Volume IV

APPENDIX I:

Adaptive Management and Monitoring Plan

Louisiana Coastal Area Program (LCA) Program: Small Diversion at Convent/Blind River Project Feasibility-Level Monitoring and Adaptive Management Plan

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Coastal Protection
and Restoration

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1.0 INTRODUCTION

This document outlines the feasibility-level monitoring and adaptive management plan for the Louisiana Coastal Area (LCA) Program: Small Diversion at Convent/Blind River project. The LCA Adaptive Management Framework Team developed this monitoring and adaptive management plan with assistance from the Project Delivery Team (PDT). This plan identifies and describes the monitoring and adaptive management activities proposed for the project and estimates their cost and duration. This plan will be further developed in the preconstruction, engineering, and design (PED) phase as specific design details are made available.

1.1 Authorization for Adaptive Management in the LCA Program

The LCA Ecosystem Restoration Study Chief's Report (2005) states (for the 15 near-term features aimed at addressing the critical restoration needs)

> *"…the feasibility level of detail decision documents will identify specific sites, scales, and adaptive management measures, and will optimize features and outputs necessary to achieve the restoration objectives…to ensure that LCA ecosystem restoration objectives are realized, monitoring and adaptive management must be a critical element of LCA projects."*

Section 7003(a) of Water Resources Development Act of 2007 (WRDA 2007) stipulates:

> "*The Secretary may carry out a program for ecosystem restoration, Louisiana Coastal Area, Louisiana, substantially in accordance with the report of the Chief of Engineers, dated January 31, 2005*."

Additionally, Section 2039 of WRDA 2007 directs the Secretary of the Army to ensure that, when conducting a feasibility study for a project (or component of a project) for ecosystem restoration, the recommended project includes a plan for monitoring the success of the ecosystem restoration. The implementation guidance for Section 2039, in the form of a CECW-PB Memo dated 31 August 2009, also requires that an adaptive management plan be developed for all ecosystem restoration projects.

At the programmatic level, knowledge gained from monitoring one project can be applied to other projects. Opportunities for this type of adaptive management are common for the projects within the LCA, Ecosystem Restoration Study (USACE 2004), which also builds upon lessons learned in other related efforts such as the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA). Oversight by the LCA Science and Technology (S&T) Program and the LCA Adaptive Management Planning Team provides the basic structure to ensure that knowledge gained is effectively shared across programs and projects.

1.2 Procedure for Drafting Adaptive Management Plans for LCA Projects

The U.S. Army Corps of Engineers, Mississippi Valley Division, New Orleans District (USACE MVN), Louisiana Office of Coastal Protection and Restoration (OCPR), and the LCA S&T Program collaborated to establish a general framework for adaptive management to be applied to all LCA projects. The framework for adaptive management is consistent with the previously mentioned implementation guidance, as well as with the guidance provided by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration's (NOAA) "Availability of a Final Addendum to the Handbook for Habitat Conservation Planning and Incidental Take Permitting Process" in Federal Register vol. 65, No. 106 35242. The LCA adaptive management framework includes both a set-up phase (Figure 1) and an implementation phase (Figure 2).

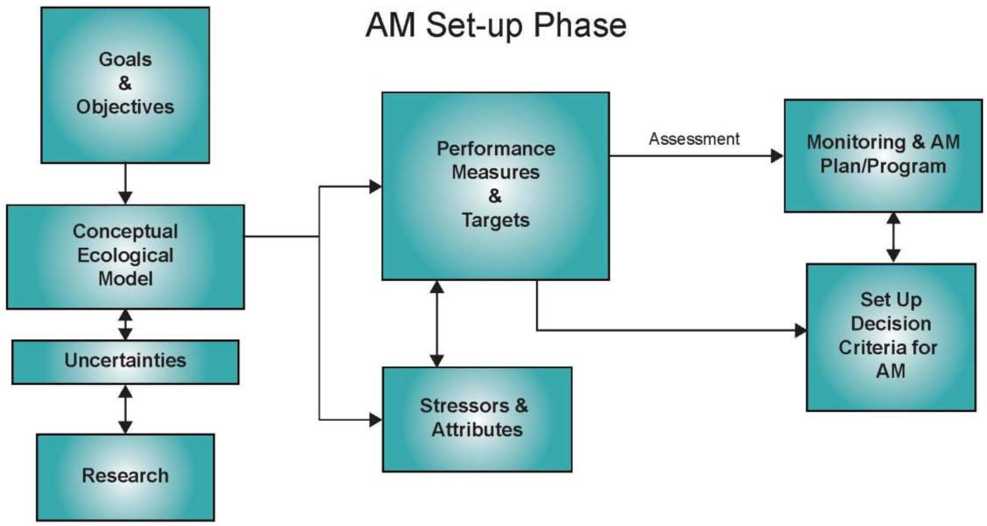

Figure 1. Set-up Phase of the LCA Adaptive Management Framework.

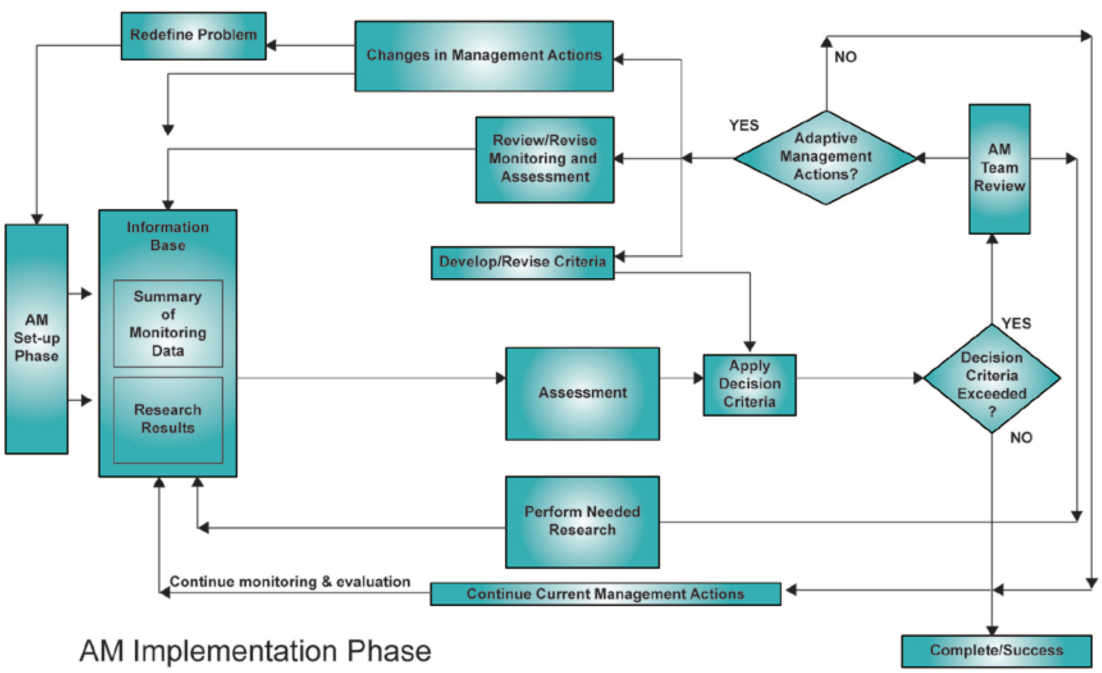

Figure 2. Implementation Phase of the LCA Adaptive Management Framework.

1.3 LCA Communication Structure for Implementation of Adaptive Management

To execute an adaptive management strategy for the LCA Ecosystem Restoration Plan, a communication structure has been identified (Figure 3). The structure establishes clear lines of communication between LCA Program Management, an Adaptive Management Planning Team, the S&T Program, PDTs, and stakeholders. Successful implementation will require the right resources being coupled at the right time to support the framework components.

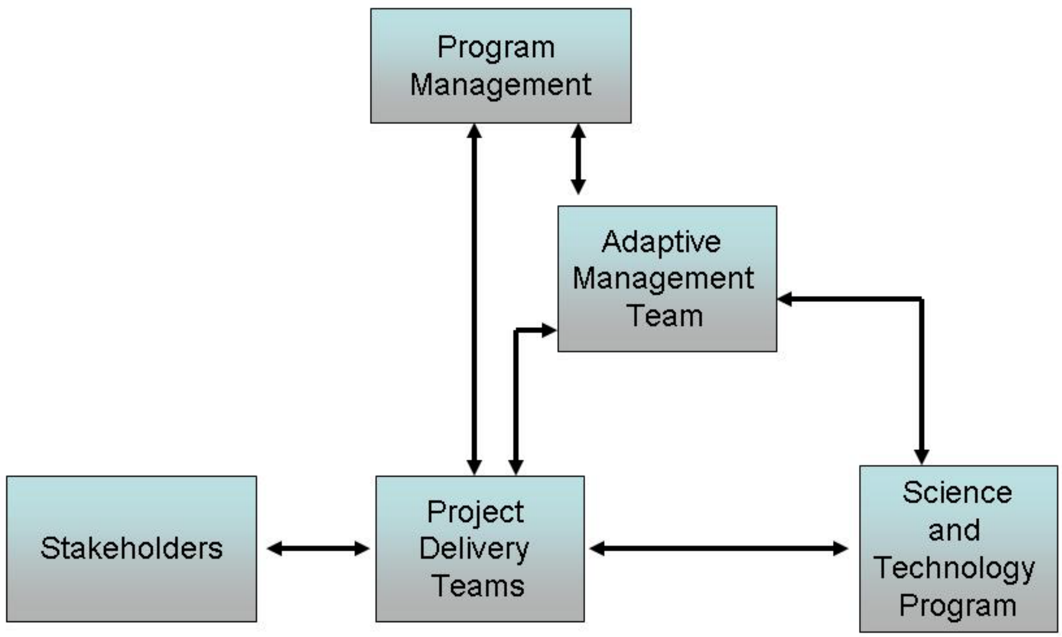

Figure 3. LCA Communication Structure for Implementation of Adaptive Management.

As part of the LCA Program communication structure for implementation of adaptive management (Figure 3), an LCA Adaptive Management Planning Team will be established. This team will be led jointly by a Senior Planner from the USACE and a counterpart from the OCPR. Other team members include USACE and State support staff and representatives from USFWS, NOAA, Natural Resources Conservation Service (NRCS), and Louisiana Department of Wildlife and Fisheries (LDWF). These members will be selected on the basis of their knowledge of ecosystem restoration, coastal Louisiana ecosystems and adaptive management. Other resources and expertise will be brought in as needed. This team will be responsible for recommending project and program adaptive management actions to the LCA Management Team.

The LCA Science and Technology (S&T) Office was established by the USACE and the State of Louisiana (the non-Federal sponsor) to effectively address coastal ecosystem restoration needs and to provide a strategy, organizational structure, and process to facilitate integration of science and technology into the adaptive management process. Under the Adaptive Management Framework, there are five primary elements in the LCA S&T Program, and each element differs in emphasis and requirements. These elements include: (1) science information needs, (2) data acquisition and monitoring, (3) modeling, (4) research, and (5) data management and reporting (assessment).

Under the LCA S&T Program, an Assessment Team will be established. This team will be led by the S&T Director and a representative of the U.S. Geological Survey (USGS) who will also serve as direct liaisons between the S&T Assessment Team and the LCA Adaptive Management Planning Team. Other members will be identified from Federal and State agencies. Responsibilities of this team include analysis and reporting of data to the LCA Adaptive Management Planning Team and the LCA Program Management Team.

2.0 PROJECT ADAPTIVE MANAGEMENT PLANNING

Specific LCA PDTs assisted the LCA Adaptive Management Framework Team in developing the monitoring and adaptive management plan for each specific project. The members of the Adaptive Management Framework Team for this project were Tomma Barnes, USACE-MVN; Steve Bartell, E2 Consulting Engineers; Laura Brandt, USFWS; Craig Fischenich, USACE/Engineer Research and Development Center; Barbara Kleiss, USACE Mississippi Valley Division; Carol Parsons Richards, OCPR; Greg Steyer, USGS National Wetlands Research Center; and John Troutman, OCPR.

The resulting adaptive management plan for the Small Diversion at Convent/Blind River project describes and justifies whether adaptive management is needed in relation to the tentatively selected plan (TSP) identified in the Feasibility Study. The plan also identifies how adaptive management would be conducted for the project and who would be responsible for this project-specific adaptive management program. The developed plan outlines how the results of the project-specific monitoring program would be used to adaptively manage the project, including specification of conditions that would demonstrate project success and terminate the adaptive management program.

The Adaptive Management Plan for this project reflects a level of detail consistent with the project Feasibility Study. The primary intent was to develop monitoring and adaptive management actions appropriate for the project's restoration goals and objectives. The specified management actions permit estimation of the adaptive management program costs and duration for the project.

The following adaptive management plan section (1) identifies the restoration goals and objectives identified for the Small Diversion at Convent/Blind River project, (2) outlines management actions that can be undertaken to achieve the project goals and objectives, (3) presents a conceptual ecological model that relates management actions to desired project outcomes, and (4) lists sources of uncertainty that would recommend the use of adaptive management for this project. Subsequent sections describe monitoring, assessment, decision-making, and data management in support of adaptive management.

The level of detail in this plan is based on currently available data and information developed during plan formulation as part of the feasibility study. Uncertainties remain concerning the exact project features, monitoring elements, and adaptive management opportunities. Components of the monitoring and adaptive management plan, including costs, were similarly estimated using currently available information. Uncertainties will be addressed in the preconstruction, engineering, and design (PED) phase, and a detailed monitoring and adaptive management plan, including a detailed cost breakdown, will be drafted as a component of the design document.

2.1 Project Goals and Objectives

During initial stages of project development, the PDT, with stakeholder input, developed restoration goals and objectives to be achieved by the Small Diversion at Convent/Blind River project. These goal and objectives were subsequently refined through interactions with the LCA Adaptive Management Framework Team. The overarching goal of this project is to stop the continuing degradation in the southeastern portion of the Maurepas Swamp and restore coastal wetlands in the project area. This project has been planned to help achieve and sustain a larger-scale coastal ecosystem that can support and protect the environment, economy, and culture of southern Louisiana and thereby contribute to the well-being of the Nation. The specific restoration objectives of the Small Diversion at Convent/Blind River project are to:

- Promote water distribution in the southeastern portion of the Maurepas Swamp to move stagnant water out of the system.
- Facilitate swamp building, at a rate greater than swamp loss due to subsidence and sea level rise, by increasing sediment input and swamp production to maintain or increase elevation in the swamp.
- Increase the durations of dry periods in the swamp to improve baldcypress and tupelo productivity and to increase seed germination and survival of these key species.
- Improve fish and wildlife habitat in the swamp and in Blind River.

2.2 Management and Restoration Actions

The PDT performed a thorough plan formulation process to identify potential management measures and restoration actions that address the project objectives. Many alternatives were considered, evaluated, and screened in producing a final array of alternatives. The PDT subsequently identified a tentatively selected plan (TSP).

The TSP is Alternative Two (2), which is a 3,000 cubic feet per second (cfs) diversion located at Romeville, Louisiana. The proposed diversion structure includes the following features: inlet screens, three 11’ by 10’ culverts, a crossing at Highway 44, and a dissipation structure. The transmission canal is an earthen trapezoid with a water depth of approximately 10 feet, with raised berms along its banks. The canal will cross one railroad and one road. At each crossing, there will be a maximum of four features, each with three 4’x6’ culverts, for a combined maximum total of 24 culverts. The drainage channel control structures consist of six concrete structures with downward opening weir gates. There are thirty (30) berm gaps, each approximately 500 feet wide.

2.3 Conceptual Ecological Model for Monitoring and Adaptive Management

As part of the planning process, members of the Small Diversion at Convent/Blind River project PDT developed a conceptual ecological model for the swamp ecosystem in the project area to represent current understanding of ecosystem structure and function in the project area, identify performance measures, and help select parameters for monitoring (Annex 1). The model illustrates the effects of important natural and anthropogenic activities that result in different ecological stressors on the system. The effects of concern can be measured for selected performance measures defined as specific physical, chemical, and biological attributes of the system.

2.4 Sources of Uncertainty

A fundamental tenet underlying adaptive management is decision-making under uncertainty. There are many uncertainties associated with restoration of the swamp ecosystems included in the Small Diversion at Convent/Blind River project. These uncertainties can be conveniently categorized as follows:

Swamp water, sediment, and nutrient requirements

- Magnitude and duration of inundation
- Magnitude and duration of dry conditions
- Annual sediment requirements
- Nutrients required for desired productivity

Current local runoff water quantities and quality

- Distribution of flow by time and quantity
- Water quality based on permitted discharges
- Flow path through channels and swamp

Mississippi River water quantities and quality

- Available river stage to produce desired flows
- Concentrations of sediment and nutrients for diversion

Swamp responses from application of water, sediment, and nutrients

- Growth curves based on hydroperiod and nutrient application
- Litter production based on nutrient and water levels
- Tree propagation in relation to regulated hydroperiod.

Subsidence, salinity, and water level trends

- Subsidence rates (+/-) throughout the project life
- Water level trends (+/-) throughout the project life
- Variable and extreme salinities that negatively impact vegetation

Potential climate change issues, such as sea level rise, in addition to regional subsidence rates are significant scientific uncertainties for all LCA projects. These issues were incorporated in the plan formulation process (Appendix L Engineering, Chapter 2 Coastal Processes) and will be monitored by gathering data on water levels, salinities, and land elevation (see section 4.2.1). These data will inform adaptive management actions.

3.0 RATIONALE FOR ADAPTIVE MANAGEMENT

The primary incentive for implementing an adaptive management program is to increase the likelihood of achieving desired project outcomes given the identified uncertainties. All projects face uncertainties with the principal sources of uncertainty including (1) incomplete description and understanding of relevant ecosystem structure and function, (2) imprecise relationships between project management actions and corresponding outcomes, (3) engineering challenges in implementing project alternatives, and (4) ambiguous management and decision-making processes.

Given these uncertainties, adaptive management provides an organized, coherent, and documented process that suggests management actions in relation to measured project performance compared to desired project outcomes. In the case of the Small Diversion at Convent/Blind River project, the adaptive management program will use the results of continued project monitoring to manage the project in order to achieve the previously stated project goals and objectives. Adaptive management establishes the critical feedback of information from project monitoring to inform project management and promote learning through reduced uncertainty.

Several questions were considered to determine if adaptive management should be applied to the Small Diversion at Convent/Blind River project:

1) Are the ecosystems to be restored sufficiently understood in terms of hydrology and ecology, and can project outcomes be accurately predicted given recognized natural and anthropogenic stressors?

2) Can the most effective project design and operation to achieve project goals and objectives be readily identified?

3) Are the measures of this restoration project's performance well understood and agreed upon by all parties?

4) Can project management actions be adjusted in relation to monitoring results?

A 'NO' answer to questions 1-3 and a "YES" answer to question 4 identifies the project as a candidate that could benefit from adaptive management. The Framework Team and the PDT decided that the project meets these qualifications, and therefore is a candidate for adaptive management.

For the Small Diversion at Convent/Blind River project, there are a number of uncertainties associated with ecosystem needs and how the ecosystem will respond to the restoration project. In addition, there are associated uncertainties about the best design and operation for the project. Using an adaptive management approach during project planning provided a mechanism for building flexibility into project design and for providing new knowledge to better define anticipated ecological responses. This also enabled better selection of appropriate design and operating scenarios to meet the project objectives. Additionally, an adaptive management approach will help define project success and identify outcomes that should realistically be expected for the project.

3.1 Adaptive Management Program for the Small Diversion at Convent/Blind River Project

An Adaptive Management Program for the Small Diversion at Convent/Blind River project is needed to ensure proper implementation of adaptive management. The Program will also facilitate coordination of projects within the LCA Program and coordination among PDTs, the LCA S&T, and LCA Program Management. The LCA Adaptive Management Planning Team will lead all LCA project and program adaptive management recommendations and actions. This team is responsible for ensuring that monitoring data and assessments are properly used in the adaptive management decision-making process. If this team determines that adaptive management actions are needed, the team will coordinate a path forward with project planners and project managers. Other PDT members may be solicited as needed; for instance, if the adaptive management measure is operational, operations and hydraulics representatives will be asked to participate.

The LCA Adaptive Management Planning Team is also responsible for project documentation, reporting, and external communication. Table 2 lists the cost estimates for these adaptive management activities.

4.0 MONITORING

Independent of adaptive management, an effective monitoring program will be required to determine if the project outcomes are consistent with original project goals and objectives. The power of a monitoring program developed to support adaptive management lies in the establishment of feedback between continued project monitoring and corresponding project management. A carefully designed monitoring program is central to the project's adaptive management program.

4.1 Rationale for Monitoring

Monitoring must be closely integrated with all other LCA adaptive management components because it is the key to the evaluation and learning components of adaptive management. Project and system level objectives must be identified to determine appropriate indicators to monitor. In order to be effective, monitoring designs must be able to discern ecosystem responses caused by project implementation (i.e., management actions) from natural variability. In coastal Louisiana, there are many existing restoration and protection projects already constructed, and many more are planned under different authorizations and programs. In combination, these projects will ultimately influence much of coastal Louisiana. Monitoring must therefore be conducted at project and system-wide scales to evaluate long-term, large-scale status and trends and short-term performance.

Achieving monitoring objectives will require monitoring that focuses on different spatial and temporal scales. Spatially, a project might achieve local objectives, but have little or no measurable effect at larger scales. Temporally, monitoring designs need to consider the amount of time it could take for slowly changing ecological variables to respond to management actions. Additionally, monitoring should be designed to measure the persistence of near-term effects. Larger-scale effects will generally take longer to develop and longer to detect than more localized effects.

Monitoring for large-scale effects can be more difficult than for local effects because the ecological linkages become more complicated as factors outside project boundaries influence processes and biota that affect desired project outcomes. The benefits of improved habitat in one location may be counteracted by degradation at another location, thus showing no overall benefit at large scales. In addition, monitoring at large scales can involve changes in underlying conditions over time or space and be very labor intensive. When possible, specific monitoring and large-scale information needs should be interrelated. In some cases, large-scale monitoring may be just an extension of local monitoring in space and time, but it may also involve designs and procedures that are separate from site-specific monitoring and extend beyond the purview of the project teams.

When possible, specific monitoring and large scale information needs should be integrated with monitoring efforts that are underway in coastal Louisiana. The CWPPRA program has been monitoring restoration and protection projects in coastal Louisiana since 1990 (Steyer and

Stewart 1992, Steyer et al. 1995). The monitoring program incorporates a system-level wetland assessment component called the Coastwide Reference Monitoring System (CRMS-Wetlands, Steyer et al. 2003). CRMS-Wetlands provides system-wide performance measures that are evaluated to help determine the cumulative effects of restoration and protection projects in coastal Louisiana. LCA monitoring plans should benefit from existing monitoring networks to the extent practicable and participate in the implementation of CRMS-Wetlands. Such participation can maintain the data consistencies necessary to conduct project and programmatic adaptive management.

4.2 Monitoring Plan for the Small Diversion at Convent/Blind River Project

According to the CECW-PB Memo dated 31 August 2009, "Monitoring includes the systemic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits." The following discussion outlines key components of a monitoring plan that will support the LCA Small Diversion at Convent/Blind River project Adaptive Management Program.

The plan identifies performance measures along with desired outcomes (i.e. targets) in relation to specific project goals and objectives. A performance measure includes specific feature(s) to be monitored to determine project performance. In addition, if applicable, a risk endpoint was identified. Risk endpoints measure undesirable outcomes of a management or restoration action. A monitoring design was established to determine if the desired outcome or risk endpoint is met.

Upon completion of the Small Diversion at Convent/Blind River project, monitoring for ecological success will be initiated and will continue until ecological success is achieved, as defined by the project-specific objectives. This monitoring plan includes the minimum monitoring actions to evaluate success. Although the law allows for a ten-year cost-shared monitoring plan, ten years of monitoring may not be required. Once ecological success has been achieved, which may occur in less than ten years post-construction, no further monitoring will be performed. If success cannot be determined within that ten-year period of monitoring, any additional monitoring will be a non-Federal responsibility. This plan estimated monitoring costs for a period of ten years because that is the maximum allowed federal contribution to monitoring. As soon as ecological success is achieved, monitoring will cease.

Additional monitoring is identified as supporting information needs that will help to further understand and corroborate project effects.

Objective 1: Promote water distribution in the southeast portion of the Maurepas Swamp to move stagnant water out of the system.

Performance Measure 1: Freshwater distribution during operational events

Desired Outcome: Increase hydrologic connectivity and area of extent of freshwater movement into the project area above pre-project conditions.

Monitoring Design: Synoptic hydrologic surveys, using salinity, temperature, dissolved oxygen, conductivity, turbidity, pH, and velocity as tracers, will be conducted during selected low flow and high flow operational events to track distribution of freshwater.

<u>Objective 2:</u> Facilitate swamp building, at a rate greater than swamp loss to subsidence and sea level rise, by increasing sediment input and swamp production to maintain or increase elevation in the swamp.

Performance Measure 2a: Sediment accretion and elevation

Desired Outcome: Accretion rate equals or exceeds subsidence rate after five years.

Monitoring Design: Sediment erosion tables (SETs) will serve as an elevation benchmark and marker horizons or sediment traps will be used to assess accretion.

Supporting Information Need: Total suspended sediment (TSS) will be collected to help understand how sediment contributions through the diversion may enhance swamp productivity and land building.

Performance Measure 2b: Swamp production and extent

Desired Outcome: A statistically significant increase in basal area increment of baldcypress and tupelo in the swamp from existing conditions, that is, existing conditions defined from pre-construction measurements from CRMS-Wetlands stations and Southeastern Louisiana University historic monitoring.

Monitoring Design: Diameter at breast height (dbh) and overstory tree cover will be measured to estimate production.

Performance Measure 2c: Annual sediment discharge

Desired Outcome: Deliver 86,480 M tons of sediment through the Convent/Blind River diversion each year.

Monitoring Design: Hourly turbidity recorders will be deployed in the outfall channel and at hydrologic sites and correlated to TSS to investigate this measure.

<u>Objective 3:</u> Establish hydroperiod fluctuation in the swamp to improve baldcypress and tupelo productivity and their seed germination and survival, by increasing the length of dry periods in the swamp.

Performance Measure 3a: Depth, duration, and frequency of flooding in the swamp

Desired Outcome: A statistically significant decrease from pre-project condition average flood durations (existing conditions defined from pre-construction measurements from CRMS stations). The project will be operated to facilitate dry periods. These dry periods should be targeted every year if possible.

Desired Outcome: Maintain dry periods (moist soils) in the swamp for a minimum 7-35 days during summer and early fall for seed germination and maintain water levels below seedling height to promote seedling survival.

Monitoring Design: Hourly hydrologic recorders will be deployed to investigate this measure.

Performance Measure 3b: Number of baldcypress and tupelo seedlings and saplings

Desired Outcome: A 25% increase in the number of baldcypress and tupelo saplings per acre from pre-project conditions five years after project implementation and 50% increase after 10 years. Performance of this measure is most dependent on achieving extended dry periods in the swamp.

Monitoring Design: Understory vegetation will be measured to determine numbers of baldcypress seedlings and saplings in order to assess regeneration. Herbaceous vegetation will also be measured to determine changes in cover classes.

<u>Objective 4.</u> Improve fish and wildlife habitat in the swamp and in Blind River.

Performance Measure: No applicable performance measure

Desired Outcome: Swamp production, hydroperiod, and water quality measures will be used to assess this objective.

Monitoring Design: Fish and wildlife habitat is linked to the performance measures associated with objectives 1-3, focused on improving habitat. Therefore, no specific monitoring is proposed for this objective.

Risk Endpoint: Water quality impairment in Blind River and Lake Maurepas

Desired Outcome: Do not create or contribute to nitrate loading in Blind River that will result in a Louisiana 303 (d) listing. If listed, a total maximum daily load (TMDL) assessment will be considered in coordination with Louisiana Department of Environmental Quality (DEQ).

Monitoring Design: Nutrient sampling will be designed in coordination with DEQ, if needed.

4.2.1 Monitoring Procedures

The following monitoring procedures will provide the information necessary to evaluate the previously identified project-specific objectives for the Small Diversion at Convent/Blind River project:

Vegetation: Swamp production and regeneration will be assessed at 5 locations within the project area and 3 reference locations annually. Retention and/or increase of overstory tree cover (objective 2) from pre-project levels will be determined using a spherical densiometer and hemispherical photography techniques as described in the CRMS-Wetlands standard operating procedures manual (Folse et al. 2008). Densiometer readings and hemispherical photographs will be taken within sampling plots at fixed time intervals. In order to track the growth of trees within the project and reference areas, especially baldcypress and tupelo, all trees (i.e., ≥ 5 cm dbh) within each sampling plot will be identified to species level, tagged with a numbered aluminum tree tag, and the diameter measured at 4.5 ft above the ground (Folse et al. 2008 and references therein). The dbh of all tagged trees will be measured annually at which time both "new" trees (i.e., grew to ≥ 5 cm dbh from previous sampling time) and dead trees will also be identified. The dbh data will be used to calculate basal area increment (BAI) which will provide estimates of primary productivity (Megonigal et al. 1997). BAI is the difference in basal area (calculated from dbh) of individual trees between sampling times. The understory (i.e., < 5 cm dbh and 50 cm – 137 cm tall) and herbaceous (i.e., < 5 cm dbh and < 50 cm tall) will be sampled according to Folse et al. (2008) to determine if baldcypress and tupelo are regenerating.

Hydrology: Continuous stage, velocity, turbidity, pH, conductivity, salinity, and dissolved oxygen measurements will be conducted at 1 Mississippi River outfall location and 5 locations on Blind River where TSS and other water quality parameters are collected. To determine whether the hydrology in the project area is being restored and maintained to that of a natural swamp, water level, salinity, temperature, turbidity pH, conductivity, and dissolved oxygen within the swamp will be measured hourly with datasondes at 5 locations within the project area and at 3 reference locations. Each water level gauge will be surveyed relative to the top of the rod-surface elevation table (RSET) (NAVD88) and will be serviced approximately 9 times per year. Duration and frequency of flooding will be calculated using water levels and the average elevation of the wetland surface. During selected operational events, synoptic hydrologic surveys will be conducted to track distribution of freshwater. Returning the hydroperiod of the project area to that of a typical swamp is essential to decreasing the mortality rate of baldcypress and tupelo trees and increasing biomass and regeneration of these species.

Sediment Input: Sediments introduced into the project area from the Mississippi River are expected to contribute to soil building and thus a net surface elevation increase or stabilization. Water discharge through the diversion structure will be monitored hourly with an acoustic Doppler current meter (ADCM). Hourly turbidity measurements will be measured with a logging optical backscatter nephlometric turbidity sensor, which will be field serviced and calibrated each month. During each field servicing event, a depth-integrated water sample will be taken from the outfall channel, and the sample will be analyzed for total suspended solids (TSS) by filtering 100-250 mL of each sample through pre-rinsed, pre-ashed, pre-weighed 47mm GF/F microfiber filters. Filters will be dried for 24 hours at 105° C, then combusted for 1 hour at 550° C and weighed following Standard Methods (1992). Thus, the inorganic fraction of TSS will be used as the metric for suspended solids in diverted river water. Linear regression will be used to estimate the relationship between turbidity and TSS, and hourly turbidity data will then be used to obtain hourly TSS values. Instantaneous sediment flux through the diversion structure $flux_{sed}$ will be calculated as

$$flux_{sed} = q_{div} \times tss$$

where q_{div} and tss are the volume discharge and suspended sediment concentrations in the outfall channel, respectively. Total sediment delivery Q over the time interval $0 - T$ will be determined as

$$Q = \int_0^T flux_{sed} dt$$

where t is time.

Distribution of diverted sediments through the project area will be assessed by collection of hourly turbidity time series at each hydrologic monitoring site (above) by affixing an optical backscatter nephlometric turbidity sensor to each water quality sonde. Water samples will be collected during monthly servicing of the sensors, and these samples will be analyzed for TSS and used to calibrate the turbidity sensors to TSS.

Sediment Accretion and Elevation: Sediment accretion and elevation will be assessed at 5 locations within the project area and 3 reference locations one to two times per year during dry periods. Sediment elevation within the project area will be measured over time by using the RSET technique which is described in Folse et al. (2008) and references therein. The RSET allows for precise, repeated measurements of the soil elevation. Marker horizons consisting of feldspar clay or crawfish pans will be used to determine vertical accretion/loss within the project area (Folse et al. 2008). If no persistent dry periods occur or sediments are too flocculant for accurate measurements from RSET or feldspar clay/crawfish pans, the top of the RSET rod will be surveyed every 3 years to estimate subsidence rate. Maintenance of elevation should help regulate flooding stress, contributing to decreased tree mortality rates and increased biomass production and regeneration.

Water Quality: Measuring and monitoring various water quality parameters, including salinity, conductivity, pH, nutrients, and TSS will dictate whether inputs from the Mississippi River are impacting water quality in the project area. Monitoring these parameters will document the quality of the diverted water and address risk endpoint concerns. To determine if these inputs are flushing saline waters from the project area, the concentration of salt in swamp water will be measured hourly at hydrology locations and discretely by using a porewater sipper device when sondes are serviced (Folse et al. 2008). Nutrients (Total Nitrogen [TN], Ammonia, Nitrate+Nitrite, Total Phosphorous [TP]) will be measured every two months at the one Mississippi River outfall location and five TSS locations on Blind River and at 8 hydrologic monitoring sites according to methods described in Day et al. (2001) to determine if input from the Mississippi River is contributing to increased nutrient loads. Duration of this sampling schedule will be dependent upon final project design and operations. Water samples will be collected in 500 mL acid-washed polyethylene bottles, stored on ice and taken to laboratory for processing. Within 24 hrs, 60 mL from each water sample will be filtered through pre-rinsed 25 mm 0.45 µm Millipore filters. Samples and filters will be frozen until analyzed within one month of collection. Nitrate and nitrite will be determined separately using automated cadmium reduction method, ammonium by automated phenate method and phosphate by automated ascorbic acid reduction method (Standard Methods 1992).

4.2.2 Use of Monitoring Results and Analyses

Project monitoring is the responsibility of the OCPR and the USACE. However, because of the need to integrate monitoring for programmatic adaptive management, extensive agency coordination is required. A monitoring workgroup, led by the LCA S&T Program and the USGS, will be responsible for ensuring that project-specific monitoring plans are technically competent and appropriately integrated within a system-wide assessment and monitoring plan (SWAMP).

The results of the monitoring program will be communicated to an Assessment Team that will use the information to assess system responses to management, evaluate overall project performance, and construct project report cards. Recommended modifications (i.e., adaptation) of the Small Diversion at Convent/Blind River project will be provided as appropriate.

5.0 DATABASE MANAGEMENT

Database management is an important component of the monitoring plan and the overall adaptive management program. Data collected as part of the monitoring and adaptive management plans for the LCA projects will be archived as prescribed in the "LCA Data Management Strategic Plan" developed for the LCA S&T Office, and further developed by the LCA S&T Data Management Working Group.

Data standards, quality assurance, and quality control procedures and metadata standards will be prescribed by the LCA S&T Data Management Working Group. Data collected for LCA with similar data types and collection frequencies as those data collected under the CRMS program will be managed by the Louisiana Strategic Online Natural Resources Information System (SONRIS). Pre-existing standard operating procedures built for SONRIS cover issues such as data upload process and format, quality assurance/quality control, and public data release. Storage of all other LCA collected data (spatial or non-spatial) will be handled by the LCA project-specific data libraries on LCA.GOV.

Where applicable, Open Geospatial Consortium standards will be used to facilitate data sharing among interested parties. Data analysis and reporting responsibilities will be shared between project assessment and adaptive management efforts in order to provide Small Diversion at Convent/Blind River project reports for the LCA Program Management Team.

5.1 Description and Location

The data management plan should identify the computing hardware and any specialized or custom software used in data management for an adaptive management program. Opportunities exist to develop either a centralized or distributed data management system. The data managers, with input from the Adaptive Management Planning Team, should determine which approach best suits the needs of the overall adaptive management program.

Individuals with responsibility for data management activities (data managers) in support of an adaptive management program should be identified. The data managers should collaborate with the Adaptive Management Planning Team in developing a data management plan to support the adaptive management program. The data management plan should be incorporated into the overall program adaptive management plan – either in the main body of the adaptive management plan or as an appendix.

5.2 Data Storage and Retrieval

Data standards, quality assurance and quality control procedures and metadata standards will be prescribed by the Data Management Working Group, and will be complementary with the CRMS-Wetlands program and SONRIS database. Data will be served using a map services tool, similar to that currently employed by the CRMS-Wetlands project.

5.3 Analysis, Summarization, and Reporting

Data analysis and reporting responsibilities will be shared between project and programmatic adaptive management efforts in order to provide reports for the Small Diversion at Convent/Blind River project Assessment Team, project managers, and decision-makers.

6.0 ASSESSMENT

The assessment phase of the framework describes the process by which the results of the monitoring efforts will be compared to the desired project performance measures and/or acceptable risk endpoints (i.e., decision criteria) that reflect the goals and objectives of the management or restoration action. The assessment process addresses the frequency and timing for comparison of monitoring results to the selected measures and endpoints. The nature and format (e.g., qualitative, quantitative) of these comparisons are defined as part of this phase. The resulting methods for assessment should be documented as part of the overall adaptive management plan.

The results of the Small Diversion at Convent/Blind River project monitoring program will be regularly assessed in relation to the desired project outcomes as described by the previously specified project performance measures. This assessment process continually measures the progress of the project in relation to the stated project goals and objectives and is critical to the project adaptive management program. The assessments will continue through the life of the project or until it is decided that the project has successfully achieved its goals and objectives.

6.1 Assessment Process

The Assessment Team assigned to the Small Diversion at Convent/Blind River project will identify a combination of qualitative (i.e., professional judgment) and quantitative methods for comparing the values of the performance measures produced by monitoring with the selected values of these measures that define criteria for evaluating project effectiveness.

The appropriate statistical comparisons (e.g., hypothesis testing, ANOVA, multivariate methods, etc.) will be used to summarize monitoring data as they are obtained and compare these data summaries with the project decision criteria. These continued assessments will be documented as part of the project reporting and data management system.

6.2 Variances and Success

The project Assessment Team will collaborate with project managers and decision-makers to define magnitudes of difference (e.g., statistical differences, significance levels) between the values of monitored performance measures and the desired values (i.e., decision criteria) that will constitute variances. Meaningful comparisons between monitoring results and desired performance will require characterization of historical and current spatial-temporal variability that define baseline conditions. Variances (or their absence) will be used to recommend adaptive management actions, including (1) continuation of the project without modification, (2) modification of the project within original design specifications, (3) development of new alternatives, or (4) termination of operation of the Convent/Blind River diversion structure.

Conceptual models have been developed for each project describing the linkages between stressors and performance measures. The assessments will help determine if the observed responses are linked to the project. Each project has been formulated to address as many system stressors as feasible. If the stressors targeted by the project have changed and the performance measure has not, the linkages in the conceptual model should be examined to determine what other factors may be influencing the performance measure response.

The assessments will also determine if the responses are undesirable (e.g., are moving away from restoration goals) and if the responses have met the success criteria for the project. If performance measures are not responding as desired because the stressor has not changed enough in the desired direction, then recommendations should be made concerning modifications to the project. If the stressor has changed as expected/desired and the performance measure has not, additional research may be necessary to understand why.

From a system-wide perspective, scientific and technical information would be generated from the implementation of a system–wide monitoring effort. Information generated from this effort should be linked to evaluation LCA performance and system response. From a project-level perspective, monitoring plans should be designed to inform adaptive management decision-making by providing monitoring data that are relevant to addressing uncertainty.

Similarly, for multiple performance measures and corresponding monitoring results, the Assessment Team will determine the number and magnitude of variances within a single assessment that will be required to recommend modifications to the project.

6.3 Frequency of Assessments

Ideally, the frequency of assessments for the Small Diversion at Convent/Blind River project would be determined by the relevant ecological scales of each performance measure. The project's technical support staff will identify for each performance measure the appropriate timescale for assessment. The project should have a combination of short-, medium-, and long-term performance measures. Assessments should be performed at a five year interval at a minimum; however, depending on the timescale of expected responses of the specific measure and frequency of data collection, it may be determined during PED that more frequent reporting may be necessary.

6.4 Documentation and Reporting

The Assessment Team will document each of the performed assessments and communicate the results of its deliberations to the managers and decision-makers designated for the Small Diversion at Convent/Blind River project. The Assessment Team will work with the project monitoring team and monitoring workgroup to produce periodic reports that will measure progress towards project goals and objectives as characterized by the selected performance measures. The results of the assessments will be communicated regularly to the project managers and decision-makers.

7.0 DECISION-MAKING

Adaptive management is distinguished from more traditional monitoring, in part, through implementation of an organized, coherent, and documented decision process. For the Small Diversion at Convent/Blind River project Adaptive Management Program, the decision process includes (1) anticipation of the kinds of management decisions that are possible within the original project design, (2) specification of values of performance measures that will be used as decision criteria, (3) establishment of a consensus approach to decision-making, and (4) a mechanism to document, report, and archive decisions made during the timeframe of the Adaptive Management Program.

7.1 Decision Criteria

Decision criteria, also referred to as adaptive management triggers, are used to determine if and when adaptive management opportunities should be implemented. These criteria are usually ranges of expected and/or desirable outcomes. They can be qualitative or quantitative based on the nature of the performance measure and the level of information necessary to make a decision. Desired outcomes can be based on reference sites, predicted values, or comparison to historic conditions. Several potential decision criteria are identified below, based on the project objectives and performance measures.

<u>Swamp water, sediment, and nutrient requirements</u>:

- Desired inundation patterns are not met and there is less than a 10% increase in duration of dry periods in the swamp
- Insufficient nutrient uptake in the swamp contributes to excess TMDLs for TN and TP in Blind River
- Insufficient sediment input leads to no net increase; therefore, the subsidence rate cannot be reversed

To meaningfully manage these parameters, hydraulic models would need to be revisited and recalibrated based on field data and observations prior to change in management of a diversion and/or in swamp structures.

Current local runoff water quantities and quality

- Local drainage upgrades and surrounding area development contribute lesser/greater flow than was anticipated
- Water quality impacts from local drainage

To change water budget and water quality, coordination with the local public works/drainage operators would be required.

Swamp responses from application of water, sediment, and nutrients

- Less than 25% increase in baldcypress/tupelo sapling numbers
- Habitat switching from swamp to marsh or open water habitat
- Fish kills

To manage these outcomes, hydraulic models may need to be revisited and recalibrated based on field data and observations prior to change in management of a diversion and/or in swamp structures. Additional modeling or experimental efforts might be required to understand and manage observed biotic responses.

7.2 Potential Adaptive Management Measures

The project report card, drafted by the Assessment Team, will be used to evaluate project status and adaptive management needs. The Assessment Team may submit recommendations for adaptive management actions to the Adaptive Management Planning Team. The Adaptive Management Planning Team will investigate and further refine adaptive management recommendations and present them to the Program Management Team. Some potential adaptive management actions for this project may include modifying the operation of the diversion structure or modifying operation of outfall management features and to allow operational flexibility, such as pulsing, based on monitoring results. The monitoring and assessment teams should continue to evaluate operations to maximize benefits and minimize dredging requirements.

7.3 Project Close-Out

Close-out of the project would occur when it is determined that the project has been successful or when the maximum ten-year monitoring period has been reached. Success would be considered to have been achieved when the following objectives have been met, or when it is clear that they will be met based upon the trends for the site conditions and processes. Project success would be based on the following:

- Promote water distribution in the southeast portion of Maurepas Swamp to move stagnant water out of the system
- Facilitate swamp building, at a rate greater than swamp loss due to subsidence and sea level rise, by increasing sediment input and swamp production to maintain or increase elevation in the swamp.
- Establish hydroperiod fluctuation in the swamp to improve baldcypress and tupelo productivity and their seed germination and survival, by increasing the length of dry periods in the swamp.
- Improve fish and wildlife habitat in the swamp and in Blind River.

There may be issues related to the sustainability of the project that would require some monitoring and management beyond achieving these objectives. Due to the variable nature of the Louisiana coastal zone, the monitoring baseline may change during the period of analysis. Consequently, it may be appropriate to consider extending project-specific monitoring and adaptive management beyond ten years

8.0 COSTS FOR IMPLEMENTATION OF MONITORING AND ADAPTIVE MANAGEMENT PROGRAMS

The costs associated with implementing the LCA monitoring and adaptive management plans were estimated based on currently available data and information developed during plan formulation as part of the feasibility study. Because uncertainties remain as to the exact project features, monitoring elements, and adaptive management opportunities, the costs estimated in Tables 1, 2, and 3 (below) will be refined in the PED phase during the development of the detailed monitoring and adaptive management plans.

8.1 Costs for Implementation of Monitoring Program

Costs to be incurred during the PED and construction phases include drafting of the detailed monitoring plan, monitoring site establishment and pre-construction and construction data acquisition to establish baseline conditions. Cost calculations for post-construction monitoring are displayed as a ten-year (maximum) total. If ecological success is determined earlier (prior to ten years post-construction), the monitoring program will cease and costs will decrease accordingly.

It is intended that monitoring conducted under the LCA program will utilize centralized data management, data analysis, and reporting functions. All data collection activities will follow consistent and standardized processes regardless of the organization responsible for monitoring. Cost estimates include monitoring equipment, monitoring station establishment, data collection, quality assurance/quality control, data analysis, assessment, and reporting for the proposed monitoring elements in Table 1 below. These estimates account for a 2.6% annual inflation rate, adopted from the CWPPRA Program. The current total estimate for implementing the monitoring and assessment program for this project is $4,841,500. Unless otherwise noted, costs will begin at the onset of the PED phase and will be budgeted as construction costs.

Table 1. Preliminary Cost Estimates for Implementation of the Monitoring Program for the LCA Small Diversion at Convent/Blind River Project.

Category	Activities	2 yr PED Set-up & Data Acquisition	3 yr Construction	10 yr Post-Construction	Total
Monitoring: planning and management	Monitoring workgroup, drafting detailed monitoring plan, working with PDTs on performance measures	$135,900	$53,200	$210,100	$399,200
Monitoring: data collection	Landrights, site construction, and surveying	$129,300			$129,300
	Vegetation	$64,900	$103,700	$409,600	$578,200
	Hydrology	$229,200	$366,600	$1,447,300	$2,043,100
	Sediment input	$37,400	$59,900	$236,300	$333,600
	Sediment accretion and elevation	$25,900	$41,500	$163,800	$231,200
	Water quality	$64,000	$102,400	$404,400	$570,800
Database management	Database development, management, and maintenance, webpage development for communication of data to stakeholders	$62,400	$99,800	$393,900	$556,100
TOTAL		**$749,000**	**$827,100**	**$3,265,400**	**$4,841,500**

8.2 Costs for Implementation of Adaptive Management Program

Costs for the project's adaptive management program were based on estimated level of effort. The current total estimate for implementing the adaptive management program is $1,780,000. Unless otherwise noted, costs will begin at the onset of the PED phase and will be budgeted as construction costs.

Table 2. Preliminary Cost Estimates for Set-up of Adaptive Management Program for the LCA Small Diversion at Convent/Blind River Project .

Category	Annual Cost	5-yr Total
Detailed AM Plan and Program set-up (during PED and Construction phases)	$100,000	$500,000
TOTAL	**$100,000**	**$500,000**

Table 3. Preliminary Cost Estimates for Implementation of Adaptive Management Program for the LCA Small Diversion at Convent/Blind River Project .

Category	Annual Cost	10 yr Total
Management of AM Program (post-construction)	$50,000	$500,000
Assessment	$47,000	$470,000
Decision-making	$31,000	$310,000
TOTAL	**$128,000**	**$1,280,000**

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ANNEX 1. LCA Small Diversion at Convent/Blind River Project
Conceptual Ecological Model

1.0 INTRODUCTION

1.1 Conceptual Ecological Model Definition

Although the term "conceptual ecological model" (CEM) may be applied to numerous disciplines, CEMs are generally simple, qualitative models, represented by a diagram, that describe general functional relationships among the essential components of an ecosystem. CEMs typically document and summarize current understanding of, and assumptions about, ecosystem function. When applied specifically to ecosystem restoration projects, CEMs also describe how restoration actions propose to alter ecosystem processes or components to improve system health (Fischenich 2008). To describe ecosystem function, a CEM usually diagrams relationships between major anthropogenic and natural drivers, biological indicators, and target ecosystem conditions.

1.2 Purpose and Functions of Conceptual Ecological Models

CEMs can be particularly helpful in providing assistance with four important tasks: ecosystem description, communication, ecosystem restoration plan formulation, and monitoring and adaptive management.

1.2.1 Ecosystem Simplification

Because natural systems are inherently complex, resource managers must utilize tools that simplify ecosystem relationships and functions within the target ecosystem. An understanding of the target ecosystem is paramount to planning and constructing achievable ecosystem restoration projects. During CEM development, known and unknown connections and causalities in the systems are identified and delineated (Fischenich 2008).

CEMs can promote ecosystem description and simplification through the following processes:

- Organization of existing scientific information;
- Clear depiction of system components and interactions;
- Promotion of understanding of the ecosystem;
- Diagnosis of underlying ecosystem problems;
- Isolation of cause and effect relationships; and
- Identification of elements most likely to demonstrate ecosystem responses.

1.2.2 Communication

CEMs are an effective tool for the communication of complex ecosystem processes to a large diverse audience (Fischenich 2008). It is vitally important that project teams understand ecosystem function in order to realistically predict accomplishments to be achieved by restoration projects. CEMs can facilitate effective communication between project team members about ecosystem function, processes, and problems, and can assist in reaching consensus within the project team on project goals and objectives.

Because CEMs summarize relationships among the important attributes of complex ecosystems, they can serve as the basis for sound scientific debate. Stakeholder groups, agency functions (e.g., planning and operations), and technical disciplines typically relate to systems resource use and management independently, but CEMs can be used to link these perspectives.

The process of model development is at least as valuable as the model itself and affords an opportunity to draw fresh insight as well as address unique concerns or characteristics for a given project. Workshops to construct CEMs facilitate brainstorming sessions that explore alternative ways to compress a complex system into a small set of variables and functions. This interactive process of system model construction facilitates communication between project team members and almost always identifies inadequately understood or controversial model components.

CEMs can promote communication by facilitating the following:

- Integrating input from multiple sources and informing groups of the ideas, interactions, and involvement of other groups (Fischenich 2008);
- Assembling project/study managers with the project team and stakeholders to discuss ecosystem condition, problems, and potential solutions;
- Synthesizing current understanding of ecosystem function;
- Developing consensus on a working set of hypotheses that explain habitat changes;
- Developing consensus on indicators that can reflect project-specific ecological conditions; and
- Establishing a shared vocabulary among project participants.

1.2.3 Plan Formulation

Formulating a plan for an effective ecosystem restoration project requires an understanding of the following elements:

- The underlying cause(s) of habitat degradation;
- The manner in which causal mechanisms influence ecosystem components and dynamics; and
- The manner in which intervening with a restoration project may reduce the effects of degradation.

These three elements should form the basis of any CEM applied to project formulation (Fischenich 2008).

CEMs can provide valuable assistance to the plan formulation process through the following:

- Supporting decision-making by assembling existing applicable science;
- Assisting with formulation of project goals and objectives, indicators, management strategies, and results;
- Providing a common framework among team members from which to develop alternatives;
- Supplementing numerical models to assess project benefits and impacts; and
- Identifying biological attributes or indicators that should be monitored to best interpret ecosystem conditions, changes, and trends.

1.2.4 Science, Monitoring, and Adaptive Management

Through the recognition of important physical, chemical, or biological processes in an ecosystem, CEMs identify aspects of the ecosystem that should be measured. Hypotheses about uncertain relationships or interactions between components may be tested and the model may be revised through research and/or an adaptive management process. Indicators for this process may occur at any level of organization, including the landscape, community, population, or genetic levels; and may be compositional (i.e., referring to the variety of elements in a system), structural (i.e., referring to the organization or pattern of the system), or functional (i.e., referring to ecological processes) in nature.

CEMs can be helpful in restoration science, monitoring, and adaptive management through the following:

- Making qualitative predictions of ecosystem response;
- Identifying possible system thresholds that can warn when ecological responses may diverge from the desired effect;
- Outlining further restoration and/or research and development needs;
- Identifying appropriate monitoring indicators and metrics;
- Providing a basis for implementing adaptive management strategies;
- Interpreting and tracking changes in project targets;
- Summarizing the most important ecosystem descriptors, spatial and temporal scales, and current and potential threats to the system;
- Facilitating open discussion and debate about the nature of the system and important management issues;
- Determining indicators for monitoring;
- Helping interpret monitoring results and explore alternative courses of management;
- Establishing an institutional record of the ideas that inspired the management and monitoring plan;
- Forecasting and evaluating effects on system integrity, stress, risks, and other changes;
- Identifying knowledge gaps and the prioritization of research;
- Interpreting and monitoring changes in target indicators; and
- Assisting in qualitative predictions and providing a key foundation for the development of benefits metrics, monitoring plans, and performance measures.

1.2.5 Limitations of Conceptual Ecological Models

CEMs cannot identify the most significant natural resources within the target ecosystem or prioritize project objectives. They do not directly contribute to the negotiations and trade-offs common to ecosystem restoration projects. CEMs are not *The truth*, but are simplified depictions of reality. They are not *Final*, but rather provide a flexible framework that evolves as understanding of the ecosystem increases. CEMs are not *Comprehensive* because they focus only upon those components of an ecosystem deemed relevant while ignoring other important (but not immediately germane) elements. CEMs do not, in and of themselves, quantify restoration outcomes, but identify indicators that can be monitored to determine responses within the target ecosystem to restoration outputs.

Good conceptual models effectively communicate which aspects of the ecosystem are essential to the problem, and distinguish those outside the control of the implementing agency. The best conceptual models focus on key ecosystem attributes, are relevant, reliable, and practical for the problem considered, and communicate the message to a wide audience.

1.3 Types of Conceptual Ecological Models

CEMs can be classified according to both their composition and their presentation format. They can take the form of any combination of narratives, tables, matrices of factors, or box-and-arrow diagrams. The most common types of CEMs are narrative, tabular, matrix, and various forms of schematic representations. A comprehensive discussion of these types of CEMs is provided in Fischenich (2008). Despite the variety in types of CEMs, "no single form will be useful in all circumstances" (Fischenich 2008). Therefore, it is of vital importance to establish the specific plan formulation needs to be addressed by the CEM, and develop the CEM accordingly because "[c]onceptual models . . . are most useful when they are adapted to solve specific problems" (Fischenich 2008).

1.3.1 Application of Conceptual Ecological Models to LCA Projects

CEMs have been widely used in other regions of North America when planning large-scale restoration projects (Barnes and Mazzotti 2005). The LCA team has decided to utilize the Ogden model (Ogden and Davis 1999). The LCA team recognizes that CEM development, like plan formulation, is likely to be an iterative process, and that CEMs developed for LCA projects during early plan formulation may be dramatically changed before project construction.

1.3.2 Model Components

The schematic organization of the CEM is depicted in Figure 1 and includes the following components:

- *Drivers*- This component includes major external driving forces that have large-scale influences on natural systems. Drivers may be natural (e.g., eustatic sea level rise) or anthropogenic (e.g., hydrologic alteration) in nature.
- *Ecological Stressors*- This component includes physical or chemical changes that occur within natural systems, which are produced or affected by drivers and are directly responsible for significant changes in biological components, patterns, and relationships in natural systems.
- *Ecological Effects*- This component includes biological, physical, or chemical responses within the natural system that are produced or affected by stressors. CEMs propose linkages between one or more ecological stressors and ecological effects and attributes to explain changes that have occurred in ecosystems.
- *Attributes*- This component (also known as indicators or end points) is a frugal subset of all potential elements or components of natural systems representative of overall

ecological conditions. Attributes may include populations, species, communities, or chemical processes. Performance measures and restoration objectives are established for each attribute. Post-project status and trends among attributes are measured by a system-wide monitoring and assessment program as a means of determining success of a program in reducing or eliminating adverse effects of stressors.

- *Performance measures*- This component includes specific features of each attribute to be monitored to determine the degree to which attribute is responding to projects designed to correct adverse effects of stressors (i.e., to determine success of the project).

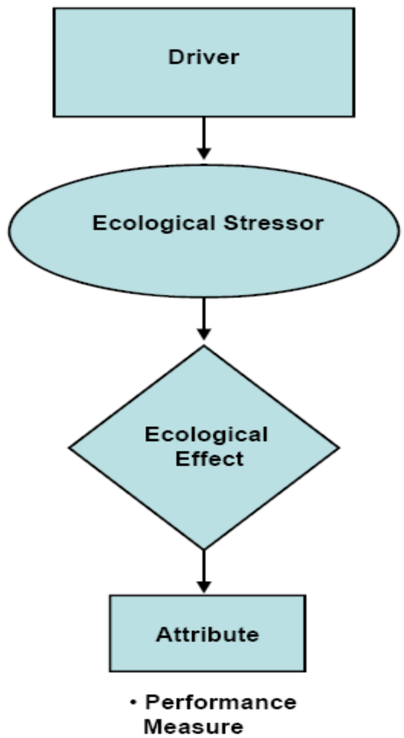


Figure 1. Conceptual Ecological Model Schematic Diagram.

This CEM does not attempt to explain all possible relationships or include all possible factors influencing the performance measure targets within natural systems in the study area. Rather, the model attempts to simplify ecosystem function by containing only information deemed most relevant to ecosystem monitoring goals.

2.0 CONCEPTUAL ECOLOGICAL MODEL DEVELOPMENT

2.1 Methodology

A CEM was developed for the Small Diversion at Convent/Blind River project by members of the project team and the interagency Project Delivery Team. The creation of this CEM was an interactive and iterative process. Prior to model development, the project team reviewed existing information on the project study area. The project team identified drivers, ecological stressors, ecological effects, attributes and performance measures for the project and a preliminary CEM was developed in two formats. The CEM in each of these formats was provided to the interagency Project Delivery Team and the then members from both teams met to clarify and improve the CEM, which is presented in this report. Additional information about the components of the CEM for this project is presented below.

2.2 Project Background

The Small Diversion at Convent/Blind River project was identified in the Louisiana Coastal Area (LCA), Louisiana - Ecosystem Restoration Study (2004 LCA Plan [USACE 2004]). The 2004 LCA Plan was recommended to the Congress by a Chief of Engineers report dated January 31, 2005. The 2004 LCA Plan recommended a coordinated, feasible solution to the identified critical water resource problems and opportunities in Coastal Louisiana.

The project was included in that plan along with other critical near-term restoration features throughout coastal Louisiana. This project, as well as ten additional projects, was recommended for further studies in anticipation that such features would be subsequently recommended for future Congressional authorization. The 2004 LCA Plan was developed by the State of Louisiana and the United States Army Corps of Engineers in order to implement some of the restoration strategies outlined in the 1998 Coast 2050 report.

The project was proposed to reverse the current decline of a portion of the Maurepas Swamp area and to prevent the transition of the swamp into marsh and open water. This project will work together with the Small Diversion at Hope Canal diversion and the LCA Amite River Diversion Canal Modification projects to bring Mississippi River water, sediment, and nutrients to the current swamp area. Reversing this decline will help to develop more sustainable wetland ecosystem which can serve to protect the local environment, economy, and culture. In light of Louisiana's extreme vulnerability to intense storms, this project may also provide some measure of flood damage protection.

The Maurepas Swamp is an area of considerable ecological, socio-economic, and cultural importance. Since the construction of the Mississippi River flood control levees, large portions of the Maurepas Swamp have largely been cut off from fresh water, sediments, and nutrients historically provided by the Mississippi River. Due to this disruption in natural processes, soil building in the swamp has been insufficient to keep up with subsidence and sea level rise. Consequently, much of the swamp is persistently flooded, the existing trees may be somewhat stressed, and there is little to no natural regeneration of baldcypress and tupelo trees, which are the dominant species in this swamp ecosystem. These factors, combined with increasing occurrences of high salinities, if not addressed, will result in a highly degraded swamp system which is at risk of conversion to open water.

This diversion project would reintroduce up to 3,000 cubic feet per second (cfs) of Mississippi River water into the southwest portion of the Maurepas Swamp, thereby increasing the flow of fresh water, nutrients, and fine-grained sediment into an area in the swamp that is somewhat stressed and in need of restoration. The diversion project is fully consistent with both the strategies used to develop the LCA restoration plan and the critical needs criteria for identifying near-term restoration opportunities.

2.2.1 Project Goals and Objectives

The purpose of the Small Diversion at Convent/Blind River project is to restore and protect the health and productivity of the swamps southwest of Lake Maurepas through reintroduction of Mississippi River water. The specific objectives of the project concept are to:

- Promote water distribution in the southeastern portion of the Maurepas Swamp to move stagnant water out of the system.
- Facilitate swamp building, at a rate greater than swamp loss due to subsidence and sea level rise, by increasing sediment input and swamp production to maintain or increase elevation in the swamp.
- Increase the durations of dry periods in the swamp to improve baldcypress and tupelo productivity and to increase seed germination and survival of these key species.

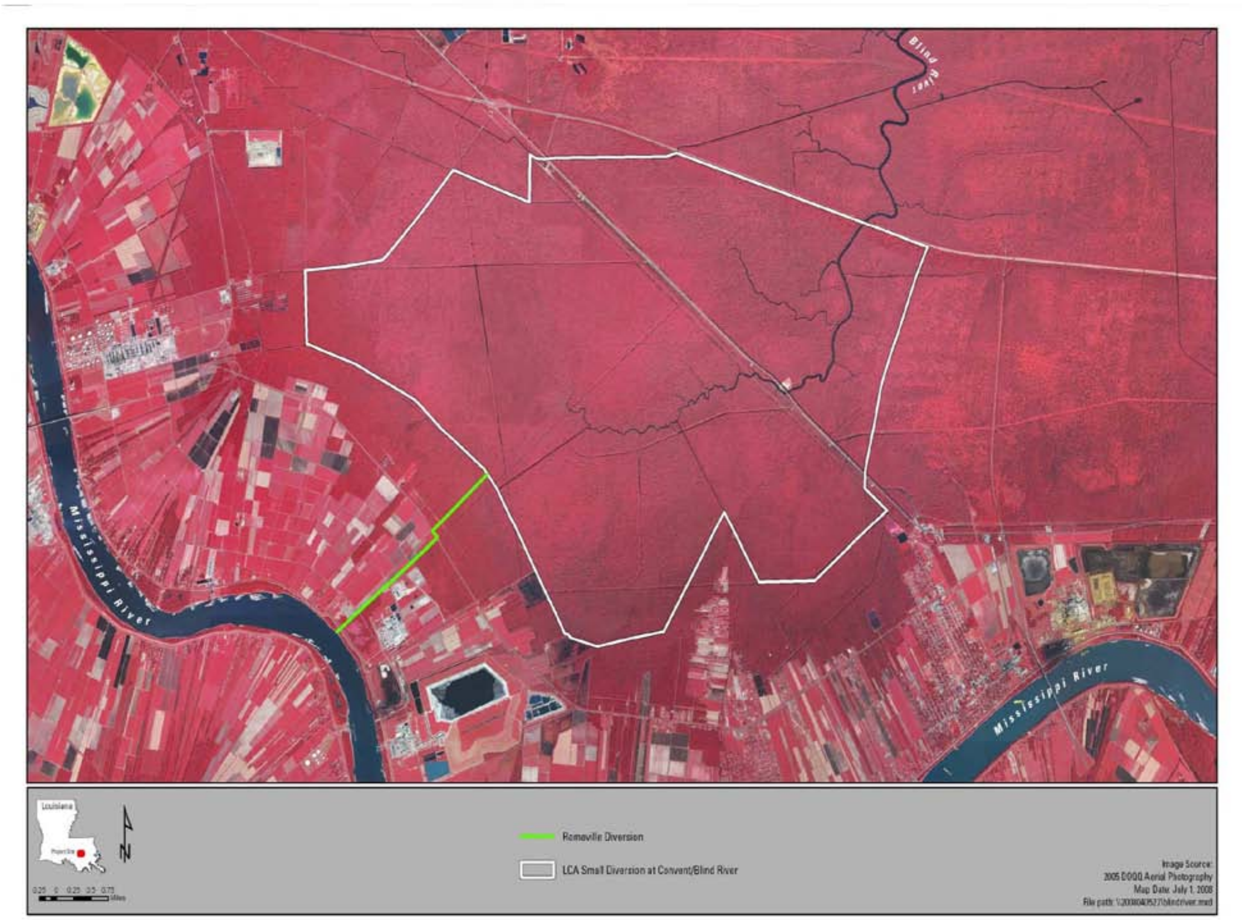
Improve fish and wildlife habitat in the swamp and in Blind River. This diversion project is located immediately west of the Hope Canal Diversion project and the influence areas are adjacent to each other. Both projects are planned to restore large areas of the Maurepas Swamp. As the diversion concepts and the swamp service areas are similar, many of the findings from the Hope Canal project will be applicable to this diversion project.

2.2.2 Project Description

The Maurepas Swamp is located in LCA Subprovince 1, west of Lake Pontchartrain and north of the I-10 corridor. The Maurepas Swamp is one of the largest remaining tracts of coastal freshwater swamp in Louisiana. Including Lake Maurepas, the Maurepas Swamp area comprises a total of approximately 232,928 acres, most of which is swamp, with some isolated areas of bottomland hardwood forest and fresh marsh. The diversion project involves evaluating a small hydraulic diversion (less than 5,000 cfs) from the Mississippi River into the Maurepas Swamp. Alternative locations for the proposed control structure in the vicinity of Romeville, located at Mississippi River Mile 161.5 above Head of Passes (AHP) were investigated. Reasonable alternatives were evaluated, and Alternative 2, diversion location at Romeville was selected.

The Blind River headwaters are located in St. James Parish approximately 23 miles north of Mississippi River at Mile 158.5 AHP. The Blind River flows north then east through Ascension and St. John the Baptist parishes before it empties into Lake Maurepas. The objective of this project is to introduce fresh water, sediment, and nutrients into the southwest portion of the Maurepas Swamp to help prevent the transition of the swamp into marsh and open water

Figure 2. Small Diversion at Convent/Blind River Project Study Area



3.0 CONCEPTUAL ECOLOGICAL MODEL DISCUSSION

The CEM developed for the Small Diversion at Convent/Blind River project is presented in Figure 3. Model components are identified and discussed in the following subsections.

3.1 Drivers

3.1.1 Natural Factors

Subsidence and Sea Level Rise

Increased subsidence is a physical response to lack of riverine input and the resulting loss of nutrients and sediments and decreased productivity in vegetation communities. The soil characteristics within the western Maurepas Swamp are indicative of a lack of riverine influence as evidenced by high soil organic matter content and low bulk density values (DeLaune et al. 1979, Hatton 1981, Messina and Conner 1998). Soil building within the Maurepas Swamp occurs almost exclusively as a result of organic productivity. Subsidence in this area is classified as intermediate, at about 1.1-2.0 feet per century (USACE 2004). With minimal soil building and moderately high subsidence, there has been a net lowering of ground surface elevation, leading to a doubling in flood frequency over the last four decades (Thomson 2000), so that the swamps are now persistently flooded. Thomson (2000) also indicated that there has been a rise in mean sea level of 1.6 mm per annum from 1957 to 2000 near the study area.

Shaffer et al. (2003) conducted a subsidence investigation in the Maurepas Swamp immediately east of the project study area in support of CWPPRA project PO-29 *Mississippi River Reintroduction into Maurepas Swamp*. Subsidence rates for the PO-29 project area were measured by the installation of two surface elevation tables at 13 representative study sites. The tables could be set in four compass directions and utilized the mean value of nine pin readings of soil elevation. Readings were collected from October-November 2001 and compared against readings collected in October-November 2002 to provide an accurate estimate of the net subsidence rates within the Maurepas Swamp. The results of this subsidence investigation indicate an average net elevation decrease of slightly less than one centimeter for the study area during the interval between sampling, although actual rates varied considerably by habitat type.

The combination of increased flood duration due to subsidence and sea level rise and increased salinity are likely to convert freshwater swamps to marsh and open water. The altered hydrology prevents the regeneration of swamps (Penfound 1952, Shaffer et al. 2003).

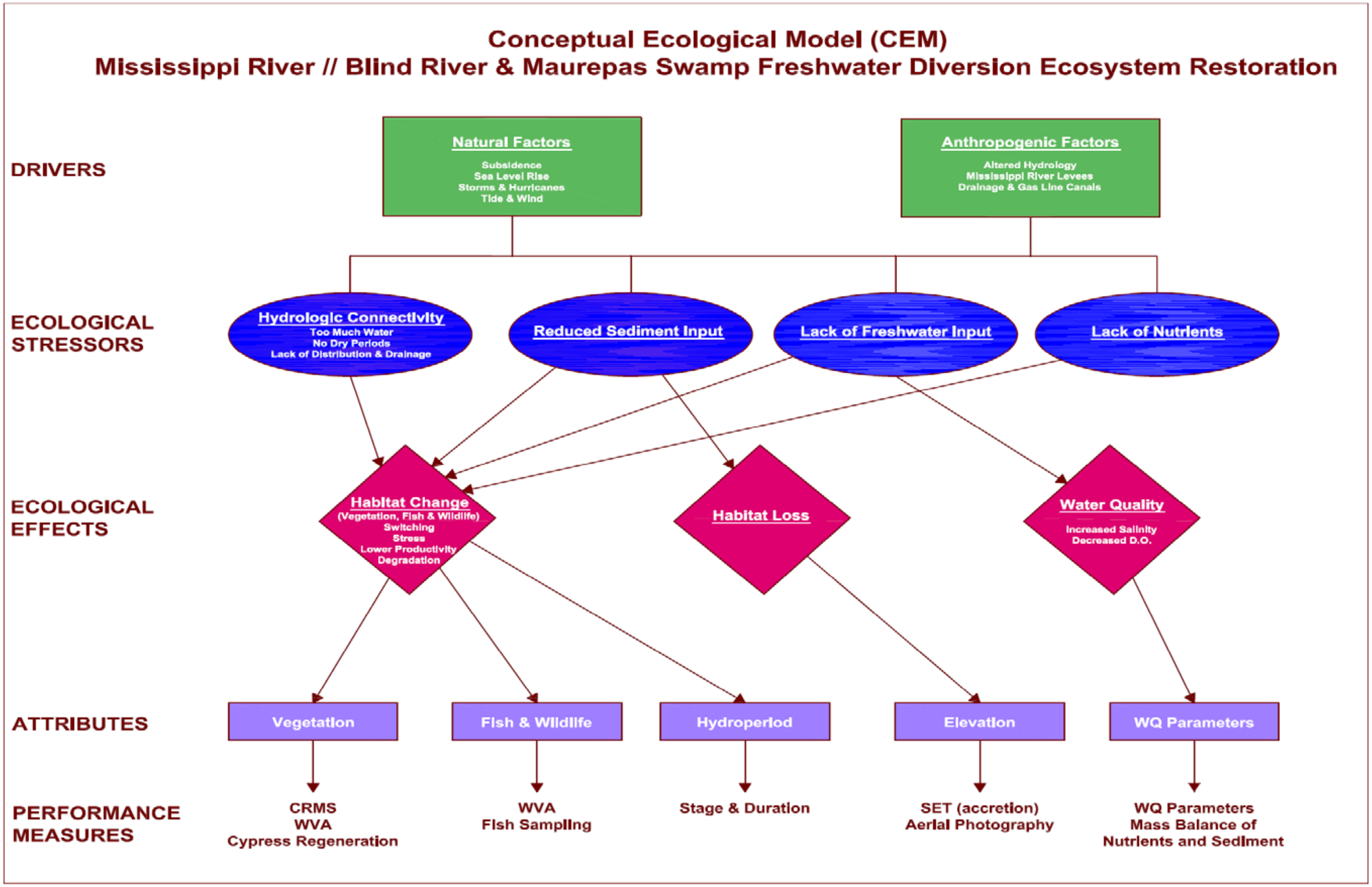


Figure 3. Conceptual Ecological Model, LCA Small Diversion at Convent/Blind River Project .

Storms and Hurricanes

Coastal storms, particularly tropical cyclone events, also exert a stochastic but severe influence on the study area. Storm surge frequency encourages continued degradation of the coastal forest habitat in and surrounding the study area, further reducing the ability of these habitats to attenuate storm surge. Consequently, an increase in storm surge and risk of flooding is imminent. Data obtained from the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center indicate that the storm centers of at least 14 tropical cyclones with a Saffir-Simpson Hurricane Scale of Category 2 or higher have passed within 50 miles of the study area during the interval 1851-2007, and at least 52 such tropical cyclones have passed within 100 miles of the study area during the same interval. The most recent tropical cyclones to affect the study area were hurricanes Katrina and Rita, which occurred in August 2005 and September 2005, respectively, and hurricanes Gustav and Ike, which occurred in September 2008.

Tides and Wind

The Blind River/Maurepas Swamp system is tidally affected although it is a freshwater system. The tides and wind affect the flow of water in the Blind River, and therefore the swamp, and are important natural driving factors. These factors were considered in addressing the hydrology and flow patterns in the system and in determining the appropriate measures for ecosystem restoration.

3.1.2 Anthropogenic Factors

Mississippi River Levees

With construction of the Mississippi River flood control levees, the Maurepas Swamp has been virtually cut off from any freshwater, sediment, and nutrient input from the Mississippi River floods. Thus, the only soil building has come from organic production within the wetlands, and vegetative productivity may be substantially depressed compared to pre-levee conditions. Subsidence in this area is classified as intermediate, at about 1.1 to 2.0 feet/century. With minimal soil building, moderately high subsidence rates, modified drainage in and around the swamp, there has been a net lowering of ground surface elevation, and the swamps are persistently inundated.

Altered Hydrology

Although the Blind River and Maurepas Swamp have been cut off from the Mississippi River, significant drainage flows to the river and the swamp from the northeast during large storms and hurricanes (that frequently occur in the study area, as indicated above). The flows are so large that the river and swamp drain slowly or not at all, resulting in high water levels, impoundment, and damping of the natural hydroperiod. With minimal ability to drain and persistent flooding, the typical seasonal drying of the swamp does not usually occur. Existing baldcypress and tupelo trees are able to grow in flooded conditions. However, neither baldcypress nor tupelo seeds can germinate when flooded. Seeds of both species remain viable when submerged in water and can germinate readily when floodwaters recede. The potential for re-establishment seems to also be hindered by the relatively low numbers of viable seeds observed in swamp seed banks and by herbivory.

Drainage Canals and Pipe Line Canals

Major drainage canals have been constructed in the project study area. These major drainage canals are associated with and essentially extend flows in Blind River throughout the project site. Canal construction has altered physical defining characteristics, including water storage, sheet flow, and nutrient and sediment input levels within swamp habitat in the study area. The canals are routinely dredged by St. James Parish and dredged material generated in the construction and maintenance of the canals is placed in spoil banks on both sides of the canal. These spoil banks form topographic high points within the study area that affect the distribution of water into the swamp.

Several gas transmission and hazardous liquid pipelines exist in the study area (refer to Table 4-33 in the main report). Dredged material banks that are higher than the natural land surface, and along with the many smaller canals dredged during exploration and pipeline installation, they alter the natural hydrology much the same way as drainage canals discussed previously. The banks constructed from dredged material create partially impounded areas that reduce water exchange resulting in water-logged areas and plant death.

3.2 Ecological Stressors

3.2.1 Hydrologic Connectivity

Hydrologic connectivity addresses the importance of the connection between the Blind River and Maurepas Swamp. The normal flow in the river and flow from large storm events and hurricanes are the ecological stressors that most affect the biological components and patterns that exist in the river and the swamp. These flows affect the drainage patterns in the system since high flows lead to impoundment and alteration of the hydroperiod. During the prolonged period of inundation, drainage is limited, resulting in too much water in the swamp for too long a period (high depth and duration). The overall effect is that there appear to be no dry periods in the swamp, which reduces or eliminates baldcypress and tupelo regeneration. Natural biological life cycle patterns can also be disturbed without dry periods. Impoundment within the study area has also resulted in decreased water quality.

3.2.2 Lack of Freshwater , Sediment, and Nutrient Input

Historically, hydrologic conditions within the study area were dominated by overbank flow from the Mississippi River, and by tidal influence from Lake Maurepas. Periodic flooding of the Mississippi River and/or the Blind River resulted in the inundation of baldcypress-tupelo habitat within the study area. Flooding occurred within the study area and vicinity on a cyclical basis, with peak water elevations in the late spring or fall. As floodwaters receded, surface waters in the study area were conveyed to the Blind River, and then to Lake Maurepas.

The implementation of flood control projects from the late 19th century to mid-20th century, including construction of flood protection levees on the Mississippi River and construction of major drainage canals, disrupted the natural hydrologic regime within the study area. Mississippi River channelization and levee construction greatly reduced overbank flooding in the study area, causing a loss of freshwater (as well as nutrients and sediments) in the ecosystem, decreased water quality, and increased subsidence. Input of freshwater, nutrients, and sediment are important to the biological make-up, productivity, and maintenance of the swamp relative to subsidence and sea level rise. The lack of periodic freshwater input has led to modifications in the swamp's ecology.

Loss of nutrients and sediments is a physical response to the lack of riverine input. Effler et al. (2006) examined the importance of nutrient influxes that accompany freshwater diversions or other hydrologic connectivity projects to swamp productivity. Nutrient augmentation of baldcypress and tupelo trees in the Maurepas Swamp (similar to nitrate loading rates expected from a small freshwater diversion) increased radial growth of both species (especially baldcypress) in degraded forest stands. Nutrient augmentation also increased nitrogen in foliage for both tree species. These findings support hypotheses that swamps in southeastern Louisiana are nutrient-limited, and existing trees can utilize, benefit from, and act as nutrient sinks for nutrient-laden river water accompanying diversions or other freshwater reintroductions.

Further evidence of nutrient starvation was identified in Shaffer et al. (2001). This study determined that nutrient augmentation significantly enhanced (by approximately 33 percent) biomass production of herbaceous vegetation at monitoring stations within the western Maurepas Swamp during 2000. Furthermore, several studies conducted over the last two decades have demonstrated that nutrient augmentation to baldcypress seedlings doubles growth rates in the western Maurepas Swamp (Boshart 1997, Forder 1995, Greene 1994, Myers et al. 1995), further indicating that the baldcypress-tupelo swamp in the study area and vicinity is nutrient-limited.

Shaffer et al. (2008) presented data at the Society of Wetland Scientists meeting on tree growth in the Maurepas Swamp. For the period 2000-2007, diameter growth was measured for over 1,800 trees. Diameter growth in the measured trees was significantly less than established growth levels for trees in healthy freshwater swamp systems. The study determined that in interior swamp locations such as the study area, the primary factor inhibiting diameter growth was nutrient-poor stagnant standing water and the lack of nutrient-rich freshwater throughput caused by the loss of hydrologic connectivity with riverine systems.

3.3 Ecological Effects

3.3.1 Habitat Change and Habitat Loss

Increased habitat conversion is a physical and biological response to both impoundment and the resulting lack of regeneration, increased seedling mortality as well as lack of riverine input and the resulting loss of nutrients and sediments resulting in decreased plant productivity. Hoeppner et al. (2007) concluded that the majority of the Maurepas Swamp is stressed and seems to be on a trajectory of slow degradation leading to a gradual conversion to marsh and open water. Stagnant flooding and nutrient deprivation appear to be the largest stressors in the swamp interior.

Natural regeneration throughout the Maurepas Swamp is very low and even absent at most sites (Hamilton and Shaffer 2001). Land conversion observations on the Manchac land-bridge and Jones Island demonstrate what is expected in the Maurepas Swamp in the coming decades, if no restoration action is taken. In 1956, most of the area of the Manchac land-bridge was dominated by second-growth swamp. By 1978, much of this swamp had converted to marsh and shrub-scrub, and by 1990 the marsh had begun to break up and convert to open water (Barras et al. 1994).

Under the continued influence of these conditions, tree mortality will continue to increase and tree density will continue to decline. Monitoring studies conducted for the CWPPRA PPL 12 proposal indicated that conversion of baldcypress-tupelo swamp to fresh marsh is already occurring in the Maurepas Swamp. The results of these monitoring studies indicate that many areas of interior swamp in the study area and vicinity that exhibit significantly stressed or dying overstory vegetation also contain bulltongue (*Sagittaria lancifolia*) or arrow arum (*Peltandra virginica*) as understory vegetation.

Factors contributing to this conversion include the much greater tolerance of baldcypress and water tupelo with respect to herbaceous understory vegetation for long-term deep inundation, and the increasingly unconsolidated nature of swamp substrate caused by the reduction of below-ground productivity. Consequently, it is expected that the swamp habitat adjacent to the Blind River Canal would convert to open water or marsh habitat without implementation of the proposed project.

Souther and Shaffer (2000) reported that in the early 20th century, baldcypress swamps were harvested *en masse* in coastal Louisiana, and that in many harvested areas, natural regeneration did not occur; instead, these areas converted to marsh or open water. The study concluded that prolonged flooding or complete submergence within the swamps may have suppressed germination or growth rates of young seedlings and even caused mortality. Neither baldcypress nor tupelo seeds can germinate when flooded (Hamilton and Shaffer 2001). Seeds of both species remain viable when submerged in water and can germinate readily when floodwaters recede. However, the seedlings require seasonal drying periods, and the substrate compaction associated with these drying periods, for their root systems to become properly established in the swamp substrate. With minimal ability to drain and persistent flooding, the typical seasonal drying of the swamp does not usually occur, leading to failure of seedlings to establish themselves and replace older trees that have been lost to other processes (CWPPRA Task Force 2002).

Decreased productivity in vegetative communities in the study area is a biological response to the lack of riverine input. Comparison of productivity in swamps that are either managed, have more favorable hydrology, and/or are receiving nutrient enrichment suggest that the existing levels of productivity in the western Maurepas Swamp are as low as 50 percent or even 25 percent of average values (Hamilton and Shaffer 2001).

As part of the CWPPRAPPL 11 effort to launch a project diverting Mississippi River water into the Maurepas Swamp, Shaffer et al. (2001) examined woody and herbaceous vegetation at 20 study sites in the Maurepas Swamp. The study examined cover values, annual production, herbaceous (understory) primary production, tree health and primary productivity, annual tree diameter growth, and litterfall production at these sites to develop a comprehensive picture of vegetation productivity in the region. The study concluded that salinity is currently an important stressor in the Maurepas Swamp, but that degradation of tupelo trees within the swamp has been occurring for decades and is almost certainly primarily due to altered hydrology and lack of throughput. The study determined that the low soil bulk densities and high soil organic matter content throughout much of this swamp are indicative of a lack of riverine influence.

The results of the Shaffer et al. (2001) and other studies indicate that the western Maurepas Swamp is highly degraded and would benefit from a substantial infusion of nutrients and freshwater from a river diversion or other freshwater reintroduction. Results of studies in wetlands receiving secondary treated sewage suggest that introduction of nutrients as well as sediments from river water could stimulate production by 300 to 500 percent (Rybczyk et al. 2002, Hamilton and Shaffer 2001).

3.3.2 Decreased Water Quality

Decreased water quality is a chemical response to the impoundment produced in the study area and the introduction of saline storm surge waters associated with tropical cyclone events. The Maurepas Swamp is characterized by nutrient-poor surface waters. Day et al. (2001) conducted a water quality analysis in support of CWPPRA Project PO-29 *Mississippi River Reintroduction into the Maurepas Swamps*. The observed concentrations of nitrate, ammonium, and nitrogen at surface water sampling stations within the western Maurepas Swamp were all reduced with respect to observed concentrations in the Mississippi River. The results of sampling of water quality parameters demonstrate that, for some nutrient forms, the Maurepas Basin has relatively low nutrient concentrations compared to the Mississippi River and other systems studied. The results of this study indicate that the baldcypress-tupelo swamp within the study area and vicinity is severely nutrient-limited.

Additionally, storm surges originating from Lake Maurepas associated with tropical cyclone events may exert a stochastic but severe stress upon the swamp habitat through salinity spikes in surface waters within the swamp. Recent tropical cyclone events, occurring at a rate of one to two per years, have produced measurable spikes in salinity within the western Maurepas Swamp (USACE 2004).

3.4 Attributes and Performance Measures

3.4.1 Vegetation Productivity

Swamp vegetation productivity has been identified as a key indicator of project success. Comparison of pre-project and post-project vegetation monitoring data would serve to determine if biomass production in plant communities within the study area increases in response to project features. A post-project increase in biomass production would also indicate the introduction of nutrients and sediment into the swamps as a result of the project. Three assessment performance measures have been identified for this attribute, including percent cover, diameter at breast height (dbh), and litterfall.

- *Percent cover* is the estimated percentage of the ground surface covered by vegetation. Canopy percent cover is the estimated percentage of the ground surface covered by tree canopies when the crowns are projected vertically. A high percent cover is indicative of significant productivity within the respective vegetation communities, and a high canopy percent cover is indicative of significant productivity within woody species.
- *Diameter at breast height (dbh)* is the measurement of tree diameter at a height of 4.5 feet above the forest floor on the uphill side of the tree. Ongoing monitoring studies of baldcypress and tupelo trees within the western Maurepas Swamp by Dr. Gary Shaffer indicate that average annual dbh increase for trees within the eastern study area is approximately one millimeter per year, a growth level that is significantly lower than expected levels of 1-2 centimeters per year for healthy baldcypress or tupelo trees (Shaffer, personal communication 2009).
- *Litterfall* is the measurement of the movement of leaves, twigs, and other forms of organic matter from the biosphere to the litter layer found in soil via interception in collection traps. Large volumes of litterfall are indicative of significant biomass production within the constituent forest community.

A post-project relative increase in productivity within the study area, as evidenced by these three measures, would be an indication of significant project success, while a post-project stabilization of these measures would be an indication of moderate project success. Conversely, a post-project decline in these measures within the study area would indicate that the project did not succeed in increasing swamp vegetation productivity.

3.4.2 Fish and Wildlife Habitat

The Maurepas Swamp is an important habitat for a variety of fish and wildlife species, including crawfish, alligators, snapping turtles, blue crab, and channel catfish. The Maurepas Swamp also provides valuable habitat to a number of avian species, including neo-tropical migratory songbirds and waterfowl. Two threatened species (the bald eagle and Gulf sturgeon) are found in this area. Bald eagles typically nest in baldcypress trees near low salinity to intermediate marshes or open water. The Gulf sturgeon is a threatened species found in Lake Maurepas. Although extremely rare, the West Indian manatee has been sighted in the area a few times over the last 25 years. The Maurepas Swamp is used for fishing, hunting, and other recreational activities, and as a large contiguous tract of baldcypress/tupelo swamp near the New Orleans metropolitan area, has considerable cultural significance. Wildlife habitat will be evaluated with the Wetland Value Assessment (WVA) procedure..

3.4.3 Hydroperiod

For any single year the hydroperiod of the swamp is bimodal. The water level generally rises in the spring, then falls to its lowest level during summer, rises to its highest level in the fall, and again falls to low levels in the winter. High water levels in the fall are attributed to tropical storms and hurricanes. Increases in flood duration are exacerbated by sea level rise and subsidence. Flood duration is one of the main drivers that control species diversity and productivity in the swamp.

Hydroperiod measurement is a key monitoring component for determining the hydrology and status of the project area. Flow in the Blind River will be measured and evaluated and piezometers will be established in Maurepas Swamp in each project area hydrologic unit.

3.4.4 Elevation

Ground surface elevation has been identified as a key indicator of project success with respect to reducing or reversing subsidence within the study area. Comparison of pre-project elevation levels with post-project elevation levels would serve to determine if sediment input and soil accretion is occurring within the study area in response to project features. A post-project increase in elevation would implicitly indicate the introduction of nutrients and sediment into the swamps as a result of the project, and would also indicate an increase in vegetation productivity and the resulting litterfall that is a principal factor in soil accretion within the Maurepas Swamp. Two assessment performance measures have been identified for this attribute, including surface elevation table (SET) measurements and feldspar marker horizon measurements.

- *Surface Elevation Table (SET) measurements* provide a constant reference plane in space from which the distance to the sediment surface can be measured by means of pins lowered to the sediment surface. Repeated measurements of elevation can be made with high precision because the orientation of the table in space remains fixed for each sampling. Elevation change measured by the SET is influenced by both surface and subsurface processes occurring within the soil profile.

- *Feldspar marker horizon measurements* involve the placement of a cohesive layer of feldspar clay on the ground surface. Soil borings are periodically extracted at the marker horizon location to measure the amount of soil deposition and/or accretion that has occurred above the horizon since placement. Significant quantities of soil atop marker horizons are indicative of soil building within the area, which in turn indicates an increase in relative elevation.

Post-project increases in elevation as evidenced by SET measurements or documented soil accretion atop a marker horizon within the study area would be an indication of significant project success, while a post-project stabilization of elevation as evidenced by these measures would be an indication of moderate project success. Conversely, a post-project decline in elevation within the study area would indicate that the project did not succeed in offsetting subsidence and, by extension, habitat conversion, and future land loss.

3.4.5 Water Quality

Surface water quality in interior locations in the study area has been identified as a key indicator of project success with respect to establishing hydrologic connectivity between the Blind River and associated major canals, and the adjacent swamp habitat. Comparison of pre-project and post-project water quality would serve to determine if freshwater throughput is introducing nutrients and flushing out saline waters within the study area in response to project features. A post-project improvement in water quality would implicitly indicate the introduction of freshwater and the associated nutrients and sediment into the swamps as a result of the project. Four assessment performance measures have been identified for this attribute, including total suspended solids (TSS), dissolved oxygen (DO), nutrients, and salinity.

- *Total suspended solids* (TSS) is a measurement of the total volume of sediment and other solids suspended in a given volume of water.

- *Dissolved oxygen* (DO) is a relative measure of the amount of oxygen that is dissolved in a given volume of water. Surface waters within the swamps in the study area are expected to exhibit lower DO concentrations than those of nearby waterbodies, because water movement (which exposes surface water to a greater volume of air through lateral movement and results in greater dissolution of oxygen) is virtually nonexistent in the swamps.

- *Nutrients* are chemical compounds or minerals contained in surface waters that are extracted by organisms for nourishment. Common nutrients in surface waters include nitrates, phosphates, and ammonia. Surface waters within the swamps adjacent to the Blind River and associated major canals have been demonstrated to be nutrient-poor with respect to other waterbodies in the area because the hydrology prevents the accumulation of nutrients from surface runoff.

- *Salinity* is a measure of the concentration of dissolved salt in a given volume of water. Surface waters within the study area often exhibit elevated salinity levels with respect to other area waterbodies because saline storm surges introduced into the swamps during tropical cyclone events become trapped in the impounded swamps and are not allowed to drain out of the study area.

Post-project improvements in water quality within the study area as evidenced by analyses of these measures would be an indication of significant project success, while a post-project stabilization or decline in water quality within the study area would indicate that the project did not succeed in reestablishing riverine input to the study area and the resulting reintroduction of nutrients and sediments associated with freshwater throughput.

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