Appendix H
Monitoring and Adaptive Management

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UPPER MISSISSIPPI RIVER RESTORATION SYSTEM
FEASIBILITY REPORT
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

HARLOW ISLAND HABITAT REHABILIATION
AND ENHANCEMENT PROJECT

MIDDLE MISSISSIPPI RIVER MILES 140.5 THROUGH 144.0
JEFFERSON COUNTY, MISSOURI

APPENDIX H
MONITORING AND ADAPTIVE MANAGEMENT

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1 INTRODUCTION

The 1985 Supplemental Appropriations Act (Public Law 99-88) and Section 1103 of the Water Resources Development Act of 1986 (Public Law 99-662) authorized implementation of ecosystem restoration projects to ensure the coordinated development and improvement of the Upper Mississippi River System. Section 2039 of WRDA 2007 requires that when conducting a feasibility study for ecosystem restoration, the proposed project includes a plan for monitoring the success of the ecosystem restoration. Additionally, paragraph (3)(d) of Section 2039 states that "an adaptive management plan will be developed for ecosystem restoration projects…appropriately scoped to the scale of the project." 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. Adaptive management "prescribes a process wherein management actions can be changed in response to monitored system response, so as to maximize restoration efficacy or achieve a desired ecological state" (Fischenich et al. 2012).

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 within the Upper Mississippi River Restoration (UMRR) Program. Using an adaptive management approach during project planning enabled better selection of appropriate design and operating scenarios to meet the Harlow Island HREP project objectives. Lessons learned in designing, constructing, and operating similar restoration projects within the UMRS have been incorporated into the planning and design of this HREP to ensure that the proposed plan represents the most effective design and operation to achieve project goals and objectives.

The adaptive management for the Harlow Island HREP describes and justifies whether adaptive management is needed in relation to the proposed project management alternatives identified in the project feasibility study. This appendix outlines how the results of the project-specific monitoring plan would be used to adaptively manage the project, including monitoring targets which demonstrate project success in meeting project objectives. The District's intent was to develop monitoring and adaptive management actions appropriate for the project's goal and objectives.

Adaptive management provides a process for making decisions in the face of uncertainty. The primary incentive for implementing an adaptive management plan is to increase the likelihood of achieving desired project outcomes given the identified uncertainties, which can include incomplete description and understanding of relevant ecosystem structure and function; imprecise relationships among project management actions and corresponding outcomes; engineering challenges in implementing project alternatives; and ambiguous management and decision-making processes. Additional uncertainties (i.e., scientific and technological) relating to the proposed project were identified by the project team which included:

- Mississippi River hydrology
- Presence and introduction of invasive species
- Measurable fish movement between the backwater and the Mississippi River
- Future climate change projections (e.g., flood events, growing season lengths, ice cover, migration patterns)

2 GOALS AND OBJECTIVES

The primary goal of the Harlow Island HREP is to improve conditions in bottomland hardwood forest ecosystems can establish and regenerate. Additionally, the Project would improve backwater depth and connectivity to the Mississippi River and improve the quality and diversity of the wetland ecosystem resources in the Project Area. Implementation of the proposed plan would increase the quality and quantity of ecosystem resources and meet the life requisites for a diverse suite of native floodplain and aquatic species. Dredging the backwater to re-establish connectivity to the main channel, while increasing the width and depth improves aquatic ecosystem function by increasing spawning and rearing opportunities for a wide variety of aquatic life. Protecting the Project Area from coarse sediment deposition and allowing backing of water from downstream allows the soils to improve over time and support larger forest community diversity. Restoring wetlands within the Project Area would increase plant species diversity and provide habitat for a variety of terrestrial wetland dependent species. Improving floodplain forest community with age, structural, and species diversity would improve terrestrial habitat for a variety of floodplain species. The following objectives and proposed restoration features were considered in detail to achieve the Project goals:

1) Restore topographic diversity in the Project Area.
2) Increase connected aquatic backwater habitat with depth diversity for enhanced fisheries benefits.
3) Increase fine soil deposition within the Project Area suitable for hard mast forest.
4) Restore floodplain forest communities.

3 SOURCES OF UNCERTAINTY

Adaptive management provides a process for making decisions in the face of uncertainty. The primary incentive for implementing an adaptive management plan is to increase the likelihood of achieving desired project outcomes given the identified uncertainties, which can include incomplete description and understanding of relevant ecosystem structure and function; imprecise relationships among project management actions and corresponding outcomes; engineering challenges in implementing project alternatives; and ambiguous management and decision-making processes. Following is a list of uncertainties associated with Harlow Island HREP.

- **Backwater Habitat**
    - River-borne sedimentation during high flow events, potentially decreasing the depth and/or disconnecting the lower entrance/exit of the backwater from the Mississippi River
    - Deposition of large woody debris during high flow events
- **Area protected from Coarse Sediment**
    - Deposition rates of silt behind the sediment deflection berm, i.e., high flow event dependent
- **Wetland Habitat**
    - Deposition within the excavated wetland area
- **Floodplain Forest Habitat**
    - Survival rates of reforestation in the MMR

4 MONITORING OF OBJECTIVES TO DETERMINE PROJECT SUCCESS AND ADAPTIVE MANAGEMENT MEASURES

The power of a monitoring program developed to support determinations of project success and inform adaptive management lies in the establishment of feedback between continued project monitoring and corresponding project management. This monitoring and adaptive management plan was developed with input from state and federal resource agencies. Performance indicators to the above objectives were developed with the best available knowledge. They were developed to be specific, measurable, attainable, realistic, and timely. Current performance indicators are summarized in Table 1. The conceptual monitoring schedule and estimated costs are provided in Table 2.

Each project objective was assessed by at least one performance indicator. For each performance indicator, the rationale behind the indicator and the methodology used are discussed. In addition, the monitoring targets (also referred to as desired outcomes) and action criteria (also referred to as adaptive management triggers) are listed. The action criteria are used to determine if and when adaptive management actions should be implemented.

Table 1. Project Objectives, Indicators, and Time before the Effects of the Harlow Island HREP become Apparent

Objective	Performance Indicator	Monitoring Target (Desired Outcome)	Action Criteria (AM triggers)	Responsible Party	AM Measure
Restore topographic diversity in the Project Area	Swale depth	Difference of 2 feet from the top of slope to bottom of wetland area	Less than 2 feet difference from bottom to ground elevation	USACE	USACE and the sponsor would evaluate excavation of the wetland feature
	Water presence	Visual presence of water during growing season	Water present between May 1 and August 31	USACE	USACE and the sponsor would evaluate excavation of the wetland feature
	Ridge height	Top ridge elevation of 399 NGVD	Greater than 1 foot difference between top of ridges and 399 NGVD	USACE	USACE and the sponsor would evaluate reconstruction of the ridge feature
Increase connected aquatic backwater habitat with depth diversity for enhanced fisheries habitat benefits	Fish species assemblage within Backwater	An increase by more than 20% of native species should be realized within 5 years of construction completion.	Apply adaptive management actions if any of the monitoring targets fall outside the desired thresholds	USACE	Consideration of installation of additional scouring rock structures should be evaluated by USACE and project partner.
	Connectivity	At least 0.5 ft/sec velocity and connectivity to the main channel.	Velocity of at least 0.5 ft/sec when St. Louis gage flows are at or above 645,000 cfs and connectivity between the Backwater and the Mississippi river is not achieved for at least 30 days between May 1 and August 31 at LWRP[1] +10	USACE	
	Habitat depth and diversity	Backwater bottom depth of at least 5 feet at LWRP[1] +5 should be realized upon construction completion.	If depth is lost (<4 feet average depth) in the backwater	USACE	
	Woody Debris	Limit woody debris buildup	If woody debris accumulates across >80% of the backwater at any point	USACE	Consideration of excavating the woody debris would be evaluated by USACE and project partner
Increase acreage protected from coarse sediment deposition	Fine sediment building	Accumulation of at least 2 inches of desirable soil on average behind the sediment deflection berm at year 9	Less than 2 inch average accumulation of desirable soil by year 9	USACE	Evaluate hydrology of site and consider longer evaluation period to capture more inundation periods in which the fine sediment is deposited
Restore floodplain forest communities	Survival and growth of existing and planted forest within the Project Area	Increase quantity and quality of floodplain forest on Harlow Island and survivability of planted trees.	70% survivorship of planted trees	USACE	USACE and the sponsor would evaluate replanting and/or install more robust deer guards to reduce antler rubbing, and/or additional mowing and/or herbicide to reduce competition

[1] Low Water Reference Plane

Table 2. Harlow Island HREP Conceptual Monitoring Schedule and Estimated Monitoring Costs.

Construction completion is set to year 0.

Feature	Performance Indicator	Activity	Year -1	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Sub-total
Backwater	Fish diversity	UMRR-LTRM fisheries survey	9,000	9,000			9,000			9,000			9,000		45,000
	Flow and connectivity	Gage data analysis		1,000		1,000					1,000				3,000
	Backwater habitat depth and diversity	Hydro-graphic /ADCP Survey and ISOPAC analysis		15,000		15,000					15,000				45,000
	AM feature: Installation of scouring rock structures									72,000					72,000
	Woody debris	Visual observation				1,000			1,000			1,000			3,000
	AM measure: Woody Debris removal									100,000					100,000
Sediment deflection berm	Soil creation	LiDAR		20,000									20,000		40,000
	AM feature: Evaluate hydrology of site and consider longer evaluation period to capture more high flow events												5,000		5,000
Swales	Wetland topographic diversity	LiDAR		10,000									10,000		20,000
	Water Presence	Visual Observation		5,000		5,000						5,000			15,000
	AM feature: re-excavate wetlands									100,000					100,000
Reforestation	Forest Community Diversity	Forest monitoring			6,000				6,000						12,000
	AM feature: supplemental planting and more robust deer protection and maintenance									140,000					140,000
Ridge	Ridge topographic diversity	LiDAR		10,000									10,000		20,000
	AM feature: Re-construct ridges									100,000					100,000
	Performance Evaluation Report	Inspection and report writing							10,000					10,000	20,000
														Subtotal of AM Measures	$517,000
														Subtotal of Monitoring	$203,000
														Subtotal of Performance Evaluation Reports	$20,000
														TOTAL	$740,000

4.1 Backwater Aquatic Monitoring

1) **Objective supported:** 2
2) **Performance Indicators:** fish species assemblage within backwater; depth; aquatic habitat complexity
3) **Rationale:** Connectivity between the backwater and the river is vital for ecosystem processes (e.g., nutrient cycling) and for providing essential resources for fish and wildlife (e.g., spawning, rearing, and food). Disconnection eliminates the transfer of nutrients between the river and its floodplain leading to reduced resources for fish and wildlife. Project features are designed to increase connectivity of the backwater upstream and downstream while providing flow through the backwater during high flow events with limited woody debris accumulation
4) **Methodology:**
    - **a.** The fish assemblage within the current backwater will be assessed using daytime electrofishing protocols of the Upper Mississippi River Restoration - Long Term Resource Monitoring element (Ratcliff et al 2014). Surveys would be completed three times per year when flows are over 250,000 cfs per the Chester, IL gage prior to construction (year -1), immediately following construction completion (year 0), and years 3, 6, and 9.
    - **b.** Flow will be determined using data from Acoustic Doppler Current Profiler (ADCP) surveys outlined in 4c with baseline conditions collected immediately following construction completion (year 0) and years 2 and 7. A comparison survey will be conducted at year 7 to map and quantify the average current velocity greater than 0.5 ft/sec when flows at St. Louis gage are at or above 645,000 cfs. Connectivity will be calculated by using gage readings to determine the number of days the side channel is connected to the main channel.
    - **c.** Habitat depth and diversity (i.e., bathymetry) of the backwater would be conducted by the use of bathymetric surveys using ADCP single-beam. A comparison survey and analysis (ISOPACH) would be conducted at years 0, 2, and 7.
    - **d.** Woody debris: Visual observations would be performed to ensure that wood debris is not accumulating in the backwater to a point in which it restrict flow and impedes on the overall functionality of the backwater.
5) **Monitoring Targets (Desired Outcomes):** For each of the above indicators, the desired outcomes to monitor project success include:
    - **a.** Native Fish Assemblage: An increase by more than 20% of native species should be realized within 5 years of construction completion.
    - **b.** Flow and connectivity: Velocity of at least 0.5 ft/sec when St. Louis gage flows are at or above 645,000 cfs. Number of days the backwater is connected to the Mississippi River >30 days at Low Water Reference Plane (LWRP) +10 minimum. These success criterion may be slightly dependent on the river hydrology and climate (i.e., drought).
    - **c.** Habitat depth and diversity: Backwater bottom depth of at least 5 feet at LWRP +5 should be realized upon construction completion.
    - **d.** Woody debris accumulation would remain under 80% of the width of the backwater at any point throughout.
6) **Adaptive Management Trigger and Measure:** If monitoring results indicate an inability to reach success criteria by year 7 *and* the following are not met:
    - **a.** Native Fish Assemblage: Less than 20% of the fish assemblage comprised of native fish, then consideration of installation of scouring rock structures should be evaluated by USACE and project partner.

b. Flow and connectivity: Velocity of at least 0.5 ft/sec at 645,000 cfs at St. Louis gage minimum. Connectivity between the Backwater and the Mississippi River is not achieved for at least 30 days between May 1 and August 31 at LWRP+10 minimum, i.e., no drought, then consideration of installation of scouring rock structures should be evaluated by USACE and project partner.

c. Habitat depth and diversity: If depth is lost (<4 feet depth at bottom grade) in the backwater at LWRP+10 minimum, then consideration of installation of scouring rock structures should be evaluated by USACE and project partner.

d. Woody debris. If woody debris accumulates and the backwater has 80% of the width blocked, then the consideration of excavating the woody debris would be evaluated by USACE and project partner.

4.2 Increase Acreage of Fine Sediment Building

1) **Objective supported:** 3
2) **Performance Indicators:** Soil height behind sediment deflection berm
3) **Rationale:** Tree species establishment is directly related to soil composition. For example, hard mast tree species cannot germinate and survive on sandy soils. Instead hard mast tree species require a higher soil composition of silt/clay and/or loam.
4) **Methodology:**

   Soil Composition: The soil height of the Project Area behind the sediment deflection berm will be measured by LiDAR. LiDAR shall be acquired immediately following project construction completion and again at year 9 following construction completion.

5) **Monitoring Targets (Desired Outcomes):** For each of the above indicators, the desired outcomes include:

   Soil Height: A rate of fine accumulation of an average of 2 inches behind the sediment deflection berm area shall be realized by year 9 following construction completion. This target is largely dependent upon river hydrology. For instance, if high flow events do not occur within the evaluation period, fine sediment deposited during backing of water will not be achieved.

6) **Adaptive Management Trigger and Measure:** If monitoring results indicate an inability to reach success criteria by year 10 *and* the following are not met

   Soil Height: Less than 2 inches increase in fine soil accumulation, then the USACE and the sponsor would evaluate using off-site material to be deposited behind the sediment deflection berm.

4.3 Enhance Wetland Ecosystem Resources

1) **Objective supported:** 1
2) **Performance Indicators:** Wetland containing topographic diversity and water during the growing season.
3) **Rationale:** Wetlands with topographic diversity and water present between May 1 and August 31 provide habitat for various amphibian and reptile species.
4) **Methodology:**
   - **a.** Elevation survey: The height of the ridges will be measured by LiDAR. LiDAR shall be acquired immediately following project construction completion and again at year 9 following construction completion.
   - **b.** Water Present: Visual presence of standing water at years 0, 2, 5, and 8.

5) **Monitoring Targets (Desired Outcomes):** For each of the above indicators, the desired outcomes include:
    - **a.** Topographic diversity: Constructed wetlands include topographic diversity on the side slopes at a difference of 2 feet from the bottom to the top.
    - **b.** Water present between May 1 and August 31

6) **Adaptive Management Trigger and Measure:** If monitoring results indicate an inability to reach success criteria by year 5 *and* the following is not met
    - **a.** Topographic diversity: Less than 2 feet difference between the bottom and the top of the wetland with a minimum of a 1V:8H slope, then the USACE and the sponsor would evaluate excavation of the wetland feature.
    - **b.** Water not present during growing season, then the USACE and the sponsor would evaluate excavation of the wetland feature.

4.4 Enhance Forest Diversity Resources

1) **Objective supported:** 1 & 4
2) **Performance Indicators:** Ridge height of 379 NGVD.
3) **Rationale:** Elevations of 10% flood frequency elevations and higher support higher hard mast species diversity
4) **Methodology:**
    - **a.** Elevation survey: The height of the ridges will be measured by LiDAR. LiDAR shall be acquired immediately following project construction completion and again at year 9 following construction completion.
5) **Monitoring Targets (Desired Outcomes):** For each of the above indicators, the desired outcomes include:
    - **a.** Topographic diversity: Constructed ridges include topographic diversity within the Project Area with the constructed top elevation of the ridges being 399 NGVD

7) **Adaptive Management Trigger and Measure:** If monitoring results indicate an inability to reach success criteria by year 10 *and* the following are not met

    Ridge Height: More than 1 foot decrease in ridge height from 399 NGVD, then the USACE and the sponsor would evaluate rebuilding the ridges to the designed elevation.

4.5 Reforestation

1) **Objectives supported:** 4
2) **Performance Indicator:** Survival and growth of existing and planted forest within the Project Area
3) **Rationale:** Floodplain forest, including bottomland hardwoods, have been reduced within the Project Area due to historic clearing for agriculture and impacts of coarse sediment deposition, limiting species survivability to only extremely sand-tolerant species. Project features of reforestation and the sediment deflection berm are expected to increase quantity and quality of floodplain forest on Harlow Island.
4) **Methodology:** Forest monitoring will follow the sampling design as outlined in the *UMRR HREP Monitoring Design Handbook Section 1: Vegetation* (McCain 2012). The nested fix plot design (Figure 1) will be used to establish 3 plots randomly in the existing forest of the Harlow Island. The 0.1-acre large plot sampling method will be used to establish 3 plots randomly within the reforestation area.

Success of planted trees will be monitored 1 and 5 years post-planting to determine basal diameter and % seedling survivorship (tree count). To determine long-term success, periodic

monitoring (every 5 years, with possible monitoring after large disturbance events) of trees planted as well as the trees in the existing forest plots will include basal diameter measurements. Differences in percent diameter increases will be used to monitor trees through time. In addition, based on Henderson et al. (2009) relative growth rate (RGR) will also be calculated to determine success/survivorship (where RGR > 0 equals positive level of production and survivorship, while RGR < 0 equals loss of production and mortality) using the following equation:

$$r = \frac{\ln(D_2) - \ln(D_1)}{t_2 - t_1}$$

D_1 and D_2 refer to growth measurements (height or diameter) at times t_1 and t_2.

Monitoring will be conducted at years 1 and 5.

5) **Monitoring Target (Desired Outcome):** The amount of floodplain forest due to reforestation would increase by a total of approximately 60 acres. Reforestation will be one of the last features completed. The monitoring target for initial and long-term monitoring is 70% survivorship of planted trees. Additionally, a target of increasing basal diameter (positive growth rate) of tagged trees will be used as in indicator of forest health.
6) **Adaptive Management Trigger and Measure:** If monitoring results indicate an inability to reach success criteria by year 5 and less than 70% of initial tree survivability then the USACE and the sponsor would replant the quantity which did not survive and/or install more robust deer guards to reduce antler rubbing, and/or additional mowing and/or herbicide to reduce competition.

5 DOCUMENTATION, IMPLEMENTATION COSTS, RESPONSIBILITIES, AND PROJECT CLOSE-OUT

Documentation, Reporting, and Coordination. The Project Delivery Team will document each of the performed assessments and communicate the results to the HREP program manager and partners designated for the Project. Periodic reports will be produced to measure progress towards the Project goal and objectives as characterized by the selected performance measures.

Cost. The costs associated with implementing monitoring an adaptive management measures 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 measures, monitoring elements, and adaptive management opportunities, the estimated costs in Table 2 will need refinement in PED during the development of the Detailed Monitoring and Adaptive Management Plans.

Responsibilities. The Corps will be responsible for collecting hydrographic surveys fisheries, soil surveys, wetland monitoring, and forestry data. The sponsor and the Corps will be responsible for site inspections and visual observations to assist in overall project success evaluation.

Project Close-Out. Close-out of the Project would occur when it is determined that the Project has successfully met the Project success criteria described above. Success would be considered to have been achieved when the Project 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:

- Success criteria met;
- Continued site inspections to determine continued Project status; and
- Continued OMRR&R into the future

6 REFERENCES

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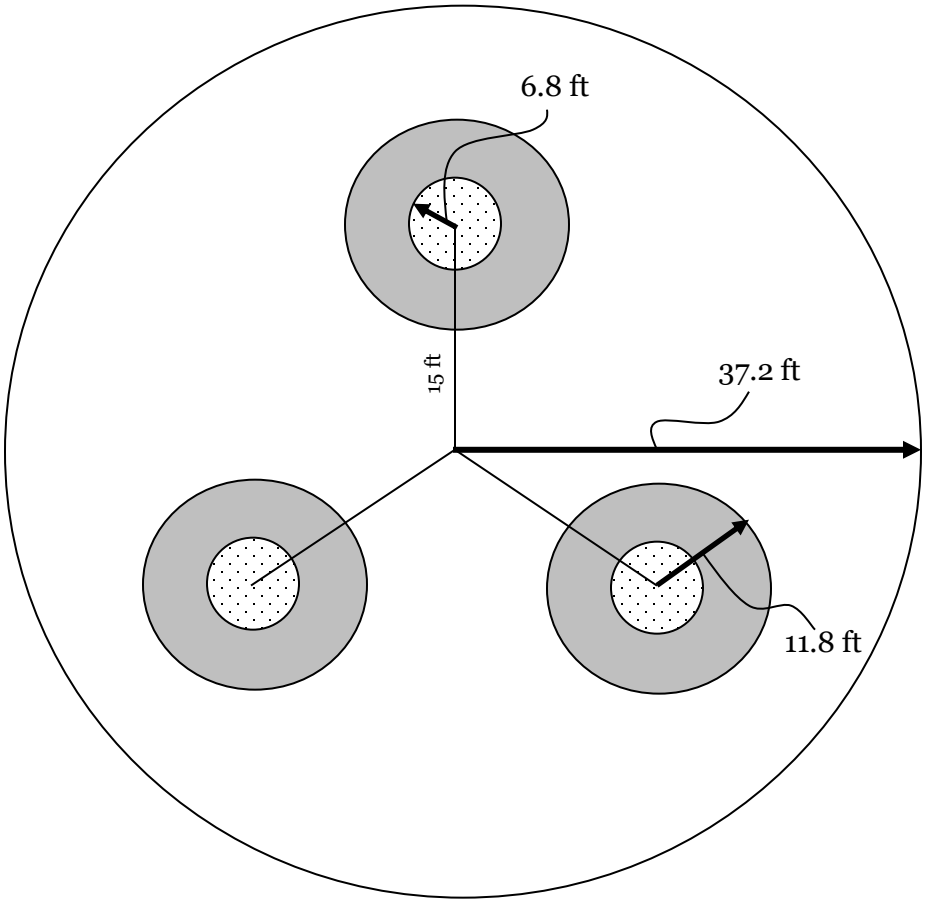

Figure 1. Nested fixed radius design. The center of the subplots and microplots are 15 feet from the large plot center. This full monitoring protocol is applicable for the exiting forested areas.

See *UMRRP HREP Monitoring Design Handbook Section 1: Vegetation* (McCain 2012) for details on field data collection