Area Science & Technology (Office/Program)

LDNR – Louisiana Department of Natural Resources

MRGO – Mississippi River Gulf Outlet

NRC – National Research Council

OCPR – Office of Coastal Protection & Restoration

OCS – Outer Continental Shelf

UMCES – University of Maryland Center for Environmental Science

WRDA – Water Resources Development Act

1. INTRODUCTION

Effective synthesis and communication of complex scientific and technical information are essential for the success of coastal ecosystem restoration and hurricane protection in Louisiana. The Louisiana Coastal Protection and Restoration Authority (CPRA) Comprehensive Master Plan for a Sustainable Coast (CPRA 2007) describes one of the most ambitious coastal restoration and management efforts ever attempted and represents one of the largest public work projects in the United States. A key element of the plan concerns gathering and applying knowledge of how the coastal landscape functions at both coast-wide and project-level scales. This is the focus of the CPRA, the Louisiana Coastal Area Science and Technology Office (LCA S&T) as well as several other State and Federally-sponsored programs (e.g. Louisiana Coastal Protection and Restoration (LaCPR), the Coastal Impact Assistance Program (CIAP) and the Coastal Wetlands Planning Protection Restoration Act (CWPPRA)). A focus of the Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Program has been to provide assistance to these programs in helping to develop synthesis and communication tools to support the various responsibilities of these groups. This executive summary describes our collective efforts in developing science communication newsletters, conceptual ecological models, web applications, and other summaries to support an adaptive management framework in coastal Louisiana.

Conceptual ecological models (CEMs) articulate the known relationships between ecosystem restoration activities, coastal protection strategies and the future trajectory of coastal ecosystem attributes. CEMs are seen as an essential component in any major ecosystem restoration effort. CEMs have proven to be valuable tools for planning and implementation of ecosystem restoration in South Florida, for the Comprehensive Everglades Restoration Plan (CERP), and for CALFED in northern California. The National Research Council criticized Louisiana's coastal restoration efforts during their 2006 review (Drawing Louisiana's New Map: Addressing Land Loss in Coastal Louisiana (NRC 2006)) for lack of attention to building a similar set of tools.

The process of developing CEMs is much more than drawing diagrams that describe an ecological system. CEMs provide a framework for assembling and disseminating scientific and technical information needed to support ecosystem management. The ecological services road map provided by CEMs can be used for conflict resolution and to help define what stakeholders stand to gain or lose as decisions are made during the restoration and protection process. Specific examples (e.g. MRGO), can be used to demonstrate how land use management plans can translate into trade-offs associated with ecological services.

The CLEAR Volume IV work continued the process of developing CEMs for coastal Louisiana and incorporating them into a broader adaptive environmental assessment and management (AEAM) program. An ongoing process for developing CEMs within the AEAM program will ensure that science is usable and understandable to stakeholders and decision-makers. Conceptual models translate restoration goals into specific performance measures that will be evaluated through comprehensive monitoring and forecasting approaches developed under AEAM, Figure 1.

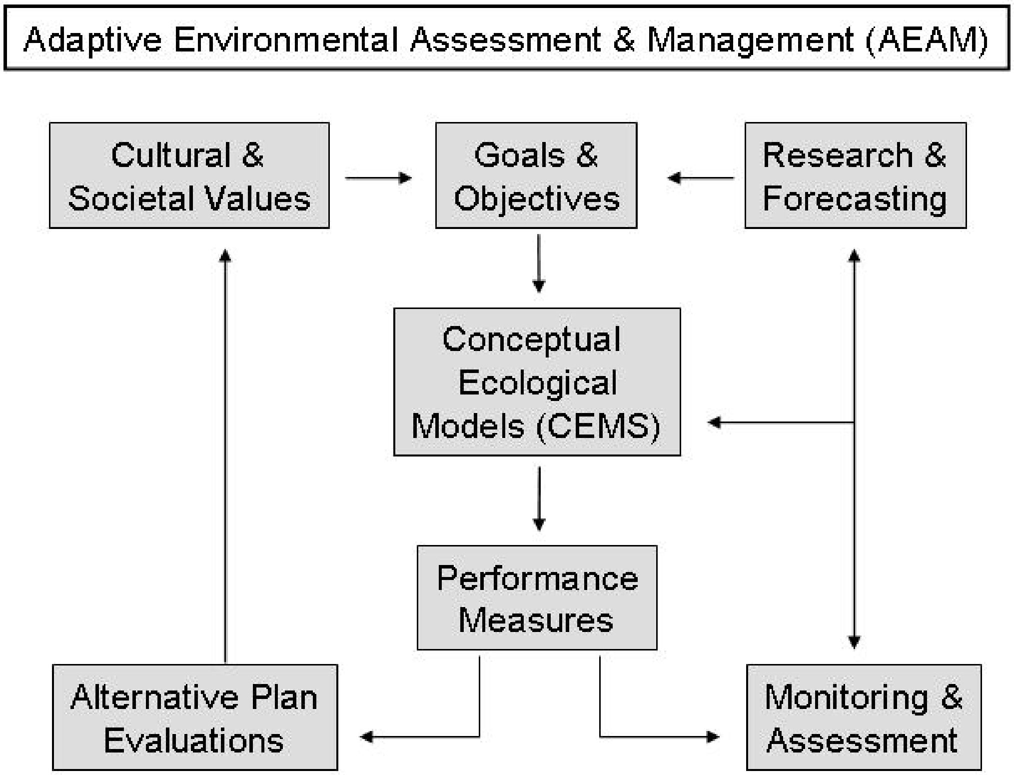

Figure 1. A proposed approach for developing conceptual ecological models (CEMs) under an adaptive environmental assessment and management framework to support coastal restoration efforts across Louisiana.

2. SUBTASKS & METHODS

2.1 SCIENCE COMMUNICATION

It is no secret that technically rigorous research, when discussed and written for other experts and publication in peer reviewed journals, is not only difficult for the non-expert to read and digest, but can also be very difficult to locate for those not familiar with technical journals. However, the scientific community, academia in particular, continues to conduct business in this manner resulting in the exclusion of nearly everyone except other experts in their field.

When technical information is conveyed in an interesting, aesthetically pleasing, and easy to understand manner, overall interest and involvement is encouraged across a much wider audience. To encourage interest and understanding by the general community non-experts and to foster a greater understanding of the issues relating to coastal restoration and protection in coastal Louisiana, the CLEAR Program teamed up with the University of Maryland Center for Environmental Sciences (UMCES) Integration and Application Network (IAN) to create a series of informational newsletters. Science integration and communication techniques were integral in generating the conceptual diagram vignettes and newsletter series. These newsletters were designed for a wide audience, including the general public and decision makers, to help foster interest and understanding.

Specific science communication tasks and products:

- The CLEAR and IAN team hosted a Conceptual Ecological Model Workshop on November 16-17, 2005, which was attended by 49 individuals from 29 State, Federal and Academic institutions. Workshop participants developed conceptual diagrams of the northern Gulf coast to formalize the synthesis and communication of scientific knowledge of these systems. The resulting product was a 4-page conceptual ecological model / science communication newsletter titled *Reducing Flood Damage in Coastal Louisiana: Communities, Culture & Commerce*. This newsletter focuses on the linkages between natural and artificial landscape features and storm surge damage. To date, over 2,000 copies have been printed and distributed, and PDF copies are available for download on the CLEAR, IAN, and LCA S&T websites.

- The CLEAR and IAN team hosted a second Conceptual Ecological Model Workshop on March 31, 2006, which was attended by 12 individuals from six State, Federal and Academic institutions. Workshop participants developed conceptual diagrams of the northern Gulf coast to formalize the synthesis and communication of scientific knowledge of these systems. The resulting product was a 4-page Conceptual Ecological Model / Science Communication newsletter titled *Enhancing Landscape Integrity in Coastal Louisiana: Water, Sediment & Ecosystems*. This newsletter focuses on the differences between the Deltaic and Chenier Plain regions of coastal Louisiana and the resulting implications for landscape-scale restoration. To date, over 2,000 copies have been printed and distributed, and PDF copies are available for download on the CLEAR, IAN, and LCA S&T websites.

- The CLEAR and IAN team hosted a third Conceptual Ecological Model Workshop on August 31, 2006, which was attended by 18 individuals from 14 State, Federal and Academic institutions. Workshop participants developed conceptual diagrams of the northern Gulf coast to formalize the synthesis and communication of scientific knowledge of these systems. The resulting product was a 4-page Conceptual Ecological Model / Science Communication newsletter titled *Restore vs. Retreat: securing ecosystem services provided by coastal Louisiana*. This newsletter focuses on ecosystem good and services provided by coastal Louisiana and the importance of aggressive coastal restoration to secure these resources. To date, over 2,000 copies have been printed and distributed, and PDF copies are available for download on the CLEAR, IAN, and LCA S&T websites.

2.2 INTERACTIVE WEBSITE DEVELOPMENT

The World Wide Web is an ever increasing conduit for communication and data / information acquisition. Bound reports have largely been replaced by electronic or virtual reports, and websites have largely become informational hubs on a global scale. Presenting data, information, and other products on an easily navigable, aesthetically pleasing website is vital in today's networking and '.com' era.

Specific website development tasks and products:

- **CLEAR Website** - The CLEAR website was fully revised with assistance from the IAN staff to highlight the CLEAR modular approach to ecosystem forecasting. The layout and visual dynamics of the site were enhanced, creating a more interesting and easy to understand web interface, and the new website also features a searchable database of Volume I – IV (2003 – 2008) publications, reports, presentations, etc. Another objective of this revision was to enhance the visibility of the CLEAR Program and associated products. The following is a list of several example Google searches, and how the CLEAR website ranked:
  - *Coastal Louisiana modeling (1st hit)*
  - *Ecosystem forecasting Louisiana (1st hit)*
  - *Louisiana habitat switching (1st hit)*
  - *Coastal Louisiana risk assessment (1st hit)*
  - *Coastal Louisiana ecosystem (2nd hit)*
  - *Coastal Louisiana box models (2nd hit)*
  - *Louisiana conceptual model (2nd hit)*
  - *Restoration management Louisiana (3rd hit)*
  - *Louisiana habitat use modeling (5th hit)*
  - *Coastal Louisiana hydrodynamic model (7th hit)*
  - *Restoration in coastal Louisiana (9th hit)*
  - *Coastal Louisiana land building model (10th hit)*

- **CLEAR MapServer** – An interactive online MapServer was developed to host input and output data and animations from the CLEAR modules. This application can be used to view and download data such as monitoring station locations, sediment basins, vegetation cover, hydrodynamic model output (salinity), landscape change model output, and habitat switching model output. Visualization of this type of information may support restoration and protection decisions, especially if it is delivered in an easily accessible and understandable way. For more information on the CLEAR MapServer and associated features, download the associated visualization report (Visualization of Model Output: CLEAR MapServer & Google Maps API (Kaiser 2008)).

- **CLEAR Google Maps Application** – An interactive Google Maps application was developed to host output from the AdCirc storm surge model. Currently, this application can be used to view current storm surge dynamics from Hurricanes Rita and Katrina, as well as storm surge dynamics associated with various restoration alternatives (i.e. 50-year future without additional restoration and 50-year future with the complete establishment of the projects outlined in the Preliminary Draft Master Plan, as designated by the Louisiana Coastal Protection and Restoration Authority). Visualization of this type of information may support decision-making related to restoration and protection features, especially if it is delivered in an easily accessible and understandable way. For technical details regarding this online application and associated features, download the associated visualization report (Visualization of Model Output: CLEAR MapServer & Google Maps API (Kaiser 2008)).

- **Interactive CEMs** – Colleagues at USGS, Craig Conzelmann, Kevin Suir, and Greg Steyer, took the lead on converting two static CEM submodels to interactive web applications. The wetland productivity and delta building applications are available on the CLEAR website as well as the CRMS website.

2.3 TECHNICAL CONCEPTUAL ECOLOGICAL MODELS

The Louisiana Comprehensive Master Plan for a Sustainable Coast (CPRA 2007) embarks on one of the most ambitious coastal restoration and management efforts ever attempted, and it represents one of the largest public work projects in the United States. A key element of the plan concerns gathering and applying knowledge of how the coastal landscape functions at both coast-wide and project-level scales. This is the focus of the Louisiana Coastal Area (LCA) Science and Technology Office and the Louisiana Coastal Protection and Restoration Authority (CPRA) as well as several other State and Federally-sponsored programs (e.g. Louisiana Coastal Protection and Restoration (LaCPRA), the Coastal Impact Assistance Program (CIAP) and the Coastal Wetlands Planning Protection Restoration Act (CWPPRA).

Conceptual ecological models (CEMs) provide a framework for assembling and disseminating scientific and technical information needed to support ecosystem management. CEMs articulate the links between restoration activities, and protection strategies and the trajectory of natural resources. CEMs are seen as an essential component in any major ecosystem restoration effort, and they have proven to be valuable tools for ecosystem restoration for the Comprehensive Everglades Restoration Plan (CERP) in South Florida, and for CALFED in northern California. Conceptual ecological models help build understanding and consensus among scientists and managers about how natural processes and human activities interact to affect natural resources. In particular, CEMs help to:

- ***Identify*** drivers of ecological processes, anthropogenic stressors, their ecological effects, and attributes useful in monitoring and forecasting ecosystem response.
- ***Diagram*** qualitative explanations of how human activities alter ecology.
- ***Develop*** consensus and ***communicate*** working hypotheses.
- ***Identify*** performance measures and ***develop*** monitoring and modeling activities to support restoration and management.

The CEM development process should help identify conflicts and synergies so that the CEMs can aid in restoration and protection planning and decision-making. CEMs should also identify key scientific uncertainties and performance measures to help frame the research questions and priorities, and help us identify tradeoffs, build an adaptive management strategy, and 'think outside the box' regarding what is possible for landscape level restoration (eg, 3rd delta, delta management, Old River Control Structure, etc).

CEMs should be able to help us answer the following types of questions:

- What does it take to build marsh, ridges, or barrier islands?
- What does it take for a marsh, ridge, or barrier island to be sustainable?
- What is the role of the estuarine landscape for storm surge attenuation?
- ***What are the effects of various freshwater diversion sizes and locations?***
- What effect do barriers have on hydrologic exchange?
- What are the consequences of pipeline sediment delivery?

When creating CEMS, we should consider whether our goal is academic in nature, such as publication in a peer reviewed journal or whether we want to create something geared toward agency use. Regardless, they should be created in such a way that makes them easy to understand and use. We should also consider whether they are being created as precursors to numerical models.

CEMs should be considered 'living' documents and regularly updated as new or other existing science emerges. By providing a common foundation of knowledge, the models can be used by the LCA S&T Office, the CPRA, and others to promote and enable discussion and scientific debate within the science and engineering community, policy-making arena, and with stakeholders (i.e. participatory approaches to science and management) under an adaptive management framework. Finally, the scientific knowledge represented by the models should be communicated to the restoration community for use in setting research agendas, developing scientific syntheses, designing monitoring and modeling programs and identifying management priorities under an adaptive management framework.

Through this particular effort, participants aimed to generate an integrated set of CEMs to address river diversions, using the Barataria Basin as a template. The group also strove to generate a suite of interconnected submodels to focus on the following key coastal processes: ***delta building, wetland productivity, residence time, aquatic primary productivity, and upper trophic level***.

A conceptual model for large-scale diversions serves coastal managers in several ways. First, constructing such a model identifies critical elements of the Louisiana coast and key processes that will be affected by a river diversion. By working with and refining the model, managers will come to understand under what circumstances large-scale diversions might be employed and the resulting tradeoffs. The conceptual model identifies *important* processes that will be affected by diversions and evaluates the current level of *understanding* and our *ability to predict* the effects of diversion on these processes. Second, by assembling the available scientific knowledge into a narrative framework, the CEM exposes critical gaps in this knowledge and reveals the resulting uncertainties in how large-scale diversions will affect coastal ecosystems. Managers can use this information to direct future research and monitoring efforts. Finally, the conceptual model helps identify key environmental attributes that can be monitored to assess progress and critical questions where additional research is needed to apply large-scale diversions effectively as a tool for coastal restoration and management.

During initial phases of this project, participants spent time defining terms and reviewing conceptual modeling approaches from South Florida Everglades (CERP) as well as from California (CALFED), Table 1.

Table 1. Comparison of CEM roles, applications and logistical approaches in CALFED and CERP.

	CALFED	**CERP**
Roles & Application	• used for pre-construction evaluations to make decisions on which projects to move into implementation; • helps us understand consequences of restoration/conservation actions (what will happen when the drivers change, how one thing affects another)	• used as a post-construction tool to guide adaptive management; • helps us decide the type of monitoring and research to proceed with; • used to identify research goals and performance measures
Logistical approach	• <u>number of CEMs created</u>: 10 • <u>contributors</u>: 4-5 people per CEM; each CEM had an expert (champion) and group of facilitators; ~40-60 people total, with 25 or so contributing the majority of effort; mostly instate (CA) participants • <u>paid participation</u>: yes • <u>timeframe</u>: 3-4 years • <u>review</u>: conducted a formalized external review	• <u>number of CEMs created</u>: 12 • <u>contributors</u>: ~40-60 people total; 2 workshops; sent drafts to the technical community for review; incorporated their revisions • <u>paid participation</u>: no • <u>timeframe</u>: 2-3 years • <u>review</u>: Wetlands 2005 publication

Project participants decided that the Louisiana CEMs should follow a modified version of the CALFED approach, by identifying *drivers, interactions, and outcomes* in terms of their *importance, predictability and understanding* (using colored, weighted arrows, or some variation thereof); however, the group also wanted to incorporate performance measures as in the CERP CEMs (Ogden et al. 2005). Achieving this second objective will require modifying the suite of CEMs generated during this task or creating an additional set of CEMs to identify performance measures. The group also decided that in order to increase the effectiveness and utility of the CEMs, the final document should contain a combination of diagrams, narratives and references.

Visual documentation for this project was finalized is in the form of a main CEM diagram, shown in Figure 2 and five corresponding submodels (delta building, wetland productivity, residence time, aquatic primary productivity, and upper trophic group). Figure 3 shows the submodel key, and Figure 4 shows the delta building submodel as an example.

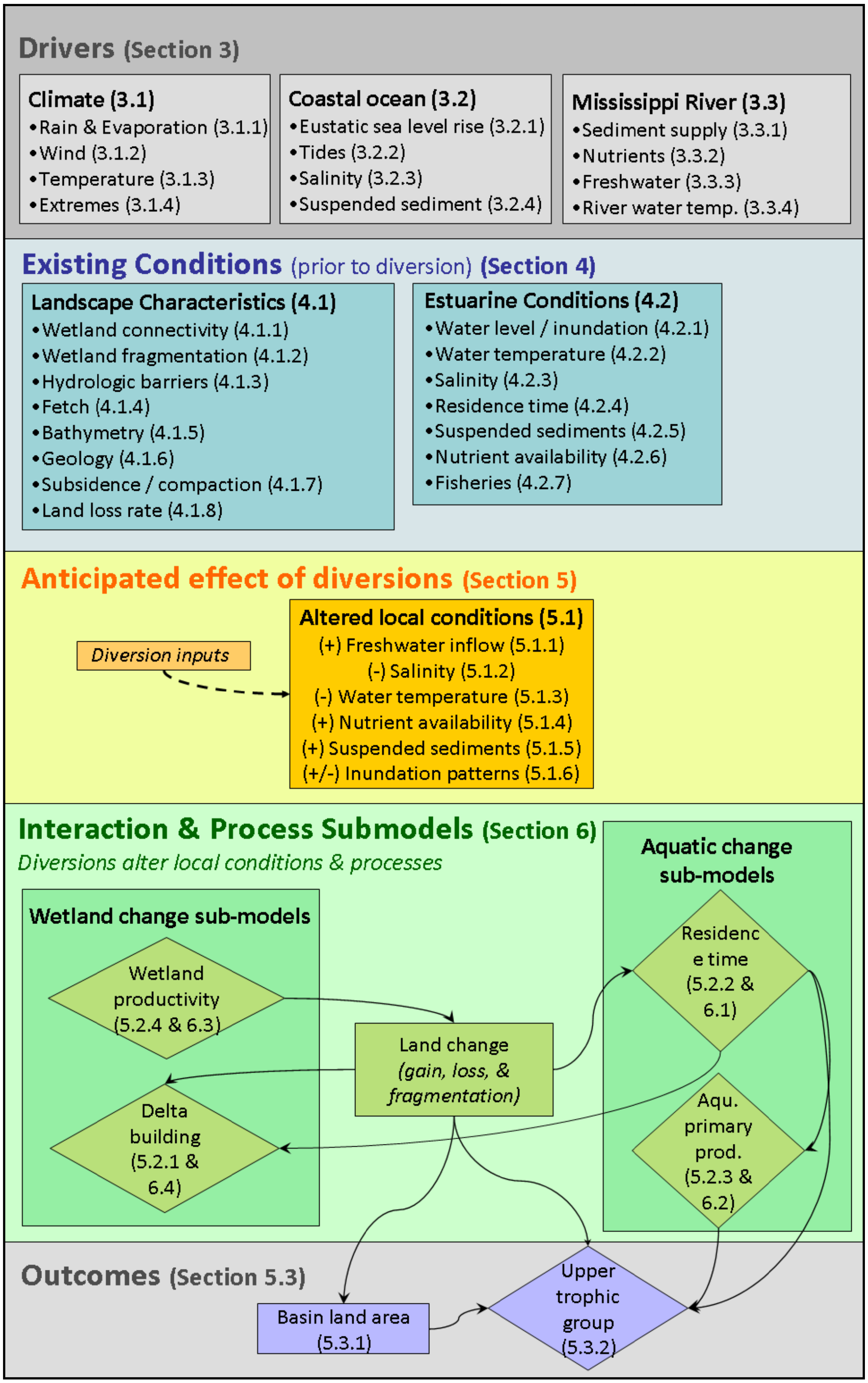

Figure 2. Conceptual diagram of the effects of a freshwater diversion, using Barataria Basin, Louisiana, as a template; numeric labels correspond to section headings in the body of the main CEM report.

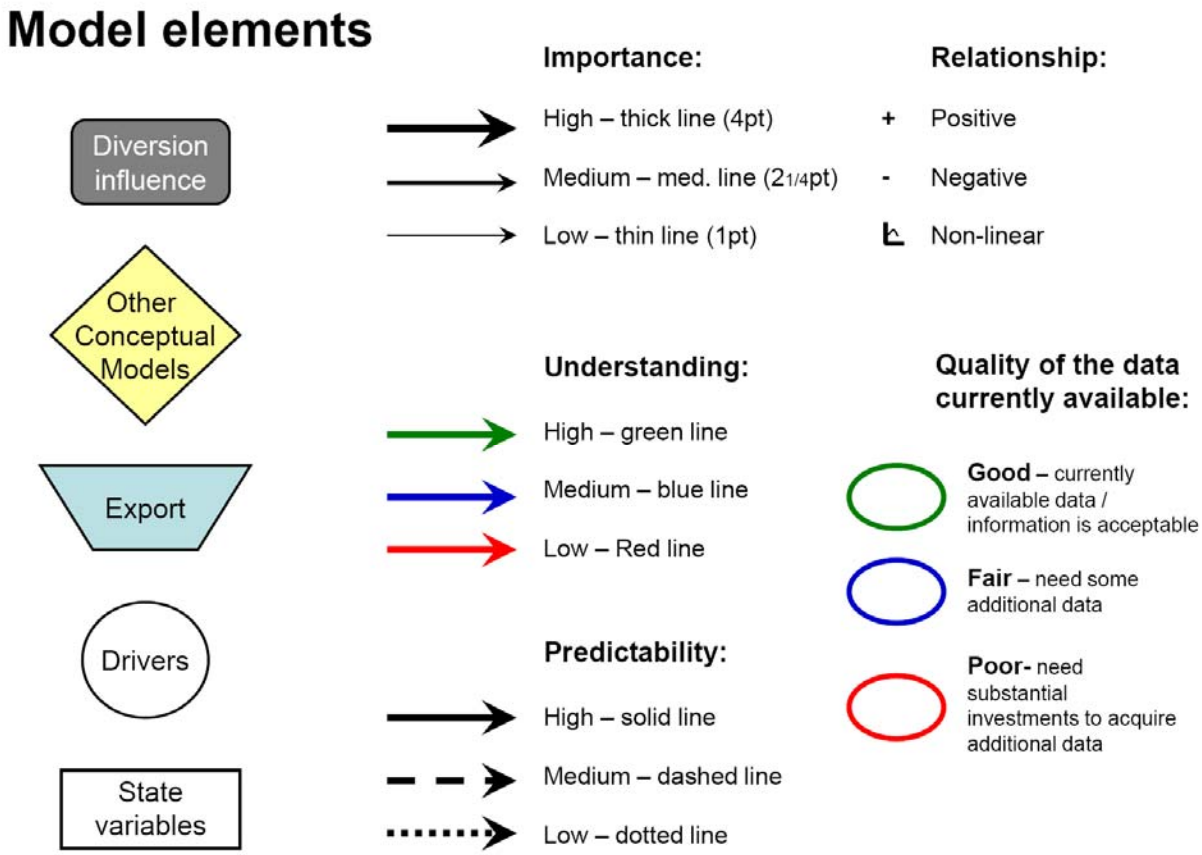

Figure 3. Model elements that were used to develop the sub-model CEMs. Delineations of Importance, Understanding, Predictability, and Quality of Data followed the strategy used to develop the CALFED models.

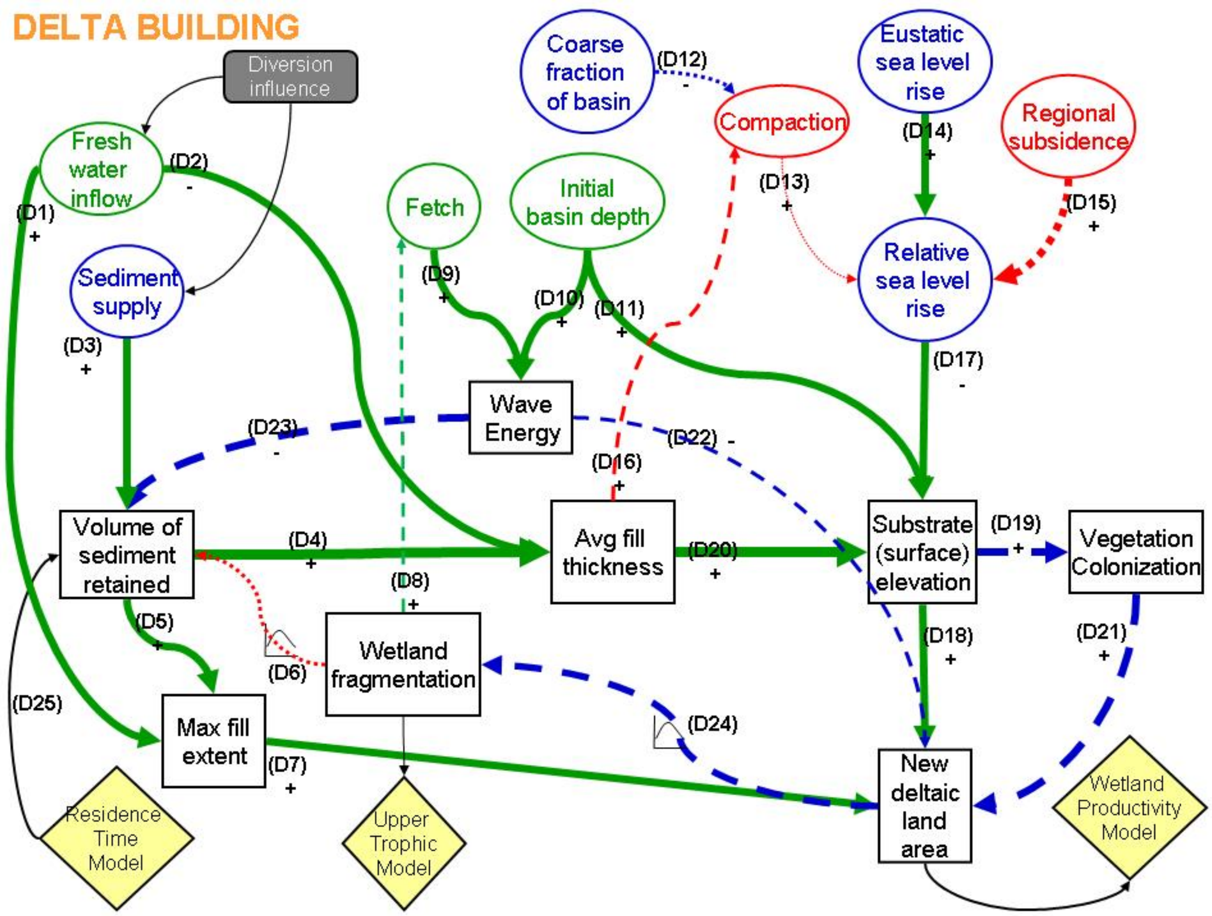

Figure 4. Conceptual diagram of delta building processes, as influenced by a freshwater diversion (using Barataria Basin as a template). This figure indicates that although regional subsidence is thought to be a ***highly important*** factor affecting relative sea level rise, it is ***poorly understood*** with a ***low predictability***, and thus an important avenue for future S&T Program effort.

Specific technical CEM development tasks and products:

- The CLEAR Office hosted 3 workshops in Baton Rouge (October 25-26, 2007, March 6-7, 2008, and May 20, 2008) with members of the science and engineering community to help develop and refine a suite of CEMs to highlight our current understanding of the effects of a freshwater diversion into coastal Louisiana, using Barataria Basin as a template.
- A main report and five appendices (submodels) were generated.
  - Main report - Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana (Nuttle et al. 2008b)
  - Appendix 1 – Delta building submodel – (Reed and Kim 2008)
  - Appendix 2 – Wetland productivity – (Steyer et al. 2008)
  - Appendix 3 – Residence time (Nuttle et al. 2008a)
  - Appendix 4 – Aquatic primary productivity (Justic et al. 2008)
  - Appendix 5 – Upper trophic level (Rose et al. 2008)
- Colleagues at USGS, Greg Steyer and Craig Conzelman, converted two static submodels (delta building and wetland productivity) to interactive web applications.
- Next steps
  - Convert additional CEM submodels into interactive (clickable) web applications.
  - Refine the overall CEM framework and submodels or create a second suite of comparable models to identify performance measures.
  - Develop system-wide CEMs, by basin, to assess how additional drivers affect component ecological resources.

2.4 ADAPTIVE MANAGEMENT

In 2004, the CLEAR Program developed an Adaptive Management Action Plan (Adaptive Environmental Assessment & Management: A Draft Framework (Steyer et al. 2004)). The document highlights the need for an Adaptive Environmental Assessment and Management (AEAM) Program to deal with the uncertainty that is unavoidable in managing large-scale ecological systems like the Louisiana coastal area. Various strategies for structuring an adaptive management framework for coastal Louisiana as well as various methods for implementing it are detailed. The report goes into specific detail regarding the following components of an adaptive management framework: goals and objectives; ecosystem models; role of targets; performance measures; project and basin-level assessments; modeling, monitoring and research; information and communication frameworks; and decision-making approaches.

An excerpt from the 2004 report follows:

> *"Institutions involved in AEAM must have a willingness to evaluate management activities and learn from experience through feedback. Making progress towards solutions through effective management actions requires clear identification of the problem and articulation of goals and objectives to remedy the problem. Setting goals and objectives requires high levels of societal contributions (e.g., stakeholder involvement). The translation of these goals and objectives into spatially explicit restoration targets requires equitable*

contributions of societal and scientific inputs. Establishing a range of conditions or different scales as a target acknowledges the uncertainty in the relationship between ecosystem structure and function and the natural variability of the system. These targets represent the "virtual" reference that defines a self-sustaining and socially desired ecosystem. The group responsible for setting these targets should be clearly identified at the time of implementation of AEAM program. At the project level, these targets will elucidate the trade-offs made among different ecosystem functions.

AEAM relies on the movement and exchange of data and information between managers, engineers, scientists, and stakeholders so that decisions can be made based on the lessons that have been learned. People involved in decision-making can be divided into two groups based on the roles they play. The first group can consist of those who have the authority and responsibility to make the choices of what will be done to manage coastal resources. The second group serves to assemble information and perform analyses required to inform the decision-making. Mechanisms for communication between these two groups will largely define the decision-making process. Capabilities must be developed for packaging the data and information into decision-making tools. Ecological risk assessment is one way of packaging data and information that should be explored. The reliability of information for evaluating the alternatives and the state of the resource depends on the data quality and rigor of scientific analysis that produced the information. Independent peer review is the preferred mechanism to assure the validity of the information.

We recommend a combination of passive and active management approaches to facilitate incorporation of existing restoration and management programs. The recommended approach will utilize monitoring data from routine project assessments and from test manipulations, in combination with a variety of different modeling approaches, to provide increasingly improved information as the basis for management decisions. It is essential that modeling, monitoring, and research development activities are integrated from the initial stages of restoration planning through AEAM decision-making."

Throughout the adaptive management process, clear, simple models can facilitate communications between: (1) scientists from different disciplines, (2) researchers and managers, and (3) managers and the public. The next steps in this process include: (1) identifying steps to refine an action plan, (2) identifying how to align multiple responsible agencies and organizations on the system-wide perspective on restoration, and (3) identifying key stakeholder and policy/ science issues for information sharing, discussion and decision making.

Under the current project, Barbara Stinson and Steve Light entered discussions with CLEAR, UMCES-IAN, and others to begin drafting approaches to facilitate the implementation of conceptual models by science, stakeholders and policy makers under an Adaptive Management Program. They also met with the LCA Science & Technology Office and others to discuss Adaptive Management approaches that can be used by the LCA as well as by the Louisiana Coastal Protection & Restoration Authority (CPRA).

Barbara Stinson and Steve Light began developing avenues of involvement focusing on a limited set of issues and potential ways of addressing them, such as: (1) Approaches and processes that create a shared understanding and commitment to adaptive management from stakeholders, scientists, managers and policy makers, (2) Prioritization of Action Plan items and approaches to build AEAM competencies, and (3) Case studies (conceptual models) to engage scientists and stakeholders in AEAM process.

As part of this task, Dr. Light drafted a report (Technical and Scientific Challenges for Responding to Large-Scale Ecological Restoration (Light 2008)) that supports the development of adaptive management strategies for Louisiana coastal areas by helping identify the mechanisms needed to facilitate communication within Louisiana's coastal restoration programs. The overarching question addressed by the report is, *"How do you integrate the legacy of existing restoration projects/programs that may be operating at a smaller scale (project) into new efforts operating at larger ecosystem and landscape-level scales?"* This report provides (1) an assessment of the scientific and technical issues for analyzing coastal programs and functions, and (2) a review of restoration efforts from other regions of the country, and (3) draft conclusions and implications for the Louisiana Office of Coastal Protection and Restoration (OCPR).

The assessments and the report have three primary intended uses (1) help position OCPR leadership for advocating for greater system-wide planning and operations of ecological restoration. Such a model would account for the social and political realities that will help shape the future of science and engineering for restoration and protection, (2) complement organizational and institutional analyses and (3) inform subsequent meeting(s) and/or workshop(s) organized by others.

This report was based on two specific considerations:

- The assessment of technical and scientific functions and programs (based on Dr. Light's skills, experience, and knowledge of existing (e.g., CWPPRA, LCA) and future (e.g., CIAP, CPRA and LaCPR; WRDA, OCS) Coastal Louisiana programs).

- The analysis of challenges faced and lessons learned from comparable large-scale restoration programs and their applicability to Coastal Louisiana—addressing the need for integrative science through decisions pertaining to operations, planning, assessment, monitoring, and field-testing.

Report Outline

Technical and Scientific Criteria for Analyzing Coastal Programs and Function (Provides commentary, technical and scientific functions and programs, questions and design criteria for the following Process Components of the Adaptive Management Program):

- Adaptive Learning Phase
    - Inputs
        - Feedback policy
        - Subsystem monitoring

        - Hypotheses
    - Throughputs
        - Analytic inquiry
        - Modeling
        - Shared understanding
        - Systems monitoring (output)
- Adaptive Assessment Phase
    - Inputs
        - Modeling
    - Throughputs
        - Systems monitoring
        - Levels of monitoring
        - Integrated inquiry and synthesis
        - Options analysis
        - Systems level management and operations
        - Communication
    - Output
        - Policy formation
        - Field tests
        - Hypotheses
- Adaptive policy design phase
    - Inputs
        - New policy mandates
        - Communication
        - Systems operation and management
        - Options analysis
    - Throughputs
        - Policy formation
        - Policy action and experimentation
        - Implementation
        - Subsystem monitoring
    - Outputs
        - Feedback policy

This report also details a matrix incorporating material from the following examples of large-scale efforts in restoration or recovery:

- California Marine Life Coastal Protection Act
- Catskills Watershed Project – New York City Water Filtration Program
- Chesapeake Bay
- Columbia Basin Fish and Wildlife Authority
- Everglades
    - Experimental Water Deliveries
    - Kissimmee River Restoration
    - Comprehensive Everglades Restoration Plan
    - Lake Okeechobee Management
    - Nutrient Removal Project

- Glen Canyon Dam Experiment in sediment dynamics and recovery of indigenous fish
- Greater Yellowstone Ecosystem
- Klamath River
- Missouri River
    - Managers' Workshop March 2007
    - Report NRC Report 2002, Panel Member
- Northwest Colorado Range Management Plan
- Pacific Northwest Forest Plan
- Pinedale Anticline Resource Management Plan
- Red River of the North – case study funded by National Science Foundation.
- Sage Steppe Restoration Strategy, Alturas, CA
- Salton Sea Restoration
- State Natural Resource Departments
    - Minnesota Department of Natural Resources
    - Missouri Department of Conservation
- Upper Mississippi River – Adaptive Environmental Assessment of UMR funded by McKnight Foundation, The Northwest Area Foundation, Corps of Engineers and the State of Minnesota.
- Western Governors Conference and Western States Water Council Proceedings, October 10-12, 2007

Finally, the report provides conclusions and implications of the following technical and scientific issues:

- Legacy to Landscape - The Challenges and Fitting Responses
- Drilling Down – One Distinctive Value of the Adaptive Process
- From Engineering Planning to Adaptive Design
- Action as Inquiry
- Systems Level Operations and Management – New Function
- Adaptive Learning – Where one loop won't do!
- The Centrality of Hypotheses
- Effective Communication of Scientific Information
- Feedback Policy
- Institutional Memory
- Analytic vs. Integrative Inquiry
- Requisite Diversity and Functionality
- Options Analysis
- Monitoring
- Measuring Performance

Specific adaptive management tasks and products:

- Adaptive Management Report - Technical and Scientific Challenges for Responding to Large-Scale Ecological Restoration (Light 2008)

3. CONCLUSIONS

These products represent an initial effort to develop effective synthesis and communication tools of complex scientific and technical information to support the coastal ecosystem restoration and hurricane protection efforts in Louisiana. The Louisiana Coastal Protection and Restoration Authority (CPRA) Comprehensive Master Plan for a Sustainable Coast will need to continue such efforts and designate a library of key elements to represent knowledge of how the coastal landscape functions at both coast-wide and project-level scales. As mentioned in several documents associated with AEAM, large scale programs need to form a legacy so that knowledge moves forward in a comprehensive and strategic manner to support decision making. The CLEAR Volume IV CEM work provides important first steps in developing such synthesis and communication tools to support the newly formed Office of Coastal Protection and Restoration.

4. REFERENCES

CPRA. 2007. Integrated Ecosystem Restoration & Hurricane Protection: Louisiana's Comprehensive master Plan for a Sustainable Coast. Coastal Protection & Restoration Authority of Louisiana, Baton Rouge, LA.

Justic, D., E. Melancon, K. Rose, M. Schexnayder, R.R. Twilley, and J.M. Visser. 2008. Conceptual Model of Aquatic Primary Productivity in Barataria Basin, Louisiana, Appendix 4. In, Nuttle, W.K, F.H. Sklar, A.B. Owens, M. Inoue, D. Justic, W. Kim, E. Melancon, J. Pahl, D. Reed, K. Rose, M. Schexnayder, G. Steyer, J. Visser and R. Twilley. 2008. Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana, Chapter 7. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.

Kaiser, C. 2008. Visualization of Model Output: CLEAR MapServer & Google Maps API, Chapter 6. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.

Light, S.S. 2008. Technical and Scientific Challenges for Responding to Large-Scale Ecological Restoration, Chapter 8. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.

NRC. 2006. Drawing Louisiana’s New Map: Addressing Land Loss in Coastal Louisiana. Committee on the Restoration and Protection of Coastal Louisiana. National Research Council. The National Academic Press, Washington, D.C. pp 206.

Nuttle, W.K., D. Justic, and M. Inoue. 2008a. Conceptual Model of Residence Time in Barataria Basin, Louisiana, Appendix 3. In, Nuttle, W.K, F.H. Sklar, A.B. Owens, M. Inoue, D. Justic, W. Kim, E. Melancon, J. Pahl, D. Reed, K. Rose, M. Schexnayder, G. Steyer, J. Visser and R. Twilley. 2008. Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana, Chapter 7. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.

Nuttle, W.K., F.H. Sklar, A.B. Owens, M. Inoue, D. Justic, W. Kim, E. Melancon, J. Pahl, D. Reed, K. Rose, M. Schexnayder, G. Steyer, J. Visser and R. Twilley. 2008b. Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana, Chapter 7. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program:

A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.

Ogden, J.C, S.M. Davis, K.J. Jacobs, T. Barnes, and H.E. Fling. 2005. The use of conceptual ecological models to guide restoration in South Florida. Wetlands 25(4):795-809.

Reed, D.J. and W. Kim. 2008. Conceptual Model of Delta Building in Barataria Basin, Louisiana, Appendix 1. In, Nuttle, W.K, F.H. Sklar, A.B. Owens, M. Inoue, D. Justic, W. Kim, E. Melancon, J. Pahl, D. Reed, K. Rose, M. Schexnayder, G. Steyer, J. Visser and R. Twilley. 2008. Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana, Chapter 7. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.

Rose, K., E. Melancon, and M. Schexnayder. 2008. Conceptual Model of the Upper Trophic Group in Barataria Basin, Louisiana, Appendix 5. In, Nuttle, W.K, F.H. Sklar, A.B. Owens, M. Inoue, D. Justic, W. Kim, E. Melancon, J. Pahl, D. Reed, K. Rose, M. Schexnayder, G. Steyer, J. Visser and R. Twilley. 2008. Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana, Chapter 7. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.

Steyer, G.D., J.M. Visser, B. Good, J.M. Nestler, W. Nuttle, D. Reed, V. Rivera-Monroy, K.A. Rose, and R.R. Twilley. 2004. Adaptive Environmental Assessment and Management: A Draft Framework, Chapter 22. In, R.R. Twilley. (ed.), Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Model of Louisiana Coastal Area (LCA) Comprehensive Ecosystem Restoration Plan. Volume II: Tasks 9-15. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2511-02-24. 355 pp.

Steyer, G.D., J.M. Visser, J.W. Pahl and F.H. Sklar. 2008. Conceptual Model of Wetland Productivity in Barataria Basin, Louisiana, Appendix 2. In, Nuttle, W.K, F.H. Sklar, A.B. Owens, M. Inoue, D. Justic, W. Kim, E. Melancon, J. Pahl, D. Reed, K. Rose, M. Schexnayder, G. Steyer, J. Visser and R. Twilley. 2008. Conceptual Ecological Model for River Diversions into Barataria Basin, Louisiana, Chapter 7. In, R.R. Twilley (ed.), Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program: A tool to support coastal restoration. Volume IV. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2512-06-02.