U. S. Army Corps of Engineers

St. Louis Riverfront - Meramec River Basin Ecosystem Restoration Feasibility Study with Integrated Environmental Assessment

Draft - 2018

Appendix J

Monitoring and Adaptive Management Plan

INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

INTRODUCTION

This appendix presents the feasibility level monitoring and adaptive management plan for the Meramec River Basin Feasibility Study. This plan identifies and describes the monitoring and adaptive management activities proposed for the considered action alternatives and estimates associated costs and duration. This appendix outlines how the results of the project-specific monitoring plan would be used to adaptively manage each of the action alternatives, including monitoring targets which demonstrate success in meeting study objectives. This plan was developed through an interagency working group of Federal and state agencies, and The Nature Conservancy, and included a workshop facilitated by the Corps' Engineering Research and Design Center (ERDC) Adaptive Management Working Group which was held in June 2017. The interagency working group's intent was to develop monitoring and adaptive management actions appropriate for the study's goal and objectives. This plan will be further developed in the planning, engineering and design (PED) phase as specific details are made available for the preferred alternative.

AUTHORIZATION

The objective of Corps feasibility studies is to investigate and recommend solutions to water resources problems. Prior to the Corps launching a civil works feasibility study, it must be authorized by Congress and subsequently Federal money appropriated.

The Meramec River Basin Ecosystem Restoration Feasibility Study was authorized by a 21 June 2000 Resolution by the Committee on Transportation and Infrastructure, U.S. House of Representatives, Docket 2642:

> *Resolved by the Committee on Transportation and Infrastructure of the United States House of Representatives, That the Secretary of the Army is requested to review the report of the Chief of Engineers on the Mississippi River, between Coon Rapids Dam and the mouth of the Ohio River, published as House Document 669, 76th Congress, 3rd Session, and other pertinent reports to determine if improvements along the Mississippi River and its tributaries in St. Louis City, St. Louis County, and Jefferson County, Missouri, and Madison County, St. Clair County, and Monroe County, Illinois, are advisable at the present time in the interest of public access, navigation, harbor safety, off-channel fleeting, intermodal facilities, water quality, environmental restoration and protection, and related purposes.*

The authority allows the Corps to investigate and recommend solutions in the portions of the Meramec River Basin that lie in within the designated geographical scope.

FRAMEWORK

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). The Meramec River Basin adaptive management framework follows the two phased approached for set-up and implementation (Figure 1).

GOVERNANCE STRUCTURE

To execute an adaptive management framework for the Meramec River Basin Ecosystem Restoration Feasibility Study, a communication structure has been identified (Figure 2). The structure establishes clear lines of communication and data exchange between the Corps, the non-Federal sponsor, the executive board, technical committee, Project Delivery Team (PDT) and stakeholders. Successful implementation will require the right resources being coupled at the right time to support the framework components.

ADAPTIVE MANAGEMENT PLANNING

The resulting adaptive management plan for the Meramec River Basin Ecosystem Restoration Feasibility Study describes and discusses whether adaptive management is needed in relation to the considered action alternatives identified in the Feasibility Study. The plan also identifies how adaptive management would be conducted and who would be responsible for specific adaptive management actions. The developed plan outlines how the results of study-specific monitoring would be used to adaptively manage the considered action alternatives, including specifications that will define success.

The Adaptive Management Plan reflects a level of detail consistent with the feasibility study. The primary intent was to develop monitoring and adaptive management actions appropriate for the study's restoration goal and objectives. The specified management actions permit estimation of the adaptive management plan costs and duration. The Adaptive Management Plan:

- identifies the restoration goal and objectives;
- presents a conceptual model that relates management actions to desired Project outcomes; and
- lists sources of uncertainty that would lend themselves to adaptive management.

Following the discussion of the above, the subsequent sections of this appendix describe monitoring, assessment, and decision-making in support of adaptive management. The level of detail in this plan is based on currently available data and information developed during plan formulation as part of the Feasibility Study. Uncertainties remain concerning the exact restoration measures, monitoring elements and adaptive management opportunities. Components of the monitoring and adaptive management plan, including costs, were similarly estimated using currently available information.

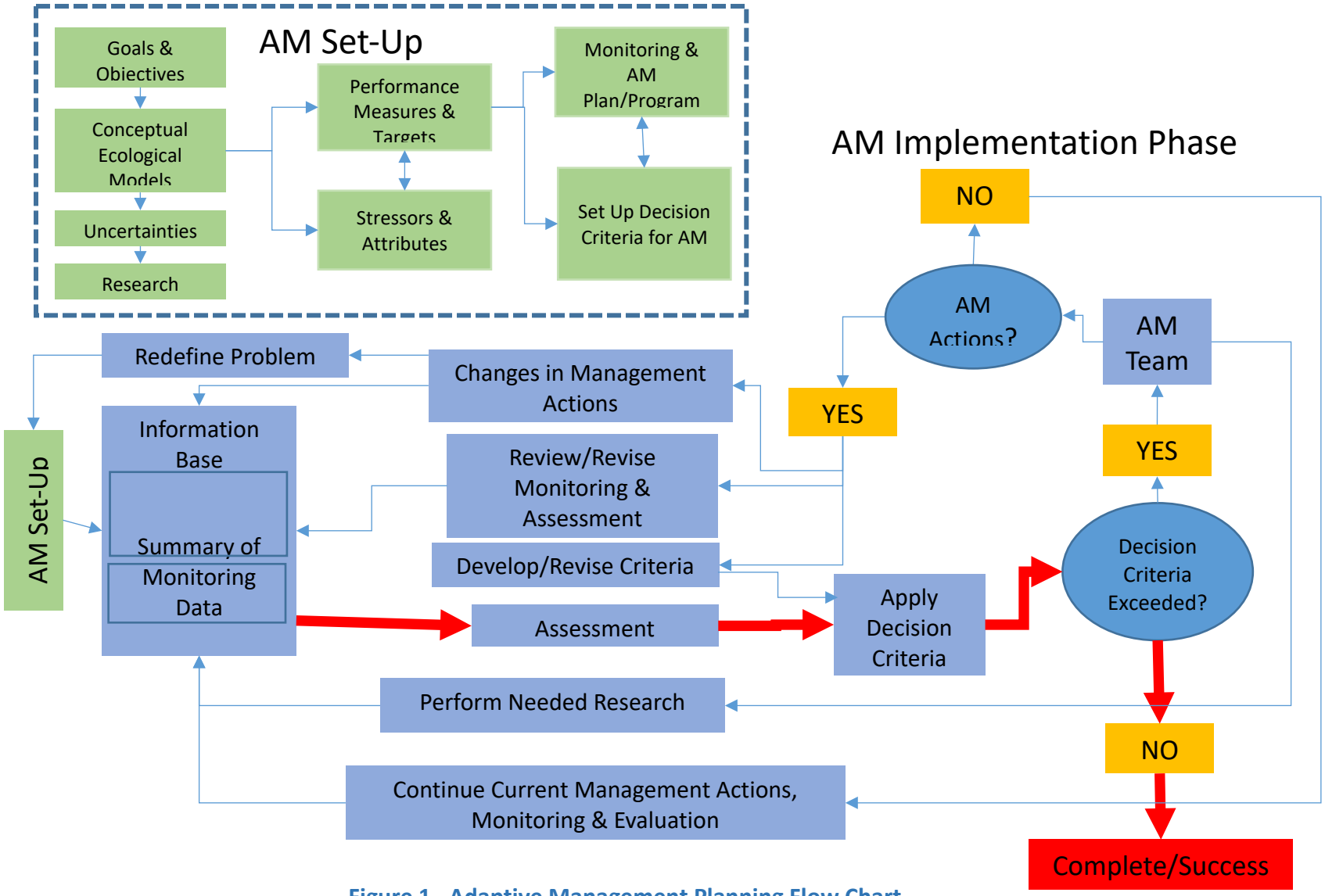

Figure 1. Adaptive Management Planning Flow Chart

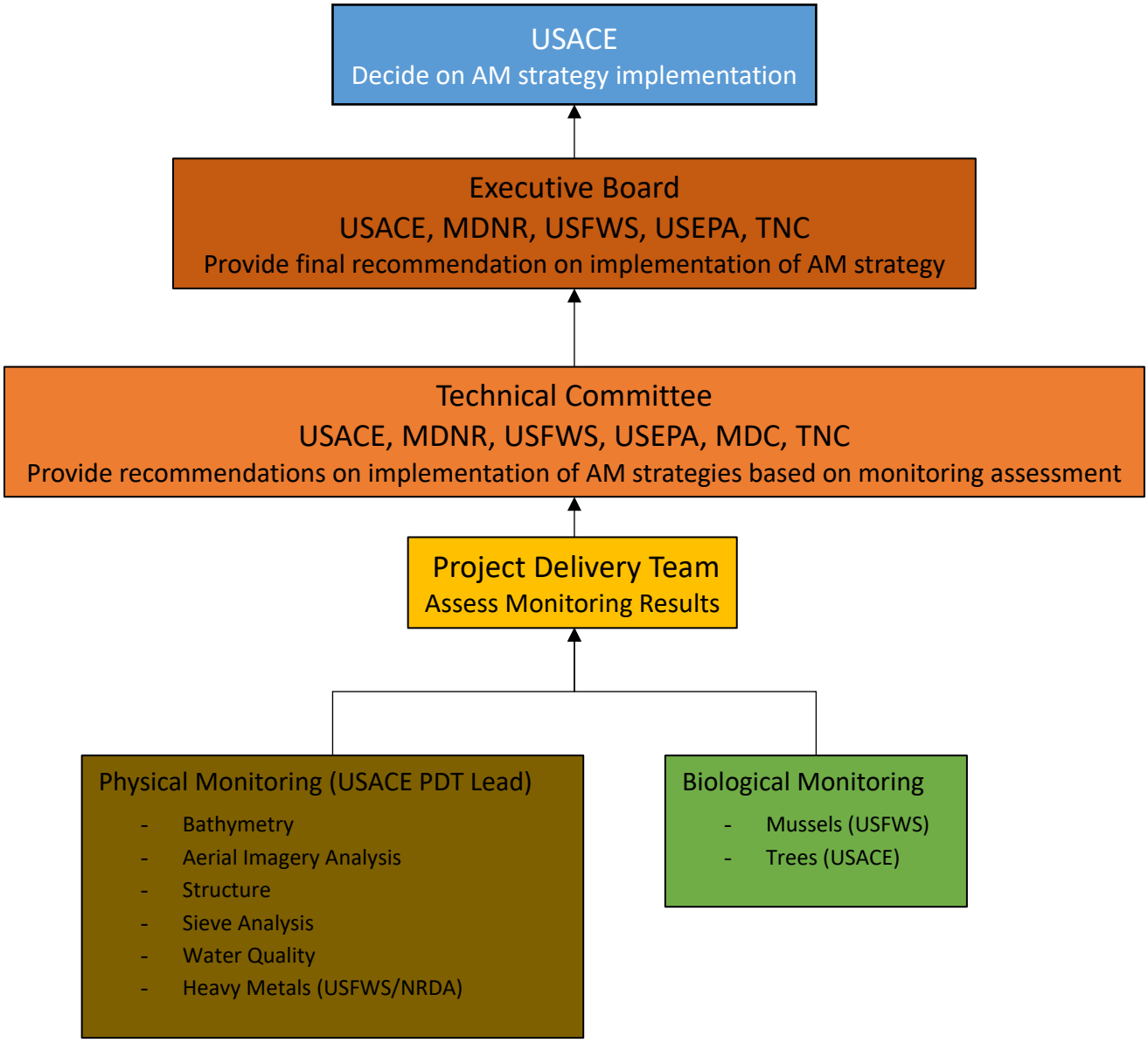

Figure 2. Monitoring and Adaptive Management Governance Structure

STUDY GOALS AND OBJECTIVES

The overarching goal of this study is to formulate an alternative that can restore the aquatic ecosystem and determine if Federal participation in repairing habitat functionality within the authorized study area is justified.

As part of the USACE planning process, ecosystem restoration objectives were identified for the study:

- Reduce the downstream migration of excess mining derived sediment from the Big River in order to protect and restore degraded aquatic and freshwater mussel habitat;
- Reduce the quantity of contaminated sediment entering the Big River and Meramec River; and

- Increase riparian habitat connectivity, quantity, diversity, and complexity within the study area.

SOURCES OF UNCERTAINTY

Adaptive management provides a coherent process for making decisions in the face of uncertainty. Scientific uncertainties and technological challenges are inherent with any ecosystem restoration project. Following is a list of uncertainties identified by the PDT associated with the restoration of the aquatic ecosystem in the Meramec River Basin Ecosystem Restoration Feasibility Study for the considered action alternatives. The considered action alternatives all have some amount of the below proposed features; therefore, the uncertainty is similar across all considered action alternatives. The alternatives differ in the amount of each type of restoration measure and the location within the study area. With the similarity across alternatives, the considered action alternatives will be discussed collectively unless otherwise noted.

Floodplain Forest

The District evaluated the level of uncertainty and risk in the floodplain forest feature and determined it did not require using Adaptive Management to address the potential of the feature to meet performance criteria. Furthermore, other ecosystem restoration projects through the Upper Mississippi River Restoration (UMRR) Program has evaluated adaptive management and monitoring designs for forestry extensively and these lessons learned have been applied in the design of the floodplain forest feature. Monitoring will be conducted to determine success. Information gained from the UMRR Program will be used to guide floodplain forest restoration.

Bankline Restoration

The District evaluated the level of uncertainty and risk in the bank stabilization features of either hard structure, soft structure (e.g., bio-engineering plantings) or a combination of and determined that bank movement would be reduced as a result of whichever bank stabilization method is implemented. Associated with the bank stabilization are the use of pilot channels to aid in the new river alignment and reduce the likelihood that high flow events from outflanking any of the bank stabilization features. The main sources of uncertainty involved with bank stabilization and pilot channels include:

- Longevity of the soft structures and the potential for excessive scour particularly before any bio-engineering plantings develop.
- Placement of keys where the structures tie into the bankline since they are of high importance for any bankline feature
- Unanticipated in-channel sediment depositing post pilot-channel excavation leading to bank stabilization features being outflanked or to fail.

Sediment Capture

Capture of suspended and bedded sediments within the study area are of importance for project success; however, bedded and suspended sediments have unique uncertainties associated with them and will be discussed separately.

Bedded Sediment Capture

The District evaluated the level of uncertainty and risk in the bedded sediment capture features including the use of gravel collectors, gravel bar removal and excavation behind existing mill dams. It is expected these features will capture the target grain size of 4-16 mm. The sources of uncertainty with these features are the following:

- Gravel collectors: amount of bedded sediment that this feature will collect; constructability, operation and maintenance, and ability to withstand extreme flood events
- In-channel excavation: regulatory and state permit guidelines will be followed; however, there is still uncertainty on unanticipated hydraulic changes that may result by removing the bars from the system
- Excavation behind mill dams: amount of bedded material currently captured and the estimated fill rate of filling in post excavation
- Grade control: existing location of head-cut and unforeseen new head cut if existing mill dams fail between now and implementation of the proposed plan

Suspended Sediment Capture

The District evaluated the level of uncertainty and risk in the suspended sediment capture features including the use of off-channel sediment basins. It is expected this feature will capture the target grain size of <2mm. The sources of uncertainty with this feature include:

- Ability to capture the target grain size
- Potential of structures to be outflanked or experience erosion
- Estimated fill rate of basins

Freshwater Mussel Habitat

It is expected that implementation of the bank stabilization features, bedded and suspended sediment features and reforestation will not significantly alter hydraulic forces within existing mussel beds and would continue to provide stabilization of the stream. If monitoring demonstrates a significant negative impact to mussels of existing mussel beds as related to implemented structures, then modification of structures would be required.

CONCEPTUAL MODEL

Figure 3 shows the conceptual ecological model. This model identifies the drivers and stressors of the system and how they relate to the five essential ecosystem characteristics. This model was developed through an interagency and interdisciplinary partnership and aids in identifying the problems and potential management actions that could be implemented to counter the stressors that are degrading the ecosystem.

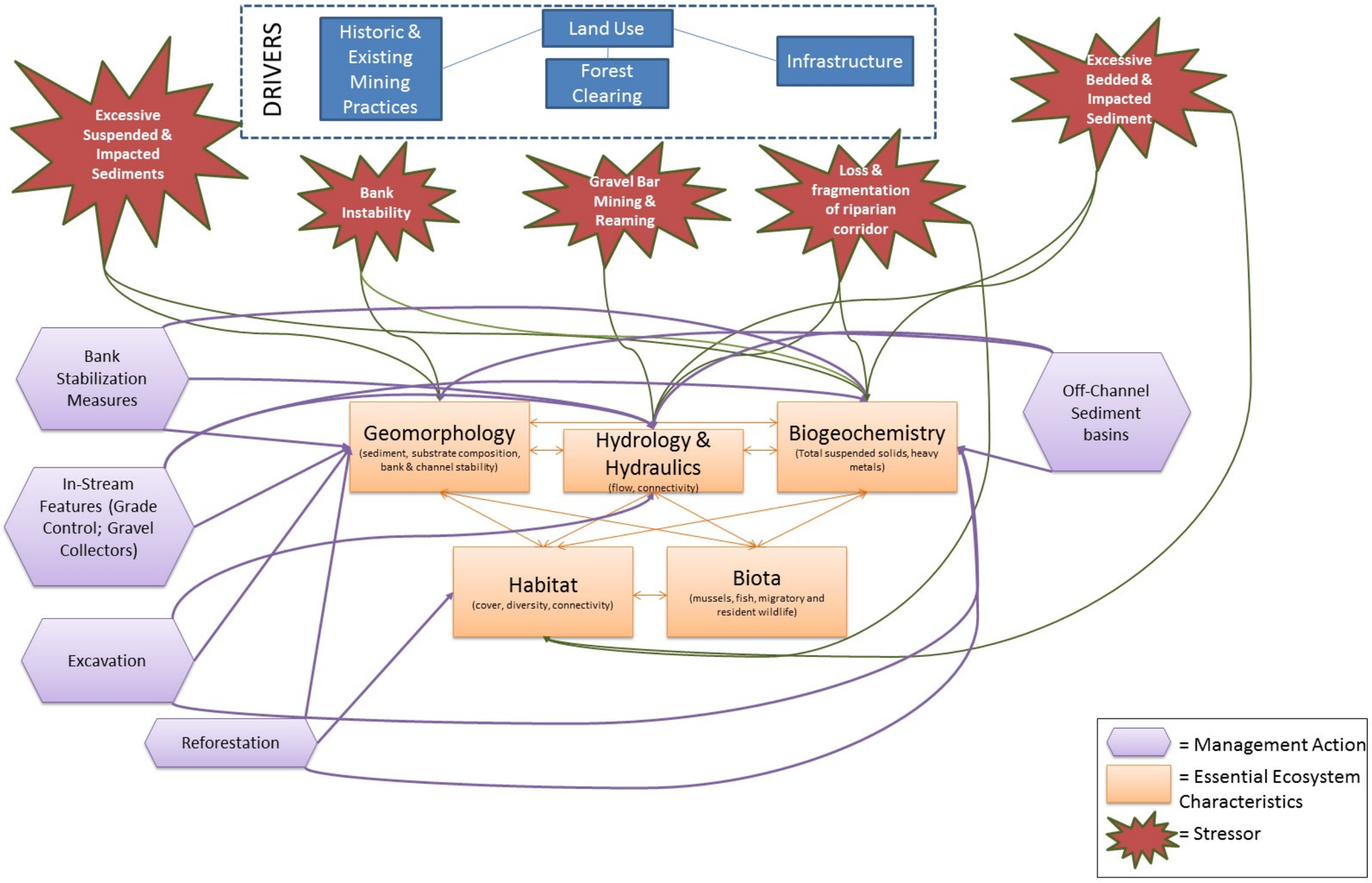

Figure 3. Conceptual ecological model

MONITORING OF OBJECTIVES TO DETERMINE PROJECT SUCCESS AND ADAPTIVE MANAGEMENT MEASURES

The power of a monitoring program developed to support determinations of success and inform adaptive management lies in the establishment of feedback between continued monitoring and corresponding project management. The considered action alternatives all have some amount of the proposed features (reforestation, bankline stabilization and suspended and bedded sediment capture); therefore, the monitoring plans are similar. The alternatives differ in the amount of each type of restoration measure and the location within the study area; however, the monitoring plans would be similar with minor differences due to amount or location within the study area. With the similarity across alternatives, considered action alternatives will be discussed collectively unless otherwise noted. The main differences among alternatives are provided in Table 1. Table 2 provides the generalized monitoring schedule for each monitoring component. Table 3 provides the monitoring and adaptive management costs for the final array of alternatives. These costs were included as part the cost effective incremental cost analysis.

Table 1. Quantity of Types of Restoration Measures Within the Final Array of Alternatives

		Bank Stabilization Features									Sediment Removal Features					Reforestation (acres)
											Sediment Capture Basins					
#	Alternative	Sites (#)	LPSTP (LF)	Stream Barbs (#)	Weirs (#)	Bank Shaping (linear feet)	Rootwad Revetment (linear feet)	Channel Excavation (acres)	Plantings (acres)	Grade Control Structure Sites (#)	#	Acres	In-stream Excavation Sites (#)	Bed Sediment Removal Sites (#)	Bed Collectors (#)	
1	No Action	0	0	0	0	0	0	0	0	0	0	0	0		0	0
2	Subset Maximize Ecosystem Restoration in Big River RM 0-10.2	3	5,899	22	8	2,012	0	0	3.6	1	1	5.9	2	0	0	149
3	Subset Maximize Ecosystem Restoration in Big River RM 0-35	17	19,068	60	52	11,559	929	6.7	21.6	3	5	143.2	4	1	2	440
4	Maximizes Ecosystem Benefits in Meramec River	5	2,019	0	19	4,872	2,064	3.6	26.5	0	0	0	0	0	0	19
5	Maximizes Efficiency in Priority Areas (Big River)	35	17,717	43	66	7,679	1,950	15.8	16.2	3	6	154.1	4	4	6	675
6	Maximizes Ecosystem Benefits in Priority Areas (Big River)	51	29,447	61	102	16,052	5,590	28	38	3	6	154.1	4	16	6	679
7	Maximizes Ecosystem Benefits in Study Area	56	33,041	61	112	21,434	7,654	28	64.5	3	6	154.1	4	16	6	698

Table 2. Generalized Monitoring Schedule, Applicable For Considered Action Alternatives

Features	Work Category	Activity	*PED	Post-construction Years									
				1	2	3	4	5	6	7	8	9	10
Site Visits	Monitoring & Analysis	Site Visits	x		x			x				x	
Reforestation	Monitoring & Analysis	Forest surveys		x				x					x
Bankline Restoration	Monitoring & Analysis	Aerial Imagery Analysis			x			x			x		
Suspended Sediment Capture	Monitoring & Analysis	Sieve Analysis	x					x					x
		Inspection						x					x
Bedded Sediment Capture Bed Sediment Removal Excavation Grade Control	Monitoring & Analysis	Cross Section Survey	x					x				x	
Mussel Habitat	Monitoring & Analysis	Survey	x		x			x			x		

Table 3. Estimated Costs (rounded to the nearest $1000) for Monitoring and Adaptive Management For Each Considered Action Alternative

	Estimated Monitoring Cost by Year per Considered Alternative ($)												AM Cost ($)
Alt	PED	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	TOTAL	Years 1-10
1	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2	61,200	5,000	53,200			76,200			50,000	15,200	11,000	**211,000**	**687,000**
3	86,800	15,000	66,800			154,800			50,000	61,800	46,800	**395,000**	**2,638,000**
4	62,800	0	54,800			72,800			50,000	22,800	0	**200,000**	**1,184,000**
5	179,800	60,000	78,800			255,800			50,000	109,000	96,000	**650,000**	**4,697,000**
6	273,200	40,000	97,200			323,200			50,000	197,200	76,000	**784,000**	**8,196,000**
7	296,000	40,000	102,000			346,000			50,000	220,000	76,000	**834,000**	**9,308,000**

FLOODPLAIN FOREST

1) Methodology: Forest monitoring will follow the sampling design as outlined in the *Upper Mississippi River Restoration Habitat Rehabilitation and Enhancement Project Monitoring Design Handbook* (McCain 2012). The nested fix plot design as described in this monitoring design will be used to establish 3-5 plots randomly within the reforestation area (depending on size of site). Success of planted trees will be monitored 1, 5 and 10 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 hydrologic events) of trees planted 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 (where RGR > 0 equals positive level of production, while <0 equals loss of production) 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.

2) Success Criteria (Desired Outcome): The amount of floodplain forest due to reforestation would be increased by a total number of acres for each alternative (see Table 1 for acres per alternative). The monitoring target for initial (1-year post planting) and longer term (years 5 and 10) monitoring is 70% survivorship of planted trees. Additionally, a target of increasing basal diameter (positive RGR) would be used as an indicator of forest health.

BANKLINE RESTORATION

1) Methodology: Bathymetric and topographic cross section surveys of sites will be completed pre-construction and post-construction to determine base conditions and construction compliance. Repeated cross section surveys, or surveys using the same cross section line, will be conducted at years 5 and 10. Analysis of the survey data will be performed to determine movement and bank slopes. In

addition, site visits to each site will occur annually the first 3 years and then corresponding with cross-section surveys conducted at year 2, 5 and 9, as well as after meaningful large hydrological events to determine condition of implemented structures. Aerial imagery analysis will also be performed using publicly available images to estimate bank movement.

2) Success Criteria (Desired Outcome):

Criterion 1. Bank stabilization features will be considered successful if after 3 years, bank location post-construction is within the following limits:

- Toe Zone: very limited erosion
- Mid Bank Zone: 1-2 feet of the as-built design
- High Bank Zone: 5-10 feet of the as-built design

Criterion 2. Bank stabilization features with rock structures will be considered successful if sagging/settling is < 15% of design height within first 3 years of construction.

Criterion 3. Bank stabilization features will be considered successful if after 3 years based on aerial imagery analysis, estimated erosion rate be less than 2 feet per year.

Criterion 4. Bank stabilization features with rock or soft structures will be considered successful if no visible scour that undermines the constructed features within first 3 years of construction.

Criterion 5. Bank stabilization features with rock or soft structures will be considered successful if features are not outflanked during high water events.

Criterion 6: Bank stabilization features with soft structures will be considered successful if greater than 80% of these structures are retained within 5 years of construction.

3) Adaptive Management Trigger and Measures: If monitoring results indicate an inability to reach success criteria within two observations then adaptive management may be warranted. If any of the items below begin to occur within one monitoring observation, then adaptive management would be implemented.

- Excessive erosion between weirs, stream barbs or other measures.
- Keys of the structure are outflanked.
- Excessive erosion above the toe at the mid or high bank area is discovered.

If monitoring results indicate an inability to reach success criteria after two observations, modification to the bank stabilization features will be implemented to increase protection of the bank, improve bank slope geometry, reduce upstream/downstream scour or a combination. If monitoring results indicate an inability to reach success criteria within two observations, then adaptive management may be warranted.

Preliminary information suggests additional rock on sites primarily implemented with soft structures or modify elevation of rock structures or alignment would be warranted to better direct flow.

SUSPENDED SEDIMENT CAPTURE

1) Methodology: Within each sediment basin, a sieve analysis will be performed of sediment collected at year 5 and 10 post-construction and when sediment basins are filled and material is removed.

2) Success Criterion (Desired Outcome). An assumed success criterion of grain size <2 mm will be used. The success criterion will be verified by sampling during Planning, Engineering and Design. Targets will be calibrated and validated based on other sediment basins currently in operation within the watershed.

3) Adaptive Management Trigger and Measures: If any of the items below begin to occur within one monitoring observation, then adaptive management would be implemented to restore the structure:

- The inflow and outflow channel has excessive erosion or deposition.
- The inlet structure or overflow structure has excessive scour or is outflanked.

If monitoring results indicate an inability to capture the <2mm grain size for two observations, modification to the inlet structure of the sediment basin will be implemented to better capture the target desired grain size in the water column. Preliminary information suggest that if >2mm, then raising of the inlet would be required to allow only particles in the higher portions of the water column to enter the basin.

BEDDED SEDIMENT CAPTURE, BAR SEDIMENT REMOVAL, EXCAVATION, GRADE CONTROL

1) Methodology: Cross-section repeated surveys will be performed throughout the study area at years 5 and 10 in conjunction with the surveys collected for bankline restoration described above.

2) Success Criterion (Desired Outcome):

- Reduction in bedded system migration downstream
- Constructed features are maintained during high water events
- Constructed features and excavation do not result in bed or bank instability elsewhere

3) Adaptive Management Trigger and Measures: If after construction of features and/or excavation bank instability tied to these features result, then adaptive management actions would be taken to correct any concerns. The exact action would be evaluated by the interagency team based on the site specific concerns.

FRESHWATER MUSSEL HABITAT

1) Methodology: A series of mussel survey methodologies including dive surveys, timed searches and randomized quadrant surveys will be used to survey the existing known mussel beds within the Project Area. This will occur with a multi-agency team pre-Project and after construction at years 2, 5 and 8. Surveys will determine species diversity, age structure, substrate relationships and density. Data analysis will include simple analyses of mussel diversity, density, age structure and relationships to implemented features or location. Collection of habitat characteristics would occur at each survey site,

including, but not limited to substrate, velocity and water depth. Results of the analyses will be used to inform success.

2) Success Criteria (Desired Outcome):

Criterion 1. Persistence of existing mussel beds and or increase in species diversity and density over pre-constructions surveys will determine success of the overall Project components.

Criterion 2. Desirable physical habitat characteristics related to substrate and velocity within the survey sites remain suitable for mussel habitat.

3) Adaptive Management Trigger and Measures: If species diversity and density decrease significantly and conditions become unsuitable to mussel habitat, then further investigation would be needed to determine the source of the change. If investigations show that a constructed feature is the source, then adaptive management to that feature would be needed to restore the physical conditions for suitable mussel habitat.

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 Project Manager and Technical Steering Committee designed for the Project. Periodic reports will be produced to measure progress towards the Project goals and objectives as characterized by the selected performance measures.

COSTS.

The costs associated with implementing monitoring and adaptive management measures were estimated based on current available data and information developed during plan formulation as part of the feasibility study. Because uncertainties remain as to the exact project features, monitoring elements and adaptive management opportunities, the estimate costs in Table 3 will need refinement during PED during the development of the Detailed Monitoring and Adaptive Management Plan.

RESPONSIBILITIES.

Floodplain Forest. Feasibility and PED activities are limited to one pre-construction evaluation of the proposed sites for reforestation. Currently, these areas lack tree cover. Post-planting monitoring would be conducted at years 1, 5 and 10. Responsibility of these features will be a coordinated effort between the Corps, MDNR and USFWS.

Bankline Restoration. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, feature performance will be evaluated at years 2, 5 and 8. Responsibility of these features will be a coordinated effort between the Corps, MDNR and USFWS.

Bedded Sediment Capture. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, feature will be evaluated at years 5 and 9. Responsibility of these features will be coordinated between the Corps, MDNR and USFWS.

Suspended Sediment Capture. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, feature performance will be evaluated at years 3 and 8. Responsibility of these features will be a coordinated effort between the Corps, MDNR and USFWS.

Grade Control. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, feature performance will be evaluated years 5 and 9. Responsibility of these features will be a coordinated effort between the Corps, MDNR and USFWS.

Excavation Behind Mill Dams. PED activities will be limited to one evaluation to reassess existing hydraulics. Following construction, feature performance will be evaluated years 5 and 9. Responsibility of these features will be a coordinated effort between the Corps, MDNR and USFWS.

Mussel Habitat. Feasibility and PED data collection will consist of pre-Project data collection and analyses. Following construction, mussel surveys will be conducted at years 2, 5 and 8. Responsibility for these efforts will be a coordinated effort between the Corps, MNDR and USFWS.

PROJECT CLOSE-OUT

Close-out would occur when it is determined that the restoration project has successfully met the success criteria as described within this appendix. Success would be considered to have been achieved when the study objectives have been met, or when it is clear that they will be met based upon the trends for the site conditions and processes. Success would be based on the following:

- success criteria met;
- continued site inspections to determine continued Project status; and
- continued operation, maintenance, repair, rehabilitation and replacement (OMRR&R).

REFERENCES

Fischenich, C., C. Vogt, and others. 2012. The application of adaptive management to ecosystem restoration projects. ERDC TN-EMRRP-EBA-10 April 2012, Vicksburg, MS: U.S. Army Corps of Engineers Ecological Management and Restoration Research Program.

Henderson, D., P. Botch, J. Cussimanio, D. Ryan, J. Kabrick, and D. Dey. 2009. Growth and Mortality of Pin Oak and Pecan Reforestation in a Constructed Wetland: Analysis with Management Implications. Missouri Conservation Technical Report Series: 2009, Number. Missouri Department of Conservation, Jefferson City, MO.

McCain, K.N.S., editor. 2012. Upper Mississippi River Restoration-Environmental Management Program Monitoring Design Handbook Section 1: Vegetation. U.S. Army Corps of Engineers, Rock Island, Illinois.