Mississippi Valley Division,
Regional Planning and Environment Division South

Hatchie-Loosahatchie Mississippi River Ecosystem Restoration Study

Appendix 9 – Monitoring and Adaptive Management

February 2023

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Section 1
Introduction

1.1 INTRODUCTION

This Monitoring and Adaptive Management (M&AM) Plan is designed to aid in the success of the Hatchie-Loosahatchie Mississippi River Ecosystem Restoration Project. Section 2039 of the Water Resources Development Act of 2007 and Implementation guidance for Section 2039, as amended by Section 1161 of the WRDA 2016, in the form of a Chief of Civil Works – Planning Bulletin (CECW-PB) Memorandum dated 31 August 2009, and Implementation Guidance dated 19 October 2017 directs the Secretary of the Army to ensure, that when conducting a feasibility study for a project (or component of a project) under the Corps ecosystem restoration mission, that the recommended project includes a monitoring plan to measure the success of the ecosystem restoration and to dictate the direction adaptive management should proceed, if needed. This monitoring and adaptive management plan shall include a description of types and number of restoration activities to be carried out; physical actions to be undertaken to achieve project objectives; functions and values that will result from the restoration plan; monitoring activities to be carried out; criteria for ecosystem restoration success; the estimated cost and duration of the monitoring; and a contingency plan for taking corrective actions in cases in which the monitoring demonstrates that the restoration measures are not achieving ecological success in accordance with the criteria described in the monitoring plan. Within a period of ten years from completion of construction of an ecosystem restoration project, monitoring shall be a cost-shared project cost. Any additional monitoring required beyond ten years will be a non-Federal responsibility.

Section 2039 of WRDA 2007, as amended by Section 1161 of the WRDA 2016, also directs the Corps to develop an adaptive management plan for all ecosystem restoration projects. The adaptive management plan must be appropriately scoped to the scale of the project. The information generated by the monitoring plan will be used by the District in consultation with the Federal and State resource agencies and the MSC to guide decisions on operational or structural changes that may be needed to ensure that the ecosystem restoration project meets the success criteria.

An effective monitoring program is necessary to assess the status and trends of ecological health and biota richness and abundance on a per project basis, as well as to report on regional program success within the United States. Assessing status and trends includes both spatial and temporal variations. Gathered information under this monitoring plan will provide insights into the effectiveness of current restoration projects and adaptive management strategies, and indicate where goals have been met, if actions should continue, and/or whether more aggressive management is warranted.

Monitoring the changes at a project site is not always a simple task. Ecosystems, by their very nature, are dynamic systems where populations of macroinvertebrates, fish, birds, and other organisms fluctuate both spatially and temporally. Water quality also varies, particularly as seasonal and annual weather patterns change. The task of tracking environmental changes can be difficult, and distinguishing the changes caused by human actions from natural variations can be even more difficult. This is why a focused monitoring protocol tied directly to the planning objectives needs to be followed. In light of uncertainty regarding the success and performance of the proposed restoration measures in the lower Mississippi River (LMR), a "flexible decision making" process is required where operational adjustments and management may be explored and tested. We recognize the importance of natural variability to ecological resilience and productivity in the LMR. Adaptive management is not a "trial and error" process, but rather emphasizes "learning while doing." By developing an M&AM plan, we can more effectively make operational decisions, apply maintenance, and enhance socio-economic and ecological benefits. In addition, based on the results and interim conclusions made during the prescribed monitoring process, adjustments can be made in the monitoring plan ("adaptive monitoring") to improve sampling efficacy, reduce monitoring costs and target key geomorphological, physiochemical and biological indicators of successful restoration activities.

This M&AM plan contains both a monitoring component and an adaptive management component that is based on a plethora of studies conducted on the LMR by USACE's Engineer Research and Development Center (ERDC), the USACE-Memphis District, the non-Federal Sponsor (NFS) Lower Mississippi River Conservation Committee (LMRCC) and others. This M&AM Plan describes the existing habitats and monitoring methods that could be utilized to assess projects. By reporting on environmental changes, the results from this monitoring effort will be able to evaluate whether measurable results have been achieved. Many factors such as ecosystem dynamics, engineering applications, institutional requirements, and other key uncertainties can change and/or evolve over a project's life. The M&AM Plan is a living document and will be regularly updated to reflect monitoring-acquired and other new information as well as resolution of and progress on resolving and/or discovery of key uncertainties and lessons learned to help with management of the environmental resources.

1.2 GUIDANCE

The following documents provide distinct Corps policy and guidance that are pertinent to developing this monitoring and adaptive management plan:

- Section 2039 of WRDA 2007, as amended by Section 1161 of WRDA 2016. MONITORING ECOSYSTEM RESTORATION

(a) IN GENERAL-In conducting a feasibility study for a project (or a component of a project) for ecosystem restoration, the Secretary shall ensure that the recommended project includes, as an integral part of the project, a plan for monitoring the success of the ecosystem restoration.

(b) MONITORING PLAN.-The monitoring plan shall- (1) include a description of the monitoring activities to be carried out, the criteria for ecosystem restoration success, and the estimated cost and duration of the monitoring; and (2) specify that the monitoring shall continue until such time as the Secretary determines that the criteria for ecosystem restoration success will be met.

(c) COST SHARE.-For a period of 10 years from completion of construction of a project (or a component of a project) for ecosystem restoration, the Secretary shall consider the cost of carrying out the monitoring as a project cost. If the monitoring plan under subsection (b) requires monitoring beyond the 10-year period, the cost of monitoring shall be a non-federal responsibility.

(d) INCLUSIONS.-A monitoring plan under subsection (b) shall include a description of- (1) the types and number of restoration activities to be conducted; (2) the physical action to be undertaken to achieve the restoration objectives of the project; (3) the functions and values that will result from the restoration plan; and (4) a contingency plan for taking corrective actions in cases in which monitoring demonstrates that restoration measures are not achieving ecological success in accordance with criteria described in the monitoring plan.

(e) CONCLUSION OF OPERATION AND MAINTENANCE RESPONSIBILITY.-The responsibility of a non-federal interest for operation and maintenance of the nonstructural and nonmechanical elements of a project, or a component of a project, for ecosystem restoration shall cease 10 years after the date on which the Secretary makes a determination of success under subsection (b)(2).

(f) FEDERAL OBLIGATIONS.-The Secretary is not responsible for the operation or maintenance of any components of a project with respect to which a non-federal interest is released from obligations under subsection (e). Section 2039 of WRDA 2007 Monitoring Ecosystem Restoration

- USACE. 2009. Planning Memorandum. Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007) - Monitoring Ecosystem Restoration

- USACE. 2000. ER 1105-2-100, Guidance for Conducting Civil Works Planning Studies. Washington D.C.

- USACE. 2003a. ER 1105-2-404. Planning Civil Work Projects under the Environmental Operating Principles. Washington, D.C.

- Section 1131 of the Water Resources Development Act of 2016 (WRDA 2016).

- USACE. 2019. EP 1105-2-58. Planning Continuing Authorities Program. Washington D.C.
- USACE. 2017. Implementation Guidance for Section 1161 of the Water Resources Development Act of 2016 (WRDA 2016), Completion of Ecosystem Restoration Projects.

1.3 PROJECT DESCRIPTION

The purpose and need for the proposed action is to restore habitat and ecosystem function along an approximate 39-mile reach of the LMR and its floodplain in harmony with the existing USACE mission areas of ensuring navigation and flood risk reduction. The project area is a 39-mile reach of the Mississippi River and the surrounding batture (the riverside area between the levee and main channel) beginning at the mouth of the Hatchie River and extending south to the mouth of the Wolf River Harbor (River Mile 775-736). The project area is located in Lauderdale, Tipton, and Shelby Counties, in Tennessee and Mississippi and Crittenden Counties in Arkansas. The tentatively selected plan (TSP), Alternative C3, is a comprehensive plan that collectively addresses historically significant and ecologically important habitats across the 11 geographic complexes of the study area. There are 38 proposed measures across the study area designed to restore ecological structure and function to the mosaic of habitats along the Mississippi River and its active floodplain and an additional 2 measures designed to improve recreational opportunities, public education, and access to public spaces in the study area. The proposed activities include reforestation and forest stand improvements to the bottomland hardwood community focusing on increases in hard mast producing species, creation and enhancement of cypress-tupelo forest communities, creation of riparian buffers along the Mississippi River, restoration and creation of wetland complexes and moist soil management areas, restoration of flow in meander scarps by lowering invert elevations of obstructions and dike notching, increasing connectivity of secondary channels through dike notching, bank protection within secondary channels, installation of large woody debris traps in secondary channels for aquatic invertebrates and fish, and restoring flow/connectivity to floodplain waterbodies primarily through lowering invert elevations of obstructions. The TSP provides 4,673 average annual habitat units (AAHUs) to habitats supporting federally listed endangered aquatic species such as the fat pocketbook mussel and the pallid sturgeon and vegetative habitats that host numerous species of conservation concern. The TSP also supports the promotion of alligator gar spawning habitats, a species known to assist in the control of invasive species such as invasive carp. This TSP selection also contributes to the protection of meander scarps which are rare geological features that no longer occur naturally due to engineering controls along the Mississippi River. Restoring hydrologic connectivity to meander scarps would promote habitat resiliency to sensitive species that are at risk of endangerment as a result of increases in drought intensity due to climate change. The TSP (Alternative C3) and 38 measures with ecological output and is displayed in Figure A9-1 below. Measure descriptions associated with the TSP are included in Table A9-1 below. Additional details of the measures included can be found in the main report.

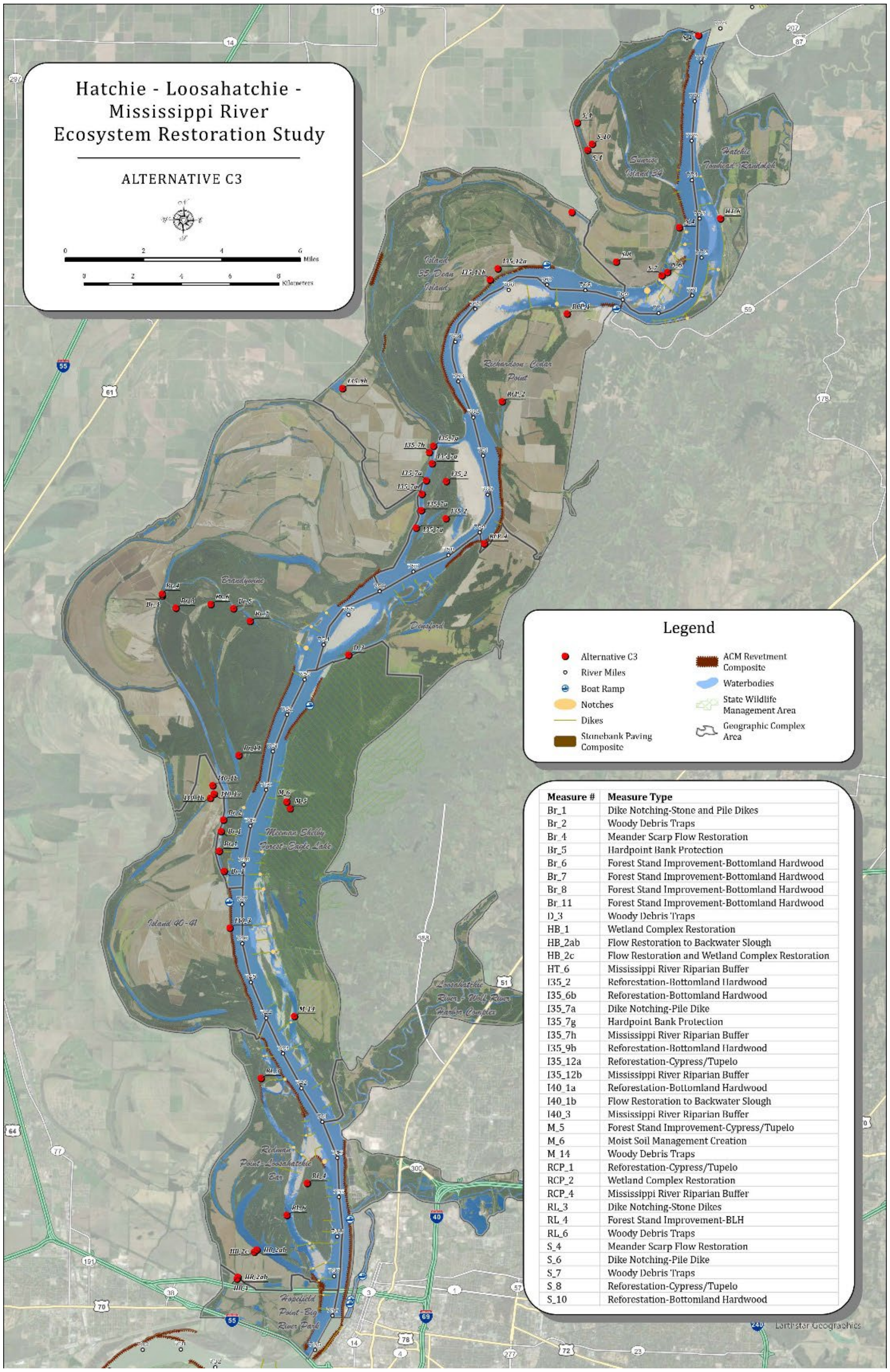


Figure A9- 1. Map of the study area and ecosystem restoration measures comprising the tentatively selected plan.

Table A9- 1: Measure descriptions of the tentatively selected plan and associated habitats.

Measure Number	Habitat	Measure Type
BR_1	Secondary Channels	Dike Notching – Stone and Pile Dikes
BR_2	Secondary Channels	Woody Debris Traps
BR_4	Meander Scarp/Tertiary Channels	Meander Scarp Flow Restoration
BR_5	BLH	Hardpoint Bank Protection
BR_6	BLH	Forest Stand Improvements - BLH
BR_7	BLH	Forest Stand Improvements - BLH
BR_8	BLH	Forest Stand Improvements - BLH
BR_11	BLH	Forest Stand Improvements - BLH
D_3	Secondary Channels	Woody Debris Traps
HB_1	Seasonally Herbaceous Wetland	Wetland Complex Restoration
HB_2ab	Slough	Flow Restoration to Backwater Slough
HB_2c	Seasonally Herbaceous Wetland	Flow Restoration and Wetland Complex Restoration
HT_6	Riverfront Forest – Riparian Buffers	Restoring Habitat Complexity in Borrow Area
I35_2	BLH	Reforestation-BLH
I35_6b	BLH	Reforestation-BLH
I35_7a	Secondary Channels	Dike Notching-Pile Dike
I35_7g	Secondary Channels	Hardpoint Bank Protection
I35_7h	Riverfront Forest – Riparian Buffers	MS River Riparian Buffer
I35_9b	BLH	Reforestation-BLH
I35_12a	Cypress Tupelo	Reforestation-Cypress/Tupelo
I35_12b	Riverfront Forest – Riparian Buffers	MS River Riparian Buffer
I40_1a	BLH	Reforestation-BLH
I40_1b	Slough	Flow Restoration to Backwater Slough
I40_3	Riverfront Forest – Riparian Buffers	MS River Riparian Buffer
M_5	Cypress Tupelo	Forest Stand Improvements-Cypress/Tupelo
M_6	Moist Soil	Moist Soil Management Creation

Measure Number	Habitat	Measure Type
M_14	Secondary Channels	Woody Debris Traps
RCP_1	Cypress Tupelo	Reforestation-Cypress/Tupelo
RCP_2	Seasonally Herbaceous Wetland	Wetland Complex Restoration
RCP_4	Riverfront Forest	MS River Riparian Buffer
RL_3	Secondary Channels	Dike Notching-Stone Dikes
RL_4	BLH	Forest Stand Improvement-BLH
RL_6	Secondary Channels	Woody Debris Traps
S_4	Meander Scarp/Tertiary Channels	Meander Scarp Flow Restoration
S_6	Secondary Channels	Dike Notching-Pile Dike
S_7	Secondary Channels	Woody Debris Traps
S_8	Cypress Tupelo	Reforestation-Cypress/Tupelo
S_10	Riverfront Forest – Riparian Buffers	Reforestation-BLH
LW_1	N/A – Recreation only	Interpretive Media and Demonstration
M_2	N/A – Recreation only	Trails and Signage

The cost share non-federal sponsor for the proposed activities is the Lower Mississippi River Conservation Committee comprised of the state water quality and wildlife agencies along the Lower Mississippi River. Likely cost-share construction sponsors would be comprised of the States of Arkansas and Tennessee and construction is expected to extend for several years dependent on future annual appropriations.

Section 2
Monitoring Plan

2.1 BACKGROUND

A diverse riverine fauna is dependent on habitat diversity, such as diversity in connection frequency, substrate heterogeneity and structural complexity. The 38 measures within the tentatively selected plan (TSP) will improve the habitat within the project reach benefiting the over 100 species of fish living in the Lower Mississippi River (Baker et al 1991). Many of these fish depend on the floodplain for spawning, rearing, and foraging and species, such as suckers, gar, and various species of minnows and shiners move from the river into the floodplain for spawning. Once the eggs hatch, larval fish utilize the diverse food resources found in permanent lakes and flooded bottomland hardwoods before returning to the main channel.

This monitoring plan proposes the framework for monitoring the changes in aquatic species and habitat that will occur with construction of the TSP. Fish, invertebrate, water quality and habitat data will ideally be collected seasonally in habitats affected by project measures or stratified representative habitats within the project reach. Proposed monitoring will be finalized during Preconstruction, Engineering and Design (PED) as measures are refined and site conditions are investigated. Monitoring surveys will assist in presence/absence surveys of federally listed species, potential avoid and minimization measures, and associated tiered Endangered Species Act (ESA) consultations with implementation of individual measures, as detailed in the ESA discussions of the main report. As monitoring is completed, data will be reported and analyzed by USACE and the NFS to facilitate adaptive management. At the completion of the monitoring period, a technical note and/or journal article will be prepared.

2.2 AQUATIC MONITORING

The following activities summarize the basic aquatic monitoring steps.

- Choose representative measures and habitat types and complete: bathymetry, aquatic habitat, water quality, and aquatic fauna surveys.
- Conduct field work to document species and habitat pre- and post-project
- Incorporate data into USACE Engineering Research and Development Center Environmental Lab (ERDC-EL) relational Access databases gathered under the Mississippi River Geomorphology and Potamology program (MRG&P).
- Compare field data to habitat benefit model predictions.

Table A9- 2: Sampling will include sites such as those listed below.

Measure	Actions	Site name	Habitat Type
S_4	Lower obstructions and install chevron	Sunrise Towhead Chute	Meander Scarp
S_4	Remove obstructions	Island 34 Chute	Meander Scarp
S_6	Notch downstream dike and wood trap	Lookout Bar	Secondary Channel
I35_6b	Reforest shore	MRL Borrow Pit 17	Borrow
RCP_2	Plant forest buffer	Richardson Point	Slough
I35_7g I35_7a	Notch pile dikes and hard point bank protection	Dean Island	Secondary Channel

I35_9b	Reforest shore	Pecan Point	Borrow
Br_4	Install weir	McKenzie Chute	Slough
D_3	Wood trap	Densford	Secondary Channel
Br_4 Br_5	Lower bridge, and hard point bank protection	Brandywine Chute	Meander Scarp
I40_1b	Improve connectivity	Danner Lake	Slough
Br_1 Br_2	Notch pile dikes and wood trap	Poker Point	Secondary Channel
M_14	Wood trap	Hickman Bar	Secondary Channel
RL_3	Notch dike in small channel	Redman	Secondary Channel
RL_6	Wood trap	Loosahatchie Bar	Secondary Channel
HB_2ab	Improve connectivity	Big River Park	Slough

2.2.1 Data Acquisition

- Elevation – channel or waterbody bed surveys, swale ground surveys
- Benthic invertebrates and mussels – benthic sled (meander scarps, secondary channels), colonization baskets (wood traps),
- petite ponar (sloughs, borrow areas)
- Adult and juvenile fish – trawls, electrofishing, seines, gillnets
- Water quality – YSI hydrolab and turbidimeter (temperature, pH, conductivity, dissolved oxygen, turbidity)
- Physical parameters – stadia rod and flowmeter (substrate, aquatic vegetation coverage, velocity, and depth cross section)

2.2.2 Elevation Surveys

These surveys will be used to monitor geomorphic change, determine the need for adaptive management, and estimate pre and post project connectivity. Additional more frequent surveys may be needed by engineering to monitor project design and channel conditions.

Survey boat: Large waterbodies that are well connected to the main channel or which have boat ramps can be surveyed using USACE MVM survey boats. Monitoring survey capabilities include single beam surveys, multi-beam surveys and doppler (velocity) surveys. Ideally there will be at least two multibeam surveys of each unidirectional, wood trap, and accessible bidirectional measure's benefit area. These should be completed during high water prior to construction and 5 – 10 years after construction. A point density around 10 ft should be sufficient to capture habitats of interest and model change between pre and post project. Surveying at high water is important to capture shallow areas and areas around structures that would otherwise be inaccessible. The 5 – 10 years between pre and post survey should allow sufficient time for flood and low flows to alter bed material in response to the new flow pattern. A second post project multibeam survey would document if the bed had stabilized.

Drone: Both ERDC and MVN have small aerial drones capable of Lidar data acquisition. With appropriate FAA approval, drone surveys can be an efficient method to gather Lidar data over a small area such as the proposed swales in the Island 40 and Hopefield Big River complexes. Surveys would be completed during low water when the swales were dry. A point density of 5 - 10 ft should be sufficient to capture habitats of interest and model change. One pre and one post project survey could be used to estimate connectivity and monitor geomorphic change. Surveys should be conducted at least five years apart to ensure numerous connection events have occurred and the channel bed has stabilized. A second post project survey would provide additional information on post project bed stability.

Eco-mapper: For small, isolated floodplain waterbodies, bathymetric data could be collected by a YSI i3XO EcoMapper ® autonomous underwater vehicle (AUV) or other remote survey vehicle such as ERDC-CHL's remotely operated survey vessel. Where possible, an evenly ≤ 20 ft spaced grid of depth readings collected during higher water would provide good coverage of the waterbody's bed. If a grid is not possible, the depth readings could be recorded parallel and closest to the shoreline and then in transects perpendicular to the waterbody's long axis with a transect spacing of ≤ 100 ft and at least three transects per waterbody. Stadia rod readings with GPS coordinates may provide supplemental depth readings for large shallow < 2 ft deep areas of the waterbody.

Depending on time and monetary constraints, water surface elevation to convert depth readings may be determined in several ways. The National Geodetic Survey database could be searched to find suitable benchmarks. A Trimble R8 RTK GPS receiver could be utilized to provide survey vessel navigation and positioning. This would provide real time sub-meter level accuracy latitude and longitude for each depth reading. An R8 Base Station affixed with a high output radio could allow for RTK water surface elevation collection at random intervals throughout the survey. A less time-consuming low-cost alternative may be used by intersecting GPS points collected at the water's edge with Lidar data, or by using a surveyor's level set up on the nearby levee slope. For this method, multiple water surface elevations would be calculated, where possible, and averaged to improve accuracy.

2.2.3 Aquatic Fauna Surveys

Sampling is proposed seasonally though climate, site, and funding conditions may alter sampling frequency and timing. Unidirectional channels such as secondary channels and meander scarps and large accessible floodplain waterbodies will be divided up into thirds and sampled with the benthic sled, trawls, seining and electrofishing. Small floodplain lakes such as borrow pits and sloughs will be sampled by seining, petite ponar and possibly gillnets.

These surveys will provide information on fish and invertebrate species that utilize LMRRA waterbodies, including the presence/absence of federally listed species such as fat pocketbook mussel and pallid sturgeon to assist in tiered Endangered Species Act Consultations. In habitats with variable unidirectional flow regimes, the sessile nature of juvenile and some adult macroinvertebrates adapted to lotic or lentic conditions can lead to die offs as conditions change. Therefore, the macroinvertebrate community should respond to the proposed measures that increase the frequency of flowing (lotic) conditions. Collected fish and invertebrate data will be used to compare species presence/absence, abundance, and richness before and after project construction. Data will also be compared to habitat benefit model predictions and to extant data collected since 2000 using the same field techniques.

Benthic Sled: The invertebrate community in unidirectional flowing water habitat will be sampled using a benthic sled described by Harrison et al (2018). Each channel will be divided into upstream, middle, and downstream thirds (where possible). For narrow meander scarps, one benthic sled sample will be completed near the middle of each third. For wider secondary channels, a transect running perpendicular to the channel's long axis will be established near the middle of each third. Three samples will be taken along each transect with the objective of acquiring samples from all substrates present. The sled will be pulled approximately 50-m downstream for each sample. Upon retrieval, a standardized 8-L sample of the collected substrate will be processed. Sediments will be washed on-board and sieved to separate living organisms from inorganic particles and characterize substrate. Organisms will be returned to the laboratory in Vicksburg, MS, for counting and identification. Insects will be identified to genus when possible. Early instars and Chironomidae will likely be identified to family. Mollusks captured live will be identified to family and released (relict mollusks will not be identified). Aquatic worms will be identified to subclass or family if possible. Macroinvertebrates will be assigned into different functional groups (environment, habit, functional feeding group) using available taxonomic literature and professional opinion. The differences in abundance, richness and functional group will be compared pre and post project and between habitats.

Colonization Baskets: Invertebrates will be monitored in colonization baskets to capture their response to the wood traps and associated substrates. Wood traps are vertical driven pilings whose base is protected by rip rap. The pilings are spaced approximately 3 – 5 m apart to capture wood and leaf debris. Thus, cylindrical baskets will be filled with sand, leaf packs (representing leaf debris captured by wood), wood, or rip rap and attached to the wood trap or lollipop buoy. These baskets will serve as a surrogate to sampling the wood traps themselves for invertebrate colonization. Three bouys with six colonization baskets will be placed on or around the proposed wood traps. Each buoy or wood trap will be fitted with each substrate, at randomized positions. Baskets will be retrieved every 3-6 weeks during an 8-month period (invertebrate colonization is very low in winter) to capture seasonal diversity. Upon retrieval, baskets will be placed in buckets of ethanol, and returned to the laboratory for washing, picking, identification, and enumeration. The success of the wood traps will be demonstrated by invertebrate colonization of the wood, rip rap and leaf baskets. As the wood traps add habitat rather than change it, invertebrate colonization of the basket substrates represents an addition of individuals and possibly species that would not be present without project. These additional individuals enhance the aquatic and terrestrial nutrient cycles and riverine food webs, serving as prey items for a multitude of fish species including an LMRRA priority species: Pallid Sturgeon.

Ponar/Ekman: The inaccessibility of floodplain waterbodies means these cannot be sampled with the boat pulled benthic sled. Floodplain waterbodies will be sampled with either a petite Ponar or Ekman grab sampler. These samplers are spring loaded catchment devices. They are lowered to the waterbody bed and the spring released at which point the device snaps closed scooping up soft bed material. This material is then processed similarly to the benthic sled.

Seining: Seining will be used to sample the shallow areas of all waterbodies. For floodplain lakes that are inaccessible by ERDC's trawling/electroshocking boat, seining may be the only method employed to sample the fish community. A seine sample consists of ten seine hauls stratified among all apparent macrohabitats. For flowing and large waterbodies, a sample will be gathered in the upper, middle, and lower sections of the waterbody. One sample will be gathered in smaller floodplain waterbodies. Seines consist of a 10' long and 4' deep net tied to 6' tall poles. The net consists of 3/16" mesh knotless 34lb test nylon with a 1/8" braided nylon top and bottom rope. A lead weight is placed every 12" on the bottom rope and SB3 floats occur every 18" on the top rope. Large fish will be identified to species, measured, and released. Small fish will be preserved in ethanol and transported to the lab for identification and measuring.

Trawling: Trawls have been used by ERDC-EL since the early 2000's to sample benthic fish including Pallid Sturgeon. The Missouri-type otter trawl is similar to that described by Herzog and Barko (2005) and will be used to sample accessible waterbodies (generally unidirectional channels and oxbow lakes). The foot rope of the trawl is 3.3-m wide and fitted with a tickler chain to maintain bottom contact. Two ropes on either side of the trawl opening attach to 0.3x0.6m otter boards which keep the net open while towed along the bottom. When in operation, the gape size is assumed to be 3-m wide and 1-m tall. The trawl has two mesh sizes - 3.8-cm exterior stretch mesh to retain small fish and 5.1-cm interior stretch mesh. Trawl rope length is adjusted to be about three times water depth to ensure the trawl mouth maintains contact with the bottom at a proper angle. The trawl is deployed from the bow while the boat backs downstream. All fish will be identified to species, counted, measured for total length (fork length for sturgeon), and released. Sturgeon will be tagged and weighed. Tissue samples and a pectoral fin ray section from Pallid Sturgeon will be retained for genetic analysis and aging, respectively.

Electroshocking: In all boat accessible waterbodies, fish will be collected with a boat-mounted electroshocker. One electoshocking sample consists of 5-minutes of shocking time with 1 – 3 samples in upper, middle, and lower thirds of large waterbodies and 1 – 3 samples total in smaller waterbodies. Electroshocking will mostly be conducted in littoral habitats, with and without structure, in waters ranging from 1-15 feet to maximize shocking efficiency. The electroshocker consists of 2 anode dropper arrays suspended from a boom in front of the boat. The system is operated with DC pulse at 4-6 amps using a Smith-Root

7.5 GPP system, a 7,500-watt generator, and an estimated output of 2-3 volts/cm within a meter from the anodes. Two people stand at the bow and attempt to collect all visible stunned fish and sweep the substrate to collect stunned fishes lying on the bottom. Fish are collected with l8-inch diameter dipnets made of 1/8-inch mesh to retain small fishes such as minnows, shiners, and juvenile sunfishes. Fish will be identified to species, counted, measured for total length (eye to fork length for Paddlefish, fork length for sturgeon), and released.

<u>Gillnetting</u>: Project measures are proposed for a borrow area surveyed with seines and gillnets as part of the Mississippi River Levees effort. Gillnetting may be included to sample the large-bodied fish community which is rarely captured while seining. Gillnets consist of two 90' X 6' nets with monofilament mesh ranging from 0.75 – 6”. A standard effort includes overnight sets of 5-6 gillnets set perpendicular to shore with the small mesh toward shore. Fish will be counted, measured, may be weighed, and released the following morning.

2.2.4 **Water Quality and Habitat**

Maximum water depth, water velocity, and instream structure, if any, will be recorded along with water quality (temperature C, dissolved oxygen mg/l, conductivity microsiemiens/cm, pH, and turbidity nephelometric turbidity units (NTU)). Water quality will be recorded in flowing and floodplain waterbodies with a YSI ProDss unit. Readings will be taken throughout the water column and sampling area to characterize sampling conditions and if stratification is present. In select waterbodies, data loggers may be deployed to collect more frequent readings.

2.3 VEGETATIVE MONITORING

Vegetative monitoring would utilize established monitoring techniques and published scientific resources to 1) document increases in wetland functions as a result of the restoration activities, 2) identify data-driven success trajectories and milestones, 3) adaptively manage wetland conditions within the project area based upon observed data related to changes in wetland functional capacity over time, and 4) promote native species.

2.3.1 **Data Acquisition**

- tree density (e.g., tree basal area, density by coverage),
- vegetative speciation (e.g., overstory composition),
- sustainability (e.g., regeneration, species represented in vertical strata)
- soil conditions (e.g., O and A horizon)

2.3.2 **Native species**

To promote the native vegetation, with an emphasis on those hard mast species lacking in the study area, appropriate vegetation should be planted on sites designated for reforestation of bottomland hardwood (BLH) and cypress/tupelo communities, riparian buffers, seasonal herbaceous wetland complexes, and forest stand improvements. Only native plants should be planted (Table A9-3) depending on availability at nurseries. Typical planting densities were assumed to be on 10-ft centers; however, site specific determinations would be determined once a site and specific vegetation suite has been selected.

Table A9- 3. Native vegetation targeted for planting at restoration sites.

Acer drummondii	*Planera aquatica*
Acer negundo	*Platanus occidentalis*
Acer rubrum	*Populus heterophylla*
Acer saccharinum	*Quercus lyrata*
Carya aquatica	*Quercus nigra*
Carya laciniosa	*Quercus nuttallii*
Celtis laevigata	*Quercus pagoda*
Diospyros virginiana	*Quercus palustris*
Forestiera acuminata	*Quercus phellos*
Fraxinus pennsylvanica	*Salix nigra*
Fraxinus tomentosa	*Taxodium distichum*
Gleditsia aquatica	*Taxodium ascendens*
Liquidambar styraciflua	*Ulmus americana*
Nyssa aquatica	*Ulmus crassifolia*
Nyssa sylvatica	*Emergent Wetland Seed Mix*

Since all vegetative restoration sites are within the active floodplain, monitoring would also be conducted to demonstrate that vegetation satisfies USACE hydrophytic vegetation criteria. The community would be monitored to ensure it exhibits characteristics and diversity indicative of a viable native forested wetland community, i.e. vegetation community where more than 50% of all dominant species are facultative (FAC), FAC wet and/or obligate. Table A9-4 shows the common wetland vegetation likely at the proposed restoration sites.

Table A9- 4. Common vegetation of the Lower Mississippi Valley.

Abbreviation	**Scientific Name**	**Common Name**	**Status**
ACNE	*Acer negundo*	box elder	FACW
ACRU	*Acer rubrum*	red maple	FACW
ACSA	*Acer saccharinum*	silver maple	FAC
ALPH	*Alteranthera philoxeroides*	alligator weed	OBL
AMTR	*Ambrosia trifida*	ragweed	FAC

AMAR	*Ampelopsis arborea*	pepper vine	FAC+
AMBR	*Amphicarpa bracteata*	hog peanut	FAC
ANVI	*Adropogon virginicus*	Broom sedge	FAC-
ANCA	*Anisostichus capreolata*	cross vine	Upland
ARGI	*Arundinaria gigantea*	river cane	FACW
ARTE	*Arundinaria tecta*	switch cane	FACW
ARTR	*Arisaema triphyllum*	Jack-in-the-pulpit	FACW-
ASPE	*Asclepias perenius*	milkweed	OBL
ASPA	*Asimina parviflora*	Paw Paw	FACU
BESC	*Berchemia scandens*	rattan vine	FACW
BICA	*Bignonia capreolata*	cross vine	FAC
BOCY	*Boehmeria cylindrica*	bog hemp	FACW+
BRCI	*Brunnichia cirrhosa*	redvine	FACW
CACAM	*Callicarpa americana*	beauty-berry	FACU-
CAFL	*Calycanthus floridus*	spicebush	FACU+
CARA	*Campsis radicans*	trumpet creeper	FAC
CACH	*Carex cherokeensis*	Cherokee sedge	FACW
CATA	*Chaerophyllum tainturieri*	Hairfruit chervil	FAC
CACA	*Carpinus caroliniana*	ironwood	FAC
CAAQ	*Carya aquatica*	bitter pecan	OBL
CAGL	*Carya glabra*	pignut hickory	FACU
CAIL	*Carya illinoinensis*	pecan	FACU
CATO	*Carya tomentosa*	mockernut hickory	Upland
CEOC	*Cephalanthus occidentalis*	buttonbush	OBL
CECA	*Cercis canadensis*	redbud	FACU
CELA	*Celtis laevigata*	sugarberry	FACW
COCA	*Cocculus carolina*	Caroline snailseed	FAC
COCO	*Commelina communis*	dayflower	FAC
COAM	*Cornus amomum*	swamp dogwood	FACW+
COFL	*Cornus florida*	flowering dogwood	FACU
COST	*Cornus foemina (stricta?)*	stiff dogwood	FACW-
CRSP	*Crataegus spathulata*	hawthorne	FAC
DEBA	*Decumaria barbara*	climbing hydrangea	FACW
DEIL	*Desmanthus illinoensis*	Illinois bundleflower	FAC
DIVI	*Diospyros virginiana*	persimmon	FAC
ECCR	*Echinochloa crus-galli*	American barnyard grass	FACW
ELUM	*Elaeagnus umbellata*	silverberry	FACU
ELCA	*Elephantopus carolinianus*	elephant's-foot	FAC
FIAU	*Fimbristylis autumnalis*	beak rush	OBL
FOAC	*Forestiera acuminata*	swamp privet	OBL
FRVI	*Fragaria virginiana*	wild strawberry	FAC-

FRAM	*Fraxinus americana*	white ash	FACU
FRPE	*Fraxinus pennsylvanica*	green ash	FACW
GECA	*Geum canadense*	white avens	FAC
GLTR	*Gleditsia triacanthos*	honey locust	FAC-
HACA	*Halesia carolina*	Carolina silverbell	FACU+
HIMI	*Hibiscus laevis (militaris)*	rose mallow	OBL
ILDE	*Ilex decidua*	deciduous holly	FACW-
IMCA	*Impatiens capensis*	jewel-weed	FACW
IVAN	*Iva annua*	Sump weed	FAC
JUNI	*Juglans nigra*	black walnut	FACU
JURE	*Juncus repens*	lesser creeping rush	OBL
JUTE	*Juncus tenuous*	path rush	FAC
LELE	*Leersia lenticularis*	catchfly cutgrass	OBL
LISI	*Ligustrum sinense*	privet	FAC
LIST	*Liquidambar styraciflua*	sweetgum	FAC+
LITU	*Liriodendron tulipifera*	yellow poplar	FAC
LOJA	*Lonicera japonica*	Japanese honeysuckle	FAC-
LUPA	*Ludwigia papilloides*	floating primrose-willow	OBL
MIVI	*Microstegium virmineum*	Microstegium	NL
MORU	*Morus rubra*	red mulberry	FAC
NYSY	*Nyssa sylvatica*	blackgum	FAC
OPHI	*Oplismenus hirtellus*	basket grass	FACU+
OSVI	*Ostrya virginiana*	hop hornbeam	FACU-
PAQU	*Parthenocissus quinquefolia*	Virginia creeper	FAC
PHAU	*Phyllostachys aurea*	Chinese bamboo	
PIPU	*Pilea pumila*	clearweed	FACW+
PITA	*Pinus taeda*	loblolly pine	FAC
PLAQ	*Planera aquatica*	water elm	OBL
PLOC	*Platanus occidentalis*	sycamore	FACW-
POAC	*Polystichum acrostichoides*	Christmas fern	FAC
PODE	*Populus deltoides*	cottonwood	FAC+
POHY	*Polygonum hydropiperoides*	swamp smartweed	OBL
POPU	*Polygonum punctatum*	knotweed	FACW+
POPE	*Polygonum pennsylvanica*	Pennsylvania Smartweed	FACW
PRSE	*Prunus serotina*	black cherry	FACU
PULO	*Pueraria lobata*	kudzu	Upland
QULY	*Quercus lyrata*	overcup oak	OBL
QUNI	*Quercus nigra*	water oak	FAC

QUNU	*Quercus nuttallii*	Nuttall oak	OBL
QUPA	*Quercus pagoda*	cherrybark oak	FAC
QUPH	*Quercus phellos*	willow oak	FACW-
QURU	*Quercus rubra*	red oak	FACU
RUAR	*Rubus argutus*	blackberry	FAC-
RUCR	*Rumex crispus*	Curly dock	FAC
SACE	*Saururus cernuus*	lizard's tail	OBL
SANI	*Salix nigra*	black willow	OBL
SACA	*Sambucus canadensis*	elderberry	FACW-
SEEX	*Sesbania exaltata*	bigpod sesbania	FACW
SMLA	*Smilax laurifolia*	green briar	FACW+
SMRO	*Smilax rotundifolia*	green briar	FAC
SOAL	*Solidago altisima*	Goldenrod	FACU
SOHA	*Sorghum halpense*	Johnson grass	FACU
TADI	*Taxodium distichum*	Cypress	OBL
TORA	*Toxicodendron radicans*	poison ivy	FAC
TRDE	*Treclospermum deforma*	climbing star-jasmine	FACW
TOVI	*Tovara virginiana*	jumpseed	FAC
ULAL	*Ulmus alata*	winged elm	FACU+
ULAM	*Ulmus americana*	American elm	FACW
UNLA	*Chasmanthium latifolium*	Spikegrass	FACU
VAST	*Vaccinium stamineum*	huckleberry	FACU
VEHA	*Verbena hastata*	swamp verbena	FAC
VIFL	*Viola floridana*	common blue violet	FACW-
VICI	*Vitus cinerea*	graybark grape	FAC+
VIRO	*Vitus rotundifolia*	muscadine	FAC

2.3.3 **Invasive species**

The promotion of native vegetation, often requires control of invasive vegetative species. Table A9-5 shows a list of invasive species that would be monitored for at the LMR restoration sites that could trigger adaptive management actions.

Table A9- 5. Invasive species potentially found at restoration sites during monitoring events.

Common Name	**Species**
Alligatorweed	*Alternanthera philoxeroides*
Water hyacinth	*Eichhornia crassipes*
Parrotfeather	*Myriophyllum aquaticum*

Cuban bulrush	*Oxycaryum cubense*
Giant salvinia	*Salvinia molesta*
Chinese tallow	*Triadica sebifera*
Common privet	*Ligustrum vulgare*
Eurasian water milfoil	*Myriophyllum spicatum*
Brazilian elodea	*Egeria densa*
Purple loosestrife	*Lythrum salicaria*
Canary reed grass	*Phalaris arundinacea*
Cogongrass	*Imperata cylindrica*
Kudzu	*Pueraria montana*
Japanese climbing fern	*Lygodium japonicum*
Tree of heaven	*Ailanthus altissima*
Japanese wisteria	*Wisteria floribunda*
Trifoliate orange	*Poncirus trifoliata*
Russian olive	*Elaeagnus angustifolia*
Canada thistle	*Cirsium arvense*
Leafy spurge	*Euphorbia esula*
Common reed	*Phragmites australis*
Japanese honeysuckle	*Linceria japaneas*

2.4 SCHEDULE

Field sampling will occur periodically over the ten-year monitoring period to track progress of restoration effects. Analysis will continue over the study period as new data become available. A schedule of monitoring is included in See additional details in Cost and Schedule (Section 3).

Table A9- 6. Table of scheduled monitoring activities.

Monitoring/Adaptive Management Action	Measure Type	**Year(s) conducted	*Stratified across similar habitats/measures (Yes/No)
Aquatic Bathymetric Survey - (Aquatic)	Dike Notching; Woody Debris Traps; Meander Scarp Flow Restoration; Hardpoint Bank Protection	0,1,3,5,7,10	No
Aquatic Lidar Surveys (ROV)-Small Channels (Aquatic)	Flow Restoration to Backwater Slough	0,7	Yes

Fish & Invertebrate Surveys Monitoring - (Aquatic)	Dike Notching; Meander Scarp Flow Restoration; Flow Restoration to Backwater Slough	0,3,5,7,10	Yes
Fish Surveys Monitoring – River Training Sturcutres (Aquatic)	Hardpoint Bank Protection	0,3,5,7,10	Yes
Fish Surveys - Borrow Areas (Aquatic)	None in tentatively selected plan (TSP)****	0,3,5,7,10	Yes
Colonization Basket (Aquatic)	Woody Debris Traps	1,3,5,7,10	Yes
Monitoring and Invasive Species Control (Vegetative)	Reforestation; Forest Stand Improvements; Wetland Complex Restoration; MS River Riparian Buffer	0,1,3,5,9	No

* aquatic faunal surveys would be stratified according to similar habitats and restoration activities.

**year 0= baseline monitoring

*** no baseline vegetative monitoring needed at Year 0 on agricultural fields to be reforested.

****no measures in TSP included borrow areas (some measures were included in other alternatives in the final array).

2.5 RESULTS AND DELIVERABLES

Annual monitoring reports will be prepared at the conclusion of each monitoring event that summarizes the data collected and determines if adaptive management is needed. A final monitoring report would be completed to detail the outcomes of the restoration actions. This study will result in documented ecosystem response to restoration, a better understanding of the importance of restoration measures and habitats to endangered species and priority species, and a better understanding of the effects of environmental engineering techniques on species assemblage, habitat, and sustainability. The data collected will be combined with ERDC-EL’s long term database to be used for years to come to inform multiple types of investigations, including but not limited to habitat restoration. Additional products may be prepared as collaboration continues between USACE project and programs, non-federal sponsors, NGO’s, and other research groups.

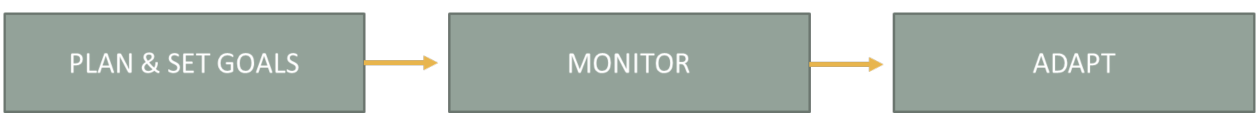
Section 3
Adaptive Management

3.1 INTRODUCTION

Adaptive Management prescribes a process wherein management actions can be changed in response to monitored system response, as to maximize restoration efficacy or achieve a desired ecological state. The basic steps include:

- Plan: Defining the desired goals and objectives, evaluating alternative actions, and selecting a preferred strategy with recognition of sources of uncertainty.
- Design: Identifying or designing a flexible management action to address the challenge.
- Implement: Implementing the selected action according to its design.
- Monitor: Monitoring the results or outcomes of the management action.
- Evaluate: Evaluating the system response in relation to specified goals and objectives.
- Adjust: Adjusting (adapting) the action if necessary to achieve the stated goals and objectives.

The challenges of ecosystem restoration and the philosophy behind Adaptive Management are captured in the following summary statement: Because of the changing conditions and uncertainties, ecosystem stability can only be viewed as a short-term objective. Long-term restoration must be an ongoing process whereby restoration implementation becomes a continuing series of management decisions. Each decision should be based upon a growing pool of research information, updated measurements of ecosystem responses, and evaluations of degrees of progress in reaching a set of goals or targets that have been identified as indicative of ecosystem vitality (Davis and Ogden 1994).



3.2 CONCEPTUAL ECOLOGICAL MODEL

A Conceptual Ecological Model (CEM) identifies the major stressors and drivers affecting the proposed ecosystem restoration project. Figure A9-2 shows the CEM developed as part of the Lower Mississippi River Resources Assessment (LMRRA) that recommended this feasibility study in the Hatchie-Loosahatchie Reach (USACE 2015).

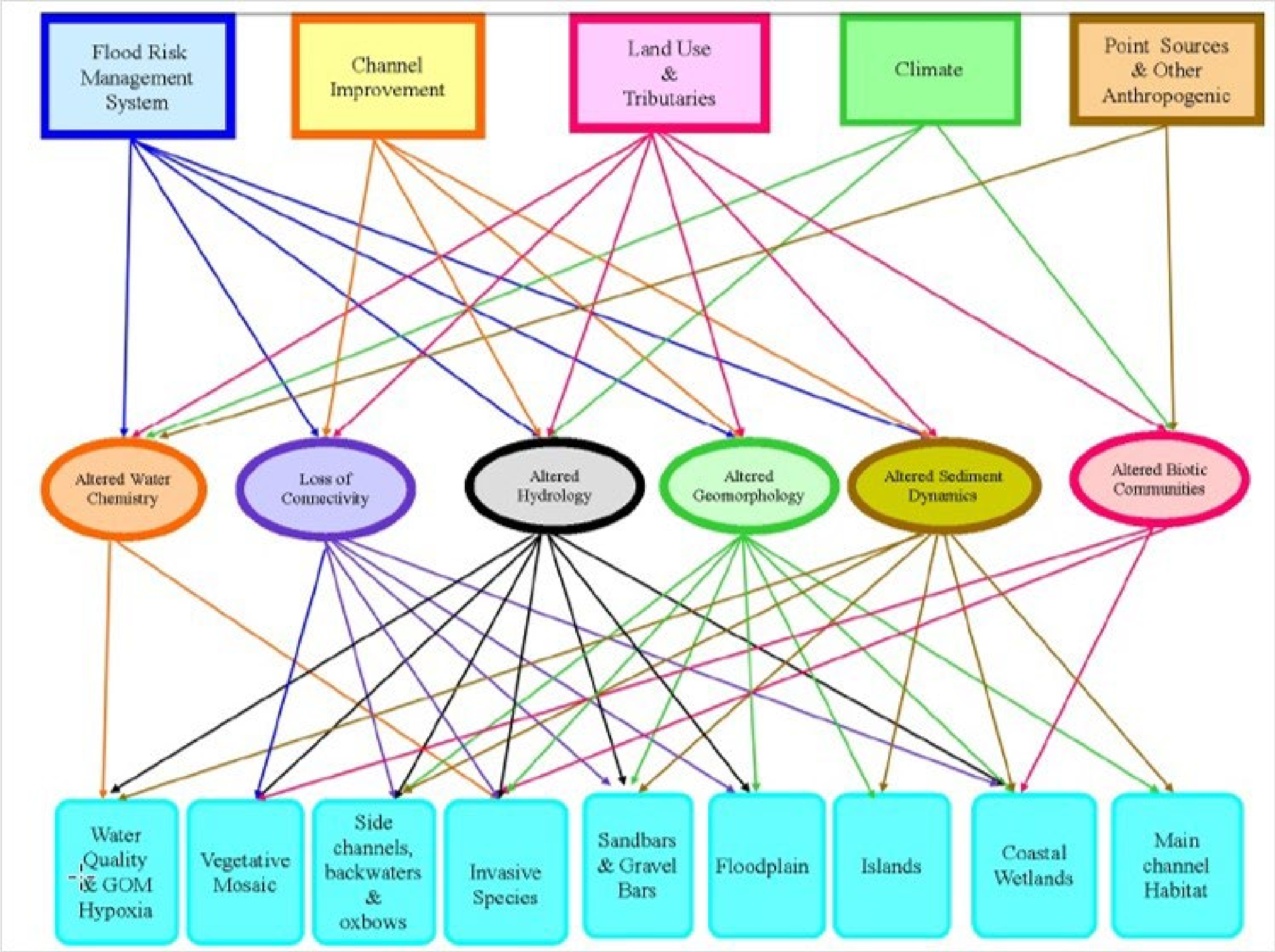


Figure A9- 2. Conceptual Ecological Model for the Lower Mississippi River Resources Assessment.

3.3 OBJECTIVES, MONITORING TASKS, PERFORMANCE CRITERIA, AND ADAPTIVE MANAGEMENT

The monitoring objectives are specific to the proposed features and are different from the planning objectives.

Monitoring Objective 1: Reforestation, Forest Stand Improvements, and seasonal herbaceous wetland active plantings

Floodplain reforestation always involves planting either Cypress/Tupelo or bottomland hardwood species (with a focus on hard mast species) to reintroduce these rare forest types, as previously described. Floodplain reforestation targeted areas of migratory bird priority to address goals of the Lower Mississippi Valley Joint Venture for reforestation to benefit breeding birds (https://www.lmvjv.org/), areas on public land, and frequently inundated agriculture. Floodplain reforestation introduces rare forest types back into the local ecosystem. These trees will provide unique habitat and benefit the species that utilize the surrounding forest. Enlarging contiguous tracts of forest (to create forest core areas with > 1 km of forest in all directions) will benefit declining populations of birds that rely on forest interior (Twedt et al. 2006). Finally, the seeds produced could result in further increases of these forest types.

Forest enhancement involved improving existing areas of forest. These areas were generally identified by the project delivery team and NFS members with local site knowledge. Creating canopy gaps by tree girdling was the primary method chosen to improve forest stands to create canopy gaps, followed by active plantings of native hard mast species. During plans and specifications, property or personal safety concerns may modify this approach. Tree girdling creates standing dead trees which are eaten by insects that then feed birds, and other wildlife, and roosting habitats for sensitive bat species. Additionally, many birds, including the Prothonotary warbler, and mammals create and use nest cavities in dead trees. Eventually when the trees fall, they provide a source of floodplain and aquatic dead wood benefiting numerous additional insect and fungus species.

Herbaceous wetland planting proposed to plant wetland species via a wetland seed mix on suitable wet agricultural ground. The distribution of emergent, floating, and submersed aquatic vegetation is dependent on flow regime and elevation relative to the river. River flows scour many aquatic habitats preventing aquatic vegetation establishment. With increased disconnection from the Mississippi River’s turbid and scouring flows and protection from agricultural runoff, floodplain waterbodies (borrow areas, sloughs, crevasses) can develop a variety of vegetation types. As water clarity improves, the most protected lakes can support submersed aquatic plants such as pondweeds. Due to extensive floodplain agriculture, floodplain channelization, and invasive species, aquatic vegetation has likely declined.

Monitoring Task: Monitoring would include surveying planted trees for survivability and to ensure the sites exhibit characteristics and diversity indicative of a viable native forested wetland community, i.e. vegetation community where more than 50% of all dominant species are facultative (FAC), FAC wet and/or obligate.

Performance Criteria: Maintaining a minimum survival of 70% of planted living native canopy species per acre (density may include planted trees and/or naturally recruited native canopy species would be used as success criteria. The goal is to ensure that desirable native species, including mast-producers are included in the reforestation since these are not usually readily available in the local seed bank. Minimum survival of planted canopy species is necessary to ensure that a suitable amount of canopy is replaced, in time, to promote species diversity, improve forage and nutrient cycling, enhance surface protection, and to restore habitat for migratory songbirds and other species. Demonstrating that vegetation satisfies USACE hydrophytic vegetation criteria. Community must exhibit characteristics and diversity indicative of a viable native forested wetland community, i.e. vegetation community where more than 50% of all dominant species are facultative (FAC), FAC wet and/or obligate would be used as success criteria. Total average vegetative cover accounted for by invasive species constituting less than 5% of the total average plant cover would be used as success criteria. If tree density and/or invasive species success criteria are not met, adaptive management would be required.

Adaptive Management: If invasive species are present, invasive species control and species management would occur. If tree survivability is low, the trees will be inventoried by species to determine if some species are more successful than others. The area would be replanted with a mix of trees with a higher probability of survival.

Monitoring Objective 2: Mississippi River Riparian Buffer

In areas where there is not an existing 300-ft. buffer along the top bank of the Mississippi River, restoration activities involve restoration through natural succession. Due to the small likelihood of planting success and abundant seed sources along the top bank of the Mississippi River, allowing for natural succession to occur with black willows, cottonwood, sycamore, and other riverfront species quickly invading the area is the proposed restoration measure. The top bank of the Mississippi River exhibits high flows and erosive activity during annual high water events. Reestablishing a 300-ft buffer will allow for increased bank stability, nutrient retention, habitat for migratory birds and travel corridors for other wildlife, and additional detritus to make its way into the aquatic environment for increased invertebrate abundance and diversity leading to larger and more numerous fish populations.

Monitoring Task: Vegetative speciation and stem densities of native trees will be measured and recorded.

Performance Criteria: In mature riparian floodplain forests, canopy tree stem density is roughly 150 stems per acre, indicating a tree spacing of 16 to 18 feet, according to USDA-NRCS Riparian Forest Buffer Specifications. This stem density of native trees will be used as the success criteria. Total average vegetative cover accounted for by invasive species constituting less than 5% of the total average plant cover would be used as success criteria. If tree density and/or invasive species success criteria are not met, adaptive management would be required.

Adaptive Management: Invasive species control would occur if the specified stem densities of native trees are not met. Planting of native trees would occur if invasive species control is ineffective.

Monitoring Objective 3: Alter aquatic connectivity

All waterbodies within the active floodplain experience a variety of flow regimes. For this study, regimes were characterized by the primary direction of flow: upstream to downstream flow (unidirectional), bidirectional (backwater) flow where river water flows into and out of the same channel, and minimal flow (isolation). Secondary channels and meander scarps flow from upstream to downstream at most river stages. As the river level drops, these channels can experience bidirectional flow as obstructions (sand, bedrock, clay deposits, rock, pile, and road crossings) become exposed and block unidirectional flow. When this occurs, groundwater and connected lakes can feed water into the channel. This water can then flow out the upstream and/or downstream ends to the main channel. Alternatively, river water can flow in and back up to the obstruction creating connected backwaters. If there are multiple obstructions, isolated pools may occur.

It is likely that secondary channels and meander scarps experienced all of these conditions with fluctuating river levels prior to European colonization. Maintaining channels in a variety of conditions will likely lead to greater system biodiversity. It is also likely that manmade obstructions (rock dikes, pile dikes, and road crossings) have skewed the system wide connectivity of primarily unidirectional waterbodies towards a less connected system. Additionally, increasing the time period, quantity, and velocity of unidirectional flow can increase sediment removal. In other words, sediment deposits in secondary channels and meander scarps as flow decreases. With enough time this sediment may vegetate leading to these habitats transitioning to isolated floodplain sloughs and eventually wetlands. In addition to improving waterbody longevity, increasing unidirectional flow ensures aquatic species access to these channels and the habitats that connect to them, and promotes persistence of species that require flowing water away from navigation disturbances.

Floodplain borrow areas, crevasses, sloughs, scour holes and oxbow lakes predominantly connect to the river through bidirectional flow. During moderate stages typically from late winter to early summer, the main channel rises enough for river water to flow up small natural and manmade floodplain channels and into floodplain waterbodies. When the river drops, the direction of flow reverses and water flows from the waterbodies back into the river. The water brought in during these backwater events carries minimal sediment because it is low velocity water from the top of the water column. During larger more infrequent floods, the Mississippi flows across the floodplain resulting in floodplain waterbodies experiencing unidirectional flows which can scour/deposit sediment and flush organisms, organic matter, and nutrients into the main channel. In some instances, large floods can create new floodplain waterbodies or completely fill existing waterbodies. Improving bidirectional connectivity allows aquatic organisms to access waterbodies through lower velocity backwater flows. Measures seek to restore bidirectional connectivity to a more natural state removing or altering man made obstructions and alterations. This often includes removing or replacing culverts, berms and crossings and removing sediment from agricultural runoff. Because access to the active floodplain's private lands had to be maintained, fish friendly structures were proposed incorporating minimal vertical drop, maximizing the amount of time at least 1 foot of water was present and considering the need for baffles to provide velocity refugia for upstream passage.

Low uni- and bidirectional connectivity creates isolated aquatic habitats which promote unique backwater and wetland species. Prior to levee construction, isolated waterbodies were likely widespread on the edges of the LMR floodplain. During infrequent large floods, these waterbodies were connected to the river. When connected the rare fish community was picked up in flood waters and spread. These fish sometimes perished but sometimes settled in new suitable habitats, preserving, and increasing system species diversity.

Today every year or every other year, floodwaters spread across the great majority of the active floodplain because it is constrained by the levees. This connects all but the most elevated waterbodies. With this connection, competitive riverine fish move in and dominate most communities until water quality or predation diminish their numbers. This decreases the prevalence of wetland fishes including Flier, Taillight Shiner, Pirate Perch, Banded Pygmy Sunfish, Bantam Sunfish, several species of darters and others. Isolated waterbodies may also have lower turbidity as bottom sediments are less frequently mobilized with inflowing water. Lower turbidity and compacted bed sediment promotes aquatic and wetland plant species, further increasing habitat value. Finally decreased connectivity may decrease abundance of invasive species. Invasive Carp utilize flow paths to move into floodplain waterbodies to feed on the abundant plankton depleting the food supply at the base of the food chain. They can also disrupt native fish nest building and guarding (most sunfishes), and eventually become the dominant biomass. Reducing connectivity may reduce carp recruitment and will provide better management options.

Monitoring Task: Aquatic bathymetric surveys would occur on secondary channels and meander scarps and aquatic lidar surveys would occur on smaller bi-directional flowpaths connecting to sloughs and other floodplain waterbodies, as detailed in Section 2.2.2. Fish and aquatic macroinvertebrate surveys would be conducted using the methods identified in Section 2.2.2.

Performance Criteria: Bathymetric and lidar elevation data would be analyzed to determine increases or decreases in connectivity. Success criteria includes increased or decreased connectivity, depending on individual measure goals, compared to baseline conditions. There are no specific success criteria for aquatic fauna.

Adaptive Management: If connectivity goals from baseline conditions are not achieved, modifications of obstructions such as blockage removals or modifications to invert elevations would be required.

Monitoring Objective 4: Aquatic channel enhancement through Woody Debris Traps or rock structures

Aquatic enhancement includes measures that 1) modify or build rock structures like hardpoints or chevrons, or 2) install wood debris traps in secondary channels. Unlike unidirectional and bidirectional measures, the primary purpose of these measures does not involve connectivity but rather diversifying the hydraulic environment and promoting more structural diversity.

Rock structures are proposed to alter the flow of water creating diverse flow patterns which in turn alter sediment distribution and create a riverbed with varying substrate and elevation. Measures propose to enlarge or add to existing dike notches which would divert more water into the downstream secondary channel but not alter connectivity. Hard points are proposed along banklines to create bathymetric diversity and protect adjacent floodplain. Eddies form around hard points which benefit numerous species which feed on the small-bodied organisms trapped in the swirling currents. The final type of rock structure proposed in this study are chevrons. Chevrons look like a horseshoe pointed upstream and have scouring flows along the legs that can clear fine sediment off of gravel, and/or protect valuable floodplain habitat and recreational infrastructure.

Wood debris traps are proposed to add additional woody debris to the Lower Mississippi River. Bank stabilization and floodplain forest management has likely led to a decrease in the amount of woody debris within the river affecting nutrient dynamics and the species that utilize woody habitat. Secondary channels are an ideal location to add woody debris. Secondary channel velocities are generally lower so the wood will not be washed away, the habitat is accessible to main channel species, and the wood will not impact navigation.

Monitoring Task: Monitoring tasks for rock structures entail bathymetric monitoring, fish surveys utilizing various gear types, and invertebrate surveys using a benthic sled, as detailed in Section 2.2.3. Monitoring of woody debris traps include bathymetric monitoring and monitoring of colonization baskets for aquatic macroinvertebrates, as detailed in Section 2.2.3.

Performance Criteria: Structures and bathymetric monitoring would be inspected to ensure structure integrity and stabilization and habitat conditions. Habitat conditions and faunal communities would be compared to baseline conditions to document changes. There are no specific performance criteria for this. Generally, increased habitat complexity of structures and the addition of large woody debris will result in new habitats for aquatic communities. If the surveys show the structures are not performing as expected or anomalies in habitat conditions, modifications during operations and maintenance activities would occur. Structures would continue to provide aquatic habitat in non-pristine conditions.

Adaptive Management: If localized issues are identified to woody debris traps, they can be addressed with field crews and equipment such as chainsaws, boats, and winches. If rock structures were completely destroyed, it would require design changes and new structures during operation and maintenance. The report addressed this risk and found it to be very low, therefore no cost for this is included for adaptive management.

Section 4
Costs and Schedule

4.1 COSTS AND SCHEDULE

Costs associated with implementing this M&AM Program were estimated based on available data and may be revised as additional information becomes available. Section 2039 of the WRDA 2007 allows monitoring for up to ten years post-construction. For cost estimating purposes, this ten-year monitoring timeframe was assumed for all performance measures. The need for additional monitoring to determine the project's ecological success would be assessed at the end of the 10-year cost-shared period, and any additional monitoring would be a 100-percent non-Federal Sponsor responsibility. Section 2039(e) of WRDA 2007, as amended, directs that the responsibility of a non-federal interest for operations and maintenance (O&M) of the nonstructural and nonmechanical elements of a project (or component of a project) for ecosystem restoration shall cease 10 years after the date on which the Secretary makes a determination of success. The Secretary is not responsible for the O&M of any components of a project with respect to which a nonfederal interest is released from obligations. The M&AM program establishes a feedback mechanism whereby monitored conditions will be used to adjust or refine construction and or maintenance actions to better achieve project goals and objectives. Table A3-8 presents the breakdown of the schedule and associated costs for the various types of measures in the TSP for M&AM.

Table A9- 7. Cost breakdown form Monitoring and Adaptive Management of proposed measures in the TSP.

Monitoring/Adaptive Management Action	Measure Type	Year(s) conducted/ assumed	Unit Price Cost	Cost Assumptions
Aquatic Bathymetric Surveys - Rivers/Secondary Channels (Aquatic)	Dike Notching; Woody Debris Traps; Meander Scarp Flow Restoration; Hardpoint Bank Protection	0**,1,3,5,7,10	$450/mile	
Aquatic Lidar Surveys (ROV)- Small Channels (Aquatic)	Flow Restoration to Backwater Slough	0**,7	$2,400/event	Unit price is $60,000 by the total number of locations (25) that apply to this function; the cost of the survey is $30,000 per event, two events at year 0 & 7
Fish & Invertebrate Surveys Monitoring - Bidirectional, Unidirectional, Isolation (Aquatic)	Dike Notching; Meander Scarp Flow Restoration; Flow Restoration to Backwater Slough	0**,3,5,7,10	$4,167/event	Unit price is $125,000 divided by the total number of locations (30) due to monitoring being stratified across measures
Fish Surveys Monitoring - Velocity and Eddy (Aquatic)	Hardpoint Bank Protection	0**,3,5,7,10	$12,000/event	Unit price is $60,000 divided by the total number of locations (5) due to monitoring being stratified across measures
Fish Surveys - Borrow Areas (Aquatic)	None in TSP****	0**,3,5,7,10	$5,455/event	Unit price is $60,000 divided by the total number of locations (11) due to monitoring being stratified across measures
Colonization Basket (Aquatic)	Woody Debris Traps	1,3,5,7,10	$6,000/event	Unit price is $30,000 divided by the total number of locations (5) due to monitoring being stratified across measures

Vegetative Monitoring and Invasive Species Control (Vegetative)	Reforestation; Forest Stand Improvements; Wetland Complex Restoration; MS River Riparian Buffer	0***,1,3,5, 9	$240/hour + 3% inflation each year	Includes hourly cost/acre for monitoring, and concurrent control of competition/invasive species control. This includes: 1 scientist and 1-technician @ $240/hour; 0.5hrs/acre for tracts <$100 acre and 0.1hrs/acre for tracts >100acres; and additional 3%/year added for inflation.
5% Replanting Cost (Vegetative)	Reforestation-BLH and Cypress/Tupelo; Forest Stand Improvements; Wetland Complex Restoration; Moist Soil Management	5*	5% of initial planting cost	5% of initial planting costs (materials and labor).

* aquatic faunal surveys would be stratified according to similar habitats and restoration activities.

**year 0= baseline monitoring

*** no baseline vegetative monitoring needed at Year 0 on agricultural fields to be reforested.

****no measures in TSP included borrow areas (some measures were included in other alternatives in the final array).

In addition to the costs shown in Table A9-1, Adaptive Management and Monitoring Program Management, Data Management and Implementation Costs were included; the total Cost for the M&AM of the TSP is estimated at $3,943,901.

References and Resources

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List of Acronyms and Abbreviations

AUV	Autonomous Underwater Vehicle
BLH	Bottomland Hardwood
ERDC-EL	Engineer Research and Development Center – Environmental Lab
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FAC	Facultative
LMRRA	Lower Mississippi River Resources Assessment
M&AM	Monitoring and Adaptive Management
MVM	Memphis District
MVN	New Orleans District
NGO	Non-governmental Organization
PED	Preconstruction Engineering and Design
TSP	Tentatively Selected Plan
USACE	US Army Corps of Engineers
WRDA	Water Resources Development Act